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</tr>
<tr>
<td></td>
<td>1427 s</td>
<td>969.82</td>
<td>963.49</td>
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<td>1433 s</td>
<td>969.74</td>
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<tr>
<td></td>
<td>1806 s</td>
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<td></td>
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<td></td>
<td>1816 s</td>
<td>929.31</td>
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<tr>
<td></td>
<td>1970</td>
<td>s</td>
<td>905.95</td>
<td>1042.15</td>
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<td></td>
<td>1102 s</td>
<td>906.78</td>
<td>937.47</td>
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</table>
Figure 13.02. Polar Coordinate Grid for Uniface Measurement.

Uniface Descriptions

All 176 unifaces collected at Hop Hill, like the bifaces, were not "collector's pieces", although they provide important information for the archaeologist. A coding form was created to collect the maximum amount of information from each uniface. The shape of each uniface was then measured on a polar coordinate grid. The artifact was placed on the grid (Figure 13.02) with the bit toward the upper end of the grid so that the cord interface line (separation of bit from haft) is defined by axis X and divided into two equal segments by axis Y.

After various runs of principle components analysis on the data, a principal components analysis of the polar coordinate measurements resulted in the separation of bit from haft. This study and a previous one indicate that the bit and haft of unifaces are the best discriminators between typological, and perhaps in the future functional, subgroups of unifaces. Based on these results, component scores were plotted along these two dimensions, with haft size along the y axis and bit size along the x axis (See Figure 13.03). This plotting aided in the separation of seven major groups of unifaces and twenty-four subgroups which served as the basis for the following typology.

1.0 End Trimmed Unifaces N=20

All specimens are trimmed at the end opposite from the bulb of percussion, typically the longest axis (Weir 1976:66). The specimens are further subdivided according to bit and haft size.
1.1 End Trimmed Unifaces, Small to Med. Haft/Small Bit

(N=3, L $\bar{x}$=29 mm, W $\bar{x}$=37 mm, Th $\bar{x}$=7 mm, Wt $\bar{x}$=11 gm, Bcl $\bar{x}$=32)

See Table 13.01 for FN's and provenience. The members of this group have a straight to semi-concave edge and are subtriangular in shape (Figure 13.04). These specimens could have been hafted and are similar to, although not as finely worked as, those specimens found in Coahuila, Mexico (Hester 1971).

1.2 End Trimmed Unifaces, Small to Med. Haft/Med. Bit

(N=9, L $\bar{x}$=33 mm, W $\bar{x}$=29 mm, Th $\bar{x}$=12 mm, Wt $\bar{x}$=12 gm, Bcl $\bar{x}$=29)

See Table 13.01 for FN's and provenience. Members of this group have a convex bit and vary in total outline. Unless these tools were used on very soft or small items, it is also possible that they could be hafted since this process would increase potential force (Figure 13.04b).
Figure 13.04. *End Trimmed Unifaces.* a, group 1.1; b, group 1.2; c, group 1.3; d, group 1.4; e, group 1.5.
Figure 13.05. Unilaterally Trimmed Unifaces. a, group 2.1; b, group 2.2; c, group 2.3; d, group 2.4; e, group 2.5.
1.3 End Trimmed Unifaces, Med. Haft/Med. Bit

(N=3, L $\bar{x}$=43 mm, W $\bar{x}$=46 mm, Th $\bar{x}$=12 mm, Wt $\bar{x}$=27 gm, Bcl $\bar{x}$=40)

See Table 13.01 for FN's and provenience. Members of this group are similar to those from group 1.1 except that they are larger and self-hafted. They have straight bits and are triangular in outline (Figure 13.04c).

1.4 End Trimmed Unifaces, Large Haft/Med. Bit

(N=3, L $\bar{x}$=88 mm, W $\bar{x}$=71 mm, Th $\bar{x}$=42 mm, Wt $\bar{x}$=275 gm, Bcl $\bar{x}$=53)

See Table 13.01 for FN's and provenience. Members of this group are large, self-hafted tools, possibly cores rejuvenated into end trimmed unifaces (Figure 13.04d).

1.5 End Trimmed Unifaces, Med. Haft/Large Bit

(N=2, L $\bar{x}$=55 mm, W $\bar{x}$=55 mm, Th $\bar{x}$=12 mm, Wt $\bar{x}$=55 gm, Bcl $\bar{x}$=55)

See Table 13.01 for FN's and provenience. The two members in this group had bits that were larger than their hafts perhaps due to retouching (Figure 13.04e). They may be examples of exhausted and trimmed unifaces, or perhaps misgrouped due to sampling biases.

2.0 Unilaterally Trimmed Unifaces (N=55)

All specimens are trimmed on one lateral edge (Weir 1976:66). They vary from straight to concave bits and are made on both thin and crude flakes. These tools are usually thought to be cutting rather than scraping tools (Figure 13.05).

2.1 Unilaterally Trimmed Unifaces, Small to Med. Haft/Small Bit

(N=25, L $\bar{x}$=29 mm, W $\bar{x}$=35 mm, Th $\bar{x}$=10 mm, Wt $\bar{x}$=11 gm, Bcl $\bar{x}$=29)

See Table 13.01 for FN's and provenience. The members of this group have convex bits and are usually referred to as convex side scrapers (Figure 13.05a).

2.2 Unilaterally Trimmed Unifaces, Med. Haft/Med. Bit

(N=3, L $\bar{x}$=47 mm, W $\bar{x}$=53 mm, Th $\bar{x}$=22 mm, Wt $\bar{x}$=86 gm, Bcl $\bar{x}$=55)

See Table 13.01 for FN's and provenience. The members of this group have straight to semi-straight bits (Figure 13.05b).

2.3 Unilaterally Trimmed Unifaces, Med. Haft/Large Bit

(N=3, L $\bar{x}$=47 mm, W $\bar{x}$=53 mm, Th $\bar{x}$=22 mm, Wt $\bar{x}$=86 gm, Bcl $\bar{x}$=55)

See Table 13.01 for FN's and provenience. Members of this group, like those from group 2.1, have convex bits but they are much larger (Figure 13.05c).
Figure 13.06. Unilaterally and End Trimmed Unifaces. a, group 3.1; b, group 3.2; c, group 3.3; d, group 3.4.
2.4 Unilaterally Trimmed Unifaces, Med. to Large Haft/Small to Med. Bit
(N=13, L $\bar{x}$=43 mm, W $\bar{x}$=53 mm, Th $\bar{x}$=12 mm, Wt $\bar{x}$=38 gm, Bcl $\bar{x}$=51)

See Table 13.01 for FN's and provenience. Members of this group have irregular outlines and straight bits (Figure 13.05d).

2.5 Unilaterally Trimmed Unifaces, Large Haft/Large Bit
(N=6, L $\bar{x}$=17 mm, W $\bar{x}$=74 mm, Th $\bar{x}$=29 mm, Wt $\bar{x}$=69 gm, Bcl $\bar{x}$=69)

See Table 13.01 for FN's and provenience. Members of this group have convex bits (Figure 13.05e).

3.0 Unilaterally and End Trimmed Unifaces (N=18)

All specimens are trimmed at the end opposite the bulb of percussion and along one lateral edge. They vary from the large core type to the small flake type.

3.1 Unilaterally and End Trimmed Unifaces, Small Haft/Med. Bit
(N=2, L $\bar{x}$=25 mm, W $\bar{x}$=29 mm, Th $\bar{x}$=8 mm, Wt $\bar{x}$=3 gm, Bcl $\bar{x}$=39)

See Table 13.01 for FN's and provenience; also see Figure 13.06a)

3.2 Unilaterally and End Trimmed Unifaces, Med. Haft/Small to Med. Bit
(N=9, L $\bar{x}$=38 mm, W $\bar{x}$=44 mm, Th $\bar{x}$=10 mm, Wt $\bar{x}$=24 gm, Bcl $\bar{x}$=42)

See Table for FN's and provenience; also see Figure 13.06b.

3.3 Unilaterally and End Trimmed Unifaces, Large Haft/Small to Med. Bit
(N=6, L $\bar{x}$=52 mm, W $\bar{x}$=48 mm, Th $\bar{x}$=14 mm, Wt $\bar{x}$=48 gm, Bcl $\bar{x}$=36)

See Table 13.01 for FN's and provenience; also see Figure 13.06c.

3.4 Unilaterally and End Trimmed Unifaces, Large Haft/Large Bit
(N=1, L $\bar{x}$=95 mm, W $\bar{x}$=102 mm, Th $\bar{x}$=40 mm, Wt $\bar{x}$=310 gm, Bcl $\bar{x}$=36)

See Table 13.01 for FN's and provenience; also see Figure 13.06d.

4.0 Bilaterally and End Trimmed Unifaces (N=20)

All specimens are trimmed at the end opposite the bulb of percussion and along two semi-parallel edges (Weir 1976:66). The specimens progress in a linear fashion from very small "thumbnail" unifaces to large ovates (Figure 13.07).
Figure 13.07. Bilaterally and End Trimmed Unifaces. a, group 4.1; b, group 4.2; c, group 4.3; d, group 4.4; e, group 4.5.
4.1 Bilaterally and End Trimmed Unifaces, Small Haft/Small to Med. Bit
(N=6, L x=21 mm, W x=19 mm, Th x=4 mm, Wt x=3 gm, Bcl x=19)
See Table 13.01 for FN's and provenience. Members of this group are commonly known as thumbnail scrapers. They are made on interior flakes (Figure 13.07a).

4.2 Bilaterally and End Trimmed Unifaces, Small Haft/Med. Bit
(N=3, L x=20 mm, W x=32 mm, Th x=14 mm, Wt x=16 gm, Bcl x=24)
See Table 13.01 for FN's and provenience. All members of this group are made on interior flakes and have irregular retouch (Figure 13.07b).

4.3 Bilaterally and End Trimmed Unifaces, Small Haft/Med. to Large Bit
(N=4, L x=39 mm, W x=46 mm, Th x=25 mm, Wt x=29 gm, Bcl x=32)
See Table 13.01 for FN's and provenience. Members of this group are made in a manner that suggests that they were hafted (Figure 13.07c).

4.4 Bilaterally and End Trimmed Unifaces, Small Haft/Large Bit
(N=2, L x=64 mm, W x=70 mm, Th x=23 mm, Wt x=112 gm, Bcl x=44)
See Table 13.01 for FN's and provenience; also see Figure 13.07d.

4.5 Bilaterally and End Trimmed Unifaces, Med. Haft/Med. to Large Bit
(N=4, L x=44 mm, W x=52 mm, Th x=14 mm, Wt x=38 gm, Bcl x=50)
See Table 13.01 for FN's and provenience. Members of this group have a very ovate outline and are finely worked (Figure 13.07e).

4.6 Bilaterally and End Trimmed Unifaces, Large Haft/Large Bit
(N=1, L x=68 mm, W x=72 mm, Th x=27 mm, Wt x=111 gm, Bcl x=71)
See Table 13.01 for FN's and provenience; also see Figure 13.07f.

5.0 Circular Trimmed Uniface (N=1)
This was the only circular trimmed uniface recovered during the Hop Hill survey. It is from the same area of the specialized core group (Figure 13.08a)

6.0 Miscellaneous Trimmed Unifaces (N=23)
These specimens were irregularly trimmed items which did not cluster with any specific subgroup of unifaces. These tools may be examples of the sporadically made tools.
Figure 13.08  Circular Trimmed and Notched Unifaces.  a, group 5.0; b, group 7.1; c, group 7.2; d, group 7.3; e, group 7.4.
7.0 Notched Trimmed Unifaces (N=28)

All specimens have a trimmed indentation, usually made by pressure flaking (Crabtree 1972:79). The specimens vary from notched flake-blades to irregular notched pieces. Notched pieces have been thought to be woodworking tools.

7.1 Notched Trimmed Unifaces, Small to Med. Haft and Small Bit

(N=15, L $\bar{x}$=25 mm, W $\bar{x}$=32 mm, Th $\bar{x}$=7 mm, Wt $\bar{x}$=41 gm, Bc1 $\bar{x}$=29)

See Table 13.01 for FN's and provenience. Members of this group are typical of flake-blades and three members are double notched (Figure 13.08b).

7.2 Notched Trimmed Unifaces, Med. Haft/Small Bit

(N=6, L $\bar{x}$=33 mm, W $\bar{x}$=44 mm, Th $\bar{x}$=11 mm, Wt $\bar{x}$=18 gm, Bc1 $\bar{x}$=30)

See Table 13.01 for FN's and provenience. Members of this group are made on small interior flakes and are single notched specimens (Figure 13.08c).

7.3 Notched Trimmed Unifaces, Med. to Large Haft/Small Bit

(N=5, L $\bar{x}$=40 mm, W $\bar{x}$=57 mm, Th $\bar{x}$=23 mm, Wt $\bar{x}$=35 gm, Bc1 $\bar{x}$=34)

See Table 13.01 for FN's and provenience. Members of this group are made on long flakes (Figure 13.08d).

7.4 Notched Trimmed Unifaces, Large Haft/Small Bit

(N=2, L $\bar{x}$=53 mm, W $\bar{x}$=57 mm, Th $\bar{x}$=17 mm, Wt $\bar{x}$=62 gm, Bc1 $\bar{x}$=32)

See Table 13.01 for FN's and provenience. Members of this group are irregular in outline and tend to have larger notches (Figure 13.08e).

Conclusion

The purpose of this study was not to create a whole array of dangling categories, but to develop a tool which might facilitate future uniface research. This environmentally oriented method is not considered to be sufficient in and of itself. It must be implemented in conjunction with other techniques such as microwear analysis and the new information being discovered on extractions of organic materials from unifaces. Only then may the envirocultural associations begin to be drawn.
14.0 AN EXPERIMENT IN STONE BOILING (W. Max Witkind)

During the survey and excavation of the Hop Hill locality, a large collection of fire-altered limestones, tentatively identified as "boiling stones", was recovered from what have been interpreted as cooking areas. The following report presents condensed data generated in a preliminary experiment endeavoring to produce stones exhibiting colors, textures, surface fissures and fracture angles similar to those boiling stones recovered from Hop Hill.

Experiment Procedures

The test specimens used in conducting this experiment included dolomite stream cobbles, pieces of tabular dolomite and pieces of tabular limestone collected from four separate locations and divided into Groups A, B, C and D. The specimens ranged from six centimeters to twelve centimeters in diameter.

All firing was done in a medium-sized campfire of oakwood. Fire temperature was measured with Orton standard pyrometric cones #21 and #15. The temperature of the fire during the testing procedures reached 1140°F but did not exceed 1480°. Pre-firing and post-firing weights were measured on a single-beam balance scale. Color coding was done with a Geological Society of America Rock-Color Chart. Boiling was done in a fifteen-quart, plastic dishpan.

Groups A, B and C were used primarily in test runs to discover obtainable temperatures and to establish control procedures for firing and boiling Group D. Data was derived from analysis of Group D specimens.

Group D

Group D included 34 tabular dolomite and tabular limestone specimens. The specimens were divided into two groups, designated as Series I and Series II, and numbered one through 34. Series I included specimens one through ten. Series II was selected and randomly and included specimens 11, 13, 14, 16, 17, 19, 26, 28, 29 and 30 (see Table 14.01). The remaining specimens were not fired but held for later comparison. The specimens in Series I were fired and boiled twice. The Series II specimens were fired and boiled once.
### TABLE 14.01 BOILING STONE DATA
GROUP D

<table>
<thead>
<tr>
<th>Rock #</th>
<th>Pre-fire Weight (grams)</th>
<th>Pre-fire Color</th>
<th>Post-fire Weight</th>
<th>Post-fire Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>351.6</td>
<td>10YR8/2 VPO</td>
<td>334.4 +</td>
<td>10R616 to 5R812</td>
</tr>
<tr>
<td>2</td>
<td>208.3</td>
<td>10YR8/2 VPO</td>
<td>204.6 +</td>
<td>10R812 to 5R812</td>
</tr>
<tr>
<td>3</td>
<td>308.5</td>
<td>10YR6/2 PYB</td>
<td>292.7 +</td>
<td>10R616 to 10YR812</td>
</tr>
<tr>
<td>4</td>
<td>567.3</td>
<td>&quot;</td>
<td>336.5</td>
<td>10R616 to 10YR812</td>
</tr>
<tr>
<td>5</td>
<td>625.5</td>
<td>5YR7/2 GOR</td>
<td>578.0</td>
<td>10R616 to &quot;</td>
</tr>
<tr>
<td>6</td>
<td>617.8</td>
<td>5YR6/14</td>
<td>602.8 +</td>
<td>&quot;</td>
</tr>
<tr>
<td>7</td>
<td>624.3</td>
<td>10YR8/12 VPO</td>
<td>608.1 +</td>
<td>&quot;</td>
</tr>
<tr>
<td>8</td>
<td>493.5</td>
<td>&quot;</td>
<td>472.5 +</td>
<td>&quot;</td>
</tr>
<tr>
<td>9</td>
<td>588.0</td>
<td>10YR6/12</td>
<td>550.0</td>
<td>&quot;</td>
</tr>
<tr>
<td>10</td>
<td>682.0</td>
<td>10YR8/12</td>
<td>667.3 +</td>
<td>&quot;</td>
</tr>
<tr>
<td>11</td>
<td>706.0</td>
<td>5YR8/14</td>
<td>702.0 +</td>
<td>5YR6/14+White</td>
</tr>
<tr>
<td>12</td>
<td>466.2</td>
<td>5YR8/14</td>
<td>372.6 ?</td>
<td>5YR8/14 &amp; 10YR812</td>
</tr>
<tr>
<td>14</td>
<td>804.6</td>
<td>&quot;</td>
<td>798.9 +</td>
<td>5YR6/14 &amp; Lt. Grey</td>
</tr>
<tr>
<td>16</td>
<td>815.0</td>
<td>&quot;</td>
<td>763.4</td>
<td>10R616 &amp; 10YR812</td>
</tr>
<tr>
<td>17</td>
<td>622.5</td>
<td>5YR8/16/10YR7/14</td>
<td>583.7</td>
<td>10R616 &amp; &quot;</td>
</tr>
<tr>
<td>19</td>
<td>534.4</td>
<td>10YR6/12</td>
<td>426.5</td>
<td>10R812 to 10R616</td>
</tr>
<tr>
<td>26</td>
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<td>10YR8/16</td>
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<td>10R812 to 10R616</td>
</tr>
<tr>
<td>28</td>
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<td>10YR6/12</td>
<td>349.4 +</td>
<td>10YR7/14 to Stark White</td>
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<td>699.2</td>
<td>5Y411</td>
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<td>10R616 to White</td>
</tr>
<tr>
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<td>441.1</td>
<td>10YR8/12</td>
<td>435.3 +</td>
<td>10R616 to 5R812</td>
</tr>
</tbody>
</table>

+ = Loss due to moisture release.

