Mapping the Lithic Landscape: A GIS-Assisted Technique for Characterizing the Distribution of Moderate Scale Artifact and Geo Facts with Application to the Green River Terraces of Southwestern Wyoming | 2012-13

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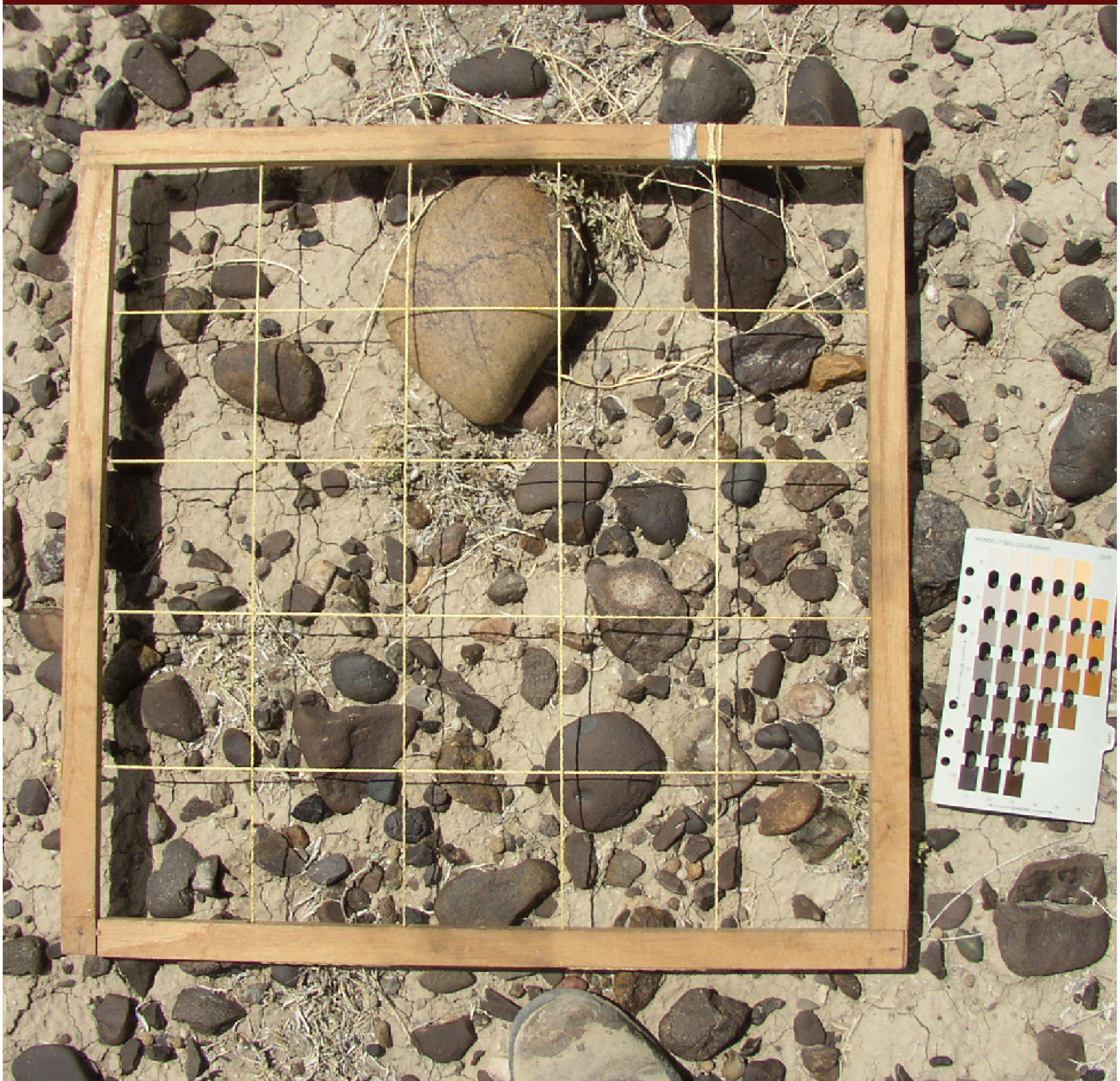

National Park Service
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Mapping the Lithic Landscape: A GIS-Assisted Technique for Characterizing the Distribution and Dimensions of Moderate Scale Artifact and Geofacts with Application to the Green River Terraces of Southwestern Wyoming (USA)

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Abstract

Past people satisfied their tool stone needs while negotiating a lithic landscape that varyied along multiple dimensions. To appreciate decisions made by past people, then, the lithic landscape must be known. This paper reports on a technique to rapidly and reliably characterize the lithic landscape in terms of nodule frequency, dimensions, and lithology using strategic fieldwork coupled with Geographic Information Systems (GIS)-based lab work. As a case study, we consider gravel terrace deposits from the Green River Basin of SW Wyoming. Using the technique detailed here, we were able to collect information on over 5,000 cobbles in approximately 11 person-days of field work and 40 hours of lab work. These data are then used to develop a picture of the lithic landscape that can be used to better interpret nearby archaeological assemblages.

Keywords

alluvial terraces, lithic characterization, lithic landscape, lithic procurement, GIS application, SW Wyoming

Dissected terrace deposits in the interior Wyoming Basin (North America; FIG. 1) served as an important source of tool stone for past occupants. But, not all tool stone is equal and we know that past peoples mapped on to specific lithic landscapes, with specific characteristics. To better interpret the patterning we find in lithic assemblages at particular points on the landscape, it is necessary to develop tools for rapidly and reliably characterizing the lithic landscape. Here, we offer a tool that couples strategic field work with laboratory-based Geographic Information Systems (GIS) manipulations of field data to provide consistent information on several aspects of the lithic landscape, raw material frequency, dimensions and spatial distribution. We detail its application to the documentation of cobbles on surfaces that have formed on cut-in terraces in the southwestern Green River Basin of Wyoming. This technique, however, could be extended to documenting the size of any moderate scale (1-25 cm size range) artifact (e.g., fire-cracked rock, tipi ring rocks) or geofact (e.g., cobbles) that contrasts well with other surface materials.

The Lithic Landscape

The lithic landscape of a region is a multi-dimensional phenomenon, with variation occurring in the location and density of potentially knappable material, the package size (e.g., pebble, gravel) and shape (e.g., tabular, oval) of potential core material and material quality (e.g., tractable, intractable; fine, coarse;

yielding durable or less durable edges) (Gould and Saggers 1985; see recent overviews in Andrefsky 2009 and Wilson 2007). Archaeological assemblages of chipped stone look the way they do in part because of the nature of the lithic landscape but also because of what Wilson refers to as "human factors." These include knapper ability, the organization of technology (and mobility and subsistence), mode of reduction, decisions made about economizing or transport (see also Goodman 1944 for an earlier similar statement). One other macro factor has been identified, that of time (Kuhn 1991; Sullivan 1987; Wilson 2007). Variation in chipped stone assemblages is also owed to occupation intensity and/or the length of time over which they have accumulated, with assemblages often becoming more diverse, for example, as they integrate more people events and time (e.g., Yellen 1977).

