Evaluation of Remote Sensing Tools for Documenting and Characterizing Terrace Cobble Deposits in the Interior Wyoming Basin: Continuing Studies

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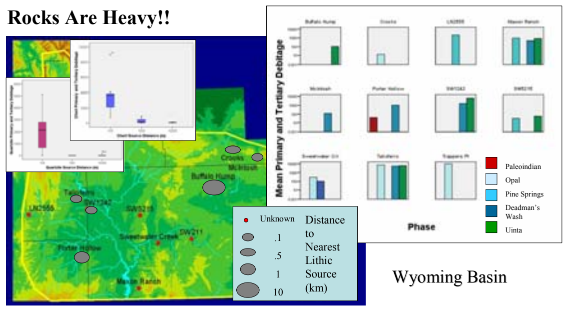
Abstract
Terrace cobble deposits in the Wyoming Basin provided a rich source of tool-stone that was used by prehistoric groups throughout the Holocene. Understanding the extent and character of these deposits is important for interpreting the distribution of chipped-stone artifacts throughout the area. This research evaluates a variety of remote sensing tools for detecting the extent and nature of terrace cobble deposits. Using a multi-scalar approach, we consider the utility of color infrared digital orthophotos and ASTER satellite imagery for documenting terrace cobble deposits in a small portion of the Wyoming Basin. Our preliminary findings suggest that each of these data sources are useful for detecting and characterizing terrace cobble deposits in the interior Wyoming Basin; but that further research is necessary to determine which source is more reliable at different spatial scales of observation.

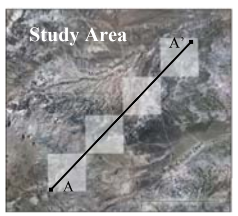
Rocks Are Heavy!!



Wyoming Basin

We know that rocks are heavy (Beck et al. 2002). Thus, we are not surprised to find that chipped stone assemblage size is often inversely correlated with distance to particular sources, as for sites Buffalo Hump, 48SW1242 and Talioferro. But, the relationship is more complex, as for sites Crooks, McIntosh, and Porter Hollow. And, sometimes we have no baseline for assessment as we lack information on the nature of the lithic landscape. In this case, can we expeditiously map the local "natural" lithic landscape so as to better understand the character of site chipped stone assemblages? Can we use available technologies—low cost, high resolution imagery and off-the-shelf image processing tools—to further this understanding?

Here we report on our continuing attempts to use digital orthoquads (DOQs) and satellite imagery to locate and characterize terrace cobble sources in the Green River Basin of southwestern Wyoming (interior continental North America). Our study area is located approximately 4 km (~3 mi) south of Little America, Wyoming, where numerous prehistoric sites, dating to throughout the Holocene, have been recorded (Smith et al. 2003; Smith and McNees 1999, 2005). Typical archaeological deposits include chipped stone artifacts, pit and basin thermal features, and fire-cracked rock (McNees in preparation). Within the study area, we focus on four 1x1-mile BLM parcels located between Meadow Springs Wash and Chicken Draw.

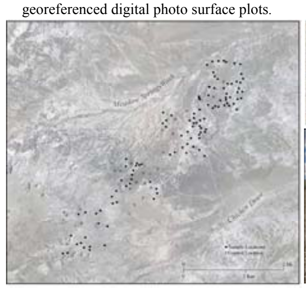


The map to the left is a close-up view of the study area showing color infrared (CIR) airphotos taken in 2002. The light blocks represent the 1x1-mile BLM parcels targeted for this study. The A-A' section is described in following paragraphs.

Study area in southwestern Wyoming. The image is a LANDSAT Thematic Mapper (TM) false color composite (R,G,B = NIR, Red, Green) acquired in May, 2006. Red tones indicate lush vegetation, while black tones indicate clear bodies of water. At this scale, terrace cobble deposits appear as light to medium blue.

