# AN ANALYSIS OF VOIDS IN CERAMICS

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Archaeological analysis of ceramics has, in the past, mainly concerned itself with the temporal and spatial distribution of different ceramic types. These types are defined on the basis of decoration and temper. Little attention has been paid to the processes that went into forming the ceramic vessels from which those types are derived.

Pottery manufacturing techniques have been, for the most part, inferred from the recovery of potters' tool kits from archaeological contexts. From the southwestern United States, pottery scraping tools used in the smoothing of coil constructed vessels are well known (Guernsey,1931:110-111; Kidder, 1934:154-155). Pottery anvils which functioned to help thin a vessel's walls by squeezing have been found throughout the southeast (Holmes 1903:35-36), western Illinois (Cole and Deuel 1937:123), and northern Arizona (Bartlett, 1937). Unfortunately, many ceramic-making archaeological cultures lack this sort of evidence for their respective methods of ceramic manufacture.

One of the characteristics of clay is its plasticity. This property allows clay to be shaped by pressure and retain that shape when that pressure is released. This plasticity is due to the absorption of water by the clay particles. Water is ionicly bonded to the surface of the platey clay particles and acts as a lubricant, allowing the particles to slide over one another. The firing process and the mineralogical changes that accompany it stabilize the ceramic form, yet, they do not modify the form into which it was molded. By using this property of retention of molding stress, it should be possible to describe the forming process of a ceramic vessel.

Studies of the edges of broken vessels occasionally show independent coils laid one on top of the next (Stevenson 1939: 239; 1953:65-68). This type of feature is unfortunately rare in ceramic products. If clay bodies do remember the form placed on them prior to firing, such strains such as coil joins should be visible.

It was decided to look for evidence of this and other types of strains in a collection of sherds spanning the prehistoric ceramic making period from the lower Illinois River Valley. Prehistoric and historic sherds from Arizona, Colorado, New Mexico, Kansas, Nebraska, and Mexico were also used in the analysis for comparative purposes. The features under consideration were likely to be small, the best way to view them would be as petrographic thin sections. In this way not only could the structure imposed on the clay be observed but other attributes of the ceramic such as temper and paste be monitored as well.

Each sample was first prepared by cutting a slab perpendicular to the vessel lip. The face to be prepared for thin sections was ground smooth using 600 grit abrasive. Then the sample was dried in an electric oven. After the samples had dried for several hours they were placed in aluminum troughs partly filled with salt, the surface to be analyzed facing upwards. These samples were then placed in a vacuum chamber and a layer of blue-dyed epoxy spread across the surface of each sherd. The vacuum was then activated. This was done to replace the air within the voids present so that they might be more easily observed. The process of epoxy impregnation also added durability to the samples to help them withstand the later cutting and polishing. Applying epoxy and vacuum impregnation was continued until no more air bubbles broke the surface of the epoxy. The samples were then put into an electric oven at 120 c and the epoxy allowed to harden. After the epoxy had hardened, the excess epoxy was ground off on 250 grip emory paper to the level of the surface to be observed. Many of the Illinois ceramics required three or four impregnations of epoxy and subsequent removal of excess epoxy before most of the visible voids could be filled. When the surface was flat and all voids appeared to be filled, the sherd was attached to a petrographic slide on a hot plate with a surface temperature of 120$^{o}$ using undyed epoxy. Just prior to the setting of the epoxy on the slide surface, the sherd was removed and the face to be observed was re-epoxyed and placed on another slide to harden. This was done to seal the surface of the sherd to keep heated air from escaping from unfilled voids and causing bubbles to form on the thin sections. After the attachment of the sherd to the slide surface, the excess sherd was cut away and the surface ground to the proper thickness using 1000 grit abrasive. The resulting thin sections were then observed under both petrographic and binocular microscopes.

The voids obscured during this analysis were divisible into three groups depending on their origin. Voids may be formed by air trapped in the plastic clay during the kneading and construction process. Voids also form during the firing process due to the uneven shrinkage of the ceramic paste and expansion of the temper particles. Leaching of the tempering agent as a result of burial in an acidic environment also serves to create voids.

Initially, the aboriginal vessels were constructed by successive coils or a continuous rope of clay, possibly to a handmolded base (Griffin 1952:96). The joins between coils are an area of structural weakness, and every attempt was made on the part of the potter to create a solid bond between coils (figure 1). Coils may be stacked vertically or partly overlapped to create a broader area of attachment. When coil joins are found, they may be seen as an area of structural weakness between coils. This weakness is characterized by a void caused by air trapped between the two coils (Figure 2). Such voids have fairly smooth sides and have an orientation at least partly perpendicular but never parallel to the vessel walls. This depends on the amount of overlap between coils.

After the vessel had been constructed by coiling, the walls were then thinned and smoothed. If this was not done, several problems might occur. Coils might not be bonded as well, causing areas of structural weakness. If the walls were of uneven thickness, the vessel could not support its own weight. During firing, the vessel might break due to uneven drying of the clay and varying rates of shrinkage in different parts of the vessel.

Within the United States, there are two aboriginal methods of assuring even thickness of vessell walls and more complete joining of coils. One method is by scraping the surface of a vessel with a tool which conforms to the vessel's curvature during the coiling of the pot. This method is practiced by the Puebloan peoples of Arizona and New Mexico (Gifford 1928: 356-361) and the Cherokees of the Carolinas and Tennessee (Fewkes 1944). Scraping affects only the vessel's surface and leaves no structure within the vessel. Occasional parallel striations left by temper particles adhering to the scraping tool are occasionally found on vessel surfaces.

The other method involves the use of a wooden paddle and the potters' hand, a stone or mushroom-shaped pottery anvil. The hand or anvil is held against the inside wall of the vessel to receive the squeezing force of a blow from the paddle. This method was widely practiced by aboriginals living throughout the eastern and central United States and southern Arizona and California. As this thinning method directly affects the vessel body, it leaves characteristic voids. These voids are thin, smooth-sided units which have a preferred orientation pralleling the vessel walls which results from the compression of air trapped in the clay during kneading. Kneading is a process which takes place prior to vessel construction. Water is added to the pottery clay in order to turn it into a useable plastic paste. The clay is mixed by hand in order to evenly wet all the clay particles. It is at this time that temper was added to alleviate the problem of shrinkage when the water of mixing and structurally bonded water of the clay minerals are driven off by firing. The kneading process, if done by hand, will also include a lot of air that becomes trapped in the clay body as voids. These airpockets, trapped in the coils of the vessel, take up a characteristic orientation of paralleling the vessel walls as a result of the squeezing process (Figures 3 and 4). Voids vary in length and width depending on the amount of air present and the force applied to the clay body. If the paste has little air or the coil being sqeezed is small, this will result in smaller voids than if the coils were larger or the force of compression stronger. This process of compressing the clay will cause the individual temper particles to take up a preferred orientation paralleling that of the voids. Experimentally produced paddle and anvil thinned ceramics display this preferred orientation of temper particles with the grains' long axis paralleling the vessel walls (Hodges 1964: 59-60). This orientation of temper particles and air pockets has been indirectly observed by Rye (1976:205-211) in x-ray photographs of whole ceramic vessels from Papua, New Guinea. His x-ray photographs show fairly circular resulting from voids present in the vessel. These photographs represent the actual geometry of the air pockets in the vessel in plane view rather than profile.

