Some Experiments In Petroglyph Technology

John C. Whittaker, Sarah Koeman, and Rachel Taylor

The technology of petroglyph production is a neglected aspect of rock art studies. Different manufacturing techniques help distinguish petroglyph styles, change through time, and vary according to available materials, so we need to be able to accurately identify the traces left by different tools and techniques. The time and effort involved in creating rock art should be considered in evaluating its social and symbolic significance; replication experiments provide some insights. We performed two petroglyph replication experiments. In one, a series of standard glyphs were made using a variety of tools and techniques, including pecking, punching, and chiseling with stone hammers and antler tines, and incising. We compare the efficiency of the different tools and techniques, and the marks they made. A second experiment provided further evaluation of pecking. We conclude that most petroglyphs can be made rapidly, and that pecking with a sharpened hammerstone is usually the most effective technique.

Modern rock art studies have produced much information about the style and meaning of petroglyphs and pictographs, and the social and environmental contexts associated with rock art. Despite wide interest in rock art among a growing cadre of enthusiasts and professional archaeologists, most work has focused on issues of recording, typology, chronology, and interpretation. There has been remarkably little investigation of the technology of rock art production. It is our contention that a better understanding of rock art manufacturing techniques and the ability to distinguish them in sites would be useful even to those primarily interested in social and symbolic interpretations of rock art. Techniques of manufacture are likely to distinguish individual, group, and regional styles (Schaafsma 1980:28; Grant 1967; Hedges 1982), change through time (Pilles 1975), and vary according to available tools and rock surfaces (Schaafsma 1980:32). Estimates of the time and effort involved in creating rock art would allow more informed statements about some aspects of its social and symbolic significance. As a step in this direction, we conducted two different experiments in petroglyph manufacture.

John C. Whittaker, Sarah Koeman, Rachel Taylor
Department of Anthropology, Grinnell College

BACKGROUND

While there has been an explosion of rock art research in the last two decades, almost no one has bothered to investigate the basic technologies in any systematic way, although one suspects that many rock art enthusiasts have at least “fooled around” with imitating what they see. A few rely on “personal experience” to evaluate rock art, or mention unrecorded experiments but give no details (e.g. Turner 1963:2, Anati 1977). Descriptive statements that imply knowledge of manufacturing techniques abound. Petroglyphs are manufactured “by pecking, abrading, scratching, or carving the surface of the rock” (Ricks 1995:78). Other terms such as “incising,” “grooving,” “bruising,” (Salzer 1987:279), “crumbling” (Treganza 1955:21), and “cutting,” “pounding,” and “etching” are also used. The overall effect is considerable inconsistency in terminology and vagueness or inaccuracy in many descriptions (Bednarik 1998).

Other descriptions include quite specific statements about the implements and techniques used to create particular petroglyphs, but provide little or no description of the evidence on which these interpretations might be based. For instance, in his study of the Hensler site, Favour (1987:404) suggests that one petroglyph was “produced by extensive secondary pecking with an instrument of small diameter.” Favour does not discuss how he determined the diameter of the instrument or the technique used to create the glyph. Similarly, Lothson (1976:23) asserts that “all of the carvings at the Jeffers site were produced by pecking the surface with a pointed rock, a fire-hardened wooden stake, or a sharp antler held in the fist or used as a punch struck with a hammerstone,” but does not provide evidence, such as descriptions of the physical appearance of the petroglyphs, to support the use of any of these tools or to distinguish between them. Even where probable tools are found on site, there is often little effort made to test their efficacy and wear patterns by experiment or to compare marks on rocks with tool edges (e.g. Hanson-Stiles 1987:328; Boreson 1995:107).

Assumptions are often made about the efficiency of particular techniques. For instance, there is a widely held belief that accuracy and fine detail would require an indirect percussion technique (e.g. Sundstrom 1990; Grant 1967:12, 1978; Schaalnsma 1980:28; Turner 1963:2). “The thin lines and fine detail on most of the glyphs could only have been achieved using indirect percussion, which allows the carver more accurately to control the blows to the surface of the cliff” (Sundstrom 1990:112), while pecking “gives a sloppy appearance imposed by varieties of muscular coordination” (Turner 1963:2). It is also generally felt that petroglyphs are hard work (e.g. Coles 1979:203; Grant 1976). “Given a choice, aboriginal man probably preferred to paint. Painting is far-easier and faster than the laborious pecking of a design into hard rock...” (Grant 1976:157).

A few previous experiments are exceptions to the general trend. There has been some work with painting techniques and pigments (Lehnert 1990; Lewin 1993; Loendorf 1994) but we will confine ourselves to petroglyphs, which are made by damaging rock surfaces rather than pigmenting them.

