Analysis of Lithic Flakes at the Calico Site, California

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A discussion is presented of an analysis of lithic specimens recovered from the Calico Early Man Site in California. The purpose of the analysis was to determine whether there are consistent patterns of attributes that are characteristic of lithic manufacturing by man. For comparison, the same analysis was also performed on the products of experimental knapping of lithic raw materials obtained near the Calico Site. A number of conclusions from this study support the concept that the Calico lithic collection contains man-made specimens.

Introduction

The Calico Site is well known as a proposed very early human occupation site in the New World. It is located near Yermo, California, on an ancient alluvial fan, on the shoreline of a Pleistocene lake bed in the Mohave Desert. While general descriptions have been given of excavation work at this site (Simpson 1979, 1980), few details have been published on the various categories of lithic specimens excavated here. Two papers (Simpson, Patterson, and Singer 1986; Simpson and Patterson 1984) have given some technological reasons for proposing that the Calico lithic assemblage is not simply naturally-broken rock.

Two principal questions concerning Calico have to do with dating and whether or not the lithic specimens are actually man-made. No human skeletal remains have been found here. One published study (Bischoff et al. 1981) concludes that the deepest stratum of this site has a date of approximately 200,000 years before the present; even critics of this site accept the concept that it is very old. The apparent great antiquity of this site has been a major reason for its lack of acceptance by many archaeologists. A number of investigators (Jennings 1974: 47) do not believe that humans had developed the ability to traverse areas with very cold climates to enter the New World by the Bering Land Bridge (Hopkins 1967) until the end of the Pleistocene period. There has been a general reluctance to accept evidence for the presence of man in the New World before the Clovis period, which began about 12,000 years ago (Humphrey and Stanford 1979).

Many of the arguments as to whether or not the lithic assemblage at Calico is man-made have centered around small samples of specimens that are candidates for classification as simple stone tools such as scrapers, gravers, and choppers. Proposed tool types are mostly unifacial in nature. Comments by Haynes (1973) typify remarks by critics of the Calico lithic assemblage.

The Calico lithic assemblage is large, numbering many thousand specimens of fractured stone, mainly of siliceous varieties. Few details of this collection have been published; it is difficult to obtain research grants for controversial archaeological sites. Of equal importance is the fact that until recently little methodology had been de-
developed for the detailed analysis of this type of lithic collection (Patterson 1983). This paper represents the first phase of an overall effort to present detailed studies of the Calico lithic assemblage. In this case, an analysis has been made of a large representative sample of lithic flakes, in order to study possible manufacturing patterns. This is also the first detailed technical study of Calico lithic materials to be presented by investigators directly connected with the Calico project.

Hoffman has performed some knapping experiments on raw, Calico-type lithic materials. The results are included in this paper to provide a comparison of the results of known human percussion-flaking with the Calico lithic assemblage attributes.

Studies by Outside Investigators

There have been two studies of attributes of Calico lithic objects by outside investigators. In neither case is it apparent that representative samples were used. The main criticism of these studies, however, concerns their methodologies and conclusions.

Payen (1982) has studied the beta angles of some Calico flakes, applying the Barnes method (Barnes 1939) for determining human lithic workmanship. The beta angle is the angle between the ventral surface and the platform plane, and Barnes concluded that this will generally be acute (less than 90°) if the result of human workmanship. Patterson (1981a) has discussed problems in employing this analytical method as compared to use of the striking platform angle (between the dorsal surface and the platform plane). Probably the greatest problem with the Barnes method is that it considers only a single attribute, and it is very difficult to conclusively demonstrate the presence or absence of human workmanship in that manner.

Payen (1982) concluded that the Calico flake sample was not the result of human workmanship, based on study of beta angles. The study of Calico flakes presented here does not agree with that conclusion. Striking-platform angles on flakes analyzed for this present study are generally acute, consistent with the results of human workmanship. A question can be raised as to the nature of Payen’s sample. Only specimens that are candidates for representation as products of controlled flaking should be subject to analysis of platform geometry. A large amount of analytical “noise” can be introduced by analyzing miscellaneous specimens of broken stone that possibly are not the result of controlled flaking. It is common in many lithic industries to find large quantities of non-diagnostic broken stone that are not the products of controlled flaking. Another source of error in the analysis of striking platform geometry is the confusion of secondary fracture planes with true residual striking platforms on flakes.

Duval and Venner (1979) made a statistical comparison of selected attributes between some Calico flakes and flakes from a well-known Paleo-Indian collection, and also concluded that the Calico flakes were not man-made. This study has been criticized on the basis of the statistical methodology used (Gruhn and Young 1980) and on the basis that the statistical comparisons may not be relevant (Patterson 1980). Statistical comparison of a sophisticated Paleo-Indian lithic industry with a possible primitive lithic industry, such as that represented at Calico, does not seem to have any specific meaning.

Basis for the Study

Distinguishing between man-made lithic workmanship and the results of stone fracture by natural causes involves the search for repetitive patterns that are typical of human activities. Random natural forces are not likely to produce the same patterns of lithic attributes on a high frequency basis, as is typical of human lithic manufacturing. In human lithic industries, distinct tendencies can often be shown for selective use of raw materials, specific spatial distributions of specimens, and qualitative and quantitative patterns of lithic attributes. The repetitive nature of human activities constitutes a major basis for archaeological analysis (Deetz 1967: 109).

The study described in this report followed a plan formulated by L.W. Patterson. The analytical work was performed in the Archaeological Laboratory of the San Bernardino County Museum by Rose Marie Higginbotham and Louis V. Hoffman, under the supervision of the principal archaeologist for the Calico Site, Ruth D. Simpson.

