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A Milling-Implement Quarry at Elephant Mountain, California

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Tabular slabs of porphyritic hornblende andesite from Elephant Mountain were shaped into aboriginal milling stones and pestles and carried to living and processing locations in the Mojave River region. The milling-implement quarry at Elephant Mountain, first described by Nuez in 1819, was identified archaeologically and subsequently studied. Worked slabs of andesite, broken and discarded preforms, andesite debitage, and hammerstone quarrying and production tools characterize the archaeological deposit at the quarry. Production technology differs somewhat from that employed at other milling-implement quarries. It is proposed that the long-term retention of the abrasive quality of the Elephant Mountain stone made it especially useful for milling. Milling stones from the Hinkley site, about 15 mi. upstream on the Mojave River, originated at Elephant Mountain, as demonstrated by thin-section petrography. Certain lines of evidence suggest that the Elephant Mountain stone may have been exploited as early as 3,500 B.P., that it may have been used by groups expressing or influenced by material culture traits of the Lower Colorado River region, and that the quarry may not be unique in the region. Sourcing of milling implements to their quarry has the potential to add to our understanding of regional prehistoric economic and social networks.

MILLING implements are common in the archaeological record of California and the Great Basin and often are considered the archaeological material correlates of human behaviors involved with processing food and nonfood items (Schneider 1993a, 1993b). The importance of milling implements apparently increased progressively from the time of the Pleistocene-Holocene interface to the Late Prehistoric Period. In spite of the archaeological ubiquity and visibility of milling implements (i.e., lower milling stones [metates], handstones [manos], pestles, and mortars), little attention has been given to the origins of the tools: the selection of stone and the means of production. Relatively recently, archaeologists have begun to recognize sites where debris and broken preforms indicate aboriginal milling-implement production of varying intensities (e.g., Hoffman and Doyel 1985; Huckell 1986; Schneider 1993a, 1994, 1996). Early peoples often were highly selective in their choices of milling-tool materials; labor investment in the procurement of raw material, production, and transport varied with the substances being processed, intensity of processing, settlement pattern, raw material availability, and other factors (see Schneider 1993a).

The purposes of this paper are threefold: (1) to describe Elephant Mountain Quarry (the first bedrock milling-implement quarry in the Mojave River region to be described) so that other sites of this type can be recognized; (2) to model the prehistoric human behaviors involved in quarrying and production through the study of the archaeological deposits at the quarry, petrology of the quarry stone, and experimental replication of the production sequence; and (3) to place the Elephant Mountain Quarry within environmen-

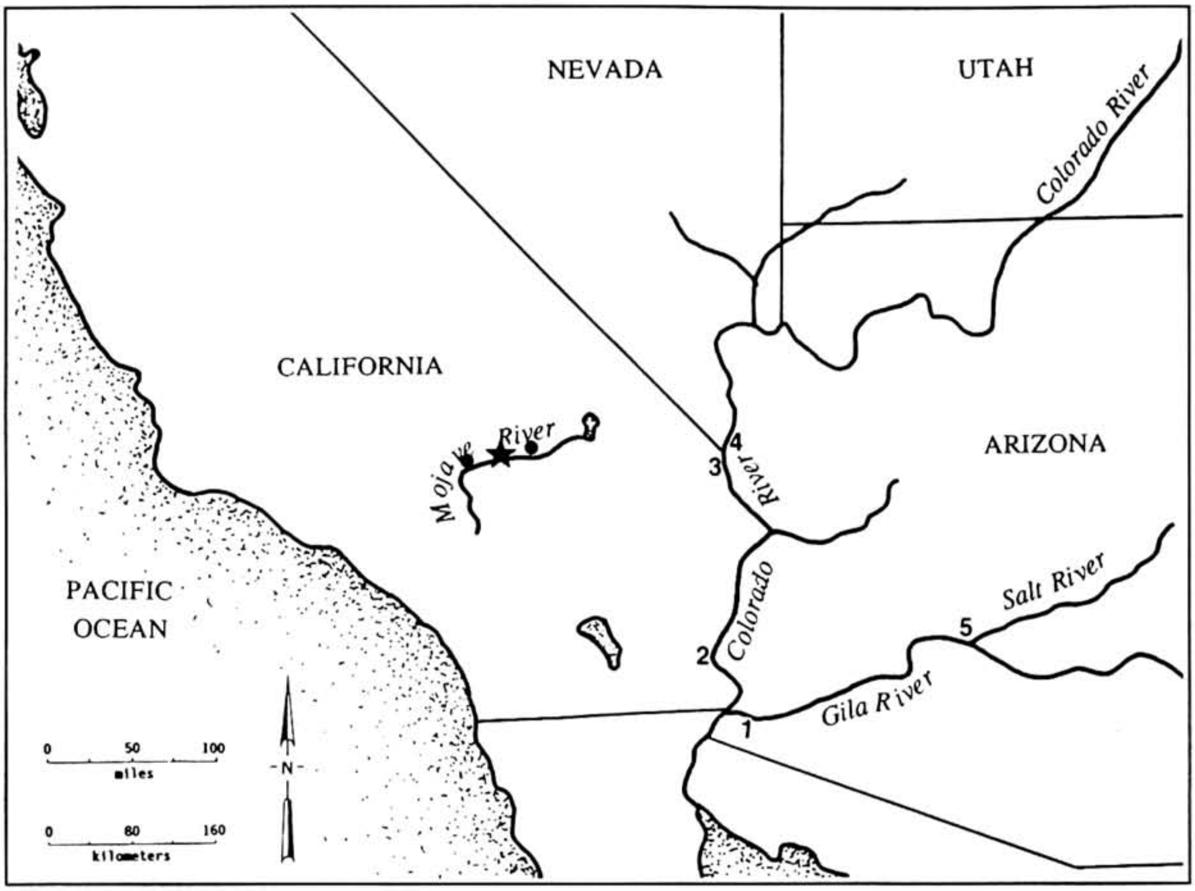

Fig. 1. Location of the Elephant Mountain Quarry (star). Dots indicate the approximate locations of CA-SBR-189 (the Hinkley site, upstream to the west) and CA-SBR-6605 (downstream to the east). Numbers indicate the locations of other known quarries mentioned in text: (1) Antelope Hill, (2) Chip Hill I and other quarries of the Palo Verde Quarry District, (3) Polodori, (4) Bullhead City, (5) Hohokam quarry area.

tal, cultural, and economic contexts, so that the potential of this site type can be appreciated in terms of increasing our understanding of regional prehistory and larger economic patterns.

THE ELEPHANT MOUNTAIN QUARRY AND ITS ENVIRONMENT

Elephant Mountain is located on the north side of the Mojave River, at Daggett, California, in the central Mojave Desert region of the southwestern Great Basin. The local environment is best described as "desert riparian" (Fig. 1). The relatively flat mesa that comprises the "trunk" of the "elephant" and its southwestern extension (Fig. 2) have been intensively quarried for stone to manufacture milling implements, mostly metates (lower milling stones). Within the quarried area on the mesa and adjoining region (Fig. 3), bedrock outcrops weather in a foliated pattern (Fig. 4) and tabular stone slabs, many tested or worked, abound (Fig. 5).

Quarrying and production debris and tools are the major elements of the Elephant Mountain Quarry. A few petroglyphs exist on andesite boulders along the southern edge of the mesa (other petroglyphs, formerly on boulders at the

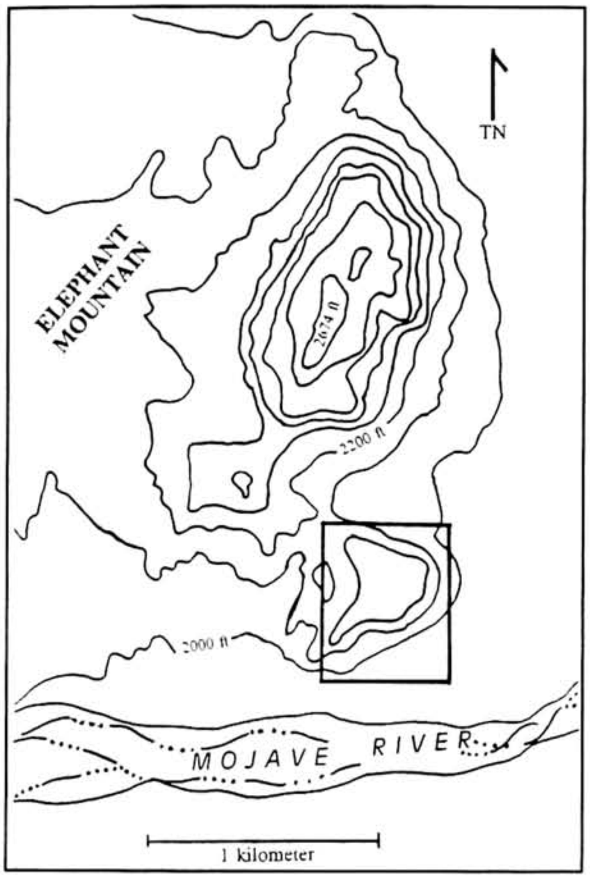

Fig. 2. Elephant Mountain. Rectangular outlined area is the mesa portion that comprises the milling-implement quarry. Contour intervals are 100 ft. (Adapted from the Nebo and Daggett 7.5' USGS quadrangles.)

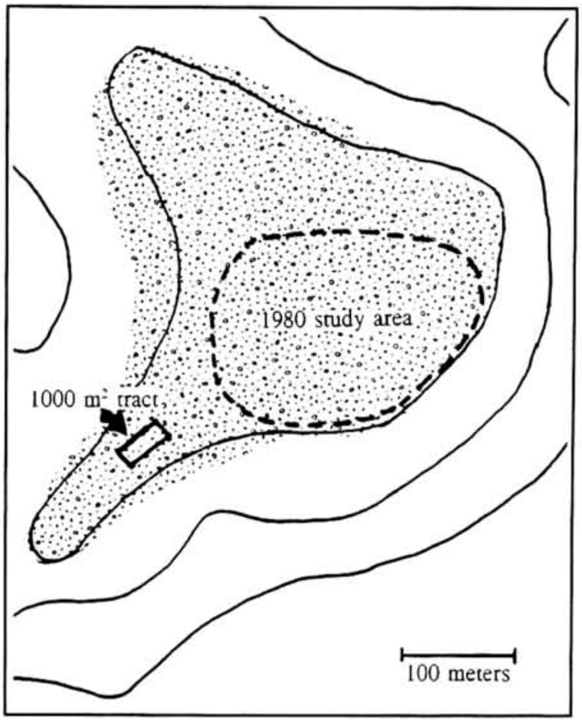

Fig. 3. Elephant Mountain Quarry. Stipled area is the approximate extent of the aboriginal quarrying and production. Locations of the 1980 study area and 1993 1,000 m.[2] sample tract are indicated.

southern toe of the mountain at river level, have been removed or destroyed). Two isolated, nondiagnostic biface fragments have been found on the surface of the site, but other surface evidence of aboriginal campsites or other prehistoric archaeological features is lacking. The remains of a historic silver-ore processing operation, including two stamp mills and associated wastes, are located at the southeastern foot of the mesa. The site has been disturbed, much of it by modern military activity most likely associated with the nearby Yermo Marine Corps Supply Center; several low-walled structures, modern in origin and constructed from tabular andesite, as well as cairn survey markers, modern campfire circles, and vehicle tracks are present on the mesa.

Today, the Mojave River is dry at the surface along most of its course due to upstream dams and lowering of the water table by intensive modern usage. A truer picture of prehistoric environmental conditions is available at several places along the river where subsurface bedrock still forces the underground stream to the surface or when, in times of exceptional precipitation, the river contains substantial surface water (Fig. 6).

