OBSIDIAN TOOLSTONE CONVEYANCE:

SOUTHERN IDAHO FORAGER MOBILITY

by

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ABSTRACT

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by

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This study examines Holocene prehistoric mobility in southern Idaho while testing a foraging model that creates expectations for forager mobility in relation to paleoclimatic variability. I use obsidian conveyance data gathered from X-ray fluorescence studies to fill a geographic gap in Great Basin and Intermountain West conveyance zone research. The argument that environmental change related to relative shifts of aridity accounts for changes in Holocene forager mobility drives this inquiry. Expectations from the foraging model show that mobility and obsidian source diversity will be higher during moister conditions than drier conditions. Data were synthesized from regional studies and 139 new artifacts were sourced from southeastern Idaho regional collections and excavations at the Fox Site near Thatcher, Idaho. The dataset totals 4,440 samples from 640 archaeological sites that originate from 37 distinct obsidian sources. Archaeology sites were grouped using hierarchical clustering analysis based on obsidian source profiles, creating conveyance zone sets that were spatially bounded by standard deviational ellipses to form conveyance zones for the clustered set of sites. Four trans-Holocene conveyance zones are proposed and described: the Malad Conveyance Zone (MCZ), Timber Butte Conveyance Zone (TBCZ), Big Southern Butte Conveyance Zone (BSBCZ), and Snake River Conveyance Zone (SRCZ). These zones are each subsequently broken down into four climatic periods, and changes in obsidian conveyance both spatially and within profiles of obsidian source use are examined. The MCZ and TBCZ both met the expectations of the foraging model, while the BSBCZ and SRCZ did not. Another test of the data reveals that obsidian source diversity and evenness are not correlated with conveyance zone size, which helps confirm that these zones reproduce behavioral patterns and are not a statistical product of regional obsidian availability. My analysis describes conveyance zones comparable in size to those proposed for neighboring regions, finds that Southern Idaho conveyance zones were firmly established in the Early Holocene, and shows that conveyance zones can be created from large datasets in a statistically robust manner. The models enable researchers to examine changes in forager mobility across large spatial and temporal scales. Expectations for forager mobility are partially supported by the variability in the paleoclimatic reconstruction. Rigorous future studies for specific regional Holocene paleoclimatic changes and obsidian sourcing studies will enable further test of this model and the ever-pertinent issue of forager mobility.

(132 pages)

PUBLIC ABSTRACT

Obsidian Toolstone Conveyance: Southern Idaho Forager Mobility

The purpose of this study is to understand how prehistoric people moved around the landscape and used major stone tool resources throughout the last 10,000 yr. B.P. in southern Idaho. Similar research has been reported in the Great Basin and western Wyoming and this study continues to fill the map with data about how large regions of the western United States were used prehistorically. This study specifically examined whether or not prehistoric mobility changed according to wet and dry climatic shifts. Based on these shifts archaeologists expect the regions people used to expand or shrink using an economic model of decision-making when foragers were confronted with the choice to stay in one resource area or move to another while pursuing plants and animals for food. To measure this decision prehistorically, obsidian projectile points and tools left behind throughout time were analyzed to determine where the stone originated geologically, a concept known as conveyance. The data were gathered from many regional studies and new sourcing of 139 artifacts from southeastern Idaho regional collections and excavations at the Fox Site near Thatcher, Idaho. In the compiled dataset are 4,440 artifacts from 640 archaeological sites in southern Idaho that originate from 37 obsidian sources.

Analysis of this dataset grouped archaeology sites based on the percentage of different obsidian sources used, creating conveyance zone sets that were encompassed by statistically created ovals in mapping software. Four trans-Holocene conveyance zones are proposed and described: the Malad Conveyance Zone (MCZ), Timber Butte Conveyance Zone (TBCZ), Big Southern Butte Conveyance Zone (BSBCZ), and Snake River Conveyance Zone (SRCZ). These zones are then separated into four wet or dry climate periods and changes in mobility are compared to the economic decision model. Overall the MCZ and TBCZ both met the expectations of the model, while the BSBCZ and SRCZ did not. Another test of the data reveals that the number of obsidian sources used and the evenness of their use is not correlated with conveyance zone size, which helps confirm that these zones reproduce prehistoric behavior and are not a statistical product of the availability of obsidian in a region.

The conveyance zones described in this study are comparable in size to those proposed in neighboring regions. Research also finds that southern Idaho conveyance zones were firmly established in the Early Holocene and shows that conveyance zones can be created from large datasets in a statistically robust manner and enable researchers to look at changes in forager mobility across large spatial and temporal scales. Expectations for forager mobility are partially supported by the variability wet and dry climate during the last 10,000 years B.P.

Benjamin L. Fowler

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INTRODUCTION

This research examines variability in southern Idaho prehistoric mobility using analysis of obsidian conveyance data, which provides patterns of toolstone conveyance and conveyance zones. Drawing on human behavioral ecology (HBE), I develop hypotheses for forager mobility coincident with climatic variability. Use of HBE models and other explanatory frameworks for understanding changing prehistoric forager mobility is lacking from many previous regional studies, though their work has shed light on prehistoric toolstone conveyance across large swaths of the American West. In the Great Basin (Earl 2010; Jones et al. 2003, 2012; Page 2008; Smith 2007, 2010), the Wyoming Basin (Harvey 2012; Scheiber and Finley 2011), and Rocky Mountains (Metcalf and McDonald 2012; Pitblado 2003) researchers have conceptualized prehistoric mobility via toolstone conveyance zones. Toolstone conveyance tracks the transport of raw material from the source to discard location. This southern Idaho study (Figure 1) fills a gap in toolstone conveyance research within this regional context and analyzes trans-Holocene mobility patterns.

I use obsidian conveyance data to address how and why forager mobility varied throughout the Holocene. I hypothesize that foraging ranges expanded and contracted as a result of climatic shifts between relatively mesic and xeric conditions. Alternatively, there may be no variability in forager mobility coincident with Holocene climatic shifts. Smith (2010) showed that forager mobility decreased between the Paleoarchaic and Archaic periods in the Great Basin but increased again during the Late Archaic, although not to Paleoarchaic levels (Smith 2010). I evaluate whether the same is true in southern Idaho. If southern Idaho forager mobility does not change in correlation with climatic variability then I anticipate that other factors, such as social boundaries, trade networks, or technological shifts may ultimately account for changing conveyance zone sizes. One possible factor affecting conveyance-based mobility reconstruction is regional density of obsidian sources. Source density is high in southern Idaho, and I analyze whether source density affects conveyance zone reconstruction and interpretation. In this case, are conveyance zones an artifact of our own analysis? These questions are tested with new and existing data from X-ray fluorescence (XRF) of sourced obsidian artifacts (Appendix 1). The dataset includes 4,440 samples from 640 sites that match profiles of 37 obsidian sources. New artifacts this study contributes are 38 projectile points from local artifact collections and 101 excavated artifacts from the Fox Site (LF1) near Thatcher, Idaho.

This thesis begins by reviewing research background information. I report southern Idaho cultural chronology and paleoclimatic trends. The patch use model of optimal foraging theory is outlined and applied to local forager mobility and toolstone conveyance to generate expectations for five periods from the Late Pleistocene through the Late Holocene. Next I describe research methodology regarding data acquisition, XRF, and data analysis. The analysis section covers quantitative analysis applied to the dataset, followed by a discussion of the findings related to model expectations. One strong result of this research is the construction of four trans-Holocene southern Idaho toolstone conveyance zones. Final summary and findings are subsumed within the conclusion.

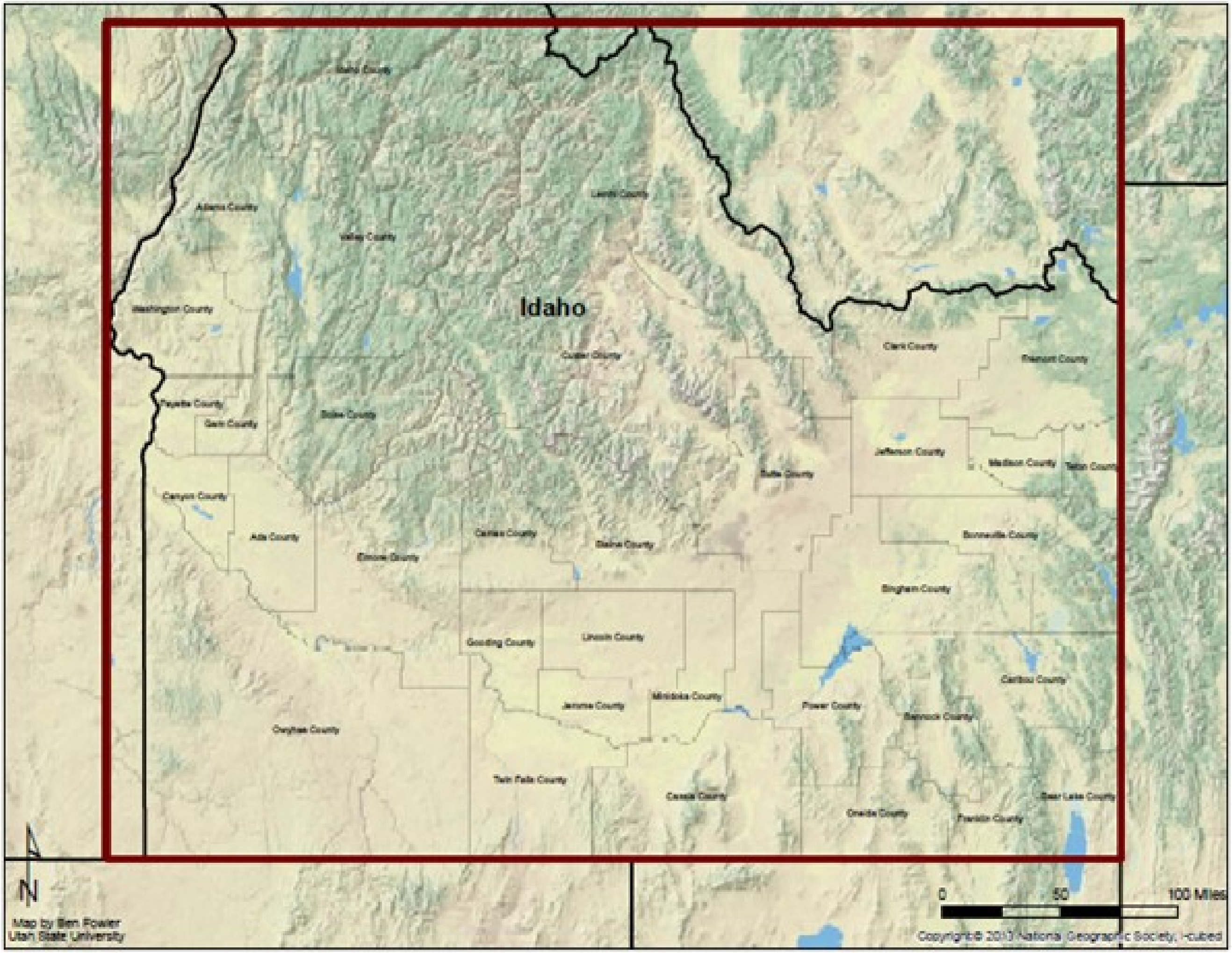

Figure 1. Map of research study area.

BACKGROUND

This section presents a context for examining Holocene forager mobility in southern Idaho. First, I describe the southern Idaho cultural chronology (Plew 2008) followed by a review of regional paleoclimatic variation (Wigand and Rhode 2002) and the patch use model (Bettinger 1991; Kelly 2007; Stephens and Krebs 1986). This background lays the groundwork for a discussion about how climate influences mobility in the context of the patch use model. Using this foundation, I lay out hypothesis of obsidian conveyance patterns given human behavior and Holocene environmental shifts. These hypotheses are tested using obsidian conveyance data presented in this study.

Southern Idaho Cultural Chronology

The Late Pleistocene (13,000-10,000 ^{14}C yr B.P.) and Early Holocene (10,000 - 8,000 ^{14}C yr B.P.) periods encompass the migration and colonization by the First Americans and subsequently the landscape filling with Native people (Simms 2008). Paleoindian occupation in North America is confirmed by 12,300 ^{14}C yr B.P. (Gilbert et al. 2008). Prehistoric assemblages from southern Idaho provide a developing picture of Paleoindian (11,300 - 7,200 ^{14}C yr B.P.) lifeways and culture possibly as early as 12,500 ^{14}C yr B.P. (Butler 1978; Gruhn 1965). Limited Idaho Clovis-age assemblages exist at Jaguar Cave, Wilson Butte Cave, and the Simon and Fenn caches (Butler 1963; Frison 1991; Gruhn 1961, 2006; Kunselman 1998; Plew 2008; Sadek-Kooros 1972). The Simon Clovis Site (Butler 1963; Woods and Titmus 1985) cache contained bifaces and spear points, confirming regional Early Paleoindian land use and toolstone use. Analysis of

Jaguar Cave (Butler 1978), Owl Cave (Butler 1978; Miller 1982), Wilson Butte Cave (Gruhn 1961, 2006), and the Buhl Burial (Green et al. 1998) revealed a broad diet of fish, bighorn sheep (Ovis canadensis), Bison (Bison antiquus), mammoth (Mammuthus spp.), and other extinct megafauna (Plew 2008). Early use of groundstone was also documented (Plew 2008). Though Paleoindian subsistence includes a broad spectrum of resources, there was an important tradition of big-game hunting that transcended much of the Archaic (Butler 1986). At Jaguar Cave and Owl Cave, mammoth and bison hunting, as well as that of bighorn sheep and other large artiodactyls supports this big-game hunting model. Fowler et al. (2009, 2011) recently documented 96 Paleoindian sites in southeastern Idaho, including some Clovis and Folsom artifacts, demonstrating widespread use of this landscape in prehistory.

Plew (2008) divides the southern Idaho Archaic into Early, Middle, and Late periods each reflecting changing culture. The Early Archaic (7,200 - 4,400 ^{14}C yr B.P.) encompassed a lot of climatic variability, as well as experiencing cultural transitions in subsistence and technology (Grayson 2011; Plew 2008; Wigand and Rhode 2002). Archaic foragers generally relied on a much broader array of subsistence resources than Paleoindians (Elston and Zeanah 2002) and saw gradual population increases through time (Kelly 1997). Changes also occurred in lithic technology, as most lanceolate projectile points styles were phased out and stemmed indented base points and large side- and corner-notched points were primarily manufactured (Holmer 2009; Lohse 1995). Southern Idaho sites show continuation of big-game hunting. Short-term residential occupation at Weston Canyon Rockshelter (10FR4) began about 7,200 ^{14}C yr B.P. and increased after 5,200 ^{14}C yr B.P. at intervals through the early and Middle Holocene (Delisio 1970; Miller 1972). The site was used as an Archaic hunting and processing camp for bighorn sheep, bison, deer, and other large mammals. Arkush (1999) suggested the site was part of a communal hunting activity in the early or mid-Autumn. Owl Cave (Butler 1978), Malad Hill (Swanson and Daley 1968), and Bison and Veratic Shelters (Butler 1978; Swanson 1972) are also eastern Idaho Early Archaic hunting-focused sites. Butler (1978) and Swanson (1972) interpreted these sites as part of a seasonal resource use strategy relying on multiple temporary hunting camps. Pavesic (1985) identified the Western Idaho Archaic Burial Complex by 5,200 ^{14}C yr B.P. at the DeMoss site (Green et al. 1986; Pavesic et al. 1993). The role of burial goods is debated, as it is unclear whether they symbolically represent social status or an ideological system within an egalitarian society. Nine sites associated with the complex indicate long-distance trade or a chain of regional trade networks with neighboring groups that reached as far as the Pacific coast.

The Middle Archaic (4,400 - 2,000 ^{14}C yr B.P.) began as the Late Holocene climate turned almost uniformly cooler and moister (Wigand and Rhode 2002). Plew (2008) cites subsistence and settlement specialization as a key process during this period. One example is the construction and use of pithouses at 15 western SRP sites indicating changes in settlement patterns, site use, and mobility (Green 1993; Plew 2008). Within this specialization trend, settlement-subsistence behavior also became more diverse throughout the environment (Plew 1985). Dietary diversity across southern Idaho is visible in hunting sites, mussel collection activities, evidence of intensified fishing activity, and a more built environment with formal structures and storage locations. For example, a collapsed lava tube in the eastern SRP named Bobcat Cave was used prehistorically for both drinking water and storage of materials, possibly including bison meat (Henrikson 1996, 2002, 2003, 2004). Whether storage focused on subsistence or material resources, Bobcat Cave shows that landscape use fundamentally changed, affecting mobility, subsistence, and settlement patterns.

Southern Idaho's Late Archaic (2,000 - 250 ^{14}C yr B.P.) record displays continued expansion of subsistence resource intensification coincident with increased population and the introduction of new technology (Plew 2008). Varied strategies were employed to exploit and intensify resources. Intensified landscape use and population increases are seen across the SRP and especially among sites with aquatic assemblages in the central SRP. Faunal assemblages with fish remains, especially salmon, and caches of specialized equipment support resource intensification in the Late Archaic (Gould and Plew 2001; Plew and Plager 1999; Schellbach 1967). Plant use included camas and biscuitroot where and when available. Bison use is also characteristic, whether via jump sites like Challis, Five Fingers, and "Y" (Plew 1987), or other faunal assemblages including Baker's Cave I and III (Breslawski and Byers 2014; Plew et al. 1987) and Rock Springs (Arkush 2002). Seasonally increased sedentism was manifested in larger winter use settlements at Wahmuza (Holmer 1990), Three Island Crossing (Gould and Plew 2001), and Corn Creek (Holmer and Ross 1985). Both pithouses and house floors were built during this time, and seminal technological changes occurred as multiple ceramic varieties were used and larger dart points were mostly phased out in favor of small projectile points fitting the bow and arrow (Green 1993; Plew 2008).

The Late Archaic material culture was primarily produced by the northern Fremont and the Shoshone (Butler 1986; Plew 2008). About A.D. 900 Fremont people flourished in the Great Basin, and since southeastern Idaho was peripheral to the Fremont center it thus contains limited evidence of the Fremont culture (Kelly 1997; Kloor 2007; Simms 2008). The ethnographically documented Shoshone and Bannock Numic groups operated with an intensive subsistence lifestyle and bow and arrow technology (Holmer 1994; Simms 2008; Steward 1938). Numic cultural continuity is an unresolved southern Idaho question where Holmer (1990, 1994) and Swanson (1972) argue continuity began between 4,000 B.P. and 7,000 B.P. and persisted until contact; however, Butler (1986) and others (Gruhn 1961, 2006; Plew 2008) viewed Birch Creek valley excavations and the Lemhi Phase (A.D. 1250 - 1850) as the first conclusive evidence of southeastern Idaho Numic groups.

Southeastern Idaho Paleoclimatic Trends

Among the many paleoclimatic records in northern Utah and eastern Idaho, the paleoclimatic variability discussed below originates from the study locations shown in Figure 2. Figure 3 charts the paleoclimate records from these study locations representing them within an array of arid to mesic condition. This section describes southeastern Idaho paleoclimatic trends beginning at the end of the last ice age and ending at the present time.

Beginning at the end of the last ice age, North American climate shifted. Temperatures were a full 10° F cooler than present though conditions were relatively dry (Thompson 1984). After 11,500 ^{14}C yr B.P. climate became more mesic and remained cool until 10,000 ^{14}C yr B.P. (Beck and Jones 1997; Beiswenger 1991; Bright 1966). Similar conditions existed in the Great Basin and western Wyoming surrounding the 10,000 ^{14}C yr B.P. Pleistocene-Holocene Transition (PHT) (Beck and Jones 1997; Gennett and Baker 1986; Wigand and Rhode 2002). The Lake Bonneville record demonstrates cool and dry late glacial conditions then rapid lake level regression to modern Great Salt Lake (GSL) levels until the moist Younger Dryas Gilbert resurgence from 10,900 - 10,000 ^{14}C yr B.P. (Grayson 2011; Oviatt 1997; Patrickson et al. 2010). Doner's (2009) Bear Lake, Utah study generally concurred with Lake Bonneville through 11,500 - 10,000 ^{14}C yr B.P. with high tree pollen and low sagebrush level reported.

From 10,000 - 6,500 ^{14}C yr B.P. climatic conditions were the warmest and most xeric, peaking between 8,000 - 6,500 ^{14}C yr B.P. depending in part on elevation differences and moisture-dominant summers versus winters (Davis 1984; Davis et al. 1986). Beiswenger (1991) reported increased aridity at 10,000 ^{14}C yr B.P. accompanying climbing average temperatures, sharply contrasting the previous period. Grays Lake aridity peaked at 8,200 ^{14}C yr B.P. and continued until 7,100 ^{14}C yr B.P. (Beiswenger 1991). At Lake Bonneville, waters retreated from the Gilbert shoreline as temperatures rose after 10,000 ^{14}C yr B.P. A possible post-Gilbert highstand occurred at 7,500 ^{14}C yr B.P. (Patrickson et al. 2010) prior to an even warmer and drier period beginning 7,000 ^{14}C yr B.P. (Godsey et al. 2005, 2011; Grayson 2011; Oviatt 1997; Wigand and Rhode 2002). At Bear Lake, Doner (2009) described high tree pollen and sagebrush steppe plants achieving a maximum by 7,200 ^{14}C yr B.P. High tree pollen may correlate to a lake highstand at 7,200 ^{14}C yr B.P. and a possible thousand-year mesic period prior to

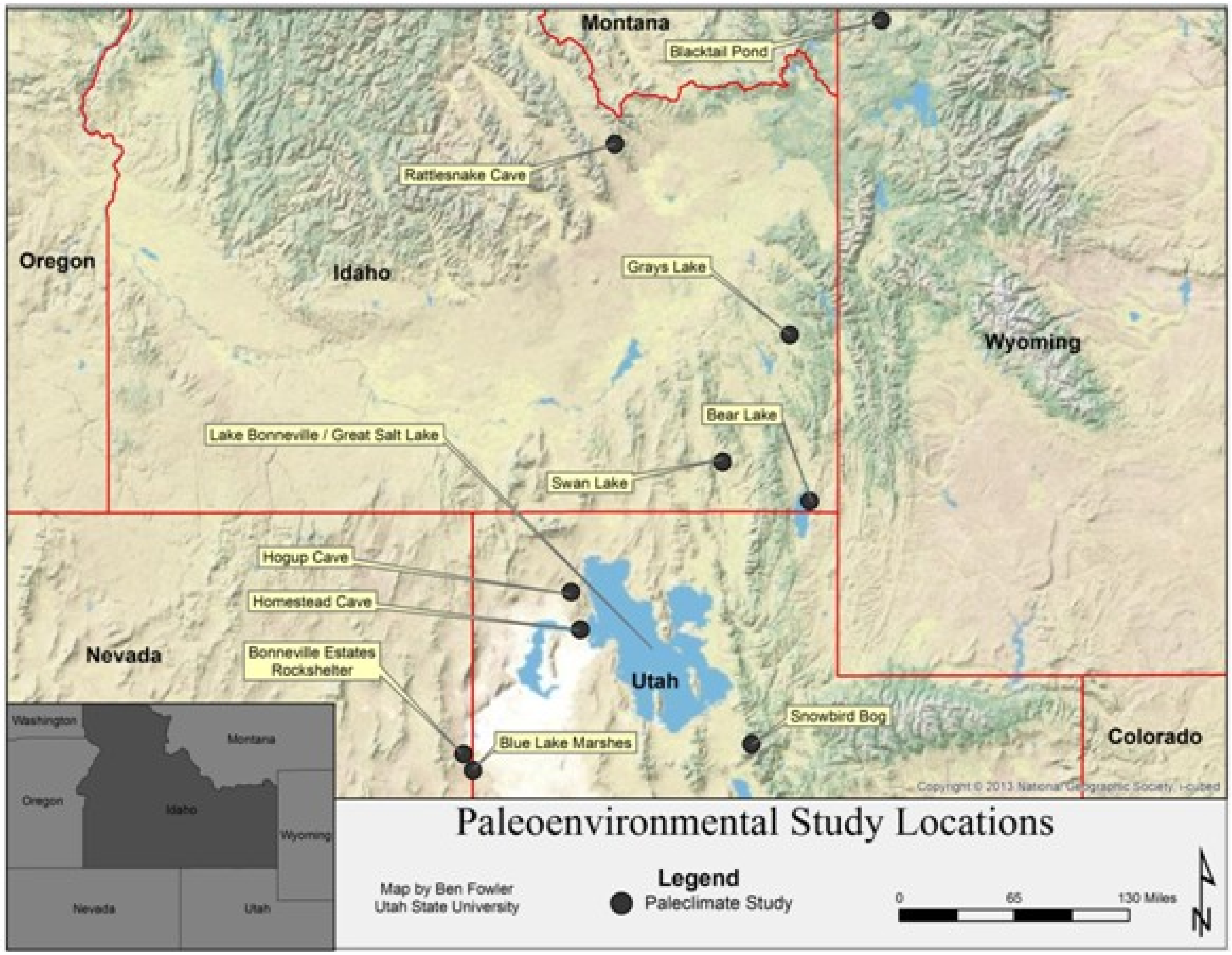

Figure 2. Paleoenvironmental study locations.

