Rethinking the Chronology of Ray Cave (CA-INY-444) in the Coso Range, California

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Abstract:

The Ray Cave, excavated in 1967, is located in the Coso Mountains of southern Inyo County, California. The assemblage provided artifactual evidence for seasonal use over a span of approximately 4,000 years, up to and including the historic period. The site has been described as primarily a Newberry period (3,150–1,350 BP) site, with intermittent use in later times; however, chronological data contained significant inconsistencies and not all data sources were used in the original analysis. The assemblage from the site has now been reanalyzed and an integrated chronology constructed based on radiocarbon, obsidian hydration, stratigraphy, and point and bead typologies. The results are now more consistent, and suggest earliest use prior to 6,000 BP, major use in the Little Lake and Newberry periods, and lesser but still significant use in the Haiwee, Marana, and Historic periods.

Introduction

The Ray Cave site (CA-INY-444) is a small rock shelter located in the Coso Mountains of southern Inyo County, California (Fig. 1). The site was excavated in 1967, and the assemblage contained artifactual evidence which was interpreted as indicating use over a span of 4,000 years, up to and including the historic period; there was no midden or other evidence of intensive occupation, so use was probably never more than seasonal (Panlaqui 1974). The site has been described as primarily a Newberry period site, with intermittent use in later times.

The chronological data reported by Panlaqui contained inconsistencies, which she pointed out in her analysis. In particular, obsidian hydration data did not match with radiocarbon or point typologies (Gilreath 2000; Hillebrand 1972; Panlaqui 1974). Furthermore, since the original work predated Bennyhoff and Hughes (1987), bead typologies were not analyzed. This paper reanalyzes the chronological data and constructs a consistent chronology, based on recent methodological advances not available to Panlaqui in 1974.

Environmental Context

The Ray Cave is situated on the south edge of Wild Horse Mesa in the Coso Mountains of eastern California. The Coso area lies on the eastern side of the Sierra Nevada south of Owens Lake, and extends east to the Argus Range, south to the Indian Wells Valley, and north to the Darwin plateau. The Coso Range is a relatively young formation, primarily volcanic, and tectonic activity continues today (Norris and Webb 1990). The area contains hot springs and fumaroles, as well as numerous obsidian sources and extensive basalt fields. The highest point is Coso Peak, at 2,488 meters (8,160 feet); Wild Horse Mesa is at approximately 1,524 m (5,000 feet); and Ray Cave is at 1,494 meters (4,900 feet).

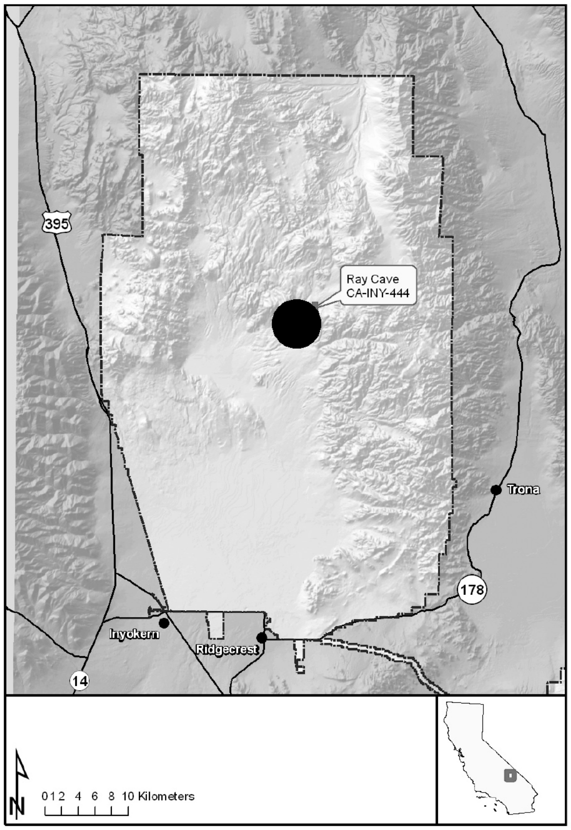

Fig. 1. Region of Ray Cave

The immediate surroundings of Ray Cave is a high plateau with a Creosote Scrub plant community, dominated by creosote brush (*Larrea tridentata*), saltbush (*Atriplex* sp.), rabbitbush (*Chrysothamnus* sp.) and grasses. At higher elevations to the north, the plant communities blend into Joshua Tree Woodland and finally Pinyon-Juniper Woodland on Coso Peak.

Present-day fauna are primarily desert species, including coyote (*Canis latrans*), fox (*Vulpes macrotis*), hare (*Lepus californicus*), rabbit (*Sylvilagus audoboni*), bobcat (*Lynx rufus*), and a variety of rodents. Large mammal species currently include bighorn sheep (*Ovis canadensis*), deer (*Odocoileus hemionus*.), mountain lion (*Felis concolor*), and the occasional bear (*Ursus Americanus*); pronghorn (*Antilocapra americana*) were once plentiful in the Indian Wells Valley (Steward 1938:81ff.).

The Cosos are desert mountains, lying in the rain shadow of the Sierra Nevada. Moisture at the higher elevations is sufficient for pinyon-juniper forest, and the peaks receive snow most winters; generally, however, the area is dry, with hot summers and cold winters. Annual mean temperature at Junction Ranch, at an altitude of 1725 meters (5658 feet), is 11.0°C (51.8 °F), with a peak summer temperature of 33.8°C (92.8°F) and a minimum winter temperature of -8.3°C (17.1°F) (Navy 2005).