A chipped stone assemblage, thus, is the product of the dynamic interaction of these many geological, human, and temporal factors. To parse out the different contributing factors is analytically challenging and the strategy often employed is to begin with that which is most accessible—the character of the lithic landscape (see Goodman 1944:416 for early statement to this effect).

Approaches to the lithic landscape have varied considerably. In North America, the locations of lithic sources are generally known for many areas (e.g., NW

Plains, Francis 1991; Miller 1996; southern High Plains, Holliday 1997), and we know the locations of some quarries that yielded high quality materials (e.g., Cloverly quartzite; Reher 1991). Past peoples, however, addressed a very specific lithic landscape, and in order to interpret specific chipped stone assemblages, more detailed information about the local lithic landscape is usually needed. For this reason, Wilson and colleagues have systemically inventoried and assessed available raw material sources within the Vaucluse region of southern France in order to better interpret Middle Paleolithic assemblages from Bau de l'Aubesier (Wilson 2007). And, Church (1994) has developed guidelines for the systematic collection of information on regional lithic sources. Also, see Church (1996) for an exhaustive geological inventory of potential lithic sources in the Bear Lodge Mountains of the western Black Hills.

Three studies have expressly focused on lithic landscapes composed of gravels. Working with alluvial gravels east of the Llano Estacado, Backhouse and colleagues (2009) systematically inventoried five 1,600 m^2 sample plots to assess the relative frequencies of cobbles of different lithologies. This information was used to comment on the lithological content of nearby archaeological assemblages. With a focus on estimating parameters for the population of cobble sizes in the vicinity of archaeological assemblages, Douglass and Holdaway (2010) employed the Wolman sampling method (1954), wherein cobbles were sampled cobbles at 100 m intervals and then mechanically weighed. Finally, specifically relevant to this study, Larralde (1990) used intensive fieldwork to assess the qualities of the lithic landscape in portions of the Green River Basin of SW Wyoming. She mechanically measured the dimensions of 2,043 cobbles from sample units in or abutting larger archaeological sample units and measured another 220 cobbles from the series of five terrace edges along the Green River. Through this work, she was able to characterize lithic landscape in terms of material lithology, density, package size and shape with respect to the Green River terrace deposits and lag gravels found on badlands and desert pavements.

Modeling is another recently employed strategy for approaching raw material availability. Thus, Goings (2003) used GIS tools to model where topography and drainage might conspire to expose particular lithological strata in SE Iowa with high potential for knappable material. The utility of the model and the qualities of knappable material remain to be assessed.

Material availability and distance to available material, two related aspects of the lithic landscape, have obvious consequences for the nature of chipped stone assemblages, and this has been the focus of many studies (see Andrefsky 1994; Beck et al. 2002; Bamforth 2006; Kuhn 1991; Wilson 2007). Other research has focused on raw material lithology or quality and how it may affect assemblage character (Amick and Mauldin 1997) as well as tool function (Beck and Jones 1990; Bradbury et al. 2008; Goodman 1944; Terry et al. 2008). Furthermore, a number of researchers have looked at the effect of raw material package size (Bradbury and Franklin 2000; Dibble et al. 2005, Douglass et al. 2008; Douglass and Holdaway 2010) and shape (Ashton and White 2003) on the character of chipped stone assemblages.

The technique described below represents a means for rapidly and reliably gaining information on several aspects of the lithic landscape, namely, raw material density and distribution as well as raw material package size. After describing the technique, we demonstrate its application to characterize terrace cobbles in SW Wyoming.

Technique Description

The technique reported on here relies on systemic field work coupled with post-field GIS processing of field images. It assumes that clasts to be measured are visible on the ground surface and that the A (maximum dimension) axis of the clast is oriented parallel with the ground (i.e., not plunging or dipping). Such an assumption is empirically warranted in our situation and would require warranting with every application.

First, sample locations are selected according to some specific criteria (see example below). At these locations, a standardized photoframe (ours was 50 x 50 cm, with marked 10 cm intervals) is placed on the surface (FIG. 2). From a near vertical position over the photoframe, a digital photograph is made of the photoframe and surface (including clasts, vegetation, and other surface materials), yielding what we term a digital photographic surface plot (DPSP). The center of the DPSP may then be georeferenced using a Global Position System (GPS) technology.

In the laboratory, the DPSP is imported into a software package with image manipulation and measurement capabilities, which are commonly found in most GIS applications (we used ESRI's ArcGIS). By design, the photoframe appearing in the digital photograph has a built-in grid system that is easily referenced to a rectangular coordinate system. A GIS data file with specific points spaced at 10-cm intervals was created using the digitizing capabilities in ArcGIS. The DPSP internal grid (visible on the photograph) is then registered to the reference points using the "Georeferencing" extension in ArcMap. New, rectified files are then created within the extension, yielding an orthogonal DPSP (FIG. 3a).

With the rectified DPSP, measurement of cobbles is now possible. Topologically independent elements, i.e., line segments representing the maximum length of a cobble, are digitized in separate GIS data layers, one layer per cobble material (FIG. 3b). The lengths of the line segments are then computed using standard GIS tools and stored in the attribute table for each data layer. The attribute tables with length information can then be imported into any statistical software package.

Application

We illustrate this technique for cobble deposits on the terraces of tributaries of the Green River, similar to those characterized by Larralde (1990, see above). Our study area lies in the Wyoming Basin approximately 2 km south of the southern limits of Larralde's study area, and 4 km (~3 mi) south of Little America, Wyoming. Here, high quality archaeological field work has recently occurred (Smith and McNees 2004), terrace deposits are abundant, and, the Bureau of Land Management (BLM) manages parcels in the area that are relatively easy to access.

The physical landscape is composed of bedrock and extensive alluvial terraces, sometimes with aolian sand sheets and dunes. The vegetation is typical of a mixed desert shrubland and big sagebrush (Knight 1994). Within this area, numerous prehistoric sites have been recorded that date throughout the Holocene (Smith 2003; Smith and McNees 1999). In documenting the lithic landscape here, numerous examples of tested cobbles and early stage reduction were noted outside of previously recorded sites. Typical archaeological deposits include chipped stone artifacts, pit and basin thermal features, and fire-cracked rock.

Fieldwork occurred during May 2006. Within the study area, we focused on four 1x1-mile BLM parcels located between Meadow Springs Creek and Chicken Draw (FIG. 1). Both drainages feed into Blacks Fork, and, in turn, the Green River further north-northeast.

The sampling we report on here was part of a larger effort to collect information on surface characteristics at a hierarchy of spatial scales so as to calibrate the information obtained by various satellite sensors. Thus, our samples were taken from representative surface cover types, a sampling design issue to which we return in the concluding section.

A total of 136 sample locations were chosen based on an initial geomorphological classification of the study area derived from 1-meter resolution color infrared (CIR) digital orthophotos. At each sample location, at least six DPSPs and two horizontal overview photographs were taken with a digital camera to document extant surface conditions (FIG. 4). DPSPs were spaced at roughly 10-meter intervals. The coordinates of all photographed locations were recorded using a

Trimble GeoXT GPS receiver. Over the course of 11 person-days, we collected 816 DPSPs at 136 sample locations.