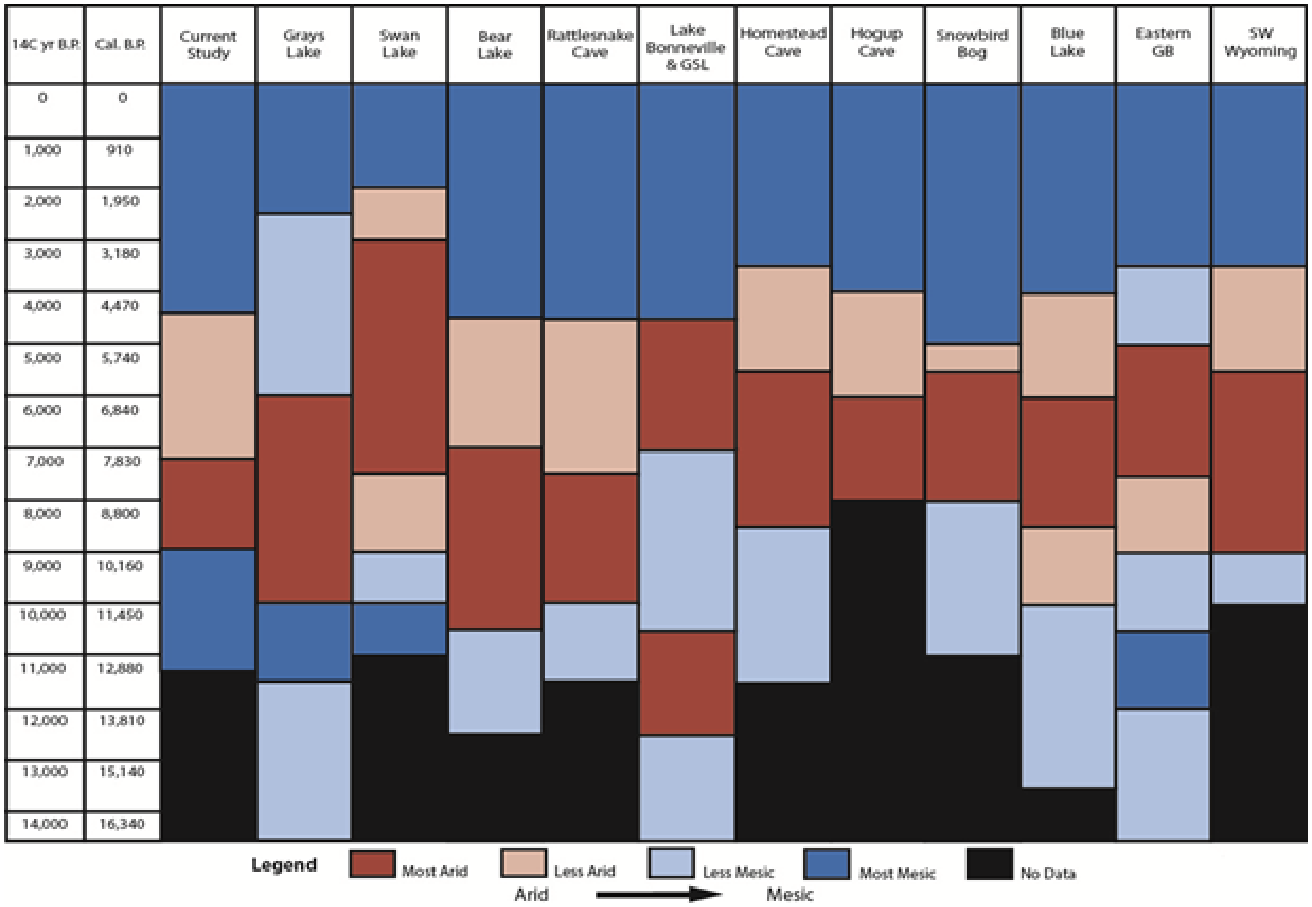

Figure 3. Paleoenvironmental record of conditions during the last 16,000 years B.P.

*The scale from arid to mesic is an ordinal data category created so periods could be ranked against each other to create periods of arid and mesic climate throughout the Holocene.

that. These interpretations are hampered by poor chronological control and limited samples for this portion of the record (Doner 2009). Utah's Blue Lake, southwest Wyoming artiodactyl data, and Rattlesnake Cave, Idaho records showed a xeric period that began at 10,000 ^{14}C yr B.P. (Byers et al. 2005; Davis 1995; Louderback and Rhode 2009). Paleoclimate records at Swan Lake, Bonneville Estates Rockshelter, Homestead Cave, Snowbird Bog, and across the eastern Great Basin reported warmer and more xeric conditions began between 500 - 1,500 years later than previously discussed studies. By 6,500 ^{14}C yr B.P. the arid maxima ended at Grays Lake, Swan Lake, Bear Lake, Blue Lake, and Rattlesnake Cave, closing a generally warm and xeric period spanning parts of the Early and Middle Holocene (Beiswenger 1991; Bright 1966; Davis 1995; Doner 2009; Louderback and Rhode 2009).

Following this period a transitional climate phase 6,500 - 4,500 ^{14}C yr B.P. brought more mesic conditions throughout the region, though still drier and warmer than subsequent Late Holocene reconstructions (Beiswenger 1991; Doner 2009). However, paleoclimate records where xeric conditions began later tended to also end later, as evidenced by Swan Lake, Snowbird Bog, Bonneville Estates Rockshelter, and Blacktail Pond (Bright 1966; Gennett and Baker 1986; Madsen and Currey 1979; Schmitt and Lupo 2012). The GSL levels plummeted after 7,500 ^{14}C yr B.P. reminiscent of the decline at 12,500 ^{14}C yr B.P. though the lake soon rebounded to a highstand. From 5,500 - 2,000 ^{14}C yr B.P. the GSL evidence showed millennial-scale fluctuations between highstands and modern levels 5,500 - 2,000 ^{14}C yr B.P. (Grayson 2011; Oviatt 1997). Grays Lake *Artemesia* pollen levels increased slightly while at very high levels and

Juniperus increased indicating a sagebrush steppe with a descending juniper treeline (Beiswenger 1991). Doner (2009) reported that fir, spruce, and mahogany pollen percentages increased during this transitional interval indicating an increasingly mesic climate with average temperatures cooling. Byers and Broughton (2004) used Homestead Cave artiodactyl fecal pellets as a proxy for big game animal abundance, which is indicative of mesic and xeric conditions related to plant biomass and foraging productivity. They reported a xeric period 5,400 - 4,800 ^{14}C yr B.P. then a 150 year mesic interval before xeric conditions returned 4,650 - 3,300 ^{14}C yr B.P. based on a greater than 75 percent decline of artiodactyl fecal pellets.

The post-transition climate from 4,500 ^{14}C yr B.P. to present was the most mesic since the PHT. Despite the general mesic trend, this period was interspersed with millennial-scale temperature or precipitation variations. Wigand and Rhode (2002) found that the eastern Great Basin had multiple wet and dry phases. GSL levels rose and fell, reaching highstands at 3,400 - 2,000 ^{14}C yr B.P. and again between 300 to 400 ^{14}C yr B.P. (Grayson 2011; Oviatt 1997). Researching west of the GSL, Byers and Broughton (2004) showed highly mesic conditions at Homestead Cave following 3,300 ^{14}C yr B.P. evidenced by faunal pellets declining in the stratigraphy by 2,700 ^{14}C yr B.P. indicating a xeric period before mesic conditions prevailed once again. Blue Lake pollen levels indicate rising pine forests and marsh influences at this time (Louderback and Rhode 2009). Additionally, Byers and Broughton (2009) worked with Durrant's (1970) Hogup Cave data that produced mesic and xeric trends similar to Homestead Cave. Archaeofaunal records from southwestern Wyoming (Byers et al. 2005) revealed mesic conditions following 3,000 ^{14}C yr B.P. and especially after 800 ^{14}C yr B.P. By 3,000 ^{14}C yr B.P. the Swan Lake record showed increased pine and decreased sagebrush pollen (Bright 1966). At Grays Lake, Beiswenger (1991) reported similarly increased *Pinus*, *Picea*, and *Abies* while *Juniperus*, *Artemesia*, and *Chenopodium/Amaranthae* pollen decreased though not until 2,000 ^{14}C yr B.P. These pollen record percentages combined with an overall decrease in pollen influx supported her interpretation of a cool and moist forest steppe environment.

Patch Use Model

The patch use model is one of several optimal foraging models, which are applied to both human and non-human foragers (Bettinger 1991). Applied to human foragers in the archaeological record, these models examine prehistoric behaviors such as foraging location, foraging time, foraging group size, and settlement location (Bettinger 1991; Kelly 2007). Patch use models are 'average-rate-maximizing models', as described by Stephens and Krebs (1986) wherein it is assumed that foragers will maximize their average rate of energy intake. The model's currency is energy, which predators and foragers are expected to maximize thereby increasing their chances for survival and reproduction (Charnov 1976; Kelly 2007; Stephens and Krebs 1986). The model ultimately addresses how long a forager should stay in a resource patch to maximize their average energy gain (Charnov 1976; Stephens and Krebs 1986).

To answer this question the patch use model requires certain constraints and assumptions. The model assumes that predators have full knowledge of the environment's patch types and associated travel costs between them, the productivity of each patch, its availability and depression rates, and all opportunity costs (Smith 1991; Spencer 2012; Stephens and Krebs 1986). Additional constraints and assumptions state that patches are distributed randomly throughout the environment, within-patch searching and hunting are mutually exclusive, prey are encountered only in patches, patches are encountered sequentially without revisiting them, and search encounter rates are independent of residence times (Stephens and Krebs 1986).

Charnov (1976) defined the environment as a "patchy habitat" of resources accessed by a predator. An environment may contain few or many patches and patch types. A single patch is an area surrounding resources that is used by a predator for a specific length of time. Patches are occupied one after another based on availability of resources and the overall productivity of the environment. The patch use model considers a set of available patches projecting an optimal residence time for each patch (Charnov 1976; Stephens and Krebs 1986). The model finds that it is optimal to stay in a patch until the marginal rate of return equals the rate averaged over all environmental patches (Charnov 1976; Kelly 2007; Stephens and Krebs 1986).

One early test of the patch use model was Cowie's (1977) experiment with the Great tit (*Parsus major*). He set up sawdust-filled cups with mealworms (patches), some of which he altered to simulate different patch return rates. Cowie's (1977) experiments validated great tit foraging behavior as consistent with the patch use model's predictions of optimal patch use. Great tits exited patches consistent with the goal of maximizing the rate of energy gain per time spent in patch, supporting the patch use model's efficacy.

Human foragers, like great tits, acquire prey from the environment and foraging models are applicable to our behavior.

Graphic depictions of the patch use model shown and described hereafter assist in conveying the relationship between the model's costs and constraints while focusing on optimal patch use and when to leave a patch. Figure 4 shows a graphic comparison of two patches (A and B) with a ray (R) indicating the mean environmental return rate including travel, search, and handling costs. The x-axis charts the mean travel time between patches and patch residence time, while the y-axis indicates the gain in energy. Travel time incurred between patches is calculated separately from patch use costs. The gain functions (A and B) therefore represent the cumulative energy acquired as patch residence time increases. The functions increase initially, as plentiful prey are acquired quickly, before reaching an apex and negatively accelerating as foraging activities depress resources and patch resource acquisition decreases as the result (Bettinger 1991; Stephens and Krebs 1986).

Functions similar to A and B are required by the model. Charnov (1976) described that given R, the ray depicting mean environmental return rate, the optimal patch use time is discovered by creating tangents parallel to R which intercept the gain functions for patches A and B. Vertical tangents (t_a and t_b) extending from the intercept of A and B with the parallel lines depict these optimal times. Patch B has the longer optimal patch residence time (t_b) based on higher cumulative energy gain through time relative to patch A.

Taking the patch used model's framework, Stephens and Krebs (1986) discussed

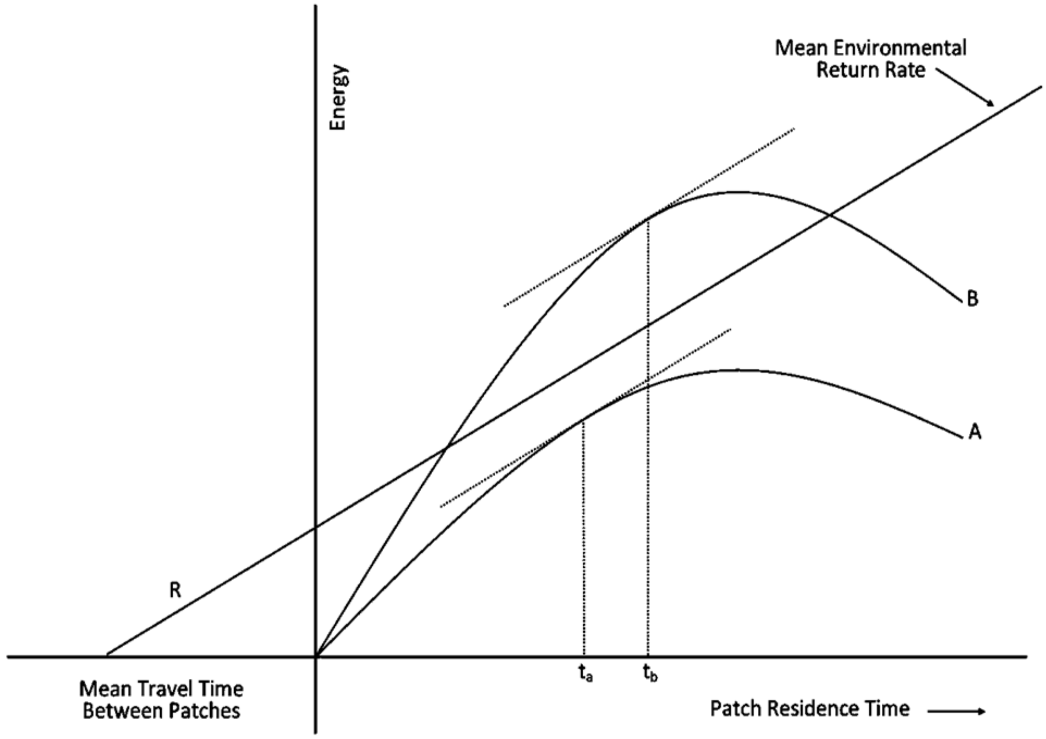

Figure 4. Patch Use Model.

an altered "one-patch-type" case of the patch use model (Figure 5). The single patch represents an environment where all patches have the same gain function and there are no search costs (Stephens and Krebs 1986). Two rays marked on the x-axis by $1/\lambda_1$ and $1/\lambda_2$, represent the average environmental rate of return given different travel times, which increase toward the left. Changing the travel time between patches alters where the gain function intersects the ray. Two vertical lines (t_1 and t_2) show these intersections on the range of patch residence time along the x-axis. As travel time increases from $1/\lambda_1$ to $1/\lambda_2$ the patch residence time increases from t_1 to t_2. The conclusion shows that short travel time results in shorter optimal patch use time and longer travel time corresponds to longer

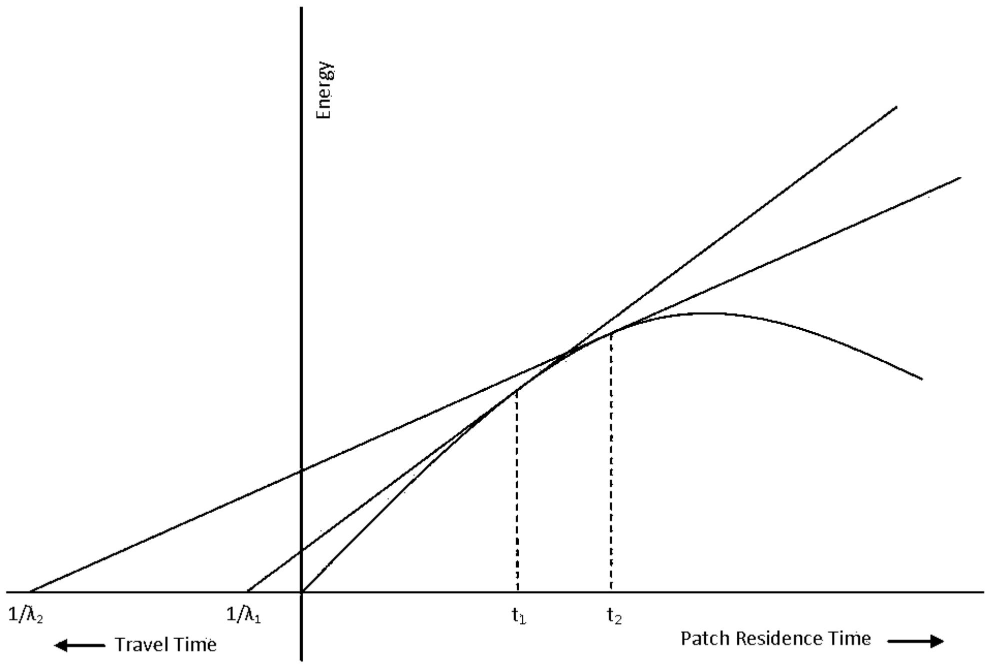

Figure 5. One-case-type of Patch Use Model with changing travel time.

optimal patch use time (Stephens and Krebs 1986).

Figure 6 is an adaptation of Figure 5 showing one last example of the patch use model. Patch 1-1, rays A and C, model the average rate of energy gain during patch residence. Intersections t_1 and t_2 show the optimal time to leave Patch 1-1 based on maximum energy gain per unit of time given the average environmental return rate. Patch 1-2 describes the average rate of energy gain in the same patch following an increase in prey abundance. Two new rays, B and D depict the average environmental return rate from the same x-axis travel time intervals. Vertical lines (t_3 and t_4) mark the intersection of rays B and D with the gain function. The lines illustrate that increased prey abundance, resulting from a more productive environment, leads to shorter optimal patch residence times.

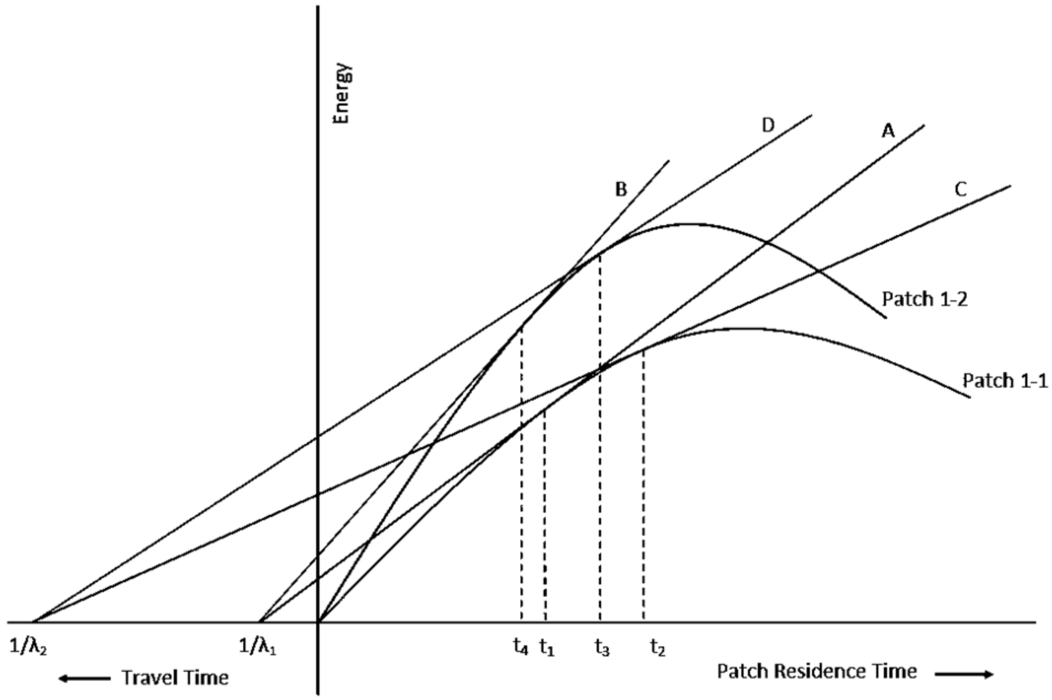

Figure 6. One-case-type of Patch Use Model and effects of increased patch productivity.

Applied Patch Use

I apply the patch use model discussed above to prehistoric foragers in southern Idaho. This research envisions a multitude of patches encompassing southern Idaho that are encountered sequentially by residentially mobile foragers. The patches are areas with specific resources, used by small residentially based foraging groups. Any specific patch may be seldom or frequently used, but here it is assumed that patches are incorporated into annual, decadal, or lifetime foraging ranges. Viewed through a lens considering long-term environmental and climatic relationships, patch productivity and therefore forager patch use changes independently of foraging activities, suggesting that the environment shaped, to some extent, foragers' decisions and behavior (Smith 1991).

Figure 4 illustrates that foragers' patch residence time relies on both individual patch productivity and average environmental productivity across all patches (Bettinger 1991; Stephens and Krebs 1986). This study predicts that toolstone conveyance zones manifesting forager mobility patterns were affected by Holocene environmental changes.

Optimal forager patch use is expected to lengthen or shorten depending on environmentally dependent resource productivity. The patch use model contains two scenarios when environmental changes alter the optimal time to leave a patch. First, environmental change affecting the average rate of energy gain from a patch increases or decreases productivity, depicted by Patch 1-2 in Figure 6, which generates changes to optimal patch use times. Second, a decreased distance between patches (inter-patch travel time) depicted in Figure 5 looking from ray $1/\lambda_2$ to $1/\lambda_1$, can result in an altered optimal patch exit time due to increased environmental productivity. Ultimately, during periods of higher environmental productivity a "moving-on threshold" is reached more quickly (Charnov 1976; Stephens and Krebs 1986). It is important to note that changing forager mobility represents increased cycling between patches, not the linear distance traveled (Smith 1991; Stephens and Krebs 1986).

In summary, this study applies the 'one-patch-type' of the patch use model, which is simplification of the environment where a multi-patch landscape is assumed to consist of a single type of patch and resources (i.e., riparian meadow) to allow for generalized predictions about forager mobility. Southern Idaho is conceived here as an environment composed of many patches that are combined into large, lifetime-scale foraging ranges. Toolstone conveyance is the proxy I use to measure mobility, parallel to studies conducted by Jones et al. (2003), Smith (2010), and Harvey (2012). Below I combine the patch use model's predictions with southeastern Idaho paleoclimatic reconstructions containing a record of fluctuating Holocene environmental. I then compare chronologically variable toolstone conveyance data and model predictions throughout the Holocene.

Hypotheses and Expectations: Patch Use Model and Paleoclimate

To create hypotheses and predictions about obsidian conveyance zones and forager mobility I employ the patch use framework as informed by southeastern Idaho's paleoclimatic record. I divide the archaeological record into five periods (Table 1): the early Paleoindian, late Paleoindian, Early Archaic, Middle Archaic, and Late Archaic (Plew 2008). These periods correspond to five paleoclimatic periods, the Late Pleistocene, Early Holocene, Middle Holocene, Late Holocene, and Terminal-Late Holocene, which I separate based on changing environmental conditions (Figure 3). Fluctuations in wet and dry periods affect environmental conditions and, per the patch use model, alter optimal forager mobility patterns. Optimal patch residence time decreases as mesic conditions increase environmental productivity and decrease travel time between patches (Figures 5 and 6). In a residentially mobile forager strategy these decreases mean that patches are used for shorter durations and more patches are visited as the forager group moves more frequently within a foraging range.

This study begins by questioning how and why forager mobility in southern Idaho varied through the Holocene. Based on the model developed here I hypothesize that foraging ranges expanded and contracted as a result of paleoclimatic shifts between mesic and xeric conditions. I use obsidian sourcing data to test the model's expectations during the five periods. Here I record the expectations for each period. I also consider whether obsidian source diversity and evenness affect the size and character of conveyance zones in southern Idaho.

Period 1. Period 1 encompasses the Late Pleistocene from 11,300 to 8,900 ^{14}C yr B.P., which corresponds to the early Paleoindian record. Conditions during this time were the most mesic compared to any subsequent climatic period. As the earliest period considered, and the most mesic, I use it as the starting point for describing past climatic variability and proposing expected toolstone conveyance and forager mobility. I expect average toolstone conveyance to be the greatest and conveyance zone size to be the largest during Period 1. Due to the large conveyance zone predicted during this period, toolstone diversity is also expected to be high.

Period 2. Early Holocene climatic conditions from 8,900 to 7,200 ^{14}C yr B.P., coinciding with the late Paleoindian were the most arid due to a considerable climatic shift to xeric conditions. I expect that Period 2 conveyance zones size will be the smallest of any period and shrink relative to Period 1. Obsidian source diversity is expected to decrease relative to Period 1 reflecting a constricted conveyance zone.

Period 3. The Middle Holocene and Early Archaic fall within Period 3. Paleoclimatic records from 7,200 to 4,400 ^{14}C yr B.P. indicate that this period was transitional with xeric conditions earlier, followed by amelioration to more mesic conditions. Overall the climate was less arid than Period 2; however, xeric conditions were still far more intense than during Period 1 or the Late Holocene. Given this mixed period I expect no statistically significant change in conveyance zone size or obsidian source diversity compared to Period 2.

Period 4. Period 4 marks the transition to the Late Holocene and Late Archaic, dating between 4,400 and 2,000 ^{14}C yr B.P. More mesic conditions replaced xeric climatic trends regionally during this time, though mesic climate is found earlier in different regions, based on elevation and latitude. The model predicts that forager mobility would increase as a result of these changes and thereby alter toolstone conveyance. I expect conveyance zone size to increase, along with obsidian source diversity.

Period 5. By 2,000 ^{14}C yr B.P. relatively mesic conditions were ubiquitous across southern Idaho. Although Plew (2008) does not recognize the Late Prehistoric period in southern Idaho I create expectations of toolstone conveyance from 2,000 to 250 ^{14}C yr B.P. to explore this commonly defined archaeological period. The same mesic conditions noted in Period 4 are present during this time, which I refer to as the Terminal-Late Holocene. I expect no change in conveyance zone size or obsidian source diversity between the two periods.