Climate in the area has varied over time. Antevs (1955) postulated three long-term climatic phases since the Pleistocene, a period of generally lower temperatures from 12,000 to 8,000 BP (the Anathermal), a period of elevated temperatures from 8,000 to 4,000 BP (the Altithermal), and a period of essentially modern temperatures since then (the Medithermal). Superimposed on these trends were higher-frequency fluctuations. Mehringer and Sheppard (1978) performed lake-core sampling at Little Lake, California, and concluded that available water increased about 3,000 BP, with subsequent xeric episodes at about 2,000, 1,250, and 250 BP. Stine (1990, 1994) reconstructed climates along the Eastern Sierra Front from lake level data at Mono Lake, and found alternating wet and dry periods. Sutton (1991) found wave-cut terraces in evidence of long-lived high stands at Koehn Lake, south of the Coso region, at 970 and 1,430 RCYBP, which correlate with two of the high stands of Mono Lake determined by Stine (1990). Other data from lake core samples, packrat middens, and plant community distribution (Jones et al. 2004) and tree rings (Graumilch 1993) give similar indications. All these sources suggest that there were times in the past when the Coso area was more hospitable than it appears today.

Ethnographic Background

The present-day Coso district was inhabited in ethnographic times by the Koso (or Panamint) Shoshone (Steward 1938:81). Steward (1938:71) further asserted that the Shoshone

> ... occupied the northern halves of Death Valley and Panamint Valley, all of Saline Valley, the southern end of Eureka Valley, the southern shore of Owens Lake, the Koso Mountain region, the northern edge of the Mojave Desert, and the eastern slope of the Sierra Nevada Mountains.

He described the Coso region as a subsistence region of approximately 1,000 square miles, centered on the Koso (Coso) Mountains, and including four principal villages: Pagunda at Little Lake; Muata at Coso Hot Springs; Uyuwumba at Cold Spring (present-day Cole Spring); and Pakwasi at Olancha, near Owens Lake.

The Owens Valley Paiute occupied the length of Owens Valley in the southwestern Great Basin. Speaking of their boundary with the Shoshone to the south, Kroeber reported that the southern boundary of Owens Lake was occupied by the Owens Valley Paiute (Kroeber 1925:586), although Steward assigned the area to the Panamint Shoshone (Steward 1933:236). Steward subsequently modified his view (1938). He showed the boundary between Owens Valley Paiute and Panamint Shoshone as skirting the southern and southeastern shores of Owens Lake, with the clear implication that the lacustrine hinterland was Shoshonean (Steward 1938:58-59, Fig. 7). This probably should not be understood as a hard-and-fast boundary line, however, because relationships between Owens Valley Paiute and Panamint Shoshone were generally good (unlike relationships with the Washoe to the north [Steward 1933:235]), and intermarriage did occur (Steward 1933:236). The boundary was probably an indefinite one, mostly defined by customary use, with the presence of individuals of both ethnic backgrounds on either side.

The area south of the Panamint Shoshone territory was occupied by another Numic group, the Kawaiisu (Earle 2005; Underwood 2006). Steward described the inhabitants of the southern end of Panamint Valley, the Argus range, and the Trona area as being Kawaiisu (Steward 1938:71); he was silent about the occupants of the northern end of the Indian Wells Valley, although his Figure 1 suggests it was Kawaiisu territory as well (see also Underwood 2006).

Within the Coso area, the Panamint Shoshone pursued a hunter-gatherer lifeway (Fowler 1986. Steward (1938) describes the seasonal round as involving winter residence in pit house villages, living on stored foods. In early spring families would move to higher areas, to harvest early-ripening seeds and greens. Rabbits were hunted near Cole Spring, and antelope were hunted in the Indian Wells Valley, as well as near Owens Lake and in Saline Valley. Mesquite beans were gathered in mid-summer, and seeds were harvested in upland areas. In September and October families moved to the pinyon zone to harvest pinyon nuts, and as the weather grew colder, they returned to winter village sites (Steward 1938:81 ff.).

Subsistence focused on plant foods, of which seeds, greens, and pinion nuts have been mentioned, and including acorns from the Sierra Nevada (Steward 1938). Animal foods were consumed as well. Steward's informants (1938) mentioned antelope, rabbit, bighorn sheep, snakes, fish, mountain lions and wildcats, lizards, frogs, and birds, as well as insects (Steward 1938:83).

Occupation prior to ethnographic times involves the related issues of the Numic homeland and the

Numic expansion. Lamb (1958) suggested that peoples speaking Northern Uto-Aztecan languages occupied the northern Mojave Desert prior to 3,000 years ago, with the languages subsequently diverging into the current language suite (Lamb 1958; Sutton 1994). The classic "Numic Spread" model (Bettinger and Baumhoff 1982, Lamb 1958, Sutton 1994, Sutton and Rhode 1994) then postulates that the Numa expanded to the north and east from this homeland about 1,000 years ago (Lamb 1958; Sutton 1986, 1987). Based on this model, the inhabitants of the Coso region would be descendents of these original Northern Uto-Aztecan speakers, with continuity for more than 3,000 years.

Alternative models of the Numic expansion have been proposed, which Rhode and Madsen (1994) have grouped into the category of "Basinist" models (e.g. Aikens 1994; Holmer 1994). These models have the common theme that an expansion is suggested, but originating from somewhere in the central Great Basin rather than from the southwestern Great Basin. More recently, Delacorte (1994) and Gold (2005) have suggested a Numic arrival in the southwestern Great Basin about 1500 BP. The models all hold in common that the current occupants of the Coso area have been in place for some 1,000–1,500 years; for periods earlier than that there is no agreement.