Perhaps the first experiments with petroglyph manufacture were those performed by Joseph M’Guire of the Smithsonian around 1891. M’Guire enthusiastically promoted the importance of hammerstones as basic to much primitive technology (M’Guire 1891), and performed a number of experiments in stone tools, including cutting a glyph (M’Guire 1892). He found that some hammerstones were flawed or too soft and did not survive, and that quartzite pebbles chipped to a sharp point were most effective and could be used for fine work and deep cuts.

More recent published experiments include those of Sierts (1968) in South Africa. He experimented with pecking, chiseling, and engraving, using a variety of tools on dolerite, diabase, and sandstone. He did not describe his experiments in detail but concluded that horn and hardwood were not suitable as tools, chiseling worked poorly and destroyed the tools rapidly, applying saliva to the cut speeds the work, and pecking petroglyphs is generally easy and accurate.

In the US, Bard and Busby (1974) performed some of the earliest controlled petroglyph experiments. They made simple glyphs, including standard bars, with hammers of four materials, evaluating the efficiency of the different stones, and of both pecking and a technique they called pecking/grounding. Simple pecking was more efficient than adding
a grinding stroke at the end of each peck, and chert cobbles were more effective than the three other softer materials. They noted that many petroglyphs, even on hard stone, take little time to make if a good tool is used, and compared their tools to battered cobbles found on their Nevada sites. Busby and others (1978) continued the experiments with direct pecking only, varying the hardness of hammers and of basalt rock surfaces. They concluded that great precision was possible in pecking.

Pilles (1976) experimented with making petroglyphs in sandstone, using a variety of tools. He did not report details of the experiments, but arrived at a number of conclusions to apply to his archaeological situation. Chert hammers tended to break, while quartzite was sufficiently durable. Unsharpened cobbles were ineffective. A flaked edge was necessary to cut into the stone, and became dulled rapidly. Pilles believed that some precisely placed deep dints would have been made by indirect percussion, but was unable to replicate them with stone tools, and concluded that prehistoric artisans were better at it than he was. He suggests that typical petroglyphs took between 20 minutes and an hour to make. He was puzzled by the dearth of manufacturing tools at his petroglyph sites.

Vastokas and Vastokas (1973:19) are typical of the kind of casual experiments that are rarely reported. They pecked a circle in limestone with a sharp gneiss pebble to compare with Canadian Algonkian glyphs. They concluded that pecking was faster than abrasion, and a five-foot sun figure could have been made in 15 to 30 hours.

Moore (1994) reports use wear in the form of microflaking and heavy attritional dulling of edges on choppers and heavy flakes associated with a Puebloan rock art panel in New Mexico. He replicated the wear patterns by pecking petroglyphs.

Loendorf (1994) pecked a series of 13 circles in Montana sandstone. His primary interest was in determining which locally available materials worked as petroglyph production tools, and he collected debris from the experiment for potential comparison with archaeological finds. Antler tines and blemnites shattered when used either as punches or for pecking. Pointed hematite nodules and siliceous gastroliths were judged successful tools. He provided no data on time or effort.

Bednarik (1998) in an extensive theoretical dis-
cussion of rock art technology, reviewed the Australian literature of petroglyph experiments, and briefly described some of his own, aimed largely at recognizing tools and techniques and the potential dating of some tools. He discounts indirect percussion techniques on a number of grounds, and makes a plea for a systematic program of research into rock art technology.

The published record of petroglyph experiments indicates four main concerns: a need for basic “how did they do this” understanding, more specific evaluations of tools and techniques, archaeological recognition of these tools and techniques, and some assessment of time and labor. The sparsity of the record shows that not many scholars have taken these concerns very far.

We addressed three main issues in our experiments: 1. What types of tools (e.g. antler or stone) or methods (e.g. pecking, punching, chiseling, or incising) are easier to use or require less effort? 2. Do the characteristics of a petroglyph (depth, width, pattern of its markings) reflect the type of tool or technique used to produce it? 3. What can we say about the labor investment in rock art?

In order to address these questions we performed two suites of experiments, the first a more controlled test of techniques using a standardized simple glyph, and the second an exploration of time and effort on a larger design.