Table 1. Paleoclimatic Periods Resulting from Changes Between Arid and Mesic Conditions and Predictions of the Patch Use Model for Foraging Mobility and Obsidian Conveyance Zone Size.

Period	**Age (^{14}C yr B.P.)**	**Age (Cal. B.P.)**	**Mesic to Arid Climate Scale**	**Change of Time Spent in Patch**	**Change in Residential Movement Frequency**	**Change in Diversity in Obsidian Source Use**
1	11,300 - 8,900	13,200 10,000	Most Mesic	▼ Patch Residence	▲ Mobility	▲ Obsidian Source Diversity
2	8,900 - 7,200	10,000 - 8,000	Most Arid	▲ Patch Residence	▼ Mobility	▼ Obsidian Source Diversity
3	7,200 - 4,400	8,000 - 5,000	Less Arid	No Change	No Change	No Change
4	4,400 - 2,000	5,000 - 2,000	More Mesic	▼ Patch Residence	▲ Mobility	▲ Obsidian Source Diversity
5	2,000 - 250	2,000 - 250	More Mesic	No Change	No Change	No Change

METHODOLOGY

The methods applied to this archaeological study are described in this section. First, I lay out the data acquisition methods that I used to collect obsidian sourcing data in southern Idaho. Using obsidian sourcing data incorporates specialized geochemical analysis that is discussed below, followed by a review of previous obsidian conveyance studies in the Great Basin, Wyoming Basin, Central Rocky Mountains, and more narrowly in southern Idaho during the past fifty years. I conclude with a discussion of data analysis methods, which include both spatial analysis and quantitative statistical methods.

Data Acquisition

This study tests the southern Idaho foraging model with obsidian artifact data from southern Idaho. I compiled data from regional and local levels. Choosing these data contexts enables this research to examine prehistoric mobility at different scales of analysis. The data I recorded for each specimen included site, UTM coordinates, source, artifact type (e.g., projectile point, biface, utilized flake, flake), artifact style (e.g., Clovis, Folsom, Great Basin Stemmed, Scottsbluff, Haskett, Hell Gap, Agate Basin, Angostura, Stemmed Indented Base, Elko, Rose Springs, Desert Side-Notched, etc.), age (e.g., Paleoindian, Archaic, Late Prehistoric, Historic), and reference information.

Regional Collections. I mined existing XRF data from PhD dissertations, Master's theses, contract archaeology reports, and journal articles (Appendix 1). The data I gathered focuses on southern Idaho. I began with a partial database collected by

Scheiber and Finley (2011) and included important studies by Holmer (1997) and Plager (2001). To this compilation I added all regionally available information.

Local Collections. Local collections provided new data and were generously supported by donor funding for XRF analysis. Projectile points from private artifact collections and professional archaeological excavation compose this local sample. I was involved in documenting a baseline Paleoindian record as part of the Southeastern Idaho-Northern Utah Paleoindian Project (SINUPP) (Fowler and Pitblado 2011; Fowler et al. 2009, 2011), which began in 2007. This involved working with local communities and amateur archaeologists targeting Paleoindian-age sites. SINUPP was successful at building local partnerships and recording nearly 100 sites. The site documentation is kept by Dr. Pitblado at University of Oklahoma.

I selected three collections from SINUPP research to sample for this study. Dave George, Cohen Croney, and Lawrence Fox granted access to projectile points with documented provenience. The term provenience is used here as the collection site of an artifact within 5 meters. I sampled 38 projectile points from these collections for XRF analysis at Dr. Richard Huhges' Geochemical Research Laboratories in Portala Valley, California. Eighteen Paleoindian projectile points bolster this underrepresented prehistoric period among toolstone sourcing studies (Holmer 1997; Plager 2001). The remaining 20 projectile points span the Archaic. These new samples within southeastern Idaho are a valuable addition to accumulated regional sourcing literature (Holmer 1997; Plager 2001; Willson 2007).

In Dave George's collection I chose three Paleoindian projectile points. These artifacts are from a well-known site near the Blackfoot Reservoir, Caribou County, Idaho. The second collection is tied to the Portneuf River Valley, Caribou County, Idaho. Cohen Croney, one of the most prominent amateur archaeologists in southeastern Idaho, has thoroughly described each site where he found and recorded the associated artifacts. I chose 25 artifacts from nine of Croney's site locations that are accurately provenienced. Fourteen Paleoindian projectile points were sampled, along with five Archaic, and two unknown projectile points. Lawrence Fox collected artifacts from the Fox Site and nearby areas prior to archaeological excavations. I selected 10 projectile points for sourcing; one is Paleoindian and nine date to the Archaic. From the excavated assemblage I sampled 101 obsidian artifacts (Table 2).

XRF and Toolstone Sourcing

Geochemical Analysis of Obsidian. Obsidian is a volcanic glass composed primarily of rhyolite or silica (Hughes and Smith 1993; Shackley 2005). Each obsidian flow has a unique geochemical fingerprint, which is distinguished best among the proportional inclusion of a suite of trace elements (Andrefsky 2005; Shackley 2011). Obsidian transported away from a geologic source by environmental forces or tool-making hunter-gatherers can therefore be identified and matched geochemically to its point of origin (Holmer 1997; Hughes 1998; Hughes and Smith 1993).

Geochemical analysis uses several technologies that identify the elemental composition of a geologic sample (Pollard et al. 2007). XRF is the method most commonly used to analyze obsidian in archaeological contexts, although LA-ICP-MS and

Table 2. Sampling Strategy for LF1 Obsidian Artifacts.

Loci	**Provenience**	**Flakes Sampled**	**Utilized Flakes Sampled**	**Total**
Loci 1	SS108, SXP1048, & SXO1047	27	14	41
Loci 2	M127 & N128	14	6	20
Loci 3	TT117 & UU117	13	7	20
None	Projectile Points & Tools			20
Total		54	47	101

NAA are better in cases where samples are small or greater precision is necessary (Andrefsky 2005). One of the earliest archaeological applications of XRF was by Edward Hall of Oxford University as he studied Imperial Roman coinage (Hall 1960). Commercial elemental analysis has been available since the 1950s and has been a focus of research in Universities since the 1960s (Shackley 2011). XRF developed into the preferred analysis method among archaeologists because it is non-destructive, requires minimal preparation of samples, is fast and easy to employ, and cost-effective.

XRF analysis irradiates an obsidian sample with an X-ray beam. Inner orbital shell electrons are excited and displaced as a result of the added energy. Valence electrons subsequently shift to low-energy orbits to fill the place of ejected electrons and release their excess energy, a process termed fluorescence (Shackley 2011). Measures of energy released during fluorescence provide the intensity and elemental concentrations contained within the sample and their relative abundance. Collected data specific to each sample are then analyzed by statistical tools, such as discriminant analysis, which matches it to a source profile from a database of known sources (Bailey 1992; Sappington 1981, 1982).

Obsidian Conveyance in the Great Basin, Wyoming Basin, and Central Rocky Mountains. Recent archaeological work in the western United States places southern Idaho in the midst of a series of proposed toolstone conveyance zones (Harvey 2012; Jones et al. 2003, 2012; Scheiber and Finley 2011; Smith 2010). Eastern Nevada Paleoarchaic lithic scatters (Jones et al. 2003) form the basis for the Eastern Conveyance Zone (ECZ) centered in the Butte and Jakes valleys of eastern Nevada. Jones et al. (2003) sourced projectile points, a curated tool among hunter-gatherers, and modeled changing Paleoarchaic mobility at a regional scale. Obsidian sources in the north and south of their study area were tied to analyzed artifacts. They interpret the ECZ and other proposed conveyance zones throughout the Great Basin as foraging territories, which may have been used throughout an individual forager's lifetime. Mobility in the ECZ is accounted for as forager groups with high residential mobility (Jones et al. 2003) or a logistically mobile organization (Madsen 2007) moved through an area exceeding 67,500 km². Jones et al. (2003) hypothesize that little social interaction occurred with regions to the east or west based on unused potential obsidian.

Madsen (2007) and Smith (2007, 2010) critiqued the ECZ's large range. They argue that prehistoric procurement strategies are more local than Jones et al. (2003) described. Newlander (2012) agreed with the limited conveyance zone model and suggested that analyzing conveyance zones from a subsistence framework is a narrow and ultimately inaccurate position to take; social and ideological necessities can account for long-distance obsidian conveyance patterns just as well. Smith (2007, 2010) and Jones et al. (2012) reviewed individual conveyance zones in the western and central

Great Basin and found that the expansive zones first proposed should be scaled back, though not to the extent prescribed by Newlander (2012).

The Wyoming Basin Obsidian Conveyance Zone (WBCZ) to the east was recently proposed by Harvey (2012). Covering between 65,000 and 90,000 km^2 the WBCZ is large, similar to the one originally proposed by Jones et al. (2003) in the Great Basin. Source use patterns show a reliance on Malad and Bear Gulch, Idaho obsidian and Teton Pass 1 and 2, Wyoming obsidian. Notably the Obsidian Cliff, Wyoming source is under-used within the WBCZ. These four sources account for greater than 88 percent of the sample, which spans the entire Holocene. Harvey's (2012) analysis shows an obsidian procurement system that was fairly stable through time. Hypothesized explanations for this obsidian use pattern are kinship ties, population dynamics, and other social obligation systems with southeastern Idaho groups.

Metcalf and McDonald's (2012) studies include the Uinta Basin along with the southern Wyoming Basin and shows ties to southeastern Idaho obsidian toolstone. Their preliminary research showed continual and stable prehistoric use of southeastern Idaho obsidian throughout the Holocene with uneven use of other sources in New Mexico, northwestern Wyoming, and central Utah. Looking east and up into the Rocky Mountains, Pitblado (2003) examined raw material use in the low and high elevations of Colorado's Rocky Mountains. A generally local (< 40 km) use of raw materials occurred in the Late Paleoindian period. Quartzite and chert are both primary components of Rocky Mountain toolstone assemblages, though obsidian material (e.g., Malad, Idaho) does show up here in low frequency (Pitblado 1998; Pitblado et al. 2013).

Southern Idaho Obsidian Sources and Known Sourcing Studies. Volcanic activity is a major force shaping the southern Idaho landscape. The Snake River Plain (SRP) formed as a rift filling with upwelling rhyolitic volcanic rock that was covered with younger basalt lava flows (Hughes et al. 1999; Mabey 1982). Volcanic activity in the SRP is associated with hot spot magmatism, a geologic phenomenon where a fixed plume of magma from Earth's mantle protrudes through the crust (Pierce et al. 2007). Alt and Hyndman (1989) hypothesize that the hot spot is related to a meteor that struck southeastern Oregon 17 Ma. This stable hot spot created the northeast trending SRP as the North American tectonic plate moved west across it. Genesis of the southwestern portion of the SRP is approximately12 Ma while the younger northeastern SRP geologic units date to about 500,000 Ka (Malde 1991). Quaternary volcanic features of the SRP are basaltic lava flows, shield volcanoes, and rhyolitic domes (Hughes et al. 1999).

As a result of volcanism in Idaho, obsidian and other toolstone quality volcanics are prevalent throughout the region (Figure 7). Holmer (1997) reported that Malad, Timber Butte, Big Southern Butte, Browns Bench, and Big Table Mountain were the five most used Idaho obsidian sources. Material from these sources was transported great distances (Holmer 1997; Thompson 2004), while 30-50 additional sources were used in localized contexts (Bailey 1992; Holmer 1997; Plager 2001; Sappington 1981, 1982; Willson 2007) (Table 3). Appendix 2 provides a complete list of Idaho obsidian sources. Archaeological understandings of these obsidian sources and their prehistoric exploitation results from source-based and major site-based studies (Arkush 2002; Bailey

1992; Corn 2006; Gallagher 1979; Harris 2011; Lohse et al. 2010; Raley 2011; Thompson 2004; Wells 1980; Willingham 1995).

Idaho's many volcanic resources supplied hunter-gatherers with a reliable and exploitable toolstone resource, which produced a record that archaeologists have analyzed for patterns of mobility, exchange, and territoriality (Plew 2008; Willson 2007). Holmer (1997) concluded that three regional conveyance patterns using primarily local obsidian dominated eastern Idaho: the Central Mountains, the Snake River Plain, and the southeastern Idaho mountains (Figure 8). Obsidian conveyance from the SRP to different regions was limited. More common was obsidian conveyance along the length of the SRP from Bear Gulch and Big Southern Butte to southwestern Idaho, while Owyhee and Timber Butte source material was conveyed to the northeastern SRP. Holmer (1997) interpreted these patterns as highly mobile hunter-gatherers making either long distance

Table 3. Expected Sources in Southern Idaho Conveyance Zones.

Source Name	**Other Names**
American Falls	Walcott, Snake River, Deep Creek
Bear Gulch	Big Table Mountain, Camas/Dry Creek, Centennial Mountain, F.M.Y. 90 Group, Reas Pass
Big Southern Butte	Webb Spring
Browns Bench Ignimbrite	Rock Creek, Mahogany Butte, Coal Bank Spring, Hudson Ridge, Jackpot
Chesterfield	Smith Creek
Kelly Canyon	Kelly, Kelley Canyon, Kelley's Canyon
Malad	Wright Creek, Oneida, Hawkins, Dairy Creek, Garden Creek Gap
Owyhee 1 & 2	Brown's Castle, Oreana, Toy Pass
Packsaddle Creek	Pack Saddle
Teton Pass 1 & 2	Fish Creek 1, Fish Creek/McNeely Ranch, Mosquito Creek, Phillips Ridge
Timber Butte	Squaw Butte, Webb Creek

movements or many short-term camps used at shorter intervals along a seasonal foraging route. High mobility is suggested from diversity and distance from source during the Early Holocene, then as climate warmed and dried mobility decreased in the Middle Holocene. The return of mesic climate during the Late Archaic coincided with a peak in forager mobility (Holmer 1997). Plager (2001) expanded on Holmer's dataset to include all of southern Idaho and confirmed his preliminary results about transport along the SRP and distinct regional obsidian transport patterns (Figure 9).

Thompson's (2004) thesis investigated the occurrence of Malad, Idaho obsidian across the Great Basin and southern Plains. Malad obsidian was transported to the west across southern Idaho and northern Utah, but a bimodal distribution existed to the southeast into the Plains, especially during the late Prehistoric. Willson (2007) reevaluated southern Idaho obsidian data and confirmed many of Holmer's (1997) and Plager's (2001) conclusions, but cautioned against interpretations of the data that may be statistically indefensible. Harris (2011) conducted a recent prehistoric land use study of a single site (10BT8) northwest of Idaho Falls, Idaho in the foothills of the Lemhi Mountains. She analyzed Middle Archaic to Historic obsidian use and found approximately a 150 km obsidian procurement range, with both nearby and distant sources used. Variation in the conveyance zone occurred with a late Archaic contraction, but expanded again in the Late Prehistoric.

Henrikson's (2008) study east of 10BT8 analyzed regional obsidian use surrounding Craters of the Moon National Park throughout the late Holocene. Long-term source use was local, but the frequency with which sources were used varied

Figure 7. Map of Idaho obsidian sources.

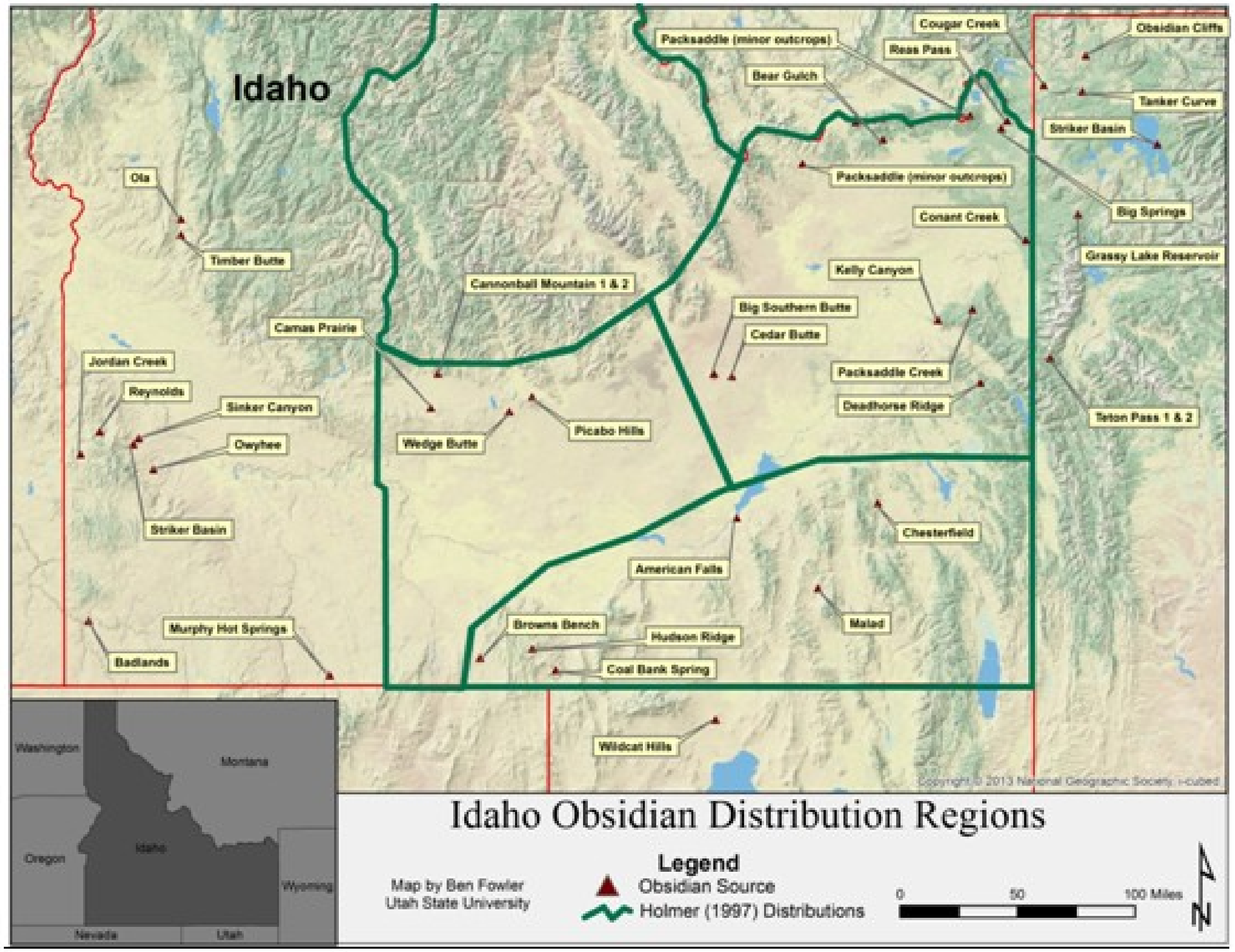

Figure 8. Four obsidian distribution regions adapted from Holmer (1997).

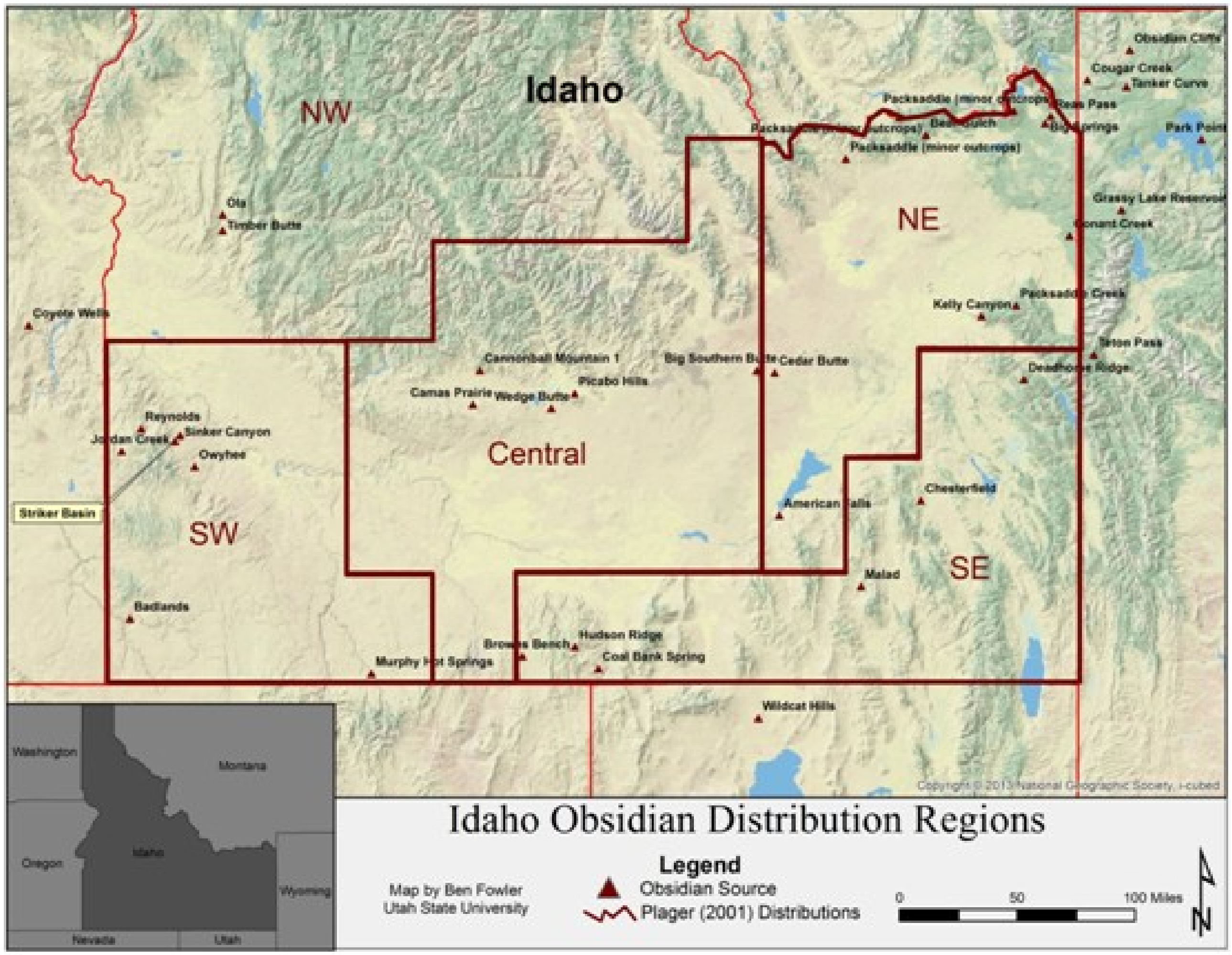

Figure 9. Five obsidian distribution regions adapted from Plager (2001).

diachronically. Though differences between dart points and bow and arrow points are evident, she concluded that changes in landscape use related to volcanic flow barriers rather than shifts in mobility brought on by climate variability or technological change.

Data Analysis

Geographic Information Systems (GIS). Geographic Information Systems (GIS) enable the visualization of spatial data, as well as the ability to interpret data through analysis to understand relationships and patterns. Exploratory spatial data analysis and more sophisticated spatial analyses were performed in this study using ESRI's ArcGIS 10.1 software. Anselin (1999) described exploratory spatial data analysis as useful for eliciting patterns and inductive hypotheses while visually allowing the spatial data to speak for itself.

Each artifact in this study is linked to an archaeological site that was represented spatially. Sites were then clustered based on their obsidian source profiles using hierarchical clustering analysis (HCA), available in SPSS 22, which I discuss in the statistical methods section below. Statistically clustered site groups represent conveyance zones. To bound sites in each conveyance zone I used the directional distribution tool in ArcGIS at the specified level of two standard deviations. This spatial statistic creates standard deviational ellipses, physically bounding each conveyance zone, by considering the direction trend, dispersion, and central tendency of the sample (Scott and Janikas 2010). An area for each ellipse was also calculated, enabling comparison between conveyance zones and across temporal periods. One of the strengths of spatial data analysis occurs when the results of these analyses are shown both in tables and representative maps.

Quantitative Analysis. I used quantitative analysis methods in this study to explore data with descriptive and inferential statistics. The descriptive statistical methods include mean, standard deviation, frequency, and proportions, which characterize the dataset and to show the dispersion and central tendency of the data. Inferential statistical methods measure causality between variables and uncertainty in the data. I use cluster analysis, the Student's t-test, analysis of variance (ANOVA), Pearson's r, and Shannon's diversity index.

Before beginning the analysis I removed obsidian sources that are outliers, which each represent less than 0.1 percent of the overall sample. I also removed the Salmon Falls/House Creek and Three Creek Landfill sources since they are newly identified by Glascock (2012), and the single report available does not allow the sources to be well integrated into this study's conveyance zones. Sites that had only a single sourced artifact were also removed from the analysis, since they could not be effectively integrated into the hierarchical cluster analysis. Following these decisions the remaining dataset contains 3,640 artifacts attributable to 243 sites; I use this set of selected data throughout my analysis unless stated otherwise.

I began analysis by using hierarchical cluster analysis (HCA) in SPSS 22 with the Ward's method measured by squared Euclidian distance, which clusters a single case of data with another based on similarities (Drennan 2010). In this case, a pair of sites is created based on the percentage of obsidian source contribution profile for each site; the aggregating process continues until each site is assigned to a cluster. Clustering based on percentage of source contribution removes the bias that artifact frequency creates and allows sites to be clustered according to a profile of individual sources conveyed to that location. Holmer (1997) and Plager (2001) used this clustering method to aggregate data into counties and 30-minute grid cells, respectively. The methodology in this study produces clusters at the site level rather than using current political boundaries or a set of grid cells to increase precision in conveyance zone size so changes are more easily observable.