In the laboratory, each DPSP was rectified as described above using ESRI ArcGIS software to enable accurate measurements of cobbles dimensions. All cobbles greater than 5 cm in maximum length were digitized in ArcMap as straight line segments extending along the A axis or maximum visible length of the cobbles. Separate GIS data layers were created for (1) quartzite cobbles, (2) brown chert cobbles, (3) other potentially knappable cobbles, (including volcanics, basalts, dacites, and Moss Agate), and (4) other cobbles (including siltstone and sandstone cobbles). Distinguishing material types was based on cobble shape and weathering as well as occasional exposure owed to flake removal by natural or prehistoric agents. Using the "Calculate Geometry" function in ArcMap, measurements along the A axis were calculated for the digitized line segments on 5,704 cobbles. Length information was then accessible in the DBF file (attribute table), which was then imported into SPSS (SPSS Statistics 17.0) for statistical summary. The laboratory component took approximately 40 hours to complete.

The Meadow Springs Wash-Chicken Draw Lithic Landscape

With information obtained through field and laboratory work, we are now in a position to offer a preliminary characterization of several aspects (i.e., cobble lithology, frequency, package size, and shape) of the lithic landscape south of Meadow Springs Wash and north of Chicken Draw. Where Larralde reports that quartzite cobbles were 10 times as common as those of brown chert, we found a hundredfold difference (TABLE 1). Interestingly, we found no examples of biogenic chert at our study locations, even though this material appears with high frequencies and with large flake sizes in nearby archaeological assemblages. Also absent from our inventory are obsidian and Granger Green chert, both of which are found in nearby archaeological assemblages. Larralde (1990:150) reports that spherical obsidian pebbles are found in terrace deposits west of the Green River while chalcedony occurs as tabular pebbles throughout her study area. If either of these material types occur in our study area, our protocol would not have captured them by virtue of their small size.

In addition to differences in the relative frequencies of cobble lithologies, we note differences in package size. Along the A axis, Larralde reported average cobble dimensions of 68.0 $\pm$ 22.1 mm for quartzite and 58.9 $\pm$ 11.4 mm for brown chert (TABLE 1). In our sample, the relative size difference between quartzite and chert cobbles is maintained. That is, quartzite cobbles are on average 1 cm larger than chert cobbles. Our sample means are larger overall, however, than those reported by Larralde, with quartzite cobbles at 77.2 ± 25.9 mm along the A axis and brown chert cobbles at 62.9 ± 14.7 mm (TABLE 1; FIG. 4). Other rare potentially knappable cobbles of volcanic and Moss Agate materials are still longer.

In our study area, terraces decrease in elevation from SW to NE, with older terraces occurring at high elevations and younger terraces, better represented in our sample here, at lower elevations (FIG. 5). Cobble densities are not uniform across terrace surface, but in general appear slightly higher on the lower terraces (FIG. 6). Here, brown chert cobbles are more frequent than on the higher terraces and quartzite cobbles are especially common. Volcanic and Moss Agate cobbles occur more frequently on the highest terraces.

Mean cobble size along the A dimension show some trends along the A-A' transect (see FIG. 7). For brown chert, sample size is small and variation in size is high; lengths vary between 50 and 75 mm and the degree of variation in this trend seems to diminish from SW to NE. For mean quartzite cobble length, there is an overall decline in mean size from SW to NE (from higher to lower terraces) from about 100 mm to 70 mm, with very large negative and positive departures from this trend. Very small quartzite cobbles occur as lag material at high elevations in the SW portion of the A-A' transect, while very large quartzite cobbles occur with the local erosional exposures associated with drainages and terrace edges. Moss

Agate and volcanic cobbles are generally larger on the high terraces and smaller on lower terraces, although a great range in values is evident.

Having characterized the Meadow Springs Wash-Chicken Draw lithic landscape in this fashion, several implications follow. Local archaeological deposits now can be assessed with respect to the relative frequencies of different kinds of materials, for example, chert and quartzite debitage and tools, allowing for interpretation of on-site vs. projected tool needs. Similarly, it may be possible to compare cobble sizes found in the immediate lithic landscape and those appearing in archaeological assemblages, again, allowing for comment on how past peoples sampled the lithic landscape.

Conclusion

Archaeologists widely acknowledge the importance of the lithic landscape in constraining the character of chipped stone assemblages. Above, we report on a portion of our attempts to characterize of the density, lithiology, and package size of the lithic landscape south of the Green River in SW Wyoming. The technique outlined here relies on both field work and laboratory work. In the field, digital photo surface plots (DPSP) are made of moderate scale phenomenon, in this case, cobbles. In the laboratory, images are rectified, making them suitable for accurate measurement. GIS layers are created representing the maximum length of cobbles. Segment lengths are calculated using standard GIS tools and then exported to a statistical software package for further analysis.

In a similar study, Larralde (1990) used mechanical measurement to characterize the lithic landscape in much of the same way (see above). Her investigation of cobble material distribution required approximately 10 person days (Signa Larralde, personal communication 2010) and yielded a sample size of 2,263 cobbles, with measurements made on three dimensions. Investigations reported here involved more time—11 person days of field work and 40 hours of laboratory time—and yielded estimates on cobble length for 5,076 cobbles. Here, we only report on one dimension, cobble length, but it would be relatively straightforward to monitor two cobble dimensions. In that these cobble measurements are tied to spatial locations measured with a GPS, it is relatively easy to generate information on terrace cobble qualities by location, of importance to interpretations of lithic assemblages.

The GIS-assisted technique reported upon here was deployed in such a way as to capture more information about surface qualities detected in aerial photos, without respect to a specific archaeological assemblage. Other applications could be implemented as part of a sampling design tethered to particular archaeological assemblages as seen in the work of Backhouse and colleagues (2009), Douglass and Holdaway (2010) and Larralde (1990).

Abe and colleagues (2002) developed a means for standardizing the frequency of cut marks by bone surface area using an approach that coupled image analysis and GIS assessment. In this way, consistently applied comparative analysis of cutmarks among archaeofauna assemblages becomes possible. Similarly, by standardizing the documentation of lithic landscapes using the technique proposed here, the comparison of different chipped stone assemblages in a way that takes into consideration the local availability of raw material becomes possible. In the case here, we argue that fruits of field work, often the most expensive components of archaeological research, can be maximized through the strategic use of image analysis and GIS tools.

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References Cited

Abe, Y., C. W. Marean, P. J. Nilssen, Z. Assefa, and E. C. Stone. 2002. "The Analysis of Cutmarks on Archaeofauna: A Review and Critique of Quantification Procedures, and a New Image-Analysis GIS Approach," *American Antiquity* 67: 643-663.

Amick, D. S., and R. P. Mauldin. 1997. "Effects of Raw Material on Flake Breakage Patterns," *Lithic Technology* 22: 18-32.

Andrefsky, J., William. 1994. "Raw-Material Availability and the Organization of Technology," *American Antiquity* 59: 21-34.

Andrefsky, W. 2009. "The Analysis of Stone Tool Procurement, Production, and Maintenance," *Journal of Archaeological Research* 17: 65-103.

Ashton, N., and M. White. 2003. "Bifaces and Raw Materials: Flexible Flaking in the British Early Paleolithic," in M. Soressi and H. L. Dibble, eds., *Multiple Approaches to the Study of Bifacial Technologies. Philadelphia: University Museum Monograph 115,* Philadelphia: University of Pennsylvania, 109-124.