THE CONTROLLED EXPERIMENT

To explore the variable efficiencies and characteristics of different tools, Koeman and Taylor produced a number of simple uniform petroglyphs on two slabs of sandstone, using a variety of tools and techniques. We procured sandstone for this experiment from a site approximately 50 feet above the shore of Red Rock Lake in Marion, County, Iowa (Sec 12, T-76N, R-20W). We chose sandstone with surfaces as smooth and uniform as possible, and we collected enough pieces and layers to provide ample practice stone as well as material for the actual experiment. The two slabs we used for the experiment came from Pennsylvanian strata of the Floris Formation (Dale Streigle, personal communication 1998) and their surface hardness on the Mohs scale is roughly 2 to 3. Even though both stones exhibited mildly weathered surfaces, we decided to lightly
spray-paint the working surfaces black. The difference in color between the black surface and the tan sandstone underneath allowed for a higher degree of accuracy in the measurement of our glyphs. Seventy crosses, each 5x5 cm, were marked on the blackened surfaces of the stones with white pencil; 53 on Sandstone One, and 17 on Sandstone Two (Figure 1). We chose a simple cross design so we could easily measure both width and depth, maintain uniformity of design, and produce a number of petroglyphs within a reasonable amount of time. Our preliminary trials indicated that we would not be able to achieve precisely the same width and depth in each glyph. We defined a petroglyph as finished to a reasonable standard when the lines of the cross measured 6-8 mm wide and 0.5-2 mm deep.

Tools and Techniques

Before beginning the experiment, we practiced various methods described in our preliminary review of the literature. The tools we used are also attested from a number of petroglyph sites (Bednarik 1998; Loendorf 1994; Vastokas and Vastokas 1973; Moore 1994). A few techniques suggested by rock art researchers proved so ineffective that they were abandoned. For example, the tip of sharpened oak stakes, although not fire-hardened as suggested by Lothson (1976), were soon smashed by the force of both direct pecking and indirect percussion punching, without creating much, if any, mark upon the sandstone. Similarly, pecking with a sharp antler tine held in the fist or using it as a stationary punch struck with a hammerstone (Lothson 1976:23) did not create significant marks on the sandstone. Loendorf (1994:96) found antler tines unsatisfactory for pecking or punching because they shattered. We did find that an antler could cut the surface of the sandstone by chiseling, and included this technique in our further trials. Our preliminary experiments also convinced us that pecking with an unsharpened cobble worked, but was not very satisfactory. Pilles thought such tools were probably used on some petroglyphs (Pilles 1975:3), but like us changed his mind after some experiments (Pilles 1976:6), and Busby et al. (1978) also found pointed tools more effective.

We settled on seven combinations of tool and technique for testing, as follow (see Table 1 and Figure 2):

1. Pecking with a dull chert cobble. In “pecking” the tool is held in the hand and struck against the rock surface. Each blow removes a bit of stone, leaving a series of individual “dints” (Turner 1963:2). The dull chert cobble was a fist-sized river-worn nodule of moderately fine-grained chert of unknown origin, weighing 219 grams. A few flakes were struck off one corner, leaving a short bifacial edge and corner. While the size of contact area varied somewhat depending on how the tool was held and the occasional detachment of small flakes, it was around 3-5 mm in diameter. Most of the work was done with the corner, which would not be much different from an unsharpened but pointed cobble.

2. Pecking with a sharp chert cobble. A smaller cobble (141 gm) of the same chert material with a much

Figure 1. Sandstone slab (1) at the end of the experiment.

Figure 2. Experimental Tools: Top row: Antler chisel, quartzite cobble, sharp chert cobble, dull chert cobble. Bottom row: Two chert flakes. All working edges are up.
Table 1: Petroglyph Experiment Summary Information

