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A Horse-Travel Approach to Landscape Archaeology

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ABSTRACT

Archaeological studies of movement between communities that had horses should use empirical evidence about horse travel over terrain types analogous to those traversed between historical archaeological sites. The experiences of equestrians are of interest to archaeologists because they reflect past processes of creating landscapes of warfare, communication, transportation, and trade. Late Spanish colonial New Mexico provides an example of how the potential of an equine perspective on landscape-scale choices might change archaeological interpretations of place and space. This article introduces an experimental approach and calls for modeling that accounts for different kinds of observed horse travel that can better articulate archaeological landscape studies with more realistic travel factors encountered by those who populated a dynamic and horse-connected frontier. Datasets generated by such a method will be well-positioned to aid in the interpretation of lived experiences on indigenous landscapes completely transformed by the colonial introduction of the horse.

Introduction

Archaeologists investigate the lived experiences of communities that once inhabited landscapes alive with commerce, communication, and violence. Few people lived the entirety of their lives on the sites excavated by archaeologists. Their movement through places of varying meaning and activities is central to the many different approaches to archaeologies of landscape. Catchment studies contextualize resources, with respect to various habitation sites, and the ability to access them in distance, energy, or time (Higgs and Vita-Finzi 1972; Jarman 1972; Flannery 1976; Ericson and Goldstein 1980; Zvelebil 1983; Wheatley and Gillings 2002). Watershed analyses (Anschuetz 1995; Harrower 2010) similarly tie agricultural and water-management facilities to layers of human spatial organization. Viewshed studies (Wheatley 1995; Lake and Woodman 2003; Llobera 2007) interrogate visibility, directionality, and other aspects of topography, dimensions that are also connected to routes and access to places both seen and unseen (Snead et al. 2011). The multitude of relationships between communities and regions implied by people's travels ties these varied intersite studies together.

For some time, geographic information system (GIS) studies of settlement patterning and least-cost pathways have been used in archaeological landscape analyses (Kvamme 1992; Wheatley and Gillings 2002). Digital spaces reconstructed with modern cartographic and modeling methods interpret archaeological perspectives on movement through past places. A popular method of modeling travel through these digital constructs is via the use of a (GIS) hiking function (Tobler 1993) used by many in least-cost paths analyses. Tobler (2003, pers. comm.) described his oft-cited and -applied walking function as quite problematic, because walking times were based on Swiss military maneuvers and unrealistically affected by uphill vs. downhill travel, much less terrain type. More recent iterations (White and Surface-Evans 2012) of pedestrian least-cost path models are becoming refined enough to be used as interpretive tools to model humans walking over varying topographies more closely. Such studies incorporate real-world biomechanical data into algorithms that refine topographical constraints based on actual travel environments. As of yet, these walking functions have not been successfully applied to nonhuman movement through archaeological landscapes. Given the long history of human/animal interactions of varied types, social and spatial scales (Russell 2011), quantitative evaluations of animal movement in narratives of the past are surprisingly underrepresented.

Historical archaeologists study eras and places in which domesticated animals had long been a significant part of organizing human activity on the landscape (Zeder 1991; Reitz 1992; Deagan 1996; Bowen 1998; Landon 2009). Pasturage, water, wallows, and security are just some of the concerns of those who managed and traveled with stock. In many places and times, horses have been central to ideas of movement, both for travel and portage (Cotterell and Kamminga 1992). Well after the roles of horses in

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Eurasia were cemented, the global expansion of human uses of horses had wide impact on indigenous societies at contact, as well as affecting how colonialisms were accomplished. Horses in the 16th-century New World became loci of contestation, food, wealth, and identity practices. In some cases, evidence of the impact of the horse's (re)arrival in the New World was found well ahead of the significant presence of colonial settlers themselves (Ireland 2005; Gifford-Gonzalez and Sunseri 2007). From the perspective of the historical archaeology of Spanish colonial regions in North America, equestrian mobility was even more important than pedestrian travel as a vector for captive raiding, communication, traction, transport, and commerce. Late Spanish colonial New Mexico provides an example of how the potential of an equine perspective on landscape-scale experience might change archaeological interpretations of place and space. To assess several parameters of horse travel, the author has used an experimental approach to study the dynamics between equestrian mobility and terrain factors, with the goal of providing actualistic data for integration in GIS analyses of archaeological landscapes.

Although it is beyond the scope of this article, follow-on GIS functions created from this approach will allow historical archaeologists to model and better understand the kinds of travel times experienced in the colonial past, including distances between neighbors and adversaries. These ideas might also lend some analytical muscle to broader studies, such as those that attempt to link archaeological concepts to the understanding of conflict in other eras (Snead 2012). Such engagements may profit through similar analyses of the connective vectors of movement and their relationships to aspects of risk, vulnerability, and resilience for communities at odds with each other. For the narrower focus introduced here, investigation of equestrian mobility is important for archaeological landscape studies of many types of sites from periods associated with horses, including villages and the trails that connect them. Integration of these concepts can add important nuance to archaeological studies that interpret lived experiences on indigenous landscapes completely transformed by the colonial introduction of the horse.

The Archaeology of Nonhuman Mobility

Studies of animal movement are implicit in many archaeological GIS models of landscape-scale human activities. Territorial circumscription (Earle 1994), trade routes (Ur 2003), and agro-pastoral site prediction (Ducke and Kroefges 2008; Ullah and Bergin 2012) are related to animal resource management, capacity for moving goods, and pasturage. Often, least-cost paths are generated for the related human movements (White and Surface-Evans 2012). Few of these models truly integrate the biomechanical constraints of animals traversing topography. Certainly, such integrative analytical models are catching up only recently in the New World.

In the Andes of South America, domesticated camelids have long served to move substantial amounts of goods across large distances. Thus far, the best modeling approach to understanding that animal movement over landscapes was at least partially reflected in the relationship between quadruped physiology and the particularities of the topographies they traversed is found in Tripcevich's (2008) fusion of GIS and actualistic research in the study of a modern llama caravan. With the goal of analyzing transport costs in a region where there was once an extensive obsidian exchange, the comparative utilities of animal shipping vs. human portage in high-relief regions had far-reaching consequences for regional economics (Tripcevich 2008:5). Such work goes to the heart of models of transport cost and assists with tracking economic valences archaeologically as they were entangled with aspects of pastoralist mobility. Tripcevich's methods included GPS datalogger tracking of an ethnographic trip to trade salt between its source and market. Evaluated in conjunction with slope rasters in GIS, these datasets were critical to his development of an asymmetrical cost–distance function for llama caravans (Tripcevich 2008:7). His approach was calibrated to track and integrate actual distances and times experienced in a far more realistic manner than the least-cost path models using a hiking function, such as Tobler's (1993).

Unfortunately for archaeologists working in regions without llamas, the digitigrade

camelids in Tripcevich's study move with biomechanical constraints quite different from those experimentally measured for horses (Riek et al. 2007). Llamas and alpacas have footpad configurations that reflect their anatomical adaptations to required stability on rough terrain (Van der Sluijs et al. 2010). Horses have evolved to be walking on, essentially, their middle fingernails, an adaptation that advantages longer leg strides for high-speed gaits over open plains (Clifford 2010). This also makes stabilization of their downhill movement quite different than camelids, an effect noticeable to equestrians spurring their mounts into a charge uphill vs. horses' cautious, hindquarter-lowering balance of movement downhill. The added height and weight of a human rider also decreases horses' stability, as their long limbs center their mass farther from the trail interface than do those of llamas and alpacas. Non-dynamic loads, such as loaded packsaddles and travois, can be, accordingly, mounted lower on a horse to reduce these effects, but, overall, the moment of inertia is increased by the human uses of horses. On the colonial New Mexican frontier especially, the patterned experiences of equestrians accounting for these parameters are of interest to archaeologists because their material expression reflects the past processes of creating landscapes of military power, communication, transportation, and trade.