Five test units from the excavations were selected for analysis. Each unit is a 5-ft square. Test units P-19 and Q-20 were selected from Master Pit 1, which is a 25-ft square, while units H-11, H-12, and J-13 were from Master Pit 2, which is a 15-ft square. A total of 13,677 lithic specimens were examined. Of these, 3,336 flakes larger than a 15 mm template (see "Methodology of the Analysis," below) were then subjected to detailed analysis. Tabulations given here include all broken specimens from the units under consideration.

Location and Geomorphic Setting

The Calico Early Man Site is located in the central Mojave Desert approximately 25 km NE of Barstow, California, in an area known informally as the Calico Hills. The general location is shown in Figure 1. These hills, mainly highly-dissected fans (Yermo deposits) overlying Miocene lacustrine sediments (Barstow For-
Close to the active San Andreas and Garlock faults, the Calico Site is in an area of high seismicity. Other faults lie nearby or literally pass through the site. There is evidence of Quaternary displacement in addition to historical neotectonics. The site is near the junction of the Calico, Manix, and other, unnamed, faults, the proximity of which has resulted in faulting and folding, causing greater dissection than is typically found elsewhere in the Mojave Desert. In the eastern Mojave, high-level fans with well-defined geomorphic divides and well-developed desert pavements may be more than 700,000 years old (Bull 1974; Shlemon 1978; Ku et al. 1979). In the Calico area, similarly dissected fans may be less than 100,000 years old. Thus, the dissection of the Calico Hills may not mean that the inferred artifact-bearing beds are at least 500,000 years old, as has been proposed (Haynes 1973). The seeming geomorphic antiquity might well reflect the high rate of neotectonic uplift, faulting, and folding that occurs in the entire area.

The Calico assemblage of lithic specimens is recovered from the Pleistocene Yermo deposits: from a basal mudflow and from overlying, interbedded debris flows and fanglomerates. Now highly dissected, these deposits are preserved as remnants of middle- and high-level fans within the Calico Hills.

**Chronology and Stratigraphy**

The stratigraphic levels that contain possible lithic artifacts are dated by two independent techniques. Uranium-series dating of the basal groundwater-derived carbonates encrusting the artifacts, that yielded a date of 200,000 ± 20,000 years B.P. (Bischoff et al. 1981), and soil stratigraphic age estimates of the strongly-developed relict paleosol capping the fan deposit over Master Pit 3. Based on comparison with strongly-developed soils elsewhere in arid and semiarid regions, the Calico relict paleosol is judged to be at least as old as the last major interglacial, the Sangamon (Gile and Grossman 1968; Morrison 1968; Nettleton et al. 1975; Bischoff et al. 1981). This is generally equated to stage 5 of the marine oxygen-isotope stage chronology, about 80,000 to 125,000 years B.P. (Bloom et al. 1974; Shackleton and Opdyke 1973). Inferentially, therefore, the underlying artifact-bearing Yermo deposits were laid down during a preceding epoch of regional alluviation, probably stage 6, about 125,000 to 200,000 years ago (Shackleton and Opdyke 1973). Because the basal Yermo beds seen in the excavations appear to be mud and debris flows, the environment is presumed to have been less arid than at present. From the soil stratigraphic age assessments, the lower levels are estimated to be 150,000 to 200,000 years old (Bischoff et al. 1981).

A tabulation of lithic specimens in reference to stra-
tigraphy for test unit H-12 is shown in Table 1. The main concentration of lithic specimens is found at a depth of 108 to 312 in within the excavated levels. There is a possibility that human occupations at the Calico Site could have occurred intermittently over a considerable period of time. Long occupation sequences are known for other very early sites, such as Choukoutien in China. It should also be noted that investigations are continuing in the Yukon (Irving, Jopling, and Beebe 1986) concerning early man in the New World at an age-level comparable to Calico.

Methodology of the Analysis

The philosophy throughout the analysis was to be conservative and not record the presence of an attribute if that presence was even questionable. Thus, the percentages of various attributes may be somewhat diluted by strict adherence to the definitions and criteria established at the beginning of the project.

As specimens were recovered at the site, those found in concentrations (discussed elsewhere) were bagged separately and identified as “clusters.” The rest of the specimens are referred to as the “general collection.”

Since this analytical work was aimed at identifying possible products of human workmanship, only flakes were subjected to detailed analysis to determine whether the typical attributes of controlled flaking were present. Other specimens of fractured stone were simply counted. Because there were many types of fractured stone specimens present in the Calico collection, there was a question as to how to define the category of “flake.” For this analysis, “flake” has been arbitrarily defined as a specimen having a length or width at least three times the maximum thickness.

Each specimen was measured with vernier calipers to the nearest millimeter and categorized as a chunk or a flake; a chunk was counted but not examined further. The size range of each flake was determined by fitting it into a series of square templates whose side dimensions ranged from 15 to 70 mm. Only flakes with at least one dimension greater than the 15 mm template were analyzed in detail. It is very time-consuming to work with large numbers of flakes smaller than that. The maximum thickness of each flake was recorded.

Attributes Examined

Flakes were examined under a high intensity light, with auxiliary tools as required, and the following attributes were recorded: force bulbs: present or absent; ripple lines: present or absent; striking platform condition: intact, crushed, or missing; striking platform angle:...
measured in degrees, using a swing arm protractor; striking platform type: single or multiple facets, presence or absence of cortex; striking platform edge: scars from trimming flakes, presence or absence; dorsal face facets: number of major facets; flake type: primary, secondary, or interior; bulb scars: presence recorded; material: classified according to appearance and character as chert, chalcedony, jasper, etc.