Before each of the three boiling procedures the specimens were heated for thirty-five minutes. During their first exposure to the water the Series I specimens raised the water's temperature from approximately 75°F to 212°F within two minutes. The boil was maintained for approximately four and one-half minutes. During their first exposure to the water the Series II specimens raised the water's temperature from approximately 195°F to 212°F within one minute and maintained a hard boil for approximately four and one-half minutes. During their second exposure to the water the Series I specimens required three minutes to raise the water's temperature from approximately 127°F to 215°F. The boil was maintained for only about two minutes. The temperature had dropped to 170°F within 17 minutes.

It is assumed that by rotating freshly-heated stones for cooled stones that a rolling boil could be maintained indefinitely.

**Analysis**

Examination of Group D specimens revealed a marked loss of weight during firing and boiling procedures. A small amount of weight was lost to fragmentation during firing. A major portion of the weight loss seems to have occurred through moisture release.
Changes in color were highly discernible. A major portion of the specimens were pre-fire coded as very pale orange, pale yellowish orange and grayish orange. Post-fire coding revealed changes to moderate reddish orange, grayish orange pink or moderate orange pink. Other specimens changed from orange pink toward gradations of light brown mixed with very pale orange. A number became fringed with light gray or white.

James Pittman (personal communication, San Antonio College, Geology Department) states that the reddish to brown colors which developed during the firing procedures reflect the presence of iron in the limestone and resulted from the oxidizing atmosphere created by the fire.

Examination of the Group D specimens also revealed a rind of material, displaying the various described colors, surrounding a major portion of each specimen. The interior stone toward the core of each specimen appears to have been less affected and altered to a lesser degree than the cortex material.

Each specimen exhibits hairline cracks running over its surface and deep into the stone. Five specimens fragmented along the cracks to produce sharp, angular fracture lines.

Comments

The experiment produced stones exhibiting similar fracture lines, surface texture and color shades to those often labeled as boiling stones by some Texas archaeologists. It should be noted, however, that limestones possibly used in cooking pits to roast or steam meat or vegetable foods might also exhibit similar characteristics. This conjecture is offered because the cracks and color similarities appear to be a product of fire exposure rather than exposure to boiling water. However, stones heated and then exposed to water may in some instances be characterized by a more friable surface texture than stones exposed only to fire. Future tests should be conducted to determine if a friable surface is the most diagnostic characteristic of a boiling stone.

The postulation that burned rock middens, to include the "boiling stones" so often associated with them, are a by-product of acorn-deer processing activities (Hester 1973, Weir 1976)

Richard Welch (personal communication, San Antonio College, Botany Department) states that lime released into boiling water being used to cook acorns would act to neutralize the distasteful tannic acid in various acorn species in South Central Texas. Limestones used in pits to steam acorns might also have similar results. (Experiments to test the neutralizing capability of lime on tannic acid are underway at UTSA.) Bearing this in mind, the possibility that the South Central Texas Indians used heated limestones to boil or steam acorns seems highly possible. Such activity may account for the relative absence of acorn-leaching pits in South Texas such as those described in ethnographic accounts of acorn-gathering Indians of California. Also, leaching away the outer surface of limestone cobbles explains the fossiliferous appearance of boiling stones, assuming the fossils are more resistant to acid.
Visual examination of the rind exhibited by the Group D specimens led to speculation that the boiling activity removed enough lime from the outer surface to render the stone unusable a third or fourth time in cooking acorns. However, casual chemical tests failed to show an appreciable difference between the lime content in the rind of stones boiled twice and the lime present in the surface material of unboiled stones.

The sharp drop in the water's temperature during the second boiling procedure of the Series I specimens suggests that stones used more than once lose heat more rapidly than stones being used for the first time.

The proclivity to fragment after several heating procedures may quite possibly have limited the re-use of stones as either boiling stones or cooking pit stones. This, coupled with the tendency of a reheated stone to lose heat more rapidly than a previously unheated stone, may have also encouraged the use of a stone only several times before it was discarded on a nearby midden. Thousands of stones, each used only a few times by people repeatedly visiting the same location for extended periods of time, could account for the numerous, and sometimes massive, burned rock midden common in South Central Texas.
15.0 CLUSTERING OF TECHNOLOGICAL TYPES (Nonlinear Technospatial Analysis, Resolv 4)  
(Joel Gunn and Douglas R. White)

In primitive societies the one reliable feature of technological structure is division of labor by sex. In archaeological remains, therefore, it should be the generating force behind a large proportion of the observable variation in archaeological assemblages. Several authors have used division of labor as an interpretive device (Binford and Binford 1966, Katz and Katz 1976:120-121, etc.). In this section we review a cross-cultural analysis of division of labor as it pertains to the problem of interpreting the prehistory of Central Texas. The discussion is set in the context of entitlement theory and is therefore methodologically consistent with the nonlinear spatial analysis to follow.

The Division of Labor code (Murdock and Provost 1973) is composed of a cross-cultural sample of 185 societies stratified by continents and randomly selected (Murdock and White 1969) from cultures in the Ethnographic Atlas (Murdock 1967). These 185 societies were coded for division of Labor by sex on 50 technological traits. The cultural complexity of the 185 societies ranges from hunters and gatherers to non-industrial civilizations such as the Romans. On a scale of cultural complexity which ranges from 0 to 40 (Murdock and Provost 1973), zero being the least complex, the societies are distributed as follows:

<table>
<thead>
<tr>
<th>Number</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-20 (Hunters and Gatherers)</td>
<td>122</td>
</tr>
<tr>
<td>21-33 (Agriculturalists)</td>
<td>38</td>
</tr>
<tr>
<td>34-40 (Civilizations)</td>
<td>25</td>
</tr>
<tr>
<td>Total</td>
<td>185</td>
</tr>
</tbody>
</table>

As is apparent, a substantial portion of the standard cross-cultural sample is comparable to the level of cultural complexity we have presumed for all of prehistory in the Central Texas Archaic (see introduction; also Weir 1976). In order to analyze the entitlement structure of the division of labor the data was recorded to 1=female activity and 0=male activity.

Entitlement will be explained in greater detail later. For now let us say that it is an analytical process which determines the relationships between traits from a logical analysis of their presence or absence. If trait X is present, then is trait Y also always present? The technique was developed by White (White et al. 1975) for the analysis of cross-cultural data.

As a focus for discussion White et al. (1975: 4-7) define a formal theory of division of labor. Three assumptions are made at the outset which are derived exclusively from the fact that infants must be nursed in pre-industrial societies where no artificial feeding devices are used. It follows, then, that 1) women as a group will assume primary responsibility for offspring, 2) women (and their offspring) will not be routinely exposed to avoidable danger, 3) women will not travel long distances from home bases.

These assumptions have direct and constraining influences on division of labor. Productive sequences are composed of tasks which can be generalized under
"collecting" and "processing" operations. Tasks for collecting raw materials are to varying degrees inherently dangerous (for example, hunting), while processing activities are not. Typically, then, males collect raw materials and females process them into finished products. Similarly, collecting often requires traveling over long distances while processing is done at the home base.

Since collecting tasks often require that males confront the environment with tough and heavy tools relative to the softer and lighter materials of processing, there is a correlative association of these attributes with the respective sexes.

![Figure 15.01. Base and Range Concept of Site Locality.](image)

As a consequence of these assumptions about child care and productive sequences the habitat of primitive people should be divided into a "Base" and a "Range" as illustrated in Figure 15.01 with the inferred properties as they are assigned. With the site as the center of activities, the Base area is of an order of magnitude of about one mile radius. The Range is of the order of ten miles.

Entailment analysis of the division of labor code produced an entailment digraph (White et al. 1975:12) which contained five activity sets, two of which pertain to the hunter-and-gatherer mode of subsistence. Entailed activities form task sequences; up to five steps long and are generally of the form "if a given sex does task X, and task Y is present, then that sex also does task Y" (White et al. 1975:13).
Cluster I of the analysis (Figure 15.02) is a collection of tasks that can be performed in the Base area or adjacent areas.

10%--------------------------------------------------80%-----------------------------------------------

F(Collect Small Land Fauna)  
F(Pottery)
F(House Building)  
F(Collect Wild Vegetables)  
F(Prepare Vegetable Foods)
M(Netmaking)
M(Care for Domesticated Animals)

Figure 15.02. Food Collecting and Related Tasks. (F=female, M=Male)

In societies characterized by this pattern of tasks houses are temporary and sometimes portable and made of soft, pliable materials such as vegetation or skins. Thus, women collect vegetation for house building and food which is consumed in association with small land fauna which they also collected. When women tend to this task sequence men care for domestic animals. Women make pottery to facilitate food preparation while men make nets for hunting and fishing.

Cluster II is much more complex, consisting of 13 traits (Figure 15.03). The entailments imply task sequences related to processing of meat, skins and fibers, their use and maintenance.

5%-----------------------------------------------45%-----------------------------------------------85%-----------------------------------------------

F(Butchering)  
F(Leather Products)
F(Fishing)  
F(Netmaking)  
F(Process Skins)  
F(Loom Weaving)  
F(Spinning)
F(Rope and Cordage)  
F(Laundering)
F(Mat Making)
F(Preserve Meat and Fish)  
F(Clothing)

Figure 15.03. Meat, Skin and Fiber Processing (F=female).
### Table 15.01 Rotated Principal Components Matrix for Loci Matrix

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VIII</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pointed Bifaces (1.1, 1.2)</td>
<td>.34</td>
<td>.33</td>
<td>-.22</td>
<td>.39</td>
<td>.24</td>
<td>.21</td>
<td>-.26</td>
</tr>
<tr>
<td>2. End Bifaces, Large Choppers (2.1-2.3)</td>
<td>-.10</td>
<td>-.23</td>
<td>.72</td>
<td>.00</td>
<td>-.07</td>
<td>-.12</td>
<td>-.28</td>
</tr>
<tr>
<td>3. End Bifaces, Celt (2.4)</td>
<td>.07</td>
<td>-.10</td>
<td>.00</td>
<td>-.18</td>
<td>.75</td>
<td>-.07</td>
<td>.09</td>
</tr>
<tr>
<td>4. Side Bifaces (3.0)</td>
<td>.02</td>
<td>.00</td>
<td>-.21</td>
<td>-.70</td>
<td>-.23</td>
<td>.14</td>
<td>-.12</td>
</tr>
<tr>
<td>5. Rectangular Bifaces (4.0)</td>
<td>.25</td>
<td>.02</td>
<td>.82</td>
<td>-.02</td>
<td>-.12</td>
<td>-.05</td>
<td>.12</td>
</tr>
<tr>
<td>6. Round Bifaces, T m (5.1)</td>
<td>.18</td>
<td>.78</td>
<td>-.02</td>
<td>-.02</td>
<td>-.01</td>
<td>-.25</td>
<td>.05</td>
</tr>
<tr>
<td>7. Round Bifaces, Thick (5.2)</td>
<td>.03</td>
<td>-.05</td>
<td>.09</td>
<td>.07</td>
<td>-.08</td>
<td>-.14</td>
<td>.85</td>
</tr>
<tr>
<td>8. Oval Biface, Thick (6.1-6.4)</td>
<td>-.14</td>
<td>.80</td>
<td>-.09</td>
<td>-.04</td>
<td>-.13</td>
<td>.01</td>
<td>-.04</td>
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<tr>
<td>9. Ovoid Biface, Small, Thinned (7.1)</td>
<td>-.27</td>
<td>.41</td>
<td>.47</td>
<td>-.00</td>
<td>.05</td>
<td>.15</td>
<td>.48</td>
</tr>
<tr>
<td>10. Ovoid Bifaces, Large, Thick (7.2)</td>
<td>.02</td>
<td>-.01</td>
<td>-.19</td>
<td>.58</td>
<td>-.28</td>
<td>.32</td>
<td>-.19</td>
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<tr>
<td>11. Triangular Bifaces, Small (8.0)</td>
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<td>-.00</td>
<td>-.04</td>
<td>.14</td>
<td>.70</td>
<td>-.04</td>
<td>-.15</td>
</tr>
<tr>
<td>12. Boiling Stones</td>
<td>.84</td>
<td>-.07</td>
<td>.00</td>
<td>.12</td>
<td>-.01</td>
<td>.19</td>
<td>.02</td>
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<td>13. Uniface-End Scraper</td>
<td>.70</td>
<td>.13</td>
<td>.07</td>
<td>.01</td>
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<td>-.09</td>
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<td>.04</td>
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<td>15. Uniface-End-Side Scraper</td>
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<td>16. Uniface-Ovate Scraper</td>
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<td>.74</td>
<td>-.02</td>
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<td>17. Uniface-Circular Scraper</td>
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<td>.08</td>
<td>.08</td>
<td>-.05</td>
<td>.65</td>
<td>-.02</td>
</tr>
<tr>
<td>18. Uniface-Thumbnail Scraper</td>
<td>.15</td>
<td>-.11</td>
<td>-.11</td>
<td>.49</td>
<td>-.05</td>
<td>.65</td>
<td>-.18</td>
</tr>
<tr>
<td>19. Uniface-Edge Altered</td>
<td>.70</td>
<td>-.32</td>
<td>.06</td>
<td>.07</td>
<td>.03</td>
<td>.34</td>
<td>.17</td>
</tr>
<tr>
<td>20. Uniface-Notches</td>
<td>.29</td>
<td>-.00</td>
<td>.09</td>
<td>.58</td>
<td>-.42</td>
<td>.15</td>
<td>.10</td>
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</table>

<table>
<thead>
<tr>
<th>Unifaces &amp; Bifaces</th>
<th>Boiling</th>
<th>Unifaces &amp; Bifaces</th>
<th>Unifaces</th>
<th>Bifaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variance Accounted for</td>
<td>12%</td>
<td>15%</td>
<td>9%</td>
<td>11%</td>
</tr>
<tr>
<td>Table 15.02 Hypothesized Tool Kits from Hop Hill</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**BIFACES**

II. Round Bifaces, thin  
   *Oval Biface, thick  
   Ovoid Bifaces, small  

VIII. *Round Bifaces, thick  
      Ovoid Bifaces, small  

III. *End bifaces, chopper  
     Rectangular Bifaces  
     Ovoid Bifaces, small  

V. End Biface, Celt  
    *Triangular Biface, small, thinned  
    -Notches  

**UNIFACES**

I. *Boiling Stones  
   End Scraper  
   Side Scraper  
   Edge-Altered Flake  

VI. Ovate Scraper  
    Circular Scraper  
    *Thumbnail Scraper  

**BIFACES AND UNIFACES**

IV. Pointed Bifaces  
    Side Bifaces  
    Ovoid Bifaces, large, thick  
    Side Scraper  
    End-Side Scraper  
    Thumbnail Scraper  
    *Notches  

* indicates pivotal tool
The digraphs illustrated here represent half the analysis. The range of percentage points across the top of each digraph shows to what degree females manage the various tasks represented below them. Thus, in very few cultures do women butcher (5%), but where they do butcher they manage all tasks subsequent to butchering in a task sequence, i.e., processing of skins, making leather items, preserving meat. The entailments clearly show that once females enter the task sequence they do not return control to males at any succeeding task. The other half of the analysis, then, is simply a story of males dropping out of the task sequence at varying junctures. If females butcher in 5% of the cultures, then males do so in 95%. It is largely a male task. When it comes time to produce leather products, on the other hand, the male component has dropped to 55% and females have taken over the sequence in 45% of the cultures. Finally, preserving meat is an almost exclusively female endeavor.