The Lithic Landscape

The "natural" lithic landscape here consists of series of terraces, mantled by quartzite, chert, volcanic, and other cobbles, and cut by local streams. We sampled terraces and other landforms along a SW-NE trending transect, collecting information on cobble frequency and size, degree of varnish, and pavement cover as documented in georeferenced digital photo surface plots.



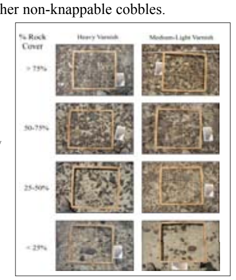
The map to the left shows the location of sample and control locations in the study area. Of these locations, 106 are located in terrace cobble deposits (sample locations) and 30 are located on other surfaces (control locations).

The image on the top right is an example of a photo-graphic surface plot covering 50x50-cm of the ground surface. The inclusion of a Munsell color chart allows for the comparison of different surface plots taken in different lighting conditions.

The image on the bottom right is an example of a horizontal overview. The pink pin flags mark the location of the six photographic surface plots recorded for each location.

Digital photographic surface plots were rectified using ArcGIS software to enable accurate measurements of cobble lengths. All cobbles greater than 5 cm in maximum length were digitized in ArcMap as straight line segments extending the maximum length of the cobbles. Separate shapefiles were created for (1) quartzite, (2) brown chert, (3) other knappable (volcanics and Moss Agate), and (4) other non-knappable cobbles.

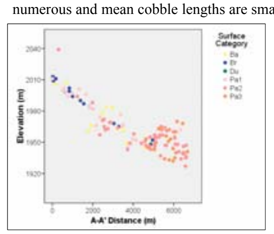
The figure to the right shows how the ordinal classifications were made. The image to the left is a screen shot of a rectified surface plot in ArcGIS. Blue, red, and black lines represent quartzite, non-knapable, and other knapable cobbles, respectively. The distinctions are based on cobble shape and weathering, since most cobbles are varnished. Thus, the reliability of these distinctions are currently unknown.

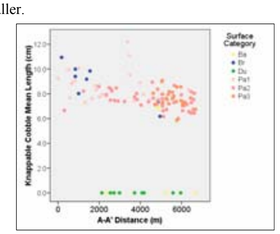


Using GIS and statistical software, length measurements were derived and then summarized for each sample location. This information served as a basis for detecting different surface types using digital airphotos and satellite imagery.

Surface Category	Abbreviation	% Clast Cover	Mean Cobble Size (cm)	Varnish	Description
Bedrock	BR	-	6.0-11.0	-	sediment with residual bedrock cobbles
Dune	DU	-	-	-	sagebrush covered dunes
Bare Sediment	BA	-	-	-	mostly bare, exposed sediment; sparse sagebrush/grass vegetation
Pavement-1	PA-1	0-50%	7.0-11.0	moderate	stone pavement w/ low density tool-stone cobbles
Pavement-2	PA-2	≥50%	6.5-9.0	mod. to heavy	stone pavement w/ medium density tool-stone cobbles
Pavement-3	PA-3	>50%	6.5-9.0	heavy	stone pavement w/ high density tool-stone cobbles

Terrace cobble deposits at lower elevations show relatively more varnish, clasts are more numerous and mean cobble lengths are smaller.





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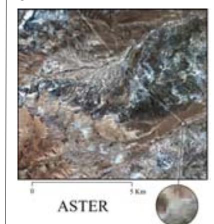
Mapping the Lithic Landscape: Satellite Imagery

The imagery considered here includes an ASTER granule acquired on 20 April 2006 by the TERRA satellite, just prior to field investigations. (This granule was obtained form a no-cost data pool with a 2-year moving wall maintained (see the Earth Observing System Data Gateway; other archived granules are available at low cost.)