Backhouse, P. N., E. Johnson, and D. Cunningham. 2009. "Lithic Technology and Toolstone Variability at Two Gravel Exposures Neighboring the Eastern Llano Estacado," *Plains Anthropologist* 54: 259-280.

Bamforth, D. B. 2006. "The Windy Ridge Quartzite Quarry: Hunter-gatherer Mining and Hunter-gatherer Land Use on the North American Continental Divide," *World Archaeology* 38: 511-527.

Beck, C., and G. T. Jones. 1990. "Toolstone Selection and Lithic Technology in Early Great Basin Prehistory," *Journal of Field Archaeology* 17: 283-299.

Beck, C., A. K. Taylor, G. T. Jones, C. M. Fadem, C. R. Cook, and S. A. Millward. 2002. "Rocks are Heavy: Transport Costs and Paleoarchaic Quarry Behavior in the Great Basin," *Journal of Anthropological Archaeology* 21: 481-507.

Bradbury, A., P. Carr, and D. R. Cooper. 2008. "Raw Material and Retouched Flakes," in W. J. Andrefsky, ed., *Lithic Technology: Measures of Production, Use, and Curation*. Cambridge: Cambridge University Press, 233-256.

Bradbury, A., and J. D. Franklin. 2000. "Material Variability, Package Size and Mass Analysis," *Lithic Technology* 25: 42-58.

Church, T. 1994. *Lithic Resource Studies: A Sourcebook for Archaeologists. Lithic Technology Special Publication 3*. Tulsa, OK: University of Tulsa.

Church, T. 1996. "Lithic Resources of the Bearlodge Mountains, Wyoming: Description, Distribution, and Implications," *Plains Anthropologist* 41: 135-164.

Dibble, H. L., U. A. Schurmans, R. P. Iovita, and M. V. McLaughlin. 2005. "The Measurement and Interpretation of Cortex in Lithic Assemblages," *American Antiquity* 70: 545-560.

Douglass, M. J., and S. J. Holdaway. 2010. "Quantifying Stone Raw Material Size Distributions: An Archaeological Application for Investigating Cortex Proportions and Prehistoric Mobility in Lithic Assemblages from Western New South Wales, Australia," in J. Specht and R. Torrence, eds., *On the Cutting Edge in Southeastern Australia.* Sydney: Technical Report of the Australian Museum.

Douglass, M. J., S. J. Holdaway, P. C. Fanning, and J. I. Shiner. 2008. "An Assessment and Archaeological Application of Cortex Measurement in Lithic Assemblages," *American Antiquity* 73: 513-526.

Francis, J. E. 1991. "Lithic Resources on the Northwestern High Plains: Problems and Perspectives in Analysis and Interpretation," in A. Montet-White and S. Holen, eds., *Raw Material Economies among Prehistoric Hunter-Gatherers, Publications in Anthropology 19.* Lawrence: University of Kansas, 305-320.

Goings, C. A. 2003. "A Predictive Model for Lithic Resources in Iowa," *Plains Anthropologist* 48: 53-67.

Goodman, M. E. 1944. "The Physical Properties of Stone Tool Materials," *American Antiquity* 9:415-433.

Gould, R. A., and S. Saggers. 1985. "Lithic Procurement in Central Australia: A Closer Look as Binford's Idea of Embeddedness in Archaeology," *American Antiquity* 50: 117-136.

Holliday, V. T. 1997. *Paleoindian Geoarchaeology of the Southern High Plains*. Austin: The University of Texas Press.

Knight, D. H. 1994. *Mountains and Plains: The Ecology of Wyoming Landscapes*. New Haven: Yale University Press.

Kuhn, S. L. 1991. "'Unpacking' Reduction: Lithic Raw Material Economy in the Mousterian of West-Central Italy," *Journal of Anthropological Archaeology* 10: 76-106.

Larralde, S. 1990. *The Design of Hunting Weapons: Archaeological Evidence from Southwestern Wyoming*. Ph.D. dissertation, University of New Mexico. Ann Arbor: University Microfilms.

Miller, J. C. 1996. Lithic Sources in the Northwestern Plains. *Archeological and Bioarcheological Resources of the Northern Plains*: 41-49.

Reher, C. A. 1991. "Large Scale Lithic Quarries and Regional Transport Systems on the High Plains of Eastern Wyoming: Spanish Diggings Revisited," in A. Montet-White and S. Holen, eds., *Raw Material Economies among Prehistoric Hunter-Gatherers, Publications in Anthropology 19*. Lawrence: University of Kansas, 251-284.

Smith, C., and L. McNees. 2004. "*Cymopterus bulbosus* and Prehistoric Foragers: Patch Size, Plant Density, and Return Rates," *Journal of Ethnobiology* 25(1): 1-23.

Smith, C. S. 2003. "Hunter-Gatherer Mobility, Storage, and Houses in a Marginal Environment: An Example from the Mid-Holocene of Wyoming," *Journal of Anthropological Archaeology* 22: 162-189.

Smith, C. S., and L. M. McNees. 1999. "Facilities and Hunter-Gatherer Long-Term Land Use Patterns: An Example from Southwest Wyoming," *American Antiquity* 64: 117-136.

Sullivan, A. P. 1987. "Probing the Sources of Lithic Assemblage Variability: A Regional Case Study near the Homolovi Ruins, Arizona," *North American Archaeologist* 8: 41-71.

Terry, K., J. Andrefsky, William, and M. V. Konstantinov. 2008. "Raw Material Durability, Function, and Retouch in Upper Paleolithic of the Transbikal Region," in B. Adams and B. S. Blades, eds., *Lithic Materials and Paleolithic Societies*. Oxford: Blackwell, 256-269.

Wilson, L. 2007. "Understanding Prehistoric Lithic Raw Material Selection: Application of a Gravity Model," *Journal of Archaeological Method and Theory* 14: 388-411.

Wolman, M. G. 1954. "A Method of Sampling Coarse River-Bed Material," *Transactions of the American Geophysics Union* 35: 951-956.

Yellen, J. E. 1977. *Archaeological Approaches to the Present*. New York: Academic Press.

Table 1. Summary of cobble dimension measurements, mean and standard deviation, for this study and Larralde (1990: 148).

Cobble Lithology	*Terrace Cobbles* (this study)*		*Terrace and Desert Pavement Cobles* (Larralde 1990)*			
	N	*A Axis (mm)*	*N*	*A Axis (mm)*	*B Axis (mm)*	*C Axis (mm)*
Quartzite	3684	77.2 ± 25.9	1296	68.0 ± 22.1	44.3 ± 18.0	19.1 ± 10.3
Brown Chert	32	62.9 ±+ 14.7	126	58.9 ± 11.4	36.2 ±10.8	111.0 ± 6.6
Other Knappable (volcanic, Moss Agate)	201	85.6 ± 33.7				
Other	1787	69.0 ± 22.6				
Total	5704		1322			

* A Axis refers to maximum dimension, B Axis to intermediate dimensions, and C Axis to minimum dimension.

Figure Caption List

Figure 1. Study area. Transect A-A' bisects the Bureau of Land Management parcels investigated here.

