associated with the obsidian source, but it was also statistical because survey zones were deliberately stratified so as to permit predictive statements about the use of space throughout the study region. Finally, the Upper Colca research also involved survey for spatial structure because it consisted of three large blocks within which the land was thoroughly surveyed so as to document intersite relationships and travel routes.

Many contemporary archaeological surveys will claim to have conducted “100% survey” of large regions, but then they will have had a survey interval of 30m or more between surveyors. Surveys focused on documenting complex societies with standing architecture are particularly likely to refer to their widely-spaced surveys as “100% surveys”. A wide surveyor interval is actually a non-explicit kind of sampling that de-prioritizes smaller sites and those lacking standing architecture, resulting in an often unstated bias in the results. Subsequently, the region is considered “surveyed” though many smaller sites falling between transects were surely missed. While smaller sites are found in these widely spaced surveys, it is only if the site happens to fall across one of the surveyor lines. More realistically, such a survey method is somewhat successful because the surveyors cover a lot of ground but then they will veer off their route to visit high likelihood locations for sites such as rock shelters and lake shores; a technique belonging to the realm of prospection survey.

5.4.4. Survey design

The Upper Colca Project survey goals emphasized investigating the Chivay source area, the geological contexts for obsidian formation, and the principal areas of human settlement within one day's walk from the source. In the implementation of the survey, high-likelihood areas in the obsidian source zone were evaluated using a prospection survey. This included a careful survey of the entire Maymeja area itself and large portions of the southern rim using a surveyor interval of 15m.

Source	Institution	Scale / Res.	Comments / Application
ASTER imagery	NASA, JPL (Abrams et al. 2002)	15m	Visual and NDVI analysis
ASTER DEM	NASA, JPL (Abrams et al. 2002)	30m	Representation, slope calculation
SRTM DEM	NASA, USGS, CGIAR (Jarvis et al. 2006)	90m	Regional relief mapping
Aerial photos	Servicio Aerofotográfica Nacional, Perú	1:60,000	Historic aerial photos.
Topographic maps	Instituto Geográfica Nacional, Perú	1:100,000	Features, toponyms (PSAD56), scanned
Geology maps	INGEMMET, Perú	1:100,000	Geology (PSAD56), scanned
VMAP1	NIMA (1995)	1:250,000	Regional map
VMAP0	NIMA (1995)	1:1 million	Continental map

Table 5-4. Digital data sources used in developing the survey strategy.

Selection of survey regions involved the use of a number of spatial data sources (Table 5-4), as well as interviews with local residents, personal visits, and consultation of previously published reports. Preliminary field visits with a Trimble Geoexplorer GPS in 2001 and 2002 involved collecting ground control points and GPS lines on major roads and other features. After post-processing using the AREQ base station (International GPS Service), these data permitted the georeferencing of aerial photos and scanned maps directly to the GPS acquired data.

Survey Area Criteria

Stage	Feature	Included	Excluded
I. SELECTIVE SURVEY Source Area	Bofedal marshlands	500m buffer around highest 33% of ASTER NDVI* values.	The top 1% of NDVI* values, corresponds to standing water.
		AND	
	Terrain	Land less than 7km from Maymeja Land over 4000m, to keep survey out of town of Chivay.	Terrain with slope over 15°.
		AND	
	Geology Map	Obsidian appears on interface between Barroso and Tacaza.**	
		AND	
	Judgmental	Grassland appearance in ASTER imagery and adjacent to 10+ Ha area of under 5° slope.	Boulder field appearance in ASTER imagery.
II. Test Excavations			
III. COMPLETE River Valley	Corridor	Land within 500m of high river terrace.	Terrain with slope over 15°.
	Total Coverage Transect	All land within a 500m by 4000m area, ridgetop to ridgetop across river valley.	None (no land is excluded).

* ASTER NDVI is 15m resolution ASTER satellite imagery Normalized Difference Vegetation Index, an index of vegetative photosynthesis activity (Jensen 1996).

** It has been noted that obsidian seems to occur where the Late Miocene Barroso group lavas cooled rapidly when in contact with the older Early/Middle Miocene Tacaza Group (Burger et al., 1998).

