Table 1. Comparison of Source Diversity by Artifact Category for Sherwin Summit.

Source Artifact	Casa Diablo	Mono Glass Mtn.	Queen	Fish Springs	Mono Craters	Bodie Hills	Mount Hicks	Coso	Totals
Formal Tools	51	16	13	5	-	-	2	-	87
Large Flakes	166	65	10	18	1	1	-	1	262
Small Flakes:									
Non-pressure	24	10	2	1	1	-	-	-	38
Pressure	7	3	7	1	1	-	-	-	19
Totals	248	94	32	25	3	1	2	1	406

we have combined Grasshopper Flat, Lost Iron Well, and Red Switchback into a single category GF/LIW/RS (see Hughes 1982; Skinner 1995).

Sherwin Summit

Sherwin Summit is located in central-eastern California on a sloping grade that separates Owens Valley, to the south, from Long Valley, to the north. The artifact sample drawn for this study comes from 14 archaeological sites located along a linear corridor, ranging in elevation between 1,400 and 2,100 m. Excavations at these sites were undertaken in 2001 by one of the authors (Eerkens) and his colleagues as part of a highway expansion project (Eerkens and King 2002). A distance of 18 km separates the two farthest sites. Analyses of flaked stone artifacts from project area sites indicate that reduction of obsidian from the two closest sources, Casa Diablo and Mono Glass Mountain (both within 30 km), into bifaces was an important part of the activities leading to the formation of these sites.

All but two of the project sites currently lie within a piñon-juniper forest on a volcanic tuff deposit, while the remaining two lie within a desert-scrub environment just below the modern piñon-juniper zone. The surrounding area is rich in obsidian, with no fewer than eight chemically distinct sources within 100 km. This is reflected in the counts of non-obsidian artifacts, which comprise less than 1 percent of the flaked stone assemblage. Obsidian hydration readings suggest nearly all the artifacts included in this study date between 2,500 and 1,000 years ago (Eerkens and King 2002).

Artifacts subjected to chemical characterization from Sherwin Summit include 262 large flakes (including 17 casual flake tools), 87 formal tools (bifaces and projectile points), and 57 small flakes. Samples of roughly equal size were drawn at random from nearly 30 discrete lithic concentrations. For this study, small flakes were further categorized by technological attributes prior to analysis by INAA, including the identification of complete late-stage reduction flakes, shatter, and flake fragments. As discussed below, this division proved particularly useful for delineating important trends in the source distribution of smaller flakes.

All 406 artifacts were attributable to known obsidian sources. Table 1 presents the results of the characterization analyses, broken down by artifact type. Note that small flakes are broken down into "pressure" vs. "non-pressure" types. As classified by Eerkens and King (2002), pressure flakes include thin and complete or nearly complete flakes that represent the latest stages of tool reduction (i.e., tool finishing). Non-pressure pieces include primarily fragments of flakes from earlier stages of reduction, as well as non-diagnostic shatter, although we do acknowledge that it is possible to produce small complete flakes with percussion flaking.

As Table 1 shows, eight different sources are represented among the 406 artifacts. However, the two sources closest to the project area, Casa Diablo and Mono Glass Mountain, account for 84 percent of the sample. Two slightly more-distant sources, Queen and Fish Springs, account for an additional 14 percent, while the remaining four sources account for only 2 percent of the artifacts. At the same time, the table also shows that while Casa Diablo and Mono Glass Mountain account for 88 percent of the large flakes, they account for a smaller fraction of the formal tools (77 percent) and small flakes (77 percent), especially pressure flakes (53 percent). A χ^2 test on the 3x2 table partitioning artifact type by geochemical source (grouping Casa Diablo with Mono Glass Mountain and Queen with Fish Springs) is significant ($p = .02$). In accordance with our model, formal tools and small flakes are more frequently from distant sources and rep-

Table 2. Comparison of Source Diversity by Artifact Category for Mohawk Valley.