Figure 2. Digital Photographic Surface Plot (DPSP) with photofame and Munsell color chart.

Figure 3a. Computer screen capture of unrectified surface plot in ESRI ArcMap.

Figure 3b. Computer screen capture of rectified surface plot in ESRI ArcMap. Line segments (enhanced to improve visibility) represent the length of quartzite, brown, chert, and other cobbles greater than 50 mm, respectively. Image was rectified to registration points (black circles) using ESRI ArcMap, Georeference Extension.

Figure 4. Sample locations. Inset gives an example of a horizontal overview of one sample location; arrows indicate locations of DPSPs.

Figure 5. Boxplot of cobble length by material.

Figure 6. Number of sample locations and mean elevation (m) along the A-A' transect.

Figure 7. Mean cobble frequencies along the A-A' transect.

Figure 8. Mean cobble length by material type along the A-A' transect.

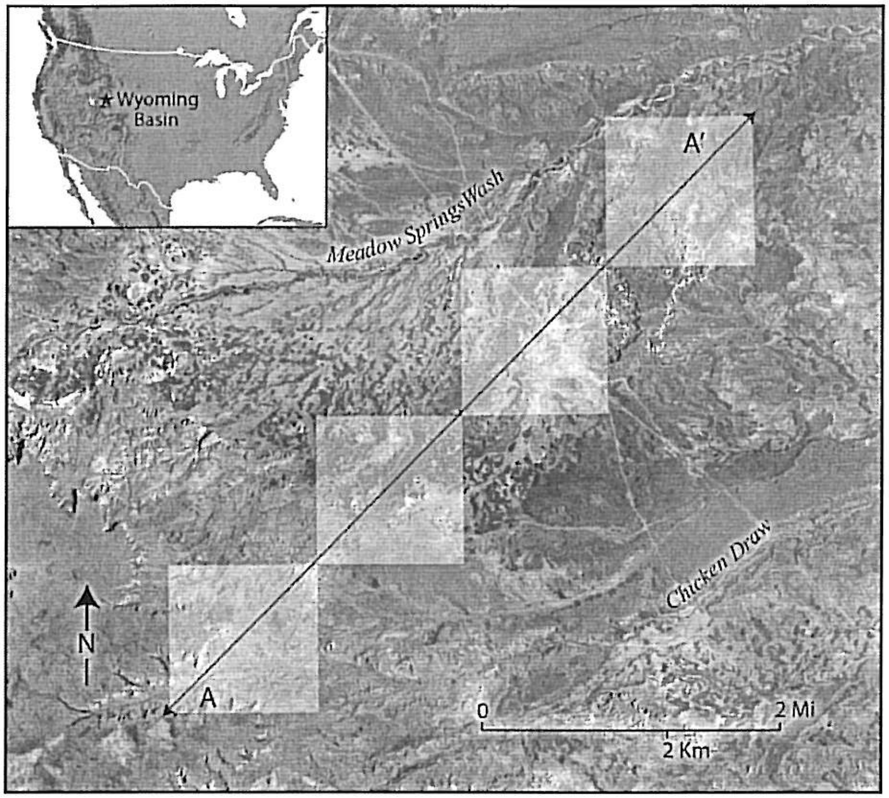
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FIG. 1