Although no substantially sized campsites have been recorded in the immediate vicinity of Elephant Mountain (apparently having been obliterated by flood events and/or modern development), environmental conditions in the past

Fig. 4. Foliated structure of the weathering outcrop at Elephant Mountain. Weathering is along flow lines in the andesite, resulting in tabular jointing pattern.

would have been conducive to human settlement in the immediate vicinity; permanent water, trees (cottonwood and willow), abundant pasturage, and other riparian vegetation existed at or very near Elephant Mountain (Nuez 1819; Norris 1854; Washington et al. 1855; Washington 1857). Varied and abundant faunal species also would have supported human occupation in the past; bighorn sheep, freshwater mussels, western pond turtles, and Mojave tui chub have been identified archaeologically along the Mojave River (Rector et al. 1983; Sutton and Yohe 1989), and greater numbers of present-day fauna, such as reptiles (various lizards and desert tortoises), would have been present. Furthermore, since the Mojave River was an important travel route across the desert during both prehistoric and historical times (Schneider 1989), travelers, as well as local residents, would have been aware of the quarry resource at Elephant Mountain.

THE GEOLOGY OF ELEPHANT MOUNTAIN

Elephant Mountain is composed of Miocene volcanic intrusive rocks. While most of the mountain is dacite, the quarried mesa portion is andesite (Bortugno and Spittler 1986). Some exposures of very similar volcanic rock lie to the north in the Calico Mountains, but have not yet been explored. Other volcanic outcrops along the Mojave River in the vicinity of Barstow and Daggett bear no evidence that they were used for milling-implement quarrying and production.

At Elephant Mountain, a highly abrasive stone needing minimal rejuvenation was available in convenient tabular form. Thin-section petrographic analysis of Elephant Mountain

Fig. 5. Tabular blocks of stone on the surface at Elephant Mountain.

Quarry rock describes a slightly vesicular porphyritic hornblende andesite with a "felty" matrix, 20 to 40 percent of its volume comprised of phenocrysts (crystals) of plagioclase and oxyhornblende (Schaller 1991). The large phenocrysts (up to 3.9 mm. for plagioclase; up to 1.8 mm. for oxyhornblende) within the finer matrix form an abrasive surface, ideal for grinding. Furthermore, this rock would tend to retain an abrasive surface even under heavy use; andesite of this type "burrs," rather than polishes with wear. Consequently, an abrasive milling surface could be maintained with a minimum need for rejuvenation. At a number of other milling-implement quarries (Schneider 1993a:Appendix E), petrographic analysis of the stone indicated similar characteristics.

The most unique and obvious macroscopic characteristic of the quarried outcrops at Elephant Mountain is the tabular jointing and weathering pattern (Fig. 4). Close examination of raw material and milling-implement preforms, both in the field and in museum collections, revealed that the andesite has a layered structure. Alternating colored banding (ranging from pinks to greys) reflect flow lines of molten magma. Rock weathering occurs along the less resistant flow lines, thus the foliated texture of the rock is responsible for the tabular raw material characteristics.

Rock varnish coats much of the exposed surfaces of the outcrops. Fresher exposures are lighter in color, less recently exposed surfaces have darker coatings. Lighter colored surfaces indicate slabs that have been removed from outcrops, naturally exfoliated slabs that have been overturned for inspection, and culturally flaked surfaces (Fig. 5).

CULTURAL AND POLITICAL SETTING

Most authorities agree that the area along the Mojave River was the territory of the Vanyume in late prehistoric times (Kroeber 1925; Bean and Smith 1978; also see Schneider 1989). The

Fig. 6. The Mojave River at the base of Elephant Mountain in February 1993. Heavy precipitation in the San Bernardino Mountains and throughout the desert area created flood conditions. View approximately north toward the mesa at Elephant Mountain. The riverbed is usually dry at this location.

Vanyume are thought to be a desert branch of the Serrano of the San Bernardino Mountains, speakers of a Takic language. By the time ethnographers were collecting information in the region, the Vanyume were extinct, known only through oral tradition. The ethnographic model for Vanyume lifeways is based on what is known about the Serrano.

Drawing on earlier ethnographic work (Benedict 1924, 1926; Kroeber 1925; Strong 1929; Drucker 1937), Bean and Smith (1978) synthesized information on Serrano lifeways. If the Vanyume were desert-dwelling Serrano, they lived in a manner similar to the hunter-gatherers of the mountains and coastal valleys, although their desert environment probably necessitated smaller groups, a more mobile settlement pattern, and a lifeway similar to other desert groups such as the Chemehuevi. The lineal resources along the Mojave River became available seasonally, and settlement and subsistence were based on mobility and scheduling. Riparian resources were supplemented by desert resources, such as tortoise and agave, and food items from high elevations acquired directly or obtained from other groups. Mesquite and tule were important staple foods, in addition to a variety of wild plant seeds and small animals.

A Mohave presence along the Mojave River has been fairly well documented; Mohave apparently traveled freely among other peoples living along the course of the river on journeys from their territory along the Colorado River to the Pacific Coast. A short-lived Mohave settlement in the eastern and east-central Mojave Desert has been postulated based on oral tradition and some material evidence (Drover 1979:56-65; Lerch 1985). Oral tradition suggests that a Mohave settlement in the Mojave Desert was wiped out in a massacre during late prehistoric or early historical times (Kelly MS; Kroeber 1959; Lerch 1985). During late prehistory or historical times, due to the influence of contacts with southern and eastern groups, Mojave River peoples may have practiced some plant cultivation at springs or along the Mojave River where there was permanent water (Rogers 1945; Warren 1984:347; Lerch 1985).

AN EARLY HISTORICAL ACCOUNT DESCRIBING ELEPHANT MOUNTAIN

Although other Euroamericans had traveled along the Mojave River in the vicinity of Elephant Mountain, starting with Francisco Garcés in 1776 (Coues 1900), the first specific written identification of the mountain and of the possibility that it was a quarry for milling implements was by Father Joaquin Pasqual Nuez (Smith 1980; Lerch and Smith 1990; also see Schneider 1989 for a review of early historical activity along the Mojave River). On November 22, 1819, the Moraga Expedition, accompanied by Father Nuez, set out from Mission San Gabriel on a punitive expedition against the Mohave Indians, traveling across the San Bernardino Mountains and down the Mojave River to its sink. The chase was abandoned at this point, and on December 3, the group turned back.

Nuez (1819) kept a diary, and the December 6 entry reads, "At seven o'clock in the morning, heartsick of not being able to proceed to Amajaba [i.e., the Mohave nation] we set out in retreat toward a place where there was considerable water below a hill of red rock very suitable for millstones, and remained there all day. I named it San Rafael" (Nuez 1819). The place of considerable water has been identified as the "Fish Ponds" (Van Dyke 1927), just upstream from Daggett; the "cerro de piedra Colorada" is probably Elephant Mountain (Lerch and Smith 1990). Having long been intrigued by this description, Smith made the first archaeological identification of the site in 1979 (Simpson 1979; Smith 1980).

The source of Father Nuez's information regarding the suitability of the red rock for millstones is not explicitly identified in the diary, although in the days just prior to this entry Nuez made a number of references to the Indians of the region who had given him and Moraga information regarding the availability of water in regions to the east. It is likely that the information about the millstones also came from local Indians (possibly Vanyume). There is some question about whether Nuez referred to Indian millstones (metates) or Spanish rotary millstones or both in his description of rock suitable for millstones. He used the term "piedras de molino." The question has been partially answered by the sourcing of metate fragments from a prehistoric archaeological site to the Elephant Mountain Quarry (see below).

ARCHAEOLOGY AT ELEPHANT MOUNTAIN

Two studies have been carried out at the Elephant Mountain Quarry. The first study consisted of a data recovery project conducted in anticipation of the construction of a large water tank and access road on the Elephant Mountain mesa and resulted in a cultural resource management report (Smith 1980). Approximately 44,600 $m.^2$ (11 acres), about 24% of the actual quarry area of approximately 187,500 $m.^2$ (46 acres), was inventoried. All features within the area of direct impact were individually mapped or photographed, the contents of some collected and stored at the San Bernardino County Museum. These data are available in the Smith (1980) report and are summarized here (Fig. 7; Table 1). Milling-implement production activity zones constituted 44 of the 61 features recorded within the area of direct impact (about one milling-implement production locus per 1,000 $m.^2$). Smith (1980) noted that there were many other similar features beyond the study area.

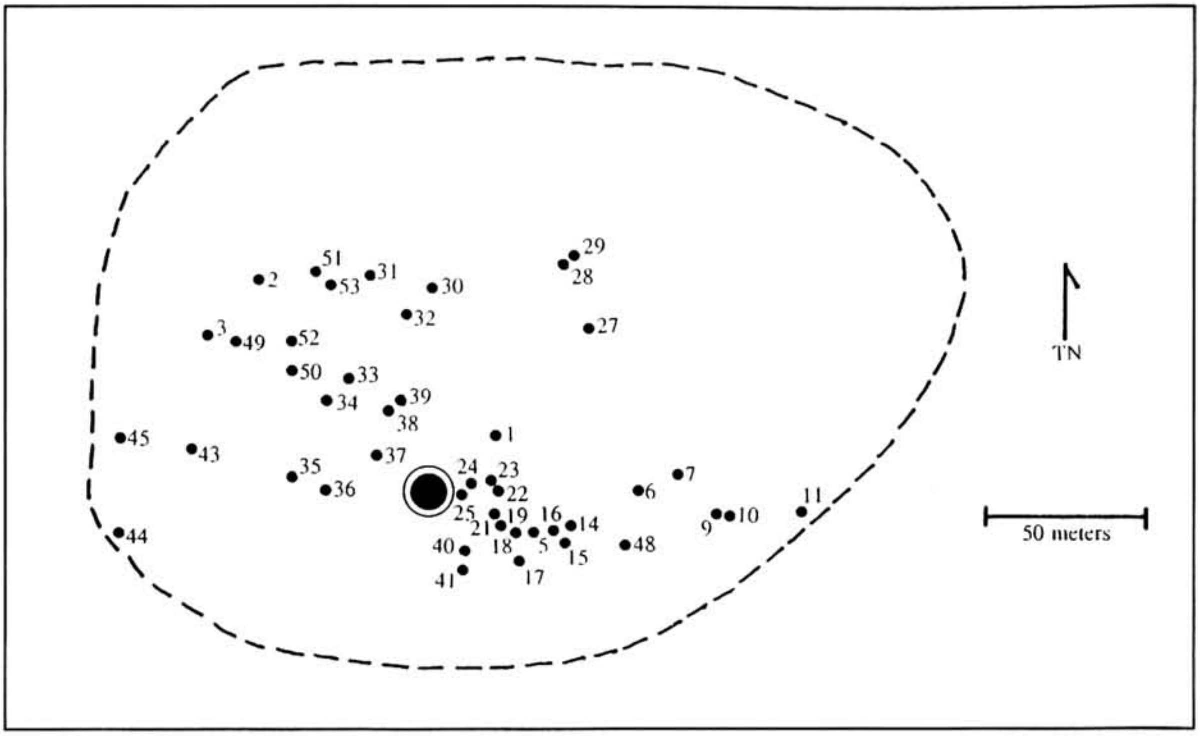

Fig. 7. Approximate area of the 1980 study. Numbered dots refer to the locations of aboriginal features recorded and correspond to the loci numbers in Table 1. Locus 47 was documented in the report, but not mapped. Feature 11 is a petroglyph panel (see Table 1). Numbers not appearing in the sequence were modern features.

Figure 7 represents the approximate distribution of prehistoric features recorded in the Smith (1980) study. With one exception (Locus 11), all are the remains of activities associated with the production of milling implements. Table 1 presents the contents of each feature (locus). Forty-three loci contained scatters of andesite percussion flakes and associated debris (in many cases the existence, but not the number, of flakes was reported). Locus 44 consisted only of two isolated hammerstones. A majority of the loci, in addition to the flake scatters, contained one or more hammerstones and one or more worked slabs of andesite. The worked slabs within the loci represented a continuum of production; some were tested slabs with only a few flakes removed, some were broken or abandoned midway in production, and some were broken during the final stage of production. At some loci, a large flake scatter, used hammerstones, and the absence of a slab suggest a successful production effort, after which the milling implement was removed from the quarry. Figures 8 and 9 represent fairly typical production loci recorded by Smith (1980).