In order to test relationships between two or more variables I employ tests of confidence and strength, which are briefly discussed below. The t-test pools data from two samples and creates a probability statement that measures the likelihood that both samples could actually be from the same population. The t-test provides the statement of confidence that the results are not attributable to the vagaries of sampling (Drennan 2010). ANOVA tests the same premise as the t-test, while allowing for more than two samples to be considered at the same time (Drennan 2010). Pearson's r statistic examines the linear relationship between two measurement variables by creating a best-fit straight line and assessing how good the best-fit is and provides a F statistic that indicates how strong the correlation is between the two variables (Drennan 2010).

Another statistical tool employed during analysis was the Shannon diversity index (Shannon and Weaver 1949), which is a mathematical measure that normalizes and quantifies a sample's diversity (Beals et al. 2000; Magurran 2004). Diversity encompasses richness and evenness (Pielou 1977; Smith and Wilson 1996). Richness is the number of obsidian sources in the sample, while evenness takes into account the relative abundance of different sources and how it is distributed across all sources (Beals et al. 2000; Grayson 1984). The scale of evenness produces values from zero, where a single source dominates, to one, representing an even distribution of obsidian across all sources. Shannon's diversity index provides important information about the rarity and commonness of species in a community (Beals et al. 2000). Scheiber and Finley (2011) and Holmer (1997) are examples of archaeological research using Shannon's diversity index to study richness and evenness of conveyed obsidian artifacts. An examination of obsidian source diversity and evenness in the conveyance zones during each climatic period allows for tests of the research model's predictions about changing forager mobility and the use of obsidian across the landscape.

ANALYSIS

This section presents analysis based on the research methodology that uses the collected dataset comprising 4,440 sourced obsidian artifacts from 33 southern Idaho counties. I suggest that future XRF studies be formulated on strong research designs and sampling strategies that allows them to contribute to this dataset and future questions regarding forager behavior. The rich dataset analyzed here is used to explore questions about Holocene toolstone conveyance and changing forager mobility. I begin by summarizing the important dataset variables, among which are artifact age, artifact function, provenience, and sample size per site and cultural period. Next, I discuss the construction of conveyance zones. The analysis uses the original obsidian dataset to create site clusters using the similarity of obsidian source profiles from percentage source contribution at each site. These clusters form trans-Holocene conveyance zones. Diachronic analysis follows as the obsidian dataset is divided into climatic periods based on the model to test the hypothesis and expectations I have set forth. Cluster analysis for each climatic period yielded four conveyance zones. Site clusters forming a conveyance zone are then statistically bounded with a standard deviational ellipse and the area of conveyance is measured in ArcGIS. Finally, diversity and evenness measures are produced for each conveyance zone across all periods and a Pearson's r correlation is conducted to examine potential relationships between conveyance zone size and obsidian diversity and evenness.

Basic Analysis

The southern Idaho sourced obsidian dataset consists of 4,440 artifacts from 640 sites spread across 33 Idaho counties. Artifact data were obtained from numerous reports, theses, journal articles, and personal communications (Appendix 1). Particular effort was given to avoid duplicating artifact entries in the dataset and to exclude questionable sourcing results. The Idaho SHPO provided site locations for recorded sites affiliated with 4,207 artifacts in the dataset. For an additional 233 artifacts (6 percent) provenience can only be determined at the county or regional scale. The numbers of sourced artifacts per site range between 1 and 506, and fewer than 10 percent of sites have ten or more sourced artifacts. Twenty-six sites contain more than 30 artifacts and three hundred eighty-four sites (60 percent) are represented by only one sourced artifact.

The dataset contains 4,284 artifacts assigned to 37 obsidian sources (Figure 7). Twenty-two of these sources are from Idaho, while seven are found in Oregon, three in Nevada, two in Wyoming, and two sources (Goodrich and Kepler) with unknown locations. These two sources are not discussed further since only three artifacts match the sources. The remaining 156 artifacts (4 percent) are coded as "Unknown" since no geochemical source profile matches the measured sample's geochemical fingerprint.

Nine Idaho obsidian sources contribute the majority of the dataset's sourced artifacts (Table 4). The most prominent source is Timber Butte, representing 30 percent (n = 1,330) of sourced artifacts. Artifacts from Malad and Bear Gulch constitute 19 percent (n = 834) and 10 percent (n = 451) of the sample, respectively. Big Southern Butte, American Falls, and Browns Bench each represent less than 10 percent of the

Table 4. Obsidian Source Contribution to Overall Sourced Artifact Database.

Source	Frequency	Percent of Sourced Obsidian
American Falls	333	8
Bear Gulch	451	10
Big Southern Butte	410	9
Browns Bench	317	7
Malad	834	19
Owyhee	159	4
Timber Butte	1,330	30

sourced artifacts. The Owyhee obsidian source, which Willson (2007) classified as a major prehistoric toolstone source, represents only four percent of this dataset.

Distance-to-source measurements quantify the geodesic distance that toolstone was transported from a geologic source before discard (Table 5). Geodesic measurement provides an accurate distance measurement taking into account the curved distance of the earth. The overall mean distance obsidian artifacts were conveyed from all sources is 96 kilometers, and that statistic remains nearly the same when only major sources are considered. The maximum distance a single artifact was conveyed is 533 kilometers, from Obsidian Cliff, Wyoming to a site in Owyhee County, Idaho. Bear Gulch obsidian was also transported 423 kilometers in the same direction. Timber Butte, Owyhee, Malad, and Big Southern Butte were also conveyed over 300 kilometers. One noticeable pattern in mean conveyance distance is that Snake River Plain obsidian from American Falls, Bear Gulch, Browns Bench, Cannonball Mountain, and Owyhee were transported further on average (Table 5). The one exception is Big Southern Butte obsidian, which on average is used within a smaller region. Conveyance from Timber Butte, Malad, and Three Creek Landfill is also smaller on average; obsidian conveyance across shorter

Table 5. Distance in Kilometers from Artifacts to Primary Obsidian Sources.

Source	Max Distance to Source	Mean Distance to Source	Standard Deviation
American Falls	276	112	40
Bear Gulch	423	120	91
Big Southern Butte	355	77	58
Browns Bench	259	103	56
Cannonball Mountain	245	104	42
Malad	359	70	54
Owyhee	338	120	99
Three Creek Landfill	88	32	21
Timber Butte	324	89	69

distances may be explained by more intensive regional use, sampling issues, or other yet to be tested hypotheses.

I also calculated the standard deviation for mean distance-to-source to provide additional information about the patterned spread of obsidian as it was conveyed from a source. Large standard deviations may indicate widespread conveyance for a source or a bimodal distribution as Thompson's (2004) study of Malad obsidian found. For example, mean transport distance for Bear Gulch and Owyhee sources is 120 kilometers, and the standard deviation for each is more than 90 kilometers indicating that both sources are widely dispersed across the region. By contrast, obsidian from Three Creek Landfill exhibits a low mean distance to source and a relatively small standard deviation indicating that it was not dispersed widely throughout the region. Measuring mean conveyance distances and obsidian dispersion informs this research by describing obsidian acquisition and discard behavior and conveyance practices within different conveyance zones. These analyses can also inform other forager behavior questions, relating to foraging activities, seasonal effects on foraging ranges, and risk-mitigating strategies associated with toolstone acquisition. An ANOVA test of the mean distance-to-source for obsidian sources returns a highly significant difference between the mean conveyance distances of American Falls, Bear Gulch, Big Southern Butte, Browns Bench, Malad, Owyhee, and Timber Butte ($F = 42.277$, $p < .001$).

Sourced artifacts are associated with an artifact type whenever possible, which indicates implied information regarding tool function and behavior (Table 6). Two thousand two hundred forty-two artifacts (50.5 percent) have an assigned artifact type and the remainder are reported with no type. Thirty-four percent of sourced artifacts are projectile points ($n = 1,525$) reflecting a research bias of selecting diagnostic tools for XRF analysis. Utilized flakes, cores, debitage, and other tool types each convey different behavioral information about prehistoric mobility and lithic toolkit composition and maintenance (Bamforth 2009; Kuhn 1994).

Examining mean distance-to-source measurements for artifact types shows that projectile points were conveyed 93 kilometers, farther on average than bifaces, utilized flakes, and debitage (Table 7). Debitage is found on average 88 kilometers, utilized flakes 82 kilometers, and bifaces 80 kilometers from the parent source. Standard deviations reveal that variability from the mean is higher for projectile point and debitage samples than utilized flakes and bifaces. An ANOVA test of mean distance-to-source for bifaces, cores, debitage, flake tools, projectile points, preforms, and utilized flakes throughout the Holocene has very high significance ($F = 4.379$, $p < 0.001$). Performing the same test on the highest frequency artifact types, bifaces, debitage, projectile points, and utilized flakes results in high significance, though somewhat lower than the more inclusive comparison of means ($F = 3.79$, $p < 0.02$). I find that prehistoric foragers transported projectile points farthest, supporting arguments that they are a highly curated artifact type and are likely to have a higher mean conveyance distance (Bamforth 2009). Bifaces and utilized flakes were conveyed shorter distances on average, which indicates that these tools were more expedient or worn and discarded more quickly. Sites containing bifaces and utilized flakes may represent prehistoric behavior occurring after a toolstone acquisition event as the group moves away from the obsidian source. It is interesting that mean debitage and core conveyance is higher than for bifaces and utilized flakes. A robust research design utilizing debitage analysis and obsidian sourcing could reveal answers that speak to the type of behavior, tool rejuvenation versus core transport and tool manufacture that created a pattern of obsidian debitage conveyed 88 kilometers on

Table 6. Specific Artifact Type Frequencies and Percentage of Dataset Composition.

Artifact Type	Frequency	Percentage
Biface	199	4.5
Burin	2	0.1
Blade	1	0
Core	17	0.4
Debitage	383	8.6
Flake Tool	27	0.6
Graver	3	0.1
Perforator	2	0.1
Projectile Point	1,525	34.4
Preform	13	0.3
Scraper	7	0.2
Utilized Flake	63	1.4
Unknown	2,198	49.5
Total	**4,440**	**100**

average.

Artifacts are also divided temporally into Paleoindian, Early Archaic, Middle Archaic, and Late Archaic periods. However, artifact age is commonly unreported and 2,237 (50 percent) artifacts are not associated with an age category (Table 8). Additionally, 577 (13 percent) artifacts are assigned to the General Archaic, a group that contains unclassified side- and corner- notched points, as well as projectile point styles like Elko, Stemmed Indented-Base, and Humboldt that were used throughout much of the Archaic (Holmer 2009). The General Archaic category helps insure that only artifacts directly attributable to different age groups are included in subsequent analyses. When the General Archaic and Unknown groups are removed from the sample, 1,626 artifacts remain in the four general periods. The Late Archaic has the most artifacts (n = 838), while the Paleoindian period has the fewest (n = 218). The Early and Middle Archaic contain 280 and 290 artifacts, respectively.

Climatic periods are assigned to artifacts when possible and are central to my research model; these periods track the previously identified cultural periods (Table 1). The one exception is the Paleoindian period which is divided into early and late Paleoindian corresponding to the Late Pleistocene and the Early Holocene (Periods 1 and 2). Period 1 includes 43 artifacts and Period 2 contains 175 artifacts. Period 3 matches the Early Archaic, Period 4 the Middle Archaic, and Period 5 the Late Archaic. Distance-to-source measurement analysis indicates that mean conveyance distance from obsidian sources vary throughout the Holocene (Table 9). During the Paleoindian period artifacts were conveyed an average of 90 kilometers. Early Archaic artifacts were conveyed 82

Table 7. Distance in Kilometers from Artifact Types to Obsidian Sources.

Source	Mean Distance to Source	Standard Deviation
Biface	80	46
Core	88	46
Debitage	88	62
Flake Tool	123	15
Graver	131	122
Preform	48	28
Projectile Point	93	61
Scraper	90	41
Utilized Flake	82	32

kilometers, the shortest distance of any Holocene period. Middle Archaic conveyance distance increased to 85 kilometers, part of an upward trend to a mean of 99 kilometers for artifacts in the Late Archaic. An ANOVA of mean distance-to-source and climatic period is not statistically significant ($F = 1.097$, $p = 0.356$). These data suggest that the differences observed in mean distance-to-source throughout the Holocene may be attributable to the particular sample of artifacts currently sourced from the total population of Idaho obsidian artifacts. Alternatively, prehistoric mobility around obsidian sources may have be organized or constrained in ways that did not create statistically significant differences in mean conveyance distance.

Projectile point typology serves to further divide General Age categories (Holmer 2009). The most common projectile point style is Elko, comprising 26 percent of the sample (n=349). Rose Spring, Northern Side-Notched, and Desert Side-Notched each constitute less than nine percent of the projectile point style data. Avonlea, Stemmed Indented-Base, Cottonwood, Rosegate, Gatecliff, and Haskett projectile points each compose between two and seven percent of the data. These projectile point styles are

Table 8. General Age of Sourced Obsidian Artifacts.

Source	Frequency	Percentage
Paleoindian	218	5
Early Archaic	280	6
Middle Archaic	290	7
Late Archaic	838	19
General Archaic	577	13
Unknown	2,237	50
Total	**4,440**	**100**

most common in the dataset, but combining multiple projectile points from a single period or associated with a cultural or behavioral adaptation increases sample size for the analysis. For example, Cottonwood, Desert Side-Notched, and Desert Tri-Notched points combined account for 12 percent of the sample (n=166). These projectile points date to the terminal Late Archaic and are representative of southern Idaho Shoshonean occupation of (Plew 2008). Analysis of projectile point style by source should be pursued at the regional and site scales since the sampling and prehistoric behavior contexts are more easily understood. Clovis artifacts (n = 12), for example, originate from Big Southern Butte (8 percent), Crescent H (8 percent), Malad (67 percent), and Teton Pass (17 percent). These eastern Idaho artifacts were added to the sourcing record by this study, which influences the obsidian sources likely to be used. More ubiquitous styles like Elko points, which source to 14 different locations may present a clearer picture of source use by style.

I examined projectile point typology distance-to-source data to further illuminate trends noted from analysis of General Age. The previously discussed sampling issues must be considered, and analysis is most appropriate at regional and site scales. The mean

Table 9. Distance-to-Source in Kilometers for General Age Artifact Groups.

Source	Mean Distance to Source	Standard Deviation
Paleoindian	90	60
Early Archaic	82	53
Middle Archaic	85	61
Late Archaic	90	56

distance-to-source for Clovis points is 97 kilometers and 74 kilometers for Folsom points. Styles that rank among those conveyed the farthest are Late Archaic period Desert Side-Notched (110 kilometers), Desert Tri-Notched (107 kilometers), and Rosegate (114 kilometers). Among the styles conveyed the shortest distance are the Early and Middle Archaic Pinto (52 kilometers) and Side-Notched points (53 kilometers). These results may be attributable to the climatic transition from the xeric Middle Holocene to the mesic Late Holocene, which fits the foraging model in this study that predicts higher foraging mobility during periods of increased environmental productivity (Table 1).

Conveyance Zone Construction

Trans-Holocene Hierarchical Cluster Analysis. Analysis of the model's hypotheses and expectations is based on a selected dataset containing 3,640 artifacts attributable to 243 sites. I use this set of selected data from this point forward unless stated otherwise. To examine obsidian conveyance I used hierarchical cluster analysis with the Ward's method measured by squared Euclidian distance in SPSS 22 to cluster sites based on the percentage of obsidian source contributions at each site. Clustering based on percentage of source contribution removes the bias of artifact frequency and allows sites to be clustered based on a profile of the conveyed sources. Holmer (1997) and Plager (2001) used this clustering method to cluster data aggregated into counties and 30-minute grid cells respectively. I produced clusters at the site level rather than using current political boundaries or a set of grid cells to increase precision in conveyance zone size so changes are more easily observable.

Hierarchical clustering results for trans-Holocene data produced four clusters with a cutoff distance of five on the rescaled log scale, where 0 indicates the closest relationship between clustered sites and 25 the most distantly related in the clustering process (Appendix 3:A). I interpret the four clusters as groups of sites representing conveyance zones, which are centered on a key obsidian source or geographic area. I hereafter refer to them by their proposed names: Malad Conveyance Zone (MCZ), Timber Butte Conveyance Zone (TBCZ), Big Southern Butte Conveyance Zone (BSBCZ), and Snake River Conveyance Zone (SRCZ). Obsidian source composition in each conveyance zone is shown in Figure 10, and the zones' spatial extents in Figure 11. The MCZ contains 38 sites, which are dominated by the Malad obsidian source (64 percent). Packsaddle Creek represents nine percent of the sample with Chesterfield, Ola, Browns Bench, and Teton Pass each representing between three and six percent of the obsidian sources. The TBCZ contains 92 sites with obsidian conveyed primarily from the Timber Butte (81 percent) and Bear Gulch (9 percent) sources. The BSBCZ contains 41 sites, which are dominated by the Big Southern Butte source (62 percent). American Falls is also prominent (16 percent), while less frequent sources like Malad, Bear Gulch, Owyhee, and Timber Butte each compose between three and seven percent of the sample. The final cluster is the SRCZ containing 72 sites represented by a more diverse suite of sources. Bear Gulch, Browns Bench, American Falls, Owyhee, and Big Southern Butte each represent 11 to 24 percent of the sample. Obsidian Cliff and Cannonball Mountain each represent between three and six percent of the conveyed obsidian, with a number of other less frequent sources represented in the SRCZ.

Hierarchical Cluster Analysis By Climatic Period. The next analytical step separates sites based on the climate periods outlined in the research model (Table 1). Period 1 is not included in this analysis because sample size is insufficient. Five sites date to the Late Pleistocene and though they are generally located in southeastern Idaho, a statistical clustering of sites could not be completed. One hundred sixty-six sites are attributed to climatic Periods 2 through 5 (Table 10). Hierarchical clustering analysis was run once per subset of sites in Periods 2 through 5. During each period four clusters were identified (Appendix 3:B - E). Clusters during each climatic period were attributed to the four proposed conveyance zones based on their obsidian source contribution profile. I find that regional associations with conveyance zones also remains generally consistent throughout the Holocene (Figures 12-19). The number of sites in the MCZ varies from 5 to 11 during different climatic periods. During Periods 2, 3, and 5 the conveyance zone is dominated by Malad obsidian with a small contribution from the Big Southern Butte source (Figure 13). The obsidian profile in Period 4 is more diverse with only 34 percent of obsidian from Malad and 29 percent from American Falls, while Bear Gulch and Big Southern Butte each contributed13 percent of the sample. The spatial extent of sites in Periods 2 and 3 is primarily limited to the far southeastern portion of the study area with

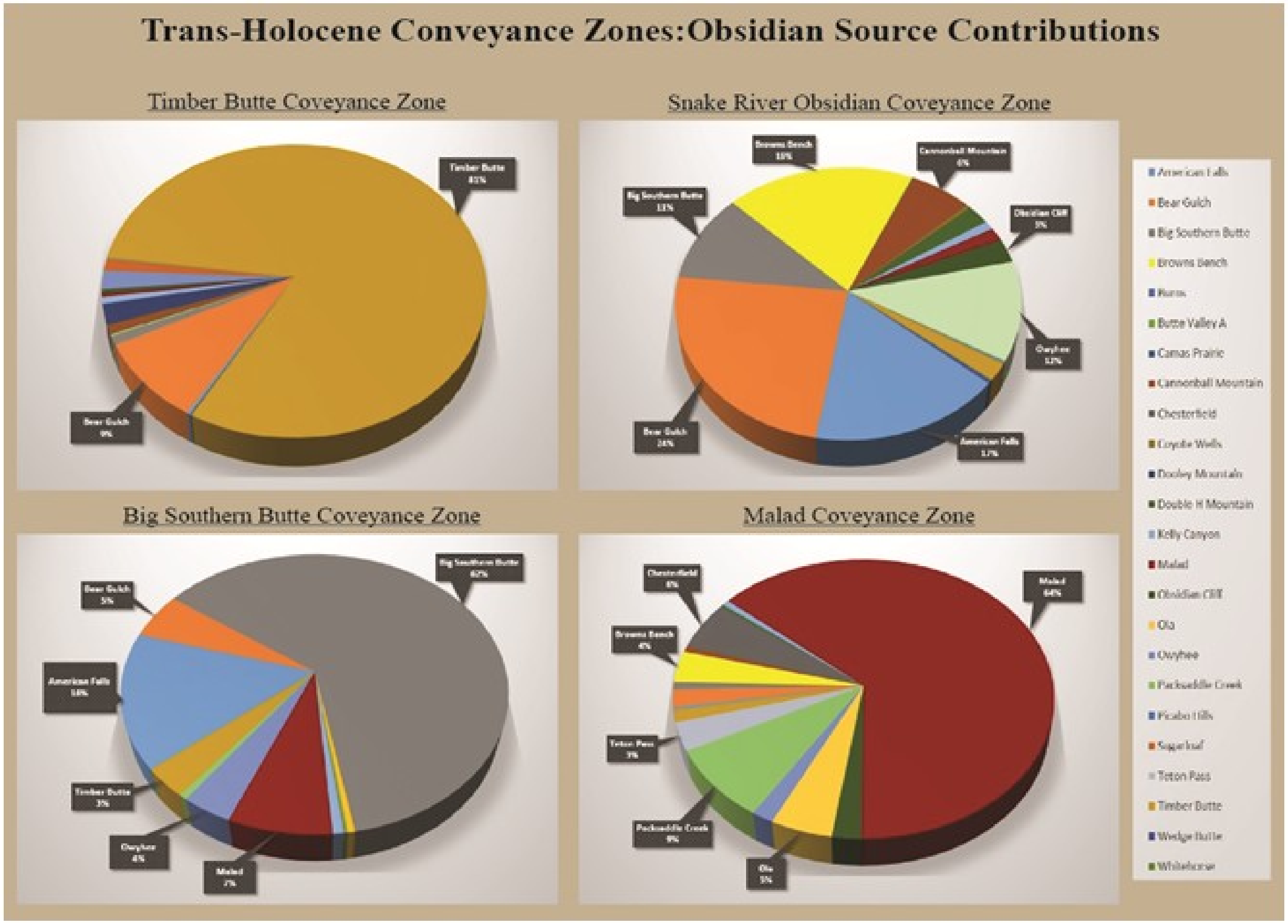

Figure 10. Contribution of obsidian sources in trans-Holocene conveyance zones.

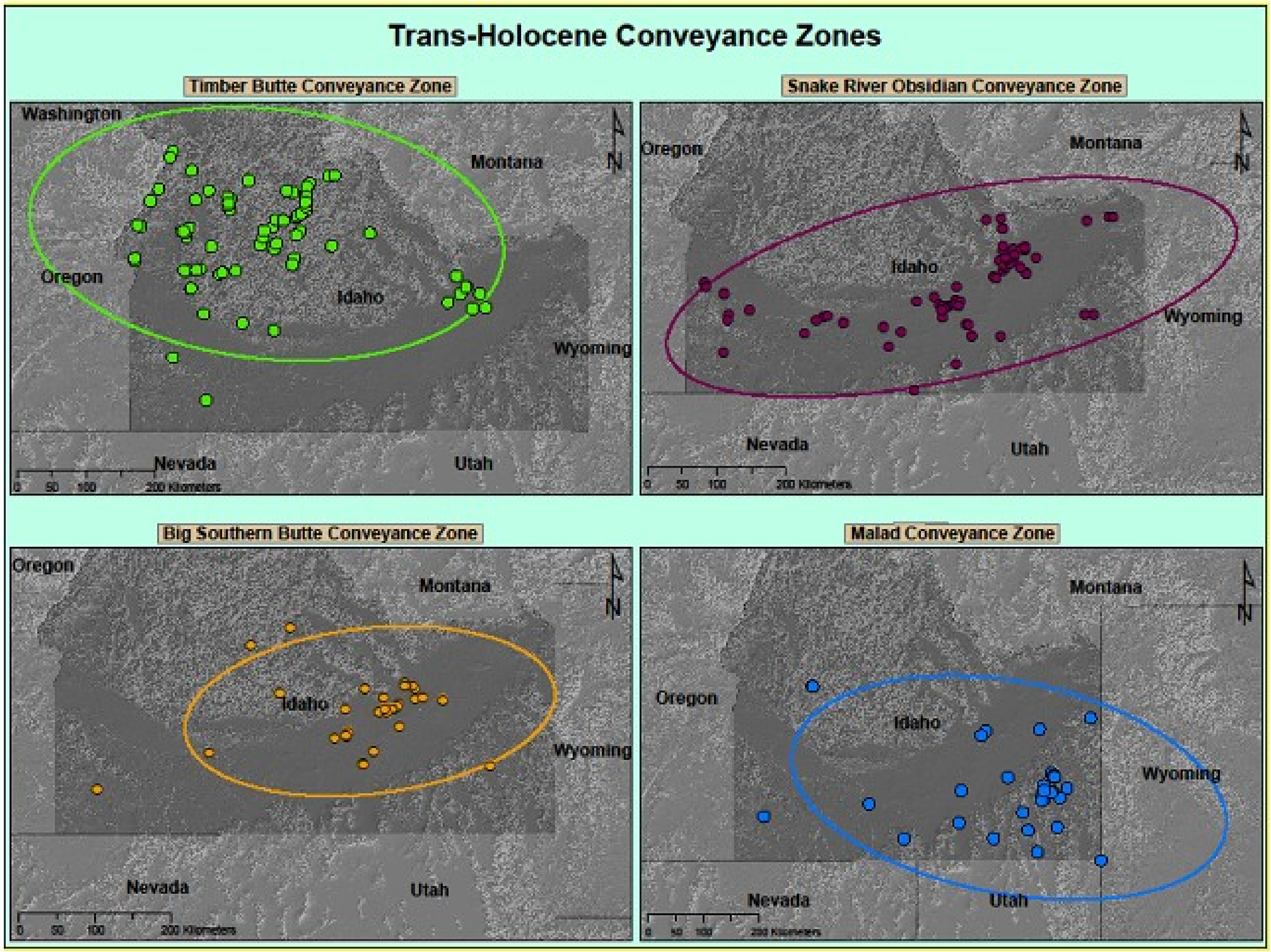

Figure 11.Four ellipses with clustered sites forming trans-Holocene conveyance zones.