In terms of the Base-Range continuum this analysis is Base-oriented. A Range-oriented analysis need only reverse the process. Tasks which do not appear because of the base orientation are those tasks which are exclusively male, tasks which are carried out in the Range or are related to hard materials such as hunting, trapping, foraging, collecting honey, working in stone, wood, horn, bone and shell, mining, quarrying, smelting of ore, metal working, etc.

Finally, firemaking (F=28%), gathering shell fish (F=69%) and fuel gathering (F=71%) form no implications because they are not a part of any production sequence and therefore are not systematically related to collecting and processing variables.

Although we cannot observe the range of tasks practiced by the prehistoric inhabitants of Central Texas directly, we can reasonably assume that their daily activities formed a subset of the task sequences observed in a worldwide sample of human behavior at a comparable level of cultural complexity. While we presume to draw no direct analogies between these patterns and prehistoric populations we do take the patterns to be a rich source of hypotheses which can be tested by various means (Binford 1967).

In fact, we have very little to build from by way of developing hypotheses of tool kit structure. Few ethnohistorical observations were collected on the pre-Apachean and Comanchean peoples of Central Texas. Virtually none were made on use of stone tools. We will, therefore, assume a very simple model of stone tool usage based on manufacturing technology. Scrapers are known for a number of reasons to be associated with (at least) skin preparation. We will generalize this and say that unifacial knapping techniques were a female tool technology. This is taken to mean that women generally use unifaces whether they make and maintain them or not. Core and bifacing technologies, on the other hand, are presumed to be of male manufacture and use. Hunting implements, such as points for instance, are often bifacial.

It should be stated at the outset that we know the hypothesis is true only in part. Unifaces are effective woodworking tools; Hester, Gilbow and Albee (1973) have demonstrated that Clear Fork tools were almost assuredly wood or bone working
implements. Furthermore, there are time trends in the Central Texas Archaic
(800-8000BP) which show that unifaces gradually are replaced through time by
bifaces (Gunn and Weir 1976). The only argument we can make here (and on
tenous grounds) is that the site appears to have been occupied predominately
in the Middle and Late Archaic time intervals, during which bifacing was the
predominant stone tool manufacturing technique (Gunn and Weir 1976).

With the tenuosity of the uniface-biface pattern in mind we can only assume
that it was the predominant trend in the tool kit structure and test the data
for that pattern. When breaches of the pattern occur we will then attempt to
determine their meaning on an ad hoc basis.

Additionally, one other tool class is large enough in sample size to affect
the analysis and may be of help in factoring out various interpretations.
Boiling stones are common on the site. As the cross-cultural data show cooking
food is a virtual female preserve in societies of low complexity. Anything
strongly associated with boiling stones should be female related.

Nonlinear Distribution Analysis Loci Matrix

Nonlinear distribution analysis as it is devised here is a strictly type
oriented approach to the distribution, and association, of artifacts over
a habitation space. Each artifact in that space is a type at a locus to which
others types are potentially associated. A "loci matrix" is composed of a
series of row vectors each of which represents a locus (artifact) in the
habitation space (Base and Range) of a site. The columns in the matrix
represent types of artifacts. This matrix is illustrated in Figure 15.04 where
T=type and L=locus. There are n

<table>
<thead>
<tr>
<th></th>
<th>T₁</th>
<th>T₂</th>
<th>T₃</th>
<th></th>
<th>E</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>L₁</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
<td>0</td>
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<td>1</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Lₘ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 15.04. Loci Matrix for Nonlinear Distribution Analysis.

Types and m loci. E and N are binary representations of east and north
respectively. Two of the rows are filled in with 1's and 0's to illustrate
the content of the matrix. A "1" means that type occurs within a specified
distance from the locus, let us say 5 meters for this example. A 0 (zero)
means it does not. Suppose that the locus is a T₂ artifact. The locus
itself is assigned a 1 in L₁ by T₃. The zero in L₁ by T₁ shows that there are
no T₁ artifacts within 5 meters of Locus 1. A 1 in L₁ by T₃, however, shows
that at least one T₃ occurs within 5 meters.
The following discussion is based on such a matrix constructed for 20 types and 347 loci. The artifacts were virtually all surface-collected from the Hop Hill locality in Central Texas. Since they represent deflated occupation floors the artifacts from different times are mixed together. We will assume, however, that the mixing process will not produce patterned association between artifact types resulting in artificial tool kits. It is important only that artifacts not be moved away from each other to preserve the integrity of the tool kits.

The program which determines the contents of the Loci Matrix does so by sweeping around each artifact within the limits of a criterion radius and determining the types of artifacts within that radius. For each artifact within the radius a 1 is entered in the appropriate type column. Before proceeding further an understanding of the importance of the criterion distance needs to be made explicit. The radius is set according to the level of social organization one wishes to test for patterned relations between types. Working up the hierarchy, the individual, the nuclear family and the band each requires a minimum amount of space in which to operate comfortably. Although these opinions can be altered according to various researchers we have set the criterion radii as follows:

- individual: 1 meter
- family: 5 meters
- band: 20 meters

It would probably do more harm to set the criterion radii too low than too high. "Too high" will just pick up more random associations while "too low" will eliminate part of the pattern.

Once the nonlinear relations between types are represented in a loci matrix they can be analyzed by any standard technique. As we have seen, entailment is peculiarly well adapted for showing operational sequences. Ultimately, then, we will rely on entailment. For the sake of comparison, however, a brief discussion of a principal components analysis of the data follows.

The loci matrix analyzed below was constructed on the basis of 347 artifacts divided into 20 types. The 5-meter radius criterion was used so the discussion involves the association of tools at the family level of social organization.

Principal components analysis extracted seven eigenvalues greater than 1.0 which accounted for 66% of the variance in the Loci Matrix. These seven components were rotated to varimax criteria. Table 15.01 shows the rotated components matrix.

Of the subsets of tools in the matrix components II, III, V, and VIII are bifacial. I and VI are unifacial and IV contains elements of both technologies. The combinations are displayed in Table 15.02.
Some suggestions as to the import of these clusters of tools can be drawn by using the "pivotal tool" concept (Gunn and Weir 1976). A pivotal tool is the tool in a numerically inferred tool kit which is best understood functionally. Pivotal tools are asterisked in Table 15.02.

The biface tool kits are crosscut by small, ovoid bifaces with one exception. These are probably preforms for projectile points. Because of errors in the knapping procedure most are detectably incomplete and were discarded. They could have been used as knives. Pivotal tools other than ovoid bifaces have been marked because the invariant distribution of the small ovoids detracts from their power as an indicator of functional variability. The pivotal elements in Tool Kits II and VIII suggest bifacial cores, so these tool combinations probably occur in lithic workshop areas. Tool Kit III, on the other hand, appears to be a functional association as the presence of the small end biface choppers suggests. Elsewhere it has been suggested that these are food-processing tools (Gunn and Weir 1976). However, their association here with two kinds of bifaces which require highly sophisticated knapping techniques probably implies male activities and calls that hypothesis into question.

Tool Kit V is composed of two bifacial types. The negative loading for notches means they are never present with celts and small, triangular bifaces. Apparently small ovoid bifaces became associated with celts once they were successfully converted into small, thinned, triangular bifaces. The ubiquitous presence of small thinned bifaces of varying types in bifacial tool kits deserves future consideration.

There are two purely uniface tool kits: I and VI. The association of boiling stones with I implies a food preparation orientation. Edward Droste of San Antonio has studied the native uses of cactus and believes peoples of the Southwest would have used flakes and scrapers to remove spines from cactus during preparation for use as food. Whether the relationship is as direct as that, or indirect as in the case where food is prepared in a normally common space with hide preparation, the tool kit suggests a clearly female orientation.

Tool Kit VI is composed of morphologically well defined scraper types. It might be a female tool kit. Alternatively, it could be a woodworking tool kit made and used by males. Thumbnail scrapers are probably the remnants of hafted scrapers which have been resharpened nearly to extinction. Males are usually given to such elaborations ethnographically while females are not.

Tool Kits IV and V are composed of both unifaces and bifaces. Tool Kit IV is a combination of source materials, heavy implements (pointed bifaces), scrapers and notches. Notches of the larger size implied here could be useful for preparing round objects such as shafts, bone points, etc. It is probably a tool preparation and maintenance kit of male usage.

The relationships between artifacts as tool kits and their consequent inferred functional and sexual associations can only be taken as hypotheses which suggest direction for future research. In the following analysis of the same
data, however, Entailment Analysis which calculates statistical tests of these relationships will be used.

In addition to statistical inference, Entailment Analysis allows the researcher a detailed and complex view of relationships in the data. Entailment is at its base the analysis of a 2 x 2 contingency table. Figure 15.05 shows such a contingency table for variables X and Y. Within each cell is the logical implication of finding the relationship between X and Y in that position.

```
Y

<table>
<thead>
<tr>
<th>Abs.</th>
<th>Pres.</th>
</tr>
</thead>
<tbody>
<tr>
<td>null</td>
<td>X→Y</td>
</tr>
<tr>
<td>X→Y</td>
<td></td>
</tr>
</tbody>
</table>
```

exclusive diagonal

In the lower right-hand cell (X and Y present) there is the implication "if X, then Y is found." This is equivalent to a Guttman scale which is also designed to locate positive implications. In addition, Entailment Analysis determines whether the absence of a trait implies the other variable. This feature is more important where both states of the binary variables are substantively meaningful as in the case of the division of labor data, 0=male, 1=female. For pure pres.-abs. data it is somewhat less interesting although in this study presence implying absence could be used as an indicator of assemblage purity.

The cells in the contingency table are grouped according to their general properties. Cells diagonally across from each other share properties. The cells on the principal diagonal (upper left and lower right) are the "inclusive" cells. Everything that includes an X includes a Y, or if there is no X there
Figure 15.06. T₁ and T₂ in Three Constructed Contingency Tables. a–c, note different locations of zero cells.
is no Y. In contrast, the cells on the secondary diagonal (lower left and upper right) are the "exclusive" cells. If there is an X, then the Y is excluded and vice versa.

Entailments are determined by searching for zero cells. The entailment is on the diagonal opposite the zero cell. Figure 15.06a shows a case where T - T \( (T_1 \text{ entails } T_2) \), or, wherever a type 1 artifact is found a type 2 is also found. Figure 15.06b shows a zero on the inclusive diagonal implying the mutually exclusive or disjointed character of the distribution, \( T_1 \text{ and } T_2 \) (\( T_1 \text{ entails not } T_2 \)).

A zero in the null cell produces overlapping sets (not illustrated) and no solution or entailment. None of the marginals can be zero; only invariant variables would produce this condition. The probability characteristics of a 2 x 2 table are readily computed by Fischer's Exact Test.

![Dendrogram](image.png)

Figure 15.07. Entailogram for Hop Hill Loci Matrix.

The entailment in Figure 15.07 shows the positive, significant relationships in the loci matrix. Sequence I reads, "if there are circular scrapers at a locus, then there are also ovate scrapers, edge-altered flakes, notches and boiling stones." Relative to the principle component analysis, the entailogram shows that Components I and VI are statistically significant.

Series II shows that where there are thumbnail scrapers, there are also small, ovate bifaces, boiling stones, edge-altered flakes and notches (mostly Component IV).

Arguing from the presence of thumbnail scrapers and small ovate bifaces in Series II, it seems likely this is a male task kit. This leaves Series I as a possible female tool kit. It seems likely that female tasks are represented because of the boiling stones but we know of no specific ethnohistorical incident or theoretical proposition that would link circular and ovate scrapers to women other than the generally demonstrated fact that women work skins and use some kind of scraper.
The cluster of tools in the center is shared by both series, either by functional association or by normal but unrelated proximity of function. Edge-altered flakes, in particular, are expectably generalized tools that could be used for any number of tasks, whether they be male or female.
16.0 ANALYSIS OF OCCUPATION FLOORS (Joel Gunn)

Burned rock middens are a standard and stubborn point of archaeological curiosity in Central Texas. Elton Prewitt (1974) has traced the development of midden studies from Pearce (1919) through later investigations such as Kelly and Campbell (1942), Suhm (1959), and Hester (1971), to mention a few. The function of the middens is so obscure it seems to be an instant topic of conversation on any occasion, and speculation as to function runs from steam baths to cactus-frying stations. Weir (1976) favors an acorn- and deer-processing station interpretation. This argument is supported by the fact that the heaviest concentration of burned rock middens is during a cool and presumably wet period in Texas prehistory (Gunn and Weir 1976). If oak woodlands expand westward during such times the acorn/deer-processing function is certainly indicated, as these were the traditional staples of the eastern woodlands. Probably people so adapted expanded their domain westward during favorable climatic episodes.

One question which this hypothesis suggests is, "What is the archaeological feature east of the Edwards Plateau of Central Texas which is the functional equivalent of the burned rock midden?" Such processing areas are marked in Central Texas by the presence of burned limestone which is abundant in the region. Burned clay balls such as those found at Poverty Point may be equivalent to boiling stones. It may be that the peculiar resources of the Edwards Plateau brought forth a regional variation of an eastern adaptation which due to available resources of boiling objects and relatively dry climate preserved a unique record of those activities.

What then of the analysis of these sites has tended to show their actual function? Bouche de Perthe noted the camp-like structure of the Somme eoliths as early as the 1840s and reported on that fact before the Royal Society of England (Daniels 1967). If the mystery of burned rock middens is to be resolved it seems likely that it will be the product of observations similar to those of that most ancient of French archaeologists, i.e., details on the internal camp structure of middens.

Hypotheses developed to explain functions of middens have ranged through virtually the extent of prehistoric human activity. Excavation techniques on the other hand, have been limited to relatively thick arbitrary levels which represent a level of resolution comparable to and capable of testing only those hypotheses which suppose an unstructured utility such as refuse heaps (Hester 1971), or broad chronological occupation periods (Suhm 1959:23). As was described in Section 9.0, the Hop Hill midden was excavated by a modified microstratigraphic technique, which, it was hoped, would lend support to either a structured or unstructured hypothesis and, if it be structured, to delineate the functional character of that structure.
Fortunately for comparative purposes, the upper two occupation floors in the Hop Hill midden appear to be camps that were coincidently located on a midden. This is a relatively common occurrence (Suhrm 1959:218). Only the third and fourth floors are in the midden proper. In the following discussion, this coincidence will be capitalized upon as a device for studying changing camp patterns in Archaic Central Texas.

The nomadic nature of prehistoric people of Central Texas (see Section 1.0) indicates that they would have preferred portable containers such as baskets, and stone boiling in waterproof baskets would have been a common mode of food preparation. In fact, such activities are known ethnohistorically in Texas (Turner n.d.). It is reasonable to assume, therefore, that some part of the accumulation of middens can be accounted for by such activities and that the analysis of occupation floors in middens should show evidence of stone boiling. Given the usual jumble of debris in middens, however, some sort of analytical device is necessary to determine if such activities did transpire.

The elements that comprise stone boiling are fire, water, some rocks of appropriate size and texture and a basket or skin bag (see Section 14.0). The process is to heat the rocks, put them into the basket with the water and food to be cooked and when the food has been removed, discard the rocks. As far as identifying the process from the archaeological record is concerned, the fire and the discarded rocks will be the only evidence left in a wet site.

![Diagram of Stone Boiling](image)

Figure 16.01. Spill-Fan Analytical Concept.

Some aspects of these two features may be helpful in identifying them. When rocks of varying sizes are discarded from a container, the small rocks should roll further than the larger rocks and rocks should splay out from the throwing point in a fan-shaped pattern. A typical "spill-fan," then, should be triangular in shape with the larger rocks at one of the points of the triangle. Furthermore, the point of the triangle with the large rocks should point generally in the direction of the fire-place (Fig. 16.01) in which the rocks were heated since it would have been the point of origin of the person discarding the debris. Using these assumptions we can reduce the spill-fan and fire hearths to a number of activity units around which other tasks were organized.
In the following discussion an attempt is made to use this device with the understanding that it is only an idea which may or may not be correct in a given instance. It should, however, account for some of the behavior which leads to the accumulation of a burned rock midden, and it provides a vector of orientation for those activity units which may be of use in analyzing complementary activity phenomena such as the chipping of stone tools.

Four definable occupation floors were sampled extensively enough to warrant analysis. Whether they were opened over a large enough area to represent a significant portion of living space is difficult to ascertain. Any conclusions drawn concerning camp habits will be distorted to the extent that a full camp is not represented. Perhaps it would be safest to say that the following discussion is predicated on less than full understanding. If a camp is a system of interactions between people and the camp environment, then, we are studying the camps at the subsystem level. The subsystems are cut short at the edge of the excavation and there is no way of knowing whether we have the whole system or not short of total excavation of the substratum. This abbreviation can only result in a bias of our view of occupation floor activities. How biased that view is depends on the amount of redundancy in the camp patterns per unit of area. If redundancy is frequent, the bias is reduced directly.

