THEORY ON DEVELOPMENT OF MOUNDS NEAR RED BLUFF, CALIF.

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ABSTRACT

Photographs are presented showing mounds in various stages of development in the flood zone of the Sacramento River near Red Bluff, Calif., and the terrain on which the mounds are located. A theory is presented to explain how the mounds were formed.

Rounded mounds of earth, such as in figure 1, are found in many parts of North, Central, and South America and possibly in other parts of the world. The striking appearance and puzzling features exhibited by the mounds have long made them objects of scientific curiosity. Of the many theories proposed during the last 100 years to account for their formation, none is universally accepted. Literature on the subject is too extensive to be cited here, but Scheffer (1947, 1958) and McGinnies (1960) list sufficient references to give a good review.

Incidental to an ecological investigation of streams as nursery areas for the production of chinook salmon (*Oncorhynchus tshawytscha*), a section of the Sacramento River near Red Bluff, Calif. (fig. 2) was studied, where mounds are in many stages of growth. When one looks at these mounds, he finds that in a restricted area, they constitute a family. They tend toward an ellipsoidal form, and their long axes are parallel to one another. If one cuts through a mound, he finds that it is composed largely of silt with some sand, stones, and decayed matter (fig. 3). The substratum of the mound is made up of gravel and coarse sand.

Our curiosity having been aroused by these observations, we developed a theory to explain how the mounds were formed. Although the subject of mounds is not directly a part of fishery studies, the agents that we think lead to the formation of mounds—namely, flooding of the stream and erosion of soil materials—also kill salmon by scouring the stream gravel or by depositing silt in the streambed. This action destroys incubating spawn by removing gravel and washing out the eggs and by depositing silt and subsequently smothering the eggs. Similarly, larvae and other aquatic forms that the salmon fry eat are either washed out or the habitat of these forms is destroyed by deposition of silt, and the food supply for the young salmon is greatly diminished.

Mounds thus serve as tangible evidence of stream phenomena that are of vital concern to the fishery biologist. We believe that an understanding of the agents involved in the formation of mounds will contribute to a better understanding of the factors that determine whether the streambed will be a productive habitat for salmon when spawning.

How dynamic conditions during flood seasons lead to the formation of mounds can best be seen by photographs. The purpose of this report therefore is to present pictures of mounds in various stages of formation and then to give a theory summarizing the photographic observations.

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FIGURE 1.—Mounds near Red Bluff, Calif.

FIGURE 3.—A cross section cut through a typical mound shows a deposition of silt, some decayed organic matter, sand, and an occasional stone on a substratum of gravel and coarse sand. This particular ellipsoidically shaped mound was 3 feet high, 13 feet wide, and 20 feet long.

FIGURE 2.—The mounds shown in figure 1 were near the middle of the extreme right area.

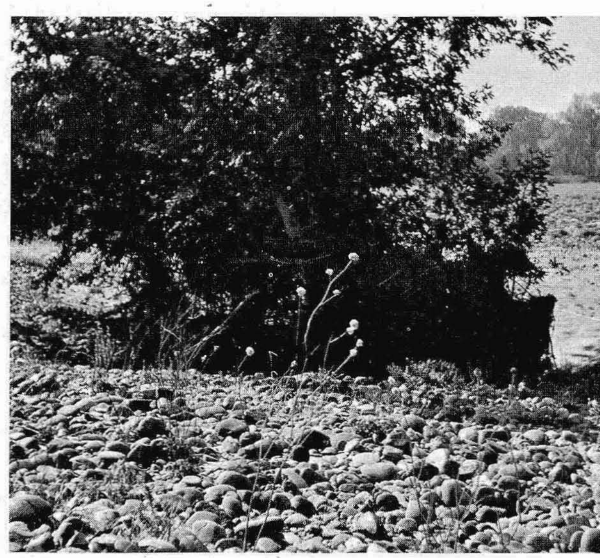

FIGURE 4.—During flood season, water moved down the river channel with tremendous force, carrying gravel, boulders, and debris and depositing these materials wherever the current slowed. The brush piled against this tree indicates how the streambed is changing continuously during a flood.

