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BUREAU OF ECONOMIC GEOLOGY
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The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of democracy. . . . It is the only dictator that freemen acknowledge and the only security that freemen desire.

Mirabeau B. Lamar

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Figure 2. Horizontal outlines of a group of etched potholes near the east foot of the north end of Mariscal Mountain in Brewster County, Texas. The group is on a bench of limestone along an orroyo. The slope of the surface is to the left in the sketch. Etched shallow furrows extend in this direction from some of the potholes. From a drawing made in the field.

ETCHED POTHOLES*

J. A. UDDEN

The exposed surface of limestones in the arid southwest of America almost always bears evidence of being etched by solution. The agent of this etching is, of course, the rainfall. Limestone is soluble in water to some extent. It is more readily soluble than quartz or other siliceous material. For this reason where limestone contains chert, or, as is sometimes the case, pebbles or sand grains, these will protrdue from the etched surface of the limestone.

Every geologist who has worked in the southwest, has no doubt seen the peculiar potholes, which occur usually on the highest hills and ledges where limestone is exposed. The local Spanish name for these potholes is "tinajitas," which is the diminutive of "tinajas," water containers, water pots. These tinajitas have a rough resemblance to potholes produced by corrosion. But it is evident that they are not made at all in the same manner as the potholes mostly associated with glacial conditions, or sometimes occurring in swiftly running waters in non-glaciated regions. A close inspection makes this evident. As a rule the erosion, or corrasion potholes, with which we are all familiar, have a well rounded bottom produced by the grinding of pebbles which excavated the rock. The tinajitas have an almost flat and only very slightly concave and smooth bottom, joining rather abruptly the surrounding, almost vertical wall. Moreover this flat bottom is invariably level, unless it happens to be made in some large limestone block which lately has been tilted, as by creeping or settling. An inspection of a number of etched potholes will also show that the interior of these vessels are never polished as by attrition. The floor, or bottom, is often quite smooth, but even on the floor any pebbles or flint nodules present in the rock will be found to stand out above the surface. The

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wall or sides of the tinajitas are, as a rule, vertical, especially if the vessel has the depth of two or three inches or more. The walls are apt to overhang a little, rather than to slant the other way. The walls are never as smooth as the floor, and present, usually, a number of irregular concavities separated by some sharp irregular ridges or points. The nature of the interior surface of the tinajitas is sufficient to demonstrate that it is the result of etching, for the protrustions on this surface, whether large or small, can often be seen to have resulted from the greater resistance of such parts to solution.

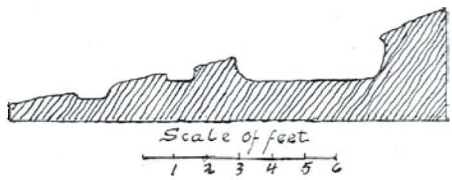


Figure 1. Diagrammatic vertical section through the centers of three etched potholes near the east foot of the north end of Mariscal Mountain in Brewster County, Texas. From a drawing made in the field.

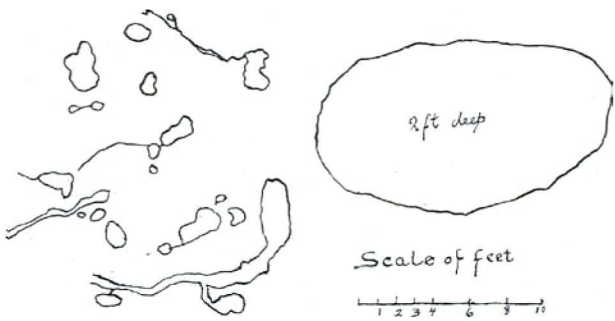


Figure 2. Horizontal outlines of a group of etched potholes near the east foot of the north end of Mariscal Mountain in Brewster County, Texas. From a drawing copied from field notes. The group is on a bench of limestone along an arroyo. The slope of the surface is to the left in the sketch. Etched shallow furrows extend in this direction from some of the potholes.