Prior Research

Ray Cave

The site was discovered in 1966 by a hunter and was excavated in 1967 by a volunteer field crew under the direction of George Kritzman and J. F. Fitzwater. Dr. Charles Rozaire of the Southwest Museum arranged the permit. The cave was reported to be 3.7 m (12 feet) deep, 5.2 m (17 feet) wide, with 1.2 m (4 feet) inside clearance, and was filled with aeolian sand and roof-fall debris over bedrock (Panlaqui 1974:12). It was excavated in a series of six units, 4 feet × 4 feet, in arbitrary 6 inch levels. Screening was by 1⁄4 inch screens. Artifacts were bagged and labeled, and field notes were kept. Lithic debitage was weighed and counted and left on site, except those flakes which appeared to have been utilized or modified (Panlaqui 1974:28). Thirty-eight metates were measured and left at the site (Panlaqui 1974:24). Extensive basketry was found on the surface of the cave (Fig 2).

Following analysis at UCLA (University of California Los Angeles), the excavated materials and associated field notes were curated at the Maturango Museum in Ridgecrest, California, under Los Angeles County Museum number A6431.67; the Maturango Museum accession number is 67.27. In July 2006 the collection was transferred to the new Navy curation facility at China Lake. The site has also been designated UCLA Iny-349 with state trinomial of CA-INY-444. The excavation was documented by Hillebrand (1972) and Panlaqui (1974).

The artifact assemblage from the site includes projectile points, modified and utilized flakes, beads, basketry, cordage, worked wood, and ground stone; historic items including cloth, rope, and tin cans were found on the surface at the site. The artifact assemblage spans approximately 4,000 years and is discussed further below.

The faunal assemblage (NISP = 839) consists mainly of rodent and lagomorph specimens (69% and 30%, respectively), with small numbers of mountain sheep (*Ovis canadensis*, NISP = 5), kit fox (*Vulpes macroti*, NISP = 6), various lizards (NISP = 4), great horned owl (Bubo virginianus, NISP = 1), and desert tortoise (*Gopherus agassizi*, NISP = 1). The faunal collection was assessed as recent, based on fossilization and condition of the bones (Panlaqui 1974:47). All species represented

Fig. 2. View of Ray Cave, showing surface artifacts (from Panlaqui 1974).

are found in the area today except marmot (*Marmota flaviventris*, NISP = 2).

The single burial was without burial goods and was assessed as "intrusive from the upper levels of the cave" (Panlaqui 1974:47). Artifacts found near the burial appeared to be random items in the burial soil rather than burial goods (Panlaqui 1974:47).

Panlaqui interpreted the site as a temporary campsite, first occupied prior to 2,000 BC (4000 BP) and with a main use period 1,500 BC–AD 1,500 (3,500–500 BP), after which use declined in later periods. The historic materials on the surface within the cave were interpreted to indicate historic period use. Her early chronological horizon was based on a radiocarbon date of a charcoal lump from 42–48 inch depth, dated at 3,390±50 RCYBP (Teledyne Isotopes I-3619). The major use period was determined by a second radiocarbon sample, a charcoal lens from a depth of 32 inches, with a date of 1,500±95 RCYBP (Teledyne Isotopes I-3619). The bulk (14/32) of the projectile points recovered were Elko, assessed as being used between 1,000 BC and AD 500 (3,000 BP and 1,500 BP) (Panlaqui 1974:34, 39–40). Rose Spring and Desert Side-Notched points were poorly represented (N=1 each; Panlaqui 1974:34). However, both Panlaqui (1974) and Hillebrand (1972) observed that obsidian hydration data from the site (rims from two flakes of 3.0 and 3.3 μ) were considerably younger than the radiocarbon or typology results.

In 1999 the Ray Cave collection was readdressed as part of a Native American Graves Protection and Repatriation Act (NAGPRA) analysis conducted by Far Western Anthropological Research Group in support of the Naval Air Weapons Station, China Lake (Gilreath 2000). This analysis examined the collections from six sites on the China Lake base, including Ray Cave, which, however, was only a small part of the overall study. The conclusions of the study were similar to those of Panlaqui (1974). Gilreath concluded the site was primarily used in the Gypsum/Newberry Period, 4,000–1,350 BP. She further suggested the site was used as a cache in protohistoric and early historic times, but there was no indication of use for habitation (Gilreath 2000). Again, the obsidian hydration data were recognized as anomalous. The analysis was based on the catalog and on published data of Hillebrand (1972) and Panlaqui (1974), but the collection was not physically inventoried nor were new obsidian or radiocarbon measurements made.

Regional Sites

Research has been conducted at various sites in the region surrounding Ray Cave. Sites on what are now Navy lands include the Chapman Caves (CA-INY-1534A,B), the Upper Renegade Canyon sites (State Primary No. 14-5488), Grant's Tomb (CA-INY-2847), Junction Ranch (CA-INY-1535), Haiwee Spring, and the site complex on the Coso Military Targets Range. In addition, the Stahl Site (CA-INY-182) is located on private land near Little Lake, Coso Junction Ranch (CA-INY-2284) is on private land east of Coso Junction, and Rose Spring (CA-INY-372) is located on BLM land.

The Chapman Caves (CA-INY-1534A,B) are two rock shelters in Upper Renegade Canyon which were excavated and reported by Hillebrand (1972). Analysis of materials recovered from Chapman 1 indicates use primarily in the Haiwee and Marana periods, continuing into the historic period. Chapman 2, on the other hand, was utilized primarily in the Haiwee Period, with little evidence of continuity into the historic era (Gilreath 2000; Hillebrand 1972). The Upper Renegade Sites (State Primary No. 14-5488) consist of an open-air midden locus and a rock shelter. They were mentioned by Grant, Baird, and Pringle (1968) as Inyo-8F, and were excavated by Phil Wilke of the University of California, Riverside, around 1980. The open-air midden locus was found to contain deposits spanning the Newberry and Haiwee Periods, while the rock shelter dated only to the Haiwee Period, with possible limited use in the Marana Period (Gilreath 2000).