While the clay of the vessels is still moist, the potter may modify that vessel and, consequently, the air pockets or compaction voids by different decorative processes. The flattening or smoothing of a vessel lip may be accomplished by several methods which have different effects on the compression voids. A potter may simply smooth down a vessel's lip by moving a wet price of soft material or a wet hand along the lip. This process truncates or loops the rim back onto itself, deforming the voids (Figures 5 and 6). The other method is to cut or pinch off the excess clay in order to leave a smooth lip. This process flexes the clay and deforms the compression voids to the point of making them parallel to the lip (Figure 7). It is possible to tell the direction from which the force was applied since compression voids will be deformed from their original orientation and bent parallel to the angle of the force. Such deformation of the compression voids will also occur when the vessel is decorated by punctation, flairing of the rim or other manipulation done to the vessel while the clay is still in a plastic state (Figure 8).

When ceramic vessels are fired, the clay minerals shrink slightly. This is caused by the loss of the water added to the clay during kneading and the loss of the hydroxal which were part of the original clay minerals. This shrinkage, is not corrected for by the right percentage of temper, will cause a vessel to break during firing. Even with the addition of temper, the loss of water by the clay body will often cause a vessel to break during firing. Even with the addition of temper, the loss of water by the clay body will often cause small fractures, usually along planes of structural weakness. (Figure 9). These drying cracks are rough-sided, sometimes having a temper grain on one side and an impression of that grain on the other. Drying cracks may also be observed to border temper particles. They may originate at compression voids and, following the plane of weakness, orient themselves parallel to the vessel walls. Drying may greatly enlarge compression voids. Such openness would make for a porous vessel which would sweat and keep water inside cool. Another zone of weakness, traced by drying cracks, are poor coil joins.

The key to identification of drying cracks from other types of voids is their rough-sideness and their association with areas of structural weakness such as coil joins or compression voids. Some types of clay have a tendency toward excessive shrinkage and if not well-controlled by the temper may have unoriented drying cracks anywhere throughout the paste.

The final type of void-forming process takes place after the vessel or sherds have been introduced into the context from which the archaeologist recovers them. These voids are small, compact, and have fairly smooth sides. Many of these voids display the same orientation as do the compression voids and temper particles. Occasionally, a small piece of limestone is located inside the void (Figure 11). This type of void, first noted by Griffin (1952:115), is caused by the conversion of limestone ($CaCO_3$) to calcium oxide ($CaO$) as a result of firing the vessel between 600° and 900°C (Shepard 1976:22), well within the firing range reported for modern aboriginal potters. The calcium oxide readily takes up water, in this case from the soil where the sherds were buried. If the clay is strong enough, it will contain the expansion of the calcium hydroxide $Ca(OH)_2$ which in time recombines with atmospheric carbon dioxide to recrystalize as calcium carbonate. However, not all limestone recrystalizes with voids as a result. Limestone tempering would also leach out in acidic soils. Similar voids have been observed in shell-tempered ceramics again caused by the leaching of the temper particles.

Ceramic-making archaeological cultures have existed in the lower Illinois River Valley for nearly fifteen hundred years. Each of these cultures produced its own distinctive styles of ceramics. These different styles are divided into wares, a term used here to describe ceramics with similar decorative treatments and products of the same cultures. More than one ware may have been produced contemporary with or only partially overlapping another in time. The pottery wares produced during the Early Woodland Period (600 B.C. to A.D. 1) include Peisker and Black Sand ware. The Middle Woodland Period (A.D. 1 to A.D. 450) includes the Havana, Hopewell and Baehr/ Pike wares. Late Woodland (A.D. 450 to A.D. 900) potters produced the White Hall, Maples Mills and Jersey Bluff wares. The Mississippian Period (A.D. 900 to A.D. 1500) has its own ceramic ware, Mississippian (Fowler 1952:150, Chapman 1980).

It is this long temporal span of pottery manufacturing in the lower Illinois River Valley which makes its ceramics attractive for an analysis of their voids. Such an analysis would add to our knowledge of how the different ceramic wares were formed and decorated and how the different techniques have changed or remained stable over time.

In the following section, the ceramics are divided into their respective wares and the voids in each sample described first as individuals, then as a group within that ware. These sections are arranged in chronological order, beginning with the earliest ceramics and ending with the latest.

## Peisker Ware

PSK Submound 2'62: Peisker Pinched: Sherd or clay temper

The paste is very homogeneous. The only voids present are those caused by the clay body drawing back slightly from the temper particles, that is, poorly developed drying cracks.

PSK II SE Quad 62-3: Peisker Pinched: Sherd or clay temper

The paste is very homogeneous. Drying cracks again partially surround the temper particles. One dendritic drying crack originates at the vessel exterior and extends about half-way into the sherd before stopping. This sherd is very similar to PSK II Submound 2'62.

PSK I 13A-7: Peisker Pinched: Crushed Granite temper

Compression voids have expanded due to drying.

PSK 33c-5: Peisker Pinched: Crushed limestone temper

Good orientation of compression voids parallel to the vessel walls. Some of these compression voids have been lengthened as a result of drying of the clay so that the ends of the compression voids may be described as drying cracks. Some leaching of the limestone temper has occurred.

## Black Sand Wares

PSK II 30A-5: Black Sand Incised: Crushed limestone temper

Good compression voids oriented parallel to the vessel walls. Those closest to the exterior walls have been slightly deformed by the incising of the vessel. Leaching voids are present.

PSK II 8A-1: Black Sand Incised: Crushed limestone temper

Compression voids present. These voids are deformed at the rim in the same way as those in Figure 6. One possible coil join exists and may also be described as a fine drying crack which begins at the vessel interior and extends perpendicular to the compression voids occasionally bordering temper particles. At approximately 4/5ths of the way across the section, the crack turns toward the rim and ends at a small compression void. Some leaching voids are present.