The second study was conducted as part of dissertation research on milling-implement quarries in the region (Schneider 1993a:214-237) and differed methodologically from the Smith (1980) study. The senior author visited Elephant Mountain on a number of occasions between June 1989 and March 1992. During this time, outcrops and the debris resulting from quarrying and production were studied and photographed in the field; a few debitage flakes from milling-implement production loci were collected for

Table 1

CONTENTS OF MILLING-IMPLEMENT PRODUCTION LOCI RECORDED IN THE SMITH (1980) STUDY

Locus[a]	Flakes/ Shatter	Discarded Milling Stone Blanks	Broken Milling Stone Preforms	Discarded Pestle Blanks[b]	Broken Pestle Preforms[c]	Tested Slabs[d]	Unworked Slabs	Hammer-stones	Comments
1	56	1	2	1	--	1	--	2	quartzite, andesite hammerstones
2	11	--	--	--	--	3	--	2	small circle of stones (modern?)
3[e]	32	--	--	--	1	--	4	1	--
5	+[f]	--	1	--	--	--	--	--	petroglyph
6	+	1	1	1	--	+	--	+	--
7	50+	--	--	--	--	1	--	+	successful production, milling implement removed
9	+	1	1	--	--	--	--	+	--
10	32	--	--	--	1	--	2	--	2 parts of same pestle preform
11	--	--	--	--	--	--	--	--	petroglyphs
14	+	--	--	--	--	--	--	--	bedrock outcrop; slabs in place
15	+	1	--	--	--	--	--	+	all well-embedded in surface, andesite hammerstone
16	+	2	--	--	--	--	--	2	andesite hammerstones
17	13	1	--	--	--	1	--	--	circular rock enclosure (modern) with associated rock pile
18	+	--	--	--	--	--	--	1	milling implement removed
19	+	--	1	--	--	--	--	1	2 rock-pile survey markers, andesite hammerstone
21	+	--	--	--	--	--	--	2	1 river-cobble hammerstone 1 andesite hammerstone modern survey marker
22	4	--	--	--	--	--	--	--	--
23	5+	--	--	--	--	--	--	1	andesite hammerstone modern survey marker
24	+	--	1	--	--	2	--	1	each tested blank in 3 pieces
25	+	--	1	--	--	--	1	2	adjacent to bedrock outcrop
27	+	--	--	--	--	--	--	1	--
28	+	1	--	--	--	--	--	--	completed milling implement may have been removed
29	+	--	--	--	--	1	--	--	milling stone propped on anvil stone
30	+	--	--	--	--	--	--	1	circular arrangement of flakes; completed milling stone probably removed
31	+	--	--	--	--	--	--	2	1 quartzite hammerstone (river cobble) 1 andesite hammerstone
32	+	1	--	--	--	--	--	1	milling stone preform propped on anvil stone
33	+	--	1	--	--	--	--	2	--
34	+	2	--	--	--	--	--	--	--
35	+	--	2	--	--	2	--	--	--

Table 1 (continued)
CONTENTS OF MILLING-IMPLEMENT PRODUCTION LOCI RECORDED IN THE SMITH (1980) STUDY

Locus	Flakes/ Shatter	Discarded Milling Stone Blanks	Broken Milling Stone Preforms	Discarded Pestle Blanks	Broken Pestle Preforms	Tested Slabs	Unworked Slabs	Hammer-stones	Comments
36	+	--	10	--	--	--	--	3	near edge of mesa overlooking river
37	+	--	1	--	--	--	--	--	completed milling stone probably removed
38	+	--	1	--	--	--	--	--	completed milling stone probably removed
39	+	--	--	--	--	--	--	+	completed milling stone probably removed
40[e]	30+	--	3	--	--	--	--	2	1 black metavolcanic hammerstone 1 andesite hammerstone
41	+	--	1	--	--	1	--	1	--
43	+	--	2	--	--	--	--	--	2 production events here
44	--	--	--	--	--	--	--	2	isolated hammerstones
45	+	--	--	--	1	--	--	1	bedrock outcrop
47[g]	+	--	2	--	--	--	--	+	--
48	+	--	--	--	--	--	--	--	large flake scatter extends to the edge of the mesa
49	+	--	--	--	--	--	--	--	indications that a completed milling stone had been removed
50	+	--	3	--	1	--	--	1	--
51	+	--	--	--	--	--	--	--	--
52	+	--	2	--	--	--	--	--	--
53	+	--	--	--	1	--	--	1	--

[a] Locus numbers in table include only those that contain evidence of prehistoric milling-implement production. Other features include modern petroglyphs, hearths, structures, vehicle tracks, etc.
[b] Discarded blanks are early-stage production discards.
[c] Broken preforms are later-stage production fractures.
[d] Tested slabs are slabs exhibiting very minimal flaking.
[e] Figures included for these loci (Figs. 8 and 9).
[f] Indicates presence, but no quantitative information available.
[g] This locus was not on original site map.

laboratory study and thin-section analysis; a few hammerstones found at production loci were collected for study; site boundaries were determined by the extent of the quarrying debris (Fig. 3); and metric data were obtained on a judgmental sample of milling-implement preforms on the site surface (Table 2).

To quantify the activity at Elephant Mountain so that it could be compared with other milling-implement quarries studied, a 1,000 m.^{2} tract was established on the ridge extending to the southwest from the center of the mesa (Fig. 3). Within the tract, all production loci (discrete concentrations of debitage flakes, broken and discarded preforms for milling implements, hammerstones and hammerstone spalls, and tested slabs or boulder outcrops) were mapped (Fig. 10). Metric data were systematically obtained on all preforms within the sample tract (included in Table 2). This study showed that

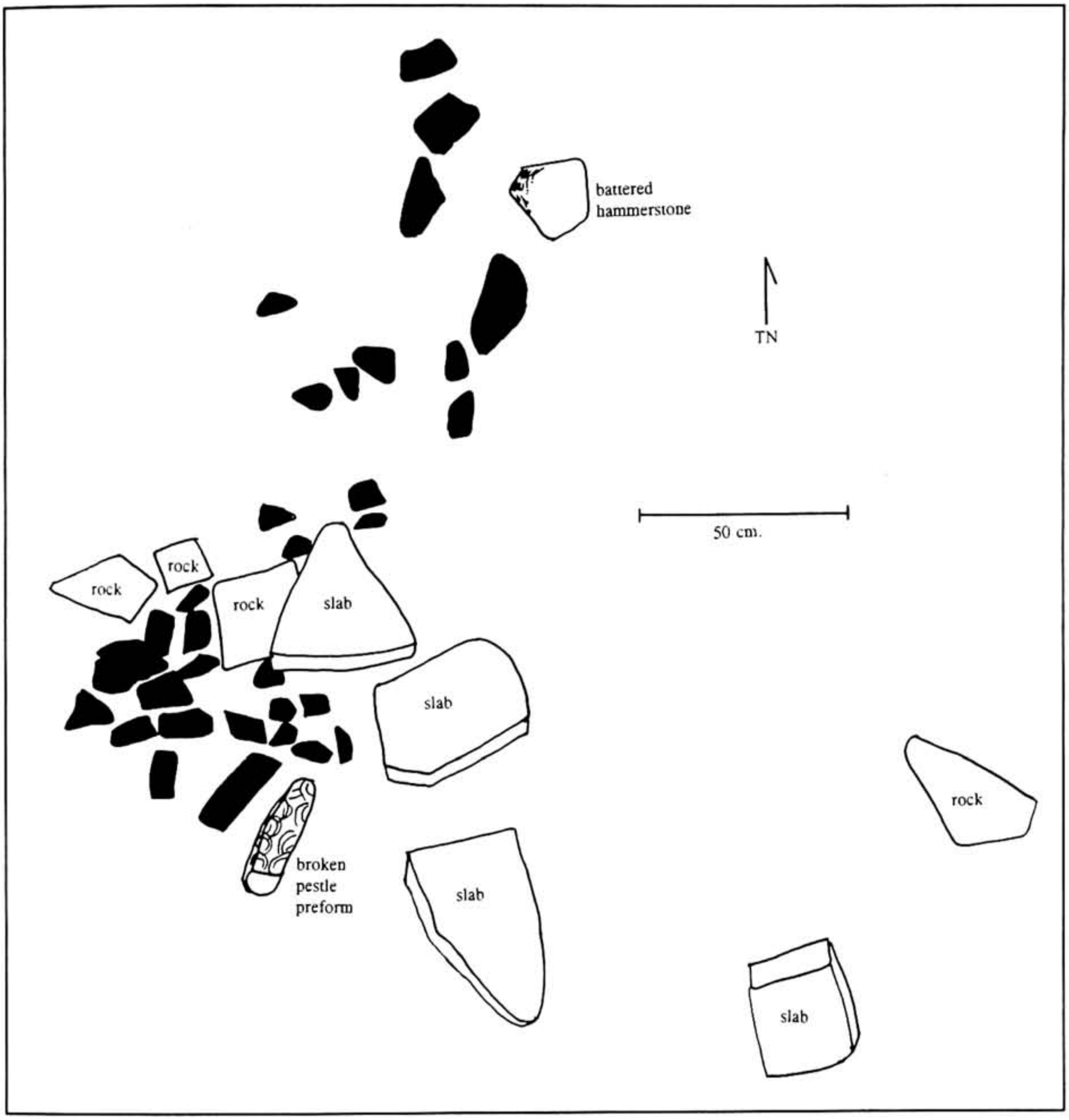

Fig. 8. Milling-implement production Locus 3. Solid black areas are percussion flakes. The broken pestle preform was nearly complete when an end-shock fracture occurred. (Adapted from Smith 1980.)

both the quarry and production areas were more extensive than previously reported (Fig. 3) and that some areas represented more intensive activity than previously reported (i.e., 29 milling-implement production loci were located within the sample tract of 1,000 $m.^2$).

QUARRYING AND PRODUCTION OF MILLING IMPLEMENTS

The surface of the Elephant Mountain Quarry is littered with production debris: tabular pieces of bedrock that have been examined, tested, and/

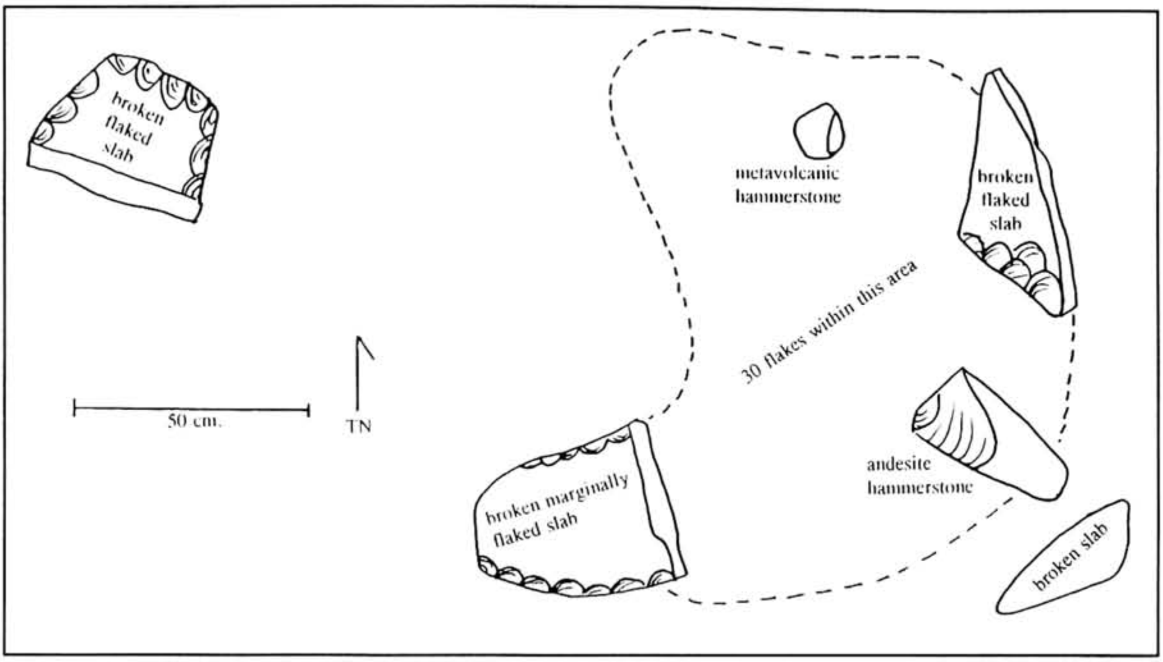

Fig. 9. Milling-implement production Locus 40. Three broken, flaked slabs represent failed attempts to make milling implements, probably metates. (Adapted from Smith 1980.)