Grant's Tomb (CA-INY-2847), near Darwin Wash, was excavated in 1989 by William Clewlow Jr. and reported in 1995 (Clewlow, Wallmann, and Clewlow 1995). The deposits were found to span nearly 4,000 years, from the Newberry Period through the Marana Period; historic period deposits were sparse (Clewlow, Wallmann, and Clewlow 1995; Gilreath 2000). Coso Junction Ranch (CA-INY-2284) was excavated by Mark Allen prior to 1986 and was found to be primarily of Haiwee age (Allen 1986). Further investigations by David Whitley in 1987 found similar results (Whitley et al. 1988; Yohe 1992). Haiwee Spring, an extensive site north of Coso Hot Springs, has been identified but not excavated as yet. Similarly, Native American use of Coso Hot Springs is well attested (Iroquois 1979), but the site has not been excavated. Gilreath and Hildebrandt (1997) performed an exhaustive study of obsidian use at the Coco Volcanic Field.

The Coso Military Targets Range, located around Coso Peak, has been surveyed by Far Western Anthropological Research Group, and a complex of fourteen sites has been identified and test excavated. The sites span the period from the Paleoindian Period to the historic and show significant use in the Little Lake and Newberry periods (Hildebrandt and Ruby 2002).

The Stahl Site (CA-INY-182) is located north of Little Lake and was excavated in 1949–1951 by Mark Raymond Harrington. He assessed the site as a Pinto site, based on similarity of lithics with the classic Pinto Basin site (Campbell and Campbell 1935; Harrington 1957). Further work was done at the Stahl Site by Adella Schroth (1994) and by Jim Pearson (1995). The Rose Spring Site (CA-INY-372), north of Little Lake, was excavated in 1951 by Harry Riddell and again in 1957 by Francis Riddell and reported by Lanning in 1963 (Lanning 1963; Yohe 1992). It was further studied by Robert Yohe in his classic work determining the time of introduction of the bow and arrow (Yohe 1992, 1998).

Finally, the Coso region contains some of the most impressive rock art areas in the world, and has been the subject of extensive rock art research since Heizer and Baumhoff (1962). Grant, Baird, and Pringle (1968) mapped rock art areas in the 1960's and created the first taxonomy of Coso rock art, and research is continuing (e.g. Garfinkel 2003; Gilreath, 1999; Monteleone and Woody 1999; Pearson 1995; Rogers and Rogers 2004; Whitley 1998).

Ray Cave Artifact Analysis

The assemblage from the site falls into three categories: an artifact collection, a faunal collection, and a human burial. This paper reports the reanalysis of the artifact assemblage and constructs an integrated chronology based on radiocarbon, obsidian hydration, stratigraphy, and point and bead typologies. The faunal assemblage was not re-examined, nor was the burial. Since the objective was chronological, the analysis focused on temporally-sensitive artifacts; ground stone artifacts, some of which were curated, were not examined. Radiocarbon data were re-examined and calibrated, projectile points and beads were analyzed (including measurement of obsidian hydration rims), and all were compared with the stratigraphic data from the field notes.

Radiocarbon

Two samples were submitted for radiocarbon measurements as part of the original 1967 investigation; their lab reports are listed as Teledyne Isotopes I-3619. The samples were from differing depths, but the horizontal position of the samples is not reported either in Panlaqui (1974) or in the field notes. One sample was charcoal from an ash lens located at a depth of 32 inches, whose age was reported as 1,500±95 years. No calibration is described, so this is presumed to be in radiocarbon years before the present (RCYBP). Using Calib 501 and Intercal 104.14c, this calibrates to 1,193–1,196 and 1,262–1,613 BP, 2-sigma (Panlaqui 1974:8). The second sample was a lump of charcoal from the 42–48 inch level; its age was reported as 3,390 ± 50 RCYBP, or, when calibrated, 3,480–3,544, 3,547–3,728, 3,748–3,765, and 3,792–3,823 BP, 2-sigma (Panlaqui 1974:8). The first sample falls within the Newberry Period (3,150–1,350 BP), while the second is Little Lake Period (6,000–3,150 BP).

Two caveats should be made on the radiocarbon data. First is the possibility of an "old wood" problem. Schiffer (1987) reported wood in excess of 1,000 years old in the Sonoran desert and the Grand Canyon, while Sutton and Yohe (1987) reported similar results in eastern California. Schiffer (1987) suggested on this basis that organic matter from small annual plants was a more reliable source for radiocarbon dating than trees. The type of wood used as samples from Ray Cave was not noted, so the possibility exists that the wood was a long-lived species or was deadfall. Second, and mitigating the first point to some degree, is the fact that the sequence of radiocarbon ages is consistent with the stratigraphy, in that the older sample was at a deeper level.

Projectile Point Typology

Analysis of projectile points was performed following the basic methodological approach of Thomas (1981) and Thomas and Bettinger (1976: 280ff.), with refinements on point identification based on Basgall and Giambastiani (1995), Yohe (1992), and Gilreath and Hildebrandt (1997). Further refinements in Humboldt typology were made based on Garfinkel and Yohe (2004). The method was applied in a qualitative sense, generally without quantitative measurements. Analysis focused on items which were either obviously projectile points, or which could be reasonably construed as fragments of points. A generally conservative strategy was followed, in that items which could not be classified with reasonable certainty were designated as "unid."