Background: Colonial New Mexico

For late-18th-century New Mexican colonists, the horse was a vehicle of honor that evoked the *reconquista* of the Iberian homeland from centuries of Islamic occupation (Bolton 1930; Kessell 1989; Weber 1992). Narratives of the patron saint of Spain, Santiago Matamoros (St. James the Moor-Slayer), prominently feature his mount and were transliterated into the New World colonial endeavor. In some accounts, he was said to have appeared in 14 separate battles with Native Americans (Spellberg 2004:152). As an internal social marker, Arabian horse breeds brought to the New World became symbols of aristocratic status, prominent in the *entradas*, campaigns, and ritual processionals that marked the upper social categories in public space (Rodríguez 1996, 2002). For at least one member of the elite, connections as "master of the horse, or *caballerizo*, in the viceroy's household" probably led to appointment as governor of the New Mexican colony (Kessell 2013). The transformation of the word "caballero" itself, from "knight" or "gentleman" in Spain to "horseman" in the American Southwest, bespoke the importance of the connection. Lower-status citizens, born of mixed heritages and labeled as such in local socioracial *casta* hierarchies (Chance 1978; Voss 2005; Martínez 2007), were depicted in *casta* paintings in positions of labor associated with hybridized working animals, such as mules bearing heavy loads (Katzew 2004).

For colonial period Native American Pueblo communities, horses introduced by the fledgling Spanish colony complicated power dynamics in New Mexico. One aspect of a new and evolving colonial economy (Frank 2000), animal imports added new pressures to internal social dynamics. Old World domestic animal husbandry (Simmons 1983) challenged precontact organizations of labor and had the potential to alter relations of power inside and outside the communities. For example, it is important to understand mounted raiding parties' increased range and potential for surprise. These new factors made going out beyond the protection of fortified pueblos and villages to get resources, such as food, clay, and fuel, more dangerous (Sunseri 2010). For those who adopted pastoralist animal-management practices, the control of sheep herds and attempts to restructure community plaza space to accommodate them in corrals are choices visible in the archaeological record (Lycett 2002). The presence of horse-mounted raiders was an important factor in decisions about whom to send afield to shepherd or gather, because it exposed those individuals to mounted captive-takers. In some cases, resistance to domesticated animal-related regimes of labor and power were dramatically illustrated, as in historical and material accounts of horse-carcass processing (Beebe and Senkewicz 2001; Gifford-Gonzalez and Sunseri 2007). In such cases, horses themselves became a site of resistance.

For less-sedentary Native American communities within and surrounding the New Mexico colony, horses became a critical lynchpin of lifestyle and regional power that led to radical

transformations of their societies. More mobile than their Pueblo neighbors, communities such as the Diné, Apache, Comanche, and Ute found that horse travel extended their range, resource acquisition capabilities, and strategic capacity. Farther out on the plains, communities of Sioux, Pawnee, and others realized completely new hunting and relocation strategies (Vigil et al. 1994). In the face of raids by groups bordering their northern realms, 18th-century colonial officials were desperate for horses to buttress flagging frontier defensive capabilities (Swadesh 1974:36). New ordinances for military responses to the evolving equestrian-raiding situation were enacted (Brinkerhoff and Faulk 1965) with new allocations of resources and landscape strategies visible in the material record (Williams 1985, 1992). For some nomadic Native American groups, horses were instrumental in the amassing of wealth and regional influence, in some cases resulting in what some have called "empire" (Hämäläinen 2008). In the case of Comanche groups, some of whom documented their exploits on stone surfaces in the Rio Grande Gorge of northern New Mexico (Figure 1), horses were central to narratives and performance of raiding (Fowles and Arterberry 2014).

At the close of the 18th century, land-grant communities on the frontier of the colony were faced with ever-increasing raiding from their horse-borne adversaries (Brooks 2002b; Rael-Gàlvez 2002). Mounted raiding groups exhausted the resources of the colony, including livestock, stores, and people taken as captives. Valued second only to people as spoils in a raid, increasing attacks decimated colonial horse herds, and *vecino* citizens, from the governor to the most humble farmer, implored their superiors to send more horses to restore their ability to travel, trade, and defend themselves, their neighbors, and the colony (Kenner 1994:48). It seemed no matter how many horses the colonial administration could muster

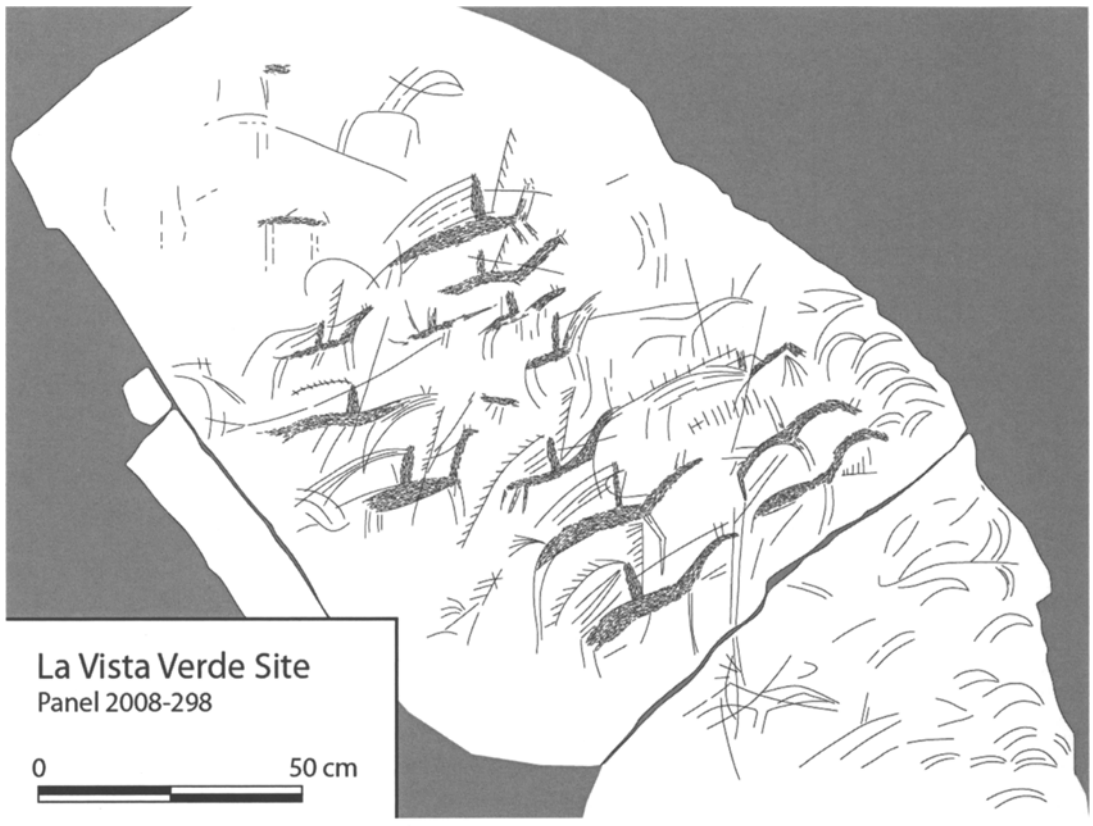

FIGURE 1. Comanche rock panel of a horse raid in the Rio Grande Gorge of northern New Mexico near Taos (Fowles and Arterberry 2014).

to send to the frontier, nomadic raiding groups always found a way to make them a part of their ever-growing herds (Swadesh 1974; Blackhawk 2007; Hämäläinen 2008). During this period, small communities were established in harm's way by a desperate colonial administration, ostensibly to staunch the mounting losses of property and people. Such buffer communities existed at the farthest reaches of the colony and granted land in exchange for defense of the frontier. A critical aspect of the defensive strategy was their understanding of horse travel through the porous border of mountain passes.