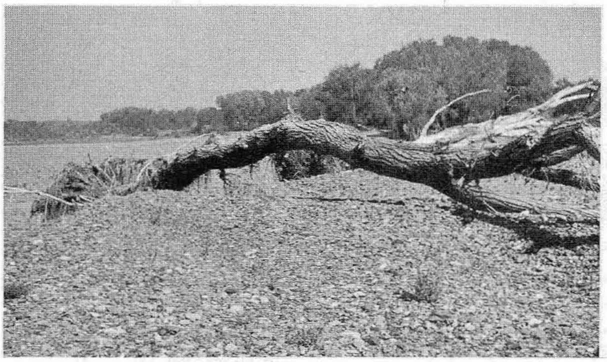

FIGURE 5.—Gravel accumulated by the force of flooding waters elevated the streambed. Note how the roots of this large tree are partially hidden by the gravel bar in the foreground. Bars such as this one are several feet above the normal height of the river seen at the base of the trees in the far distance. The large tree left here when the river receded indicates how the river valley changes during a flood. It shows how both the streambed and the direction of flow of water must be continuously varying.

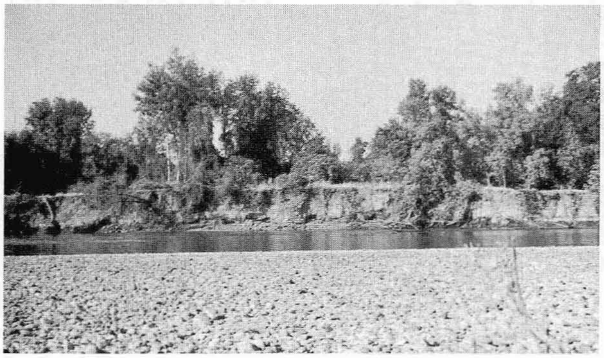

FIGURE 6.—With the increase in height of the bed, the river changed its course because a new channel was readily eroded through the comparatively light soil of the adjacent area.

FIGURE 7.—In time, the river became completely diverted from its old channel, demonstrating the dynamic and continuously changing conditions during the flood season.

FIGURE 8.—The elevated streambed was inundated during floods but was dry during a sufficiently long period of the year to allow plants such as mountain monardella (*Monardella odoratissima* Benth) and brickellbush (*Brickellia californica*) to become established and grow.

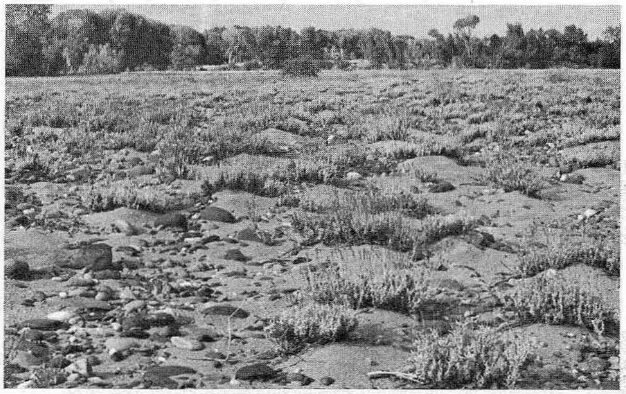

FIGURE 9.—Almost any plant in the area, such as wild buckwheat (*Eriogonum wrightii*), shown here, was capable of forming incipient mounds.

FIGURE 10.—During flood seasons, the plant was an obstacle to the flow of the soil-bearing stream, causing the rate of flow to be reduced sufficiently so that soil was deposited immediately downstream from the plant. Some of the deposits measured as long as 65 feet.

FIGURE 11.—As the incipient mound grew, the stream contoured it into teardrop shape.

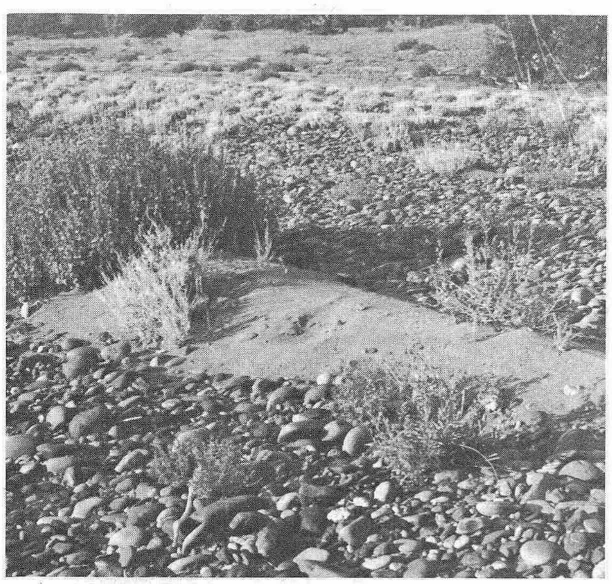

FIGURE 12.—Continued deposition resulted in a shallow, elongated accumulation of silt, sand, and pebbles.