or reduced and shaped by percussion reduction; broken and discarded metate and pestle preforms; debitage flakes resulting from reduction activities; and tools used in production. The quarry area originally extended over the entire "trunk" mesa of Elephant Mountain. Although much of the surface archaeological deposit in the central area of the site has been obliterated, considerable evidence of aboriginal quarrying and production still exists on the perimeter of the mesa, on down-sloping areas directly adjacent to the mesa, and on a southwestern ridge extension (Fig. 3). The frequency of production loci appears to increase as one moves southward on the mesa toward the edge fronting the Mojave River. Although the variable distribution of production debris has not been studied, at least two hypotheses might account for this observation: (1) the characteristics of the outcrop at the southern portion of the site may provide better quality and/or greater quantity of suitable stone, or (2) the shorter distance to carry heavy preforms from the quarry to living sites along the river may have encouraged quarrying along the southern margin of the mesa.

Slab surfaces originally in contact with the soil or other bedrock (i.e., not exposed to air) are lighter in color than long-exposed surfaces covered with dark rock varnish. Many slabs overturned by aboriginal stoneworkers during inspection, testing, or reduction are easy to identify due to their light-colored surfaces (Fig. 11).

Areas where milling-implement production took place are characterized by broken and discarded metate and pestle preforms and discrete concentrations of percussion flakes removed during shaping (Figs. 8-9, 11-13). Hammerstones of imported quartzite and others of metamorphic rock are also found at these locations, but local andesite hammerstones are more numerous (Figs. 8-10, 14; Table 1). Many artifacts are partly covered by fine silt from colluvial and/or aeolian deposition. Buried quarry and production debris exist but the depth and extent of

Table 2
METRIC ATTRIBUTES[a] OF COMPLETE MILLING-IMPLEMENT PREFORMS FROM ELEPHANT MOUNTAIN

Type	Condition	Length (cm.)	Width (cm.)	Thickness (cm.)	Weight (kg.)[b]
pestle	2 frags.	33.0	14.0	5.0	(3.5)
pestle	--	32.0	13.0	5.0	(3.1)
pestle[c]	2 frags.	51.0	13.0	8.9	6.7
pestle[c]	2 frags.	42.0	14.0	6.0	3.7
		mean = 39.5	mean = 13.5	mean = 6.2	
		SD[e] = 7.7	SD = 0.5	SD = 1.6	
metate	--	91.0	40.0	15.0	(81.9)
metate	--	94.0	46.0	20.0	(129.7)
metate	--	35.0	25.0	15.0	(19.7)
metate	2 frags.	50.0	35.0	15.0	(39.4)
metate	--	35.0	25.0	13.0	(17.1)
metate	--	35.0	22.0	15.5	(17.9)
metate	2 frags.	30.0	25.0	6.0	(6.8)
metate	2 frags.	53.0	32.0	16.0	29.0
metate	3 frags.	61.0	49.0	14.0	47.6
metate	pecked[d]	54.0	30.0	8.0	19.0
metate	--	66.0	44.0	14.0	40.8
metate	--	96.0	43.0	16.0	95.3
metate[c]	2 frags., pecked, well-shaped	52.5	26.0	10.5	21.8
metate[c]	2 frags., pecked, well-shaped	42.0	35.0	8.5	17.2
metate[c]	--	54.0	33.0	15.0	38.3
metate[c]	2 frags., pecked, well-shaped	50.0	36.0	6.0	16.6
metate[c]	2 frags., pecked, well-shaped	47.0	28.0	9.5	15.7
		mean = 55.6	mean = 33.8	mean = 12.8	
		SD = 20.0	SD = 7.7	SD = 3.9	

[a] All calculations are rounded to one place.
[b] Weights listed in parentheses are approximations based on 1.5 gm. of weight per $cm.^3$ of stone, a figure derived from measuring and weighing a series of 20 blocks of raw materials from several quarries. Other weights are actual.
[c] Artifacts collected by Smith (1980), now stored at the San Bernardino County Museum. All others were collected in the field.
[d] Pecked indicates that the preform is very close to finished size and shape.
[e] SD = standard deviation.

these have not yet been investigated. The two isolated biface fragments found on the surface may be an indication that other types of deposits may be present below the surface.

How the Bedrock Outcrops Were Quarried

Field observations and analyses of preforms in the field and in the museum collection suggest that slabs of raw material were sometimes removed from bedrock outcrops using levers or prying tools. The natural jointing and weathering pattern of the rock was used to advantage (Figs. 4, 15). This inference is based on the senior author's observation that several specimens had heavily varnished margins and *non-worked dorsal and ventral surfaces* that had min-

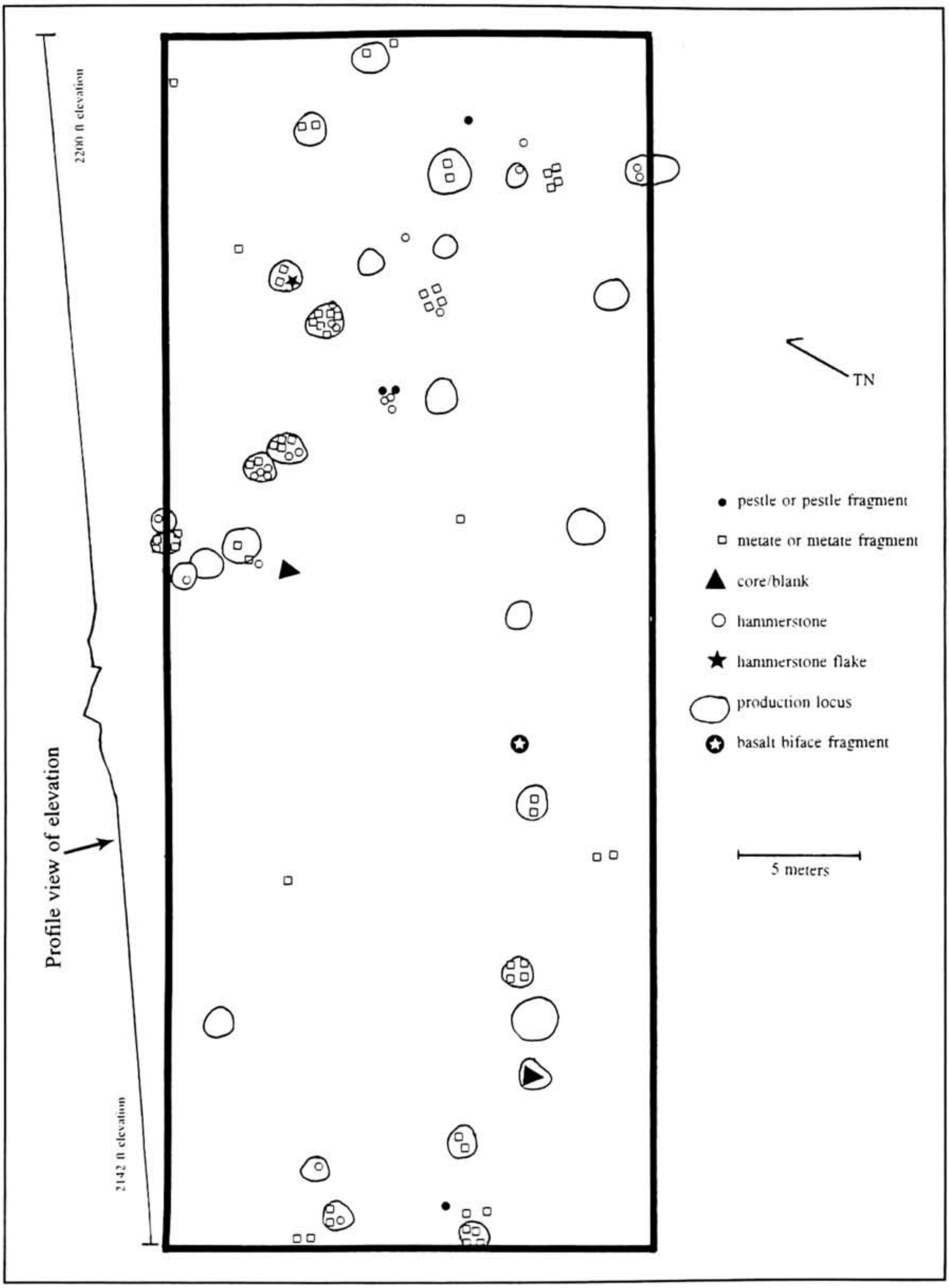

Fig. 10. Map of 1,000 m.^{2} sample tract at Elephant Mountain. Location of the tract is indicated in Fig. 3.

Fig. 11. Tabular blocks of stone showing color contrasts. Lighter colors represent blocks that have been overturned or newly exposed; darker colors represent rock-varnished surfaces that have not been disturbed. The block in the center of the photograph has been overturned and worked. It is surrounded by flakes that have been removed from its margins. Small pin flag in background for scale.

Fig. 12. Broken metate preform at Elephant Mountain. The preform was broken in the final stage of manufacture by "end shock." Lens cap for scale. The portion to the left is overturned, showing the rounded underside. The portion to the right shows the flat, pecked surface prepared for milling. This particular specimen is reminiscent of the Lower Colorado River type of metate.

Fig. 13. Broken pestle preform at Elephant Mountain. The preform was broken by "end shock." Lens cap for scale. Note the tabular nature of the material.