It was my good fortune many years ago to see this etching process going on. It is the result of gelatinous and other algae such as chara, and diatoms, that produce carbon dioxide. Many algae are distributed everywhere in the dust on top of the soil and on the surface of the rocks in the semi-deserts of the southwest. In all of the little tinajitas some of this dust and soil will be found on the bottom. During the summer months this part of our country has occasional afternoon showers and the dried algae in the dust on the bottom, quickly revive after such showers. One late afternoon, in the burning sunshine following such a shower, I found a tinajita half filled with water and it was sizzling from gas developing in the water. The water had a faint b'uish tint, evidently from the presence of a great multitude of the microscopic algae. I immediately realized that the gas was developed from the algae. It would not burn. The water had, as I thought, the acid taste of carbon dioxide. A multitude of minute bubbles could be seen rising to the surface through the water. I returned to the place after sunset and all was then quiet. Hence, I concluded that the escaping gas was produced by the growth of the algae. The same phenomenon has later been observed by myself at other places and times, but I have not seen the action as intense as in the particular case mentioned. It perfectly resembled very brisk fermentation in the making of home brew.

After one of these June showers some of the larger of the tinajitas may contain water for several days. Travelers in the region, who always have to arrange their trips with regard to water, sometimes count on finding tinajita water in places where these vessels are known to be sufficiently large, in case recent rain has fallen.

The largest tinajita, which the writer has seen, measured ten feet in length, a couple of feet in depth, and had a width of seven feet. Several tinajitas approaching this size were found on the east side of the north end of Mariscal Mountain in Brewster County, Texas. Although no rain had fallen in that country for several days these vessels had enough water for myself and my horse to last a

day and a night. Other large vessels of this kind are known in the west side of the Carmen range, a few miles northeast of the old Boquillas postoffice in the same county.

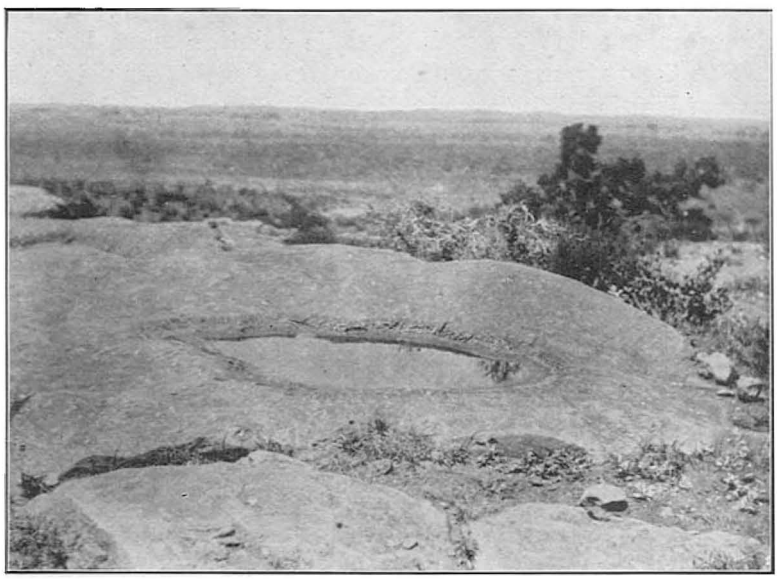
Where several tinajitas occur in groups pits will in some places be seen to have coalesced. Some oblong pits are evidently the result of extreme cases of coalescence of two or three vessels. The more common sizes of these excavations in the region examined by the writer have a diameter of from six to eighteen inches. As a rule these potholes have their greatest developments on hills and ridges of limestone, evidently for the reason that in such situations the growth of the algae is favored by intense and strong sunshine. But they can also be found in the solid limestone bottoms of dry arroyos. Presumably the process is here favored by the more slow evaporation of the water. On gentle slopes of limestones these potholes will in places occur in chains connected with shallow surface channels.