The floors are mapped in Figures 16.02, 16.05, 16.07 and 16.08. The rocks mapped on the living floors represent only those that could be picked up off the surface once a thin substratum was excavated to the bottom of the rocks nearest the surface. Perhaps the most startling result of picking up the midden in microlayers is that the normally cluttered appearance of a midden becomes a somewhat ordered and even relatively thin scatter of rocks. Furthermore, there are spaces which are relatively void of limestone debris; and though we make no claims for the patterns, the rocks seem to cluster or form outlines of ovals and circles. As often as not, concentrations of chert are associated with areas where rocks are less concentrated. All of this suggests a reasonable pattern of camp debris.

Midden Occupation 2.10 (Resolv 2.07--Fig. 16.02)

This occupation is the one closest to the surface. There were surface artifacts, redeposited materials and perhaps a few floor fragments above it. Of 2.10 was the first substratum that could be excavated with some confidence. It was opened in 15 m². The bottom is well defined by a brown substratum but the top was eroded to an unknown degree. In the south margin a rill cut through part of the floor, as indicated in Fig. 16.02. The rill cut completely through 7% of the floor. If we assume a Resolv 2 floor, the resolution is 2.07 plus an unknown quantity of erosive activity to the upper surface of the substratum.
Figure 16.02. Occupation Floor 2.10.
A metate, the one which drew our attention to the spot, is located in the northern portion of the floor. Also, most of the flaking debris is located near the metate. There are several reddened pieces of limestone to the east of the metate. A concentration of larger limestone pieces lies to the southeast of the metate about 1.5 m. There is little lithic debris of any description to the west.

The association of these elements suggests a community of activities. The proximity of the metate to the empty space at the west suggests that the person doing the grinding faced east. A series of about a half dozen oblong stones within .5 m east of the metate might have been manos and should be checked for smoothing. On the east the reddened stones indicate a fire. They are divided into two piles as would happen if someone divided the coals to put the fire out. The pile of stones to the south of the fire grade from large to small away from the fire. This would be expected if boiling stones were dumped from a container; the smaller stones roll farther than the larger ones. Judging by the relationship of the stones the trajectory of the throw was just west of grid south. The thrower, then, must have stood to the east of the fire. The stones in the throw-away pile are all larger than the reddened specimens. This suggests that the reason the reddened stones were left is because they were too small to trouble putting them in the container while the larger ones were rescued from the fire before their chemical structure was significantly oxidized. A replicative experiment could show to what temperature boiling stones were heated before they were used. The temperature may have been controlled to avoid scorching the food.

Figure 16.03. Histogram of Rock Sizes in Hearth and Spill-Fan.
The longest diameters of reddened and throw-away rocks are graphed in Fig. 16.03. It suggests that the favored size of boiling stones was between 6 and 12 cm. Some large pieces of chert in the throw-away pile indicates at least some use of chert as boiling stones.

Between the fire and the metate is a concentration of flaking debris. There seems to be nothing, however, which suggests the location of the knapper.

![Diagram](image)

**Figure 16.04. Activity Area in OF 2.10.**

From the north part of the floor (Fig. 16.04), then, it can be surmised that we have a closely spaced set of camp activities, perhaps recovered at Resolv 1, judging by the generally uncluttered density of artifacts.

The southern 3/5 of the floor offers little in the way of contrastive activity indicators. Virtually all of the debris is limestone. Various lines, circles and open places can be observed.

**Midden Occupation 2.20 (Resolv 2.0, Fig. 16-05)**

OF 2.20 was opened in 15m². The most striking feature of this floor is an apparent fire hearth in squares 930-968 and 930-969 (Fig. 16.05). A pit was apparently dug down into OF 2.30. The disturbed area in OF 2.30 (Fig. 16.07) immediately below the feature is a product of this activity. The fire pit was lined with pieces of limestone which were burned until they were reddened. There are concentrations of unplatformed flakes in the NW and SE corners of the area. Most of the larger rocks are concentrated in the SW 1/2 of the floor. Above the diagonal they tend to be randomly dispersed rather than clustered. Judging by the preferred size of boiling stones noted in the floor above, the rocks are at the proper
size to be used as boiling stones. If they are boiling stones, however, they are still in the heating pit. Also, if there was an attempt to control the temperature of boiling stones as noted above, these rocks were too hot. These two facts indicate that the rocks were either abandoned before use, or someone forgot them, did not recover them in time and did not use them. Alternatively and more probable is that the feature served another function, perhaps a roasting pit. Prewitt reports a vaguely similar one-sided pit (1974:76, Ash pit 1) from Loeve-Fox.

The cluster of rocks that centers at E930.5-N970 is fan shaped and has the larger pieces at the north and narrow end of the concentration. It may, then, represent another spill or throw-away incident.

Assuming the spill-fan should point to the fire from which the activity originates, then the reddened rocks on the south margin of square E930-N971 should represent the relevant fire place (Fig. 16.06).

There appears to be knapping to the south and east of this fire.

Midden Occupation 2.30 (Resolv 2.19, Fig 16.07).

OF 2.30 was opened in 12m². The resolution is relatively low because of two problems. Three percent of the floor was disturbed because the fire feature was excavated from the floor above. Also, 16% of the surface was not mapped because of confusion resulting from a rain storm. Not all of the information was lost because artifacts were located on maps, but the rocks and unplatformed flakes were not mapped within the two SW squares.
Figure 16.07. Occupation Floor 2.30.
The floor seems to be an undifferentiated scatter of limestone and flakes so no interpretation is offered. The reason could be that the excavated part of the site was not used for a period of time so functional loci are elsewhere; the site was not used for food preparation for a period and the debris represent stopovers without usual features, etc.

**Midden Occupation 2.40 (Resolv 2.0, Fig. 16.08)**

OF 2.40 was opened in 10m^2+. It is the lowest of the floors and is associated with a point which dates to the Middle to Late Archaic. OF 2.40 is different from the above floors in a qualitative way. The limestone rocks are much bigger in numerous cases. The variety of rocks is noticeably broader with chunks of conglomerate and sandstone appearing.

The patterning of the rocks also appears to be different. There are some reddened rocks in the center square of the excavation. There is nothing, however, that can be securely identified as a spill-fan.

There is a distinct tendency for smaller rocks to occur to the south and knapping is to some extent confined to the area of small rocks, suggesting a division of work areas into south for knapping and north for food preparation. Whether the reddened rocks and the large flat rocks in E930-N970 are associated in the food preparation task is a matter of pure conjecture without some sort of convincing analytical device. Since we have only one example to work from, an analytical device can only be posed as a very tenuous hypothesis, something to be watched for in the future. However, there is a notable barren strip between the flat rocks and the reddened rocks. It seems possible that the reddened rocks were part of some debris on top of the flat rocks. A fire was built on the flat rocks to heat them for food preparation purposes and then swept off to the southeast to clear them for use. They were swept far enough away to leave the barren strip. Since the smaller rocks were swept off with and remained in the hot coals for a substantial time, they were chemically altered enough to turn them red.

Since the sample of camp patterns is so small, no conclusions can be drawn concerning changing prehistoric lifeways on the Hop Hill midden. A hypothesis can be tentatively advanced, however. In the absence of firm dates let us assume the midden is associated with the Round Rock Phase which implies deer and acorn processing as supported by Weir (1976), and that the occupation levels above represent San Marcos and/or Twin Sisters and/or Late Prehistoric occupations. This assumption is based on the generally accepted proposition that true burned rock middens are a predominantly Round Rock Phase phenomenon (Weir 1976, Prewitt 1974).
Figure 16.08. Occupation Floor 2.40.
During the earlier period the flat and burned rock pattern, "burn-and-sweep," implies a food preparation process which is still current in Texas. Rocks are heated, and vegetation, food and more vegetation are placed on the rocks. Finally water is poured into the mix and it is covered with soil (now aluminum foil) to retain the steam until the food is cooked (James Escobedo, personal communication). Such a technique would be appropriate for steaming deer meat along with auxiliary foods.

Subsequent to the Round Rock Phase the camp pattern changed. Stone boiling and stone-lined roasting pits became a part of camp activity. The archaeological evidence for stone boiling is a characteristic pattern of basket-spilled rocks. This "boil-and-spill" technique seems like a reasonable pattern for more nomadic people such as those of the Western Desert tradition.

Based on this discussion, it is concluded that middens are of an at least somewhat structured nature. However, it is obvious that more work needs to be done using high-resolution recovery techniques to establish whether the patterns inferred from the Hop Hill midden are recurring or coincidental.
17.0 FLAKE TECHNOLOGY (Joel Gunn and Royce Mahula)

In the field, excavators were instructed to open cultural unit formats on any flaking debris found in situ which retained a platform. In the fall of 1976 the flakes so mapped were measured and observed by the UTSA Anthropology Laboratory class. Thirteen coders made 42 observations on each flake twice (see Figure 17.02). As much as time would allow, these observations were checked and corrections entered. In other cases reliability tests were given to each coder and the observations of the most reliable coder used.

Figure 17.01. Terminology for Flake Technology

Fig. 17.01 shows the terminology which will be used relative to lithic technology. "Parent Material" implies the source of a flake whether it be a nodule, a core, a biface or another flake. The "Flake" is the object removed and it may be a decortication or secondary flake, bifacing flake, a flake-blade, a blade or a pressure flake. The "Platform End" is the end prepared and struck by a percussor instrument. The "Inner Face" is the surface of the flake toward the parent material which contains the bulb of percussion, ripple marks and fissure lines; the "Outer Face" is away from the parent material which exhibits cortex, patina or scalar evidence of previous removals. "Terminal End" is opposite the platform end.

Flake Technology Data

This section will describe the general data-collecting procedures for flakes excavated from Hop Hill. The data collected are intended to answer questions posed from several problems and therefore represent a relatively broad range of attributes.
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>1</td>
<td>1 - 4</td>
<td>FN#</td>
</tr>
<tr>
<td>2</td>
<td>5 - 7</td>
<td>SEQ#</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>Technotype (1=flake 2=bifacing 3=blade 4=pressure)</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>Outer surf (1=wrked 2=bit pat 3=1/2 pat 4=patinated 5=bit cort 6=1/2 cort 7=cortex)</td>
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<td>13</td>
<td>Fragmentation (1=whole 2=platf end 3=medial 4=term)</td>
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<td>7</td>
<td>14</td>
<td>Platform shape (1=flat 2=curved 3=triangular)</td>
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<td>8</td>
<td>15</td>
<td>Platform preparation (1=none 2=facetted 3=ground)</td>
</tr>
<tr>
<td>9</td>
<td>16</td>
<td>Lip (1=none 2=slight 3=prominent)</td>
</tr>
<tr>
<td>10</td>
<td>17</td>
<td>Termination (4=feathered 5=z 6=flat 8=runoff; note use Platif. prep. slot for platform end of med &amp; term frags.)</td>
</tr>
<tr>
<td>11</td>
<td>18-19</td>
<td>Material (see list)</td>
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<td>20</td>
<td>Opaque (1=translucent 2=edge trans 3=opaque)</td>
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<td>13</td>
<td>21</td>
<td>Color (0=neut 1=red 2=brown 3=yel 4=green 5=blue 6=yellow)</td>
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<td>14</td>
<td>22</td>
<td>Saturation (1=low 2=medium 3=high 4=saturated)</td>
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<td>23</td>
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<td>Length thickness (.1 mm)</td>
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<td>Bulbar thickness (.1 mm)</td>
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<td>Weight (1/10 grams)</td>
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<td>47</td>
<td>Zone</td>
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<td>76</td>
<td>Fired (1=none 2=fire reddened 3=crazed 4=pot)</td>
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<tr>
<td>43</td>
<td>77-78</td>
<td>Coder</td>
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</table>
Some of the attributes are not completely non-redundant with others. This overlap is noted in the attribute description as a warning against analysis of non-independent variables. The reason for having some non-redundant variables in the list is for analytical convenience. Some analyses require different resolution, different scaling and slightly different points of view on the fundamentally same feature.

1. FN (4 Col.) -- Permanent field specimen number assigned by the Hop Hill project to an artifact. This number along with the sequence number and the site number, 41 GL 021, is inked onto the artifact.

2. Sequence # (3 Col.) -- A number assigned to an artifact if a field number is assigned to more than one artifact.

3. Technotype (1 Col.) -- A nominal variable with four states which represents at the most superficial level the various methods by which flakes are removed from a parent block of material:

   1 = flake, 2 = bifacing flake, 3 = blade, 4 = pressure flake.

If assumptions are made relative to the order in which each flaking technique is most probably used in a reduction sequence, the order is sequential from flakes to pressure flakes. Unspecialized flakes are produced in the initial stages of any flaking task. Bifacing flakes and blades appear as the process moves to more refined tool making. Finally, the pressure flakes come in the final stages of shaping and finishing and as a means of resharpening dulled tools subsequent to the reduction process proper. When it seems appropriate to invoke this assumption the variable is assumed to be a satisfactory linear, relative time scale.

There is some redundancy between technotype and functional type.

4. Outer Surface (1 Col.) -- A nominal variable with seven states which indicates the condition of the Outer Surface of a piece:

   1 = worked, no patina or cortex, 2 = bit patinated, only a trace, 3 = 1/2 patinated, 4 = patinated, 5 = bit cortex, only a trace, 6 = 1/2 cortex, 7 = cortex.

Outer Surface is used in conjunction with Technotype to show the primary or secondary nature of a flake.

5. Functional Type (3 Col.) -- A nominal variable which indicates in some detail all of the types of lithic and non-lithic materials found at Hop Hill. This variable is redundant with Technotype, Outer Surface, Fragmentation, and Termination.

6. Fragmentation (1 Col.) -- A nominal variable which shows the portion of the flake or if it is a whole piece:

   1 = whole, 2 = platform end, 3 = mid-section, 4 = terminal end.

This attribute is partially redundant with Functional Type.
7. Platform Shape (1 Col.) -- A nominal variable with three states that shows the outline of the platform as the observer sees it looking at the lateral aspect of a flake:

1 = flat, 2 = curved, 3 = triangular.

![Diagram of platform shapes](image)

Figure 17.03. Various Platform Shapes.

Figure 17.03 illustrates the distinction that is being attempted with this attribute. The platforms of normal flakes and bifacing flakes are quite distinct in many cases. The reason is apparent when the relationship of the two types of flakes to their respective parent masses is examined. A core is something of a block (Fig. 17.03a) from which a flake is removed. The angle between the outer face and the platform is about 90° or a little less. A biface, on the other hand, is a lenticular mass where edge angle becomes a striking platform. The result (Fig. 17.03c) is a triangular platform.

8. Platform Preparation and Platform End Break (1 Col.) -- A nominal variable of three states designed to show the extent and kind of special effort that went into platform preparation:

1 = none, 2 = faceted, 3 = ground.

Faceting implies retouching the platform area in order to shape it to desired proportions. This process leaves the platform with a scalar, undulating appearance. Grinding is done by rubbing a coarse-grained rock along the platform. The result, as one might expect, is a rounded and roughed look at the platform. If the platform is missing the type of the break on the platform end of the piece is recorded in this column. See Termination for coding scheme.
9. Lip (1 Col.) -- A ordinal attribute of three states which shows the character of the lip on the inner edge of the platform:

   1 = none, 2 = slight, 3 = prominent.

So-called "lipped flakes" have been mistakenly thought to be bifacing flakes. Virtually any flake can have a lip on it depending on how it was struck. Sollberger reports that any flake will have a lip whose cone is greater than 123° (personal communication). The purpose of including this attribute in the list was to determine the exact relationship of lip frequencies to bifacing flakes.

10. Termination (1 Col.) -- A nominal variable of five states designed to show the nature of the terminal end of a flake:

   4 = feathered, 5 = s-termination, 6 = z-termination, 7 = flat termination, 8 = runoff termination.

The states are numbered 4-8 so as to be numerically exclusive of the 1-3 used for Platform Preparation states. If the platform end is broken off the character of the break is recorded as state 5, 6, or 7 from this variable.

![Figure 17.04. Various Terminations.](attachment:diagram.jpg)

Figure 17.04 illustrates the various states of Termination. "Feathered" means the flake tapers to a fine edge at the terminal end (Fig. 17.04a). "Runoff" is the case where the terminal end would have feathered out had it not come to the end of the parent material first. Fig. 17.04c, d, and e illustrate various abnormal terminations and breaks.

Terminations and breaks are classified as follows: First, hold the piece in front of your eyes with the inner face down and the break to the right.
Second, note if it is flat or if it protrudes at the top or bottom. If it is protruding more at the top it is an s-termination; if it is more at the bottom it is a z-termination. The tentative theory is that a flat end on the terminal end of a flake fragment is an intentional break or a step fracture. An s-termination is a hinge fracture or an intentional break initiated from the inner face. A z-termination can only be a break initiated from the outer face. These distinctions will hopefully be useful for sorting functionally intended breaks from those which are a product of manufacture. As is immediately apparent, however, the model is partially indeterminant.