Fig. 14. Quartzite hammerstones from Elephant Mountain. Scale in cm. Note that the angular margins are heavily battered. These slightly rounded cobbles were carried to the quarry from elsewhere.

imal or no varnish. Removal of fresh slabs of raw material from an outcrop would produce this rock-varnish pattern (Fig. 15). It has been suggested that some types of freshly quarried stone are easier to work because they are somewhat less hard and less brittle (Holmes 1919;

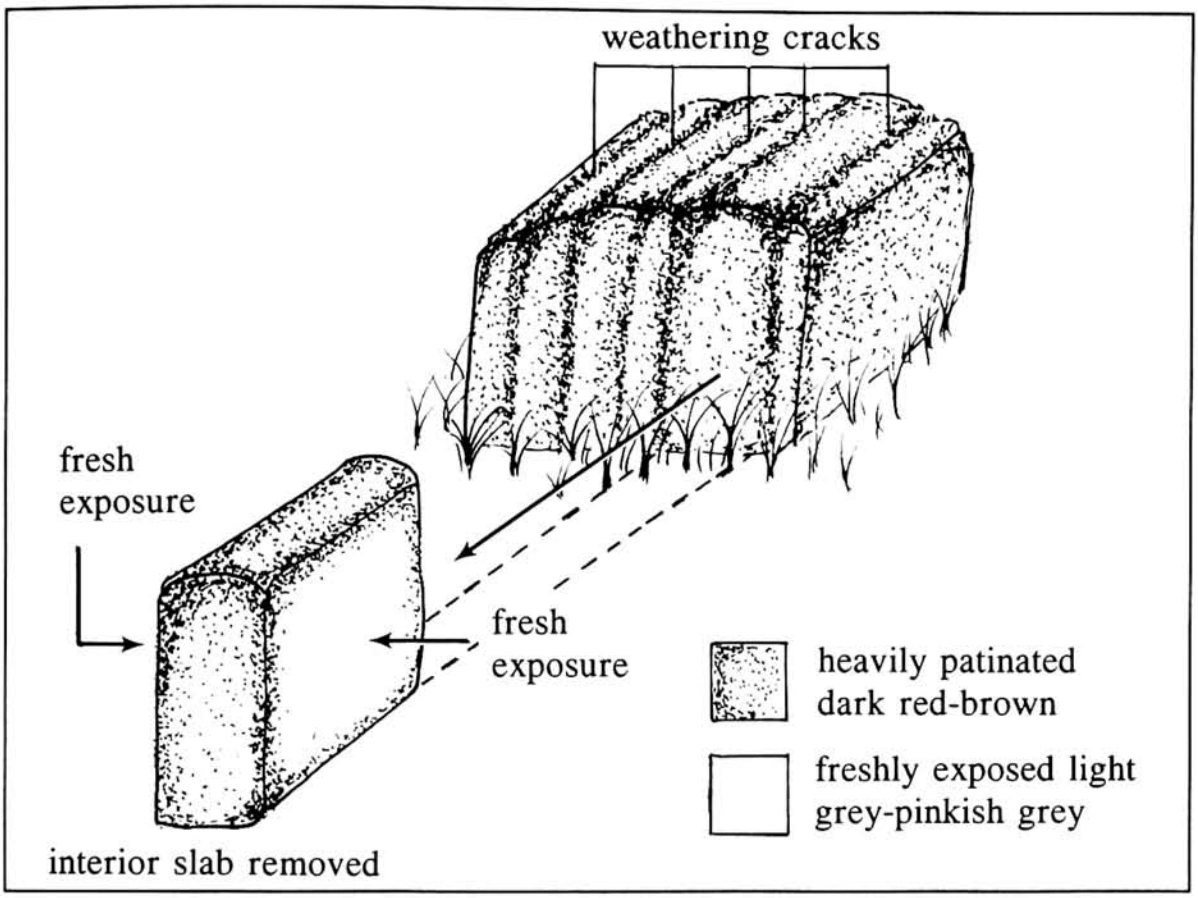

Fig. 15. Schematic representation of the quarrying technique used to remove tabular blocks of stone from the outcrop.

Binford and O'Connell 1984); this may have been an important factor to the aboriginal stone-workers at Elephant Mountain. Furthermore, if fresh slabs had not yet developed a rock-varnish coating, there would have been no need to remove the weathered, friable coating from a surface destined for milling; thus, using fresh slabs would have saved labor.

How the Milling Implements Were Produced

Studies at milling-implement quarries along the Lower Colorado and Lower Gila rivers and experimental replication of the production of milling tools (Huckell 1986; Schneider 1993a, 1993c, 1996) have led to the development of a generalized production model. First, a suitable block of stone was found or quarried from bedrock; second, the block of stone was tested for quality by removing a few percussion flakes with a hammerstone; third, a series of large percussion flakes was removed so that a rough approximation of the desired shape of the milling tool was achieved and unnecessary bulk and weight were reduced; fourth, a series of smaller flakes was removed by percussion in order to achieve a form close to the desired end product; and fifth, the preform was pecked to prepare the grinding surface and to finalize the form. In the case of the Lower Colorado-Lower Gila quarries (Fig. 1), the original block of stone was either a subangular natural boulder or a freshly quarried rectangular block. Certain

Table 3
COMPARISON OF 1,000 m.² SAMPLE TRACTS FROM THREE MILLING-IMPLEMENT QUARRIES

Tract Location	Production Loci	Pestle Preforms	Metate Preforms	Tested Blocks	Hammerstones	Hammerstone Flakes
Elephant Mountain	29	4	58	2	22	1
Antelope Hill (mean of 3 tracts)	38	72	38	26	15	33
Chip Hill I	41	81	41	14	59	179

COMPARATIVE DATA FROM OTHER MILLING-IMPLEMENT QUARRIES IN THE LOWER COLORADO RIVER REGION

Bullhead City Quarry (Huckell 1986) has 0.2 to 0.8 production loci per 1,000 m².
Polodori Quarry (Green 1990) has 0.35 production loci per 1,000 m².

characteristic milling tools are identified with Lower Colorado River region cultural groups: long cylindrical stone pestles (destined to be used in wooden mortars); relatively thick, subrectangular lower milling stones (metates) with flat milling surfaces and convex bases; and handstones (manos) long enough to extend almost the full width of the metate (Kelly MS:81; Heintzelman 1857; Forde 1931; Gifford 1931, 1933; Spier 1933; Drucker 1941; Castetter and Bell 1951; Stewart 1968; Bee 1983; Williams 1983). The morphology of these tools called for rather blocky raw material.

At Elephant Mountain, the tabular nature of the available raw material directly influenced the technological approach to production. This approach varied somewhat from the production sequence documented at other milling-implement quarries along the Lower Colorado and Lower Gila rivers, where more blocky raw material was used and greater quantities of debitage were produced. As a result, the configuration of most production loci at Elephant Mountain varies from that at other milling-implement quarry sites; classic circular or oval concentrations of debitage flakes are less frequent and the distribution of debitage is more diffuse.

Products of the Quarry. Tabular metates were the major product of the Elephant Mountain Quarry; pestles or long manos (elongated handstones)[1] were a secondary product (Table 3). Within the sample tract (Fig. 10), 58 broken or discarded metate preforms and only four pestle preforms (or fragments) were recorded, a ratio of about 14:1. The preponderance of metate preforms is substantiated by analysis of data from the earlier study (Smith 1980); of the 44 milling-implement production features recorded, 47 metate preforms and seven pestle preforms were found, a ratio of about 8:1.

Broken and discarded pestle preforms at Elephant Mountain are elliptical in cross section (Fig. 13; Table 2) and do not approach the cylindrical form of pestles produced at other milling-implement quarries (Schneider 1993a, 1993c, 1994, 1996), reflecting the nature of available raw material. Although thin in relation to width (mean thickness = 6.2 cm.; mean width = 13.5 cm.) as compared to the cylindrical pestle preforms of the Lower Colorado-Lower Gila river quarries (mean diameters = 12.0 cm. to 13.0 cm.), the Elephant Mountain pestle lengths (mean = 39.5 cm.) are slightly shorter than pestle preforms made at the Lower Colorado-Lower Gila quarries (mean lengths = 47.6 cm. to 51.7 cm.).

The metate preforms made at Elephant Mountain (Figs. 12, 16) have lengths and widths

Fig. 16. A tabular metate preform abandoned at Elephant Mountain. It was abandoned for unknown reasons before it was completed. Note the light color of the preform and the contrasting colors of other tabular blocks nearby.

(mean length = 55.6 cm.; mean width = 33.8 cm.) comparable to those made at milling-implement quarries along the Lower Colorado and Lower Gila rivers (mean lengths = 55.3 cm. to 58.2 cm.; mean widths = 30.6 cm. to 33.7 cm.), but they are relatively *thinner* (mean thickness = 12.8 cm.) when compared to Lower Colorado-Lower Gila river quarry specimens (mean thickness = 16.9 cm. to 19.4 cm.). Again, this is an expression of the tabular, rather than blocky, nature of the raw material.

The metate preforms at Elephant Mountain greatly vary in size (Table 2). For example, one large slab, abandoned during production, is 96.0 cm. long, 43.0 cm. wide, 16.0 cm. thick, and weighs 95.3 kg. (Fig. 17), while the smallest is 30.0 cm. long, 25.0 cm. wide, and 6.0 cm. thick, and weighs only 6.8 kg. The size and weight of the tools have important implications for their portability from the quarry to the place where they were used (discussed below).

In addition to the typical tabular metate preforms (see Fig. 16), a number of "Lower Colorado River" type metate preforms were observed at the quarry. This type has a flat, rectangular grinding surface and a thick, convex base (see Fig. 12) and appears to be associated with Mohave, Quechan, and Cocopa cultural groups, as well as with the Chemehuevi in relatively recent times (Kelly MS:81).

A possible mortar preform (Fig. 18), recovered during the original field project (Smith 1980), is a cube-like block of andesite that has been partially shaped by removing flakes along its margins. One surface of the block has been lightly pecked to initiate a central mortar depression. The artifact was abandoned at its initial stage, and is the only specimen of this type that has been observed at Elephant Mountain.

Tools Used in Quarrying and Production. Levers or pry bars of wood or antler may have been used for the separation of tabular pieces of bedrock; these materials would not ordinarily survive in surface contexts. Production tools present at Elephant Mountain include hammerstones of local andesite (often with angular or

Fig. 17. Extremely large block of stone that was abandoned during metate production. The photograph shows the preform-in-progress being weighed in the field. This specimen is 96 x 43 x 16 cm., and weighs approximately 210 lbs. (95 kg.).

Fig. 18. Mortar preform. Scale is 8 cm. Block has been roughly shaped by flaking the sides. The beginning of a pecked central depression is barely visible in the photograph.

chisel-shaped working edges) and subangular cobbles of quartzite and other metamorphic rocks brought to the quarry from elsewhere (Fig. 14). Most hammerstones could be held in one hand and are almost always found in association with debitage from reduction and shaping raw material (Figs. 8-10; Table 1). Large cobble hammerstones that required two-handed hefting, frequent at milling-implement quarries on the Lower Colorado and Lower Gila rivers (Schneider 1993a, 1996), were not observed at Elephant Mountain.

Production Techniques. The tabular nature of the raw material at Elephant Mountain made production of metates less labor-intensive here than at other milling-implement quarries. A relatively flat surface for milling was already provided by the tabular nature of the material. Edges were shaped by percussion flaking, facilitated by natural platforms along the margins. If thinning was necessary, the natural weaknesses along the flow lines of the andesite were exploited by the stoneworkers. Ease of working, however, was probably somewhat moderated by the relative brittleness of the andesite that caused unwanted fractures.

A model production sequence for Elephant Mountain (Fig. 19) was developed using information and observations from replication experiments[2] and the study of field and museum specimens. First, a slab was selected and tested for quality (Fig. 19, Stage 1). Large percussion flakes were removed from the margins and, in some cases, the underside. Removal of progressively smaller flakes completed the shaping (Fig. 19, Stage 2), creating accumulations of andesite debitage. The final production stage (Fig. 19, Stage 3) involved fine flaking and pecking to remove the natural cortex and rock varnish from the intended milling surface and to further refine the shape. A few field specimens exhibit characteristics indicating that milling surfaces were sometimes prepared by pecking before the margins were shaped.

Many of the broken and abandoned metate preforms are subrectangular, but others in late-stage production are oval, with one end narrower than the other (Fig. 20). Sometimes the tabular blank was positioned on an anvil stone to facilitate shaping (see Table 1). The most common breakage pattern in all stages of production is end-shock[3] (Figs. 9, 12, 20). Pestle (or elongated mano) preforms were shaped in much the same manner as the metate preforms. Elongated tabular slabs were flaked along the margins and probably pecked to finalize the shape; again, end-shock was the most common cause of breakage (Figs. 8 and 13).

Scale of Production at Elephant Mountain

The density of production loci (discrete concentrations of debitage) and discarded and broken preforms for milling implements was extrapolated from data presented in the original study of the site (Smith 1980) and from data gathered from the sample tract (Schneider 1993a). Forty-four loci relating to milling-implement production were identified within the 1980 study area, one locus per 1,014 m.^{2} Loci seem to have been widely and fairly evenly distributed, but frequency increased slightly toward the southern river-edge of the mesa.