<table>
<thead>
<tr>
<th>Tool/Technique</th>
<th>Number Glyphs</th>
<th>Glyph Labels</th>
<th>Mean Time (sec.)</th>
<th>St. Dev.</th>
<th>Mean Rock/Time (cubic mm/sec)</th>
<th>St. Dev.</th>
<th>Mean Width</th>
<th>St. Dev.</th>
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</thead>
<tbody>
<tr>
<td>I. Pecking</td>
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<tr>
<td>1. Dull Chert</td>
<td>10</td>
<td>2A,C,E,G,K,L,O-Q</td>
<td>200.1 26.3</td>
<td>2.95</td>
<td>0.88</td>
<td>7.17</td>
<td>0.55</td>
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<tr>
<td>2. Sharp Chert</td>
<td>10</td>
<td>2B,D,H,J,M,N,R-T</td>
<td>202.9 40.8</td>
<td>3.05</td>
<td>0.95</td>
<td>7.68</td>
<td>1.3</td>
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<tr>
<td>3. Quartzite</td>
<td>10</td>
<td>1A-J</td>
<td>196.7 64.9</td>
<td>3.47</td>
<td>1.45</td>
<td>7.57</td>
<td>1.25</td>
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<tr>
<td>II. Punching</td>
<td></td>
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<td></td>
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<tr>
<td>4. Sharp Chert</td>
<td>10</td>
<td>3E-G,K-Q</td>
<td>293.4 40.9</td>
<td>2.2</td>
<td>0.56</td>
<td>7.7</td>
<td>1.19</td>
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<td>III. Chiseling</td>
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<tr>
<td>5. Sharp Chert</td>
<td>10</td>
<td>3D,H,R-Y</td>
<td>243.6 60.7</td>
<td>2.37</td>
<td>0.62</td>
<td>6.42</td>
<td>1.03</td>
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<tr>
<td>6. Antler Tine</td>
<td>10</td>
<td>4A-J</td>
<td>328.6 89.1</td>
<td>1.69</td>
<td>0.57</td>
<td>7.23</td>
<td>0.65</td>
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<tr>
<td>IV. Incising</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
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<tr>
<td>7. Chert Flakes</td>
<td>10</td>
<td>5A-J</td>
<td>320.3 90.9</td>
<td>1.62</td>
<td>0.53</td>
<td>6.43</td>
<td>0.51</td>
<td></td>
</tr>
</tbody>
</table>

A sharper bifacial edge was also used for pecking. The utilized edge was longer (4-8 mm) and much sharper than that of the dull chert cobble.
3. Pecking with a medium quartzite cobble. The coarse quartzite cobble weighed about 179 grams, and the edge was not as stable as on the chert tools. It was quite dull at first and ineffective, but after resharping generally presented an appearance between the sharp and dull chert specimens and worked well. The variability in the edge may account for the larger standard errors in the results with this tool.
4. Punching with sharp chert cobble. The smaller chert cobble above was used as a punch held in the hand and struck with a hammerstone. In punching, the tool was stationary over the sandstone slab. Each blow produced a dint; the punch was then lifted and moved to the next desired location. Some preliminary trials were also made with the dull chert cobble, but indirect percussion techniques with its duller point proved ineffective and the larger stone made it difficult to see the point of the stone and place the blow.
5. Chiseling with sharp chert cobble. The chert cobble used in 2 and 4 above was struck with another hammerstone in a chiseling fashion, where the sharp edge of the tool was allowed to cut sideways.
6. Chiseling with an antler tine. The tine was held and used as a chisel, struck with a hammerstone, and cutting horizontally with each blow. The end of the antler was ground flat, perpendicular to its length, and the edges and corners of this facet were what contacted the stone. They dulled rapidly, and were resharpened after each glyph.
7. Incising with a chert flake. Four chert flakes with six edges were used to incise 10 glyphs. They were used with a back-and-forth motion, outlining the glyph and then scratching out the center of the cross arms. The cutting edges on the flakes were between 3 and 11 mm long. A flake was replaced when the sharp edges were worn down and too dull to effectively cut into the sandstone.

Measurements

Effort was measured by the time expended creating a single glyph, and by the amount of rock removed per unit of time. We used stopwatches to record the amount of time it took to achieve the predetermined minimum depth, width and length.
using each of the aforementioned tools and techniques. We did not stop the watch while removing fragments of stone by either blowing or brushing (using a toothbrush and a paintbrush) them from the surface of the glyph, which did not require much time. We did, however, stop the watches when we periodically paused to take measurements of our glyphs. Detailed records of waste from both the rock and the tools, which we did not make, would also be useful.

We used digital calipers to measure the width and depth of the glyph. The width of each vertical and horizontal line of the glyph was measured twice. Additionally, we made two measurements of the center intersection of these lines, and then averaged the two measurements. We measured the depth of many locations on the glyph in order to ensure that we had reached a minimum depth of 0.5 mm and had not exceeded the maximum depth of 2.0 mm. We recorded the minimum and maximum depth of each petroglyph. To estimate the amount of rock removed in making each glyph, we used 100 mm (the length of both arms) times the average width, minus the average width squared (so the center length was only counted once), times the average of minimum and maximum depths, divided by the time in seconds [(100 mm X avWidth) - (avWidth squared) X avDepth \ Time]. After we had produced 70 glyphs with the different tools and techniques, we examined the glyphs and described their physical characteristics.