PSK II 19A-3: Black Sand Incised: Crushed limestone temper

Compression and leaching voids are present. One group of leaching voids is bisected by a compression void. A few drying cracks are also evident.

PSK G.P.E. S.R.75: Black Sand Incised: Crushed limestone temper

Some compression voids but poorly defined perhaps due to a well-mixed paste with little air. There are several leaching voids present. A few drying cracks paralleling the compression voids.

PSK G.P.E. S.R. 77: Black Sand Incised: Crushed limestone temper

Compression voids are present. Some drying has occurred to the point which the clay body has drawn itself away from some of the temper particles along the compressions voids. Some leaching has taken place leaving voids with some limestone remaining as well.

All of the samples of Black Sand Incised seemed to have been made using the same clay and manufactured by the same technique which left distinctive compression voids parallel to the vessel walls. All possess leaching voids. Drying cracks are well-defined and often originate as compression voids by expanding out from their edges.

The samples PSK II 19A-3, PSK II 8A-1, PSK II 30A-5, and PSK G.P.E. S.R. 75 resemble each other in great detail. They are both a light brown color and limestone tempered with what appears to be about the same type of voids in the same amounts. Compression voids are uniform throughout, and the paste has contracted, causing a similar pattern of drying cracks.

## Havana Ware

Ap 74-3: Havana Cord Wrapped Stick Impressed: Crushed limestome temper

Good compression voids with some dendritic drying cracks originating at them. Some drying cracks branch off at right angles to the compression voids. The compression voids are deformed around a punctation originating at the vessel's interior, forming a boss on the exterior of the sherd.

Ap. 112B '66 Havana Cord Wrapped Stick: Crushed limestone temper

Good compression voids deformed by a punctation and some drying at the ends of the voids.

Ap. 804-11: Havana Cord Wrapped Stick: Crushed limestone temper

Good compression voids deformed by a punctation. Drying cracks surround temper particles and iron oxide concretions which may have been a natural occurrence in the clay (Brewer 1964).

Ap. 895-8: Havana Cord Wrapped Stick: Crushed limestone temper

Compression voids are present, the ends of which are slightly rough, as they were formed by the drying paste. Compression voids are rounded at the lip from the operation which smoothed and rounded it.

Md-15: Havana Straight Dentate Stamped: Crushed limestone temper

Compression voids are present. These voids are interconnected by a web of drying cracks. Voids do not reach the lip.

Md-9(1): Havana Neteler Dentate: Sand temper

Compression voids are present which do not reach the lip.

Md-9(2) Havana Zoned Straight Dentate: Crushed limestone temper

Compression voids are present which do not reach the lip. One leaching void is observable with some limestone still present. As can be seen in the samples of Havana Cord Wrapped Stick, impressed compression voids occur earlier in the formation of a vessel than does decoration. It is uncommon to see how rims are formed except in the case of Ap 895-8. This is due to compression voids not reaching to the lip. The potter may have thinned the upper-rim area by hand rather than using a paddle and anvil.

Hopewell Ware

PSK Test Pit 1-1: Montezuma Puntate: Sand temper

Some compression voids. Small irregular void at widest part of the sherd with several drying cracks radiating out from it. This void may represent a coil join with an pocket left in it. Compression voids extend to both sides of this air pocket and stop.

PSK 144: Hopewell Zoned Rocker Dentate: Temper unknown

This piece could be called "hole tempered" as all the temper has leached out. These molds of temper particles are oriented slightly with the longer axis parallel to the vessel walls. No compression voids are present.

PSK 241-12: Montezuma Puntate: Crushed limestone: Figure 11

A few compression voids are present. There are many leaching voids, some of which still have some temper left in them. These voids are also oriented parallel to the compression voids.

Ap 21-141: Hopewell Cross Hatched Rim: Crushed limestone

Some compression voids and leaching cavities. There is an unusual void in the center of the rim. It is characterized by smooth sides except at its ends, where the void has widened slightly due to shrinkage of the clay. This void is oriented vertically and parallel to the vessel walls, yet is slightly convex to the vessel exterior. Above this void are several small drying cracks which curve parallel to the angle of the rim. Just below the large void is a smaller void which extends to the interior of the vessel and resembles a coil join. This group of voids possibly represents the folding over the upper part of the vessel to the interior. This was done to make the upper rim thicker and provide a surface for decorative treatment.

Ap 261a(22): Hopewell Plain: Crushed limestone

Compression voids present deformed by smoothing of vessel lip. Some leaching of temper particles has occurred.

Md-1-A(1) Hopewell Zoned Dentate: Crushed Granite

Compression voids, some of which are deformed by U-shaped incised line on the vessel exterior.

Md-1-D: Hopewell Cross Hatched Rim: Crushed limestone

A few very thin compression voids. Those compression voids near the lip have been deformed by having the upper part of the rim bent toward the interior while the paste was still moist in order to round off the rim and create a surface for decoration.

Hopewell ware is the most highly decorated ware produced in the lower Illinois River Valley. It is most often found interred with high-status individuals within mounds, although it is found associated with domestic architecture as well. The type is also the thinnest of any of the ceramic types of the Middle Woodland Period, which may account for the amount of leaching in the limestone temper. Yet, technologically it is no different from Havana ware in that compression voids are present in both.

The difference in idiosyncratic behavior between different potters is visible in comparing the rim-forming technique of Md-1-D and Ap21-141. Both sherds represent the same pottery type and are decorated the same way; yet the rims are made differently.

## Baehr/Pike Ware

Ap 191-3: Pike Incised/Brushed: Crushed granite

Few compression voids, indicating good clay mixing. One leaching void is present. The upper part of the vessel is curved outward then back to the original plane of the vessel, giving the upper rim a convex appearance. The strain of making this rim is seen in the way the compression voids are deformed in the area stressed by flexing.

Ap 262-8: Pike Plain Rocker: Crushed limestone

There are a few compression voids present in this sherd. A possible coil join is visible at about the center of the sherd. While it may be due in part to the leaching of the temper particles along a drying crack, the walls of the crack connecting the leaching void are fairly smooth, unlike those of drying cracks. This feature extends almost diagonally across the sherd. Several leaching voids are present within the sherd.

Ap 290(MZ)-63: Baehr/Pike Rocker: Sand

There are a few compression voids present, but the clay was well-enough compacted that little air was present in the past.

Ap 364a-1: Baehr/Pike Scratched: Crushed limestone

There are some compression voids and a few leaching voids. One drying crack is present which almost isolates a piece of unmixed clay or soil, possibly a natural inclusion in the clay.