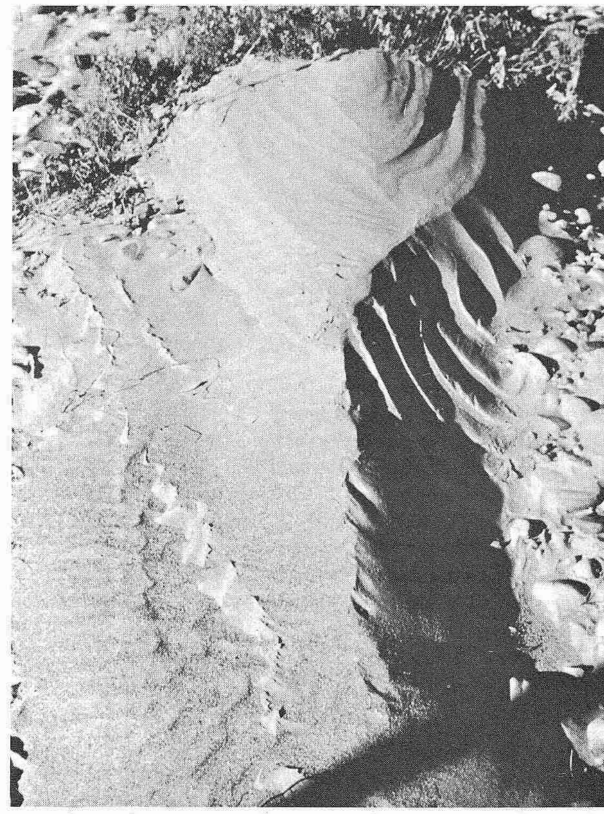

FIGURE 13.—Growth of the mound changed the local direction of the stream. Note how the head of the deposit was contoured into an ellipsoidal form. The head of the mound was composed of finer material than the tail, indicating that the flow was less swift close to the plant.

FIGURE 14.—The precise shape of the deposit was determined by the relative rates of deposition and erosion as the stream continuously changed direction of flow.

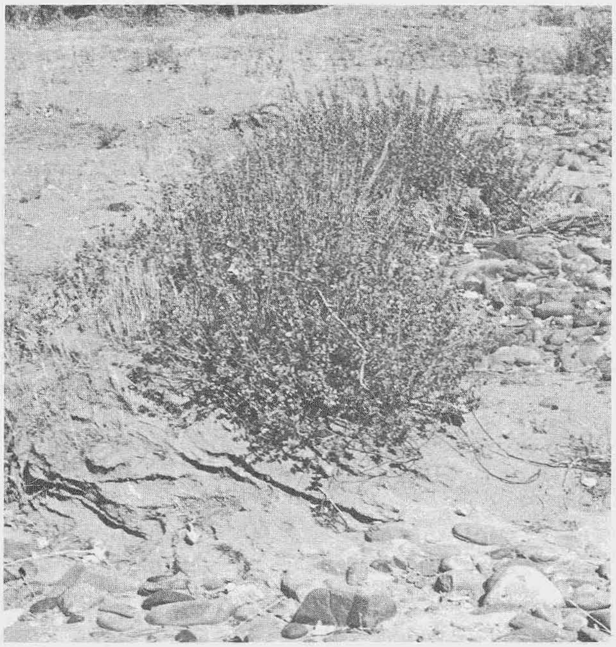

FIGURE 15.—If the velocity of the stream became too great, the mound was eroded badly, especially if large changes took place in the direction of the stream as might occur when the stream was rising or falling in a somewhat sloping area.