**Experimental Data: Efficiency**

The relative efficiency of the different tools was measured by the time it took to make standardized glyphs, and by a calculation of the amount of stone removed per time expended (Table 1). Both time and stone removed show the same trends (Figures 3, 4). Pecking was fastest and most efficient, and the times for the three pecking tools were not significantly different. It took around 200 seconds to peck a glyph. Incising with flakes and chiseling with antler were the least efficient, averaging over 320 seconds. Punching and chiseling with the sharp chert cobble were in between, with chiseling more effective than punching. The four less efficient techniques were significantly different, but at a much lower level than the difference between pecking and the other techniques.

**Accuracy**

We felt subjectively that, contrary to the expectations in some literature, pecking was generally more accurate than indirect percussion techniques. However, we were unable to quantify this impression (Table 1). Measurements of the widths of the

![Figure 3. Boxplot of time (seconds) using different tools and techniques.](image)

![Figure 4. Boxplot of Rock/Time (cubic mm per second) using different tools and techniques.](image)
Figure 5. Boxplot of Average Width (mm) using different tools and techniques. Note differing amounts of variance from the mean.

lines in the crosses were originally taken to ensure that this variable remained relatively constant (between 6-8 mm). The boxplots of average widths also shows that some techniques produced considerable variation (Figure 5).

Not surprisingly, it was easiest to maintain a narrow glyph with even lines by incising. The antler chisel cut a generally wider glyph, but also has a low standard deviation, indicating high accuracy. Chiseling with the sharp chert cobble cut a narrow but more variable line, while the pecked and punched glyphs tended to be both wide and variable, with the exception of those made by pecking with the dull chert cobble, which were anomalously regular.

Durability of Implement

During the experiment, we observed differences in durability of the tools and the need to resharpen or reflare certain tools. These observations also provide insight into the difficulty of creating each glyph and effort expended in modifying the tools for use.

Antler. During the experiment, the antler was resharpened with a file after the production of each glyph (5cm x 5cm). The sharp edges of the facet on the antler end appeared to be doing the work, and were rapidly abraded by the chiseling motion. Most of the modification of both the sandstone and the antler was by abrasion, and chiseling with the antler produced striations on the antler and a slightly blurred appearance in the glyph.

Flakes, Incising. The utilized edge of a flake showed evidence of significant dulling after the production of one cross glyph and became significantly less effective after the second glyph was produced. We replaced flakes rather than resharpening them. A bifacially or unifacially retouched edge might have lasted longer and cut more effectively, both because of the serrated nature of the edge, and because the ridges of the retouch flake scars on the faces of the tool should attack the sides of the cut.

Dull Chert Cobble, Punching. Although we abandoned our attempts to use a dull chert cobble for punching, we made some observations. Hammering the chert cobble into the sandstone caused large pieces of the utilized point of the chert to break off. The breaking of the point increased the surface area in contact with the sandstone, and after damage to the point, indirect percussion punching became ineffective. We felt that early breakage may have been in part from excessive enthusiasm in the hammering.

Sharp Chert Cobble. The sharp chert cobble, used for pecking, punching, and chiseling, was very stable, maintaining almost exactly the same edge throughout all the trials.

Quartzite Cobble. The quartzite cobble was prepared with too large and dull an edge at first, and was resharpened, after which the edge dulled slightly and then became quite sturdy.

The working edges of all the cobble tools show the same kind of wear reported elsewhere (Moore 1994), microflaking and overall dulling and rounding of the edge. In our experience, most of the wear occurs in the first few blows, after which the tool is relatively stable for quite a while.

Discussion: The work of making petroglyphs

The three variables by which we evaluated different techniques of petroglyph manufacture were efficiency, measured by the time expended producing a glyph and the amount of stone removed per time, the worker's accuracy and ability to maintain
control of the tool, and the durability of the tool. Our results indicate that it took significantly less time to create a glyph by directly pecking the surface of the sandstone, than by incising, indirect punching, or chiseling. The time expended directly pecking the sandstone did not seem to be affected by the type of tool used within the limits of our experiment; the mean pecking times were almost equal for each of the three tool types (quartzite, dull chert cobble, and sharp chert cobble). The ability to control the implement may be one factor contributing to the differences in time between glyphs made by direct percussion and glyphs made by indirect percussion. We felt that direct pecking was easier and just as controlled as indirect percussion (chiseling and punching). The relative difficulty of controlling the cobbles and the antler using indirect percussion techniques contributed to the greater amount of time expended with each of these tools. During indirect percussion, both of the worker’s hands are engaged with the tools, and care is required to place the tool accurately upon the sandstone surface, as well as in striking the hammerstone upon the tool. It is more difficult to guide two tools at once, and any degree of control affects the amount of time spent creating a glyph. Moreover, the force of the blow is somewhat diffused and absorbed by the two implements, reducing its action upon the stone face.