All specimens from unit H-11 and the experimental knapping were examined as described above and for two additional attributes: edge rounding due to transport: presence or absence, using a 10-power lens; flake differentiation: (judged visually to be a complete flake, proximal end fragment, central fragment, or distal end fragment).

Definition of Terms

The use of terms employed in the study is as follows.

1. Bulb scar: scar on a force bulb, frequently associated with percussion flaking.
2. Chalcedony: fine-grained cryptocrystalline quartz mineral that is often translucent and smooth-surfaced.
3. Chert: fine-grained opaque siliceous material.
4. Chunk: fractured rock specimen having a thickness greater than one-third its length or width.
5. Cluster: a concentration of flakes and debitage in contrast with the more common dispersed distribution of specimens.
6. Cortex: natural outer surface of a rock, usually weathered.
7. Diagnostic flake: a flake that exhibits a force bulb. There may be additional attributes commonly found in manmade flakes produced by percussion.
8. Dorsal face facet: major flake scar surface on dorsal face of flake.
9. Flake: fractured rock specimen having a length or width at least three times the maximum thickness.
10. Force bulb: a bulbous area on the ventral surface of a flake located just below the proximal end—bulb of percussion.
11. Interior flake: no cortex remaining on flake.
12. Jasper: opaque variety of colored cryptocrystalline quartz, usually reddish, yellow, or brown.
13. Non-diagnostic flake (NDF): a flake that lacks a force bulb, but may have other attributes; may be a flake fragment.
14. N.S.E.: not sufficient evidence, unable to classify.
15. Primary flake: dorsal surface of flake covered with cortex.
16. Ripple lines: concentric wave-like lines on the ventral surface of a flake.
18. Striking platform: area on flake where percussion impact occurs, causing a flake to be detached. Platform may be natural or may be prepared.
19. Striking platform angle: the angle between the residual striking platform on a flake and the dorsal surface.
20. Striking platform preparation: removal of cortex from the projected impact area. It may also have additional retouch.

Flake Attributes

One area for the investigation of whether or not a lithic assemblage is man-made is the examination of attribute patterns on flakes. Controlled flaking by humans results in predictable attribute patterns that can be subjected to qualitative and quantitative analyses. A number of attributes have been studied for the 3,336 flake specimens in this sample of Calico lithic materials. A general summary of the total lithic sample and some of the flake attributes is given in Tables 2 and 3. Some flakes from the excavations are shown in Figure 2. A discussion of each attribute analyzed follows below.

Force Bulbs

Early man most likely would have used percussive force to produce the types of fractured rock specimens present in the Calico assemblage. The presence of distinct force bulbs is the key attribute in identifying percussive fractures (Patterson 1983: 300). In contrast, natural forces would be more likely to fracture rock by pressure than by percussion, as natural situations involving frequent percussive fracturing are difficult to find. This is especially true for the alluvial deposit conditions at the Calico Site. A viscous mudflow or sheetwash does not permit much percussive action between contained rocks.

The minimum criterion used here for a diagnostic flake is the presence of a distinguishable force bulb. This is a conservative criterion. While percussive force produces high percentages of flakes with prominent force bulbs, many flakes produced by percussion can still have diffuse force bulbs (Patterson 1982a). This attribute must be handled on a statistical basis.

Of the 3,336 flakes from five Calico units, 26.1% had force bulbs and were classified as diagnostic flakes. In the experimental knapping project, using hard percussion, 24.3% of the 473 flakes possessed force bulbs and were classified as diagnostic flakes. By comparison, flakes produced by mechanical crushing (pressure force) usually have a very low percentage of distinguishable force bulbs, as shown by samples of flakes from mechanical gravel crushers (Patterson 1983: 306).

In the analysis of Calico flakes from the first four units, the total percentage of flakes having force bulbs is understated since middle and distal end fragments have
Table 2. Summary of lithic specimens.

<table>
<thead>
<tr>
<th></th>
<th>Diagnostic flakes</th>
<th>Non-diagnostic flakes</th>
<th>Total flakes</th>
<th>Total chunks</th>
<th>Unanalyzed specimens*</th>
<th>Total specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Master Pit 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-19</td>
<td>144 (15.5%)</td>
<td>787 (84.5%)</td>
<td>931 (100%)</td>
<td>761</td>
<td>4160</td>
<td>5852</td>
</tr>
<tr>
<td>Q-20</td>
<td>159 (35.9%)</td>
<td>284 (64.1%)</td>
<td>443 (100%)</td>
<td>1122</td>
<td>153</td>
<td>1718</td>
</tr>
<tr>
<td><strong>Master Pit 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H-12</td>
<td>276 (31.4%)</td>
<td>604 (68.6%)</td>
<td>880 (100%)</td>
<td>378</td>
<td>1064</td>
<td>2322</td>
</tr>
<tr>
<td>J-13</td>
<td>148 (43.1%)</td>
<td>195 (56.9%)</td>
<td>343 (100%)</td>
<td>947</td>
<td>269</td>
<td>1559</td>
</tr>
<tr>
<td>H-11</td>
<td>145 (19.6%)</td>
<td>594 (80.4%)</td>
<td>739 (100%)</td>
<td>380</td>
<td>1107</td>
<td>2226</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>872 (26.1%)</td>
<td>2464 (73.9%)</td>
<td>3336 (100%)</td>
<td>3588</td>
<td>6753</td>
<td>13677</td>
</tr>
<tr>
<td><strong>Knapping</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>experiment</td>
<td>115 (24.3%)</td>
<td>358 (75.7%)</td>
<td>473 (100%)</td>
<td>88</td>
<td>3242</td>
<td>3803</td>
</tr>
</tbody>
</table>

*Specimens smaller than the 15 mm template were not analyzed in detail.