Ap 522a-1: Baehr/Pike Scratched: Crushed limestone: Figure 3

The compression voids are quite apparent in this sherd and branch out slightly at their ends into drying cracks. These voids become deformed at the curve of the rim similar to Ap 191-3.

Ap 598c-13: Pike Plain Rocker: Crushed limestone

A few compression voids are visible in this sherd, less than Ap 552a-1. There are some leaching voids as well. Drying cracks in this sherd are confined to the center of an iron concretion which may have been a natural constituent of the clay.

Md-1-A(2): Baehr Zoned Rocker: Crushed sherds: Figure 9

Compression voids are present, but the most prominent feature in the sherds is a very strongly oriented set of dendritic drying cracks. These drying cracks parallel the compression voids. They also seem to break around temper particles, although one drying crack actually goes through one piece of temper.

Md-3: Pike Scratched: Crushed limestone

Good compression voids which deform as the rim curves away from the body. Some drying cracks are present, but they are small and connect some of the compression voids at the point of the greatest curvature of the sherd. Some leaching voids are visible. The temper particles have a profound orientation paralleling that of the compression voids.

This assemblage is similar to that of the Hopewell ware in that some sherds with similar paste and temper show or do not show compression voids. Why this variability in presence or absence of compression voids is unknown. It may be due to a lack of air trapped in the past during kneading. Leaching of crushed limestone temper is a common problem in both Hopewell and Baehr/Pike ceramics. With the exception of Md-1A(2), drying cracks are smaller than compression voids and fairly uncommon in the sherds of both wares.

The deformation of compression voids in Baehr/Pike ware in the upper rim area illustrates once again that compression voids were probably created fairly early in the manufacturing process.

## White Hall Ware

Ap 123(a): White Hall Cord Marked: Sand

There are many well defined compression voids in this sample, even though the sherd is as thin as those of the Hopewell ware.

There is a coil join near the base of the sherd where a series of small rounded voids is found across the width of the sherd. Compression voids found on either side of this line of voids end there.

Ap 178: White Hall Cord Marked: Sand: Figure 5

There are so many compression voids intermingled and connected by drying cracks that it is difficult to separate either, except for the most obvious examples of both types of voids. Compression voids are oriented parallel to the vessel walls but are connected by a network of drying cracks of the same dimensions.

Ap 868-7: White Hall Cord-Wrapped Stick: Sand

Compression voids are quite common in this sherd and are seen to deform around the punctation, as do the drying cracks which connect them. Compression voids on either side of the punctation are quite wide, which may be a result of the drying of the paste opening them up.

This is a very homogeneous groups of sherds. All the paste could have come from the same lump of potters' clay. All sherds are heavily tempered with rounded sand grains. This may have been done to offset the problem caused by an unusual amoung of shrinkage in the clay. This group of sherds has many more drying cracks which connect the compaction voids and even originate from them than any other group of ceramics studied. These drying cracks are very rough-sided, and if temper particles are imbedded in one side of a crack, they leave a negative cast of the grain on the opposite side.

The deformation of compaction voids in Ap 868-7 is the same as the pattern found in the Havana Cord Wrapped Stick samples.

The lips of all the White Hall vessels were made in the same manner. When the lip of the vessel was reached by the potter during the thinning process, the lip was simply smoothed off by the potter's wet hand. This brought the fine clay particles to the surface and truncated the compression voids that once extended to the lip.

## Maples Mills Ware

Auds II -24: Mapes Mills Cord Impressed: Crushed limestone

This sherd has a very homogeneous paste with no compression voids similar to samples of Hopewell ware. There are several leaching voids, two of which have a drying crack between them which is oriented parallel to the vessel walls. This may indicate that some sort of squeezing process formed the vessel and this drying crack is a fracture along a zone of weakness.

## Jersey Bluff Ware

Auds II -3: Jersey Bluff Cord Marked: Crushed limestone: Figure 2

The paste of this sherd is poorly mixed and seems to have been made up of clays from dissimilar sources. The clays vary in sand content, color, and percentage of iron concretions. Between the dissimilar pastes, a coil join is visible. It is smooth-sided with rounded ends like a trapped air pocket. Several drying cracks are visible, mostly around the iron concretions where the paste has shrunk away from them. Some small compression voids are present but uncommon. A few voids left by leached limestone temper are evident.

BL 5 -57: Jersey Bluff Cord Marked: Crushed limestone

Compression voids are evident in this sherd. A few leaching voids are also present. One drying crack originates at one of these leaching voids and extends to the interior edge of the sherd.

Per 1-5-2: Jersey Bluff Plain: Crushed Granite: Figure 6

There are good compression voids, some of which are extended to temper particles in the form of drying cracks. These drying cracks then skirt around the temper particles. The lip of the vessel shows how voids may be deformed by the smoothing off of the tops of the voids.

Misc. 1000: Jersey Bluff Plain: Crushed Granite

Compression voids are present, some of which form at the ends of the compression voids. Both of these features run parallel to the vessel walls. Some of these drying cracks skirt around the temper particles.

Although the sample of sherds is small and originated at different locations, they have many features in common.

All samples except Auds II -3, regardless of surface treatment, display compression voids indicating a similar manner of construction. Drying cracks are found in all samples. Rims on all samples were simply smoothed off by the potter's wet hand truncating, or slightly deforming, the compression voids and drying cracks that were present and leaving a thin layer of clay over the lip.

## Mississippian Ware

Misc. 1001: Mississippian Jar: Burned Crushed Shell

A few compression voids exist near the rim. The rest of the paste is well-compacted with the shell platelets strongly oriented parallel to the vessel walls. A slight deformation of the paste caused by the flaring of the rim is visible as a series of small fractures perpendicular to the vessel walls near the vessel exterior. Drying cracks are visible in one iron concretion. Several larger angular voids between two temper particles may also have resulted from shrinkage of the paste during firing.

Misc. 1002: Mississippian Bottle/Jar: Burned Crushed Shell: Figure 4.

Few compression voids are visible in this sherd. Those that are visible are quite thin and rough-sided and so may be drying cracks, opening up fissures which might have been compression voids were not the paste so well compacted. There is a strong orientation of the temper particles like Misc. 1001. A few drying cracks surrounding temper particles near the edge radiate into the pastes with no orientation.

Two new types of voids are visible in this sherd. One is characterized by an almost circular shape and is quite small. Dark staining of the paste surrounding them is common. This type of void may be attributed to the burning out of accidental organic inclusions. The other type of voids is somewhat elliptical in shape, although two are slightly irregular. All of this type of void have their long axes parallel to the vessel walls and temper particles. The sides of this type of void are smooth. These voids possibly represent larger air pockets which were not sufficiently compacted enough to form compression voids.