The development of these etched potholes is in many cases modified by structures, such as joints, in the limestones. On the mesas southeast of Stockton the capping limestones, which vary from a few feet up to twenty or thirty feet in thickness, are cut by joints that cross each other almost at right angles. Evidently during the underground weathering the limestones have been impregnated more or less by ferruginous and silicious materials along the joints. This leaves the sides of the blocks less soluble than the rest of the rock, and over considerable areas all these blocks are seen to be excavated on the upper surface to a depth of from one to three inches. Almost in every case the edges of the blocks stand up as rims inclosing wide and shallow potholes. This is seen in Plate IV. There is another condition involved here no doubt to some degree. I have observed weathered, that is, etched blocks of slightly siliceous limestone belonging to the Eagleford formation, having a tendency to weather so as to produce cuspidate edges on the rectangular blocks, into which this rock almost always breaks. As is well known, this limestone corresponds to the so-called "Fence Post" formation

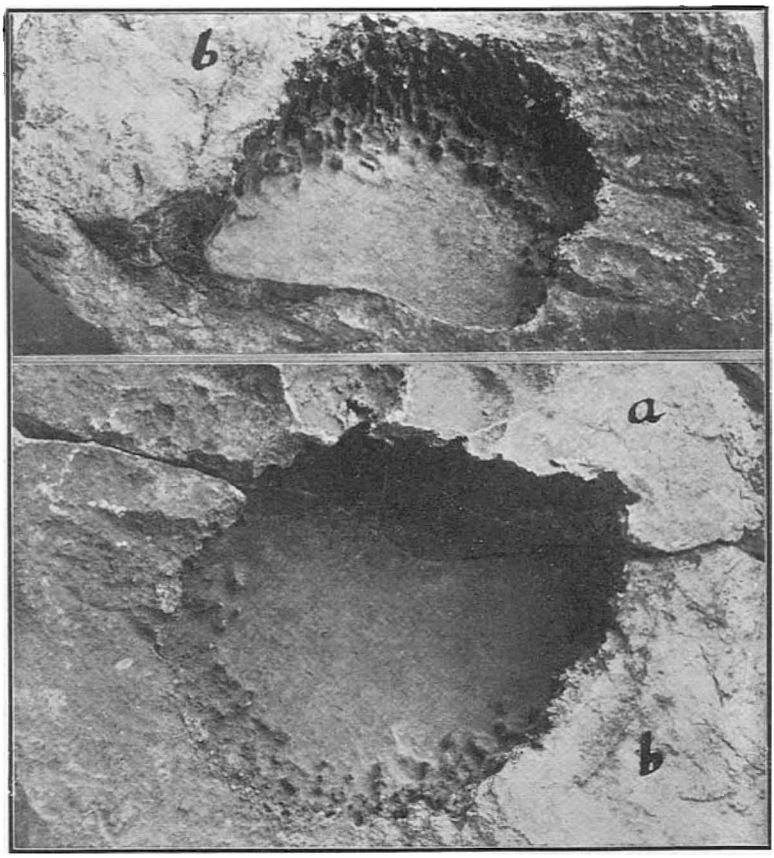
in Kansas, belonging to the Benton Series. This splits into elongated rectangular blocks of varying lengths, thicknesses and widths. When exposed to the solvent influence of rains it appears that the meeting of two weathered surfaces at right angles leave a deposit, or an accumulation, of the least soluble material on the sharp edges. These therefore are left protruding while solution more briskly affects the flat surfaces. To what extent this principle is involved in helping to make the shallow pots noted on the upper surface of the Comanchean layers on these mesas it is, of course, difficult to say, but evidently it plays a part. It will be noted in the figure that some of these shallow and wide pots have been broken. This naturally puts an end to the action of the algae as the water is then readily drained from such pots. One can find pots in all stages of development and decay on these mesas. It is here also that one occasionally observes the beginning of new potholes in older ones. It evidently happens in some cases that new potholes will have started in parts of older potholes that have been broken. The bottoms of these new potholes are developed with a level bottom and this level may lie at an angle with the level of the old potholes, wherever the position of the older potholes have been shifted, as by the settling of one side of the old pothole block.

To present the many and varied features of etched potholes it is best to rely on photographic material. Below are shown illustrations of some such material as has come under the observation of the writer during the last twenty years. The observations were made mostly in the western part of Texas.