Mountain Corridors: Tactical Homescapes

On the extreme northern frontier of New Mexico, the many entry corridors through the southern San Juan Mountains were problematic for defense of the colony. This was unlike the situation in the east, where the high Sangre de Cristo Mountains had fewer major passes, the largest of which were guarded by Pueblo allies in large settlements, such as Pecos and Taos (Figure 2). In contrast, the colonial administration put citizens of low-status socio-racial groups on the frontlines of the difficult northern areas, the most famous of which is the Pueblo de Abiquiú. This was a community of Genízaros, most of whom were people of Native American origins ransomed from captivity at trade fairs and raised in Roman Catholic homes to eventually become colonial citizens (Bustamante 1991). The people of the Pueblo de Abiquiú were granted land at a natural choke point on the Rio Chama from which many raids swept down into the colony. Their mandate was to intercept raiders and monitor trading through the northwest corner of New Mexico. Their fighting prowess was, accordingly, legendary (Magnaghi 1994). Often originating from the very communities of nomadic Native American groups, whose mounted raids caused the most grief to the colony, Genízaro citizens and their mastery of the tactical landscape became the keystone of colonial frontier defense (Chavez 1979; Brooks 2002a). In a myriad of other ways, their cross-cultural competence would also prove to be important for the colony's long-term survival, as Genízaro communities became interlocutors among many different communities in New Mexico (Rothschild and Atherton 2004; Sunseri 2009; Atherton 2013), and their trading travels and connections had effects as far away as California (Swadesh 1974:61). Intimate knowledge of the landscape, combined with textured understandings about the tactical and logistical operating parameters of mounted friends and foes, was critical to their success.

In the mid-1700s settlements of the upper Chama suffered devastating raids, some of which drove colonial settlers from the region for years, until threat of land-grant revocation by the administration forced resettlement (Ebright and Hendricks 2006). In 1747, a withering series of raids by a Ute and Comanche confederacy wiped out Spanish villages north of Santa Cruz de la Canada and at Abiquiú, and resulted in the loss of 23 women and children (Brooks 2002a:64). The ruins of Santa Rosa de Lima (Carrillo 1997:77) testify to the abandonment of that early and unsuccessful primary settlement focus and partially explain the reestablishment of Abiquiú in its current location, high on a more defensible mesa immediately to the west. Accounts of these traumatizing episodes are memorialized along historical routes into the community, as by the stone shrine of Las Crucitas de Animas at Abiquiú (Garcia and Dunn 2008:55), and remembered in community oral histories and dances in which raiders are sometimes portrayed by members of the descendant communities on horseback (Gandert et al. 2000; Lamadrid 2003). The presence of additional, flanking routes of entry around Abiquiú, due to the lower topographic relief of the southern San Juans, also necessitated the establishment of fortified plazas in satellite locations up smaller drainages.

Two such villages would be built to meet this need. San Antonio de Vallecito, at the southern boundary of the modern Abiquiú land grant, and Casitas Viejas, up the Rito Colorado drainage at the boundary of the Lobato land grant, became strategic satellites of Abiquiú by the last quarter of the 18th century (Figure 3). Placed to monitor alternate nomadic raiding and trading routes around the main Chama River valley, these plazas and associated ranchos (Quintana and Snow 1980) became "micro-frontiers of interactions" (Snow 1992:187). The colonial endeavor relied on these localized,

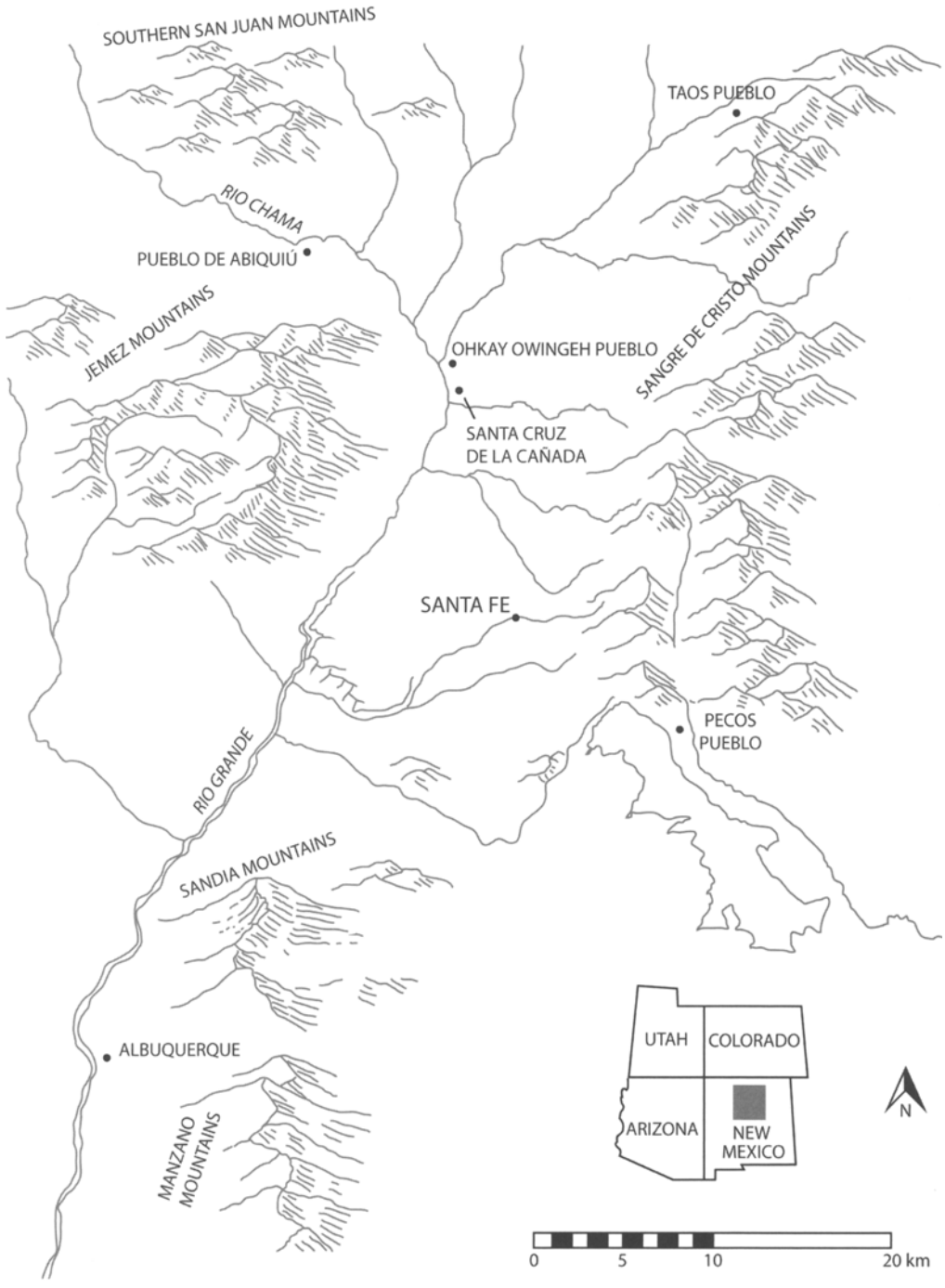

FIGURE 2. The situation of the Spanish colonial capital (Sante Fe) in northern New Mexico, with respect to the strategic location of mountain passes and allied pueblos to defend entry points. Pueblo de Abiquiú's location at the northwest frontier confronts multiple, undefended passes. (Drawing by author, 2014.)