The location of a sample tract on a southwestern ridge extending from the mesa toward the Mojave River (Fig. 3) was chosen so that it would not overlap any previously studied portion of the site and would avoid areas disturbed by previous construction and military activity. The center of the ridgetop is relatively flat, but slopes downward to the southwest. Twenty-nine discrete production loci were recorded within the 1,000 m.^{2} tract, one per 35 m.^{2} (Fig. 10). Furthermore, debitage and production debris were diffusely scattered over the entire surface of the tract. The reason for the discrepancy between the concentration of production loci in the two studies is uncertain, but any of a combination of several possibilities is suggested: production activity may have been more intense closer to the Mojave River; amounts of suitable raw material may have been greater on the southwest extension of the mesa; the area studied by Smith

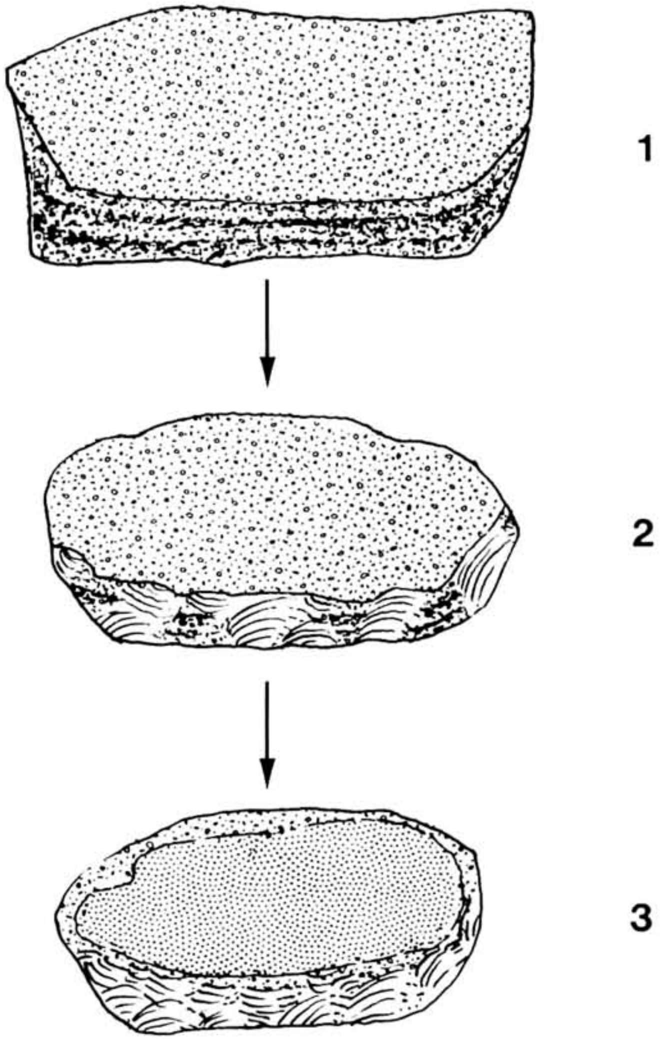

Fig. 19. Model production sequence for metates at Elephant Mountain. Stage 1: selection of tabular block covered with rock varnish; Stage 2: rough flaking of margins and underside to remove irregularities and to shape; Stage 3: further shaping by flaking and pecking of the flat surface intended for milling to remove rock varnish and/or cortex.

(1980) may have been disturbed to the extent that the archaeological record was compromised; or different methodological approaches may have produced different results.

A frequency comparison of loci, preforms, and production tools and tool debris between Elephant Mountain and several other milling-implement quarries (Table 3) shows a number of interesting trends. First, the number of production loci per 1,000 m.^{2} at Elephant Mountain is somewhat less than at other bedrock quarries (Antelope Hill [sandstone] and Chip Hill I [an-

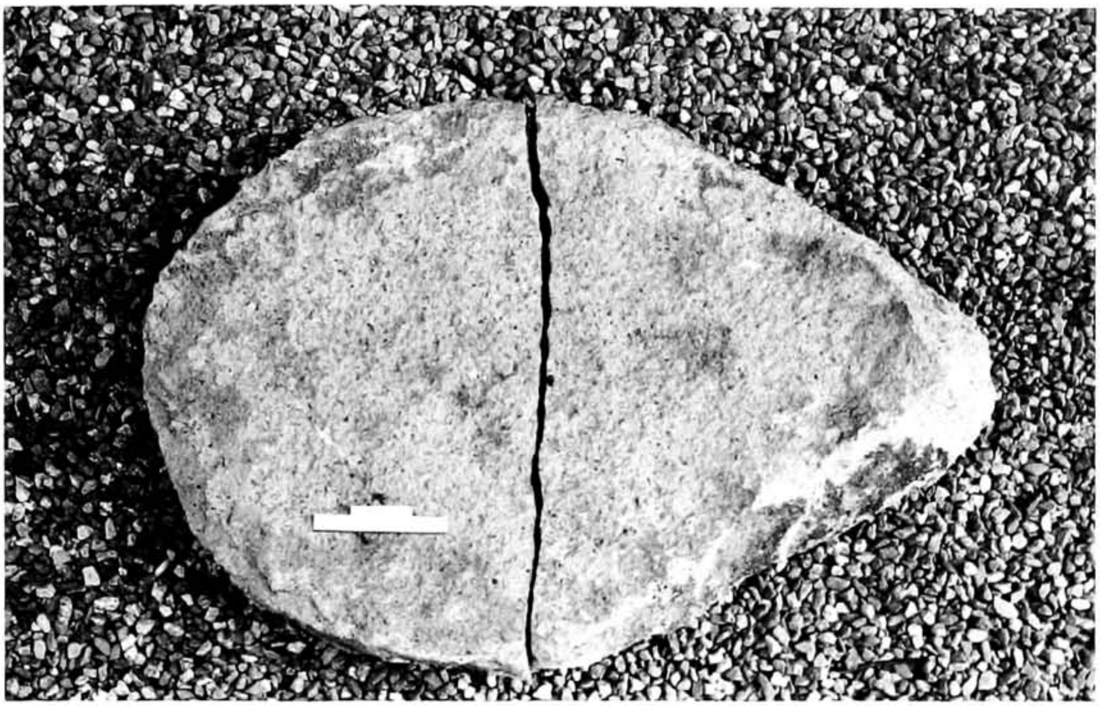

Fig. 20. "Pear-shaped" metate preform collected by Smith (1980). Scale is 8 cm. The metate preform is reassembled from two portions of the same preform that was "end-shocked" during manufacture.

desite]), but considerably greater than at isolated boulder quarries (Bullhead City [basalt] and Polodori [rhyolite]). The great differential between bedrock quarries and isolated boulder quarries is to be expected because of the distribution of raw material. Second, metate preforms were the major product of the Elephant Mountain Quarry, whereas pestle preforms were more important at both other bedrock quarries (Antelope Hill and Chip Hill I). Third, heavy labor, as represented by many hammerstone spalls and flakes at Antelope Hill and Chip Hill, is evidently much less at Elephant Mountain; the frequency of hammerstone flakes is much lower. This would support the scenario that the tabular raw material at Elephant Mountain did not require as much shaping as the more blocky material at the other quarries and that, at Elephant Mountain, often only minimal marginal flaking was required to produce a useable milling implement.

SOURCING MILLING IMPLEMENTS TO THE ELEPHANT MOUNTAIN QUARRY

A preliminary study was carried out to determine the feasibility of sourcing milling implements found at nearby archaeological campsites or processing sites to the outcrop at the Elephant Mountain Quarry. The California Archaeological Inventory records at the San Bernardino County Information Center were searched to determine the location of nearby archaeological sites along the Mojave River for which collections were available at the San Bernardino County Museum or elsewhere.

Selected collections were examined for milling implements or their fragments that appeared to be macroscopically similar to the Elephant Mountain stone, i.e., porphyritic andesite with a foliated appearance. The search was hampered by several factors: although they were reported at sites, milling implements were often not collected; very few sites in the region had been excavated or studied; and often complete milling implements that were collected had been heavily used, the worn surfaces masking the characteristics of the underlying stone (if no fresh fractures are apparent, it is difficult to macroscopically identify stone).

Nine metate fragments from two archaeological sites along the Mojave River met the criteria for macroscopic selection and were submitted for thin-section analysis and comparison with thin-section type samples from Elephant Mountain Quarry (Schneider 1993a:Appendix D): two fragments from CA-SBR-6605, located about 8 km. (5 mi.) downstream from Elephant Mountain and seven fragments selected from the Hinkley site (CA-SBR-189), located about 24 km. (15 mi.) upstream from Elephant Mountain (Fig. 1).

All seven specimens from the Hinkley site are indistinguishable from the Elephant Mountain type samples at the thin-section level of analysis and were probably quarried from that source (Fig. 21). The two specimens from CA-SBR-6605 are very similar to the Elephant Mountain material, but have a composition consistent with a more silica-rich material. The latter specimens were probably quarried from a different lava flow within the same volcanic complex (Schaller 1994). Table 4 presents the thin-section petrographic data from the Elephant Mountain type collection and from the nine artifact specimens.

Several cautionary statements about the sourcing of lithic materials are in order. This study was a test of feasibility. To date, no other sources of milling-implement stone in the Mojave River region have been identified, but they are likely to exist (e.g., the specimens from CA-SBR-6605 are from another nearby source). No sourcing studies can be considered complete in the absence of the identification and characterization of all possible stone sources in a region. In the Hohokam area, for example, initial statements about the sources of Hohokam grinding tools had to be reevaluated after other sources of stone were located (Bostwick and Burton 1993). It is important and hopeful to note, however, that the metate fragments from CA-SBR-6605, although from the same volcanic complex, could be distinguished from the Elephant Mountain Quarry stone at the thin-section level of analysis.

Ethnographic and historical accounts from the Lower Colorado-Lower Gila river region note that the Cocopa (Gifford 1933), Quechan (Cremony 1868; Forde 1931), Kamia (Gifford 1931), and Mohave (Stewart 1968) traveled or traded to secure special stone for milling implements. Utilizing thin-section comparisons, Schneider (1993a:Appendix E, 1996) was able to tentatively source a Kamia metate from Imperial County, California, and a Cocopa metate from a field site in Baja California to Antelope Hill (see Fig. 1), a milling-implement quarry on the Lower Gila River, a considerable distance from each of the sites.

With additional geological and archaeological work, the sourcing of stone milling implements has the potential to provide important data on regional economic networks and settlement patterns, similar to the type of information that has been gained by chemical characterization in obsidian sourcing. Although chemical characterization can also be carried out for andesites, basalts, and rhyolites, often the physical characteristics of stone (texture, size, and type of incorporated phenocrysts) were important in the selection of material for milling tools, information more readily available in thin-section data (Schneider 1993a:Appendix E).