While the great majority of potholes observed have been made in limestone, it is interesting to note that potholes of this kind are also formed in crystalline rocks. They have been observed in granite-like rocks in several places. One well developed pothole of this kind was noted in a granite-like sill which outcrops south of the Altuda Mountain in Brewster County. Others have been noted in intrusives in the southern part of Brewster County. One has been seen in granite in Mason County in the central part of the state.

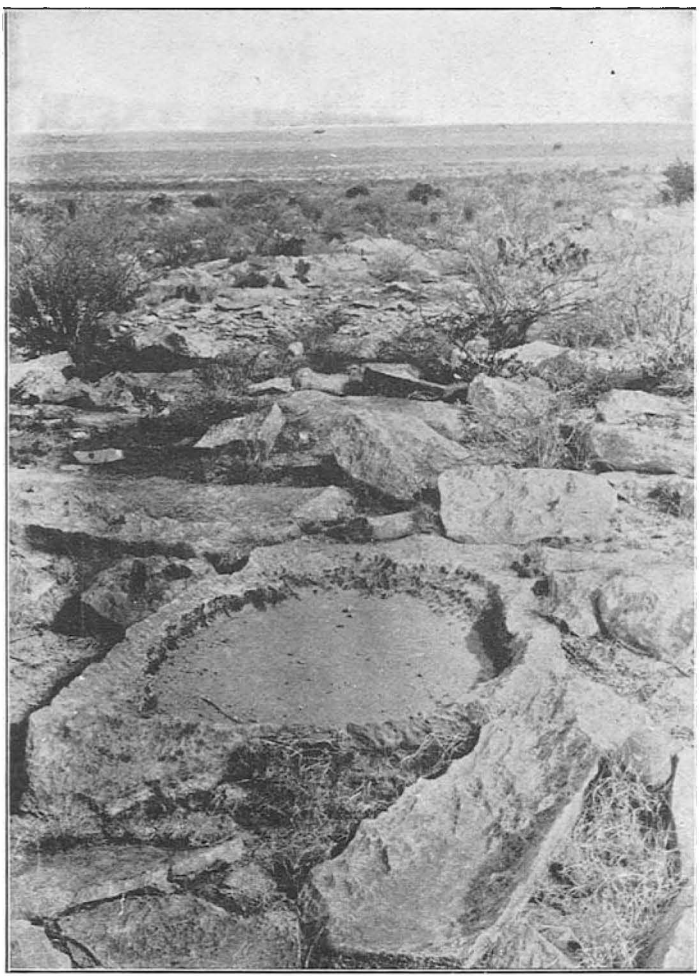


A tinajita containing water from a recent rain. It is about three feet long, nearly two feet wide, and about six inches deep. It has been etched in a hard and compact layer of yellow limestone in the Double Mountain Permian on the Swensson Ranch in Dickens County, Texas.



Pothole etched in limestone of Comanchean age. From the crest of a ridge one and one-half miles northeast of Boquillas postoffice, east of the Chisos Mountains in Brewster County, Texas. This pothole measured about seven inches in longest diameter and was a little more than four inches deep. Upper half of the photograph shows the piece "b" at an angle from the vertical section, with the piece "a" removed. The specimen was broken when removed. The specimen is typical, showing a slightly concave, smooth bottom, and having the walls etched into an irregular fretwork. In some deep potholes a "shoreline" has been observed in this fretwork. This was in cases where the water had found or made a late outlet over the rim of the basin, below an earlier level at which the water had first been standing.

Incipient tinajitas formed on a layer of the Boquillas flags (Eagleford), east from Boquillas postoffice. This rock is a tough and indurated limestone containing a certain ingredient of very fine sand. This silicious ingredient seems to accumulate on the surface of the rock as the etching goes on, and it oxidizes and gives the rock a brown color. In the most recently etched pits the oxidation seems to be less, and these show a relatively light color.



An etched pothole in a block of Comanchean limestone on top of a mesa twenty miles southeast of Stockton, in Pecos County, Texas. Dimensions about six feet in length, four feet in width, and five inches in depth. Several blocks seen in the picture show the effects of general etching. Note one small rectangular block with cuspidate angles.