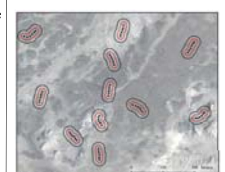
The image above is a false color composite (R,G,B =NIR, Red, Green) of the study area. ASTER bands 4-9 are at a spatial resolution of 30-meters, but were resampled to 15-meters for the purposes of this study.

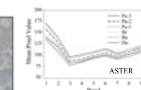
ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is an imaging instrument flying on Terra, a satellite launched in December 1999 as part of NASA's Earth Observing System. ASTER is a cooperative effort between NASA, Japan's Ministry of Economy, Trade and Industry (METI) and Japan's Earth Remote Sensing Data Analysis Center. ASTER is being used to obtain detailed maps of land surface temperature, reflectance and elevation. (http://asterweb.jpl.nasa.gov/index.asp) The spectra sampled by ASTER make it especially powerful in geological prospection.

Sensor	Spectral Region	Spatial Res.	Band*	Spectral Res. (µm)
ASTER	VNIR	15	1	0.52-0.60
		15	2	0.63-0.69
		15	3	0.76-0.86
	SWIR	30	4	1.600-1.700
		30	5	2.145-2.185
		30	6	2.185-2.225
		30	7	2.235-2.285
		30	8	2.295-2.365
		30	9	2.360-2.430

* ASTER bands 10-14 (thermal infrared), with a 90 m resolution, are not considered here.

Using ERDAS Imagine software, spectral data were collected for pixels within 15 meters (ASTER). The spectral data were then summarized according to the six gross surface categories, three of which exhibit varying densities of tool-stone cobbles.

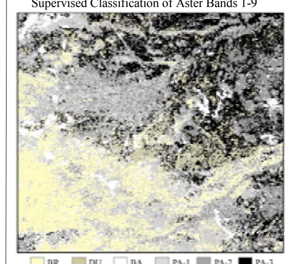




The image to the left shows (1) photographic surface plots as black dots, (2) 15-meter buffers as red outlines, and (3) 30-meter buffers as black outlines. The line graph shows the mean average pixel value for the six surface categories givern earlier.

With the spectral data, a preliminary classification of the study area was made using the ASTER images. Each of the 136 sample locations, and their associated spectral data, were used as training sites to perform a supervised classification applying the default settings in ERDAS Imagine. Each training site was then used as a ground control point to evaluate the accuracy of the preliminary classifications. While the preliminary classifications produce relatively poor results (62% correct), the results are substantially better if the study area is generalized into binary tool-stone bearing and non-tool-stone bearing units (82% correct).

Supervised Classification of Aster Bands 1-9



The image to the left shows the results of the preliminary supervised classification using the ASTER (left) satellite imagery. The table below are error matrices that were produced using the 136 sample locations as ground control points. The number of locations classified correctly are shown where row and column classes correspond. All other values report errors of omission and errors of commission. For example, in both the ASTER classifications, all DU control point locations were classified correctly as being DU surfaces. However, the ASTER classification incorrectly classified six locations as being DU surfaces (1 BA, 2 PA-2, 3 PA-3).

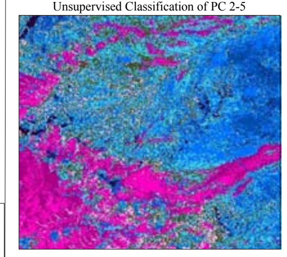
Interpreted Surface

Actual Surface	BA	BR	DU	PA-1	PA-2	PA-3	total
BA	5	5	1	0	5	1	17
BR	0	12	0	1	0	0	13
DU	0	0	9	0	0	0	9
PA-1	2	5	0	13	2	0	22
PA-2	2	4	2	3	29	14	54
PA-3	0	1	3	0	1	16	21
total	9	27	15	17	37	31	136

Percent Correct = 62%

Subsequent analysis followed Ren (2004), focusing on principle components (PC) of the 9 ASTER bands to identify and reduce redundant information. PC1 usually contains little information and was discarded. We undertook an unsupervised classification of PC 2-5 using ArcMap Maximum Likelihood Classification. An 8-class solution produced the best results, but with little specific correspondence between Surface Category and Class, as indicated in the table below.