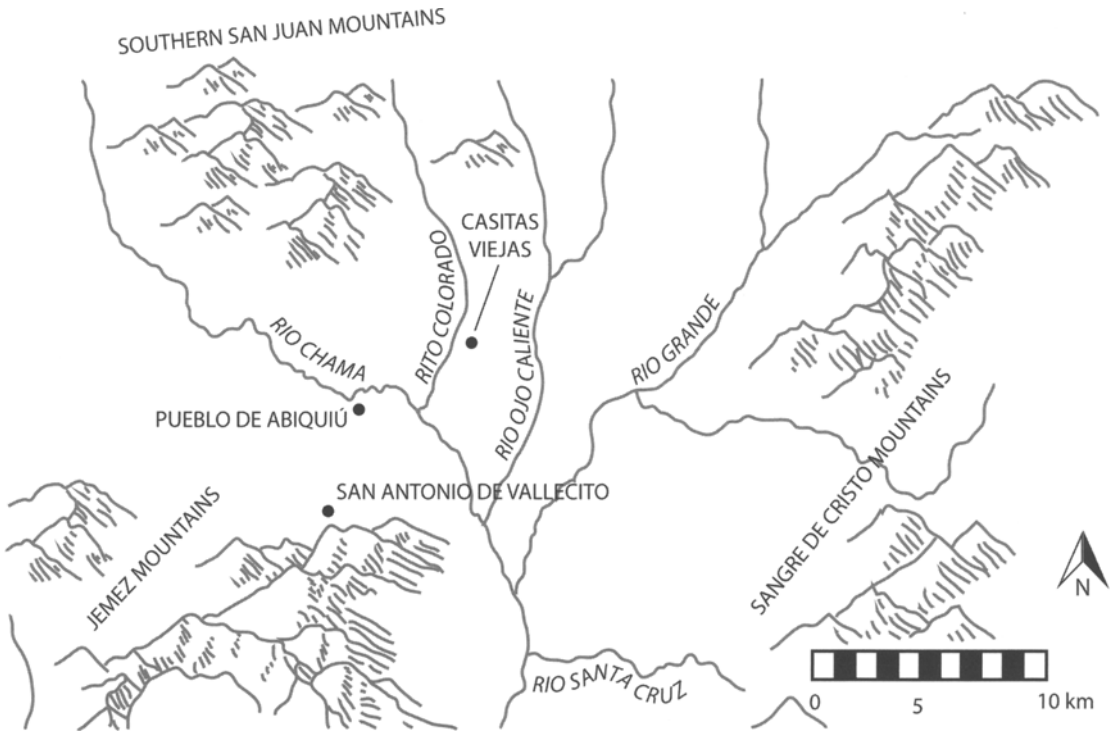

FIGURE 3. Abiquiú and its satellite villages on New Mexico's 18th-century northern frontier. These satellite villages, centered at the fortified plazas of Casitas Viejas and San Antonio de Vallecito, defended alternate entry routes to the Chama River valley along Abiquiú's flanks. (Drawing by author, 2014.)

daily interactions not only to buttress the lack of presidio troop presence, but also to build and strengthen bonds between erstwhile enemies (Brooks 2002a; Sunseri 2009). Localized memories of descendant communities refer to locations of "Comanche camps" across the river from colonial plazas, where their positions abreast of spring floods slowed down horse-mounted parties during episodes of trading. Sites like these, represented by one across the river from the modern village of El Rito, are a good example. So too are the raiding and trading routes labeled on heirloom maps held by community members that enumerate the years and casualties of major raids. The aforementioned Comanche commemorations (Figure 1) of horse raids in the Rio Grande Gorge (Fowles and Arterberry 2014), between Abiquiú and Taos, also speak to the scale of the area over which mounted parties roamed. Of the many reasons that communities in these locations were situated—with respect to pasturage, irrigation potential, and access to resources, such as clay and fuel—their strategic consideration of topographic bottlenecking, in order to bar horse travel through adjacent passes, was equally important.

Previous Approaches: Cost Surfaces

The author's previous considerations of the tactical, engineered, and ritual landscape of the Rito Colorado Valley (Sunseri 2009, 2010, 2014) and around LA917, known to the descendant community as Casitas Viejas, put the material residues of large-scale processes and patterns into dialogue with more intimate scales of household- and plaza-level material production and use. These entangled homescape and hearthscape concepts hinted at constraints and networks of movement related to the raiding frontier and implicitly referenced the ways horse-mounted mobility affected practice at other scales. Focusing on tactical aspects of homescape practices of the tiny buffer village at Casitas allows for these horse dynamics to be considered at a larger resolution. For this, the principal concern of Spanish colonial administrators and their frontier militias

was strategic and tactical constraints for raiding, interdiction, and combat near buffer villages.

Landscape archaeological analysis of these factors includes near-site fields of fire, intercept conditions, viewsheds containing raiding and trading routes, and location of geographic bottlenecks to prevent flanking by overwhelming forces during retreat to nearby settlements, such as Abiquiú and Santa Cruz de la Cañada. In previous settlement surveys (Quintana and Snow 1980) and preliminary studies of the Rito Colorado Valley's tactical landscape (Sunseri 2009), patterned relationships between the location of historical raiding and trading routes within the viewshed of the fortified plaza at Casitas Viejas were considered with respect to digital elevation models of the valley.

Viewshed maps for Casitas outline the potential for various sightlines to provide the means of spotting a raid, especially in regard to the known routes of entrance into the valley. The viewshed calculation offers a perspective on what can be seen from a given point, based on surrounding elevation data from a digital elevation model. Multipoint vectors were used for this because they allowed for viewshed calculations for each point specified to be added together. Composite viewsheds were calculated by cumulative addition of viewsheds from multiple points along the perimeter of the exterior walls at Casitas. To adjust for a sentry at the top of a *torreón* (a defensive tower integrated into a defensive wall, as at Casitas), a 5 m increment offset was added to the elevations at each point at that location. The resulting composites attempt to simulate what might have been seen from the roof of the outer edge of the room blocks enclosing the plaza at Casitas (Figure 4).

Vectors of the several routes of entrance taken into the Rito Colorado Valley by historical raiding and trading groups were overlaid on the viewsheds of the three sites. These raiding routes were digitized from trails on mid-19th-century Government Land Office maps and cross-referenced to heirloom community maps that listed raids by year and location (Tito Vigil 2007, pers. comm.). Routes were digitized with endpoints inside the valley, because at that point it could be assumed that a mounted raiding group, no longer constrained by steeper valley walls, could travel more easily in several directions across the valley and would become more visible in these locations. Along these digitized routes of entry to the valley, points were added where the routes intersected with the viewsheds. These represent the farthest extents of entrance routes that could have been observable from each of the sites. These points effectively represent when someone from Casitas (major occupation, 1760–1790) would first have been able to spot a mounted raiding party coming into the valley. Locations of the modern community of El Rito and the precontact Pueblo ruins at Sapawe—much closer to the entry points than Casitas, with potentially less time to react—suggest that neither of those communities was concerned with proximity to the northern routes of entry into the Rito Colorado Valley by horse-mounted raiding parties. This makes sense, as Sapawe was built and abandoned (ca. 1400) well before surrounding nomadic groups had equine mounts, and the community was large enough, not only to sustain a siege, but also to field a large number of warriors. The modern plaza of El Rito was established by Casitas descendants after the defeat of Comanche leader Cuerno Verde at the end of the 18th century. This happened at the beginning of a significant lull in raiding activity and during an upturn (Frank 2000:119) in colonial growth that the poor farming (but strategic) location at Casitas could not sustain.

For the era of more constant mounted raiding, the location of the fortified plaza at Casitas seems to make much more sense. Visualizing that logic is more complex. From points of intersection between the viewshed and the trails, a cost–distance calculation—an operation calculating a "Cost-Weighted" function to create a colored isopleth portraying increasing values from a point using distance and slope—was used to represent the difficulty of traveling over terrain from each of these locations. A proxy difficulty of directional movement is visualized by this process, which is based upon the degree of slope angle for each cell around the location considered in 360°, with low values given to flat terrain and high values given to steep terrain (Figure 5). In this way, the author used cost–distance as an exploratory visualization of the relative effort of reaching various locations that would otherwise be apparent through less meaningful, direct linear distance measurements.