11. Material (2 Col.) -- A nominal attribute to distinguish material types. The motive for classifying material was not to assign pieces to quarry origins. An attempt was made to group tools and debris into clusters which represent a single block of parent material. If, for instance, a knapper brought a biface to the site and removed four flakes, those flakes should be distinguishable as a cluster from all other flakes on the site, and they should define a task area.

It is probably not possible to verbalize all of the dimensions of judgment that go into clustering one material with another. Two procedural guidelines were followed. First, classification was pursued after the fashion of a comparative collection. Each flake was compared with all the pieces previously clustered to see if it would fit into an established group. If it did not appear to be from the same parent block as any of those classes, a new group was established. Second, some of the criteria of classification were as follows. There are certain dominant traits that figure into the classification; the most important of these are color, texture, and character. Color is the most prevalent hue in the material; texture is the graininess of the material. Character is something unique to the material. It may include banding, small fossils, specks and spots of various colors. Sometimes materials patinate in a special way due to metallic intrusions. Often cortex is very characteristic. Character is redundant with opaqueness, color, value and grain.

12. Opaqueness (1 Col.) -- An ordinally scaled variable of three states designed to show the light-transmitting character of the material:

1 = translucent, 2 = edge translucent, 3 = opaque.

"Translucent" is the case where light comes through most of the piece when it is held to the light. "Edge translucent" materials allows the transmission of light only through the edge. No light passes through opaque objects, or at least very little. Translucence is a property imparted by the nature of inclusions in the predominantly silicate mass of flints and cherts and as such is an important part of defining the workability and quality of the material.

13. Color (1 Col.) -- An ordinally scaled variable of seven states. The scaling is based somewhat on the color light spectrum:

1 = red, 2 = yellow, 3 = buff, 4 = brown, 5 = green, 6 = blue, 7 = purple.
14. Saturation (1 Col.) -- An ordinal scale of three states which measures saturation of color. If color is neutral saturation must be zero:

   1 = pale (low saturation), 2 = medium, 3 = high (saturated).

15. Value (1 Col.) -- An ordinal scale of four states intended to measure the gray scale of the material:

   1 = light, 2 = medium, 3 = dark, 4 = very dark.

16. Grain (1 Col.) -- An ordinal scale of four states which show the texture of material:

   1 = very fine (about like glass), 2 = fine, 3 = medium, 4 = coarse.

17. Length (2 Col.) -- A continuous scale measured perpendicular to the platform in mm.

18. Length Thickness (2 Col.) -- A continuous scale measured in tenths of mm parallel to the length of a piece. A vernier caliper is closed over the piece so the platform and terminal ends touch one arm and the highest point on the outer surface touches the other arm. The measurement is illustrated in Fig. 17.05a.

![Diagram of measurement of length and width thickness](image)

**Figure 17.05. Measurement of Length and Width Thickness.**
19. Width Thickness (2 Col.) -- A continuous scale measured in tenths of mm about halfway down the length and perpendicular to the length. Use the fine end of the caliper arm to get the thinnest possible measurement. The measurement is illustrated in Fig. 17.05b.

20. Platform Width (3 Col.) -- A continuous scale measured in tenths of mm. Platform Width is measured across the platform parallel to the width of the flake.

21. Platform Thickness (2 Col.) -- A continuous scale measured in tenths of mm. Platform Thickness is measured from the lip to the outer edge of the platform parallel to the thickness of the flake.

22. Bulbar Thickness (2 Col.) -- A continuous variable measured in tenths of mm. The measurement is taken from the most salient point on the bulb of percussion to the outer surface parallel to the thickness.

23. Platform Angle (3 Col.) -- A continuous variable measured in degrees. The measurement is taken between the inner surface as it is pressed against the arm of a goniometer and the aspect of the platform proximate to the inner face.

24. Terminal End Thickness (2 Col.) -- A continuous variable measured in tenths of mm; the thickness of the terminal end whether it be feathered or a break.

25. Weight (4 Col.) -- A continuous variable measured in tenths of grams.


27. East (5 Col.) -- A continuous variable measured in cm from the east baseline of the site. East is a horizontal Cartesian Coordinate. (Note: 3 digits, computer adds 1,000 meters if entry is below 800 meters.)

28. North (5 Col.) -- A continuous variable measured in cm from the south baseline of the site. North is a horizontal Cartesian Coordinate. (Note: only 3 digits, computer adds 1,000 meters if entry is below 800 meters.)

29. Depth (5 Col.) -- A continuous variable measured in cm from the vertical datum. Depth is a vertical Cartesian Coordinate.

30. Stratum (1 Col.) -- Stratum in which the artifact was found ordered in sequence from top to bottom of the site.

31. Occupation Floor (2 Col.) -- Occupation floor designation number.

32-40. 1st-9th Ray Length (1 Col. each for 9 Col.) -- The nine rays represent a system of polar coordinates designed to represent the shape of a flake. The platform is centered at the bottom as indicated with the inner face down. Then a pencil line is drawn around the artifact. At each ray the class in which the outline crosses it is recorded in the appropriate column. The nine classes are scaled logarithmically to make measurement and
recording as efficient as possible. Equivalents to the classes in mm are as follows:

\begin{align*}
0 &= 0-2 \text{ mm},
1 &= 2-3 \text{ mm},
2 &= 3-5 \text{ mm},
3 &= 5-7 \text{ mm},
4 &= 7-12 \text{ mm},
5 &= 12-20 \text{ mm},
6 &= 20-30 \text{ mm},
7 &= 33-55 \text{ mm},
8 &= 55-90 \text{ mm},
9 &= > 90 \text{ mm}.
\end{align*}

41. Retouch (1 Col.) -- Presence or absence of retouch:
   1 = none, 2 = nibbling, 3 = scalar retouch, 4 = stepped retouch.

42. Fired (1 Col.) -- Reflects the degree of firing:
   1 = none, 2 = reddened, 3 = crazed, 4 = potlidded.

43. Coder (2 Col.) -- Coder person's #

**Force Flake Model**

It is generally believed by the community of modern flint knappers that increasing the amount of force in the process of making a flake increases the salience or prominence of the positive bulb of percussion, the curvature of the inner face and the tendency of the flake to fold around the end of the core or "runoff" the end opposite the platform. Controlled experiments such as Speth (1972, 1975) tend to support this point of view.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{flaking_force.png}
\caption{Effects of Varying Force on Termination.}
\end{figure}
In addition, it is known that too little force results in a shortfall termination such as a hinge or step fracture. These various amounts of force can be arranged on a continuum, as in Fig. 17.06, in which the character and dimensions of terminal end thickness represent the accuracy with which the knapper of a particular flake applied force to his task. Too little force results in a hinge or step fracture. The correct amount of force produces feathered terminations, and too much force results in a runoff configuration.

A simple measurement of terminal end thickness should be a hyperbolic function. The inaccurate blows will have large measurements whether they be the result of too little or too much force. Accurate blows at the center of the continuum will produce the minutest measurements. In order to make the continuum a useful instrument for analysis by linear models all flakes with feathered, flat and s-terminations (see Termination, attribute 10, for implications of s-termination) were converted to minus values. Thus, larger minus values represent larger deviations toward too little force; large plus deviations are increasingly too much force.

The other indicators of force should correlate positively with accuracy once the effect of absolute mass is removed. These include bulbar salience which is calculated as:

$$\text{Salience} = \text{Bulbar Thickness} - \text{Platform Thickness} \quad (17.01)$$

Also, curvature is:

$$\text{Curvature} = \text{Length Thickness} - \text{Width Thickness} \quad (17.02)$$

Mass is controlled by the quantity Weight. The interaction of these variables as suggested above is illustrated in Fig. 17.07. The variables directly controlled by human ideas are to the left and the subsequent consequences of effecting those ideas are to the right.

![Diagram](image)

**Figure 17.07. Interaction of FORCE and RELATED VARIABLES.**

This process can be further elaborated since the material and the degree to which the material is heat treated also provide moderating influences on the effect FORCE has on shape (Fig. 17.08). Speth (1975) has demonstrated that platform angle influences the size of a flake.
Figure 17.08. *More Highly Specified Flake Production System.*

To determine the configuration of these emphases, a principal components analysis was run on the flakes from each midden occupation floor and also an analysis was made of all the floors combined. All analyses were rotated to varimax criteria.

\[
\begin{align*}
(\text{ALL - CI}) & \quad \text{WT} \rightarrow \text{SALIENCE} \\
(\text{ALL - CII}) & \quad \text{HEAT} \rightarrow -\text{CURVE} \\
(\text{ALL - CIII}) & \quad \text{OCCUP} \rightarrow \text{GRAIN} \\
(\text{ALL - CIV}) & \quad \text{OCCUP} \rightarrow \text{FORCE} \\
& \quad \text{PLATFORM ANGLE}
\end{align*}
\]

Figure 17.09. *Universal Patterns in Hop Hill Flake Technology, Principal Components of All Floors (OFI, } N = 350-430, \text{ Variance } = 59\%).*

Figure 17.09 shows the four principal components for all occupation floors. These are the universal trends in the assemblage. Weight affecting Salience is a dominant trend. Apparently the Hop Hill knappers simply struck larger pieces harder rather than applying any special techniques to reduce bulbar salience in larger items.

Component II shows that heat treating results in less curved inner faces. Since heat treating reduces the effort necessary to remove a flake it represents the extra force necessary to remove untreated flakes and the consequent frequent occurrence of more curved inner faces.

Components III and IV are both related to change through time. Grainier cherts were used during the early period (CIII). Also, earlier people heat treated more, prepared higher angle platforms and used more force in flake removal (CIV).

As will be shown below, some of these traits are not so universal because the sample is heavily weighted in favor of the two upper occupation floors. On the other hand, the time related variables are particularly important because
they mark the most important trend in the data, a change from bifacing to core flaking over time. The meaning of the time related relationships will become apparent as the discussion progresses.

In the next four analyses, when these trends appear it will be kept in mind that they are universal and not peculiar to the time period represented by individual occupation floors. The association of Weight with Salience and Heat treating with straight inner faces are related to the mechanics of flint knapping. Changes in Grain, along with changes in heat treating; platform preparation and the accuracy of force applied are related to time and changing ideals.

(OF1 - CI)  WT ←→ SALIENCE
(OF1 - CII)  GRAIN
            HEAT → - CURVE
                - PLATFORM
(OF1 - CIII)  EAST
              NORTH
(OF1 - CIV)  FORCE → - CURVE

Figure 17.10. Knapping Pattern in Occupation Floor 2.10 (OF1, N = 100-150, Variance = 61%).

Occupation Floor 2.10 (OF1, Fig. 17.10) has some of the universal characteristics, especially in Component I. However, in addition to heat treating reducing curvature of the inner face, curvature also decreases as graininess increases and Curvature decreases as Platform Angle decreases. Speth (1975) has determined experimentally that outside platform angle influences the length of a flake. The OF1 flakes show that reducing inner platform angle, perhaps by controlling the blow angle, decreases curvature; which is logical enough, as Fig. 17.11 indicates.

Figure 17.11. Curvature Decreases as Inner Platform Angle Decreases.
East and North appear in CIII without relations to any attributes. CIII shows that the amount of force applied is inversely related to the amount of curvature produced. This is opposite of what the model predicts and it implies some kind of a special technique.

\[(\text{OF2 - CI}) \quad \text{EAST} \quad \text{NORTH}\]
\[(\text{OF2 - CII}) \quad \text{WT} \quad \rightarrow \text{SALIENCE}\]
\[(\text{OF3 - CIII}) \quad \text{GRAIN} \quad \text{HEAT} \quad \text{PLATFORM ANGLE}\]
\[(\text{OF4 - CIV}) \quad \text{FORCE} \quad \rightarrow \text{CURVATURE}\]

Figure 17.12. Knapping Patterns of Occupation Floor 2.20 (OF2, \(N \approx 125-155\), Variance = 64%).

OF2 (Fig. 17.12) again shows the universal pattern of Weight-Salience relationship. It is, however, replaced as the component accounting for the most variance by the East-North patterning of artifacts on the occupation floor. While there is a clear tendency for artifacts to be aligned on a northeast-southwest axis, no attributes are related to the pattern.

Grain, heat treatment and platform angle (this time positive) are again on the same component. They, however, do not produce less curvature as they did in the floor above. Remarkably, the Force-Curvature relationship reverses itself to conform to the model prediction.

\[(\text{OF3 - CI}) \quad \text{GRAIN} \quad \rightarrow \text{CURVE} \quad \text{HEAT}\]
\[(\text{OF3 - CII}) \quad \text{FORCE} \quad \rightarrow \text{SALIENCE} \quad \text{PLATFORM ANGLE}\]
\[(\text{OF3 - CIII}) \quad \text{WT} \quad \text{PLATFORM ANGLE} \quad \text{FIRE}\]
\[(\text{OF3 - CIV}) \quad \text{NORTH} \quad \rightarrow \text{FORCE}\]

Figure 17.13. Knapping Patterns of Occupation Floor 2.30 (OF3, \(N \approx 40-50\), Variance = 66%).

OF3 (Fig. 17.13) marks a departure from the floors above, and suggests the presence of an earlier and quite different knapping technique. The combinations of Weight-Salience, Force-Curvature and Grain-Heat treatment-Platform
Angle disappear showing that their universality is a product of larger sample sizes in the upper floors. Knapping technique is dominated by a positive correlation between Grain, Heat treatment, and Curvature of the inner face (CI). Platform Angle is negatively related to Salience (CII). This suggests a bifacing flake technology since bifacing flakes have very high platform angles as they are measured in this study, and bifacing flakes have by necessity low saliency of the bulb of percussion. The force variable behaves negatively with Salience. The more salient the bulb the less likely there is to be a shortfall termination. This probably indicates that exceptionally thin bifacing flakes tend to break off toward termination.

In CIII smaller items tend to be heat treated and have higher Platform Angles. Both characteristics are logical bifacing procedures.

(OF4 - CI)   EAST
             NORTH
(OF4 - CII)  WT
             FORCE
(OF4 - CIII) SAL
             - CURVE
(OF4 - CIV)  GRAIN
             HEAT

Figure 17.14. Knapping Patterns of Occupation Floor 2.40 (OF4, N = 65-77,
Variance = 66%.

The striking feature of OF4 knapping is that none of the inferred causal relationships are effective. There are no arrows; also, Platform Angle drops out of the picture due to low communality. CII shows Weight and Force to be related. Larger pieces have more tendencies to be accurately or over-struck. Curvature is negatively related to Salience, certainly a bifacing characteristic, and finally (CIV) is the persistent Heat treating of coarser-grained material.

Fig. 17.15 illustrates the family tree of flint knapping at Hop Hill. Solid lines join components which share two or more variables (principal components recalculated without Time-Space variables). Dashed lines trace the wanderings of single attributes. As a composite it represents the trajectory of interaction between the various mechanical and decision-bound processes of the art much as Clarke (1968:104) does in his analysis of cultural subsystem interaction.

Grain and Heat treatment are consistently related early in time but fall apart late in the sequence. In contrast, the Weight-Salience combination appears in the third occupation floor and continues to the end of deposition.
A close examination of the changes in use of grainy materials shows that the use of very fine-grained material increased monotonically, i.e., continuously, from 13% in the earliest floor to 35% in the latest floor. Meanwhile, the use of fine- and medium-grained materials dropped in a 73%-72%-60%-58% progression. Note that the biggest change is between the lower and upper two levels. The switch to more fine-grained materials probably explains the break-up in the Grain-Heat treating complex through time observed in the principal components analysis.

Probably the Heat treatment of grainy materials was to facilitate bifacing in the early period. As the technology changed to core flaking the size of the blank and its related saliency of the bulb of percussion became the most persistent trait.

By way of supporting these inferences it is of interest to note that flat platforms increase monotonically through time from 40% to 47% of the platforms observed while triangular platforms decrease from 50% to 44%. This trend indicates a less frequent use of bifacing in later times. The highest percentage of feathered terminations is in OF3 which supports a more bifacially oriented industry in OF3 than either before or after. This could explain the extreme aberrancy of OF3 which consistently appears across several analyses. Perhaps the most interesting case is platform angle which is so random of character in the lower levels it does not appear in the pattern because of low communality. In Occupation Floor 3 it begins to take form as a consistent
trait related to two processes. Finally in most recent two floors it joins with heat treating as an important trait complex.

As shown above, the model proposed for flake production seems to apply to the later period because causally related attributes often appear on components together and thus can be assumed to represent true causal relationships. In the earlier period, however, the causal formation breaks down. All of the indications seem to be that the earlier floors represent bifacing while later knappers practiced another technique, probably core flaking.

It has been shown elsewhere that the general trend through the Holocene in Central Texas has been for bifacing to replace core flaking (Gunn and Weir 1976). However, in the San Marcos Phase (1800-2800 B.P.) there was a slight resurgence of core flaking technology, apparently associated with the re-entry of people associated with the Plains into the region.

The most plausible interpretation would seem to be that OF3 and OF4 are associated with the highly bifacial oriented Round Rock Phase of the Central Texas Archaic while the upper two occupation floors are related to the San Marcos Phase or to Late Prehistoric cultures practicing core flaking technology. The latter must be considered because of the high incidence of small arrow points recovered from the site.