Table 3. Flake attribute analysis.

<table>
<thead>
<tr>
<th></th>
<th>Master Pit 1</th>
<th>Master Pit 2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P-19</td>
<td>Q-20</td>
<td>H-12</td>
</tr>
<tr>
<td></td>
<td>DF*</td>
<td>NDF</td>
<td>Total</td>
</tr>
<tr>
<td>Force bulbs</td>
<td>144</td>
<td>0</td>
<td>159</td>
</tr>
<tr>
<td>Ripple lines</td>
<td>72</td>
<td>58</td>
<td>60</td>
</tr>
<tr>
<td>Bulb scars</td>
<td>23</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Platform intact</td>
<td>24</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>Platform crushed</td>
<td>12</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Dorsal facets:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>9</td>
<td>104</td>
<td>113</td>
</tr>
<tr>
<td>1</td>
<td>67</td>
<td>362</td>
<td>429</td>
</tr>
<tr>
<td>2</td>
<td>60</td>
<td>298</td>
<td>358</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>22</td>
<td>29</td>
</tr>
<tr>
<td>&gt;3</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Flake types:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td>9</td>
<td>104</td>
<td>113</td>
</tr>
<tr>
<td>Secondary</td>
<td>24</td>
<td>218</td>
<td>242</td>
</tr>
<tr>
<td>Interior</td>
<td>111</td>
<td>465</td>
<td>576</td>
</tr>
<tr>
<td>Type not identified</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*DF* = diagnostic flake; NDF = non-diagnostic flake.

been included in the non-diagnostic flake count. Only whole flakes and proximal end fragments are included in the diagnostic count. A more detailed analysis of unit H-11 shows that the percentage of diagnostic flakes in this unit would increase from 20% to 76% if middle and distal end fragments were not included in the non-diagnostic flake count. All other units (P-19, Q-20, J-13, H-12) analyzed probably would have a correspondingly higher percentage of diagnostic flakes if the same procedure had been used. It should be noted, however, that categorizing non-diagnostic flakes as complete, proximal end, center section, or distal end fragments is a subjective process in which the analysts did not have complete confidence.

Based on this study and other previous analytical work, it can be stated with confidence that the overall Calico lithic collection contains thousands of flakes with well-defined force bulbs. The concentrations of percussion-made flakes found in the limited areas of the excavation pits can only be compared to situations where human flaking activities have produced similar concentrations of percussion-made flakes.

It has been noted, based on experimental flintknapping, that while percussion flaking generally produces a significant percentage of flakes having prominent bulbs of percussion, many percussion-made flakes will not have such bulbs. There is no problem in fitting the so-called non-diagnostic flakes from the Calico collection into the results known from human flaking activities. To date there is no documented situation where natural forces have produced large concentrations of percussion-made flakes. The authors have heard a number of verbal statements concerning locations where significant quantities of naturally-produced percussion flakes exist, but there are never any analytical data to prove that this actually occurs. Carter (1980: 96) has had a similar experience. Where nature does produce flakes by percussion, the frequency of production is not high. High-
energy wave action on a few rocky beaches is a specific example where some percussion flaking is known to occur (Carter 1980: 105; Oakley 1972: 11), and the action of falling rocks is another example (Clark 1958).

**Bulb Scars**

Scars on force bulbs, caused by detachment of a secondary flake simultaneously with the parent flake, are common in deliberate percussion flaking. Of the diagnostic flakes from the Calico units, 11.8% showed bulb scars, and 18.3% of the diagnostic flakes in the experimental knapping project had them. Since bulb scars do not always occur on force bulbs, the bulb-scar attribute has less diagnostic value than does the force bulb itself.

**Ripple Lines**

Undulating ripple lines on the ventral faces of flakes are sometimes associated by analysts with percussion flaking. Ripple lines, however, can also occur from pressure flaking (Patterson 1983: 300), although usually they are somewhat finer than the coarse, prominent ripple lines resulting from percussion flaking of similar materials. Ripple lines seem to be related to the type of material being fractured as well as to the type of force employed. In the Calico sample, 44.2% of the diagnostic flakes and 9.4% of the non-diagnostic flakes had ripple lines. In the experimental knapping done for this study, 61.7% of the diagnostic flakes and 24.3% of the non-diagnostic had ripple lines.

**Striking Platform Angle**

For controlled flaking, the striking platform angle must generally be less than 90°. An obtuse platform angle does not allow for proper tool purchase while also producing an outward force sufficient to maintain the tensile fracture plane front during the removal of a controlled flake. Natural forces can, of course, also utilize acute platform angles that may simulate controlled flaking. In any event, consistently acute platform angles are characteristic of human flaking.

Acute platform angles were found on 94.3% of the Calico flakes with intact platforms as compared with 95.5% of the experimental sample. The average platform angle of the Calico flakes was 78.7°, with a standard deviation of 8.3°. This is consistent with the usual products of intentional flaking. Discussion of the analysis of striking platform geometry of flakes has been presented by Patterson (1981a).

There were fairly low percentages of intact residual striking platforms on flakes for both the Calico sample and the experimental project: 4.5% intact platforms in the Calico sample and 13.7% intact platforms in the experimental work. Two factors seem to have caused this low incidence in the experimental results: the use of a large-diameter hammerstone and the type of materials being knapped.