The lip of this vessel is quite interesting in that it shows a large arc-shaped void just below and paralleling it. This may have been caused by folding excess clay left on the exterior of the vessel toward the interior to round off the lip. The temper particles above this void parallel it.

Misc. 1003: Mississippian Red Film Jar: Burned Crushed Shell

A few compression voids are present along with the strongly oriented temper particles. A few of the voids surrounded by dark areas are present. At the bend for the rim flair there is a group of large rough-sided voids, some of which have small pieces of shell-tempered paste inside them. Some of these shell-tempered pieces of clay, if they are in the matrix of the rest of the vessel, are surrounded by a drying crack. This area may represent a piece of clay with temper which was not thoroughly wetted during the kneading process which drew moisture away from the rest of the clay body causing it to be surrounded by massive drying voids. Another drying void surrounds an iron concretion toward the lip of the vessel.

The vessel lip has several small arc-shaped voids parallel to it similar to, though much smaller than, those in Misc. 1002.

The three Mississippian samples are quite complex structurally. Both compression voids and temper particles are strongly oriented parallel to the vessel's sides. Yet there seems to be air bubbles in the paste which are not as compressed as the compression voids of previous types. This may be due to the use of much thicker coils in the vessel construction. By using larger coils, there would be a greater chance of trapping air inside them; yet there would also be lots of paste to compress to orient the long, thin shell-tempered particles.

Overall fewer voids are present in shell tempered ceramics than in the other types observed. This lack of voids may result from the technological innovation of the use of burned shell as a tempering agent. Mississippian ceramic clays that have been analyzed by X-ray diffraction have been found to be high in montmorillonite (Million 1975, Stimmell, Heimann and Hancock 1982). In montmorillonite, portions of the octahedrally coordinated aluminum are replaced by magnesium, thus producing an overall negative charge for the clay structure. This negative charge is balanced by alkali or alkali earth ions loosely bonded between the layered clay structure. These alkalis are susceptible to intercalation of large amounts of water that tends to separate the three layer stacks and clay particles. Vessels made using clays high in montmorillonite would be subjected to profound shrinkage due to the water expelled during drying and firing. Sufficient amounts of tempering material would have to be added in order to counteract this shrinkage.

The CaO created by burning the shell acts in two ways. First, it takes up water from the paste making the clay more workable (Million 1975:201-208). Secondly, the $Ca(OH)_2$ formed provides calcium ions that cause a flocculation; that is, the attraction of the clay platelets to one another making large clay particles. The creation of flocs occurs at the expense of a void forming environment. The increased size of the clay particles inhibits their collapse that would cause voids to form in areas of structural weakness such as air pockets. Drying cracks are also not present in shell tempered ceramics again indicating decreased shrinkage of the clay minerals.

The use of shell as a tempering agent while solving the problem of highly saturated clays creates another, lime spalling. Lime spalling is caused by the expansion of the calcium bydroxide $Ca(OH)_2$. It has been found that through the addition of NaCl to the clay lowers the onset of sintering and acts as a catalyst during the calcination of $CaCO_3$. The ethnographic usage of saltwater for construction of shell tempered vessels lends credence to this hypothesis (Rye 1976). None of the cubic void surrounded by a sodium reaction ring (Stimmell, Heimann and Hancock 1982) were observed in the Mississippian ceramics observed, but in view of the small amount of salt needed this should not be considered unusual.

Two of the samples, Misc. 1002 and Misc. 1003, have arc-shaped voids caused by smoothing and folding excess clay from rim construction over to form the lip. Both of these samples have small, dark-rimmed voids which may represent the burning out of organic material and a carbon deposit as a result.

The lower Illinois River Valley's long ceramic history may be described as a tradition. That is, while some stylistic and minor technological changes occurred, the basic method of forming vessels remained the same throughout the ceramic period. Many features are found in ceramics of each time period and probably constitute a literal passing-down of pottery-making knowledge from generation to generation. This concept of tradition can best be grasped when the ceramics from all periods are compared to one another to look at common features.

Coiling as expressed by the presence of coil joins is found in few sherds. Yet examples of coil joins are found in Hopewell, White Hall, Jersey Bluff and, possibly, Baehr/ Pike ceramics. Coil joins are an uncommon feature for two reasons. Coils are areas of weakness, and a poor coil join might cause the vessel to break along this zone of weakness. Consequently, potters made every attempt to get a good coil weld. Secondly, as all of these vessels were probably thinned by paddle and anvil, substantial reduction in coil from about 1½ inches in diameter to about ½ inch in thickness and 4½ inches in height (Fontana, et al. 1962:65). Coils in Illinois ceramics, after they had been squeezed into their final height and thickness, range from 3.5 cm (Augs II -3) to 1.75 cm (Ap 123a). Recognize, however, that these are rim coils and, and such, were subjected to a process which has removed excess clay in smoothing the lip after the vessel had been formed.

Compression voids caused by the presence of air trapped during the kneading process and given their preferred orientation by paddling are found in ceramics throughout the ceramic sequence with few exceptions. These exceptions in Peisker, Hopewell, and Baeher/Pike sherds may be due to greater pressure exerted on the clay during vessel thinning. The rarity of compression voids in Mississippian ceramics requires another explanation. Paddle and anvil thinning is suggested in Mississippian ceramics by the strong orientation of the temper particles. Mushroom shaped pottery anvils have been recovered from Mississippian sites in the lower Illinois River Valley. In Mississippian vessels there are air pockets which are only slightly oriented parallel to the vessel walls. This may indicate the use of larger-diameter coils in the construction of Mississippian vessels. The use of larger coils would make a thicker pot, if the coils were not compressed very much, and therefore would not deform the air pockets to any great extent.

The method by which rims were formed was not always indicated by voids, as, often, they did not extend to the lip area. The direct smoothing of the lip by the potter, as illustrated in Figure 6, is the common method practiced by potters from the Early Woodland to Mississippian period. The method of squeezing or cutting off excess clay, as illustrated in Figure 7, is found only in Havana and Hopewell ware. One example of this may also be present in Misc. 1002, but this sample more likely represents the complete rounding of the lip by use of clay left after forming the rim, as shown by the arc-shaped void and the orientation of the shell-tempered particles. The folded Hopewell rim Ap 21-141 remains unique in the collection.