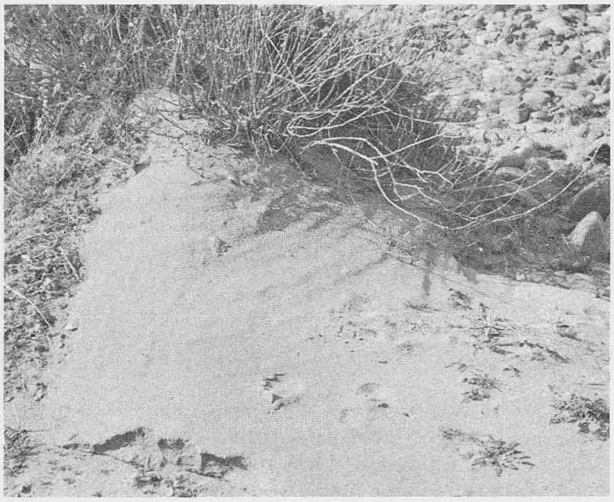

FIGURE 16.—The changes in the direction of flow of the stream tended mostly to favor the deposition and erosion of the mound into ellipsoidal or hemispherical shape. Note the circular contours on this developing mound. Note also how the growth of plants is helping to stabilize the mound.

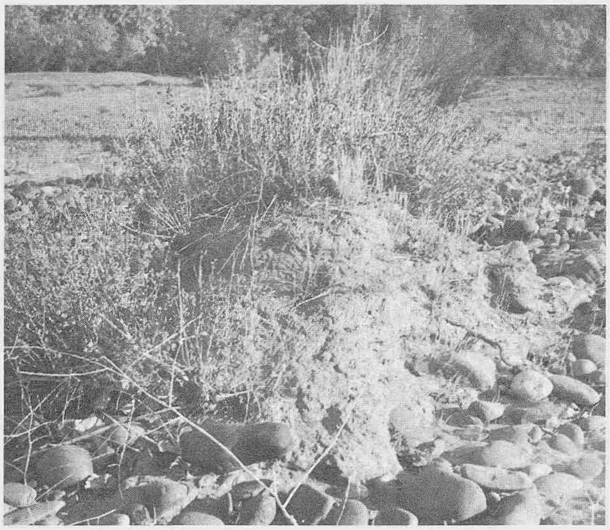

FIGURE 17.—Large changes in the direction of the stream, accompanied by high rate of flow, produced drastic changes in the shape of the mound, the change tending, however, to favor the ellipsoidal or hemispherical form.

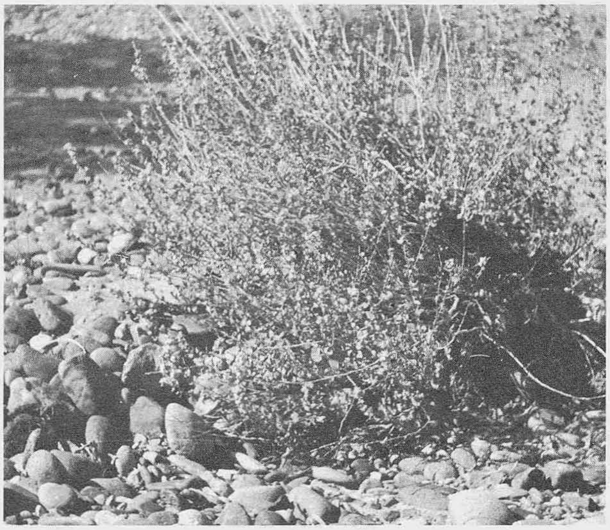

FIGURE 18.—If the stream became too rapid, the entire mound was eroded leaving the roots of the original mound-forming plant exposed.

FIGURE 19.—Only plants with exceptionally strong roots could withstand the force of the river under high velocities and changing directions of flow, and only plants such as brickellbush, which grows even when soil accumulates around it, could form mounds of appreciable size.

FIGURE 20.—A surviving plant (see figs. 18 and 19) started the formation of a new mound. This photograph was taken 1 year later.

FIGURE 21.—Mounds were haphazardly distributed, depending upon where the plants happened to grow.

FIGURE 22.—Under conditions of equilibrium, mounds attained a stable form and continued to increase in size.