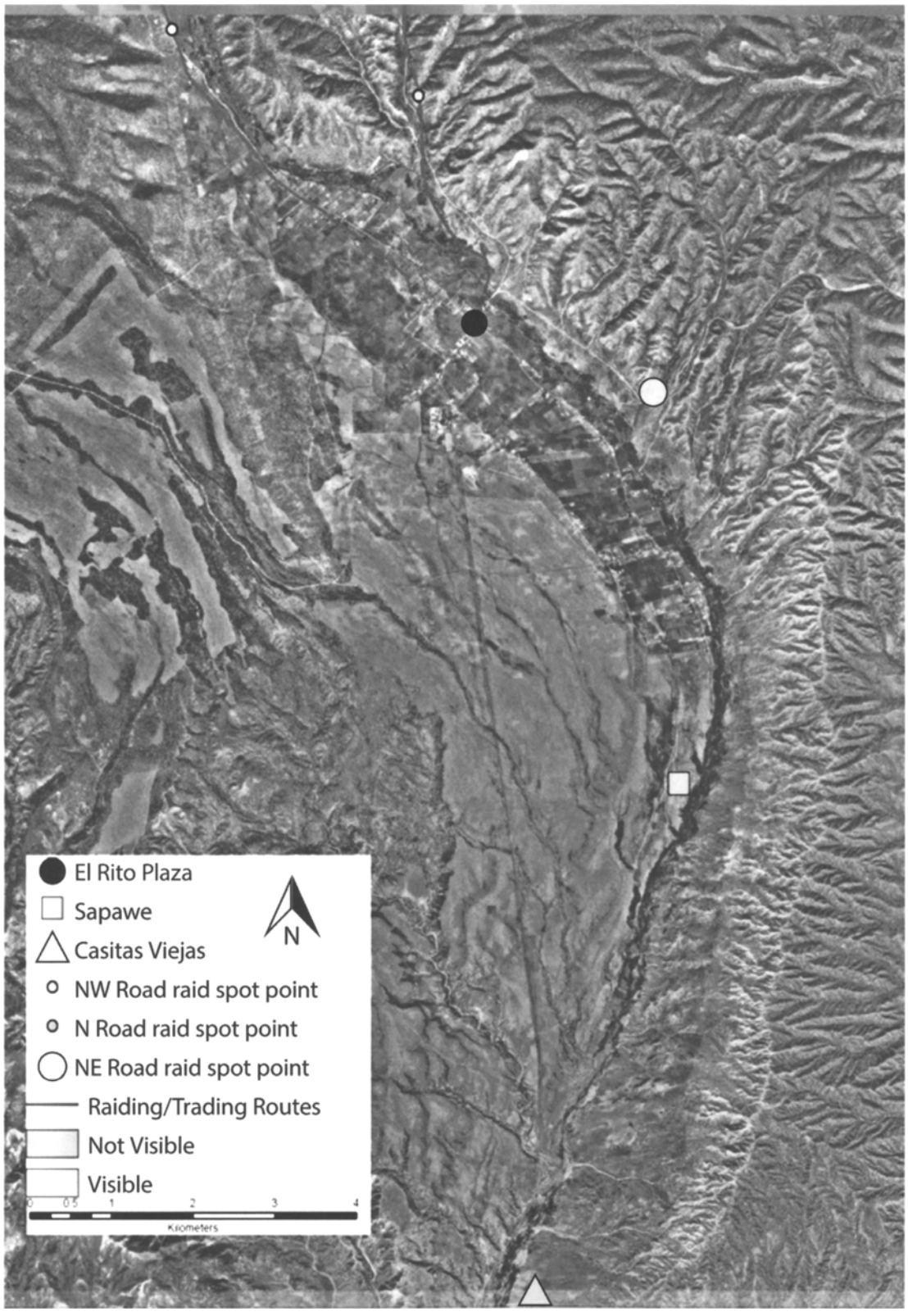

FIGURE 4. Viewshed from Casitas Viejas (triangle) and points of first visibility of the northern raiding routes into the Rito Colorado Valley. (Drawing by author, 2009.)

The problem in using such cost surfaces is in their lack of an energetically realistic representation of effort. Values in the isopleths are unitless and do not reflect any caloric or time factor in and of themselves. Although this limited use of cost surface was useful in projecting a relative comparison of which valley locations were most likely farther out of harm's way once a raid was spotted, a consideration of proximity to routes of retreat to the south would also be useful (Figure 6). The potential to fall back to more protected Chama sites, such as Abiquiú or Santa Cruz de la Cañada, is a critical aspect of the landscape from a tactical perspective (Sunseri 2010).

Use of viewshed and cost surfaces can serve only as a rough guide to the potential that different site locations would have had in spotting

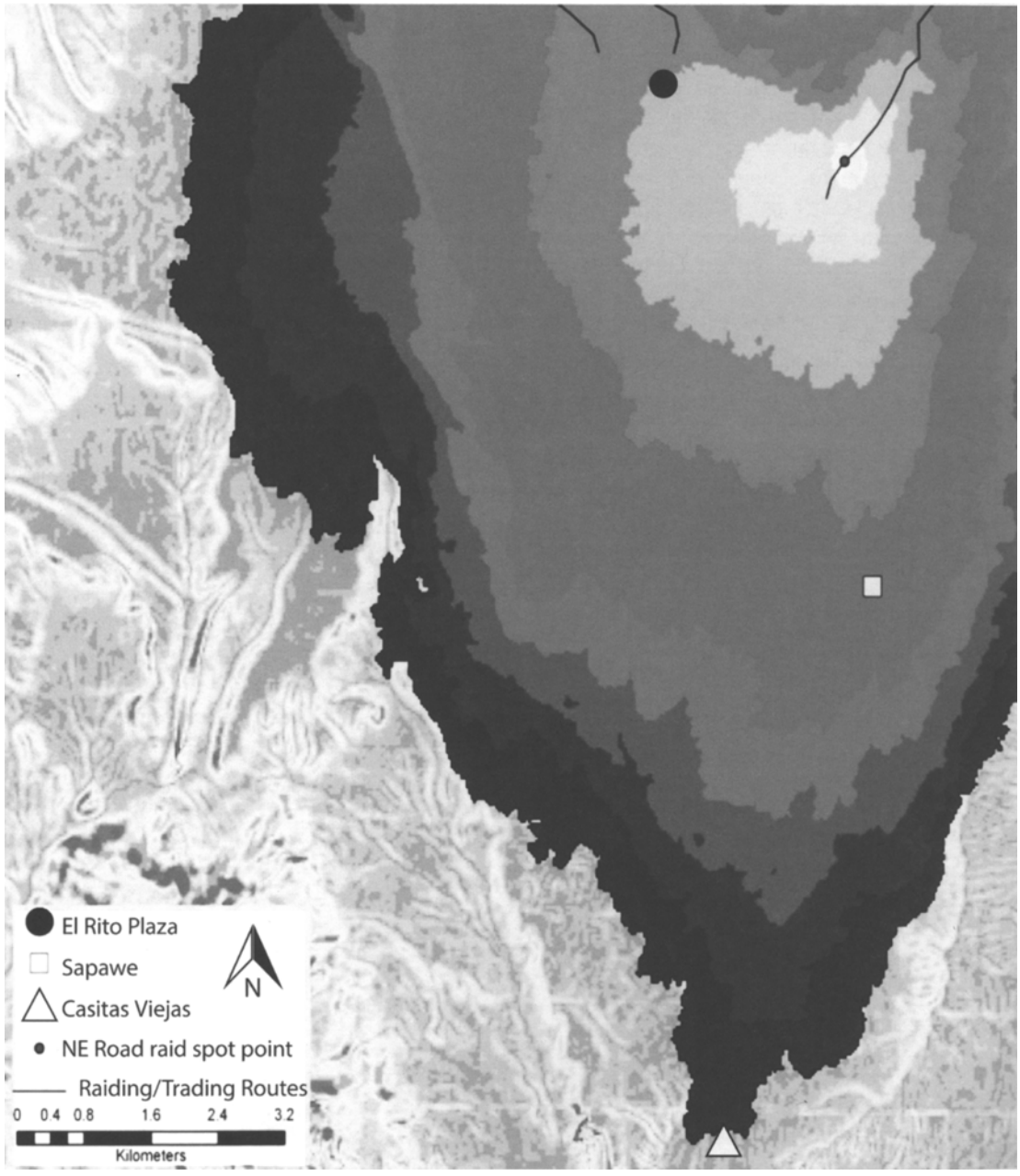

FIGURE 5. Cost–distance surface to visualize time from viewshed intercept with raiding trail to arrival at Casitas Viejas (triangle). (Drawing by author, 2009.)

a raid. Difficulty of travel for domestic animal stock, such as climbing the mountain passes to reach the three outlined northern valley entrance routes, is not well considered (Figure 6). The easiest and most-eastern route goes through the mountains toward La Madera and Ojo Caliente, with a minimal amount of elevation fluctuation (total rise of 387 ft. or 117.9 m). The other two northern routes into the valley climb farther into the mountains, toward Vallecitos and Canjilon, with much greater elevation difference—1,550 ft. (472.4 m) and 1,206 ft. (367.6 m)—respectively. This suggests that the northeastern route would have been more accessible and easier to travel because of its connection to the Rio Grande Valley and its elevation consistency, but not necessarily any more desirable as a raiding route than the others. Other lines of evidence suggest such topographic extremes were significant considerations for parties moving through them with domestic animals.