DATING THE ELEPHANT MOUNTAIN QUARRY

Although Nuez (1819) did not say that he observed quarrying and production at Elephant Mountain, thin-section data from archaeological

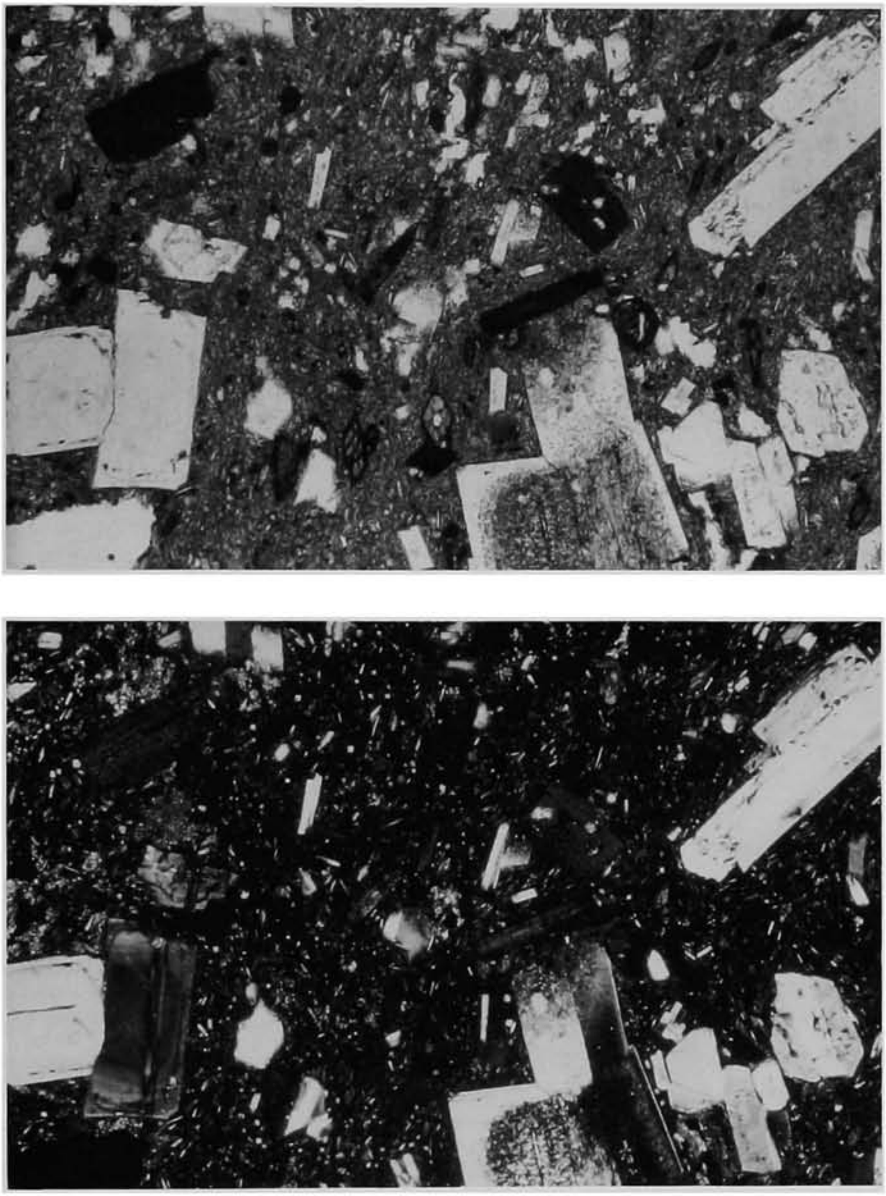

Fig. 21. Thin sections of Elephant Mountain andesite in plain-polarized (top) and cross-polarized (bottom) light. Length of the rectangular view is 2.65 mm. Photographed using a Nikon Optiphot microscope and a Nikon camera with HFX system at 200 ASA with a NCB 10 filter. See Table 4 for a description of the petrographic characteristics.

and type specimens demonstrate that milling implements were made at the quarry during aboriginal times. This activity probably continued from the Late Prehistoric Period into the early historical era (Nuez 1819; Lerch and Smith 1990), but it is uncertain how far back the activities extended.

Seven metate fragments recovered from the Hinkley site (CA-SBR-189), sourced by thin-section petrography to the Elephant Mountain

Table 4
PETROGRAPHIC DATA FROM THIN-SECTION ANALYSIS OF LITHIC MATERIALS FROM ELEPHANT MOUNTAIN AND SELECTED ARTIFACTS FROM NEARBY ARCHAEOLOGICAL SITES

Specimen	Rock Name	Rock Type	Texture(s)	Minerals	Volume %	Maximum Size (mm.)	Notes*	Groundmass or Matrix
quarry flake 176-6-1	porphyritic hornblende andesite	volcanic	porphyritic, vesicular	plagioclase	20-30	3.6	O.z.; euhedral	felty intersertal matrix of plagioclase and glass; secondary clay fills pore spaces
				oxyhornblende	5-10	1.8	pleochroic (pale yellow to dark red-brown)	
				Total Minerals	25-40			
quarry flake 176-6-2	"	"	"	plagioclase	20-30	3.9	"	"
				oxyhornblende	5-10	1.1		
				Total Minerals	25-40			
quarry flake 176-6-3	"	"	"	plagioclase	20-30	2.1	"	"
				oxyhornblende	5-10	1.3		
				Total Minerals	25-40			
metate fragment, SBCM-14-007, CA-SBR-189 (Hinkley site)	"	"	"	plagioclase	20-30	4.8	O.z.; euhedral	"
				oxyhornblende	5-10	2.3	pleochroic g/y-drb	
				biotite	2-5	1.5	euhedral-subhedral	
				augite	<1	0.3	subhedral; FeO rims	
				quartz	<1	0.7	anhedral; mantled by reaction rims	
				Total Minerals	28-45			
metate fragment SBCM-14-214 CA-SBR-189 (Hinkley site)	"	"	"	plagioclase	10-20	2.1	O.z.; euhedral	glassy matrix with microcrystalline plagioclase; secondary clay fills pore spaces
				oxyhornblende	5-10	1.3	pleochroic g/y-drb	
				biotite	<1	0.4	subhedral; oxidized	
				Total Minerals	15-30			
metate fragment SBCM-14-252 CA-SBR-189 (Hinkley site)	"	"	"	plagioclase	10-20	2.4	O.z.; euhedral	felty intersertal matrix of plagioclase and glass; secondary clay fills pore spaces
				oxyhornblende	5-10	1.1	pleochroic g/y-drb	
				biotite	1-2	1.3	subhedral; oxidized	
				Total Minerals	16-32			
metate fragment SBCM-14-255 CA-SBR-189 (Hinkley site)	"	"	"	plagioclase	20-30	2.8	O.z.; euhedral	" partly replaces groundmass
				oxyhornblende	5-10	1.3	pleochroic g/y-drb	
				biotite	<1	0.6	subhedral; oxidized	
				quartz	<1	0.7	anhedral-subhedral	
				Total Minerals	26-40			
metate fragment SBCM-14-261 CA-SBR-189 (Hinkley site)	"	"	"	plagioclase	20-30	1.8	O.z.; euhedral	"
				oxyhornblende	5-10	1.2	pleochroic g/y-drb	
				biotite	<1	1.0	subhedral; oxidized	
				quartz	<1	1.3	anhedral-subhedral	
				Total Minerals	26-40			
metate fragment SBCM-14-264 CA-SBR-189 (Hinkley site)	"	"	"	plagioclase	20-30	5.0	O.z.; euhedral	trachytic intersertal matrix of plagioclase and glass; secondary clay fills pore spaces
				oxyhornblende	5-10	1.8	pleochroic g/y-drb	
				biotite	2-5	1.6	subhedral; oxidized	
				quartz	<1	0.6	anhedral-subhedral	
				augite	<1	0.7	subhedral; FeO rims	
				Total Minerals	28-45			
metate fragment SBCM-14-x CA-SBR-189 (Hinkley site)	"	"	"	plagioclase	10-20	2.5	O.z.; euhedral	felty intersertal matrix of plagioclase and glass; secondary clay fills pore spaces and partly replaces groundmass
				oxyhornblende	5-10	1.4	pleochroic g/y-drb	
				biotite	2-5	1.6	subhedral; oxidized	
				quartz	<1	0.6	anhedal-subhedral	
				Total Minerals	17-35			

Table 4 (continued)
PETROGRAPHIC DATA FROM THIN-SECTION ANALYSIS OF LITHIC MATERIALS FROM ELEPHANT MOUNTAIN AND SELECTED ARTIFACTS FROM NEARBY ARCHAEOLOGICAL SITES

Specimen	Rock Name	Rock Type	Texture(s)	Minerals	Volume %	Maximum Size (mm.)	Notes[a]	Groundmass or Matrix
metate fragment CA-SBR-6605	porphyritic hornblende andesite-dacite	volcanic	porphyritic, vesicular	plagioclase + K-feldspar	20-30	2.5	O.z.; euhedral	felty intersertal matrix of plagioclase and glass; secondary clay fills pore spaces and partly replaces groundmass
				oxyhornblende	2-5	0.9	pleochroic g/y-drb	
				biotite	2-5	1.0	subhedral; oxidized	
				quartz	<1	2.3	anhedral-subhedral	
				Total Minerals	24-40			
metate fragment CA-SBR-6605	*	*	*	sanidine + plagioclase	20-30	3.3	O.z.; euhedral	glass; secondary clay partly fills pore spaces
				biotite	5-10	1.8	subhedral to euhedral; oxidized	
				quartz	2-5	1.7	anhedral-subhedral	
				Total Minerals	27-40			

[a] O.z. (oscillatory zoning) = variation in crystal composition (from core to margin) occurring in a wave-like configuration. This is usually due to interruptions in equilibrium during crystal growth. Pleochroic = showing more than one complexion of color; a crystal that differentially absorbs wavelengths of transmitted light in various crystallographic directions, especially seen under polarized light, thus showing different colors in different directions (e.g., g/y-drb = green/yellow to dark red-brown). Euhedral = a crystal bounded by its own crystal faces. Subhedral = a crystal bounded by some, but not all of its own crystal faces. Anhedral = a crystal exhibiting none of its own crystal faces. Intersertal = a texture of porphyritic igneous rock in which glassy or partly crystalline material (other than augite) fills the interstices between unoriented feldspar laths; the groundmass forms a relatively small proportion of the rock. Trachytic* = a texture, usually in porphyritic volcanic rocks, that has closely packed feldspar laths oriented in a subparallel arrangement corresponding to the flow lines of the lava flow.

Quarry (Schaller 1994; Table 4), may provide some general chronological parameters. At the Hinkley site, there is both a Gypsum Period component (ca. 3,000 B.P.), as determined by three radiocarbon dates and the artifact assemblage (Leonard 1980:33), and a Late Prehistoric Period component (personal observations of the authors). These collective data (and the 1819 historical account) suggest that use of the quarry could date from at least ca. 3,000 B.P. to the Late Prehistoric and Historic periods.

Although other prehistoric sites along the Mojave River have been dated as early as 3,500 B.P., there is considerable evidence that aboriginal activity in the general area may extend much further back in time (Davis and Smith 1981; Rector et al. 1983; see Warren 1984:395-403 for a review of the possibilities of earlier occupations in the Mojave River Valley). Rock-varnish studies and/or cosmogenic ^{3}He accumulations in rock may eventually hold the key to placing this quarry and others within a firm chronological context.

SUMMARY AND DISCUSSION

Evidence at the Elephant Mountain milling-implement quarry indicates that aboriginal people living along the Mojave River visited Elephant Mountain to acquire tabular andesite for production of metates and pestles. The quarry was easily accessible from the Mojave River and was in proximity to an area where there was permanent water and an abundance of plant foods. The pinkish andesite provided excellent grinding surfaces because it was hard, abrasive, did not crumble, and its roughness could be maintained with little effort. Elephant Mountain was a particularly good place to obtain stone because the weathering pattern of the rock on the mesa produced slabs of raw material that did not require a great deal of reduction or shaping. With some searching, a suitable slab could be found, tested for internal flaws, and trimmed to shape by removing flakes from the margins and underside. The milling surface itself was prepared by removing old cortex and rock varnish with careful pecking. Fresh slabs could be pried from weathering bedrock with some additional effort.

While pestles could also be shaped from the tabular material in much the same way, the naturally flat raw material surfaces compromised the desired cylindrical pestle shape. Cobble hammerstones of quartzite and metavolcanic material were evidently carried up the hill to the quarry area on occasion, but andesite cobbles available at the quarry were frequently used for the same purpose. Some of the lighter-weight slab metates may have been carried about as personal gear, but the larger metates were too heavy to transport easily, and were probably carried, with great effort, to resource processing or habitation sites where they were left for seasonal use (e.g., the Hinkley site).