Drying cracks are found in ceramics of all periods but are less common in Hopewell and Mississippian ceramics, indicating better control over the amount of temper used versus the amount of shrinkage expected in the clay. It is interesting to note that the ceramic type with the most drying cracks, White Hall ware, also was the most abundantly tempered. This may indicate a change in clay resource utilization from the source used at an earlier period and learning to cope with a moister clay.

Leaching voids are present only in limestone-tempered ceramics and often have some limestone occupying a much larger void. These voids are found in most limestone-tempered sherds.

Ceramics from the lower Illinois River Valley have, throughout their history, been formed by coiling and the coil built to walls thinned by the use of paddle and anvil. Other methods of vessel-shaping were products of a combination of individual potters' desires and the culture which produced the potters.

While the analysis of the shapes of voids has revealed much about prehistoric ceramic manufacturing processes, it leaves tantalizing questions for future research. For example, at what temperature do the different clays used form drying cracks, and is the variability in drying cracks due to differences in clay mineralogy, amount of temper, or firing temperature? More experiments need to be carried out in the realm of experimental void forming. Replicative experiments carried on by the Center for American Archaeology could provide much in the way of controlled comparative information. Perhaps in future such studies in voids and other features visible in oriented thin sections will provide clues toward producing a more complete technological and behavorial history of prehistoric ceramic production.

## ACKNOWLEDGMENTS

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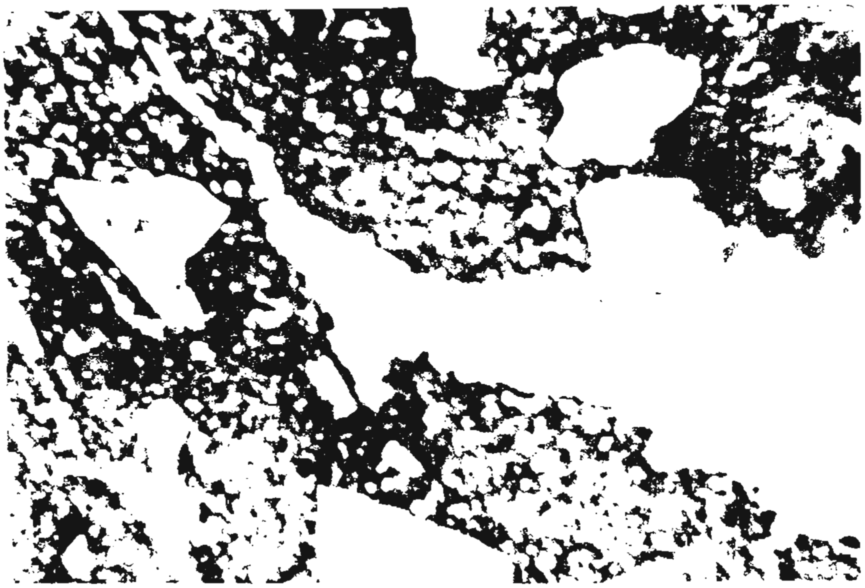

Figure 1: Coil join in Mancos Corrugated sherd: CN2826 Ewing Site Colorado. The amount of dye which has penetrated between the two coils indicates a good coil join. Exterior of the vessel is to right.

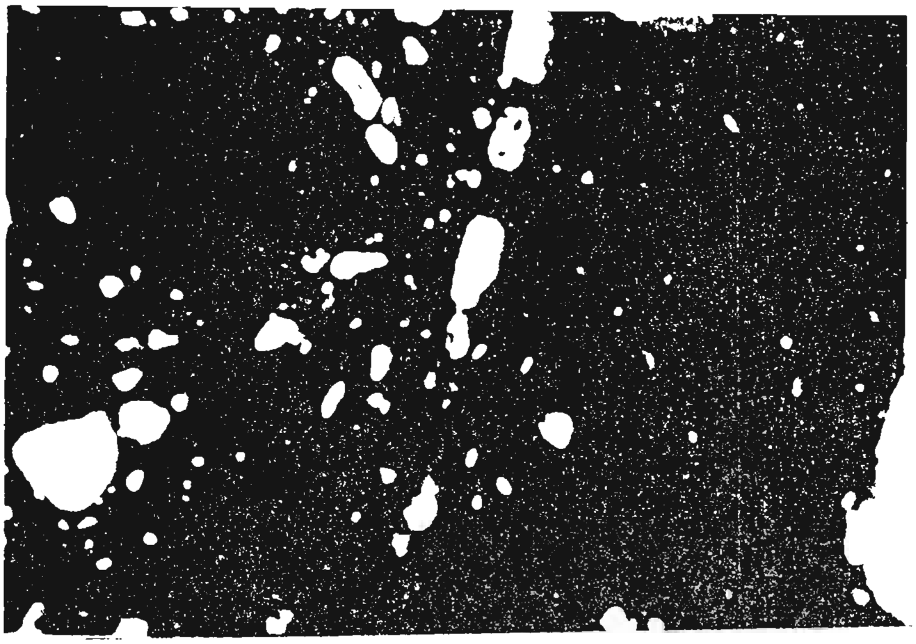

**Figure 2:** Coil join in Jersey Bluff sherd: Auds II -3. Poor coil join between coils of dissimilar pastes. The smooth sided void between the two coils is an air pocket caused by not compressing the coils together. Exterior of the vessel is to right.

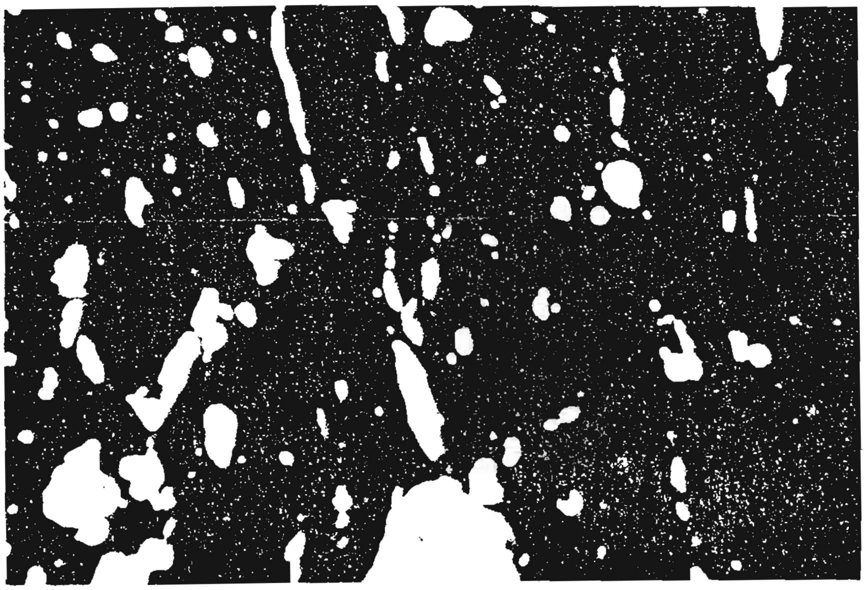

Figure 3: Compression voids in Baehr/Pike Scratched: Ap 552a-1. The parallel orientation of fairly smooth-sided voids is diagnostic. The exterior of the vessels is to right.