Projectile points may be assigned to periods based on the work of Bettinger (1976, cited in Moratto 1984), Basgall and Giambastiani (1995) and Gilreath and Hildebrandt (1997). The assignment of Desert Side-Notched and Cottonwood Triangular to the Marana Period, Rose Spring points to the Haiwee period, and Elko points to the Newberry and Little Lake Periods is relatively uncontroversial (sources above). Jennings (1986:117 Fig 3) shows the Humboldt point as essentially synchronous with the Elko, although with a slightly earlier initiation and slightly later termination. Recently Garfinkel and Yohe (2004) reanalyzed Humboldt points from the western and southwestern Great Basin and proposed that the Humboldt Concave Base and the Humboldt Basal-notched Wide (basal width > ≈24 millimeters) correspond roughly with the Jennings time scale, but the Humboldt Basal-notched Narrow (basal width < ≈24 millimeters) are older, Lake Mojave or early Little Lake period. Gilreath and Hildebrandt (1997) found that leaf-shaped dart points are largely Little Lake period and older. (Gilreath and Hildebrandt 1997:73 Table 16).

Table 1 integrates these perspectives for the present collection into a single point type chronology based on Bettinger and Taylor (1974) and Gilreath (2000), and is the basis of this analysis, recognizing that some of the Humboldt period assignments are not exact (Garfinkel and Yohe 2004:110,111). Point types not present in the collection are omitted.

The Ray Cave collection was reported by Panlaqui (1974) to include 32 projectile points. A review of the manuscript catalog showed 32 points, although the typological distribution was slightly different (Table 2). When the collection was physically inventoried and analyzed, a total of 35 points was discovered, with yet a third distribution (Table 2). For the analysis below the physical inventory data were used.

Table 1. Projectile Point Chronological Markers

Period Designation	Ray Cave Point Types
Marana (650–200 BP)	Desert Side-notched, Cottonwood triangular
Haiwee (1,350 – 650 BP)	Rose Spring
Newberry/Little Lake (6,000 –3,150 and 3,150–1,350 BP)	Elko, Humboldt Basal-notched, Wide
Lake Mojave (8,000–6,000 BP)	Leaf

Table 2. Ray Cave Projectile Points.

Type	Panlaqui 1974	Catalog Review	Inventory
Desert Side-notched	1	1	3
Rose Spring	1	2	1
Elko (all types)	14	8	10
Humboldt Basal-notched, Wide	4	5	6
Leaf	0	1	1
Unidentified	12	16	14
Total	32	32	35

If the point data in Table 2 are assigned to temporal periods as in Table 1, the resulting frequencies are as portrayed in Fig. 3. Clearly the dominant period of use is again the Newberry/Little Lake Period, with very little use in subsequent times. However, the figure as shown is deceptive, because the Newberry/Little Lake Period was much longer than the Haiwee or Marana Periods. If the frequencies are normalized by dividing each frequency by the relative length of the period, Fig. 4 results, which gives a somewhat different picture. Significant use in the Marana Period is now suggested, as well as use in the Newberry/Little Lake Period, with the

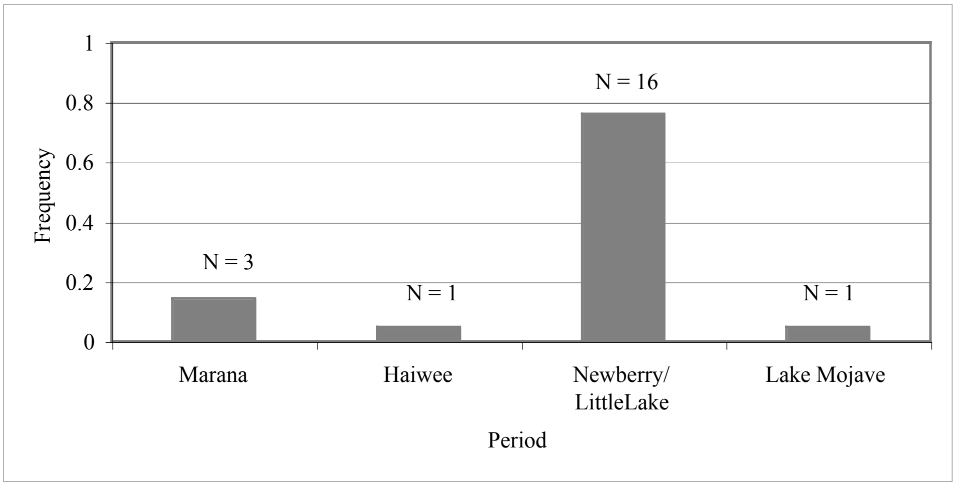

Fig. 3. Projectile point frequency at Ray Cave, by period.

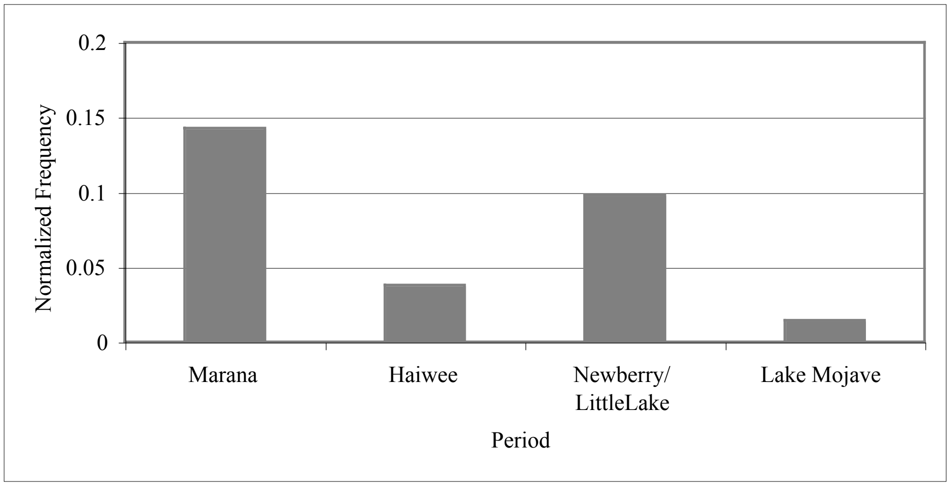

Fig. 4. Projectile point frequency at Ray Cave, normalized by period duration.

caveat that the sample size is small, so the results are indicative but not definitive by themselves.