Table 10. Number of Sites by Climate Period in Obsidian Conveyance Zones.

Climatic Period	**Trans-Holocene Sites**	**MCZ**	**TBCZ**	**BSBCZ**	**SRCZ**
2	35	9	5	11	10
3	24	5	4	5	10
4	28	11	6	6	5
5	79	11	30	12	26
Total	166	36	45	34	51

some conveyance into south-central Idaho (Figure 12). There are fewer sites in southeastern Idaho during Period 4, although the conveyance zone expands to include multiple sites in the eastern SRP. The site distribution in Period 5 is smaller than Period 4 but does include some sites in the eastern and central SRP.

The TBCZ has between 4 and 6 sites during Periods 2 through 4 and 30 sites in Period 5. Periods 2, 3, and 4 are dominated by the Timber Butte obsidian source, with a 17 percent contribution of Bear Gulch in Period 3 (Figure 15). Period 5 is the most diverse with Browns Bench and Big Southern Butte each contributing around 25 percent and Bear Gulch, American Falls, Malad, and Timber Butte each representing 5 to10 percent of the contributed obsidian. There are few sites in northwest Idaho that are attributable to a specific climatic period because the data were not collected or reported or only a single artifact was sourced from each site. The conveyance zone is not more expansive than other time periods, but includes many more sites in the central SRP.

Analysis shows that obsidian sources in the SRP were conveyed the length of the plain along the Snake River with only small contributions of obsidian from the southeast and northwest regions. The BSBCZ and SRCZ were distinguished based on the similarity of obsidian conveyance profiles to the trans-Holocene conveyance zones. While sites in these two groups are statistically clustered, distributions for these conveyance zones are often geographically indistinguishable (Figures 17 and 19). The BSBCZ has 6 to 12 sites in each period primarily located in the eastern portion of the SRP (Figure 16). During Periods 3 through 5 the Big Southern Butte source is dominant, accounting for between 93 and 100 percent of obsidian (Figure 17). In Period 2 Big Southern Butte is a primary source, but occurs in concert with large contributions of Bear Gulch and American Falls sources. The SRCZ has 5 to 26 sites in each period and along with the BSBCZ is the most tightly clustered conveyance region throughout the Holocene (Figure 18). The conveyance profile in Period 2 is interesting as the largest contributor is Malad obsidian. In the MCZ during Period 2 Malad is almost exclusively used in a narrow east to west conveyance zone (Figures 12 and 13). The Period 2 distribution in the SRCZ is spread north to south, and Packsaddle Creek obsidian is a large contributor with Browns Bench, Chesterfield, Obsidian Cliff, and Teton Pass also used (Figures 18 and 19). During Periods 3 and 5 Bear Gulch and American Falls are dominant sources. Other sources in the vicinity of the eastern SRP like Obsidian Cliff, Packsaddle Creek, and Teton Pass occur, as do Browns Bench, Cannonball Mountain, and Browns Bench from the west. Period 4 is unique with 93 percent of obsidian from Browns Bench and 7 percent from Big Southern Butte.

Statistically Bounding Conveyance Zones. The clustered sites with their obsidian source profiles described above are statistically derived conveyance zones. To bound sites in each conveyance zone for each of the four climatic periods I used the Directional

Distribution tool in ArcGIS at the specified level of two standard deviations. This spatial statistic creates standard deviational ellipses by considering the direction trend, dispersion, and central tendency of the sample (Scott and Janikas 2010). Ellipses area was calculated allowing comparison of conveyance zone size changes through time. Diachronic comparison of conveyance zones by climate period shows the sizes and percent change through time (Table 11). Additionally, the trans-Holocene conveyance zones provide a baseline against which conveyance zones for each climatic period are compared (Table 11). In the MCZ and TBCZ Period 3 zones are much smaller than in Period 2, while conveyance zones in the SRP expand between those periods; the SRCZ grows by almost 50 percent. Large increases in size occur between Periods 3 and 4 in the MCZ and TBCZ, also between Periods 4 and 5 in the BSBCZ. Large decreases occur between Periods 3 and 4 in the BSBCZ and the SRCZ and from Periods 4 to 5 in the MCZ and TBCZ.

Table 11. Conveyance Zone Sizes and Changes by Climate Period.

	MCZ (km^2)	**TBCZ (km^2)**	**BSBCZ (km^2)**	**SRCZ (km^2)**
Trans-Holocene	129,670	140,150	62,220	130,570
Period 2	174,610	208,210	43,270	33,060
Percent Change	-71	-89	+22	+43
Period 3	50,700	22,120	52,970	47,170
Percent Change	+298	+823	-69	-84
Period 4	201,940	204,290	16,170	7,680
Percent Change	-53	-56	+370	+67
Period 5	95,370	89,010	76,000	12,790

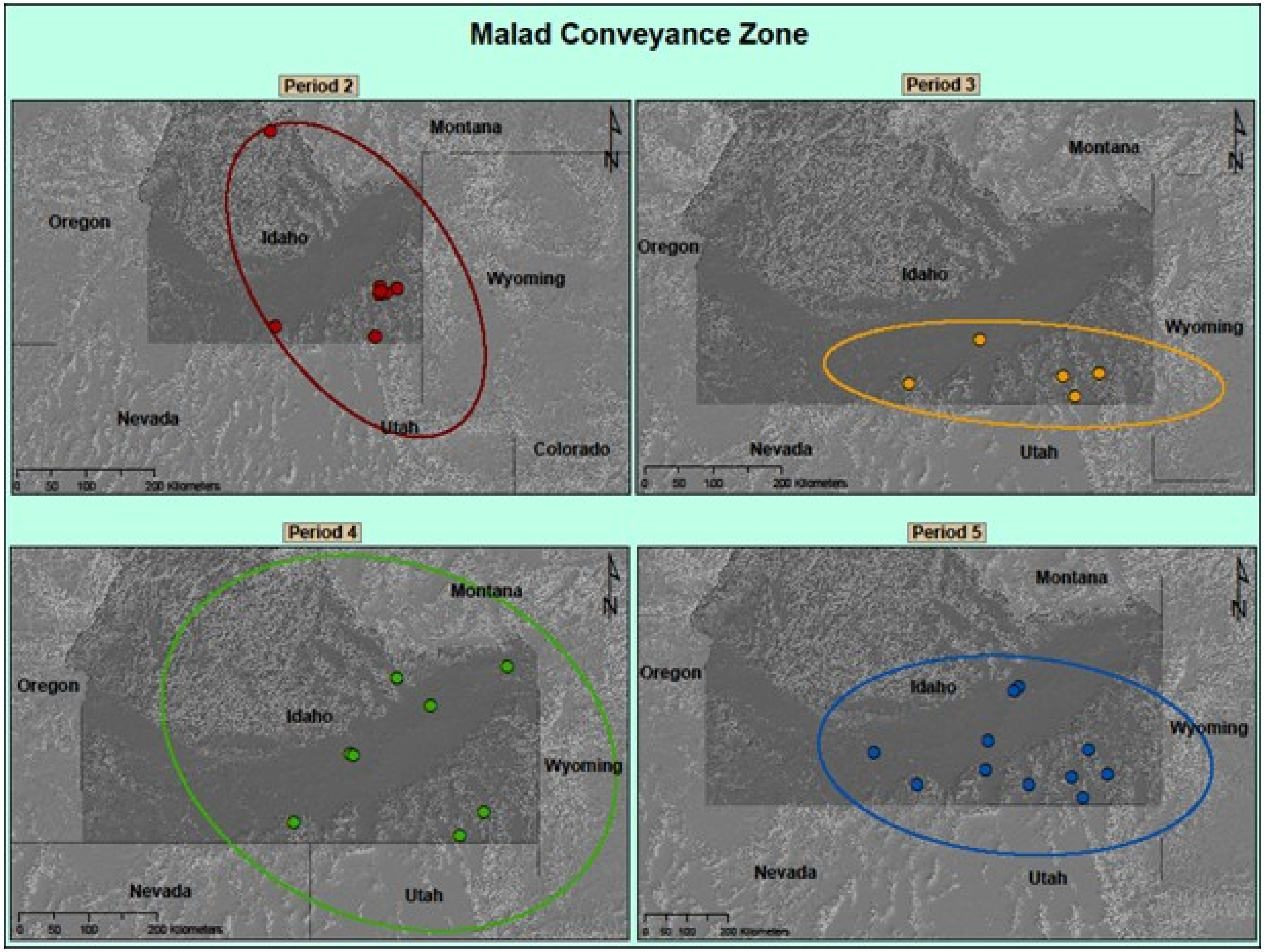

Figure 12. Map of four ellipses with clustered sites in the Malad Conveyance Zone during Periods 2 through 5.

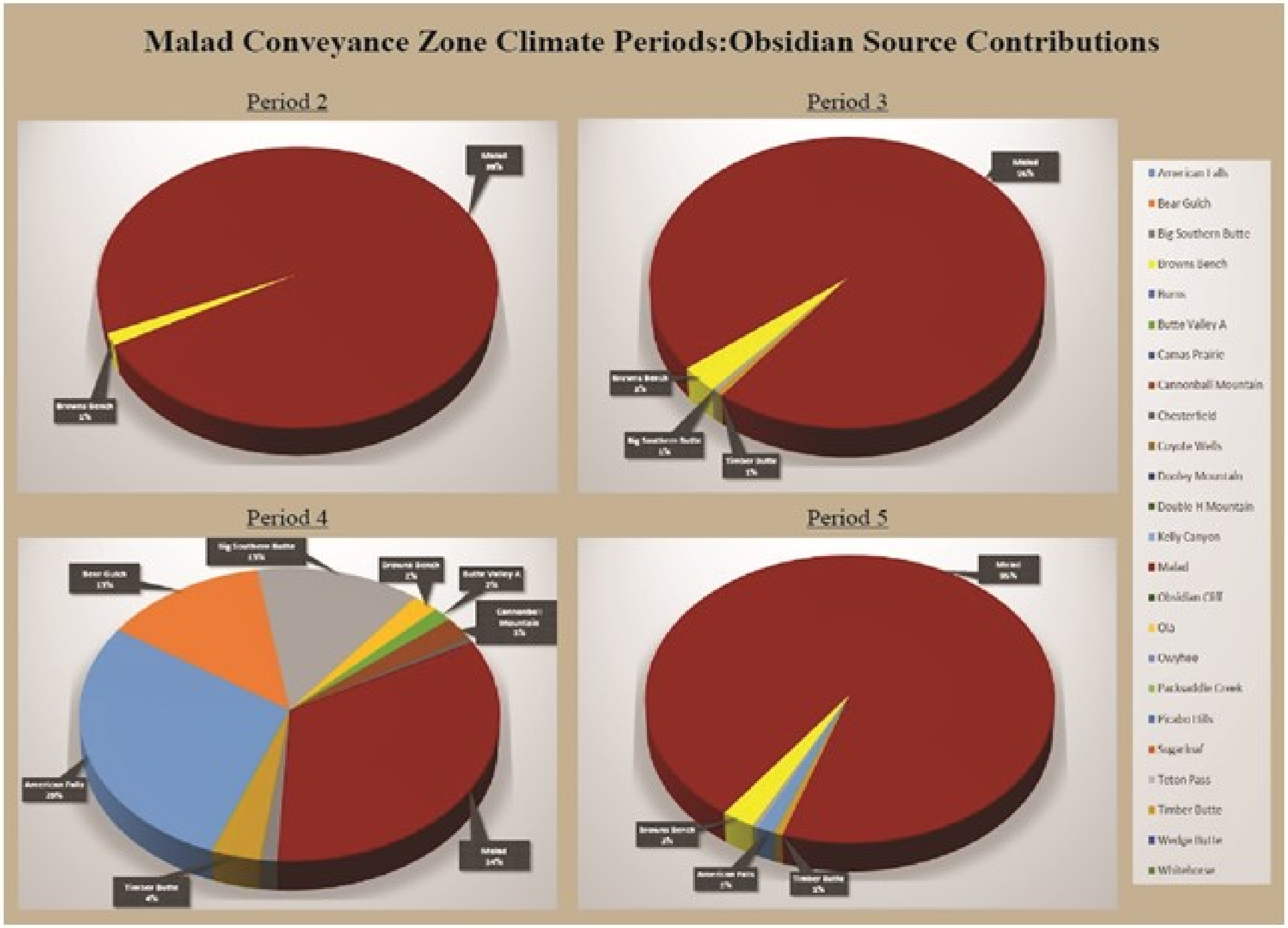

Figure 13. Contribution of obsidian sources in the Malad Conveyance Zone during Periods 2 through 5.

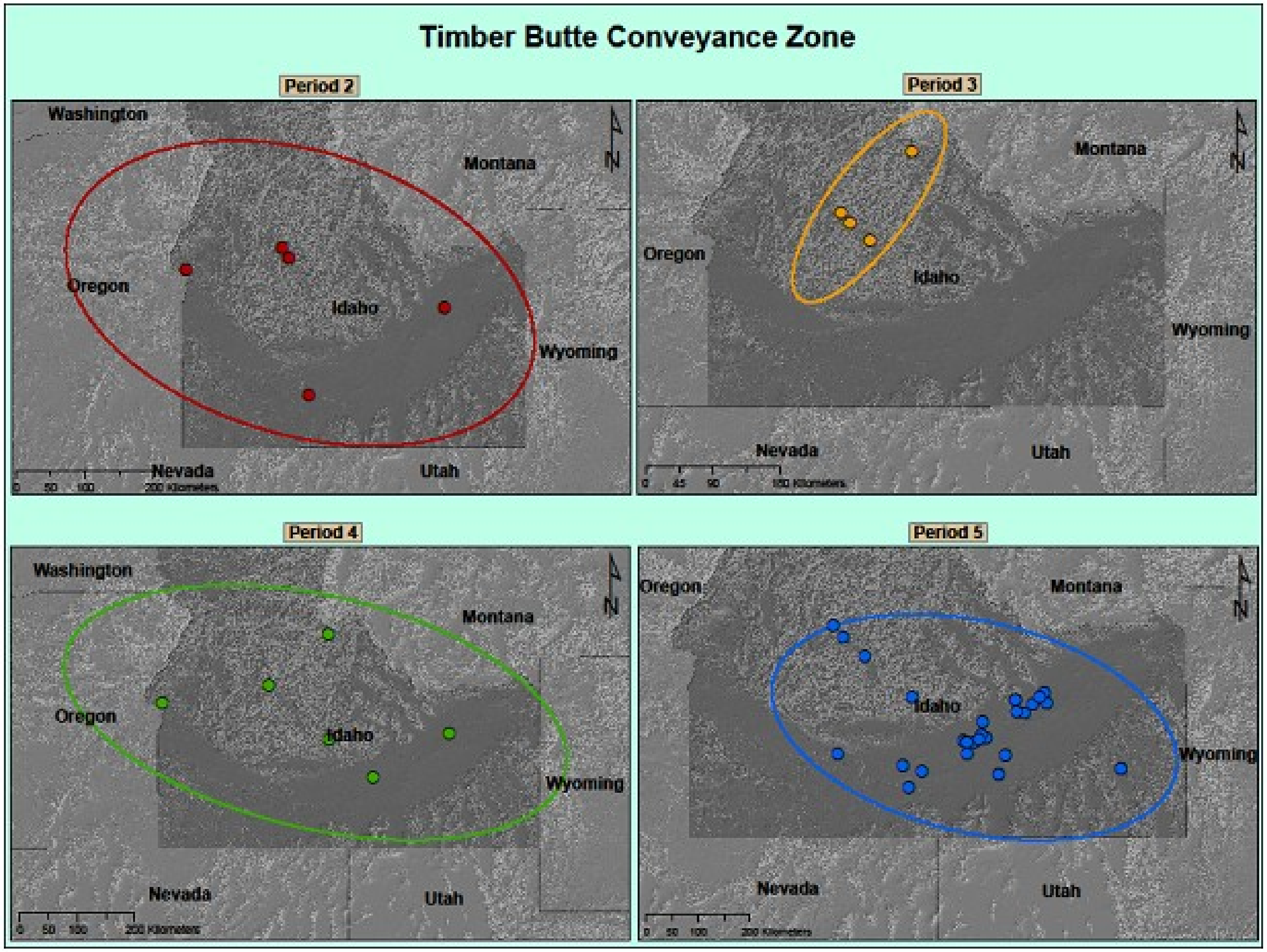

Figure 14. Map of four ellipses with clustered sites in the Timber Butte Conveyance Zone during Periods 2 through 5.

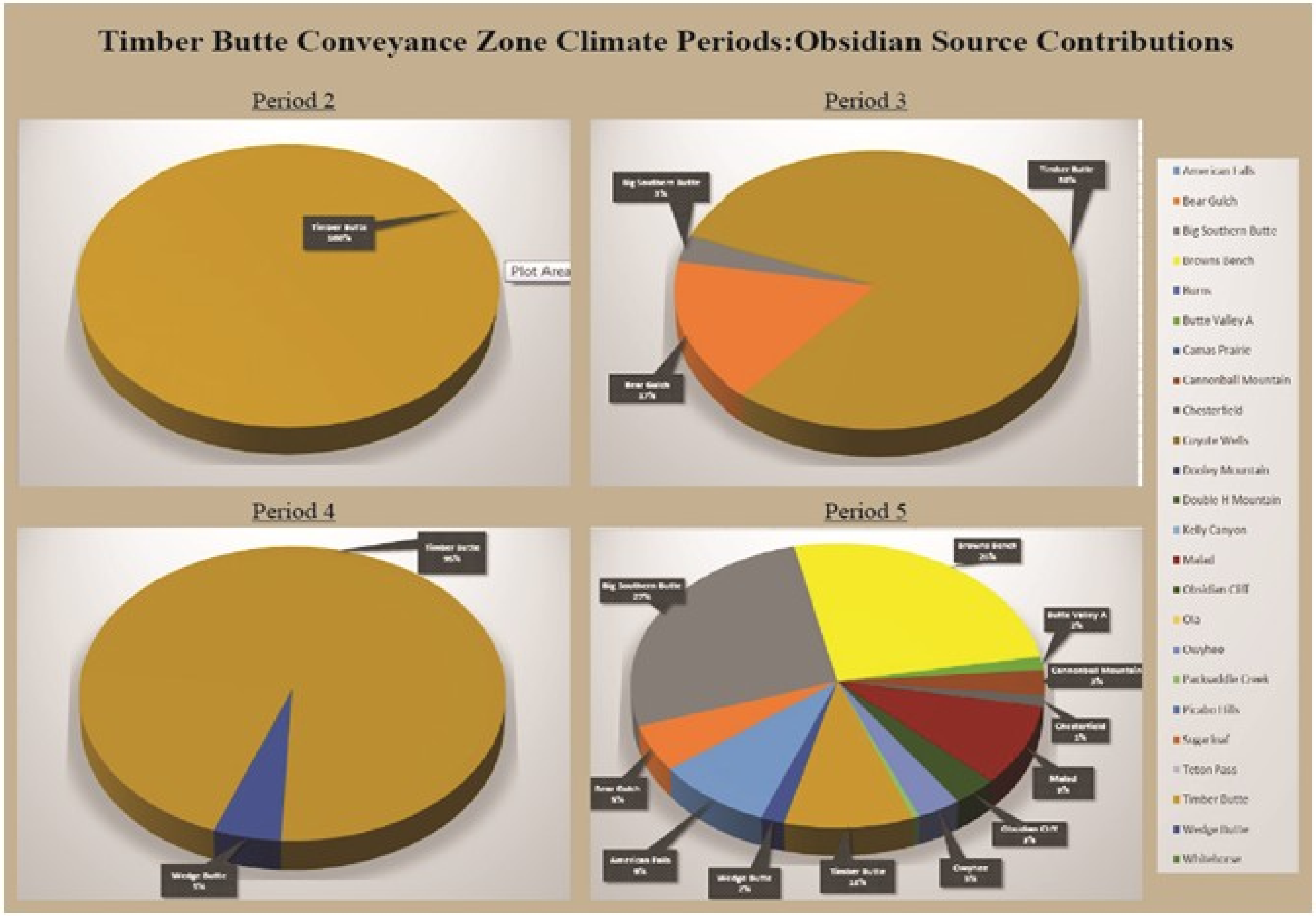

Figure 15. Contribution of obsidian sources in the Timber Butte Conveyance Zone during Periods 2 through 5.

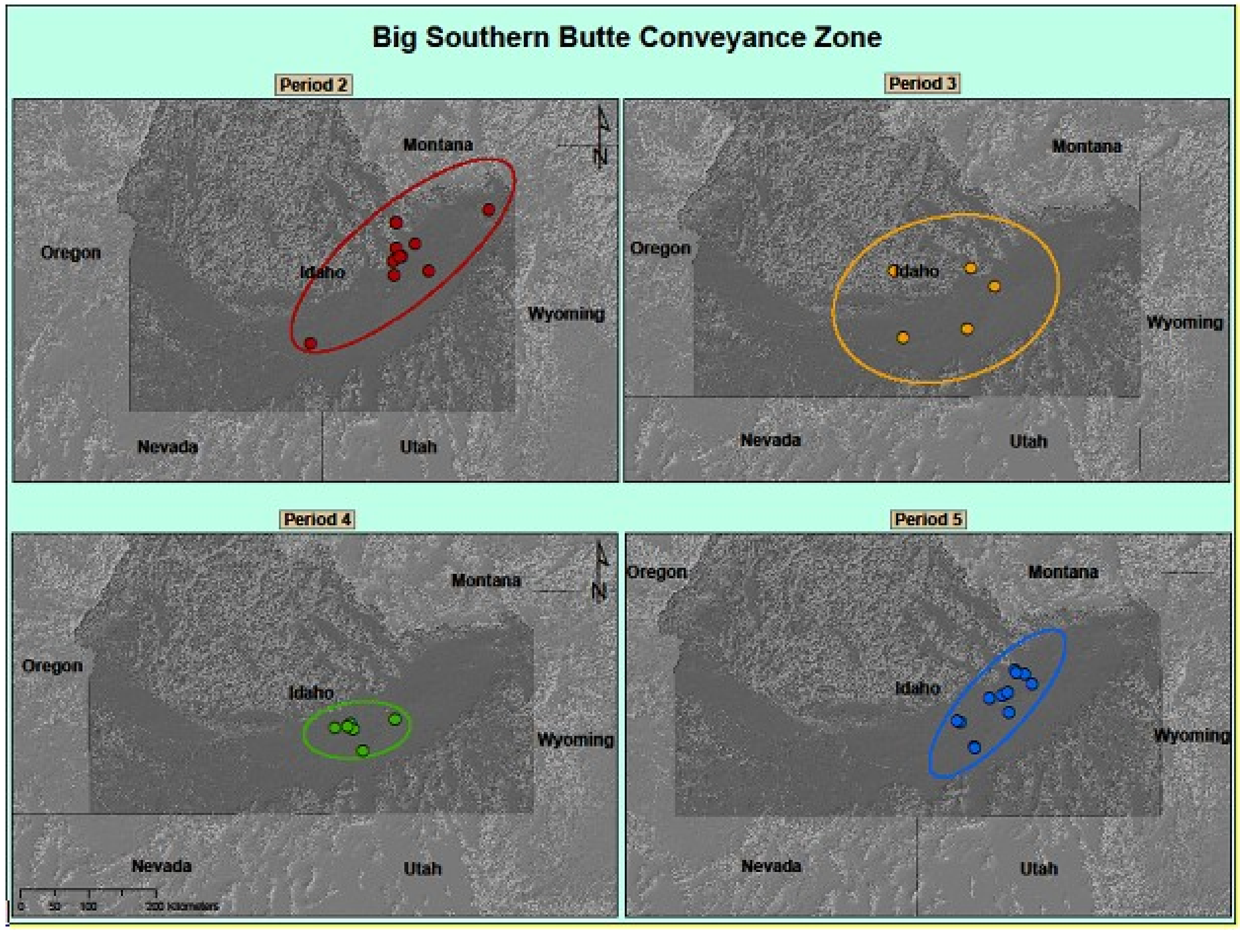

Figure 16. Map of four ellipses with clustered sites in the Big Southern Butte Conveyance Zone during Periods 2 through 5.