These criteria were established from field visits and the locational modeling literature. The source area is in remote and relatively rugged terrain, so a selective survey was designed in order to efficiently document the area.

Figure 5-1. Criteria in designing regional survey from three stage research proposal including obsidian source survey, testing program, and concluding with the river valley survey.

Survey in the area of the obsidian source, outside of the Maymeja depression itself, was selective as it focused on high likelihood areas. Survey coverage in the Blocks 2 and 3 zones was contiguous with a 15m surveyor interval although here the survey region was delimited by other criteria. First, in the Block 2 (San Bartolomé area) a particular strip of land was targeted that paralleled the terminus of a Barroso lava flow. The survey block was surveyed 100% at 15m intervals along this densely occupied region. In Block 3, a maximum steepness and distance to river criteria was used to concentrate survey efforts to the river corridor region. Thus, in Block 3, all lands were surveyed within 500m of the high river terrace above the principal drainage (Colca, Llapa, and Pulpera drainages), and terrain over 15° slope (33% slope) were not surveyed. This maximum steepness limitation excluded many eroded regions where preservation is poor, but it also excluded a number of areas that were perhaps occupied. In order to evaluate the survey criteria in Block 3, a swath of land 1 km wide by 3 km long was surveyed at truly 100% coverage at 15m interval, and these areas could then evaluated to gauge the effects of the survey criteria used elsewhere in Block 3 that excluded the high slope and non-riverside areas. This 100% survey test swath will be described in more detail below.