The stratigraphic location of the projectile points was generally noted in the field notes and reported by Panlaqui (1974:34). Of the three Desert Side-notched points, two were recovered at depths less than 12 inches (the third was unprovenienced). The single Rose Spring point was recovered from the 12–18 inch level. Out of 10 Elko points, seven were recovered from the 12–18 inch level or deeper, with the remaining three shallower. Five out of six of the Humboldt Basal-notched points were at 18–24 inch or deeper. The single leaf-shaped point was recovered in the 0–6 inch level.

From this description it can be seen that the stratigraphic sequence correlates reasonably well with the expected ages of the point types. Some site bioturbation has clearly taken place, and, in particular, the leaf-shaped point is out of place. As expected, the dart point types have suffered greater displacement than the later arrow point types, having been exposed to site formation processes longer.

Bead Analysis

The Ray Cave collection contains 11 beads: six *Olivella* sp., four *Haliotis* sp., and one bone, which also provide chronological indicators. Bennyhoff and Hughes (1987) defined a comparative taxonomy of *Olivella* sp. beads and argued that beads could be used as indicators of trade routes. They further found that certain bead types were manufactured during specific periods and, hence, were effective temporal indicators. More recently, Milliken (1999) has extended the database of Bennyhoff and Hughes to include recent data from sites in the Owens Valley. Milliken also extended the taxonomy to include beads of *Haliotis* sp., bone, and stone (Milliken 1999). Analysis of the Ray Cave beads was performed following the classification taxonomy of Bennyhoff and Hughes (1987), augmented by Milliken's *Haliotis* sp. and bone taxonomy, and with chronological assignments based on Milliken (1999).

The *Haliotis* sp. beads were interpreted to be Milliken's disk beads, type H3a3, dated to 2,600–1,600 BP in the Owens Valley (Milliken 1999:98). All were recovered from depths greater than 30 inches. Five of the six *Olivella* sp. beads were classified as saddles (type F3a), dated to 1,500–1,300 BP (Milliken 1999:91); all were from depths less than 30 inches. The single bone bead was classified as a nocked tube, with a probable age between 1,500 and 1,300 years; it too was from a depth less than 30 inches. The remaining *Olivella* sp. bead was a punched bead, type D1, with an age between 1,250 and 750 years, and unfortunately was not provenienced. The estimated ages of the beads correlates with the stratigraphy, and suggests use in the Newberry Period with possibly some Haiwee Period use.

Obsidian Hydration Data

Obsidian hydration measurements were made on a number of artifacts from Ray Cave over a period of years. Hillebrand measured hydration rims on two flakes in 1969, acc. no. 126 and 127 (Hillebrand 1972). In 1978 Garfinkel made measurements on four Humboldt basal-notched points, acc. nos. 84, 87, 93, and 424 (A. Garfinkel, field notes); these measurements were repeated in 2003 by Yohe and Garfinkel (Garfinkel and Yohe 2004). At an unknown time three Elko points (acc. nos. 83, 94, and 315) were measured, along with one large triangular point of unknown type (acc. no. 151), although the data are lost. Finally, in 2005 all ten artifacts were remeasured. The data are summarized in Table 3. It should be noted that the rim data for the two flakes were incorrectly reported by Hillebrand (1972) and by Panlaqui (1974), apparently due to a transcription error; the data in Table 3 are from the original laboratory report from the University of California, Davis. The consistency of measurement over a period of 36 years is remarkable, since the errors claimed by most modern labs are of the order on 0.2–0.3 μ.

The analysis of hydration results is based on the mean data in Table 3, with an effective hydration temperature (EHT) correction. The definitive analysis of obsidian from the Coso Volcanic Field is that of Gilreath and Hildebrandt (1997), which used a correction factor for EHT based on the Lubkin Creek area (CA-INY-30) as a baseline. The EHT calculations reported therein were based on Basgall (1990), who in turn used the EHT equation of Lee (1969), which yielded an EHT of 16.0°C for Lubkin Creek. However, the Lee equation is not an accurate indicator of effective hydration temperature, as shown in Rogers (2006). A more rigorous calculation of EHT is required which integrates the hydration constant over time, explicitly modeling the annual and diurnal variation of the temperature

Table 3. Ray Cave obsidian hydration data.

Acc. No.	Level, inches	Description	Rim Thickness, μ					
			1969	1978	2003	2005	Mean	Std. Dev.
151	48-54	Large triangular point	-	-	-	4.6	4.6	-
83	42-48	Elko Corner-notched	-	-	-	6.3	6.3	-
94	54-60	Elko Eared	-	-	-	4.1	4.1	-
315	30-36	Elko Eared, base only	-	-	-	4.8	4.8	-
126	30-36	Cortical flake	4.0	-	-	4.2	4.1	0.07
127	30-36	Secondary flake	4.3	-	-	3.9	4.1	0.14
84	36-42	Humboldt Basal-notched	-	5.1	5.0	4.6	4.9	0.13
87	30-36	Humboldt Basal-notched	-	3.0	3.9	3.4	3.4	0.21
93	18-24	Humboldt Basal-notched	-	4.5	4.1	4.1	4.2	0.11
424	12-24	Humboldt Basal-notched	-	3.5	4.0	3.9	3.8	0.12

and the variation of temperature with depth in the ground. A technique and computer program for performing this calculation were reported in Rogers (2006a,b).