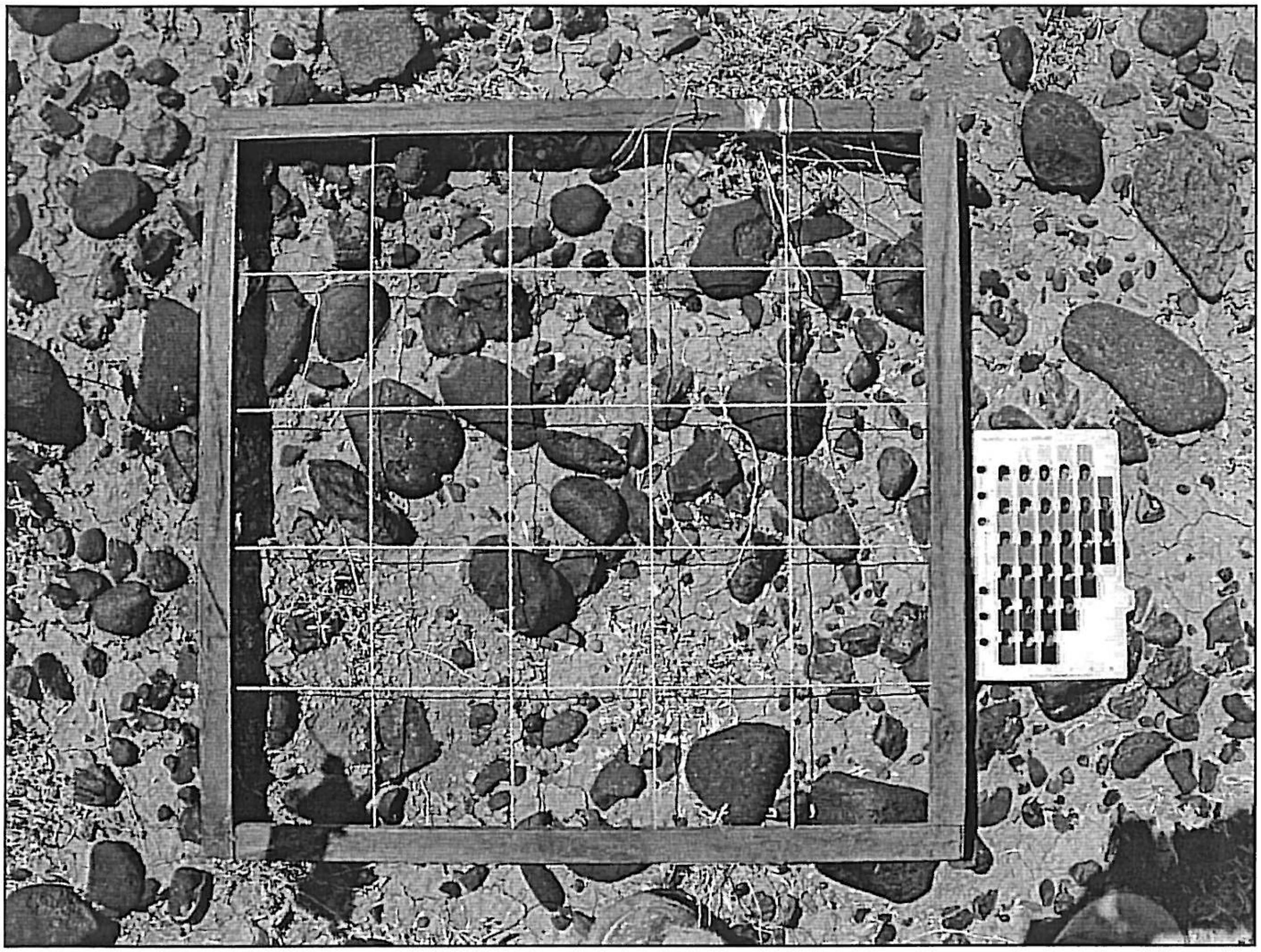

FIG. 2

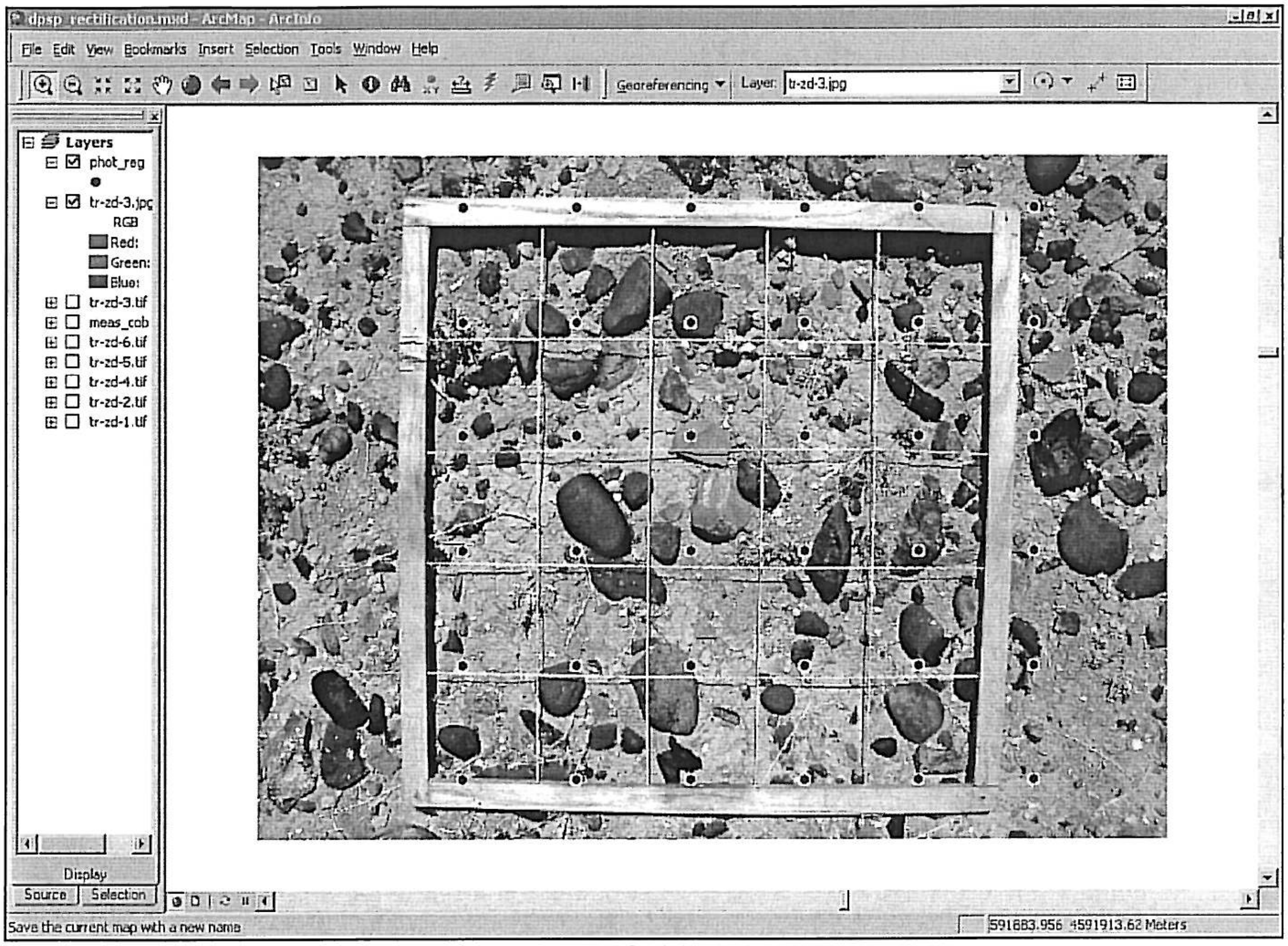
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FIG. 3A