Measurements of glyph width reflect both the width of the tool point and the worker’s ability to control the tool. In punching and chiseling it was sometimes difficult to follow the demarcated line of the cross, and unless we were careful, the tool attacked larger areas than we intended. The large dull chert cobble was abandoned as a punch not only because it was so dull that it cut poorly, but because it was so wide that it obscured the view of the glyph and was difficult to use with any accuracy.

Although our feelings about indirect percussion techniques are contrary to the expectations voiced in the rock art literature, they should not really be surprising. Pecking with a hand-held stone can be very precise. Any flintknapper strikes with a hammerstone to much higher standards of accuracy than are required for making petroglyphs. Indirect percussion techniques are not as precise as they sound. It is difficult to strike the rounded and uneven surface of a chisel stone with an equally irregular hammerstone and consistently and accurately transmit the force to a distant cutting tip. Additionally, a rounded hammerstone used as a chisel makes it difficult for the worker to see the surface he or she is chiseling. Sharp, narrow stone chisels are theoretically possible (a thick flake for instance) but would be weak in use.

Incising is very different from the various percussion techniques. The chert flakes afforded the most control of any of the implements, for they did not require any percussive force and they were always in contact with the surface of the stone. Nevertheless, it took an average of almost two more minutes to complete one of the cross patterns by incising than it did by pecking. The small edges of the flakes and the nature of the technique that did not remove material very fast contributed to the amount of time expended incising with the chert flakes.

The durability of the tool may also affect the time spent creating a glyph. While we did not think to measure the time it took to resharpen or repair the tools dulled or damaged during production, this variable should be considered when assessing labor costs. After chiseling one glyph with the antler, the working edge of the antler had to be resharpened. In order to effectively peck with the chert or quartzite cobbles, a point had to be prepared by flaking, and tools in long use would have to be refaked. Additionally four different flakes (with 6 working edges) were needed to make 10 glyphs because the sharp edges were soon dulled by the incising. Of all the tools assembled, only the sharp chert cobble did not need to be reworked at any point. The actions of reworking the antler, quartzite and chert cobbles did not require a prodigious amount of time but they did add to the overall labor cost.

Subjective observations regarding glyph production also illuminate the many factors that contribute to differences in effort expended. While time, width, and depth may be measured, our subjective feelings about the relative ease or difficulty with which we produced each glyph can not be measured quantitatively. None of us are experienced petroglyph makers, and while Koeman and Taylor practiced with each tool and method prior to making the experimental glyphs, inexperience certainly contributed to the effort we had to expend. It was easiest to handle
and control the small sharp chert cobble, due to its size and shape. The small chert cobble also proved to have a particularly well-shaped working edge for our efforts, but when we began this experiment we did not know what kinds of points or edges would be most effective with the methods we employed. We observed that pecking with a small and relatively sharp edge allowed for more control of the depth and width of the glyph. Additionally, we observed that chiseling with an antler required significantly more force and physical effort than any of the other methods tested.

Our data and experience indicate that given sandstone such as ours, direct percussion pecking required the least effort and proved more time-efficient than the other methods. Indirect chiseling and punching with stone tools and antler was also satisfactory, but more difficult and less efficient. Incising produced the cleanest, most accurate line but took more time to execute.

These findings may differ according to the surface material and the skill of the producer. Indirect punching did not afford us any advantage over other methods, but perhaps might be more useful on a harder stone, where the extra force needed might decrease the accuracy of pecking. Additionally, with more practice, creating glyphs through indirect percussion may become easier and more controllable. Nevertheless, as novices, we were able to easily create well defined petroglyphs through direct percussion and see no reason to use indirect percussion.

Even though our results suggest differences in effort expended according to tool type and technique, there are some limitations to our experiment. While we considered efficiency, accuracy, and the durability of the tool itself, we did not have a means to measure the physical force each worker or technique exerted. Force certainly varied according to our physical capabilities, energy, and skill-levels, as well as by technique. In spite of some uncontrolled variability, we believe that our results mainly reflect differences in the techniques utilized. The standard deviation of the mean time expended was low for each tool type and did not vary systematically between the workers, and the differences between the three tool types used in indirect percussion are not notable.

### Petroglyph Characteristics

There are identifiable distinctions between the marks produced by the different tools and techniques. The individual dints within each glyph reflect the size and shape of the tool used to create it and, to a degree, the technique employed. Recognizing the differences between marks may allow more accurate understanding of how specific archaeological petroglyphs were produced.