Source Artifact	Buf. Hills	South War.	BS PP FM	GF LIW RS	Cow. Lake	Coug Butte	Buck Mtn.	Napa	Borax Lake	Bodie Hills	Mt. Hicks	Queen	Totals
Formal Tools	1	3	4	3	1	1	1	-	-	-	-	-	14
Large Flakes	4	13	12	5	-	-	-	1	-	2	-	-	37
Small Flakes	14	-	8	2	-	3	1	8	2	6	3	1	48
Totals	19	16	24	10	1	4	2	9	2	8	3	1	99

Notes: Sources are, left to right, Buffalo Hills; South Warners; Bordwell Spring/Pinto Peak/Fox Mountain/Hart Mountain (BS/PP/FM); Grasshopper Flat/Lost Iron Well/Red Switchback (GF/LIW/RS); Cowhead Lake; Cougar Butte; Buck Mountain; Napa Valley; Borax Lake; Bodie Hills; Mt. Hicks; and Truman/Queen.

resent a more diverse distribution of sources, while large flakes are dominated by nearby sources.

Mohawk Valley

Five archaeological sites in the Mohawk Valley of northeastern California were included in this study, CA-PLU-130/H, CA-PLU-131, CA-PLU-226, CA-PLU-237, and CA-PLU-421 (Dreyer and Kowta 1986; Neuenschwander 1991; Waechter 2001, 2002). This region is located along the Middle Fork of the Feather River at approximately 1350 m in elevation. Unlike the Sherwin Summit area, there are no sources of obsidian in the surrounding area. The closest obsidian source is in the Buffalo Hills (formerly known as "Unknown B"), some 145 km to the northeast.

Inhabitants of Mohawk Valley made great use of high-quality basalt toolstone, which is immediately available in local moraines and the Feather River bedload. Basalt typically represents more than 90 percent of waste flakes and 70 percent of formal tools, regardless of site type or age. At the same time, obsidian was clearly an important commodity in prehistoric times and was transported into the valley in large amounts. Despite its remoteness, obsidian typically comprises 2–10 percent of waste flakes and 10–30 percent of formal tools. Prior to work by one of the authors (SAW), only XRF methods had been used to determine obsidian sources. In these earlier XRF studies, a wide range of sources from several geographic areas in California and Nevada was identified, including some of the same sources encountered in the Sherwin Summit study. INAA small-flake samples submitted to MURR by Waechter (2002) expanded the range of sources even further.

For the geochemical analyses, all artifacts large enough to be analyzed by XRF were characterized. The small-flake sample represents a complete sample of flakes from only two sites (PLU-131 and PLU-421). In total, 16 formal tools (seven projectile points, nine bifaces), 52 large flakes, and 56 small flakes analyzed by XRF and INAA were included in this analysis. Of these, two formal tools, 15 large flakes, and eight small flakes were not attributable to a known obsidian source and are not included in the analysis. Hydration analyses indicate that the vast majority were deposited after 3500 B.P. Although not specifically tabulated, the small-flake sample is believed to represent a high proportion of latest-stage tool finishing and tool maintenance debris. Table 2 shows the results of the combined characterization studies for Mohawk Valley without the specimens of unknown provenance.

Results show that more diverse obsidian sources were brought into the Mohawk Valley sites than into the Sherwin Summit sites. Even though only 99 artifacts are attributable to source, no less than 12 geochemically distinct obsidians are present, representing at least four geographical areas, including the North Coast Ranges of western California, the Mono Basin area of central-eastern California, northwestern Nevada, and extreme northeastern California. In addition, between six and ten additional "unknown" obsidian sources are represented. We cannot resolve the exact number because the older XRF studies (Dreyer and Kowta 1986; Neuenschwander 1991) did not report raw data by artifact, making it impossible to compare the INAA unknowns (n = 4 discrete sources) to the XRF unknowns (n = 6). We address this issue below.

Despite the small sample size, several patterns are evident. First, as with Sherwin Summit, larger flakes are far more likely to be from closer sources than other artifacts. Thus, the three closest sources, including Buffalo Hills, South Warners, and the combined Bordwell Spring/Pinto Peak/Fox Moun-

Table 3. Comparison of Source Diversity by Artifact Category for Bone Cave.