**Striking Platform Preparation**

The absence of remaining cortex on a high percentage of flake platforms can be an indication of prepared strik-
ing platforms. Non-selective rock fracture by nature would be more likely to produce a high percentage of flakes with some cortex on striking platforms. In the Calico flake sample, only 1.3% of the flakes had cortex on the striking platforms. In the experimental knapping, 25.4% of the platforms had remaining cortex, reflecting the initial use of natural platforms in the reduction of pieces of stone that were fully covered with cortex. The general lack of remaining cortex on Calico flake platforms is possibly an indication of striking-platform preparation by man, as well as a possible indication of human transport of trimmed pieces of lithic raw materials to this location.

**Striking Platform Edge Preparation**

A sophisticated knapper will frequently trim the edge of the platform prior to striking a flake in order to create a uniform edge and to remove concavities on the core face. This is accomplished by a series of light blows to the platform's edge, the evidence of which can be seen on detached flakes as a series of small flake scars on the dorsal face at the platform edge. Few flakes in this Calico sample displayed indications of platform edge-trimming. This may be interpreted as an indication that knapping at Calico did not include highly-refined core preparation. This should not be surprising, in view of the overall nature of the Calico lithic collection and the postulated age of this site.

**Dorsal Face Facets**

Humans will often strike multiple flakes in series from a single core, usually resulting in the production of some flakes with multiple facets on the dorsal face. In contrast, the removal of a few flakes from cores by random natural forces would not be expected to occur often by serial removals, and therefore only a small percentage of multifaceted flakes would be expected. For example, the presence of three major dorsal face facets indicates at least three blows in the flake removal sequence.

The numbers and percentages of major facets on the dorsal faces of flakes from the five Calico units are as follows: no facets: 333 (10.0%); one facet: 1445 (43.3%); two facets: 1372 (41.1%); three facets: 170 (5.1%); more than three facets: 16 (0.5%). For those flakes produced by the knapping experiment: no facets: 43 (9.1%); one facet: 234 (49.5%); two facets: 169 (35.7%); three facets: 25 (5.3%); and not identified: 2 (0.4%). In this summary, an absence of facets indicates a primary flake, and a single facet can be a secondary flake with a single flake scar or a dorsal face formed completely from a single flake scar.

The percentage of flakes in the Calico sample with single-faceted dorsal faces is fairly high, but it is consistent with experimental knapping results for the same types of material. The high percentage of flakes in the Calico sample with single-faceted dorsal faces might be due to high production of “nested” flakes and general shatter when using large hammerstones to work these relatively tough materials. The percentages of flakes having various numbers of dorsal-face facets are fairly similar for the Calico sample and the knapping experiment.

In general, the major facets on the dorsal faces of flakes in the Calico collection are judged to be unidirectional, starting from a single platform. It is characteristic in human lithic manufacturing processes to use the same striking platform for multiple flake removals.

**Flake Thickness and Size**

As part of the analysis, measurements were made of flake thicknesses (in mm). The average thickness of diagnostic flakes in the Calico sample is 6.5 mm, with a standard deviation of 2.7 and a range of 2 to 22 mm. Non-diagnostic flakes in the Calico sample have an average thickness of 7.0 mm, a standard deviation of 3.4, and a range of 2 to 30 mm. Diagnostic flakes from the knapping experiment have an average thickness of 6.1 mm, a standard deviation of 3.4, and a range of 2 to 20 mm. Non-diagnostic flakes from the knapping experiment have an average thickness of 5.5 mm, a standard deviation of 2.8, and a range of 1 to 17 mm.

Although flake thickness may not be a very diagnostic attribute in evaluating the possibility of human workmanship, it can be shown that flake thicknesses are fairly comparable for the Calico sample and the experimental results.

**Flake-Size Distribution**

It has been noted by Patterson (1982b) that flake-size distribution can be an important part of the study of lithic debitage. The size distributions for experimental and Calico flakes are shown in Figure 3. The curves are highly skewed toward higher percentages of smaller-sized flakes and are fairly regular in shape. It would not be expected that random flaking by natural forces would produce such uniformly-patterned flake-size distributions. These data appear to be another indication of human knapping activity at Calico.

It may be seen in Figure 3 that the flake-size distributions from the Calico units are similar to those from the experimental knapping performed by Hoffman. He used several platform locations on each core to achieve a high degree of core reduction. This reduction strategy produces amorphously-shaped cores that are often sim-
ply classified as miscellaneous cores at prehistoric sites throughout North America. The production of unclassified chunks, such as are found in the Calico collection, would be expected as by-products from this reduction strategy.

Patterson (1982b: 71) has previously noted that bifacial reduction debitage has a flake-size distribution that produces an exponential curve that is equivalent to a log-log linear form. The flake-size distributions given here can be fitted only loosely to this curve form. It is concluded that bifacial reduction is not a major factor in the analysis of the Calico lithic assemblage, even though some specimens with bifacial reduction are present.

**Flake Type**

When a knapper reduces a core, the initial (primary) flakes will have a dorsal surface that is covered with cortex. As the cortex is progressively removed, secondary flakes will be produced that have some remaining cortex. A high degree of reduction of a core will produce many interior flakes with no remaining cortex.

Of the total Calico sample of 3,336 flakes, 10.0% were primary flakes, 19.3% were secondary flakes, and 70.7% were interior flakes. The knapping experiment yielded 9.1% primary flakes, 29.8% secondary flakes, and 61.1% interior flakes.