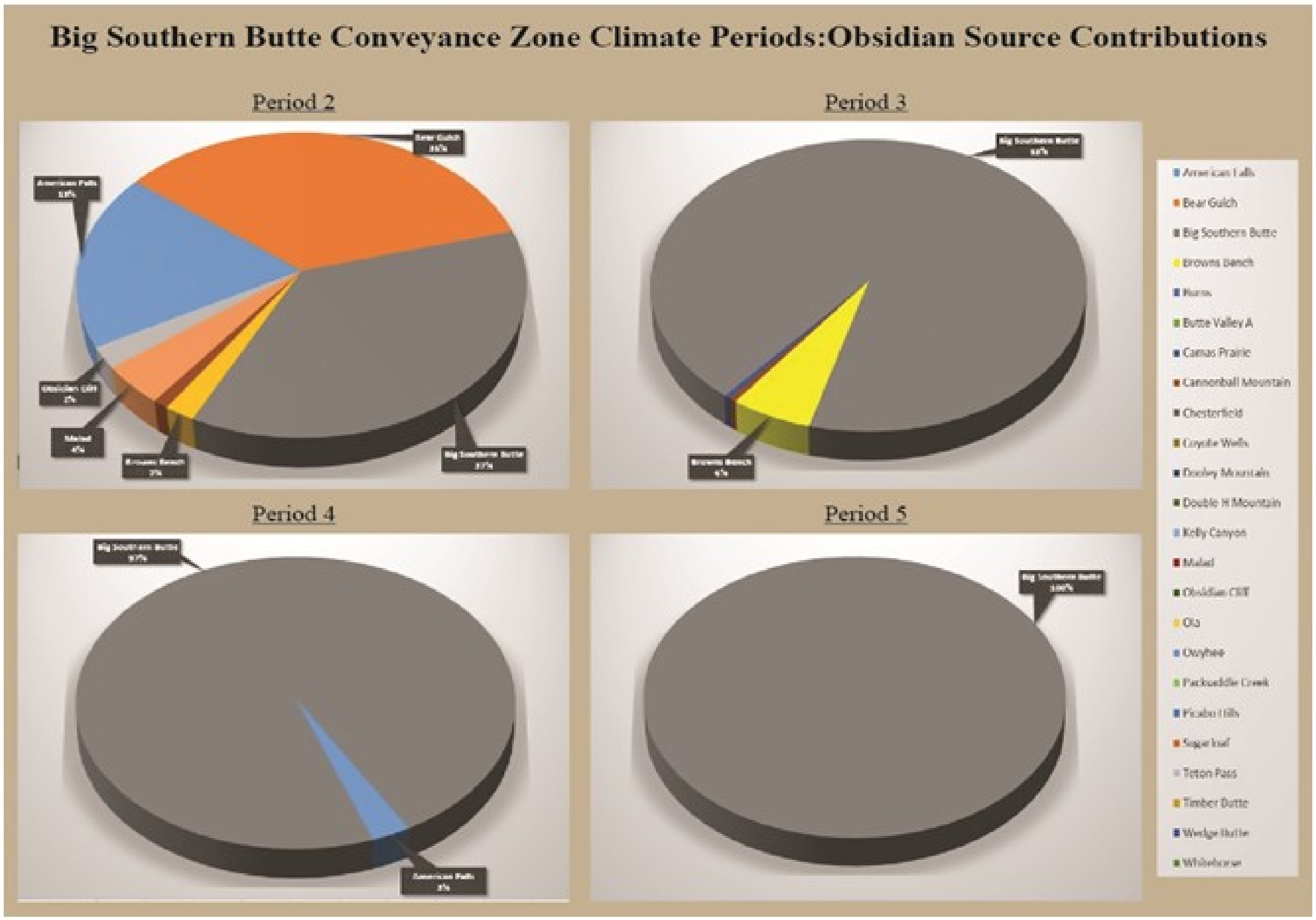

Figure 17. Contribution of obsidian sources in the Big Southern Butte Conveyance Zone during Periods 2 through 5.

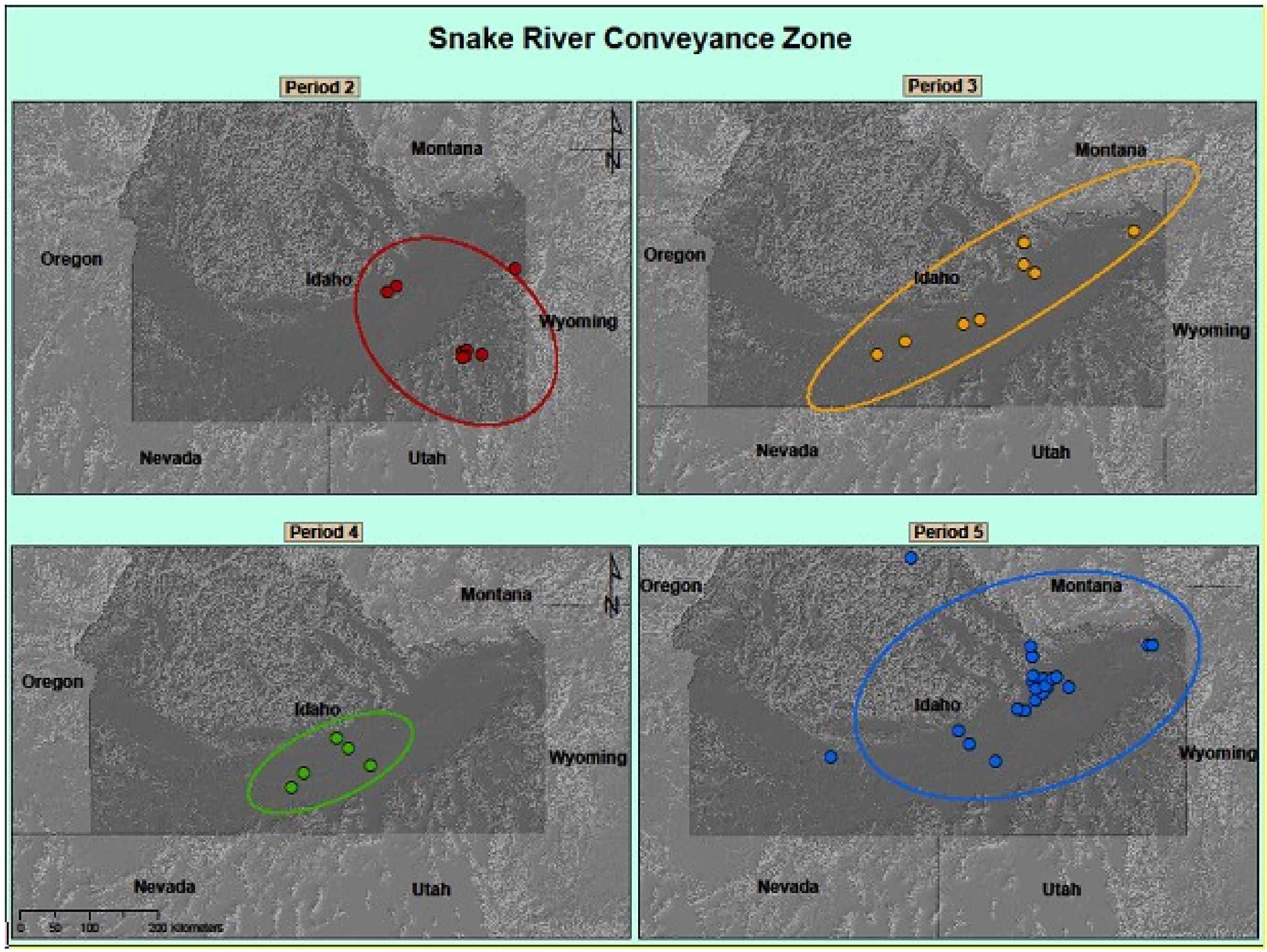

Figure 18. Map of four ellipses with clustered sites in the Snake River Conveyance Zone during Periods 2 through 5.

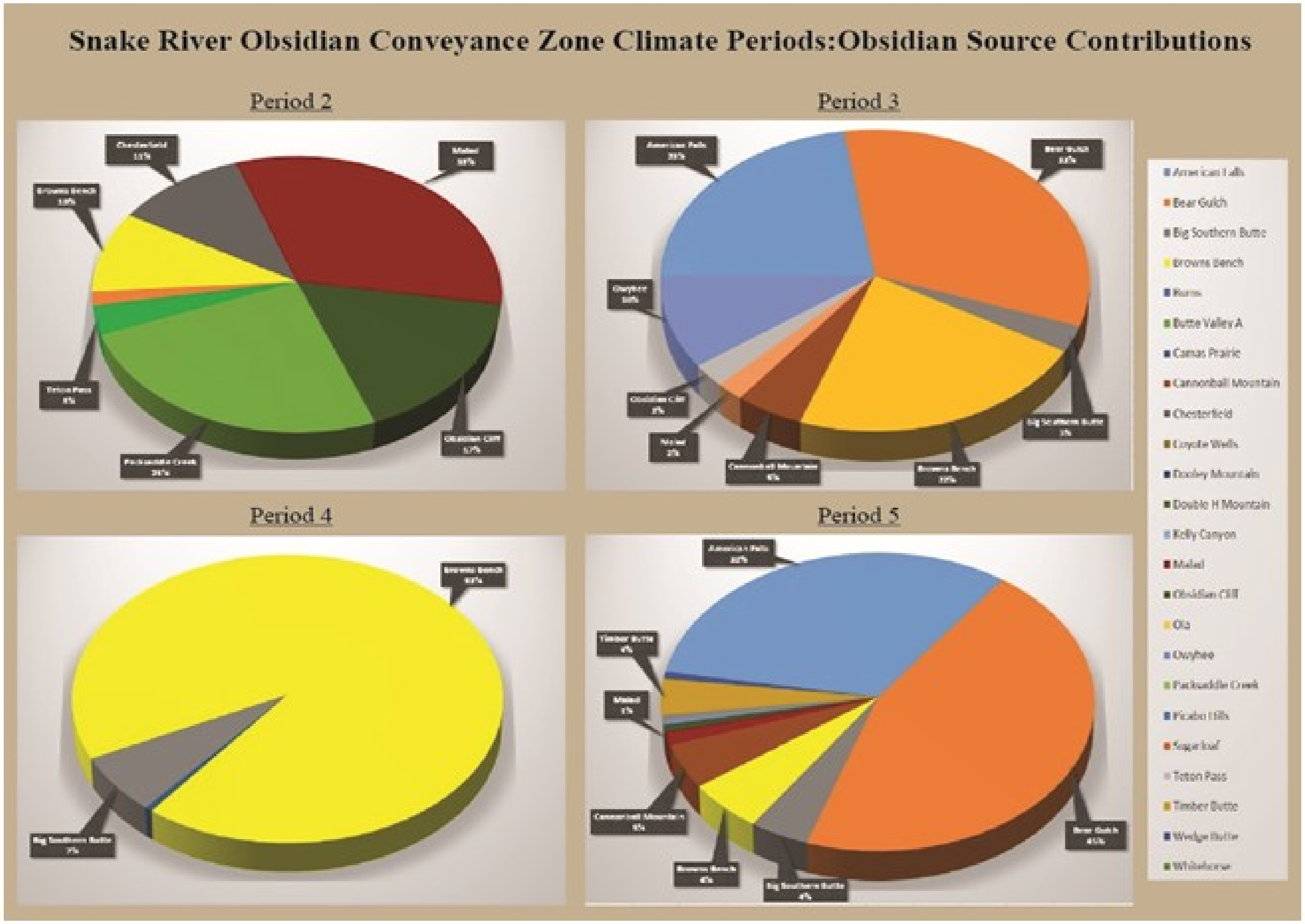

Figure 19. Contribution of obsidian sources in the Snake River Conveyance Zone during Periods 2 through 5.

Diversity and Evenness Analysis

This study analyzed obsidian source diversity and evenness in the trans-Holocene zones and in conveyance zones during each climatic period to test the research model's expectations of obsidian source use and the implication of paleoclimatic effects on landscape use. The Shannon diversity index shows that across Idaho diversity is highest in Period 2 (2.07), drops in Period 3(1.63) and Period 4 (1.61) before increasing in Period 5 (2.04) (Figure 20). Shannon's equitability conveys evenness, which is fairly high in Period 2 (0.78), then drops in Period 3 (0.66) and Period 4 (0.63), before climbing during Period 5 (0.72).

Shannon's diversity and evenness indices were also created for clustered sites in each climatic period for each of the four conveyance zones discussed previously (Table 12; Figures 12-19). I found that diversity and evenness values for conveyance zones by climatic period do not follow a linear pattern of increasing or decreasing through the Holocene, nor are there discernible patterns from one conveyance zone to the next (Figures 21 and 22). Analysis of diversity and evenness indices often reveals that they are

Table 12. Diversity and Evenness Indices in Conveyance Zones by Climate Period.

	Period 2	**Period 3**	**Period 4**	**Period 5**
MCZ Diversity	0.07	0.20	1.70	0.26
TBCZ Diversity	0.00	0.58	0.41	2.18
BSBCZ Diversity	1.40	0.29	0.13	0.00
SRCZ Diversity	1.66	1.69	0.28	1.48
MCZ Evenness	0.11	0.14	0.74	0.16
TBCZ Evenness	0.00	0.53	0.59	0.85
BSBCZ Evenness	0.71	0.21	0.18	0.00
SRCZ Evenness	0.85	0.81	0.26	0.62

positively correlated because as source diversity of equally used sources increases the evenness of a sample necessarily increases. Idaho obsidian sources were not equally used; however, the relationship between diversity and evenness can lend interpretation to prehistoric behavior. I ran a partial correlation using Pearson's r and found that when controlling for climate period there is a strong positive and significant correlation between diversity and evenness ($r = .935$, $df = 13$, $F < .001$). A bivariate correlation of diversity and evenness indices in a single conveyance zone demonstrates strong positive correlations with the MCZ significant at 0.01 and BSBCZ and SRCZ significant at 0.05. The TBCZ has a strong positive correlation, but it is not statistically significant ($r = .822$, $F = .178$). Looking at Periods 3 and 4 when diversity is low in the TBCZ evenness is comparatively high at 0.53 and 0.59, likely accounting for the deviation from the correlations seen in other conveyance zones.

Few other general trends were observed in these data, though examination of

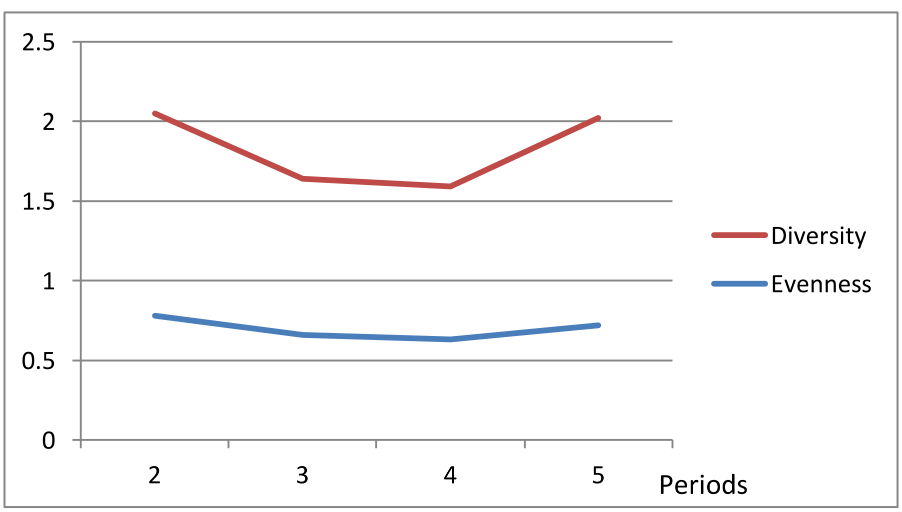

Figure 20. Graph of trans-Holocene diversity and evenness indices.

diversity and evenness expressed in each conveyance zone across the climate periods is informative in interpreting prehistoric toolstone conveyance behaviors through different environmental conditions and across different spatial extents. It is notable that diversity in Period 4 is low in the TBCZ, BSBCZ, and SRCZ possible indicating a relationship between environmental variability and conveyance patterns.

I considered the relationship between diversity and evenness measures and conveyance zone size using a Pearson's r correlation. The bivariate correlation using all data for the diversity index versus conveyance zone size shows no correlation ($r = -0.01$, $F = .969$). Similarly, there was no correlation between grouped data for area and evenness ($r = 0.001$, $F = .996$). The outcome is the same when controlling for climatic period using a partial correlation. No significant correlation was found when diversity or evenness was compared to conveyance zone size in each of the conveyance zones separately. Varying degrees of positive or negative correlations are present in this analysis but never approach statistical significance. There is no apparent relationship between conveyance zone size and source use diversity.

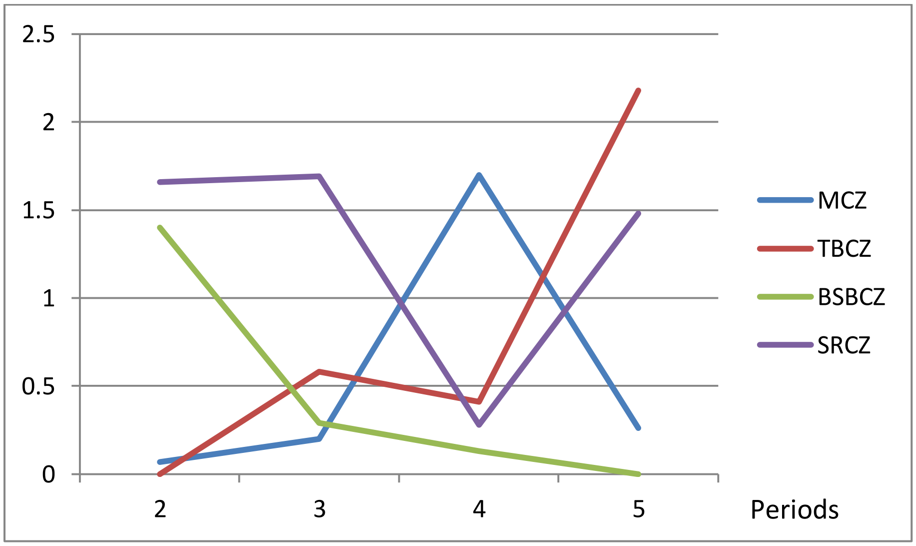

Figure 21. Diversity indices in conveyance zones by climate period.

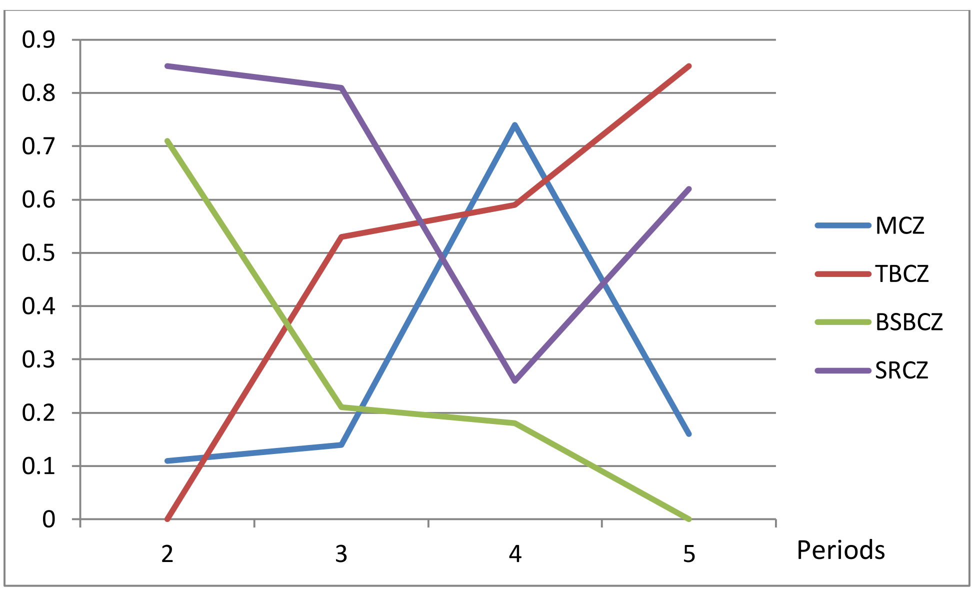

Figure 22. Evenness indices in conveyance zones by climate period.

DISCUSSION

The discussion begins by addressing expectations for Periods 1 through 5 of the research model set forth earlier. Next I examine the results of specific conveyance zones and the research model viability after analysis. I also discuss whether obsidian diversity and evenness affected conveyance zone construction.

This section references research model expectations shown in Table 1. Figures 12 through 19 contain conveyance zone construction results for the MCZ, TBCZ, BSBCZ, and SRCZ. They show the obsidian source contributions in Periods 2 through 5, as well as toolstone conveyance region maps. Multiple tables display analysis results from which this discussion draws. Table 11 lists changes in conveyance zone size by climate period. Table 12 shows diversity and evenness indices by climate period. Table 13 simplifies data from these two tables into "yes" or "no" indications of fit for the research model's expectations.

Period 1

Period 1 analysis is not included during this research because only five sites dating to the Late Pleistocene contain sourced artifacts. These sites are generally located in southeastern Idaho but a statistical clustering of sites could not be completed according to the research methodology. The data available are insufficient to evaluate whether Period 1 conveyance zones were the largest. Further obsidian sourcing and analysis regarding this question will test the model's Late Pleistocene expectations and greatly increase our understanding of southern Idaho forager behavior.

Period 2

Period 2 was the most arid paleoclimatic period and the model's expectations are a small conveyance zone with low obsidian diversity. Comparison with Period 1 is not possible thus it cannot be determined whether Early Holocene conveyance was reduced compared to earlier times; however, Early Holocene conveyance zone sizes are relatively large compared even to the mesic Late Holocene (Period 5). The one possible exception is the MCZ where one site in north-central Idaho was clustered with southeastern Idaho sites and may artificially enlarge the conveyance zone. Within the MCZ and TBCZ the Malad and Timber Butte sources dominate source profiles and an obsidian source diversity measure shows that diversity was low. Alternatively, the BSBCZ and SRCZ had high diversity. The results of individual conveyance zone diversity measures are mixed, but when diversity is combined it is high during Period 2 with the greatest evenness of any time. The model's expectations are not generally upheld during Period 2 with the possible exception of the MCZ, which requires further data and analysis to evaluate.

Period 3

The research model expected no statistically significant change for Period 3compared to Period 2. Conveyance zone size is expected to remain small with low obsidian source diversity. Climatic conditions were transitional at this time with early xeric conditions before trending to more mesic conditions. Data analysis found that expectations of conveyance zone size were met in the MCZ, TBCZ, and BSBCZ. Results of obsidian source diversity are mixed with increases in the MCZ and TBCZ diversity. Evenness is still quite low, which indicates that major regional sources still dominate the obsidian used specific conveyance zones. The BSBCZ and SRCZ had little change in diversity which meets the model's expectations.

Period 4

During Period 4, which marks the beginning of the Late Holocene, the model expects increased toolstone conveyance and obsidian source diversity. The MCZ size increased 298 percent and the TBCZ increased 823 percent. These conveyance trends fit the model, although compared to Period 3 the SRCZ and BSBCZ shrink contrary to expectations. Only the MCZ had increased source diversity during this period, while the other zones had low evenness measures due to dominance of the major regional source in the dataset. This period is the only time that the Malad source does not dominate the MCZ toolstone, which may be due the expanded zone including more SRP sites than southeastern Idaho sites.

Period 5

No change of conveyance patterns or toolstone diversity is expected in Period 5 compared to Period 4. Large conveyance zone sizes are expected with high obsidian source diversity. MCZ and TBCZ sizes decrease somewhat compared to Period 4, but remain large compared to Period 3. The BSBCZ and SRCZ both expand compared to Period 4, however the strength of these positive indicators is weak. Obsidian source diversity meets the model expectations in the MCZ, TBCZ and SRCZ.

Results of the Research Model and Conveyance Zones

Expectations for toolstone conveyance and obsidian source diversity were established according to hypothesized forager mobility based on the research model. The model assumes that climatic changes affect environmental productivity. As environmental shifts occur, forager mobility increases or decreases leading in turn to larger or smaller foraging zones. This study follows the idea that toolstone conveyance zones are a proxy for decadal-scale or lifetime foraging ranges (Jones et al. 2003). Thus, changes in conveyance zone size and source diversity within zones are measures of predicted forager mobility (Tables 11 and 12).

Overall the model's expectations were met in the MCZ and TBCZ but were not met in the BSBCZ and SRCZ. Judging the adequacy of the research model's indicators is challenging. Some indicators, for instance, show when the model's predictions were met for each conveyance zone and climatic period, but there are cases when an indicator is lagging or when the overall trend is met but the immediate prediction failed (Table 13). These uncertain indicators may indicate temporal problems derived from weaknesses in our understanding of Holocene climatic shifts, faults regarding assumptions about forager toolstone acquisition strategies, or forces like non-climatic environmental pressures and cultural push-pull factors that may have shifted forager mobility or toolstone use strategies. An example from analysis shows that during Period 2 in the MCZ when low mobility is expected the conveyance zone size remains high, but during Period 3 when no change is expected the conveyance zone shrinks, which I have described as a lagging indicator. Also, from Period 3 to 5 there is an overall trend of increasing mobility that is met in the MCZ and TBCZ since the area increases, but the immediate predictions failed because the size decreased by half from Period 4 to 5 when no change was expected.

The MCZ is the best test of the model since climate periods are based on southeastern Idaho, northern Great Basin, and southwestern Wyoming paleoclimate studies. In the MCZ, Periods 2 and 3 are expected to have small conveyance zones with low diversity. Though we cannot compare a Period 1 conveyance zone the Period 2 conveyance zone is very large, but by Period 3 the size is greatly reduced fitting the model. There is also a single site clustered with the MCZ north of the SRP that may be artificially increasing the size during this period. I found low Period 2 diversity as expected followed by only a slight increase during Period 3, which violates the expectation but only marginally. The Period 4 expectation is increased conveyance zone size, and analysis confirmed that area increased to 201,940 km^2 matching a large increase in source diversity. Area decreases in Period 5, but is still almost twice as large as Period 3 so the overall expectation of larger zones is supported. Period 5 diversity decreases nearly to Period 3 values, but the overall expectation of increased diversity is supported, albeit weakly. Based on the MCZ results it appears that foraging ranges associated with the conveyance zones created through analysis vary based on expectations derived from Holocene climatic shifts.