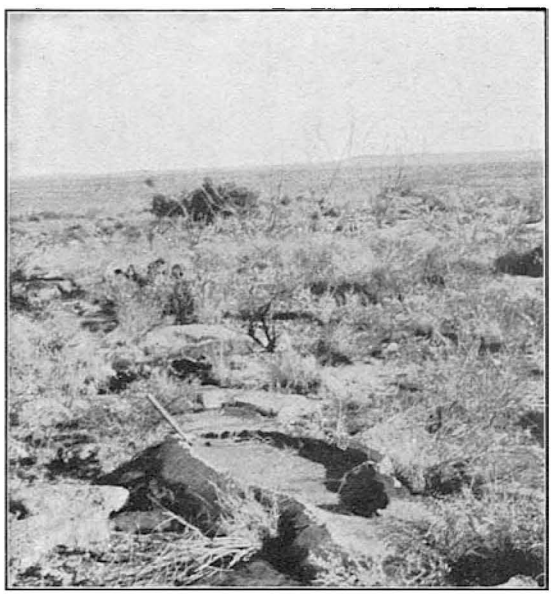
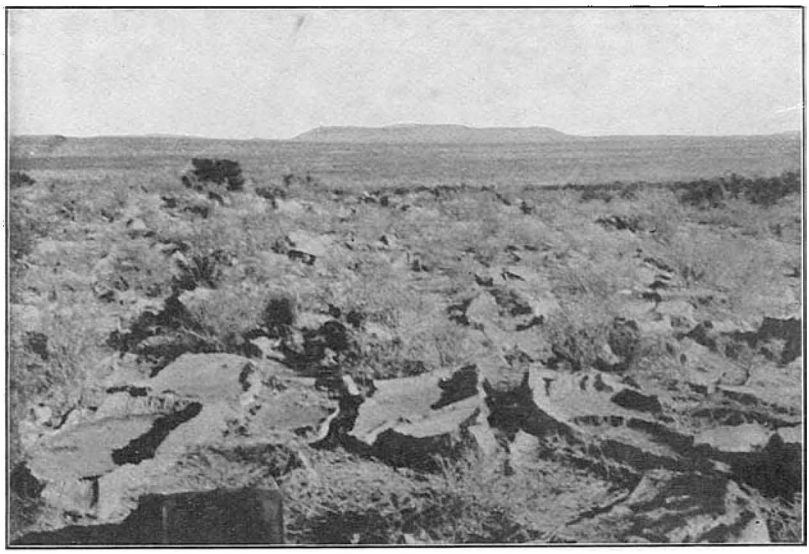


Figure 2. An etched pothole in Comanchean limestone on a mesa about twelve miles southeast of Stockton, Pecos County, Texas. Notice that almost the entire upper face of this stone slab has been etched away, leaving a rim all around the edge. The handle of a hammer leans on this rim at the left. Resistant silicious parts of the rock are seen at the far end of this tinajita, rising from its flat floor, or bottom. The vegetation seen is mostly small sage bush. Farther away some okotilla is seen.



Etched potholes in Comanchean limestone capping a mesa twenty miles southeast of Stockton, in Pecos County, Texas. Five potholes are to be noted in the foreground. They are all in advanced stages of development. The one farthest to the right has been fractured and etching has ceased on the old floor or bottom. Later etching has cut into the old bottom and has developed a new pothole with a bottom, that now lies about three inches below the old one. Etching is now going on only on this lower floor. To the left in the picture a pothole is seen where etching has cut away all of the rim of the vessel to the right and thus brought the process to an end, as water is no longer retained in this vessel. In this locality the limestone is cut by two sets of parallel joints into four-sided blocks which in most cases exhibit shallow concavities caused by the etching process, evidently controlled to some extent by differential resistance of the rock. Along the joints the limestone has an increased content of iron oxide, which apparently makes it more resistant to solution than the rock which is away from the joints in the main part of the block. The result is that in places the joints are left as ridges separating a series of shallow excavations in the blocks on either side. Algal action may be difficult to recognize in such cases from simple differential etching by aqueous solution.