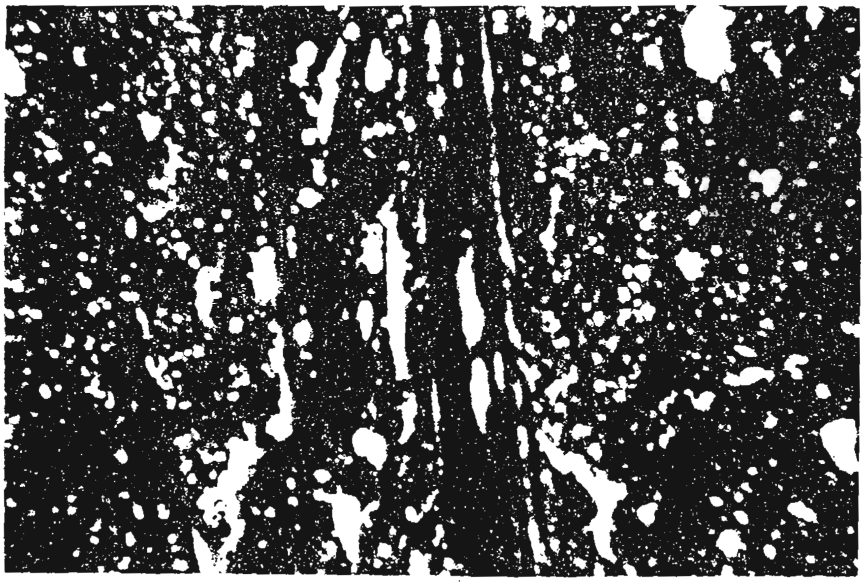

Figure 4: Compression voids in Mississippian Jar:. The particles of shell temper are oriented parallel to the vessel walls. The exterior of the vessel is to the left.

Figure 5: Deformation of compression voids of White Hall Cord marked: Ap 185e(2). Smoothing of the lip truncates compression voids and leaves a clay film which caps some voids. The exterior of the vessel is to the left.

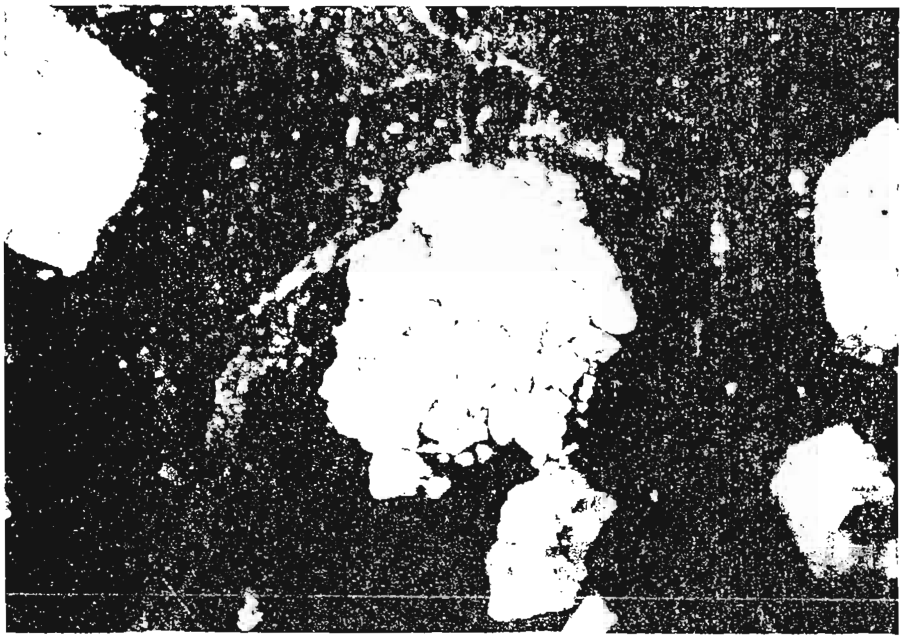

Figure 6: Deformation of compression voids at lip of Jersey Bluff Per 1-5-2. The curved compression voids indicate that the lip was shaped by folding it over onto itself. The exterior of the vessel is to the left.

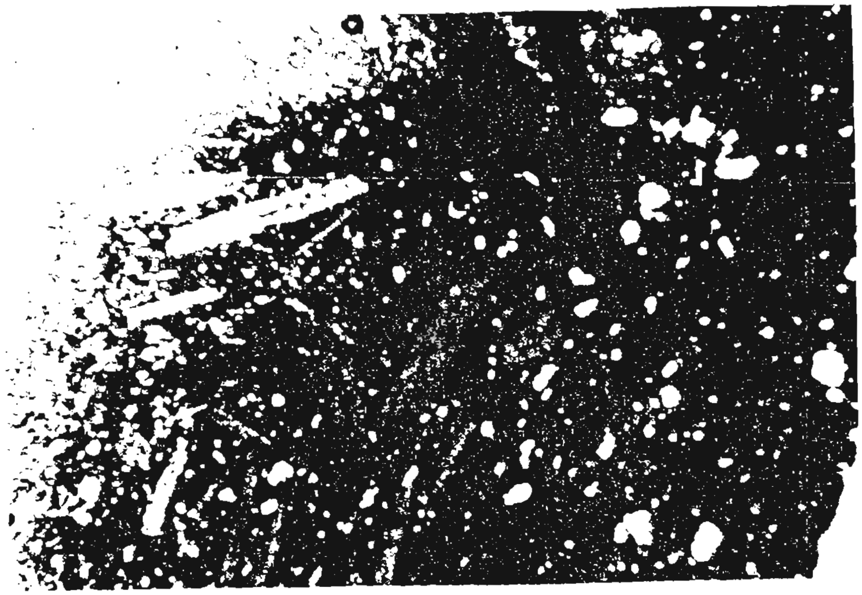

Figure 7: Deformation of compression voids and temper particle alignment at the rim of a Cowley Plain sherd, Rice County, Kansas. The verticle orientation of the temper particles and voids have been modified by the rounding off of the lip.