The TBCZ conveyance zone sizes mirror the pattern set by the MCZ (Table 13). Diversity in this conveyance zone fits the model during Period 2 when there was only a single obsidian source and during Period 5 which had high diversity. Period 3 and 4 also had low diversity and it is clear that Timber Butte was the dominant source from 8,900 to

2,000 ^{14}C yr B.P. Overall the TBCZ fits the expectations of the research model. In contrast, the BSBCZ and SRCZ do not fit the model. Upon examination by climate period the indicators for these zones during Period 3, and to a greater extent Period 5, more closely fit the model expectations. Period 3 is a xeric period when small conveyance zones and low obsidian source diversity was expected. The mesic Late Holocene Period 5 was expected to exhibit large conveyance zones and high source diversity.

Southern Idaho toolstone conveyance zone variability is also demonstrated through another observed pattern. While the zones are identified by obsidian source profiles that center around Malad, Timber Butte, Big Southern Butte, and Snake River sources there is at least one climatic period in each conveyance zone that exhibits a

Table 13. Indication of Fit for Size and Diversity for Foraging Model (Table 1).

		Period 2	**Period 3**	**Period 4**	**Period 5**
	Expectations	Small Zone Low Diversity	No Change Small Zone Low Diversity	Large Zone High Diversity	No Change Large Zone High Diversity
MCZ	Size	No	Yes*	Yes	Yes**
	Diversity	Yes	No	Yes	Yes**
TBCZ	Size	No	Yes*	Yes	Yes**
	Diversity	Yes	No	No	Yes*
BSBCZ	Size	No	Yes*	No	Yes*
	Diversity	No	Yes*	No	No
SRCZ	Size	No	No	No	Yes*
	Diversity	No	Yes	No	Yes*

*Indicates when model's predictions are met but the signal is lagging or weak.
**Indicates when model's overall trend is met but the immediate prediction failed.

degree of separation from those profiles. For example, during Period 4 in the MCZ Malad was the most common source, but American Falls, Bear Gulch, and Big Southern Butte all played a major role during this period with more sites from the central and eastern SRP grouped into the conveyance zone. Period 5 in the TBCZ follows the same pattern where more SRP sites are included in the conveyance zone and obsidian source diversity was greatly increased. The question is whether these variable obsidian profiles reflect prehistoric behavior or are simply a product of the statistical analysis.

Effect of Obsidian Diversity and Evenness on Conveyance Zone Construction

This research examined obsidian source diversity and evenness to determine whether the density of obsidian sources affects the size of reconstructed conveyance zones. Regional obsidian source density in southern Idaho is high, thus a relatively minor expansion of conveyance zone size can incorporate additional obsidian sources. Analysis found that conveyance zone sizes either aggregated as trans-Holocene zones or separated by climatic period are not correlated with source diversity.

The reconstructed source profiles for the zones track major obsidian sources, but diversity and evenness profiles vary throughout prehistory (Table 12; Figures 22 and 23). Holmer (1997), Plager (2001), and Willson (2007) also found that obsidian use in southern Idaho centered on major obsidian sources. Conclusions drawn by Earl (2010) in the eastern Great Basin suggest uneven obsidian source profiles are based on source quality. I suggest that volume of toolstone available at a source and size of procurable material could affect evenness. Cultural factors may also prove to be an important influence in source variability and evenness on a region by region basis. This study finds that there are numerous secondary (< 3 percent of sourced obsidian) and tertiary (< 0.002 percent of sourced obsidian) sources located in southern Idaho, but data analysis suggest that these are used at a rate that renders them insignificant in discussing behavioral mechanisms since their frequency may not reflect toolstone procurement patterns (Willson 2007).

CONCLUSION

This southern Idaho research fills a geographic gap in obsidian conveyance zone research in western North America. I highlight the fact that Holmer (1997) and Plager's (2001) research were valuable foundations I used to begin this study, and many of the patterns and ideas formulated by these researchers were confirmed by this most recent endeavor. Surrounding this project, conveyance zones from eastern California to western Utah have been proposed and studied throughout the Great Basin (Earl 2010; Jones et al. 2003, 2012; Newlander 2012; Page 2008; Scheiber and Finley 2011; Smith 2010). Another conveyance zone was recently proposed in the Wyoming Basin to the east. The majority of these studies show ties to southern and eastern Idaho obsidian sources. The dataset compiled for this study contains 4,440 samples from 640 sites in southern Idaho that reference 37 obsidian sources that I use to provide a more complete picture of prehistoric toolstone conveyance through the formation of conveyance zones. I have proposed four conveyance zones: the Malad Conveyance Zone, Timber Butte Conveyance Zone, Big Southern Butte Conveyance Zone, and Snake River Obsidian Conveyance Zone. The strength of these proposed zones is that they were constructed from a rich obsidian sourcing dataset using a novel process involving statistical methods to group sites and create standard deviational ellipses, which function as boundaries for the conveyance zones.

Comparing the conveyance zone size for these newly proposed zones, which range from 62,000 to 140,000 km^2, I find that they are most similar to Jones et al.'s (2003, 2012) proposed zones, between 46,000 and 107,000 km^2 and Harvey (2012) at

60,000 to 90,000 km^2. If average conveyance zone size is considered by climate period then the new zones range from 25,180 to 130,910 km^2, a somewhat lower range especially at the smaller end (Table 11). Smith (2010) proposed conveyance zone sizes in the western Great Basin between 10,000 and 20,000 km^2. To answer my research question about toolstone conveyance zones and the influence of obsidian source diversity, I analyzed obsidian source diversity in each conveyance zone questioning whether regional density of obsidian sources, which is high in southeastern Idaho, affect reconstruction of conveyance zones and interpretation of forager mobility. The size of conveyance zones either aggregated as trans-Holocene zones or separated by climate period are not correlated with source diversity. This supports the idea that these statistically derived conveyance zones are not simply an artifact of our own analysis. The reconstructed source profiles for the zones track major obsidian sources but with changing diversity and evenness across Periods 2 through 5 (Table 12; Figures 21 and 22). Similar to conclusions by Holmer (1997), Plager (2001), and Willson (2007), I find that obsidian use in southern Idaho centers on major obsidian sources. Conclusions drawn by Earl (2010) in the eastern Great Basin perhaps suggest these uneven profiles are based on source quality, and I would add amount of available toolstone and cultural factors affecting availability. There are numerous secondary (< 3 percent of sourced obsidian) and tertiary (< 0.002 percent of sourced obsidian) sources located in southern Idaho, but these are used at a rate that renders them insignificant in discussing behavioral mechanisms since their frequency may not reflect toolstone procurement patterns (Willson 2007).

Jones et al. (2003, 2012) proposed the ECZ in eastern Nevada, running north to south in two overlapping conveyance zones stacked south and north on top of each other. Their research, along with Smith (2010) and Harvey (2012), showed that geographically prescribed conveyance zones were established early in regional prehistory. This research records the formation of four conveyance zones in southern Idaho as early as 8,900 ^{14}C yr B.P. Analysis found that although source profiles associated with individual conveyance zones remain primarily anchored on the same major sources there is an abundance of variability with the size of conveyance zones, source diversity, and evenness throughout the Holocene (Tables 11 and 12). When Smith (2010) conducted a diachronic comparison between Paleoarchaic artifacts and samples from 7,000 ^{14}C yr B.P. to present he also identified changes in conveyance zone size, distance of transport, and obsidian source profiles that decreased through the middle Holocene but increased again in the Late Holocene.

The WBCZ includes obsidian conveyed primarily from Malad, Teton Pass, and Bear Gulch with a notable lack of Obsidian Cliff artifacts (Harvey 2012). Their research established that a stable connection existed between the eastern SRP and southeastern Idaho throughout the Holocene based on the need for obsidian toolstone and posited a probable social link with foragers in these regions that factored into costs of acquisition. This research also identified a strong and stable MCZ throughout the Holocene in southeastern Idaho. The hypothesis of social links by Harvey (2012) is supported by this research. Current analysis is unable to identify southwestern Wyoming foragers' use of Malad obsidian as evidence of long distance direct procurement or representing a potential trans-Holocene exchange network. The MCZ extends into southwestern Wyoming both in the trans-Holocene zone and during each individual conveyance zone by period based on the standard deviational ellipse (Figures 10 - 19). This statistically derived ellipse expected Malad obsidian to be transported into this region based on known conveyance patterns within southeastern Idaho. Potentially significant is the amount of Malad obsidian found in southwestern Wyoming and the transport distance. The region occupied by the WBCZ is on the periphery of the MCZ ellipse and contains a concentration of sites where Malad obsidian was conveyed. The distance from the WBCZ's geographic center point to the Malad source is 250 to 370 km. Analysis of the Idaho dataset yields a maximum transport distance of 359 km for Malad obsidian and an average transport distance of 70 ± 54 km. Based on this trans-Holocene trend and the conveyance distance for WBCZ sites located on the margin of the MCZ credence is given to a strong social link between this zones and the potential existence of a trade network. Anecdotally there are southeastern Idaho sites with artifacts made from Wyoming Basin chert. If such social links or trade networks existed then toolstone, ideas, and prehistoric people likely flowed back and forth across this connection throughout the Holocene.

This research, like Scheiber and Finley (2011) and Harvey (2012) found limited connection to the Yellowstone region via Obsidian Cliff toolstone. Less than one percent of obsidian (n = 41) in the dataset was conveyed from this source. Also, while several artifacts from Obsidian Cliff were conveyed up to 532,500 km, the length of the SRP, average conveyance distance was 252,000 km, relegated to the eastern SRP.

This study has examined conveyance zones in the Great Basin and Wyoming Basin and subsequently proposed four additional prehistoric conveyance zones located within the modern political boundaries of the state of Idaho. Analysis of a rich obsidian sourcing dataset allowed for a novel process to create conveyance zones. Archaeological assemblages from sites with two or more artifacts were transformed so sourced obsidian data was presented as a percent contribution to the site's profile for each obsidian source. Clustering analysis then combined sites into ever larger clusters based on these percentages of obsidian source profiles. Clusters were identified based on separation from others in the dendrogram, leaving four conveyance zone with inclusive sets of sites. A conveyance zone boundary was then applied to each conveyance zone set using a directional distribution tool, which factors directional trend, dispersion, and central tendency. I define conveyance zones in this study to be the statistically bounded spatial range through which obsidian toolstone was conveyed during a specific time period. Conveyance zones are viewed as a material proxy for the foraging range used by prehistoric hunter-gatherers over decadal- or lifetime scales. Obsidian procurement and use is assumed to be embedded in the context of a residentially-mobile forager group's subsistence and settlement strategy (Binford 1980). Conveyance zones should exhibit stability and patterning of obsidian source preferences but are expected to change through time in response to environmental or cultural shifts. Additionally, zones reflecting prehistoric behavior shouldn't be strictly correlated to diversity and evenness measures via a measure of foraging area, nor should conveyance zone sizes match perfectly the predictions of a climatic model that is based on forager subsistence decisions. In summary, I propose that the conveyance zones in this research represent meaningful depictions of toolstone use and foraging zones at a large temporal scale. Deviations of conveyance zones from the expectations derived by the foraging model and patterns illuminated in the results and analysis sections of this research are opportunities to further inquire about the effects of environment, subsistence and settlement, trade or exchange networks, social interaction and group dynamics, migrations or population replacements, and other cultural phenomena on this material record of southern Idaho mobility.

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APPENDICES

Appendix 1

Research database bibliographic reference list.

Reference	Frequency	Analysis Laboratory
Arkush 2002	97	Geochemical Research Lab - XRF
Arkush 1999	26	Geochemical Research Lab - XRF
Bailey 1992	238	Simon Fraser Univ. - XRF
Bonita Wyse	9	Idaho State University - XRF
Burkman 2008	3	Geochemical Research Lab - XRF
Croney (Personal Comm.)	42	Idaho State University - XRF
Eastman 2011	10	
Frison 1991; Kunselman 1998	8	
Glascock 2012	110	Archaeometry Lab at MURR
Green 1982	358	University of Idaho, UC Berkeley - XRF
Green 1983	27	University of Idaho - XRF
Green 1984	41	University of Idaho - XRF
Harris 2009	22	Geochemical Research Lab - XRF
Harris 2011	101	Northwestern Research Lab - XRF
Henrikson (Personal Comm.)	68	Northwestern Research Lab - XRF
Henrikson 2008	132	Northwestern Research Lab - XRF
Holmer (Personal Comm.)	386	
Holmer 1997; Plager 2001	1727	
Holmer 2012	50	Idaho State University - XRF
Hughes 1997	17	Geochemical Research Lab - XRF
Hughes 1998	20	Geochemical Research Lab - XRF
Hughes 1999	38	Geochemical Research Lab - XRF
Hughes 2007	20	Geochemical Research Lab - XRF
Hughes 2011-83	11	Geochemical Research Lab - XRF
Hughes 2013 (Fowler 2014)	139	Geochemical Research Lab - XRF
Huter et al. (1999)	6	
Lapp 2007	20	Geochemical Research Lab - XRF
Lohse et al. 2010	73	Idaho State University - XRF
Marler (Personal Comm.)	520	
Plew and Wilson 2007	2	Northwestern Research Lab - XRF
Plew et al. 2006	12	
Rudolph 1995	69	
Torgler 1993	28	Geochemical Research Lab - XRF
Willson and Plew 2007	10	Northwestern Research Lab - XRF

Appendix 2

Source	Other Names	Description	References
American Falls	Walcott Snake River Deep Creek	American Falls is an ignimbrite outcrop that occurs in gullies and canyons that run into the Snake River near American Falls and near the Raft River and I-15 (Moore 2009). Power County, T8S R31E Section 6, American Falls SW Quadrangle	Bailey 1992; Gallagher 1979; Holmer 1997; Moore 2009; Nelson 1984; Sappington 1981
Bear Gulch	Big Table Mountain, Camas/Dry Creek, Centennial Mountain, F.M.Y. 90 Group, Reas Pass	Cobbles from this source, near Kilgore, Idaho, are found eroding from cuts near various roads and at a private gravel pit (Bailey 1992). Size of obsidian was up to 20 cm. There have been discussions among the researchers regarding the chemical distinctness and similarity of the sources in the Centennial Mountains, with Sappington (1981) opting to refer to the Centennial Source. Early in sourcing literature this source was known as F.M.Y 90 Group, an unidentified obsidian source found in prehistoric assemblages around Yellowstone NP. Hughes and Nelson (1987) report that the Dry Creek Locality has a distinct chemical signature. Clark County, Ashton Quadrangle Locality 1: T13N R38E Section 16 NE1/4 NW1/4, Section 9 E1/2 SW1/4 Locality 2: T13N R38E Section 15 SW1/4 NW1/4 Locality 3: T13N R38E Section 36 Center of South Boundary Locality 4: T13N R38E Section 22 NE1/4 NE1/4	Bailey 1992; Holmer 1997; Hughes and Nelson 1987; Sappington 1981; Willingham 1995; Wright and Chaya 1985

Big Southern Butte	Webb Spring	Big Southern Butte formed around 300,000 years ago (Kuntz 1978). Obsidian outcrops and occasionally cobbles are found near the summit of this lava dome. Appearance is variable, from black to nearly transparent, with other reference to a milky grey/green. The obsidian is not found in cobbles, but rather angular blocks. Butte County, T1N R29E Section 1, 11, or 14 or 23 Northern1/2, Big Southern Butte Quadrangle	Bailey 1992; Holmer 1997; Moore 2009; Nelson 1984; Sappington 1981
Big Table Mountain	Bear Gulch, Camas-Dry Creek, Centennial Mountains, F.M.Y. 90 Group, Spring Creek, Warm Creek Spring, West Camas Creek	This Big Table Mountain source has a long history of interest from researchers in Yellowstone NP. When it was still unidentified they referred to it as F.M.Y. 90 Group. It is located on a ridge bordered by East and West Camas Creeks, near Kilgore, Idaho. The source is discontinuous, but outcrops over a 28 km² area. Big Table Mountain was formed during Tertiary age volcanics. Willingham (1995) uses the name Big Table Mountain as a more accurate description of the source, though it is often referred to as Bear Gulch, a location where obsidian was sampled early in archaeological research. T13N R38 E Sections 19, 20, 28, 29,30, 33, 34 and T14N R38E Sections 2, 3, 4, 10, 11, 13, 14	Bailey 1992; Bohn 2007; Gallagher 1979; Griffin et al 1969; Holmer 1997; Hughes and Nelson 1987; Kimball 1976; Michels 1983; Moore 2009; Raley 2011; Sappington 1981; Willingham 1995; Wright et al. 1986
Big Springs Fire Tower	Big Springs	Upon examination, no toolstone quality material was found at the geologic source. Fremont County, T14N R44E Section 34, West Yellowstone Quadrangle 15'	Holmer 1997; Nelson 1984

Browns Bench Ignimbrite	Rock Creek, Mahogany Butte, Coal Bank Spring, Hudson Ridge, Jackpot	This source is very extensive and found over and area of 2600 km² in south central Idaho. The flow caps many peaks in the Cassia Mountains. Toolstone is opaque and usually free of visible phenocrysts, but is variable in color (black, brownish red, and lavender). Cobbles range in size from pebbles to 30 cm in diameter. Twin Falls & Cassia Counties; T12S R13E Section 11, Tuanna Butte Quadrangle; T14S R14E Section 30, Brown Bench South Quadrangle	Bailey 1992; Holmer 1997; Hughes 1990; Moore 2009; Nelson 1984; Reed 1985; Sappington 1981
Camas Prairie Ignimbrite	Camas Prairie A Camas Prairie 1	Two distinct sources occur in this area and are referred to as Camas Prairie #1 and Camas Prairie #2. Both black and red cobbles are reported from the source. Chemically these sources overlap with the Brown's Bench type making discrimination difficult. Camas County, T2S R15E Section 36; T2S R15E Section 35 SW1/4; T3S R15E Section 2, S1/2 Section 11, Fairfield Quadrangle	Bailey 1992; Holmer 1997; Reed 1985; Sappington 1981

Cannonball Mountain	Cannonball Mountain 1, Camas Prairie 2	Sampling of the Cannonball Mountain sources was done by archaeologist William G. Reed in 1983 for the BLM. Obsidian was opaque black with dark brown thin edges, black/grey banded, black speckled, or containing phenocrysts. Many flakes had sandy inclusions, sometimes in bands. There is high macroscopic variability, but good chemical consistency among localities. Camas County, Fairfield Quadrangle Locality 1: T1N R15E Section 19 N1/2 NW1/4 Locality 2: T1N R14E Section 12 N1/2 Locality 3: T1N R14E Section 14 Locality 4: T1N R14 E Unknown Section Locality 6: T1N R14E Section 14 SE1/4	Bailey 1992; Henrikson 2008; Holmer 1997; Reed 1985; Sappington 1981
Cannonball Mountain 2		This source was Locality 5 of William G. Reed's 1983 testing of the Cannonball Mountain toolstone and was determined to be chemically distinct. Additional testing is recommended to understand the volcanic activity that occurred in this area. Camas County, Fairfield Quadrangle T1N R15E Section 6 SW1/4 SW1/4, Section 7 NW1/4 NW1/4	Bailey 1992; Holmer 1997
Cedar Creek Ignimbrite		Cedar Creek source is observed as black and red ignimbrite. This source is located adjacent to the Cedar Creek Reservoir and at the northern end of Brown's Bench. Cobbles are usually 10 cm to 20 cm in diameter. This source is not well characterized (Bailey 1992). Owyhee County, T14S R13E Section 14 S1/2 SE 1/4, Rogerson Quadrangle	Bailey 1992; Holmer 1997

Cedar Butte Sources			
Centennial	West Camas Creek, Spring Creek, Bear Gulch, Reas Pass, Mud Lake	This source occurs across the north and south flanks of the Centennial Mountains, referred to as a vitrophyre by Sappington (1981). The Bear Gulch, Reas Pass, and Spring Creek sources all relate to this flow. Clark, Fremont, Jefferson, and Teton Counties	Gallagher 1975; Kimball 1976; Moore 2009; Murray et al. 1977; Raley 2011; Sappington 1981
Chesterfield	Smith Creek	This source is part of a rhyolite flow reported by David Corliss and James P. Green. The source has been exploited locally, but is not a major source in a region with plentiful toolstone resources. The geologic formation for this source has not been adequately explored (Sappington 1981). Bannock & Caribou Counties; T6S & 7S R37E & 38E Sections 9 & 10; Portneuf Quadrangle 15'	Bailey 1992; Green 1982; Holmer 1997; Moore 2009; Nelson 1984; Sappington 1981
China Hat		No toolstone quality material has been found at the geologic source. Caribou County	Holmer 1997; MacDonald et al. 1992
Coal Bank Spring	Browns Bench	The obsidian from Coal Bank Spring is green, gray and banded obsidian with a crystalline-like texture. The exposure is primarily block and angular rocks, but ropy extrusions are present. Cassia County, T16S R12E Section 18 NW1/4 NE1/4, Oakley Quadrangle	Bailey 1992; Green 1982; Holmer 1997
Conant Creek Ignimbrite	Buggy Springs	This source contains black and gray cobbles in a secondary source. A prediction for the primary source is Conant Pass, Wyoming. Toolstone quality is reported as moderate. Fremont County, T8N R45E Section 24 NW1/4 SW1/4, Ashton Quadrangle	Bailey 1992; Holmer 1997

Deadhorse Ridge	Bear Gulch 2	Bonneville County,	
Deep Creek Ignimbrite	Snake River, Walcott, American Falls, Deep Creek	The Deep Creek source is located on an N-S ridge northwest of Dubois. Material may be mostly buried, but high-quality black ignimbrite cobbles are found in erosional contexts. Current results (Bailey 1992) cannot distinguish this source from the Snake River source. Clark County, T11N R33E Section 29 N1/2 NE1/4, Section 20 NE1/4 SE1/4, Section 27 Center NW1/4, Ashton Quadrangle	Bailey 1992; Holmer 1997
Dry Creek Ignimbrite		The 5 cm - 60 cm cobbles at this source were collected from the creek bed and are of poor quality. Though located near Bear Gulch the chemical signature is distinct. Clark County, T13N R40E Section 9 N1/2 SW1/4, Ashton Quadrangle	Bailey 1992; Holmer 1997
Fish Creek Ignimbrite	Upper Fish Creek Road, Partridge Creek, South Partridge Creek, Lower Fish Creek Road	This source is a red and black ignimbrite full of phenocrysts. Though samples were brittle they are flakeable (Bailey 1992). Red cobbles seem to be of higher quality. The geologic source had material in size from pebbles to boulders. Fremont County, T12N R45E Sections 29 & 32	Bailey 1992; Holmer 1997; Nelson 1984

Gibson Creek Chemical Group Ignimbrite	Moody Swamp, Graham Spring, Packsaddle Creek	Angular pieces of light grey to black ignimbrite were found at the source. The material is brittle and described as moderate in flaking quality. The three sampling localities are chemically the same. Madison, Teton, and Bonneville Counties, Gibson Creek: T1N R42E Section 20 N edge NW1/4, Palisades Quadrangle Moody Swamp: T4N R42E Section 13, Rexburg Quadrangle Graham Spring: T5N R43E Section 21, Rexburg Quadrangle	Bailey 1992; Holmer 1997
House Creek			Holmer 1997; Glascock 2012
Jasper Flats Ignimbrite	Jasper Flats Type 1 & 2	The source contains small cobbles of black ignimbrite, poor in quality. Two chemically distinct sources were found, though the material may be unsuitable for common use among prehistoric groups. Blaine County, T1N R20E Section 31	Bailey 1992; Holmer 1997
Kelly Canyon	Kelly, Kelley Canyon, Kelley's Canyon	Pebbles of obsidian are found in alluvium above Heise Hot Springs, near Idaho Falls. Other material of possibly the same source has been collected from a great distance away (Moore 2009). Jefferson County; T4N R41E Section 28; Heise Quadrangle	Holmer 1997; Moore 2009; Nelson 1984
Lightning Creek	Jordan Creek	This source consists of five intact plugs intruding through a rhyolite dome. It is possible the northernmost source in the state. Custer County, T13N R14E Section 14 NE1/4	Crist 1978; Sappington 1982

Malad	Wright Creek, Oneida, Hawkins, Dairy Creek, Garden Creek Gap	The Malad source outcrops in the central Bannock Range as part of a pumice and perlite deposit. Nodules are usually large and transparent black, though mahogany obsidian occurs occasionally. This obsidian source is considered a high-quality material and is found scattered thousands of kilometers across many states (Thompson 2004). Oneida County; T11S R35E Section 26 (Wright Creek); T12S R35E Section 4 NW1/4 (Hess Pumice Mine); T11S R35E Section 9 Center; T11S R35E Section 16 NE1/4 SW1/4, Wakley Peak Quadrangle	Bailey 1992; Bohn 2007; Frison et al. 1968; Gallagher 1979; Green 1982; Holmer 1997; Moore 2009; Nelson 1984; Nelson and Holmes 1979; Sappington 1981; Thompson 2004
Medicine Lodge Canyon Ignimbrite	Corral Creek, Cow Creek, Lava Creek	This source has multiple locations where exposures occur. Ignimbrite can be found on the hillsides on the west side of Medicine Lodge Canyon. The material was black and fairly brittle (Bailey 1992). Some exposures contain only small packages of material. Clark County, Dubois Quadrangle Medicine Lodge Canyon: T11N R34E Section 18 NW1/4 SE1/4 NW1/4 Corral Creek: T13N R35E Section 33 NW1/4	Bailey 1992; Holmer 1997