**Dull Chert Cobble, Pecking.** (Figure 6: 2P) The larger chert cobble, with a dull point, created rounded pit-like dints approximately 2.3 by 2.2 mm, making them appear relatively larger than the marks produced by the sharp chert cobble. The edges of the crosses appear more irregular than those created by the sharp chert cobble.

**Sharp Chert Cobble, Pecking.** (Figure 6: 2S) All of these crosses are easily distinguishable from the other glyphs. The dints are shallow, but slightly elongated, ranging in length from 2.6 - 4 mm, with widths of 1.10 -1.8 mm. They tend to be linearly aligned, especially in comparison with the larger marks produced by the dull chert cobble. The edges of the glyphs are not perfectly even and straight, but are nicked by the ends of the linear peck marks, and the ends of the crosses appear rounded, rather than square.

**Quartzite, Pecking.** The dints first produced by this tool were similar to those of the dull chert cobble, but larger, measuring approximately 2.9 x 3.5 mm. After resharpening, the quartzite dints were smaller.

![Figure 6. Representative glyphs: 4F, 4D = antler chiseling; 3W = sharp chert chiseling; 2P = dull chert pecking; 2S = sharp chert pecking; 3G = sharp chert punching.](image-url)
than the dull chert dints, but were not linear like those produced by the sharp chert cobble. **Sharp Chert Cobble, Punching** (Figure 6: 3G) and Chiseling Figure 6: 3W). The shapes of these dints are similar to those produced by direct percussion pecking, but individual dints are much deeper and more distinct. The edges of the lines of the crosses however, tend to be more irregular than those created by pecking with the same tool, as the larger, more erratic dints overlap the edges. Individual dints from chiseling are more blurred into one another and more linearly aligned in the direction of the work. **Antler, Chiseling**. (Figure 6: 4D, 4F) The edges of the lines of the cross are well defined, although not as precise as the edges produced by incising with flakes. The end of each line of the cross is rounded to approximately the same degree as the tip of the antler. The glyph looks smoother, and under a hand lens, patches of the surface appear blurred or smeared in the direction of work. The antler chisel appears to work primarily by abrasion, and detached bits of the sandstone are probably as much responsible as the antler itself. This is probably why punching with the antler stationary is so ineffective. The crosses are not as straight as the incised ones, but bend or curve slightly. This may have resulted from an inequality in the force exerted by the hand with the hammer stone, and that of the hand steadying and guiding the antler. **Flakes, Incising**. (Figure 7: 5D, 5E, 5B) Incision leaves very long, narrow, and shallow individual marks that run parallel to one another. The incisions often extend beyond the marked ends of the crosses, which as a result are not uniform. With greater care, this could have been controlled. The edges of the crosses are even and undisturbed by nicks and appear to be perpendicular to the horizontal plane of the sandstone. The edges are more defined than those produced by multiple peck marks.

Our results suggest that the size of the tool’s point or edge can be inferred from the petroglyph characteristics no matter how wide the lines of the petroglyph may be. Obviously, an implement with a point larger than the line could not have created the petroglyph. Nevertheless, repetitive markings (either pecked or incised) of small points can be distinguished from repetitive markings made with a large point, even when they cover the same area. In addition, differences between incising, chiseling and pecking can sometimes be inferred.

**REPLICATION EXPERIMENT**

In order to test pecking as the most effective method, on a larger scale, two typical southwestern petroglyphs were replicated by Whittaker and his daughter April Kamp-Whittaker.

Whittaker used a slab of Kaibab sandstone from a road cut near Williams, Arizona. This is moderately hard sandstone comparable to many petroglyph surfaces throughout the Southwest, and harder than that used in the controlled experiment. The slab was an irregular parallelogram in form, 15 cm thick, 66 cm high and 90 cm across with an estimated weight of about 100 kg. Three figures were laid out in charcoal and two pecked: a mountain sheep and an anthropomorph (Figure 8). Both were modeled after figures from the Little Colorado drainage in central northern Arizona (Pilles 1976, 1976), but are representative forms that are widely distributed over the Southwest (Cole 1990; Grant 1976; Schaafsma 1980; Turner 1963). The mountain sheep is a typical quadruped motif, common throughout Southwestern prehistory from Archaic times to the late pueblos. The anthropomorph imitates Basketmaker figures (Cole 1994) typical of the period between 500 and 750 A.D, but is not a replication of any particular example.

The tools used were hard flat quartzite cobbles with a few flakes removed to leave a short section of
Figure 8. Two experimental petroglyphs. The hammerstones used are at the base of the slab with their working edges turned up.

ragged bifacial edge. They were similar to the pecking tools of chert and quartzite in the experiment above. We have observed similar tools at southwestern petroglyph sites, including those in the Chevelon drainage, and they are reported elsewhere as well (Boreson 1995; Moore 1994).