Future research into the model appropriate for flake technology analysis should give emphasis to constructing a concept which will encompass both core and bifacing technology. The model used in this study seems to be appropriate to core flaking but all that can be said with assurance about the bifacing flakes is that some traits are logically related; mainly we just know it is not a core flaking technology.

**Flake Morphology**

In recent years it has become increasingly apparent that flakes are at the same time the most abundant and most neglected archaeological resource. The following is an attempt to distinguish variation in flake morphology using a method of analysis that is fast and reliable and would therefore be useful in characterizing large assemblages of debris.

The shape morphology of whole flakes was recorded by outlining them on a polar coordinate grid of nine rays and measuring from the origin of the polar coordinates to the point where flake outline intersects the rays (Montet-White 1973). The platform is centered on the origin with the trend of the platform parallel to the bottom line of the grid (see Flake Technology Coding format). The rays are 10° apart. Observations were made by classes defined in log mm, see attributes 32-40 for full discussion. The weight of flakes in .1 grams (.01 would be better) was also analyzed to get an estimate of thickness. Principal components were calculated on the data from the various occupation floors and rotated to varimax criteria. Two components generally appeared from each occupation floor, one for length and one for width. It was hoped that subtle variations in these component structures would show
Figure 17.16. Length and Width Components of Hop Hill Flakes from Hidden Occupation Floors.
the characteristics of the various time periods with which the floors were associated.

Figure 17.16a-b are plots of the components. Distances from the origin are component loadings and therefore represent the degree of correlation between adjacent rays. (Component loadings are transformed by the antilog of the loading to emphasize larger values.)

In the length vectors, Occupation Floors 2.30 and 2.40 are asymmetrical to the left while Floors 2.10 and 2.20 are essentially symmetrical. Floor 2.30 is typically the most aberrant. The variability is probably a reflection of the change from bifacing to core flaking technology dealt with above, and could serve as the basis for characterizing assemblages.

There is apparently a tendency for bifacing flakes to be asymmetrical to the left while core flakes are symmetrical. Sollberger (1976) has pointed out that diagonal or chevron flaking is desirable and in some cases necessary to biface points. The degree of asymmetry and perhaps the direction of asymmetry could be used as an indicator of the core-biface flaking mix in an assemblage and as an indicator of period of manufacture. This would require reliably large collections of flakes from known time periods before assemblages of unknown chronology could be classified.

An index of asymmetry, the application of a goodness-of-fit test or the use of discriminant function as in Gunn and Prewitt (1975) could be used as classificatory devices.

Conclusions

The most important finding to come from analysis of the flakes on sequentially related occupation floors at the Hop Hill midden is the apparent shift from bifacing to core flaking technology through relative time. Both the causal force-flaking model and the Flake Morphology analysis suggest changes in attributes which could logically be attributed to such a technological shift.

While the finding does not provide a firm basis for placing the survey results in temporal perspective it does suggest that the core analysis pertains more to later occupations while the biface analysis is more important to earlier times. Based on lipped flakes, Hester found a similar diminution of bifacing at La Jita (1971:113).

As a consequence of the shift in techniques the inability of a commonly held model of flake mechanics to explain both core and biface flaking became apparent. More theoretical development is necessary in this area.

Finally, there seems to be variability in the symmetry of flakes depending on the technology used. Bifacing flakes are asymmetrical to the left while core flakes are symmetrical.

Since the two technologies have definite ups-and-downs in the region, an index of symmetry may prove useful as a means of roughly dating sites where no other chronological information is available.
17.1 LITHIC RAW MATERIALS (James Escobedo)

Rock samples collected at the Hop Hill locality were compared to artifacts representing the four occupation floors. The rock samples were broken open, exposing the interiors, then divided into five major types and one subtype (Table 17.1.01).

Three criteria were used to classify materials into types:

1. The amount of clay in the silicates as shown by translucence;
2. The range of grain structure; and
3. The color of the material which ranged from light red to yellow, brown, gray and black.

Table 17.1.01 Chert Types From Hop Hill Quarry

TYPE 1 Number sampled - 20, cobble size
Translucent-very fine grain--dense with banding--thin limestone cortex--dark interiors--color range: black-dark/brown-dark/gray.

TYPE 2 Number sampled - 26, cobble size
Translucent-fine grain--dense with banding--thin limestone cortex--light interior--color range: light/gray-reddish/brown-light/brown.

TYPE 2a Number sampled - 13, cobble size
Translucent-medium grain flint--dense with white spots--thick limestone cortex--medium interiors--color range: brown-light/brown.

TYPE 3 Number sampled - 15, cobble size
Opaque-medium grain chert--dense with high amounts of clay--thin limestone cortex--medium to light interiors--color range: brown-brown/yellow.

TYPE 4 Number sampled - 17, cobble size
Edge transparent to opaque-coarse grain--medium dense with evidence of air pockets during crystallization--thin, rough limestone cortex--light interiors--color range: light/brown-yellow/brown-gray.

TYPE 5 Number sampled - 9 chunks
Opaque-fine to medium grain--dense with white spots--thin, rough limestone cortex--light to dark interiors--color range: light/gray-reddish/white-reddish/brown.

The exotic category contained all those flakes that could not be classified according to the local core samples. In all there were 17 exotic items (Table 17.02). These had several common features, one being that they were red flint and chert flakes. Although there are reddened nodules in the local collection, none had the red saturation of the exotic pieces.
Table 17.02 Breakdown of Artifacts to Rock Samples

<table>
<thead>
<tr>
<th>LEVEL 1</th>
<th>90 Artifacts</th>
<th>LEVEL 2</th>
<th>143 Artifacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1-</td>
<td>12</td>
<td>Type 1-</td>
<td>10</td>
</tr>
<tr>
<td>Type 2-</td>
<td>46</td>
<td>Type 2-</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>Type 2a-7</td>
<td>Type 2a-</td>
<td>6</td>
</tr>
<tr>
<td>Type 3-</td>
<td>7</td>
<td>Type 3-</td>
<td>15</td>
</tr>
<tr>
<td>Type 4-</td>
<td>8</td>
<td>Type 4-</td>
<td>12</td>
</tr>
<tr>
<td>Type 5-</td>
<td>3</td>
<td>Type 5-</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>exotic- 7</td>
<td>exotic-</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LEVEL 3</th>
<th>23 Artifacts</th>
<th>LEVEL 4</th>
<th>65 Artifacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1-</td>
<td>2</td>
<td>Type 1-</td>
<td>6</td>
</tr>
<tr>
<td>Type 2-</td>
<td>12</td>
<td>Type 2-</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Type 2a-2</td>
<td>Type 2a-</td>
<td>4</td>
</tr>
<tr>
<td>Type 3-</td>
<td>4</td>
<td>Type 3-</td>
<td>17</td>
</tr>
<tr>
<td>Type 4-</td>
<td>2</td>
<td>Type 4-</td>
<td>1</td>
</tr>
<tr>
<td>Type 5-</td>
<td>0</td>
<td>Type 5-</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>exotic- 1</td>
<td>exotic-</td>
<td>3</td>
</tr>
</tbody>
</table>

Of the most common materials found on the occupation floors, type 2 with 180 items, had the highest total of matches with source materials. The rest followed as shown:

- Type 2 - 180
- Type 3 - 43
- Type 1 - 30
- Type 4 - 25
- Type 2a- 19
- Type 5 - 9

Type 5 contained in its description red color material. However, these were small, exhausted cores. No nodules from the Hop Hill Quarry were found to contain this red material. Type 5 was also a category in which most of the flint was already exposed by previous knapping.
This study shows that some outside lithic material may have been carried into the site during all levels of occupation. However, locally gathered materials were generally used in knapping.
18.0 ENVIROCULTURAL SYSTEM FOR CENTRAL TEXAS (Joel Gunn)

The previous sections of this study have dealt with the various elements of the cultural and environmental system which could be observed or inferred for the inhabitants of the Hop Hill locality.

Ultimately, the goal of any such study is to conjoin elements into reasonable representation of the whole system, the ecosphere as it was discussed in the Introduction. Of the two benefits that come from such an exercise, two deserve emphasis here. First, a systems level examination of processes allows for broader and more insightful perception of the probable lifeways of prehistoric peoples whose lives we can only examine in general terms. Serendipity, (unexpected insights) is often the product of such undertakings. Second, at a site like Hop Hill, the observed appearances are often suggestive but may also be misleading due to pilfering and/or destruction of the record. Kelly, for instance, thinks that larger points were probably collected from the site because of their greater visibility to collectors. This would tend to bias estimates of earlier occupation frequencies downward since larger points are earlier points. A well-worked-out simulation which took into account factors of climate, population density, cultural adaptation, etc. could project probable occupation frequencies based on known cultural and climatic data and thus suggest alternatives to some of the more obstinate unknowns.

In this section, a system trajectory is adopted for the Hop Hill locality. The climatic aspects of that trajectory are derived from previous discussion in this study. The cultural trajectory adopted is that of Weir. While his sequence is not fully accepted, it does offer conceptual underpinnings in systems and information theory and is therefore infinitely more compatible to the approach taken here than chronologies founded in lithomorphic change.

Further assumptions are made about the character and source of cultural adaptations under varying climatic regimes, and from these assumptions a system is derived which attempts to explain some of the observed variation in Archaic settlement patterns and occupation frequencies. Since time precludes programming of the more complex statistical properties of the system, the reader will have to be content with the serendipity of system building for now. A commitment has been made, however, to program a simulation of the system and a report will be issued in a later publication.

Central Texas Cultural Trajectory and Cultural Processes

The Central Texas Archaic has long been regarded as a very endurable and stable Holocene adaptation to a prairie/land environment. Recent studies confirm that culture change in the normal sense of transformation from technologically simple to technologically complex is indeed absent. There is every reason to believe, however, that Central Texas is environmentally unstable and required numerous adaptive responses on the part of the nomadic people who occupied it prehistorically. The evidence for this instability is accumulated in this volume and constitutes the empirical background for what follows.
Frank Weir (1976) systemically analyzed the Central Texas Archaic which he defines as a period from 700 BP to 8000 BP. It is divided into five Phases (Table 18.01).

<table>
<thead>
<tr>
<th></th>
<th>Dates BP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late Prehistoric</td>
<td></td>
</tr>
<tr>
<td>Central</td>
<td>7000-2000</td>
</tr>
<tr>
<td>Twin Sisters</td>
<td></td>
</tr>
<tr>
<td>San Marcos</td>
<td>1800-2800</td>
</tr>
<tr>
<td>Texas</td>
<td>2600-4200</td>
</tr>
<tr>
<td>Round Rock</td>
<td></td>
</tr>
<tr>
<td>Clear Fork</td>
<td>4000-5000</td>
</tr>
<tr>
<td>Archaic</td>
<td>4500-8000</td>
</tr>
<tr>
<td>San Geronimo</td>
<td></td>
</tr>
<tr>
<td>Paleo-Indian</td>
<td>7000-?</td>
</tr>
</tbody>
</table>

Weir's phases are bounded periods of relative systemic stability separated by episodes of relative instability and adaptive adjustment. The goal of the investigation was to study "the complexity of those subsystems that regulated stability and effected change in the five phases of the Central Texas Archaic" (1976:5). Each phase is a period of stability fostered by negative feedback.

The mechanisms of positive feedback and "kickers," or unpredictable (by the system) events, are posed as the reasons for changes from one mode of systemization to the other. The interface between phases is bridged by a brief kicker induced period of positive feedback.

Three negative feedback configurations are adopted from Birdsell's array of demographic equilibrium processes as being applicable to Central Texas. The Density process provides that, given environmental restriction, any population deviation will be restored to its normal relationship to the environment. If the population is deflected downward it will be restored to normal by excessive human fertility. If it is deflected upward, it will be restored to normal by groups budding off to colonize areas of below normal population.

The Communications process maintains the size of dialectical tribes which are social units composed of local bands speaking the same dialect. Spacing of bands is again controlled by the environment since groups can only be as close as the food supply will allow. On the other hand, if groups are too far apart, they will lose their tribal identification and split into more dialectical tribes reducing the tribal size. If bands of a tribe are too few in number, their identity is overwhelmed by their neighbors and they lose their tribal coherence. The balance between too few and too many groups, therefore, has to be close to a normal value for the tribe to retain its dialectical integrity.

The Local Group process maintains the fundamental social unit at above 25 persons. A smaller unit is not demographically viable for a number of reasons.
Among them is the fact that a group of less than 25 has precariously few women of reproductive age. Birdsell's original idea presumed that the size of the local groups is adjusted upward as resources allow for the gathering of larger numbers of people into smaller spaces. Some recent thinking by Sahiins (1972) and Wobst (1974) seems to suggest that the local group may in fact seek an equilibrium which tends downward toward 25 rather than upward toward carrying capacity. This point of view will be elaborated in subsequent discussions. Each of these processes controls key variables in the cultural system.

Table 18.02 Summary of Weir's (1976:120) Findings, Variable Trajectories

<table>
<thead>
<tr>
<th>Late Prehistoric (400-1500)</th>
<th>SOcio-PoLitiCAL SpeCial-iZatiOn DeLimiTaTions</th>
<th>CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twin Sisters (700-2000)</td>
<td>unstructured</td>
<td>unstructured</td>
</tr>
<tr>
<td>San Marcos (1800-2800)</td>
<td>unstructured</td>
<td>specialized</td>
</tr>
<tr>
<td>Round Rock (2600-4200)</td>
<td>highly structured</td>
<td>specialized</td>
</tr>
<tr>
<td>Clear Fork (4000-5000)</td>
<td>unstructured</td>
<td>specialized</td>
</tr>
<tr>
<td>San Geronimo (4500-8000)</td>
<td>unstructured</td>
<td>unspecialized</td>
</tr>
<tr>
<td>Paleo-Indian (7000-?)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 18.02 summarizes the trajectories of the various cultural quantities Weir attempts to estimate in his analysis. He ultimately encapsulates these trends through time in the sequence "dissemination-coalescence-proliferation." During the early part of the Holocene the San Geronimo (4500-8000 BP) people subsisted in a generalized fashion on small game and gathering. They were probably organized very informally and unspecialized in their technological functions. No particular limits to their domain can be found. They seem to have been at the crossroads of the East and West as well as being influenced from the Southwest.

With the Clear Fork (4000-5000 BP) Phase structures began to move toward coalescence. Population appeared to increase, and social organization and technology became more complex and specialized, perhaps at the beckon of oak woodlands which supplied abundant acorns as a new source of energy. Burned rock
middens increased in number and complexity and the Clear Fork Gouge was prominent in the tool inventory; it was probably a woodworking tool. There was only a hint of influence from the East. On the main the Central Texas Archaic seems to have taken a character and role of its own.

In the subsequent Round Rock Phase (2600-4200) these trends were carried to exorbitant extremes. All of the evidence indicates a tremendous, highly structured population, a focal economy and a completely local and strong character to the culture. Bifacing tools during this period were so dominant that they are the most characteristic feature of the lithic technology for the entire Archaic trajectory. Weir speculates that the Round Rock people may have been instrumental in expanding the potential of their environment by unintentionally spreading acorns to all parts of the countryside. Subsequent work (Gunn and Weir 1976) shows that this phase flourished in a cool, damp period which would have encouraged an eastern woodland life environment.

At the beginning of the San Marcos Phase (1800-2800 BP) bison reoccupied the southern plains and with them came influences and/or people of the Plains. Whether by barbarian invasion or some other means, the bison hunters appear to have shattered the Round Rock hegemony. Population dropped off and the economy became diffuse. Organization and local integrity of the culture disappeared.

By the time of the Twin Sisters Phase (700-2000 BP), the fickle bison returned to the north and the Central Texas Archaic was left as it began, small game hunters and gatherers. Weir believes that with the exception of bows and arrows this assemblage and pattern of life continue through the Late Prehistoric period.

The relationship between the succession of cultures in Archaic Texas, the lithic assemblages which mark their passage in the archaeological record, and progressive developments in climate are discussed in Gunn and Weir (1976). Numerical analysis shows that there is a general trend through time from a flake core lithic technology to bifacing. This trend is buffeted about, either hurried or retarded as the case may be, by periods of radical change in environment. Some time after the Round Rock Phase there seems to have been a slight return to core flaking technology (Hester 1971; and Section 17.0, Flake Technology, this volume).

Modern Biota

As has been suggested, these changes in technology can be interpreted as cultural responses to fluctuations in global climatic parameters which presumably act through the intermediary of biota to vary the available necessities of life. The basic outline of past biota can be best understood in terms of the modern biotic distribution.
Figure 18.01. Biotic Provinces and Supraprovinces of Texas. (Adapted from Blair 1950)
The classic work on biotic provinces of Texas was published by Blair (1950) and is probably the most cited publication in the archaeological literature of the region. Blair compiled his assessment of Texas biotic provinces from various surveys of plant and animal life made in 1901, 1905, 1931, 1938, 1939, 1940, 1942, 1943, 1944, 1946, 1947, 1948 and 1949. There was notable change in global temperatures during these five decades (see Section 4.0). However, the bulk of the work appears to have been done in the 1930s and 1940s. In a way, this is ideal because these two decades represent the apex of global temperatures during the present cold-warm-cold cycle. Being at the top of a cycle mitigates to some extent the problem of calibrating the present regime with those of the past.