To apply this technique to Lubkin Creek, temperature data are required. A conventional understanding in the meteorological community is that a 10-year run of data is required to give reasonable assurance that the data are representative. The closest source of such a run of data is Independence, California, which lies at approximately the same altitude and within the same weather patterns and has similar topography (data from the Cottonwood Power House only span 1948–1953). Data for Independence indicate an annual mean temperature of 15.5°C, an annual variation of 22.3°C, and a diurnal variation of 16.6°C (WRCC 2006), which results in an EHT for Coso obsidian of 20.4°C. The value is higher than that obtained by Basgall (1990) and occurs because EHT is very sensitive to both annual and diurnal variations, while Lee's equation addresses only a single variation.

Temperature data for Wild Horse Mesa, where Ray Cave is situated, were estimated from Navy weather records at China Lake. The mean annual temperature for Haiwee Reservoir has been reported as 15.1°C (WRCC 2006), and it is located at an altitude of 1093 meters (3586 feet). Mean annual temperature for Junction Ranch, at an altitude of 1725 meters (5658 feet), is reported to be 11.0°C (Navy 2005). Ray Cave is located at 1494 meters (4900 feet), so the mean annual temperature was interpolated to be 12.5°C. Diurnal and annual variation at Junction Ranch were reported to be 18.3°C and 17.4°C, respectively (Navy 2005). However, Ray Cave is a rock shelter, which may be expected to ameliorate temperature variations in the interior. Everett-Curran, Milo, and Quiatt (1991), reporting on measurements at Mesa Verde, measured diurnal variations of approximately 5°C for an unprotected area within a rock shelter, so this value was used for Ray Cave calculations. Everett-Curran, Milo, and Quiatt (1991) did not report annual variations, but there is no reason to expect them to be different from the outside temperature variations. For Ray Cave a value of 17.4°C for annual variation was assumed, equal to the variation observed in the open at Junction Ranch. When these values are used, an EHT of 14.7°C is calculated for Coso obsidian on the surface in the interior of Ray Cave. Thus, there is a -5.7°C difference in surface EHT between Lubkin Creek and the interior of Ray Cave, and this becomes increasingly negative with depth.

Finally, the effect of the EHT difference on rim thickness is (Rogers 2006)

$$\Delta x/x = \exp(-E\Delta T_e/RT_e^2), \qquad (1)$$

where $\Delta x/x$ is the relative change in hydration rim thickness, E is the activation energy of the hydration process, R is the universal gas constant, T_e is effective hydration temperature (in degrees Kelvin), and ΔT_e is the change in effective hydration temperature. For Coso obsidian, E/R is 9,687°K (Friedman and Long 1976), so, for an EHT of 293.2°K for Lubkin Creek (=273+20.2), and a ΔT_e of –5.1°C, equation (1) becomes

$$\Delta x/x = \exp(-0.06\Delta T_e). \qquad (2)$$

The EHT-corrected values of rim thickness for the Ray Cave artifacts can be calculated from equation (2) and are summarized in Table 4.

The corresponding ages were calculated by deriving a quadratic best fit equation to the radiocarbon-correlated obsidian data set in Gilreath and Hildebrandt (1997:15: Table 4). The Lubkin Creek conditions were again adopted as the standard, and data from other sites corrected for EHT by the method of Rogers (2006); a least-squares best fit based on the theoretically-predicted quadratic curve was then calculated. The resulting equation is

$$t = 46.8\, x^2 \qquad (3)$$

where t is age in years and x is the EHT-corrected rim thickness in microns. The ages computed by this equation are summarized in Table 4 and in Fig. 5. As can be seen, they fall predominantly within the Newberry Period.

Other equations have been proposed for calculating age for Coso obsidian. Basgall (1990) derived the equation

Table 4. EHT-Corrected Rim Thickness

Acc. No.	Level, inches	Description	Rim Thickness, μ	EHT- Corrected Rim Thickness, μ	Age, years BP
151	48-54	Large triangular point	4.6	6.5	1,963
83	42-48	Elko corner-notched	6.3	8.9	3,681
94	54-60	Elko Eared	4.1	5.8	1,559
315	30-36	Elko Eared, base only	4.8	6.8	2,137
126	30-36	Cortical flake	4.1	5.8	1,559
127	30-36	Secondary flake	4.1	5.8	1,559
84	36-42	Humboldt Basal-notched	4.9	6.9	2,227
87	30-36	Humboldt Basal-notched	3.4	4.8	1,093
93	18-24	Humboldt Basal-notched	4.2	6.3	1,662
424	12-24	Humboldt Basal-notched	3.8	5.2	1,339

$$t = 31.62\ x^{2.32} \qquad (4)$$

based on the obsidian set from Lubkin Creek (CA-INY-30) (Basgall 1990). Pearson (1995), analyzing Coso obsidian in the Little Lake area, derived the expression

$$t = 125\ x + 25\ x^2 \qquad (5)$$

Ages computed by Basgall's equation are generally older than those from the quadratic fit, equation (3), and those computed from Pearson's equation are younger. It is notable that the majority of the ages based on EHT-corrected rim thickness data fall within the Newberry Period, regardless of the equation used, which correlates with the typological assignment of ages (Fig. 6).