Excavated material from Casitas also speaks to the large role these routes played in shaping lifeways in the Rito Colorado landscape (Sunseri 2009). The archaeofaunal caprine assemblage from middens at Casitas consistently exhibits morphological elaborations suggesting increased musculature (Bower 2006). This suggests that the rugged northern routes were traversed frequently by some of the goat and sheep herds. The deep ponderosa-pine forest contexts for these passes suggest drive herding, rather than pasturage, for these animals. If raided or traded animals were driven over these higher passes with any frequency, they must have been cardiovascularly and musculoskeletally fit indeed. Horses would have been more the rule than an exception. The author's skeletonization of an Arabian mare that had lived as an endurance racehorse (50–100 mi. events) provided a comparative zooarchaeological specimen with significantly developed muscle-attachment points that suggest similar processes. Such a specimen more closely represents the far-ranging horses of the colonial frontier in both pedigree and athleticism. With such considerations, it became obvious that more refined

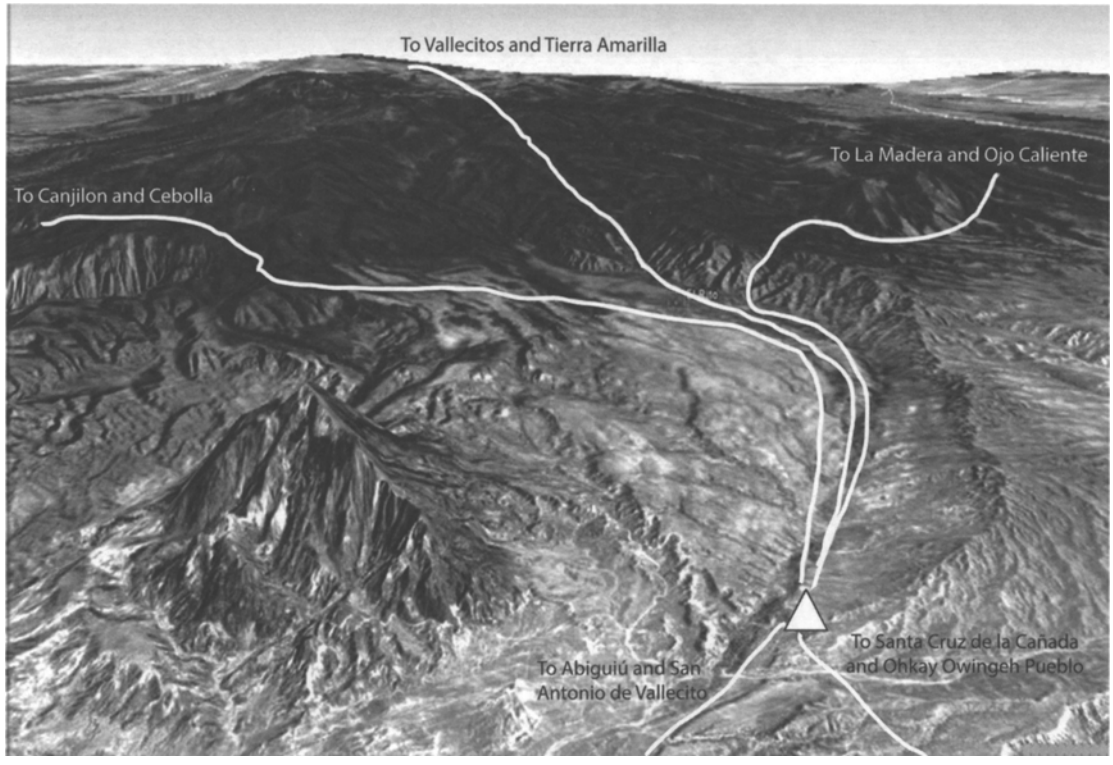

FIGURE 6. Three historical raiding and trading routes penetrating the northern frontier of New Mexico via the Rito Colorado Valley, with respect to interdiction and retreat potentials for the fortified village at Casitas Viejas (triangle). (Drawing by author, 2014.)

landscape models would be useful for understanding the lived experience of living on and riding through a raiding frontier.

Mountain-Trail Equestrian Proxies

To evaluate horse-travel parameters through mountainous terrain, an experimental, empirical approach to equine movement was needed. Several factors complicate using historical routes of the Rito Colorado Valley. Modern New Mexico is a tapestry of colonial land-grant boundaries, national forests, Native American lands, and private inholdings. In the area of Casitas Viejas, these and other boundaries between private and public lands complicate and restrict access to historical routes. Different rangeland and forest-management techniques and priorities have also changed the known historical trails into a range of more-or-less recognizable segments that are often less passable than they were when in regular use. Moreover, contemporary road and double-track access to much of the area has reduced laden-horse transit to only the occasional enterprise. Despite toponyms that link oral traditions to a much-ridden landscape, such as "Comanche Camp," "Overnight Cave," and "Soldier Springs," there is very little multiday or long-distance equestrian travel occurring regularly in the area anymore. If such travel had persisted, it would lend itself to data capture of laden-horse movement through the mountainous northern passes described above.

The Sierra Nevada Mountains of California were selected as a proxy trail-system location because of their extreme topographic relief and extensive network of trails in consistent use by equestrians. The High Sierra Camps, in service through Yosemite National Park's northern ranges since the 1920s, continue to be serviced by teams of horse wranglers and muleskinners, with pack animals in strings of 12–15 animals each (Figure 7). Each animal is loaded with 100–150