Unsupervised Classification of PC 2-5



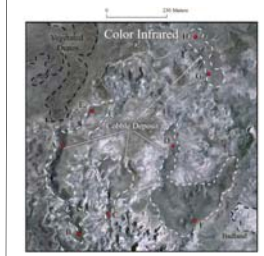
Both classifications, however, show trends along a SW-NE axis (perhaps reflecting the lithic landscape at a coarser scale of resolution), and may in fact represent well what past humans mapped onto (Beck et al. 2002).

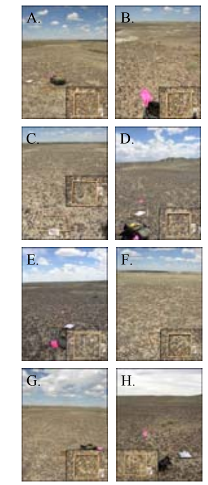
Class

Surface Category	1	2	3	4	5	6	7	8	Total
BA	2	4	2	3	2	1	2	0	16
BR	0	0	0	2	3	6	3	0	14
DU	0	0	3	5	0	1	0	0	9
PA-1	1	2	3	1	4	5	4	2	22
PA-2	0	8	23	10	8	2	2	1	54
PA-3	0	1	10	8	2	0	0	0	21
total	3	15	41	29	19	15	11	3	136

Mapping the Lithic Landscape: DOQs

Finally, we consider 1-meter resolution color infrared (CIR) digital orthophotos for documenting terrace cobble deposits. On the CIR airphotos, cobble deposits appear smooth in texture and range in color from light to dark bluish-gray. On these airphotos, cobble deposits generally lack a reddish hue associated with grass and sage-covered dunes, and are much darker than exposed sediment found in badland settings. The apparent darkness of cobble deposits depends on clast density and/or the degree of rock varnish (see figures below).





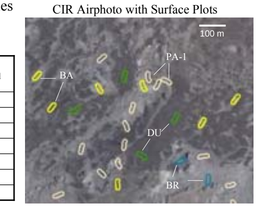
The image above show an example of terrace cobble deposits and other surface types as they appear on CIR airphotos. Dashed white lines show selected examples of cobble deposits where field observations were made. The red points correspond with the horizontal overviews and surface plots shown on the right. The CIT airphotos were flown in July 2001 and were downloaded from the Wyoming Geographic Information Advisory Council website (http://wgiac.state.wy.us/html/index.asp).

Using the above criteria, a "heads-up" interpretation of the CIR airphotos was conducted in the vicinity of the sample units. Dune (DU) and dense, heavily varnished pavements (PA-3) were readily discernible, while it was more difficult to correctly identify Bare (BA) and Bedrock (BR) Surface Categories (see table below).

Interpreted Class

Surface Category	Pave-ment	Inde-termi-nant	No Pave-ment	total
BA	6	4	6	16
BR	6	0	8	14
DU	0	0	9	9
PA-1	15	2	5	22
PA-2	44	1	9	54
PA-3	21	0	0	21
total	92	7	37	136

CIR Airphoto with Surface Plots



Conclusions and Future Research

1. Simple multi-spectral classification of ASTER so far has yielded less than satisfactory results when a fine scale of resolution is considered, consistent with findings by Hamblin and Crofts (2000). However, research by Epema and Bom (1994) focused on the spatial variability in field reflectance and reported some success in distinguishing variation in surfaces with stones, vegetation and surface crusts. We propose to explore this analytic alternative as well as issues of "scaling-up."
2. "Heads-up" interpretation of CIR airphotos yielded good results for some but not all surface classes. This resource is readily available although usually for only one point in time. For small projects, such interpretations undertaken within a 1000 m radius of the project site (following Beck et al. 2002) may usefully inform chipped stone assemblage analysis.

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