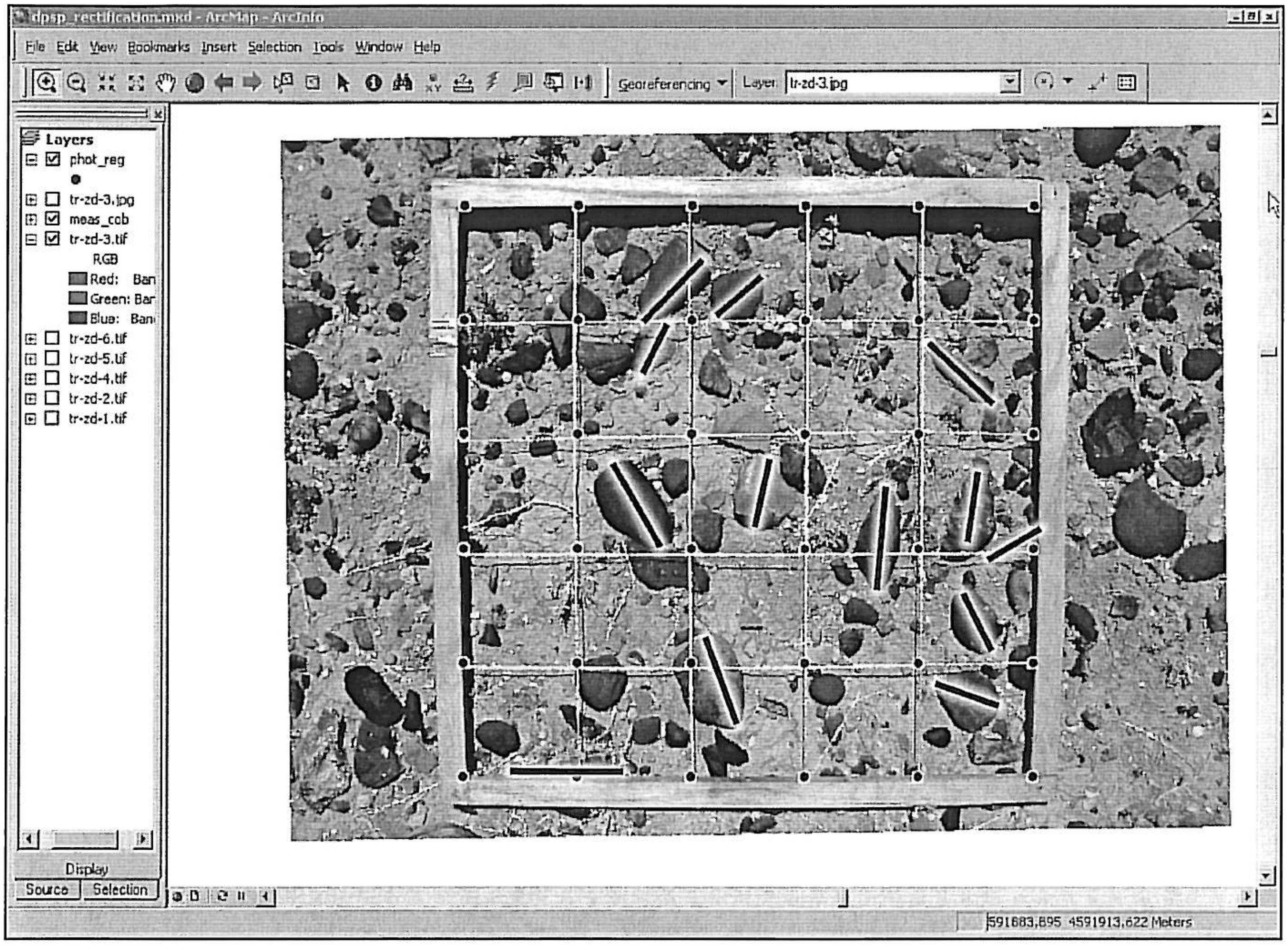
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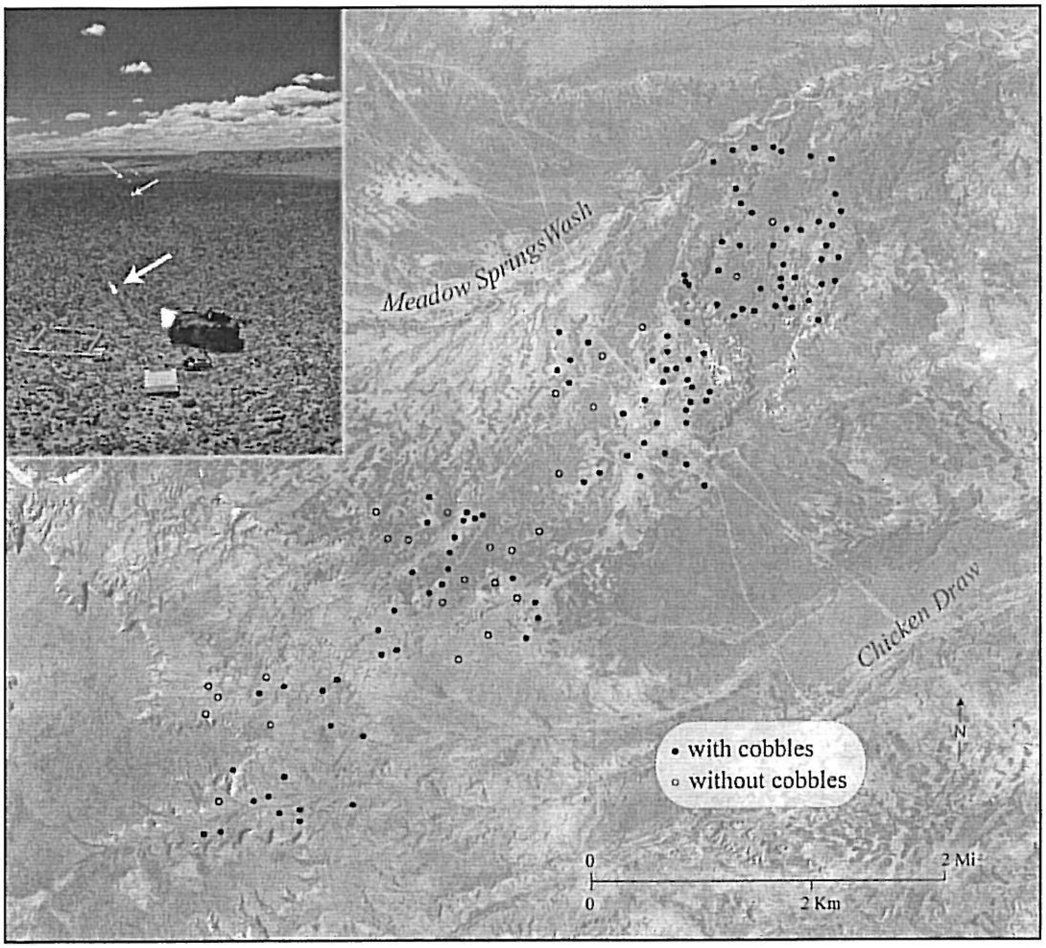
FIG. 3B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Chicken Draw
• with cobbles
◦ without cobbles
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2 Km

FIG. 4

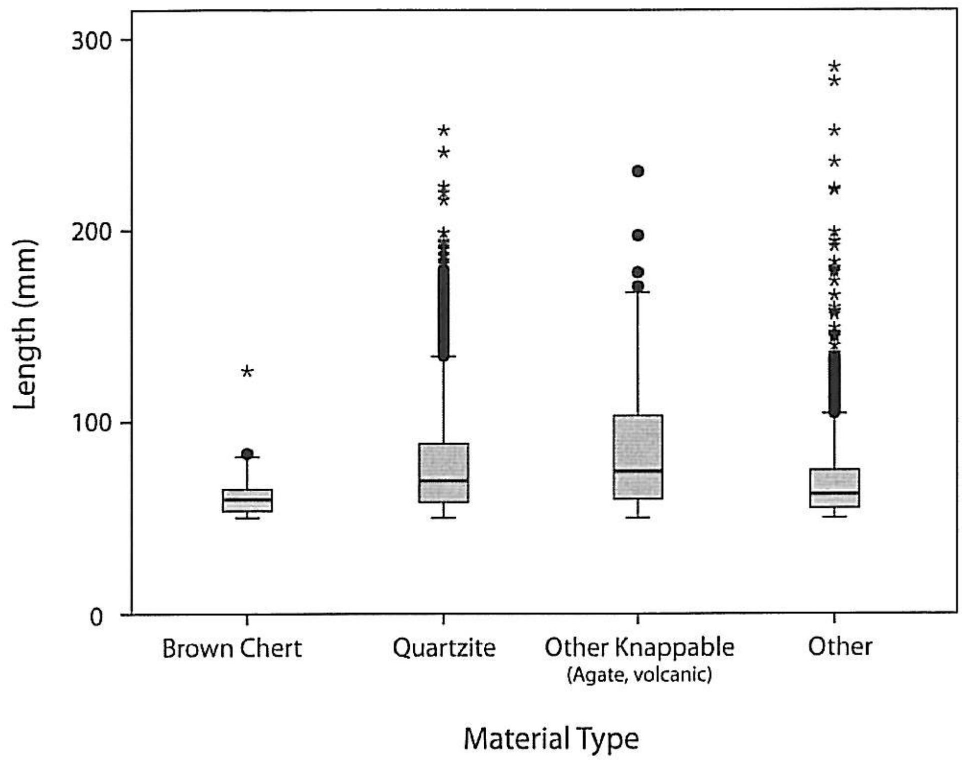
300
200
100
0
Length (mm)
Brown Chert
Quartzite
Other Knappable
(Agate, volcanic)
Other
Material Type