Murphy Hot Springs Ignimbrite	Murphy Hotsprings, Murphy Springs	The localities for this source are on a hill west of Murphy Hot Springs. Locality 1 is on the hillside and contains small and sparse pebbles and cobbles. Locality 2, on the hilltop, has a more dense accumulation of cobbles, 5 - 10 cm in size. The material is black, with varied quality for flaking. Owyhee County, Sheep Creek Quadrangle Locality 1: T16S R9E Section 24 SW1/4 NW1/4 Locality 2: T16S R9E Section 27 W1/2 SE1/4	Bailey 1992; Holmer 1997; Moore 2009
Ola		Located near the Timber Butte source and may be found to be chemically the same source.	Moore and Ames 1979; Plager 2001
Owyhee	Brown's Castle, Oreana, Toy Pass	Owyhee source is primarily small obsidian nodules in gravel deposits located on slopes in Owyhee Mountain Range. Cobbles have been collected near Brown Creek. Pieces were generally less than 12 cm in diameter. The obsidian is mostly translucent or nearly transparent black. Owyhee County, T6S R2W Section 14 & 22 NW1/4; T5S R1W Section 1 NE1/4 NE1/4 and Section 6 NW1/4 NW1/4; T5S R1W Section 30 SE1/4 SW1/4 and N1/2 SE1/4, Triangle Quadrangle 15', Murphy Quadrangle 7.5'	Bailey 1992; Holmer 1997; Moore 2009; Nelson 1984; Sappington 1981

Owyhee 2		Cobbles at this locality are larger than the Owyhee 1 source. Though macroscopically similar to Owyhee 1 it is chemically distinct. Sappington (1981) says that obsidian occurs on both slopes of the Owyhee Mountain Range across 1600 km². These volcanics are around 13.8 million years old. Owyhee County, T7S R2W Section 6 East-Central part, Murphy Quadrangle	Bailey 1992; Holmer 1997;
Ozone Ignimbrite		This material is very dark brown to black ignimbrite with phenocrysts. Exposures are found on north side of Rock Creek near Flint Hill. Cobbles are 5 - 40 cm in size. Sit 10BV78 is likely associated with this source (Bailey 1992). Bonneville County, T1N R39E Section 36, Palisades Quadrangle	Bailey 1992; Holmer 1997
Packsaddle Creek	Pack Saddle	 Teton County, Packsaddle Lake Quadrangle	Bohn 2007; Hughes1997; Nelson 1984;
Partridge Creek		 Fremont County, T11N R45E Section 26, Warm River Butte Quadrangle 15'	Nelson 1984
Picabo Hills Ignimbrite		The exact source location for this material is unknown (Bailey 1982). Current characterization samples were collected at 10BN183. The samples were less than 10 cm in size and were black with phenocryst inclusions. Blaine County, T1S R20E Section 24 W1/2, Fairfield Quadrangle	Bailey 1992; Holmer 1997

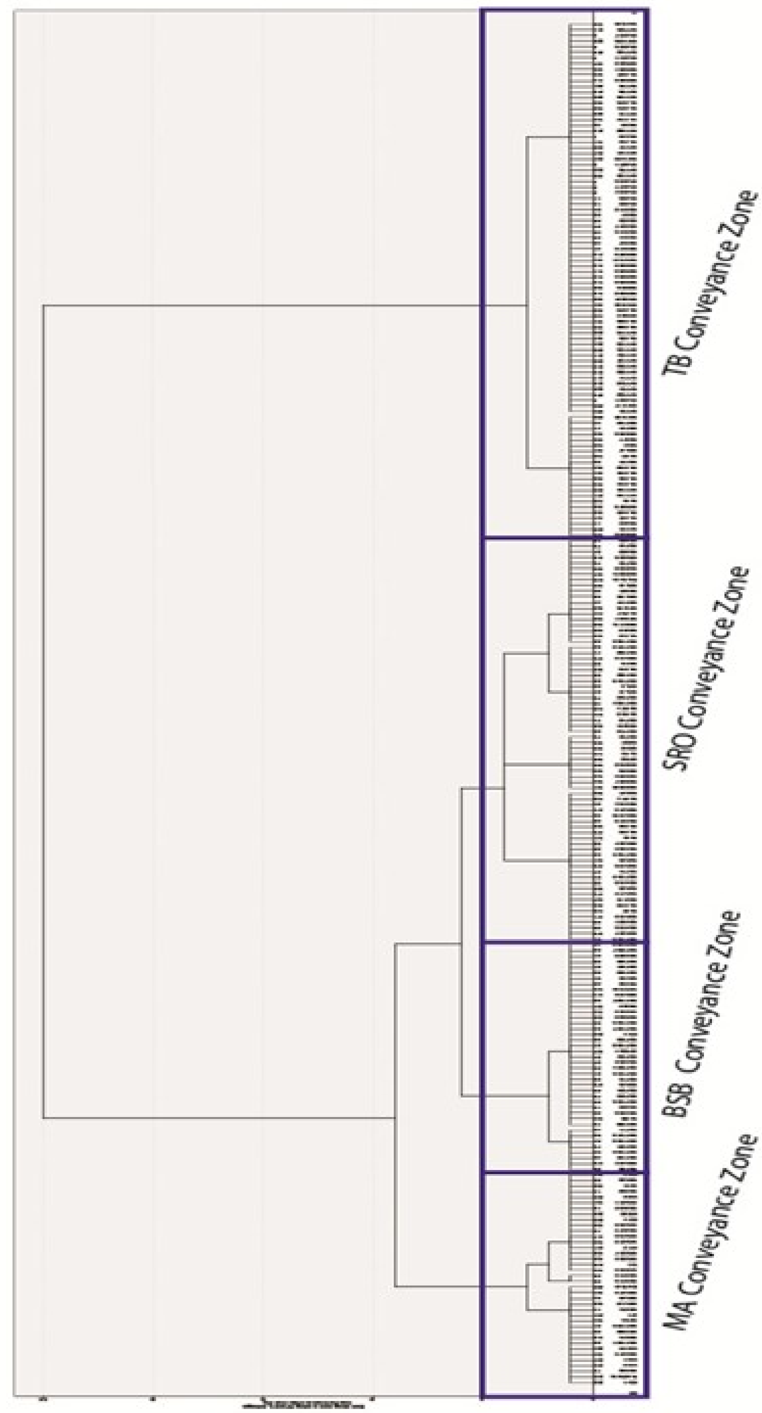
Pine Mountain Ignimbrite		At the base of Pine Mountain, black and brown ignimbrite cobbles were collected. Most samples were smaller than 15 cm. The Timber Butte source is located nearby, but these cobbles are eroding from Pine Mountain. Blaine County, T1N R22E Section 12 S1/2 SW1/4, Craters of the Moon Quadrangle	Bailey 1992; Holmer 1997
Reas Pass Ignimbrite	Centennial Mountains, Big Table Mountain, Bear Gulch, Argument Ridge, Bear Gulch B, Bear Gulch 2, Point Lookout, Yale Creek, Lost Spring	Located in the Centennial Mountains, this cobble source contains friable phenocrystic black ignimbrite. Cobbles are 25 - 30 cm in size. Sappington (1981) links this source to Bear Gulch and the Centennial Mountains sources, while Bailey (1992) considers the source to be separate. Fremont County, T14N R45E Section 6, West Yellowstone Quadrangle 15', Hebgen Lake, Montana, Idaho, Wyoming Quadrangle	Bailey 1992; Holmer 1997; Nelson 1984; Sappington 1981
Reynolds		The Reynolds source is small nodules located in the upper part of Reynolds Creek basin. Only small pebbles have been located, but larger pieces were available prehistorically. Further study is needed to examine the extent of this source. Owyhee County, T3S R4W (Boise Meridian), Murphy Quadrangle	Bailey 1992; Holmer 1997; Moore 2009; Sappington 1982

Snake River Ignimbrite	American Falls, Deep Creek, Walcott	Bailey (1982) links this source to Deep Creek ignimbrite, while Sappington (1981) identifies it with the Walcott source. The American Falls source is related to the Walcott Tuff. Specific to this source are cobbles of a brittle black ignimbrite near the American Falls landfill and Massacre Rocks Park. The suitability of this material for toolstone is unknown Power and Bonneville Counties, Pocatello Quadrangle Locality 1: T8S R31E Section 6 NW1/4 Locality 2: T8S R30E Section 32 NW1/4 NW1/4 SW1/4 Locality 3: T8S R30E Section 29 SW1/4	Bailey 1992; Sappington 1981
South Partridge Creek and Lower Fish Creek Road		Fremont County, T11N R45E Sections 17 & 19, Buffalo Lake Quadrangle 15'	Nelson 1984
Teton Pass 1 & 2	Fish Creek 1, Fish Creek/McNeely Ranch, Mosquito Creek, Phillips Ridge	The Teton Pass site has been recorded as 48TE960 and is known as the "Love Quarry". Another location, 48TE930 is geochemically the same source. The material quality is thought to be good. Outcrops are found in at least two isolated locations within a 100 m area.	Bohn 2007; Cannon et al. 2001; Frison 1974; Gordus et al. 1971; Holmer 1997; Hughes 1995; Love 1972; Sappington 1981; Wright 1968

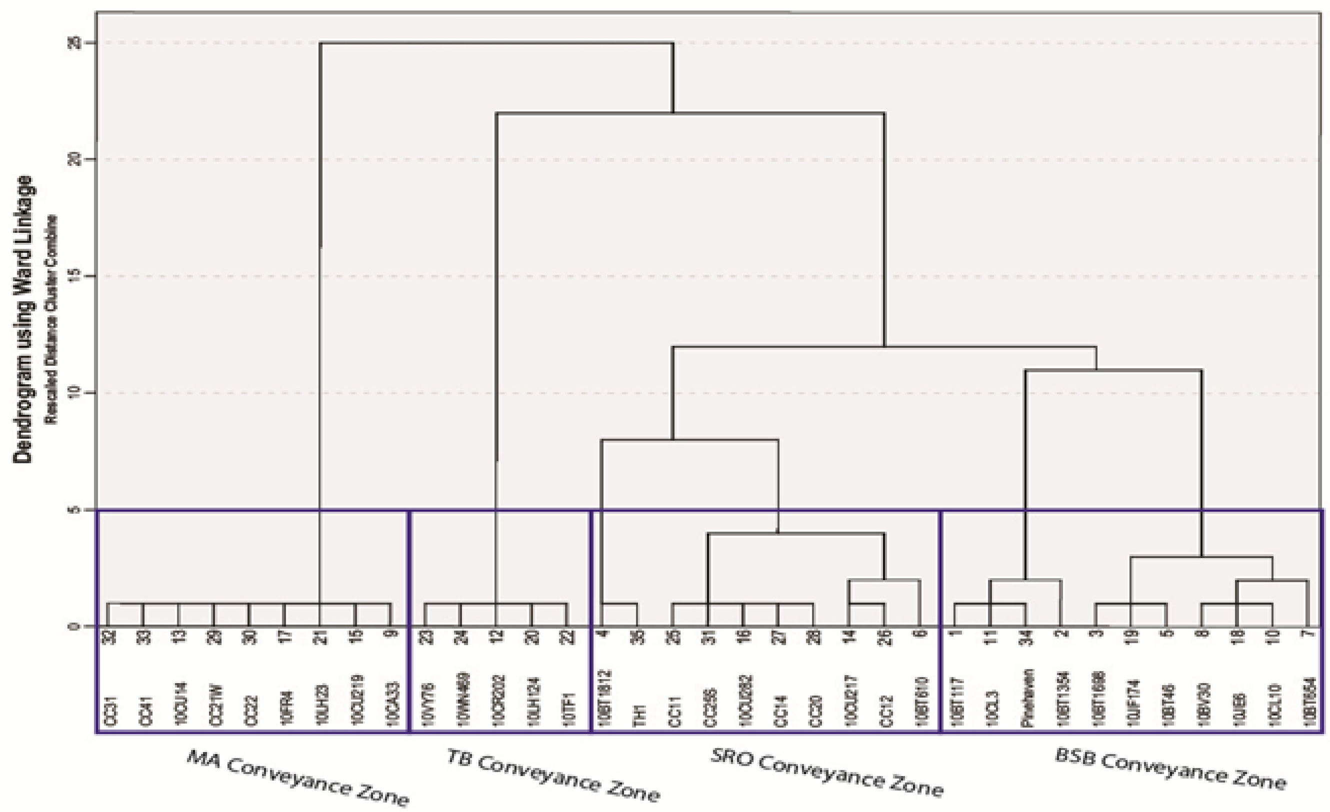
Three Creek Ignimbrite	Three Creek Landfill, Three Creek 1	This source was classified based on a single cobble found during research on the Browns Bench material. Further work is needed to validate this chemical type (Bailey 1992). More recently, Moore (2009) reports that site 10OE61 is a quarry location for this source. The location is near the crossing of Three Creeks Road and Devil Creek. Owyhee County, T16S R11E Section 10 N1/2; T15S R12E Section 22	Bailey 1992; Holmer 1997; Moore 2009
Three Creek 2			Bailey 1992; Holmer 1997
Timber Butte	Squaw Butte, Webb Creek	This source occurs on Timber Butte and in gravels in Squaw Creek Valley along a 16 km path. The obsidian is commonly almost transparent or sometimes translucent black with black or gray bands. Gem and Boise Counties, T10N R41E Section 35; T8N R2E Section 6 SE1/4, Ola and Weiser Quadrangles	Bohn 2007; Corn 2006; Moore 2009; Nelson 1984; Sappington 1981; Wells 1980
Upper Fish Creek Road		Fremont County, T12N R45E Section 33, Buffalo Lake Quadrangle 15'	Nelson 1984
Walcott	American Falls, Deep Creek, Snake River	This source is located between American Falls, Idaho Falls and Neely. The Walcott Tuff Formation's minimum age is 6.1 ± 0.3 million years B.P. The material is opaque black, often containing spherulites. Power and Bonneville Counties	Sappington 1981

Wedge Butte	Snowflake	Source material has plentiful inclusions and is of moderate flaking quality (Bailey 1992). Only small cobbles have been found recently, but prehistorically larger cobbles were available. Blaine County, T2S R18E Section 14 SW1/4 SW1/4, Fairfield Quadrangle	Bailey 1992; Henrikson 2008; Holmer 1997; Reed 1985
Yale Creek Ignimbrite		Small cobbles of black ignimbrite were found near Yale Creek. Flaking quality is moderate and size ranges from 3 - 8 cm. The primary source for this material is not yet known. Fremont County, T13N R42E Section 1 NW1/4 NE1/4, T14N R42E Section 36 SE1/4, Ashton Quadrangle	Bailey 1992; Holmer 1997

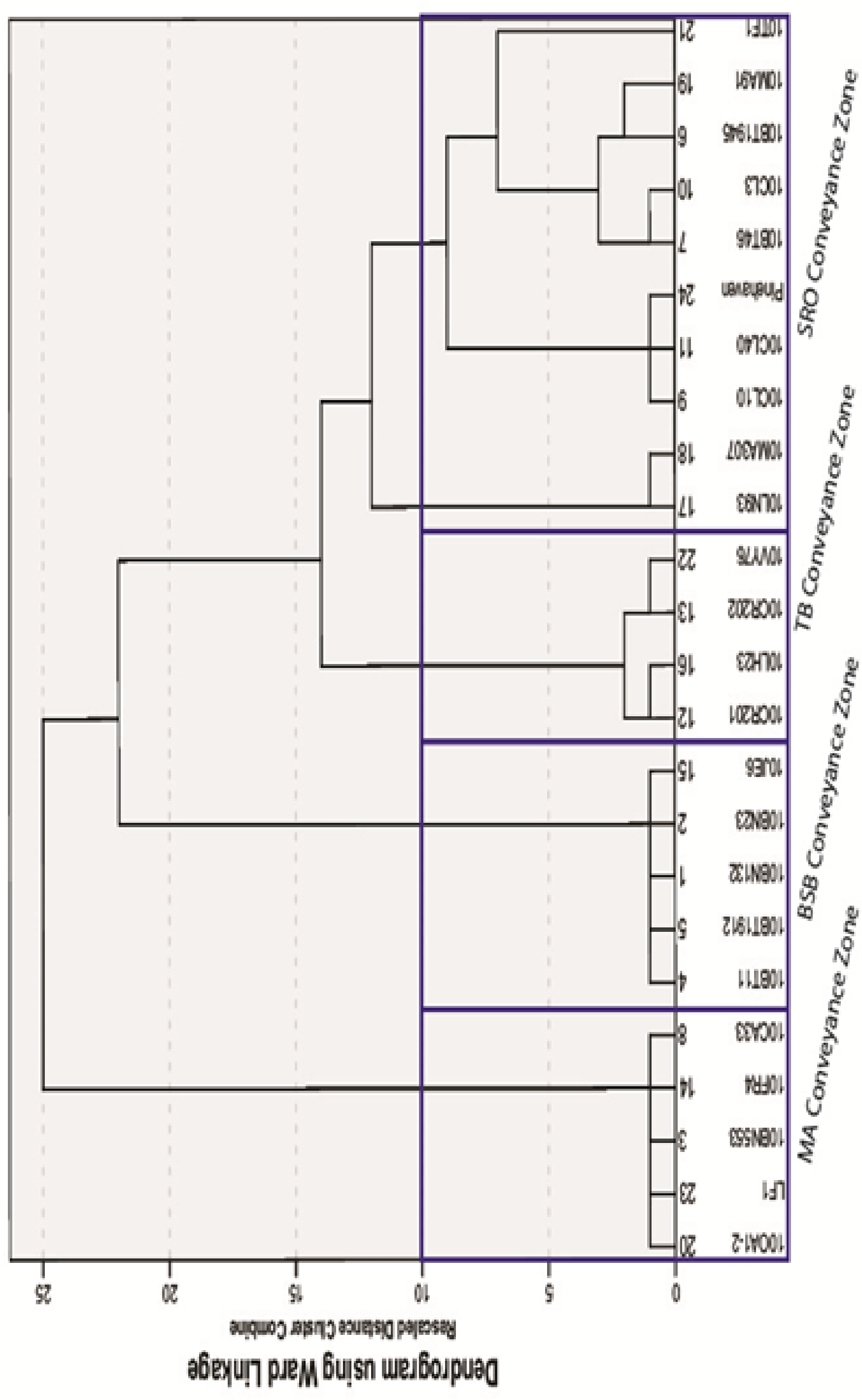
Appendix 3



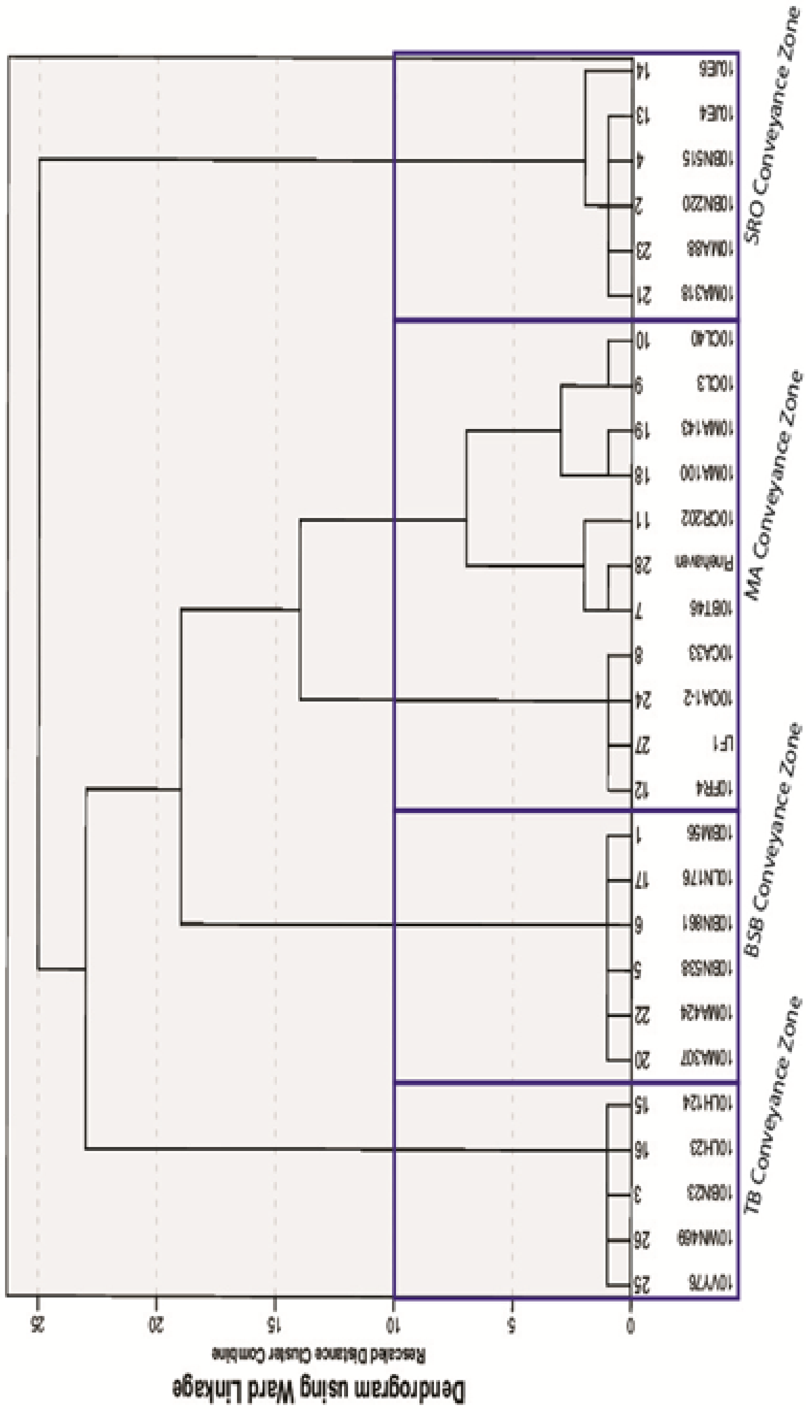
A. Hierarchical Clustering Dendrogram Showing Trans-Holocene Conveyance Zone Groups.



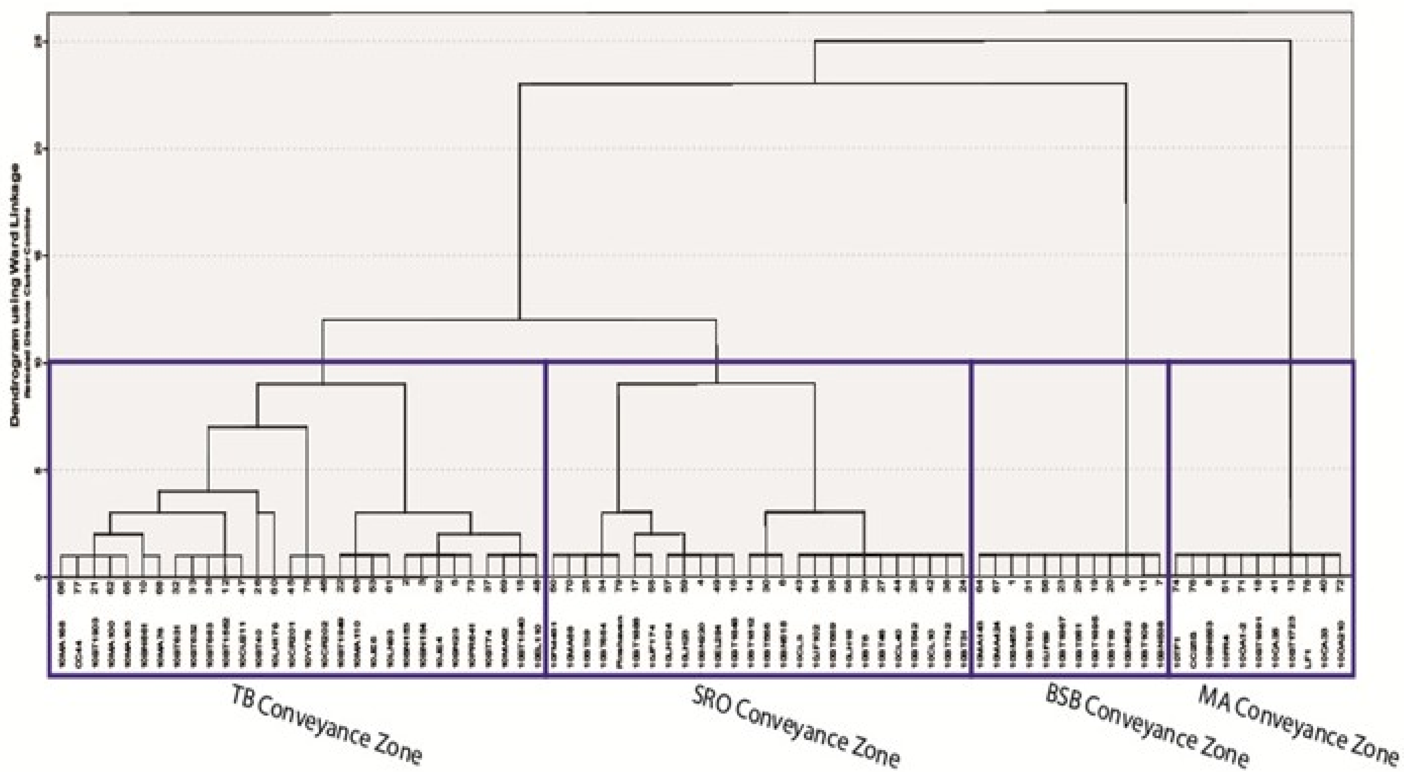
B. Hierarchical Clustering Dendrogram for Period 2 Sites.



C. Hierarchical Clustering Dendrogram for Period 3 Sites.



D. Hierarchical Clustering Dendrogram for Period 4 Sites.



E. Hierarchical Clustering Dendrogram for Period 5 Sites.