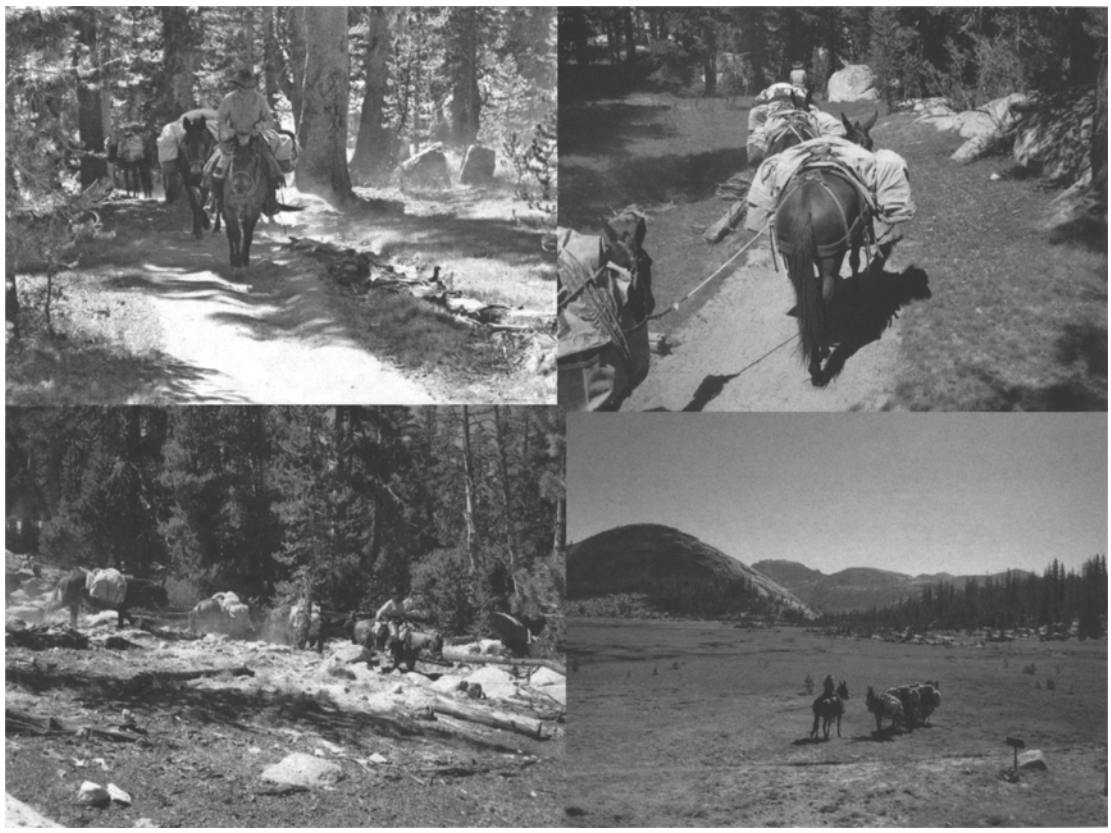

FIGURE 7. "Strings" of loaded horses and mules along the High Sierra Camp Loop in Yosemite. (Photo by author, 2011.)

lb. of supplies, equipment, or a human rider, while moving over the extensive trail network. A week-long, 57 m (91.7 km) route (Figure 8) used by strings of both supply packers and riding parties traverses the high country of the Sierras, crossing many trail types (Figure 9), geological substrates, and ecosystems between 6,991 ft. (2131 m) and 9,730 ft. (2966 m) of elevation. At times, the trails follow routes used by Sierra Miwok and Kutzadika'a Pauite communities in their travels to and from the Mono Lake Basin from times before contact and into the present. At other times, contemporary riders are following sections of trail once used by the famed "Buffalo Soldiers" of the U.S. 9th Cavalry when they patrolled the nascent park at the turn of the 20th century. These trail systems have long histories of importance in regional transit and strategy, and have proven to be amenable to both laden pedestrian and equestrian movement.

Coordinated to travel during the same week of summer, three different teams traversed the same High Sierra Camp Loop, each carrying global positioning system (GPS) dataloggers to record their legs of the journey by foot, on horseback trailing loaded mules, and riding as a group on horseback. The GPS dataloggers recorded information every 30 sec. during the trip, including date, time, location, speed, and bearing (Figure 10). In addition, the equestrian teams recorded load weights for each destination along the loop, scheduled stops for watering and feeding the strings, and overnight paddocking locations. The pedestrian team added geospatial information to its datasets that included changing surface geology that intersected trail segments. Information about these intersections, including eroding granite outcroppings, glacier-polished rock slabs, sandy alluvium, moraine termini, and talus slopes, was recorded in order to build a database of characteristic trail surfaces. Information recorded at these locations included slope, coordinates, matrix conditions (sandy, loamy, etc.), and average spacing between rock elements over 5 cm in size in a 1 × 1 m grid on the trail.

Development of a mathematical function for use in GIS computational analyses of equestrian landscapes is in progress and beyond the scope of this introductory consideration. As an illustration from colonial New Mexico,

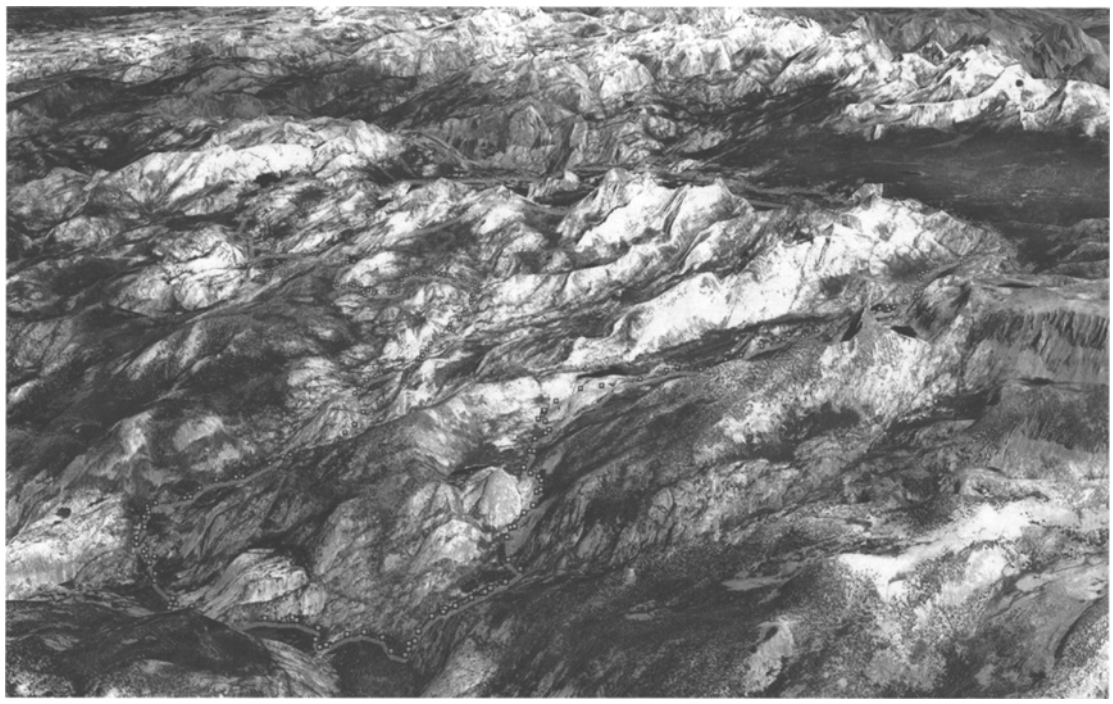

FIGURE 8. High Sierra Camp trail-system loop traversed by horse-mounted and pedestrian trail teams with GPS dataloggers. (Drawing by author, 2014.)

FIGURE 9. Examples of trail surfaces with differing localized topographies, cobble counts, and interstitial matrices (*left*: sand, *right*: decomposed granite). (Photo by author, 2011.)

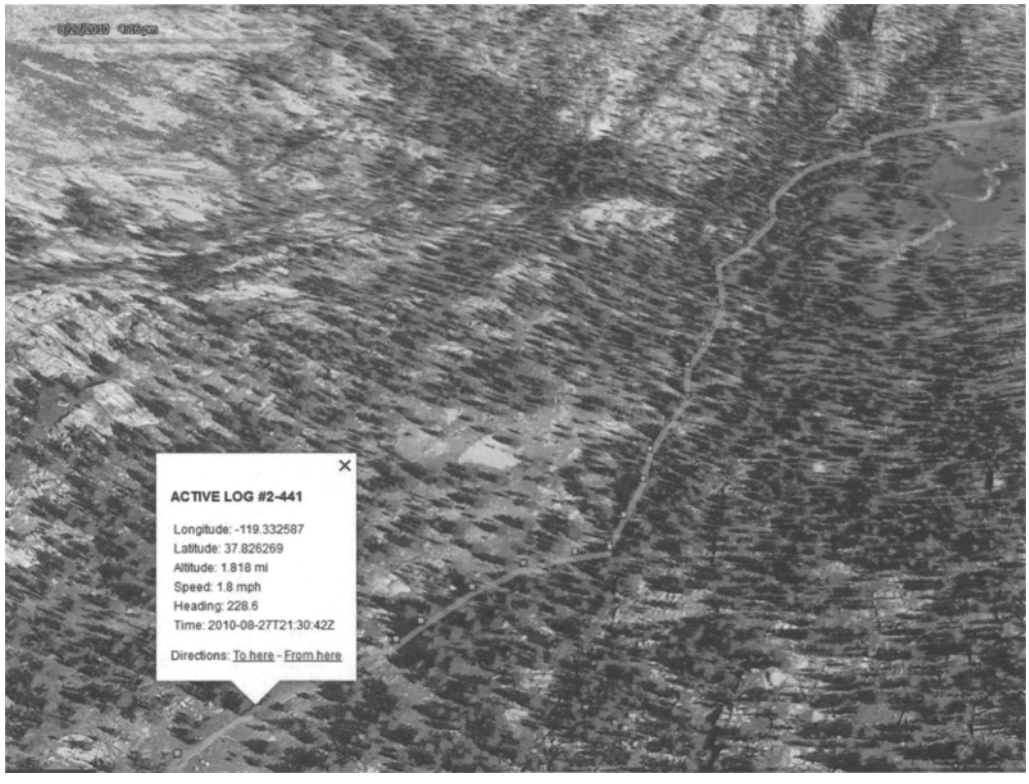

FIGURE 10. Datalogger point capture of horse "string" time, coordinates, speed, and heading. (Drawing by author, 2014.)