Flakes from the Calico sample with various amounts of remaining cortex show an even higher degree of raw material reduction than both experimental results from intensive bifacial reduction of large chert cobbles (Patterson 1981b) and the experimental work for this study. With reference to the Calico flake collection, it would not be expected that natural forces would cause such complete reduction of large cobbles with high frequency. The small number of large cores in the Calico collection supports the conclusion that there was rather complete reduction of large numbers of cobbles of siliceous minerals in a selective manner.

If the flakes at Calico were produced by natural forces, it would be expected that many cores in various stages of reduction would be present. This is not the case. Pieces of siliceous minerals in the Calico collection are either highly reduced or exhibit few flake scars. Most of the nodules of siliceous materials in the Calico field stockpile of non-diagnostic materials from excavations are essentially intact, largely or completely covered by cortex. A study of all siliceous rock specimens that could be observed on the surface of the stockpile for Master Pit 2 shows that 97.2% of these specimens are not fractured, with 2.7% having one or two flake scars and only 0.1% having three or more flake scars. Materials in the Calico stockpile are shown in Figures 4 and 5.

**Lithic Material Selection**

Patterson (1983: 305) has noted that the selective occurrence of certain types of raw material can be useful
in identifying human activity at a specific location. Humans would tend to be selective in their use of lithic raw materials, while nature would tend to fracture a wide variety of stone types in a random manner. Of course, both man and nature are limited in fracture possibilities by the physical properties of each rock type.

Louis Leakey (1979: 95) expressed a similar opinion in his remarks made at the International Conference on the Calico Mountains Excavations, held in San Bernardino, California, October 22–25, 1970:

Finally there is the point that nature is never selective. At places where you get a natural flaking, the flakes have been pushed off good material and bad material. A flake from a lump of chert that is riddled with holes and full of irregularities is pushed off by earth pressure, and the resulting flake is, therefore, also full of holes and other irregularities. One of the most striking things about the Calico specimens, even with cortex flakes, is that, almost without exception, they are not flakes struck off a piece of chert of poor quality. . . . This selectivity is something nature never does. Nature splits off flakes at random. Man knocks off flakes for a specific purpose.

According to George F. Carter (1980: 113):

The earliest men used the stone locally available; later man often ignored the local stone but went great distances to get superior stone. . . . Where there were abundant local supplies, early men used stone profligately; they threw away useful flakes, for they could anywhere any time make others.

During the excavation, the rocks removed from Calico Master Pit 1 were categorized as non-siliceous rock or siliceous material. Non-siliceous rocks were mainly andesite and dacite. In the upper levels, the ratio of non-siliceous rock to siliceous material was as great as 9:1.
In the deeper strata the ratio fell to 2:1 or less (Simpson 1979: 13).

For Master Pit 2 the ratio of non-siliceous rock to siliceous material also varied with depth, being about 60:1 at a depth of 95 in and decreasing irregularly to 1:1 at 150 in, and thereafter remaining nearly constant at 1:1 to a depth of 350 in.

The rock types making up the alluvial fan in which the Calico Site occurs include andesite, dacite, chalcedony, chert, rhyolite, porphyry, limestone, granite, and andesite tuff. Of the 3,336 flakes from the five Calico units, 85.8% was chalcedony, 5.8% chert, 1.8% jasper, 4.5% agate, 0.1% andesite and rhyolite, and 2.0% unidentified. Siliceous materials therefore comprised at least 97.9% of the flakes. This material selectivity is one of the strong indications of human lithic manufacturing activities at the site.

### Evidence for Lack of Redeposition

Lithic specimens transported in a stream become rounded in a short distance, 0.5–1.5 mi (Carter 1980: 99). If the specimen being transported is a sharp-edged flake, rounding will initially take place on the peaks and ridges of the edge with little or no rounding in the valleys. Examination of the edges with a 10-power lens will show whether the flake was made very near the place where it was found or if it had been transported a substantial distance by stream or mudflow.

Of all the 739 flakes and flake fragments examined from Calico unit H-1, only one showed possible edge-rounding. Sharp edges were characteristically evident on the rest of the flakes in this unit, and the flakes from the experimental knapping project all showed sharp edges, as was to be expected. It appears that the Calico flakes were produced at or near the site location and were not introduced by natural transport. If that is true, then the flakes could not have been produced by collisions of rocks in a mudflow.

The flake-size distributions for the Calico samples also indicate that these materials have not been redeposited by natural forces. The Calico flake-size distributions are similar to those observed in the experimental results. This indicates that the Calico flake collection has remained intact after manufacture, without resorting of flake sizes due to natural transport.

### Clusters

Throughout the excavations at Calico, concentrations of broken siliceous stones were found. They are called clusters because that word describes the typical distribution—never more than a very few inches deep and apparently about 5–10 ft in diameter, although the lateral dimension is somewhat tenuous because the clusters sometimes extended beyond the pit walls. Materials from a typical cluster are shown in Figure 6.

Whenever a cluster was encountered, all specimens that did not pass through a ½-in screen were recovered for analysis and were bagged separately. Materials found in clusters were always of several siliceous types, usually variations of chalcedony and chert. It is concluded that the materials found in any one cluster were from at least several parent pebbles or cobbles.