The presence of a type of metate that has been associated with aboriginal groups living along the Lower Colorado River is particularly interesting. This type is much less frequent at Elephant Mountain than at the milling-implement quarries along the Lower Colorado and Lower Gila rivers (see Schneider 1993a); nevertheless, a tool type associated with Lower Colorado groups was manufactured on the Mojave River. This evidence might be used to support the hypothesis of the existence of a permanent settlement of Mohave peoples in the area (see above). However, Kelly (MS) noted that the Chemehuevi adopted many items of Mohave material culture, among them the "squared" metate. A Chemehuevi presence in the area, especially during the ethnohistoric period, has been well recognized. The petroglyphs present at Elephant Mountain are unremarkable and the motifs cannot be identified with any specific cultural group; thus, they do not lend any clarification to the issue of who may have used the quarry and when.

To date, the Elephant Mountain Quarry is the only milling-implement quarry in the Mojave River region that has been described. The bedrock outcrop on the mesa is a combination of stone with excellent grinding characteristics and a tabular weathering pattern that provides slabs that need a minimum of shaping in order to make useable milling tools. The authors believe, however, that the site may not be unique. It is likely that other porphyritic volcanic flows in the area were also quarried for stone for milling implements, but these locations have not yet been identified. One of the purposes of this paper is to provide archaeologists with information that may lead to the discovery of other such sites in the region. In the Lower Colorado-Lower Gila river region (Schneider 1994) and in the Hohokam region (e.g., Bostwick and Burton 1993), series of bedrock milling-implement quarry sites have been discovered, all sharing certain petrologic characteristics. Hopefully, further inventory projects, along with thin-section sourcing of milling tools thought to originate at Elephant Mountain and other quarries, will broaden our views of milling implement procurement, production, and transportation in the Mojave Desert, as well as adding to our understanding of prehistoric regional economic and social patterns.

NOTES

1. It has not been determined if the elongated forms were used as pestles or as manos or perhaps had a dual purpose. Pestles with elliptical cross sections are not unusual in the region; those formed of schist or other tabular raw materials often have the same characteristic.

2. Replication experiments were carried out with the considerable help of Philip Wilke and Leslie Quintero (see Schneider 1993a:Appendix A).

3. End-shock causes a transverse fracture, perpendicular to the long axis of a piece. It can occur at any stage of production. It is caused by the improper application of force near one end of the piece and/or insufficient support or stabilization when hit by a hammerstone. Elongated pieces are especially susceptible to end-shock.

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REFERENCES

Bean, Lowell John, and Charles R. Smith
1978 Serrano. In: Handbook of North American Indians, Vol. 8, California, Robert F. Heizer, ed., pp. 570-574. Washington: Smithsonian Institution.

Bee, Robert L.
1983 Quechan. In: Handbook of North American Indians, Vol. 10, Southwest, Alfonzo Ortiz, ed., pp. 86-98. Washington: Smithsonian Institution.

Benedict, Ruth F.
1924 A Brief Sketch of Serrano Culture. American Anthropologist 26(3):366-392.
1926 Serrano Tales. Journal of American Folk-Lore 39(151):1-17.

Binford, Lewis R., and James F. O'Connell
1984 An Alyawara Day: The Stone Quarry. Journal of Anthropological Research 40(1):406-432.

Bortugno, E. J., and T. E. Spittler
1986 San Bernardino Quadrangle 1:250,000. Sacramento: California Division of Mines and Geology.

Bostwick, Todd W., and James H. Burton
1993 A Study in Sourcing Hohokam Basalt Ground Stone Implements. Kiva 58(3): 357-372.

Castetter, Edward F., and William H. Bell
1951 Yuman Indian Agriculture. Albuquerque: University of New Mexico Press.

Coues, Elliot
1900 On the Trail of a Spanish Pioneer: The Diary and Itinerary of Francisco Garcés in His Travels Through Sonora, Arizona, and California 1775-1776. New York: Francis P. Harper.

Cremony, John C.
1868 Life Among the Apaches. San Francisco: A. Roman & Company.

Davis, C. Alan, and Gerald A. Smith
1981 Newberry Cave. Redlands: San Bernardino County Museum Association.

Drover, Christopher E.
1979 The Late Prehistoric Human Ecology of the Northern Mohave Sink, San Bernardino County, California. Ph.D. dissertation, University of California, Riverside.

Drucker, Philip
1937 Culture Element Distributions: V, Southern California. University of California Anthropological Records 1(1).
1941 Culture Element Distributions: XVII, Yuman-Piman. University of California Anthropological Records 6(3).

Forde, C. Darryl
1931 Ethnography of the Yuma Indians. University of California Publications in American Archaeology and Ethnology 28(4).

Gifford, Edward W.
1931 The Kamia of Imperial Valley. Bureau of American Ethnology Bulletin 97.
1933 The Cocopa. University of California Publications in American Archaeology and Ethnology 31(5).

Green, James P.
1990 Cultural Resources Evaluation of a Proposed Direct Sale of 40.09 Acres of Public Land. Report on file at the Bureau of Land Management, Havasu Resource Area, Yuma District, Arizona.

Heintzelman, Samuel P.
1857 Reports on the Numbers, Characteristics, Localities, etc., etc., of the Indians in the Department of the Pacific: Report of Bre-

vet Major S.P. Heintzelman, July 15, 1853. In: U.S. Congress, House of Representatives Document No. 76, 34th Congress, 3rd Session, Indian Affairs of the Pacific, pp. 34-58.

Hoffman, Theresa L., and David E. Doyel
1985 Ground Stone Tool Production in the New River Basin. In: Hohokam Settlement and Economic Systems in the Central New River Drainage, Arizona, Vol. 2, D. E. Doyel and M. D. Elson, eds., pp. 521-564. Phoenix: Soil Systems Publications in Archaeology No. 4.

Holmes, William Henry
1919 Handbook of Aboriginal American Antiquities. Part I: The Lithic Industries. Bureau of American Ethnology Bulletin 60.

Huckell, Bruce B.
1986 A Ground Stone Implement Quarry on the Lower Colorado River, Northwestern Arizona. Phoenix: Bureau of Land Management Cultural Resources Series Monograph No. 3.

Kelly, Isabel T.
MS Chemehuevi Field Notes: General Ethnological Information [1934]. Berkeley: University of California Archives Microfilm No. 138.1, Anthropology Document 17.

Kroeber, Alfred L.
1925 Handbook of the Indians of California. Bureau of American Ethnology Bulletin 78.

1959 Ethnographic Interpretations 7-11. University of California Publications in American Archaeology and Ethnology 47(2).

Leonard, Joanne C.
1980 A Final Report of the Surface Collection and Excavation of SBr-189. Report on file at the San Bernardino County Archaeological Information Center, San Bernardino County Museum, Redlands.

Lerch, Michael K.
1985 The Desert Mojave: A Review of Ethnohistoric Data and Archaeological Implications. Paper on file at the Department of Anthropology, University of California, Riverside.

Lerch, Michael K., and Gerald A. Smith
1990 A Metate Quarry at Elephant Mountain, Daggett Area, Mojave Desert, California. Paper presented at the annual meetings of the Society for California Archaeology, San Francisco.

Norris, R. W.
1854 Field Notes. U.S. Land Office Survey of Township 9 North, Range 1 West, San Bernardino Base Meridian. San Francisco: U.S. Surveyor General's Office, U.S. Department of the Interior. [Microfiche copy on file at the U.S. Department of the Interior, Bureau of Land Management, Desert District Office, Riverside.]

Nuez, Fr. Joaquin Pascual
1819 Diary of Fr. Joaquin Pasqual Nuez, Minister of San Gabriel and Chaplain of the Expedition Against the Mohave Indians, Begun by Lieutenant Gabriel Moraga, November 1819, G. W. Beattie, trans. In: Preliminary Report of the Archaeological Survey of the Deep Creek Site on the Upper Mojave River, by G. A. Smith. San Bernardino County Museum Quarterly 2(2):Appendix 3. [Original Spanish manuscript in Santa Barbara Archives, Tomo IV, pp. 137-149.]

Rector, Carol H., James D. Swenson, and Philip J. Wilke (eds.)
1983 Archaeological Studies at Oro Grande, Mojave Desert, California. Redlands: San Bernardino County Museum Association.

Rogers, Malcolm J.
1945 An Outline of Yuman Prehistory. Southwestern Journal of Anthropology 1(2):167-198.

Schaller, David M.
1991 Lithic Artifact Identification Records. Thin-section Analysis Type Collection curated at the Department of Anthropology, University of California, Riverside, Accession 176.

1994 Lithic Artifact Identification Records for Specimens from the Hinkley site and JDB site curated at the Department of Anthropology, University of California, Riverside, Accession 176.

Schneider, Joan S.
1989 The Archaeology of the Afton Canyon Site. San Bernardino County Museum Association Quarterly 36(1).

1993a Aboriginal Milling-Implement Quarries in Eastern California and Western Arizona: A Behavioral Perspective. Ph.D. dissertation, University of California, Riverside.

1993b Milling Implements: Biases and Problems in Their Use as Indicators of Behavior and Paleoenvironment. Pacific Coast Archaeological Society Quarterly 29(4):5-21.

1993c Antelope Hill: A Cultural Resources Inventory and Inquiry into Prehistoric Milling-Implement Quarrying and Production Behaviors Along the Lower Colorado River. In: Glyphs and Quarries of the Lower Colorado River Valley, J. A. Ezzo and Jeffrey H. Altschul, comps. Tucson: Statistical Research Technical Series 44.

1994 Milling-Implement Quarrying and Production Bordering the Lower Colorado and Lower Gila Rivers: Archaeological, Ethnographic, and Historical Evidence for an Aboriginal Industry. In: Recent Research Along the Lower Colorado River, J. A. Ezzo, ed., pp. 101-117. Tucson: Statistical Research Technical Series 51.

1996 Quarrying and Production of Milling Implements at Antelope Hill, Arizona. Journal of Field Archaeology 23(2) (in press).

Simpson, Ruth D.
1979 Cultural Resources Assessment, Daggett Community Services District Water System Improvement, North Reservoir and Well Systems. Report on file at the San Bernardino County Archaeological Information Center, San Bernardino County Museum, Redlands.

Smith, Gerald A.
1980 Archaeological Studies at the Daggett Hill Project. Mitigation for Construction of a Water Reservoir on the Southeast Portion of the Extension of Elephant Mountain. Report on file at the San Bernardino County Archaeological Information Center, San Bernardino County Museum, Redlands.

Spier, Leslie
1933 Yuman Tribes of the Gila River. Chicago: University of Chicago Press.

Stewart, Kenneth M.
1968 Culinary Practices of the Mohave Indians. El Palacio 79(4):2-12.

Strong, William Duncan
1929 Aboriginal Society in Southern California. University of California Publications in American Archaeology and Ethnology 26.

Sutton, Mark Q., and Robert M. Yohe II
1989 An Analysis of the Vertebrate Faunal Remains from the Afton Canyon Site (CA-SBR-85). In: The Archaeology of the Afton Canyon Site, by Joan S. Schneider, pp. 143-158. San Bernardino County Museum Association Quarterly 36(1).

Van Dyke, Dix
1927 A Modern Interpretation of the Garcés Route. Historical Society of Southern California 12:353-359.

Warren, Claude N.
1984 The Desert Region. In: California Archaeology, by Michael J. Moratto, pp. 339-430. Orlando: Academic Press.

Washington, H.
1857 Plat Maps, Township 9 North, Ranges 1 West and 1 East, San Bernardino Base Meridian. San Francisco: U.S. Surveyor General's Office, U.S. Department of the Interior. [Microfiche copies on file at the Tomas Rivera Library Map Room, University of California, Riverside.]

Washington, H., H. S. Washburn, and A. P. Greene
1855 Field Notes. Survey of Township 9 North, Range 1 East, San Bernardino Base Meridian. San Francisco: U.S. Surveyor General's Office, U.S. Department of the Interior. [Microfiche copy on file at the U.S. Department of the Interior, Bureau of Land Management, Desert District Office, Riverside.]

Williams, Anita Alvarez de
1983 Cocopa. In: Handbook of North American Indians, Vol. 10, Southwest, Alfonzo Ortiz, ed., pp. 99-112. Washington: Smithsonian Institution.