April Kamp-Whittaker (14 years old) pecked the sheep, using a light (125 gm) quartzite cobble with a sharp corner that was resharpened twice by striking off small flakes with a hammerstone. The sheep is 20 cm across and 23 cm high. April pecked it quite lightly, merely crushing the surface patina of the stone. Many prehistoric examples are not very distinct, and like this one, represent minimal work. The sheep took 32 minutes to peck, of which 2-5 minutes should be subtracted for consultation and sharpening the hammerstone.

Whittaker pecked the anthropomorph, using a much heavier (585 gm) quartzite cobble with a bifacially flaked edge, and striking with several of the projecting points along the edge. They rapidly became dull and rounded but continued to be effective and the edge was not resharpened. The finished anthropomorph was 36 cm across the hands and 53 cm high. It was cut well through the softer patinated surface of the stone into fresh stone beneath; the figure averaged 2-3 mm deep. The whole operation took 52 minutes, minus 5-8 minutes for photography, notes, and supervision of the sheep. A comfortable work rhythm was timed at 200-240 blows a minute, so the whole took 8800-11280 pecks.

Technique makes some difference in petroglyph manufacture. April used a small stone and a light blow, and her petroglyph is relatively ephemeral. A heavier hammerstone and a stronger blow produced faster and deeper results, and the anthropomorph should last as long as the prehistoric ones, which are now more than a thousand years old. The dull round ends of the quartzite cobbles were tried and convinced us that the sharpened edge was vastly more efficient. A hard hammerstone with a sharply pointed unflaked corner should also work well. In making a deep petroglyph, where pecking was intended to remove a lot of stone, it was most effective to start a deep cut and then work along the edges to expand it. This crumbled away chips and dust where the stone was unsupported on the edge of the cut.

CONCLUSIONS

Although each surface upon which petroglyphs are produced will differ, as will the tools, techniques and skills of the workers, our general conclusions should be widely applicable. Our experiments in producing petroglyphs have led us to question some of the assertions and assumptions made in some petroglyph studies. For instance, as a wooden stake proved totally ineffective on our soft sandstone, we must question Lothson's conclusion that such a tool (though fire-hardened) was used upon quartzite, a metamorphic rock much harder than sandstone (1976: 23). Our results also indicate that antler proves more effective as a chiseling tool than as a punch, contrary to Lothson's statement regarding petroglyph production at the Jeffers site (1976:23).

Our results also appear to contradict the widespread belief that indirect percussion is more accurate and efficient than direct pecking. In our experiments, producing petroglyphs by indirect percussion punching or chiseling required more time and afforded no more control of the tool than direct percussion pecking, and pecking was quite capable of efficiently producing a large petroglyph with small details accurately delineated.

Incising produced very accurate lines, but was slow and would probably not work well on a hard stone surface. The hardness of the stone surface, a variable we did not manipulate, would surely have played a part in the choice of petroglyph technique,
as would the available tools, and the strength and skill of the worker. To some extent, the choice of techniques and tools is archaeologically visible in the distinctive marks they leave on the stone.

The size and detail of a petroglyph would also strongly affect the amount of time necessary to make it. The replicative experiment showed that a quite substantial petroglyph, deeply cut and moderately detailed, takes less than an hour to peck into hard sandstone. Obviously there will have been much variation, depending on aforementioned variables such as the size of the figure, the hardness of the stone, the choice of tools, and the determination and skill of the worker, but it would be difficult to argue that any southwestern petroglyph we have seen represents a major labor. Large panels with many individual glyphs probably result in most cases from repeated visits over long spans of time. Even when they do not, the expenditure of labor is probably not large enough to require a concerted communal effort.

A further social implication of the relative ease of petroglyph manufacture is that such an activity could have been easily incorporated into any ceremonial occasion, whether hunting ritual, initiations, invocations for fertility, or the shamanistic practices favored by current theorists. For that matter, many petroglyphs are so easily produced that they could be casual doodling or graffiti. They may have been of great symbolic importance, or not, but they did not require esoteric technical skills, and rarely if ever cost much in terms of either labor or resources.

Acknowledgments Kathy Kamp assisted in the conception of the controlled experiment, and provided feedback on the experiment and comments on the manuscript. April Kamp-Whittaker obliged her father’s whims and pecked a sheep in the hot sun. Peter Pilles, Larry Loendorf, Bill Green, and Rex Weeks helped with bibliographic tips and comments on the manuscript.

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