According to Blair,

A great area in central Texas, from the Pecos on the west to the western boundary of the Austroriparian forest on the east, is principally a region of transition between the Sonoran and Austroriparian biotas. In this area the two major biotas intermix or interdigitate. Two biotic provinces, the Balcónian and Texan, are recognized in this transition area. Several obvious factors influence the distribution of plants and animals in the transition area, or great ecotone, that comprises much of the area of Texas. These factors are principally edaphic or physiographic ones. Austroriparian species may be expected to range westward in this area wherever local conditions result in more mesic environment than the regional average. Western species may be expected to occur eastward in this area where local conditions produce a more xeric environment than the regional average. The stream systems of Texas provide important routes for the westward distribution of Austroriparian species into comparatively arid, generally treeless environments. Rock outcrops on dissected plateaus and on escarpments provide avenues for dispersal of... Chihuahuan province species... eastward (Blair 1950:95-96).

Settlement Patterns

Recent work by Valdez (n.d.) shows that when the biota of these zones are reduced by multivariate procedures and plotted, the Austroriparian and Texan Zones, wet provinces to the east, are very close together and form a group which contrasts strongly with the Kansan, Balcónian and Tamaulipan Zones, dryer provinces to the west. Since the grosser biotic characteristics of a given piece of land determine the general character of cultural adaptations to it, in the following study Texas will be assumed to be composed of two culturally relevant biotic supr Provinces, the Humid and the Arid Zones. Cultural adaptations to these zones are taken to be analogs of the Desert Archaic for the Arid Zone and the Eastern Archaic Tradition for the Humid Zone. While both adaptations involve a certain amount of annual movement in the quest for subsistence resources, the Eastern woodland tradition is more of a transhumant process while the western tradition is more of a nomadic seasonal round with a number of collecting stations of relatively equal importance. Without being too specific I would suggest Steward's (1938) Great Basin Study of the Shoshone as an extreme example of western nomadism and Winters' (1969) Riverton Culture as an example of the Eastern Archaic Tradition. The Desert Tradition should be reflected in the archaeological record as sites of similar and small size while the Eastern Tradition
sides would be found to contrast in size between more permanent settlements and seasonal, transhumant collecting stations.

An important distinction to be made between the settlement patterns of the far western Desert Archaic and the probable semi-arid Archaic of western Texas is this. The systems of the desert are oriented to the exploitation of broad, unbroken stretches of ground which approach Christaller's ideal of an unbounded plain with all resources equally distributed (Hester et al. 1977). As Blair's description shows, however, west Texas is not of such a nature. Relatively rich riparian zones infested with the dense fauna of the eastern woodlands finger out onto an otherwise sparsely vegetated plain. Resources are clearly not equally distributed. Under such conditions base camps can be expected to be located near these richer areas. On the other hand, such river valleys are not broad enough to provide a stable existence and frequent exploitation camps can be expected in the open areas as well, evidence of the systematic exploitation of the interriparian areas. As a hypothesis, it might be suggested that the uplands would be less intensively exploited as floodplains become broader and richer to the east.

The nomadic and transhumant processes associated with these settlement patterns can likewise be inferred to imply somewhat different cognitive approaches to coping with the environment. Relative to the Desert Tradition, recent anthropological studies of nomadic hunters and gatherers have virtually reversed everything that has been thought about them for millennia. Empirical studies such as those by Lee and Devore (1973) show that they were not pitifully hard pressed victims of circumstance. More importantly Sahlin (1972) has demonstrated that they probably had a view of their economic world which was diametrically opposed to our own and which was founded in the realities of their technology, population density and resource availability. That economic philosophy is most readily summed up as "do as little as you can and carry as little as you can with you." This sounds like the western definition for laziness but in primitive cultures it is a viable strategy for survival which the most ambitious people cleverly follow. (Sahlin thinks the concept of laziness was probably a neolithic invention and I am sure Childe would have said it was the invention of priests in order to subvert the masses.) The full impact of these ideas is difficult to realize until they are implemented into our systems formulations of how primitive cultures operate. Wobst (1974) has shown that the "magic number 25," which seems to an almost ubiquitous band size, represents the minimum demographic unit which can be expected to survive stochastic fluctuations in demographic variables.

It has always been assumed before that primitive cultures, like our own, were continually pressing against the carrying capacity of the land and no little effort has been expended groping about for an elusive formula which shows how much below carrying capacity primitives tried to maintain themselves in order to avoid problems of overpopulation. The present trend of research seems to show that primitives did exactly the opposite. They tried to see how small they could make their population without getting caught by the "fickle finger" of stochastic, demographic fate. They are trying to depress rather than increase
their population. The reasons are quite tenable within the context of hunter-gatherer philosophy. The more people there are in a group the harder everyone has to work. This is easily demonstrated by the fact that the more people there are in a band the sooner the resources are used up around a camp and the sooner everyone has to move to a new location. Therefore, keep population of the band to a bare minimum. In the case of primitive cultures, then, the equilibrium is not between population and carrying capacity; the equilibrium is between demography and chance. They gamble with the fate of the band rather than the fate of the individuals who would starve if the carrying capacity were overrun. When it is considered that bands are loosely organized and if a band proves inviable its members simply disband and go to live with relatives in other groups, the gamble seems remarkably palatable. As Birdsell (1973) has pointed out, their loyalty is with the dialectic tribe rather than the band.

It seems to me that this orientation has the potential to bring order out of chaos of thinking that has revolved around primitive society for the last few years.

The next question has to be, "How does carrying capacity fit into the picture?" It obviously has an influence or people would be spaced over the world in an even distribution regardless of the density of resources. In principle carrying capacity increases the number of people that can be clustered in an area without causing more work for everyone.

Increasing density can be effected by packing bands closer together or by increasing band size. The characteristics of the two approaches are radically different. Band packing can be accomplished with no fundamental changes in the social organization of the band. Band enlarging, on the other hand, requires an elaboration of the social structure to keep the increased unit size functioning in an orderly manner. As Flannery (1972) has pointed out, elaboration of the social structure requires that everyone pay overhead to ceremonialism or to those appointed to position of power. In terms of primitive economic philosophy this is causing everyone more work and therefore would not be an acceptable alternative.

Band enlargement requires a different philosophy of life. For one thing the populace has to be willing to give up the principle of least work and pay the overhead to maintain ceremonial or governmental mechanisms to direct the order of social progress. Furthermore, such organization appears to be inextricably bound to the ability to materialize the symbols of power and order. People of the primitive order could carry elaborate symbols about only with difficulty. Thus, band enlargement and social elaboration implies some form of sedentariness.

So far as we can guess, Central Texas was generally occupied by people of the Desert Archaic variety except for periods of lower global temperature during which the eastern woodland and presumably eastern woodland-like people would have dominated the biotic and the cultural milieu. Exceptionally large sites during the Round Rock Phase of the Archaic which was during a cold interval tend to confirm this (Weir 1976; Prewitt 1974; Gunn and Weir 1976). Based
on the foregoing discussion the assumption is made that these people were of a very different philosophy of life and would have been adverse to their Desert Archaic contemporaries to the west. This diversity of subsistence and economic operation would have dampened serious interaction across the ecotone between the Humid and Arid Zones.

In summary, then, general explanation of prehistoric demography and site distributions in Central Texas can be encompassed by adequate modeling of three processes. The first is the shift of the broad Arid-Humid ecotone in concordance with global temperatures. The second is the nomadic, labor reducing, broad spectrum subsistence adaptations of the Desert Archaic people of the Arid Zone. The third is the transhumant, labor inducing, focal economy of the Eastern Archaic Tradition. In the following pages an attempt will be made to reduce these processes to mathematical and statistical relationships. The effort is superficial and tentative, a first step intended to explore the potential of the approach as a tool for the study of prehistoric Central Texas.

Envirocultural Model for Occupation Frequency

It should be noted that in the following discussion "A model...is a description of subsystems within the system being studied, each having its own properties and all--interacting together according to their individual properties--being responsible for observed appearances" (Powers 1973:14). Thus, concepts such as density equilibrium, communications equilibrium, local group equilibrium as per Birdsell and Weir, and labor equilibria, subsistence spectrum equilibria, mobility equilibria, etc., are observed properties of socio-cultural groups or subsystems. They are the variables which control the subsystems and result in the observable archaeological record.

The first and perhaps easiest problem to deal with is a deterministic mapping of climatic conditions in Texas at different global temperature levels. The formulas that follow are systems of equations which conjoin climatic, temporal relationships. The driving force is a climatic curve of average Northern Hemispheric temperatures (National Academy of Science 1975; Section 3.0, this volume).

During the 1931-1969 period, Texas received an annual average of 1422 mm of precipitation in the East and 200 mm in the West. A study of Texas weather patterns (Bielser and Gunn this volume) suggests resolution of precipitation into two vectors representing two processes. Spring and summer rain is predominantly from a monsoon effect which draws supersaturated air off the Gulf of Mexico and deposits it on land as rain, due either to cooling in the spring or convection cells during the summer. The effect of monsoon and convection circulation spreads westward with cooling of global temperatures. Fall and winter precipitation appears to be the product of a peculiar relationship to the mountains in Western North America. Warm global temperatures drive the westerlies northward so most of the moisture is combed out of the clouds in California and in other high mountainous regions. Global cooling, however, generally moves weather systems southward (Sanchez and Kutzbach 1974). To the west of central and south Texas, the mountains of northern Mexico are relatively low and they allow moisture to pass into the southern Plains. Here northern
Figure 18.01. Monsoonal Precipitation Gradient on an East-West Transect Through Study Area.
Figure 18.03. Climatic Variation During the Holocene.
cold fronts collide with the moist westerlies causing spectacular increases in precipitation during colder winters.

Estimating how far changing global temperatures displace the monsoon circulation is something of an inexact science right now. However, Jose Enrique de la Pena who traveled with Santa Anna's army to the Alamo in the winter of 1936 reported a very hard journey due to weather conditions which do not resemble those in south Texas and northern Mexico today. He saw cypress trees in northern Mexico about 300 kilometers west of their present range which is in areas of greater than 700 mm of rainfall (Figure 18.02). This would effectively move the 700-mm rainfall line out to the present 400-mm line. 1836 was preceded by a half-century of lower than usual sunspot activity (Eddy 1977); and judging by several graphs such as those published by the National Academy of Science (1975), the temperature of the Northern Hemisphere was probably depressed about 1.5°C. Until better evidence is found a figure of 200 km displacement per 1°C of climatic change will be assumed. (300 km ± 1.5°C)

The 1°:200km ratio is somewhat questionable because of the simultaneous southward movement of the westerlies. The westerlies, however, affect fall and winter precipitation and the mesic cypress would have to be sustained through the summer by monsoonal activity. It may, therefore, be at least of the correct order of magnitude. It is a conservative estimate because we do not know how far cypress extended west beyond the place where de la Pena saw them.

To simplify the problems of calculating monsoonal displacement, a 1000 meter square was superimposed on Texas as is illustrated in Figure 18.03. Figure 18.02 shows the present monsoonal precipitation gradient on an east-west transect that goes across Gillespie County where Hop Hill is located. If the precipitation is 305 mm at 250 km east on the grid and 1397 mm at 100 km east, the moisture gradient across the grid is like the triangle at the top of Figure 18.03. The trigonometric formula to find the opposite leg of a triangle when the angle and adjacent leg are known is:

\[
\frac{P}{E} = \tan G \tag{18.01}
\]

Since we know P (precipitation in mm) and E (distance east in km) in both cases we can solve for angle G by subtracting the unknown displacement distance (D) from both equations and setting them equal to each other. Cross multiplying and solving for D obtains:

\[
\tan G = \frac{P}{E-D} = \frac{305\text{mm}}{250\text{km}-D} = \frac{1397\text{mm}}{1000\text{km}-D} \therefore D = 40.5 \text{ km.} \tag{18.02}
\]

Substituting D = 40.5 we find that tan G = 1.45.

If we want to find out what the precipitation is at any point on the east-west gradient (\(P_e\)), say 560 km east, it can be obtained by reformulating equation 18.02:
\[ P_e = \tan \theta (E-D). \]  \hspace{1cm} (18.03)

Entering the Values:

\[ Pe = 1.45 \hspace{1cm} (650 - 40.5) = 884 \text{ mm}. \]  \hspace{1cm} (18.04)

If it is assumed that the gradient stays the same when global temperatures change, then changes in precipitation can be represented as changes in the length of D. It was decided earlier that 1 °C would represent a 200-km shift in the precipitation regime. Since the present displacement is 400 km and the present mean temperature of the Northern Hemisphere is 15 °C a displacement factor can be calculated as:

\[ D = \left[ (C-15) - 200 \right] + 40.5, \]  \hspace{1cm} (18.05)

where C equals the new mean hemispheric temperature. Calculations for 14 °C and 16.2 °C, the lowest and highest Holocene temperatures, were made and entered on Figure 18.03 as dashed lines. Lines projected from where these estimates intersect the 700-mm rain line on the graph onto the map show a rough estimate of the range of variation of the Humid-Arid ecotone in post-Pleistocene times. The Hop Hill locality in Gillespie County is in the center of the zone of variation.

Estimating values for the north-south or westerlies gradient is even more difficult. Warmer winters bring less rain to both south and north Texas because the westerlies move out of south Texas and points west capture the rain that might have come to the central and northern sections of the region. As the westerlies move south, the south receives unbelievable increases in rainfall. The fall of 1976 saw as much as 50 inches of rain in a previously semi-arid region. Water tables rose to higher than any point on record and springs appeared that had been dormant within the scope of living memory.

For now let us assume that the area down specified jet stream tracks receives rain in inverse proportion to the height of the mountains to the west and in inverse proportion to the distance from the center of the jet stream. The center of the jet stream and accompanying westerlies will move southward in inverse proportion to the mean November temperature. In 1976 the mean November temperature was 8.33 °C (47 °F) which is 2.00 °C below 19xx and it moved the jet stream 400 km south.

\[ \frac{400 \text{ km}}{2} = 200 \text{ km} \]  \hspace{1cm} (18.06)

As equation 18.06 shows, we can take a 200 km per °C shift as a working figure. This rate of change implies a 5 °C potential from north to south in the 1000 km grid.

Since the jet stream tracks are northwesterly in origin the location of the jet stream in 1976 cannot be directly to the west of point E-S (Figure 18.03). If a storm track (T) 22° north of west is assumed, the relevant point on the west
margin of the grid is J km south of grid origin, where

\[ J = S - [\tan T(E)]. \]

Thus, for a point at \( E = 500, \ S = 700, \)

\[ J = 498 \text{ km} = 700 - [0.404 \times 500]. \quad (18.07) \]

The location of the jet stream for a given year is calculated as

\[ J = [(C - 8.33) \times 200] + 498. \quad (18.08) \]

The height of the mountains at point J is the quantity which is inversely related to rainfall. Judging by 1976 the jet stream coming through at the lowest point has the potential to increase fall precipitation about 760 mm. The mountains range from 900 to 3000 meters, a range of 2100 meters. Dividing precipitation potential by elevation range shows that a meter of elevation influences 0.36 mm of precipitation. Thus, if mountain height is 2300 meters, westerly precipitation at the center of the jet stream is,

\[ P_s = 252 \text{ mm} = [2100 - (H-900)] \times 0.36. \quad (18.09) \]

While it makes sense that the amount of precipitation would decrease away from the center of the jet stream I have not studied the rate of diminution. Just as a working figure the distance from the jet stream on the western grid margin was divided by 50 and the inverse of that number multiplied times precipitation at the center of the jet stream. If a site were 200 km from the storm track, then the influenced track calculated in (18.09) would be:

\[ P_s = \frac{1}{200/50} \times 252 \text{ m} = 63 \text{ mm} \quad (18.10) \]

(note: distance to the storm track must be >50 km)

For any given location:

\[ P = P_s + P_e. \quad (18.11) \]

On the left Figure 18.03 shows the elevations of mountains directly to the west. Since weather systems veer slightly south of east it is south rather than central Texas which receives the precipitation. Because the precipitation is in the fall and winter one might question the utility of modeling this source of moisture. Our research, however, has shown that summer temperatures are affected far more than winter temperatures. Over the last two decades summer monthly means in the vicinity of Hop Hill have fallen nearly 3°C. Such reduced temperatures result in reduced evaporation and an increase in effective moisture, higher water tables, etc., for the rest of the year. Hopefully, the curves developed here will reflect in part the increased effective moisture.