The size of the specimens in the features was predominantly quite small. For example, in Calico unit P-19 at a depth of 139-142 in, there were 325 total specimens. Of these, 192 were smaller than the 15 mm template. The largest specimen in that cluster was ca. 35 × 35 mm. Only 6.8% of the specimens from this cluster were diagnostic flakes. The distribution of flake types for the total cluster specimens in P-19 is similar to specimen types from the knapping experiment. The clusters from P-19 contained 1.8% diagnostic flakes, 14.3% non-diagnostic flakes, and 83.9% specimens smaller than the 15 mm template. The knapping experiment produced 3.0% diagnostic flakes, 9.4% non-diagnostic flakes, and 87.6% specimens smaller than the 15 mm template. The P-19 clusters also contained 462 chunks not included in the above flake-type comparisons.

Specimens in clusters ranged from sharp-edged flakes with force bulbs and ripple lines to amorphous chunks with no discernible attributes characteristic of flaking by man. All things considered, these clusters have the characteristics of workshop areas where early man reduced large pieces of siliceous material by knapping and recovered selected pieces for further shaping or used them

![Figure 5. Typical materials in stockpile. Photograph by Yvonne Lipking.](image)
“as is” for tools. Experimental knapping by modern man produces clusters of similar distribution of size, shape of specimens, and area over which specimens are found, as demonstrated by the knapping experiment performed in this study.

**Hammerstones**

A number of possible hammerstone specimens have been identified in the Calico lithic assemblage, consistent with the possibility of human flintknapping activities. Specimens have been morphologically sub-classified as hammerstones and pecking stones, although only one type of function may be represented. Hammerstones are described as sub-rounded to sub-angular stones that exhibit concentrated areas of crushing or battering on localized ends or edge segments. Pecking stones are similar in size and shape except that they tend to be tapered at one end.

In Master Pit 1, where basic analysis has been completed, 197 such specimens were recovered. Sizes ranged from $4.0 \times 3.5 \times 2.0$ cm to $17.1 \times 7.3 \times 5.9$ cm. The average measurements were approximately $8 \times 6 \times 4$ cm. Materials used were predominantly chert and chalcedonic chert, and included a small percentage of jasper, rhyolite, andesite, and volcanic porphyry.

The following is a description of two representative examples of hammerstones that were recovered from unit S-20 in Master Pit 1.

Specimen 1 was found at a depth of 74 in, and measured $8.5 \times 7.5 \times 5.9$ cm. It was fashioned from a cobble of chalcedonic chert and shows preparation as well as utilization. Cortex remains over about one-fifth of the surface. Step flaking and face flaking are apparent on those areas from which the cortex was removed. The butt is a naturally flat surface, and the distal end, which is heavily crushed and battered, is a blunt natural projection positioned off-line to the right from the butt.

Specimen 2, with dimensions of $7.9 \times 6.6 \times 6.8$ cm, was recovered at a depth of 90 in. It is an unmodified cobble of
volcanic porphyry, having four naturally flat surfaces that taper from an oval butt to the distal end. The distal end appears as a stout ridge. A portion of one tapered surface is shattered, and the distal end is crushed and battered.

Modern flintknapping experiments (including the experience of Patterson) show that chert is the least desirable material to use for hammerstones because this material tends to shatter during percussion flaking. Exceptionally tough and coarse-grained chert, however, can approximate the performance of quartzite for hammerstone use, so the use of chert for hammerstones is not precluded at Calico.

Experimental Knapping

Patterson (1983: 306) has commented on the value of experimental verification of lithic studies as follows.

All types of objects in proposed early man collections can be replicated, using the same types of raw material as the original specimens. Attributes of experimental, man-made specimens can be compared with matching items in the collections under study. Possible manufacturing techniques and patterns can thus be studied with more confidence in conclusions.

L. V. Hoffman undertook an experimental knapping project to replicate the types of lithic specimens found at Calico, as suggested by Patterson. Siliceous cobbles were picked up from a hillside about 2 mi from the Calico Site. A rounded piece of rhyolite weighing 1.5 lb was picked up in the same area for use as a hammerstone. Obtained elsewhere was a fine-grained quartzite beach pebble that was also employed as a hammerstone.

A carport was the place selected to do the knapping, and the concrete floor was swept clean. Cobbles utilized had naturally-occurring striking platforms with platform angles of less than 90° that could be used to start reduction. Multiple platforms were used for flake removals, and the cobbles were gradually reduced to chunks with insufficient mass for further knapping. Toward the end of this process, the rhyolite hammerstone itself began to lose flakes, and the beach pebble was substituted with good results. Flakes and debitage covered the floor adjacent to the knapper and in some pieces were as far away as 12 ft in front of him, approximately 8 ft to either side, and relatively few behind him. The distribution in area was reminiscent of the Calico clusters.

The floor was again swept and all material retrieved. The total weight of retrieved material, including spent cores, was 6 lb 10 oz (not including hammerstones). All of the material was screened. Six oz passed through window screen. All of the 3,803 specimens that did not pass through the ¼-inch screen were subjected to the same analysis process as the specimens from the Calico Site. There were 473 flakes produced larger than the 15 mm template, and an analysis of these flakes is summarized in Table 4. The materials of these flakes consisted of 52.6% chalcedony, 40.6% chert, 5.3% rhyolite, 0.2% agate, and 1.3% petrified wood.

Comments on Fracture Patterns

There are two types of prismatic blades found in small numbers in the overall Calico flake collection. One type is obviously percussion-made. The other type consists of very flat, uniform prismatic blades, with smooth ventral faces that show no attributes typical of percussion flaking. This latter type of blade may have been produced by natural starch fractures, as described by Watson (1967: 32). Blades that may have been produced by starch fractures are not a statistically significant portion of the large Calico flake collection and have been included in the non-diagnostic flake counts.