FIG. 5

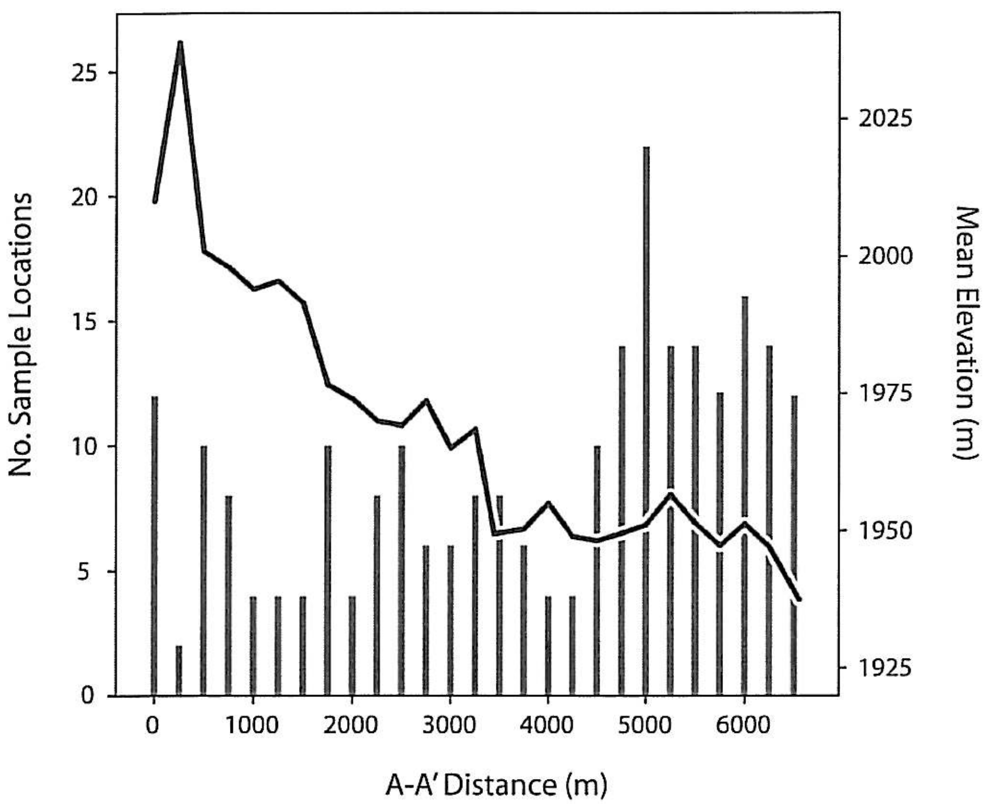
No. Sample Locations
0
5
10
15
20
25
Mean Elevation (m)
1925
1950
1975
2000
2025
0
1000
2000
3000
4000
5000
6000
A-A' Distance (m)

FIG. 6

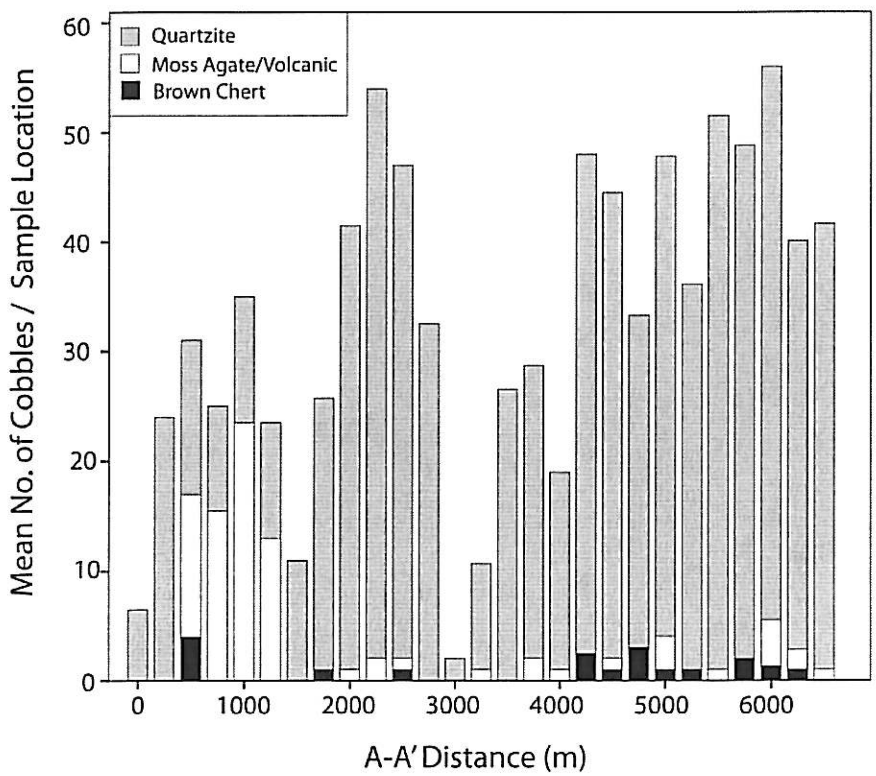
Quartzite
Moss Agate/Volcanic
Brown Chert
Mean No. of Cobbles / Sample Location
60
50
40
30
20
10
0
0
1000
2000
3000
4000
5000
6000
A-A' Distance (m)

FIG. 7

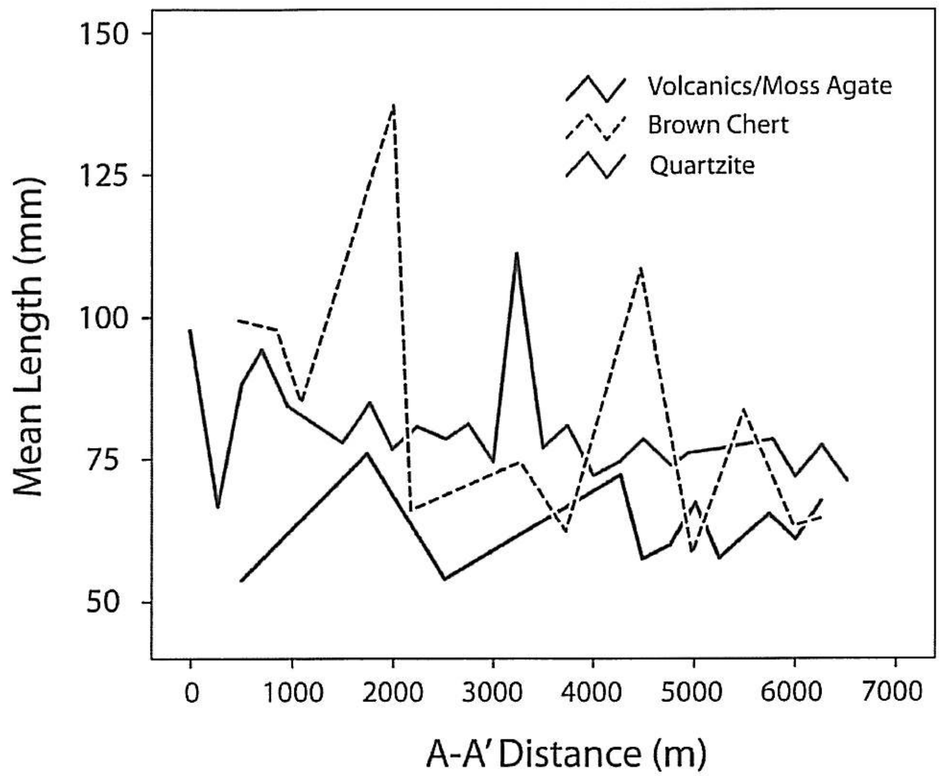
150
125
100
75
50
Mean Length (mm)
Volcanics/Moss Agate
Brown Chert
Quartzite
0
1000
2000
3000
4000
5000
6000
7000
A-A' Distance (m)

FIG. 8