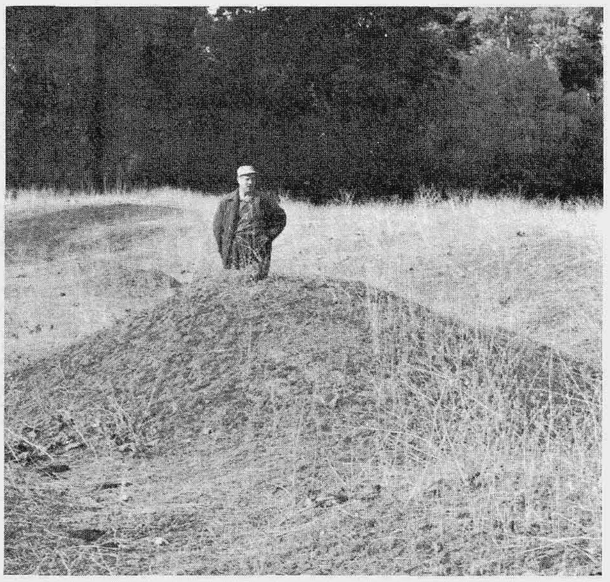

FIGURE 23.—Because of the shift in the course of the river, the environment changed, creating conditions adverse to the mound-forming plants and resulting in the death and disappearance of these plants on the mounds farthest from the stream.

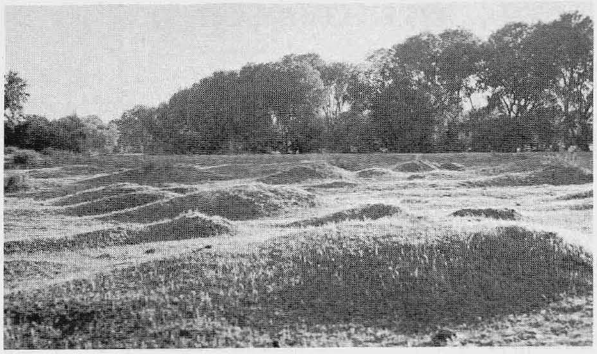

FIGURE 24.—The mounds were all oriented with the elongated axes in the direction of flow of the river. This photograph was taken at right angles to the flow and points in the direction that the river channel has shifted. Moving away from the camera toward the river, we find three zones of transition: first, no brickellbush (in the foreground); second, brickellbush struggling for existence (in the middle background); and finally closest to the river, healthy brickellbush (left background).

FIGURE 25.—On the older mounds, all signs of the orginal mound-forming plants disappeared except possibly for the partially decayed roots (brickellbush in this case). Roots such as these extended down into the substratum at the upstream extremity of all mounds examined.

THEORY

1. During flood seasons such plants as mountain monardella and brickellbush, which grow on the flood plain between flood seasons, are obstacles to the flow of water. Because the rate of flow has been slowed, silt is deposited in an elongated pattern immediately downstream from the plants. During the period of early growth of the mound, the elongated deposit tends to be molded into a teardrop shape by the stream.

2. The head of the mound, being protected by the mound-forming plants, tends to be more permanent than is the tail. Any major changes in the direction of flow of the floodwater will tend to erode the tail faster than the head.

3. As the head of the mound grows in size, it produces local changes in the direction of flow of the floodwater in such a manner as to contour the mound into ellipsoidal form, with the hemispherical form being the limit toward which the contouring tends.

4. Owing to the mounds having been formed by deposition of silt, sand, and stones from moving floodwater, the long axes of the mounds are all parallel to one another and to the direction of flow of the floodwater.

5. Any plant growing on the flood plain can form an incipient mound, but only plants that have strong roots, that can withstand having their lower portion covered gradually by silt, and that have a long life span, such as brickellbush, will form large mounds.

6. Shifting of the streambed produces a change in environment that is unfavorable to the mound-forming plant, so it eventually dies and disappears. The mound now exhibits no surface evidence of this essential agent in its formation.

SUMMARY

Photographs taken on the flood plain of the Sacramento River near Red Bluff, Calif., are presented showing present-day development of mounds in all stages from incipient to mature. A theory is given summarizing the photographic observations.

The essential feature of the theory is that the mounds are formed immediately downstream from certain plants such as mountain monardella (*Monardella odoratissima* Benth) and brickellbush (*Brickellia californica*) during flood seasons, owing to the resistance offered by the plant to the flow of water and consequent slowing of the stream and deposition of suspended soil. The ellipsoidal shape of the mounds is explained as the product of two opposing tendencies: Deposition and erosion. The deposition is elongated downstream from the plant, whereas the erosion tends to shape the deposit into hemispherical form—that being the most stable to changing direction of flow.

The parallel orientation of the long axes of the mounds is explained by all of the mounds being formed by deposition from the same stream.

ACKNOWLEDGMENTS

T. C. Fuller and S. T. Ancell of the California Department of Agriculture identified the plants mentioned in the report. John Riggs of the California Department of Fish and Game took the photograph in figure 2. Albert Redamonti gave permission to make the observations on his property.

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