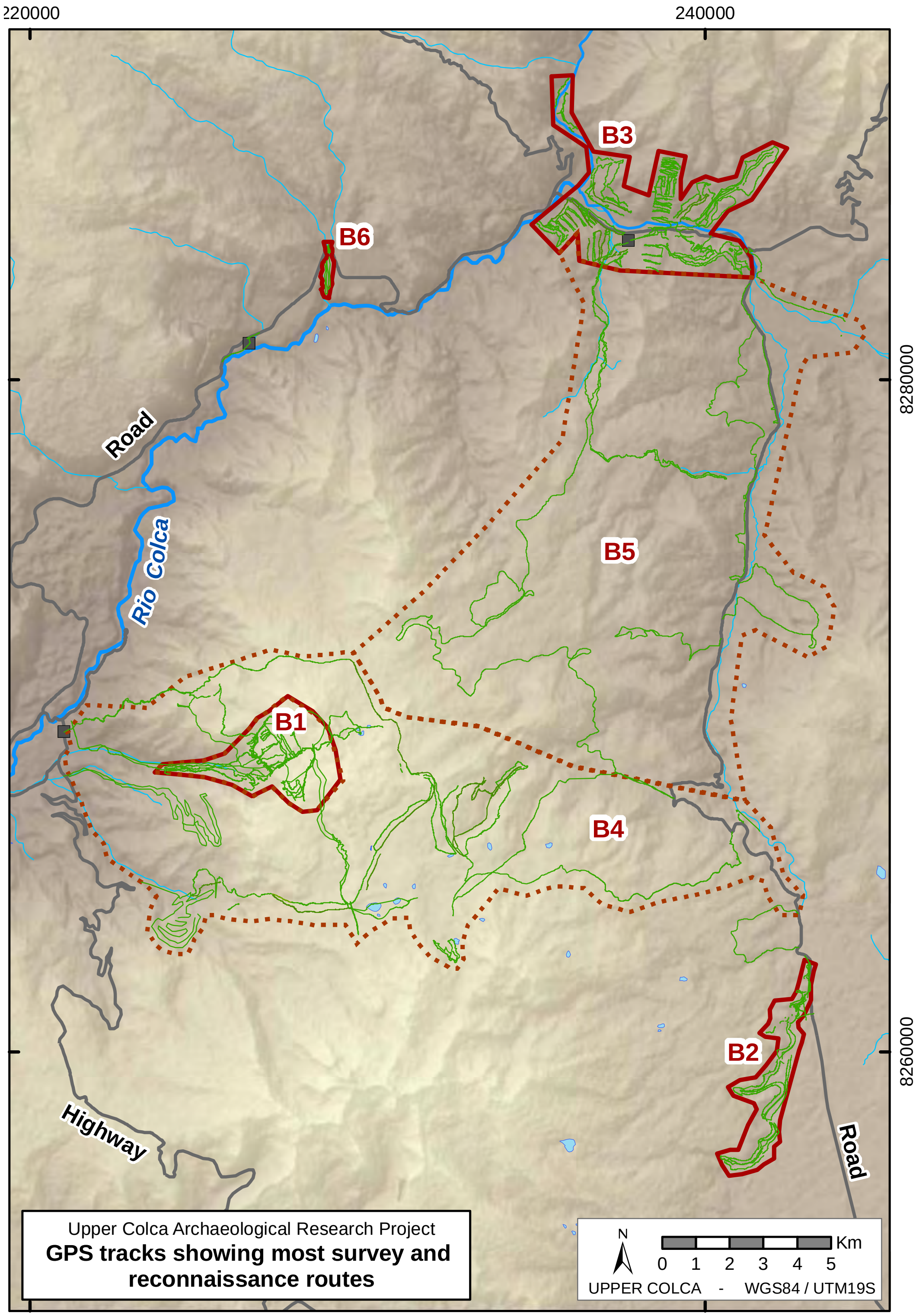

Figure 5-2. GPS tracks from edges of most survey routes showing emphasis on Blocks 1, 2, 3 and 6.

With GPS units the survey coverage and spatial sampling is made relatively explicit, permitting future researchers in the region to focus on areas that were under-investigated in the 2001, 2002 and 2003 survey efforts. With GPS track loggers becoming easily available, explicit coverage reporting will likely be more widely adopted in the future.

5.4.5. Testing the effectiveness of the B3 survey strategy

While survey criteria for coverage in Block 3 were relatively restrictive, a swath in the vicinity of Callalli with a diversity of topographic and ecological conditions was selected for conducting a "100% survey". The goal of covering ground at a 100% was to evaluate the effectiveness of the survey strategy that was being applied throughout the rest of Block 3. The survey coverage in Block 3 included only areas within 500m of the highest river terrace, and slopes under 15° (33.3%) incline.

The 100% survey revealed seven small sites, some lithic isolates, a lone broken vessel and a wall on a hilltop location that was undiagnostic but is probably a Late Intermediate Period pukara construction. The area of the 100% survey swath is 0.5 km wide by 3.5 km long (area = 1.7 km^2) and if *only* the area outside of the regular survey model is included, the area is 1.1 km^2. The sites located in the areas outside of the survey model fall into two major groups: pukaras on hilltops and small, eroding lithic scatters with no reliable temporal assignment found on steep open slopes. Other regional evidence points to a pattern of intensified pastoral production during the LIP and Late Horizon, and these dispersed sites may result from herders working while they monitor their flock during the wet season when the hillslopes of Callalli contain rich graze.

ArchID	Slope°	Altitude	Feature type	Notes
587	29.4	4185	lithic_p	
588	15.1	4128	site_a	
589	20.3	4156	site_a	Visib is +33
590	8.9	4100	site_a	
591	16.0	4073	site_a	
592	18.2	4077	site_a	
593	21.0	4020	lithic_p	
594	22.8	3967	site_a	
605	11.7	4087	ceram_p	
607	13	4164	site_a	Pukara. Visib is +3.12
608	15.3	4161	ceram_p	
609	19.6	4149	struct_l	Possible Pukara wall.

Table 5-5. Sites and isolates from 100% survey strip that would not have been encountered using the regular Block 3 survey strategy.

Given the high effort expended in completing the 100% survey, and the eroded condition of most sites on steep slopes, a slight modification of the survey strategy would have resulted in the group encountering virtually all the informative sites in the region. The improved survey model would be like the one that was employed (500m from the high terrace and < 15° slope), and furthermore it would include a visit to all the major hilltops in the region searching for pukaras. With prospection survey, it is often true that pukara walls can be identified with binoculars or on imagery (Arkush 2005), allowing for targeted climbs of only those hills with visible walls.