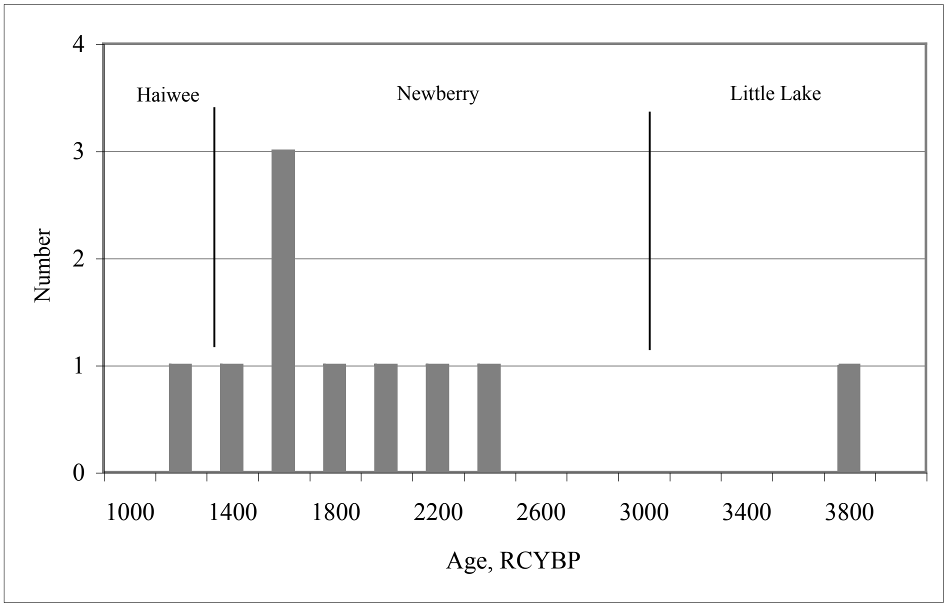

Fig. 5. Obsidian hydration ages based on quadratic fit, eq. (3).

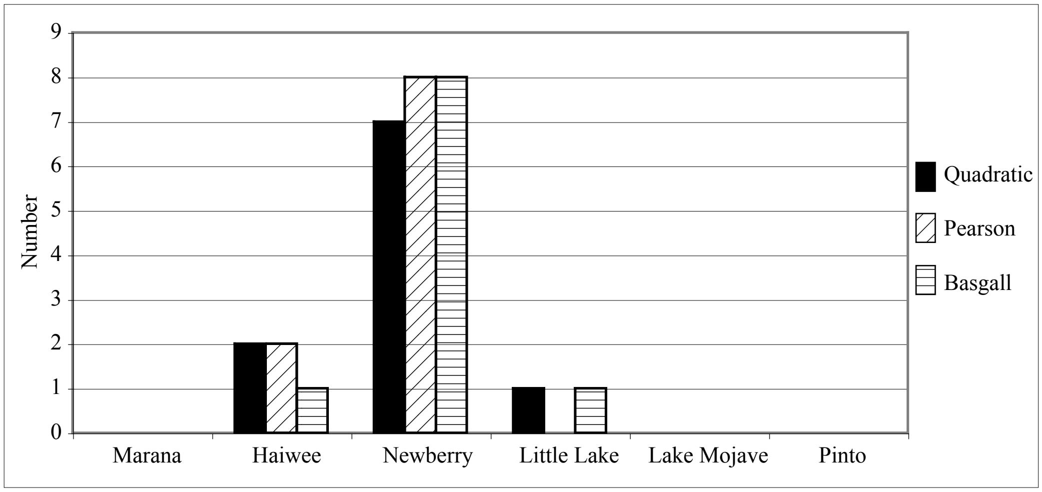

Fig. 6. Summary of obsidian hydration age computations.

Based on an extensive study of obsidian from the Coso Volcanic Field, Gilreath and Hildebrandt (1997:86, Table 18) concluded that Elko points should exhibit a rim value between 6.0 and 9.3 µ; two of the three EHT-corrected Ray Cave Elko points fall within this range, although the third is smaller. If the large triangular point (acc. no. 151), whose base is missing, is an Elko point, then it falls within this range as well. Similarly, Garfinkel and Yohe (2004:110) concluded the range for wide Humboldt basal-notched points should be 4.7 to 7.7 µ, and all of the four EHT-corrected points meet this criterion. (They defined as "wide" those points with a width greater than 24 millimeters, which includes all four of the Ray Cave Humboldt points). Thus, the ages estimated based on EHT-corrected obsidian data generally correlate with the expectations based on point typology.

Conclusions

This reconsideration of the Ray Cave chronology has been based on radiocarbon, stratigraphy, projectile point typology, obsidian hydration, and analysis of beads. Many of the analytical resources employed were not available to Panlaqui (1974), notably the bead chronology of Bennyhoff and Hughes (1987) and Milliken (1999), and the effective hydration temperature methodology; furthermore, the presence of a significant transcription error in Hillebrand (1972) added confusion to the obsidian analysis in 1974. In addition, calibration of radiocarbon dates was not a widely-employed technique at that time.

The first evidence for use of the Ray Cave site dates tenuously to the Lake Mojave Period, prior to 6,000 BP, based on the presence of a single leaf-shaped projectile point. More extensive use occurred in the Newberry Period/Little Lake Periods (3,150–1,350 BP and 6,000–3,150 BP respectively), as indicated by the projectile point typology (Figs. 3 and 4). Within this span of time, a single radiocarbon date and one obsidian hydration date fall within the Little Lake Period; greater use is indicated in the Newberry Period, based on ten of the eleven beads, eight of ten obsidian hydration data points, and one radiocarbon date. Lesser use continued into the Haiwee Period (1,350–650 BP), as suggested by the presence of Rose Spring points and the single split *Olivella* sp. bead. The presence of Desert Side-notched points indicates continued use in the Marana Period. Finally, the presence of historic artifacts on the surface suggests use in the historic period. The chronological use data are thus consistent, whether derived from radiocarbon, bead typology, point typology, or obsidian hydration.

Although there are indications of use as early as 4,000 BP, the major use seems to have been since 3,000 BP. A relative hiatus occurred in the Haiwee Period, possibly due to the Medieval Climatic Anomaly, with a subsequent increase in use in the Marana Period as the climate ameliorated. Occupation was probably intermittent, as pointed out by both Panlaqui (1974) and Gilreath (2000), possibly as a seasonal camp and cache for tools and equipment; in particular, the lack of an observable midden suggests use was never very intensive. Occupation beginning in the Newberry Period is consistent with the occupation patterns at sites in the surrounding Coso region.

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