There seems to be confusion on the part of some archaeologists concerning what types of fracture patterns natural forces are capable of producing. Some of this confusion appears to be a failure to differentiate between macro- and micro-forces in nature. Patterned fractures in nature are usually related to micro-forces that operate on the molecular level in crystalline structures. Examples of patterned fractures caused by micro-forces are those along natural fracture planes inherent to the crystalline structures of some minerals and starch fractures that may be due to the dehydration of some types of crystalline structures.

The fracture patterns being studied in the Calico flake collection are primarily related to external macro-forces of a percussive nature. Man employs percussive force in a patterned manner, while natural percussive forces would be generated and applied in a random manner. Natural macro-forces are not likely to cause a series of patterned fractures on a high-frequency basis. To date, there have been no convincing demonstrations that nature can simulate the products of a human flaking industry to a statistically significant degree.

Summary

A total of 13,677 lithic specimens, which includes 3,336 flakes recovered from five units of Calico Master Pit 1 and Master Pit 2, were measured and examined. The products of experimental knapping, using material obtained near the Calico Site, were examined using the same criteria. This comparison group totaled 3,803 lithic specimens, including 473 flakes larger than the 15 mm template.
Table 4. Analysis of flake attributes from the knapping experiment. Each value within parentheses is the percentage of the occurrence of a particular attribute for the total number of flakes in that category. For example, of the 115 diagnostic flakes, 21 (18.3%) had bulb scars.

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Diagnostic</th>
<th>Non-diagnostic</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n=115</td>
<td>n=358</td>
<td>n=473</td>
</tr>
<tr>
<td>Force bulbs*</td>
<td>115 (100)</td>
<td>0</td>
<td>115 (24.3)</td>
</tr>
<tr>
<td>Bulb scars*</td>
<td>21 (18.3)</td>
<td>0</td>
<td>21 (4.4)</td>
</tr>
<tr>
<td>Ripple lines*</td>
<td>71 (61.7)</td>
<td>87 (24.3)</td>
<td>158 (33.4)</td>
</tr>
<tr>
<td>Platform intact*</td>
<td>52 (45.2)</td>
<td>13 (3.6)</td>
<td>65 (13.7)</td>
</tr>
<tr>
<td>Platform crushed*</td>
<td>29 (25.2)</td>
<td>20 (5.6)</td>
<td>49 (10.4)</td>
</tr>
<tr>
<td>Dorsal facets:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0†</td>
<td>7 (6.1)</td>
<td>36 (10.1)</td>
<td>43 (9.1)</td>
</tr>
<tr>
<td>1†</td>
<td>72 (62.6)</td>
<td>162 (45.3)</td>
<td>234 (49.5)</td>
</tr>
<tr>
<td>2†</td>
<td>28 (24.3)</td>
<td>141 (39.4)</td>
<td>169 (35.7)</td>
</tr>
<tr>
<td>3†</td>
<td>8 (7.0)</td>
<td>17 (4.7)</td>
<td>25 (5.3)</td>
</tr>
<tr>
<td>unidentified†</td>
<td>0</td>
<td>2 (0.5)</td>
<td>2 (0.4)</td>
</tr>
<tr>
<td>Flakes:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary‡</td>
<td>7 (6.1)</td>
<td>36 (10.0)</td>
<td>43 (9.1)</td>
</tr>
<tr>
<td>Secondary‡</td>
<td>48 (41.7)</td>
<td>93 (26.0)</td>
<td>141 (29.8)</td>
</tr>
<tr>
<td>Interior‡</td>
<td>60 (52.2)</td>
<td>229 (64.0)</td>
<td>289 (61.1)</td>
</tr>
</tbody>
</table>

*These attributes are not necessarily mutually exclusive; hence, the proportions of their incidence do not add up to 100%.
†These attributes are mutually exclusive; hence, the proportions of their incidence add up to 100%.
‡These attributes are mutually exclusive; hence, the proportions of their incidence add up to 100%.

The most significant data and conclusions from this flake analysis are as follows:

1. A high percentage (26.1%) of flakes have distinct force bulbs, which indicates extensive use of percussive force.
2. There is a large percentage (70.6%) of interior flakes, indicating a high degree of reduction of each core.
3. A large percentage (46.7%) of flakes have two or more dorsal face facets, demonstrating serial flake removals from a core.
4. Specimens show a consistent selection of a limited number of specific raw material types (85.8% chalcedony, 5.8% chert, and 1.8% jasper), as is typical of human lithic manufacturing.
5. Large numbers of flaked stone specimens are found in clusters, as would be expected at a human lithic industrial site.
6. Patterned flake-size distributions are present, similar to the products of modern flintknapping experiments.
7. The striking platform angles are nearly all acute, consistent with the products of flintknapping experiments.
8. Most of the attributes of the Calico flakes are consistent with the attributes of flakes from experimental knapping, done as part of this study using materials from the same area.
9. The apparent high degree of reduction of pieces of siliceous minerals on a selective basis, with few examples of intermediate degrees of reduction of cores, supports the presence of human lithic manufacturing activities.
10. Both the flake-size distributions and the absence of rounding on flake edges support the concept that the Calico flakes have been found at the location of manufacture and that these flakes have not been redeposited by natural forces.

These highly repetitive patterns of attributes are characteristic of the products of human flintknapping. To date, it has not been demonstrated that natural forces are capable of simulating the patterns of product attributes from human lithic manufacturing on a high-frequency basis. The evidence found on a statistically significant number of lithic specimens from Calico indicates a good possibility that they are products of lithic manufacturing by early man at this site. The need to support further research at this site is strongly indicated by the results of this study.

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