Source Artifact	Obs. Cliff	McK Butte	Big Obs.	East Lake	Qtz. Mtn.	Coug. Mtn.	Silver/ Sycan	Brooks Cyn.	Glass Butte	Burn Butte	Rimr. Spring	Whit. Ridge	Totals
Formal Tools	-	3	-	-	1	1	-	-	-	-	-	-	5
Large Flakes	23	64	67	-	14	1	15	-	-	-	1	2	187
Small Flakes	7	20	8	6	6	-	2	3	3	2	-	1	58
Totals	30	87	75	6	21	2	17	3	3	2	1	3	250

Notes: Sources are, left to right, Obsidian Cliffs; McKay Butte; Big Obsidian Flow; East Lake Flow (Newberry Crater); Quartz Mountain; Cougar Mountain; Silver Lake/Sycan Marsh; Brooks Canyon; Glass Buttes; Burns Butte; Rimrock Spring; Whitewater Ridge.

the smaller vs. larger flakes (10 vs. 8), despite the fact the large flake sample is over 300 percent larger (187 large vs. 58 small flakes). Adjusted for sample size, this amounts to a fourfold increase in source diversity in small flakes. The diversity of sources is much more evenly spread across the small flake sample (i.e., not dominated by a single or small number of geochemical sources). As well, the average distance to source of small flakes is farther than that for large flakes (see Table 4). In opposition to the predictions of our model, however, the average distance to source is shorter for formal tools than for both large and small flakes. This finding is likely attributable to the exceptionally small sample size ($n = 5$) of formal tools available for analysis. The small sample of formal artifacts also precludes statistically meaningful calculation of source diversity for comparison with the flake samples.

Discussion

All three case studies show a clear relationship between artifact type, distance from source, and source diversity. Table 4 summarizes the results from the three case studies. The average distance from site to source was calculated in kilometers. Diversity was calculated in two different ways. First, the Shannon-Wiener Diversity Index is given. This is a statistical index analogous to richness and is commonly used in ecological studies to gauge the diversity of species or samples within a community; higher numbers indicate greater diversity or richness. Since this measure does not take sample size into account, and sample size is often correlated with diversity as measured by the number of classes represented within a sample (Kintigh 1984), we created a second statistic to directly compare artifact types, because sample sizes varied greatly across our tool, large flake, and small flake collections. We used the program Excel to generate 100 random subsamples at a size equal to the smallest data set (i.e., either tool, large flake, or small flake) within each region, in other words, we bootstrapped the larger samples. This was done by randomly picking (with replacement) a predetermined number of artifacts (i.e., the size of the smallest sample) from the full sample, and tallying the number of observed sources (i.e., the diversity). We then averaged these diversity measures across the 100 subsamples that were generated. In other words, if a study included 75 formal tools, 50 small flakes, and 250 large flakes, 50 artifacts (the smallest of the three) were randomly selected from the tool and large flake samples. This was done 100 times, with the number of unique sources in the subsample calculated each time. The average of the 100 diversity measures was then computed. This statistic was generated so that we could directly compare diversity between the three different samples. Table 4 reports this second diversity measure in the columns labeled "Avg # Srcs," which represents a sample-size-adjusted measure of diversity.

As shown in Table 4, small flakes (i.e., those under 10 mm) in each area are on average consistently farther from their source than larger flakes. For Mohawk Valley and Bone Cave, this distance is 13 percent and 21 percent farther, respectively. For Sherwin Summit sites, this distance is only 2.5 percent greater for small flakes, but increases to 13 percent if we consider only pressure flakes. With the exception of Bone Cave, where the formal tool sample is small, the average distance-to-source of formal tools is also greater than large flakes. In fact, the average distance-to-source is nearly equal for formal tools and small flakes, especially if we consider the pressure flake sample from Sherwin Summit rather than the total small flake sample, which includes flake fragments and pieces of shatter.