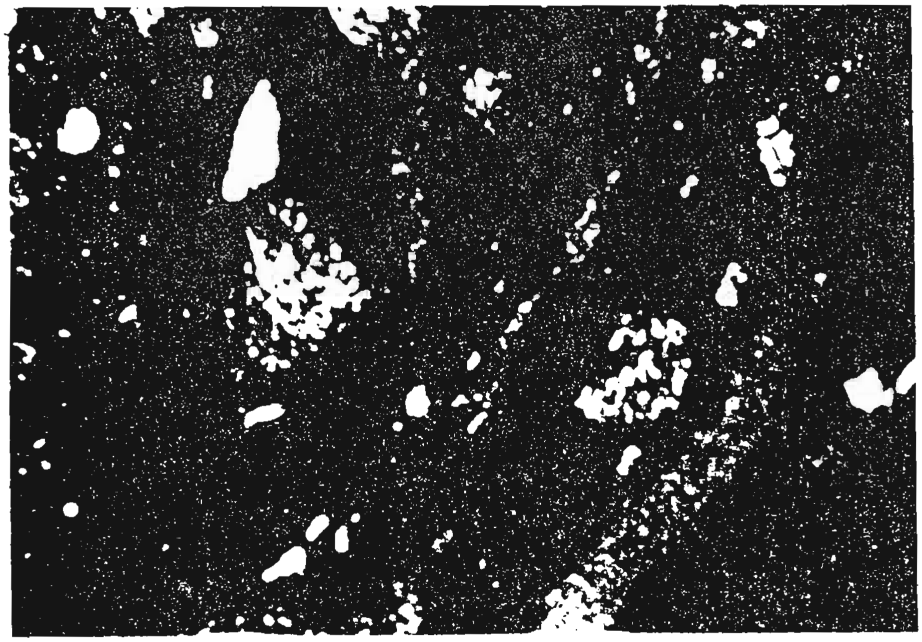

**Figure 8:** Deformation of compression voids of Havana Cord Wrapped Stick: Ap 112B'66. These compression voids were deformed by a punctation $90^{o}$ perpendicular to their original orientation. The exterior of the vessel is to the left.

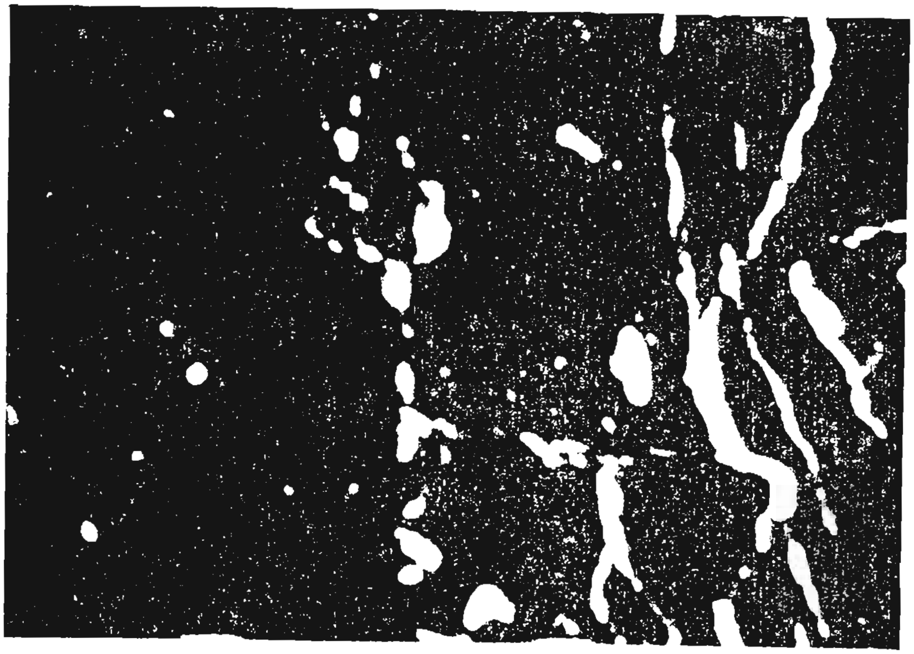

Figure 9: Drying cracks in Baehr Zoned Rocker: Md-1-A(2). The drying cracks run through both paste and through the crushed sherd temper particles. Note their strong orientation paralleling the vessel walls. The exterior of the vessel is to the left.

Figure 10: Drying cracks in Peisker Pinched: PSK I 13A-7. The paste has drawn away from the temper particles. The exterior of the vessel is to the left.

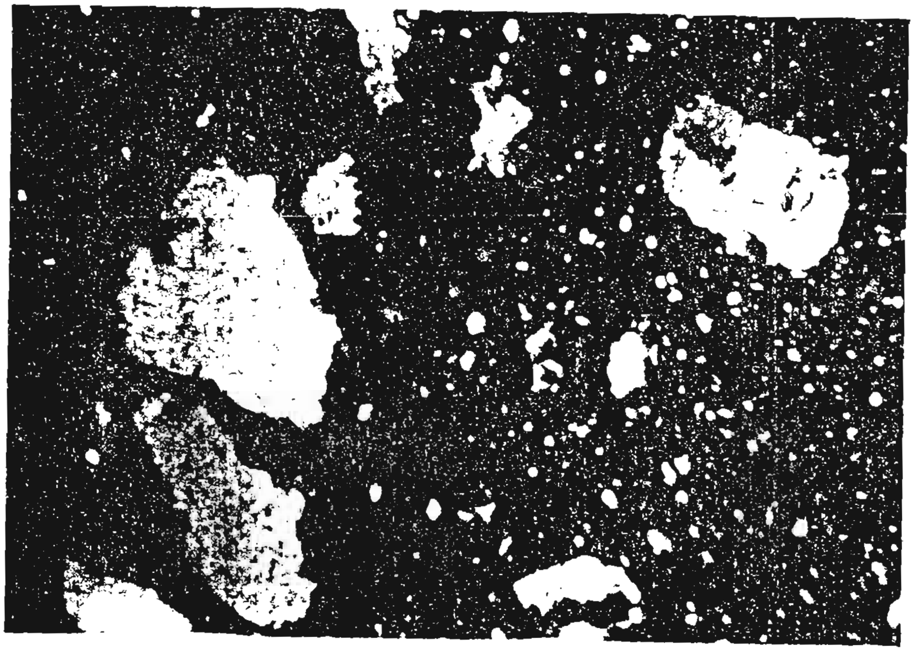

Figure 11: Leaching voids in Montezuma Punctate: PSK 241-12. Note the vertical orientation of the leaching voids. The mineral occupying the void at the right is limestone. The exterior of the vessel is to the right.

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