Within the context set by the calculations of moisture the settlement processes of the two cultural systems need to be specified. Thomas (1974) has devoted
considerable effort to testing Julian Steward's (1936) model of Desert Archaic subsistence patterns. Also, Prewitt (1974:1-20) briefly outlines a system designed to explain site location during the Texas Archaic. In a derived form it could go far toward delineating the processes which explain the observed appearances. Prewitt assumes that his prehistoric subjects were responsive rather than active toward the environment. Next he distinguishes between "exploitive" systems and "management" systems. Exploitive systems gather resources in a location until they reach a point of diminishing returns. Management systems consciously manipulate resources in a manner designed to conserve them, as in the case of some modern cattle ranchers. I take this to mean that a hunter-gatherer band would leave "seed," whether floral or faunal, so that the environment can assuredly and rapidly replenish itself after the band departs. In practice, then, management probably consists of leaving too early, before the perceived rate of returns is fully diminished. I have seen ethnographic reports which indicate management is within the behavioral repertoire of primitive people, though there is no reason to think that it was universally practiced.

Whichever system is active, site locations are determined by surface topography and by proximity to unequally valued resources. Unequally valued resources imply an element of immediacy. Locations, for instance, are more likely to be proximate to food than to raw materials for tools.

Figure 18.04. Nomadic Seasonal Round. A = site A, etc., A* = Resource at site A, etc., A' = Alternate site with resource A*, X = new site with new resource X*. 
Repeated occupation of a given site is governed in theory by foreknowledge of the location of desired resources, or in the case where different cultures have located at the same spot, resources that were coincidentally valued in all cases were available at the same place over long periods of time.

When the resources of a given locality were depleted to a determined point of efficiency in energy-versus-yield, movement to a new locality was initiated on a course drawn from foreknowledge of the next scheduled resource and its location. Seasonal variation would be a limiting factor on the time of movement. As Figure 18.04 shows, this model can be flow charted so it could be satisfactorily simulated with a system of resources, seasonal availability schedules, area maps, climatic change effects, potential but unused resources, etc. The flow chart shows that as a group exploits resource A it checks the energy-expended/energy-returned ratio (E) and the progress of the seasons (S). As long as these quantities are positive, checking is initiated on a patterned or stochastic basis but no action is taken relative to a new site. When energy status changes or the season changes a cognitive map of the resource area is checked and the move from A to B effected.

If the expected resources are found at B the process of checking as it is done in the "normal" system is resumed. If B is not found a series of procedures are initiated. I have arranged these procedures on the basis of conservatism. The first procedure is the "search" for a substitute site B' that has the same resource, B*. If the search procedure is successful the activity goes back to the normal system with B' as a known alternative which may eventually replace B on the seasonal round if it is reliable.

If search is not successful another alternative such as "spanning" may be attempted. Spanning is, or is something like, trying to make resource A last in its waning hours until a skimpy bit of C becomes available. Thus, the tails of A and C span the duration of missing resource B. This might also be called "making ends meet."

A third alternative is "resource innovation," looking for something that has not been used before. The Chinese eating stewed mud in The Good Earth would be a desperate example of resource innovation. This is symbolized as a resource X which will replace B in nutrition and scheduling characteristics. It would be the underlying process in primary forest efficiency as defined by Caldwell (1958).

Any number of procedures could be entered in the Alternate System, and the procedures in the alternate system are subject to innovation. It is an expandable list. Also, in reality alternative procedures would probably be used in combinations rather than singularly as the simulation flow chart suggests.

Two things should be noted about this model. First, it is an attempt to escape the purely stimulus-response function which has been a large part of archaeological modeling in the past. It allows either patterned or innovative movement in the environment. The groundwork for these arguments is in psychological studies of brain function such as those by Ross-Ashby (1960) and Powers (1973) and of cultural function (Flannery 1972; Gunn 1977). Second, the model explains the
behavior of an entity with recognizable boundary condition which exists in a world of similarly conceived entities.

Given this system, what are the probabilities that a given location will be occupied in a given year? The phenomenon of break in the archaeological record is relatively common and can probably be best explained in terms of band life span (Wobst 1974:174). A site as we have described it is a station on a cognitively mapped seasonal round. It is a member of a finite number of loci chosen from a large number of potential stations within a band territory which forms a regular and predictable part of a band's annual life cycle. If a band dies out due to any of the stochastic or systematic phenomena which tend to end such organizations, the site will not be reoccupied again until a system search determines its suitability, and that suitability is routinized. While certain highly desirable loci may have a higher probability of being chosen, there is no reason to think that selection of any site is not a matter of probability and combinations of diverse selective pressures.

![Diagram of Load Length to Various Substations](image)

Figure 18.05. Load Length to Various Substations.

Implementing such a statistical scheme requires an exact model of land use patterns. Central Place theory provides the basis for such a scheme. Previous work (Hester et al. 1977) has shown that in broad open desert conditions a pattern of unpacked hexagons is an at least interesting potential model. That is, hexagons are desirable to gatherers for the standard reason of equal access to substations from base stations. These hexagons, however, would not be packed together because it would only result in walking to an area which was already half gathered.

An additional consideration needs to be made in an area like Central Texas which is richly supplied with water courses. Most main sites appear to be on upland margins, valley slopes, or floodplains. Such locations were, no doubt, chosen because of access to water, richer riparian habitats and
observability, lithic material, even perhaps for issues of prevailing winds and other camp comfort considerations. Such camps are probably parts of hexagonal systems which are distorted as the one in Figure 18.05. A possible line of research might be to show that each of the rays from station to substations has a "load length." Water and riparian resources have relatively heavy concentrations and are frequently required. The camp is, therefore, located to minimize the distance relatively "heavy" loads must be carried. Upland resources, in contrast, are sparse and light, both suggesting a longer acceptable load length. In Figure 18.05 the paths are darkened to show relative load length ratios. Presumably the heavier paths should always be shorter.

Such a model provides a rationale for saying that the margins of stream courses are more probably occupied than upland substations and the occupation of such stations is contingent on occupation of streamside stations.

Other influences might act to increase the probability of a site being occupied on the stream side such as good vantage points. Figure 18.06 shows the relative probabilities of various locations along an occupied stream. Locations on curves in the stream are highly probable even more so if they are at the juncture of two streams. Straight runs are less probable. Uplands away from the stream margin are low probability. Again, working quantities are set:

\[ VH = .8, H = .7, M = .4, L = .1 \]  

(18.12)

In a simulation, when the research area is showing values for arid environment, each site cell adjacent to a stream would be tested for occupation during a given season according to its probability structure as modified by the needs of the local band. These needs are worked out on the basis of proximity to the band, rate of change in the environment which might cause them to look for new sites, band half life, etc. Over the years the debris is cumulated in relative terms posited on the number of visits.

The third and final process to be made explicit is the one of the transhumant, labor inducing, focal economy of the Eastern Archaic. In this case, and in contrast to the previous process, labor intensification is taken to be a desirable alternative to mobility intensification. They would rather "fight than move." Since there is no reason to think we are dealing with agriculturalists in the strict sense, effort will be lavished on broadening the resource spectrum if the availability of primary resources is diminished by climate or overuse. Accumulation of goods and balance of population with environment probably become matters of concern since carrying infants is no longer a convincing influence to limit family size. Also, the inception of desire for large families may have its roots in the need for a large labor force to collect food and deal with a potentially competitive social milieu.

In this scheme the initiator does not consider the diminishing returns as an indicator for mobility (Figure 18.07). The seasons are checked and the labor force is dispatched to A* working at home and/or working away, B*. At the transhumant stations food is collected and, if sufficient, carried home. If not sufficient, other localities are tested and collected until sufficiency is
Figure 18.06. Relative Probability of Occupation at Various Geographic Localities.
reached. At the village the transported and local resources are tested for sufficiency. If sufficiency is not reached trading, raiding and migration are alternatives in order of caste to the community. In certain circumstances trade and raid may be reversed depending on value systems. Migration, however, is undesirable.

Note that the system is posited on a very broad and rich riparian environment or woodland regime. The settlement pattern is modified to reflect a broader emphasis in a richer environment. Sites are more probably occupied in direct proportion to water available not only for household tasks but also for fishing and transportation (UH = .9, H = .6, M = .4, L = .1). A group has a bigger territory and is willing to transport large quantities of food by improved transportation methods longer distances to a permanent village.
19.0 CONCLUSIONS (Joel Cunn and Royce Mahula)

The foregoing sections of this report have dealt with a broad range of information as viewed by a relatively large number of individuals. It is the purpose of this section to summarize the findings of these analyses and draw them together into the broader picture. It may appear that these discoveries are stated in a somewhat over-definite manner. It would indeed be scientifically unsound to presume that all of what follows is "conclusions" in the sense of firmly established truths. The conclusion of each individual study represents an hypothesis which the author felt was supported by his data. This conclusion section represents the final systematic hypothesis which in part sums the efforts and discoveries of those involved. This is not to imply that all of the work included here is conjecture. Some of the analyses were preceded by years of careful study and as a result are relatively sophisticated. Reference should be made to the character of the background studies preceding each analysis to determine the degree of certainty with which a given remark is offered.

In the introduction the various aspects of the Hop Hill research project were generally organized around a set of concepts centering on an ecosphere, with relevant variables grouped according to whether they pertained to the atmosphere, geosphere or ground plane of the system. The summary which follows is similarly organized. The key variables and the trajectory of those variables are discussed in each case. The order taken is atmosphere - geosphere - ground plane reflecting the idea that causal processes are predominantly ordered in that sequence.

Atmosphere

The atmosphere is an unstable aspect of the ecosphere which responds to a complex set of factors as ultimate as the sun's heat radiation and as finite as local altitude. One of the major indices of atmospheric variation appears to be average annual Northern Hemispheric temperature which is controlled to some large degree by secular variations in the Earth's orbital relationship to the sun. Also, solar heat production, which is reflected in sun spot activity and volcanic eruptions, appears to have significant effects on global temperatures. The variations engendered by these larger causes are reflected in the atmosphere as shifts in the tracts and behaviors of weather systems which deliver the local weather. Specifically, lowering of global temperatures causes weather systems to move southward and an extension of monsoonal moisture to the west which in sum produces more precipitation. Lower temperatures also reduce evaporation which increases effective moisture.

As a consequence, under colder climatic regimes, the humid eastern biota extend westward to occupy areas which are arid during warmer periods. Based on calculated displacement of the humid-arid ecotone, we are of the opinion that the Hop Hill locality would have experienced changes from essentially arid to essentially humid conditions within the global temperature variation known to have occurred during the Holocene. As of this writing, evidence has been obtained from the study mollusks, ethnohistorical records, and inferred from cultural adaptations to the effect that such climatic changes did occur. Further evidence is being sought to substantiate the hypothesis of climatic instabilities.
**Geosphere**

The geosphere is a quasi-stable medium below the ground plane which in large part reacts to more active agents of the atmosphere. Examination of the geology of the Hop Hill region shows the general area to be underlain by a permeable limestone formation which is richly course with underground waterways. An underlying impermeable clay acts to facilitate an accessible and reliable water table. This favorable hydrological situation acts to foster springs and rivers which appear to be consistently reliable sources of water even under relatively severe drought conditions such as those in the 1930's. Thus, while uplands between water courses might be subject to drying under more arid conditions, valleys and spring localities would provide a reliable source of water for human populations. The width of riparian zones, however, could vary directly with the amount of precipitation and would therefore be an inconstant source of subsistence requiring frequent adjustments in adaptation.

**Ground Plane**

The ground plane bisects the ecosphere and is composed of biotic and cultural processes which respond to the atmosphere, alter the upper surface of the geosphere resulting in soil, and leave a record of those responses in a biocultural residue within the soil.

Findings in various studies show that within the Hop Hill locality, the soils themselves respond post-depositionally to active agents in the atmosphere. The tougher Pedernales soil in the eastern half is erosion resistant. Relative to preservation of biocultural residues, this is a mixed blessing. The remains that were deposited there were apparently well preserved. However, prehistoric people came to the locality to gather lithic materials eroding out of the more erodable Hensley soils to the west and as a consequence tended to also leave cultural materials in greater quantities in that area.

Predominately within the permeable Hensley soil area of the locality, human activity divides into three relatively discrete areas. On the valley slope is the quarry area. On the upland margin there is an occupation-workshop complex with occupation activities concentrated more to the west and workshop pursuits more to the east. Simultaneous occupation of the quarry and occupation-workshop is indicated by the use of quarry materials in the occupation-workshop area with only rare exotic introductions from other sources. That there was differential use of the areas is shown by the fact that decortication flakes appear in the quarry while shaping and sharpening is more prevalent in the occupation-workshop complex.

The locality was utilized on occasion from the Early Archaic to the present. A major focus of prehistoric activity was during the Late Archaic, according to projectile point frequencies, and also the presence of a burned rock midden implies some sort of Archaic association.

On the upland margin several lines of evidence suggest an occupation-workshop and a division of labor within the heavily utilized area. Specialized cores, large choppers, heat treating, etc., are localized to the east, while the midden, as well as choppers, picks, metate, manos, boiling stones, etc., are to the west.
The fact that these tendencies show up in an eroded site bespeaks a relatively long lived tradition of arranging living patterns in this way. The reason for maintaining such a tradition over a long period of time suggests an inherent relationship between camp patterns and topography. Since the site is on a prominence which extends out into the Pedernales floodplain, the arrangement may have related to an advantageous position from which to observe game and intruders.

**Subsistence**

Recovered evidence of subsistence of people who visited the locality is limited to fresh water mollusks. Inferences from patterns of food preparation suggested by patterns of limestone scatter on successive occupation floors may support a deer and acorn processing phase earlier followed by a change; perhaps to a more broad spectrum "Desert Culture" type of subsistence. The pioneer vegetation observed in the abandoned stock pens probably reflects the character and range of seed plants which would have been available annually to prehistoric inhabitants in the Pedernales floodplain after floods destroyed more xeric grasses. These include various chenopods, etc., which have been standard fare for western arid zone cultures. We are inclined to believe that limestone cobbles 6-12 cm long, and which are limy-grey or red in color and are unusually fossiliferous in appearance and have angular breaks on an otherwise smooth surface are boiling stones. The key to this complex of traits is the acid in acorns which must be leached before consumption. Using limestone boiling stones would neutralize the acid while simultaneously eating away the outside rind of the stones. The more acid resistant fossils in the limestone would be left as prominances on the otherwise leached away surface. Breakage due to frequent heating resulted in the ultimate discard of the boiling stone. Large limestone fragments (>12) probably represent other food preparation processes.

**Ethnohistory**

Ethnohistorically, European-derived inhabitants of the Fredericksburg area appeared during the relatively cold period of the "Little Ice Age." The tall prairie grasses used in the construction of thatched roofs attests to the Texan biotic province character of the vegetation at the time. Also typical of the eastern habitat is the abundance of bears which the Indians hunted extensively in order to obtain bear grease to trade to German settlers. It is of interest to note that early European inhabitants first adopted bear grease and corn to insure survival and only later were able to experiment with European crops and integrate them into the local economy.

During the first hundred years of intensive European settlement material culture slowly incorporated the realities of the Pedernales River basin into an increasingly characteristic modified German culture. Subsistence changed from an almost exclusive reliance on native crops and wildlife for subsistence level agriculture and collecting to an increasingly market-oriented, non-native domesticant orientation. In other words, native habitat and culture profoundly affected early settlers and it was only after a time that the flow of the population was reinserted into the Euro-American cultural milieu.
Recommendations

The various numerical analyses in this report should be refined in two ways. Both are related to auto correlation. The seriousness of the auto correlation problem did not become apparent until the various papers were in final form and the completion deadline for the report was near. Auto correlation was removed from time series such as global climatic parameters and local Fredericksburg climatic indicators. It might also be helpful to remove auto correlation from polar coordinate data. The procedure would be executed by rows to remove auto correlation effects from individual artifacts. A special computer program would have to be written but would not be complicated. Also, spatial auto correlation appears to be thwarting our efforts to determine directional tendencies in artifact distributions (linear technospatial analysis). The degree to which auto correlation is effective appears to be directly related to sample size. Linear technospatial analysis worked well with 27 cores, not so well with 121 bifaces and hardly at all with 176 unifaces. Removal of spatial auto correlation would probably clarify much relative to distributions of artifact classes containing large numbers of artifacts.

With respect to future excavation, the 1976 field season showed that there was little to be gained by excavation in the Pedernales soil area. The Hensley soil was much more productive yielding several thousand artifacts. Future archaeological activity at the Hop Hill locality would be most profitably concentrated in the midden excavation area in this Hensley soil. Due to the level of recovery deemed necessary to retrieve the maximum amount of cultural information on camp deposition and patterning, only the top 10 cm of the midden were excavated. Soundings to obtain soil samples show that there are at least 34 cm of deposits in the midden. Provided that future excavation is continued at the level of resolution initiated during the 1976 field season, the Hop Hill midden could provide the basis for a different order of approach to the problem of excavation and interpretation of middens. However, though further midden excavation would no doubt prove valuable additional collecting would probably change the statistical characteristics of the collection very little, and we have only begun to scratch the surface of the study potential of the materials already recovered. For example, to further maximize recovery of cultural information, soils from microlevels could be processed by froth flotation to determine if carbonized microbiotic materials can be obtained. A feasibility study is planned under the present project, but has not yet been conducted.
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