the limited use of cost surface was useful in projecting a relative comparison of the sites that were most likely farther from harm's way once raiders were spotted in the north part of a constrained valley. Data capture of the movement of mounted and cargo-laden horse groups through mountainous terrain is a start on the path toward fitting curves of speed to slope, although this must be sorted out from the variation in speed caused by different trail surfaces. The pedestrian team's work in characterizing trail surfaces was a useful addition to the experiment in the Sierra Nevada range. Observation and characterization of a greater range of trail surfaces and more intensive data capture of their effect on horse travel will no doubt refine future models, as will work with a greater selection of horse breeds and wrangler choices about feed and containment along the way.

Preliminary observations of the returned GPS data included variable rates of horse travel corresponding to changing trail conditions encountered by the riding teams. Surface-matrix changes and cobble densities were recorded by the hiking team, which only intersected with the other teams twice during the week-long course of the experiment. It is hypothesized that the increase of cobbles per square meter of trail surface combined with increasing negative slope were the two most dramatic affectors of mounted-travel speed reductions. Complete exposure of glacier-polished granite and extreme (>20° angle) uphill slope changes were rarer, but also created traction situations that slowed the equine teams far more than the pedestrian team. In almost all cases, the teams did not clearly exhibit the range and rate-of-speed changes that might be derived from the usual GIS least-cost path-hiking function models, certainly not the teams comprised of strings of loaded animals. Quite the opposite, horses can often travel faster uphill than downhill, and much slower than pedestrians on sloped and highly (glacier-) polished smooth stone surfaces.

Consider the example of a single string of loaded equines moving downhill into and then climbing sharply out of a valley (Figure 11). Unlike the slightly higher downhill (negative slope) speeds that would have been predicted for human hikers by the Tobler function, more often the equestrian team was traveling faster on flat to moderately uphill (positive slope)

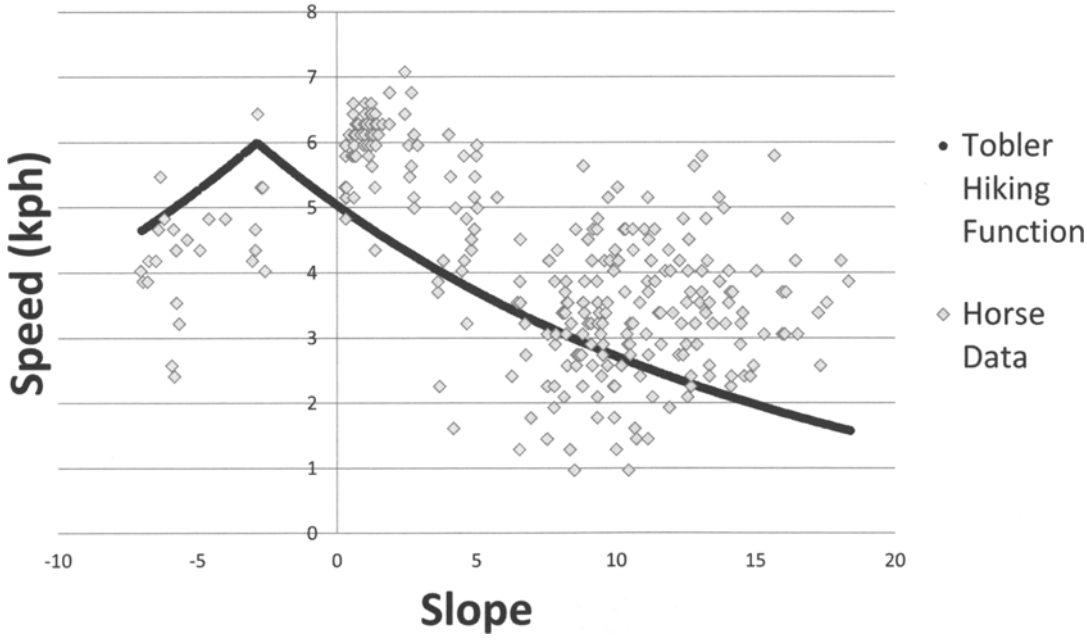

FIGURE 11. Comparison of recorded equestrian speeds on downhill and uphill slopes, compared to human hiker speeds predicted by Tobler's hiking function. (Drawing by author, 2014)

trail sections. The same laden team was able to sustain higher speeds on uphill trail segments of 8°–15° slopes, where human hikers would be predicted by the Tobler function to slow consistently. By extension, least-cost paths and cost distances derived by GIS analyses using hiking functions would be difficult to justify in interpretations of archaeological landscapes where horses were prominent. In short, what the experiment produced was the raw travel data needed to interpolate energetic equations relating mounted-horse travel over composite surfaces into GIS analyses of archaeological landscapes.

Reconsidering the New Mexico situation, it seems that the historical raiding and trading routes into the Rito Colorado Valley are better understood through the intersection of the trails with rates of elevation change and near-surface geological exposures. Radical changes in slope over those passes north of Casitas Viejas and the rockiness of the trail are related to the way the system traverses changes in geologic substrate. By extension, those aspects of the trail system were most likely important considerations for those riding horses, leading pack trains, or herding sheep, goat, and cattle over the passes. Integrating them more fully into the interpretations of historical landscapes may reveal tensions between the lived realities of travel and colonial administrators' ideas about citizens living "not farther than a day's travel from their district officer" (Kessell 2013:43), and other strategic, economic, and social mandates of the era. Using the observed changes in speed and distance covered by equestrians to model how past riders would have made time or distance will lend itself to reinterpretation of the tactical location of buffer settlements like Casitas. Such reconsiderations could extend to the distances between major settlements all along the mountainous northern frontier, trade routes across the Southwest to California, and add new dimensions of landscape-scale understanding to how travel was organized and experienced in the past.

Future Directions

Use of friction surfaces based on horse biomechanics will provide for finer-grained analyses of travel potentials across ancient landscapes, but should be refined for different scenarios. For example, since most raiders were equestrians, in the New Mexico situation mounted-rider cost surfaces could be intersected with cost surfaces for foot travel (shepherds and field hands) to aid interpretations of field house and corral locations at increasing distances from fortified plazas like Casitas, and to explore the relative potential to escape from raids. Additionally, such horse-travel cost surfaces could be intersected with vector features representing high- or low-flow levels in the Rito Colorado, in order to compare seasonal access to Casitas by upstream raiding parties.

Characterization of trail surface conditions may serve as potential cost–surface proxies to be incorporated into GIS models by giving negative values to cells in which more- or less-challenging trail conditions might exist. The locations of such characteristic trail surfaces themselves may be interpolated by intersections of known historical raiding and trading routes with near-surface geologies that are exposed as trails cross from one geologic exposure to the next. It may be expected that as a trail transitions from the soft, silty deposits of an alluvial fan to that of a decomposing-granite exposure, equestrian travel would slow to accommodate the increased density of cobbles in the path. Geological maps of an area can be combined with the historical trail and digital elevation models to identify the sections requiring commensurately more time to travel. Additional uses of similar intersections of data sets, such as geology, biotic communities, or other rasters, to weight values in a computational cost surface for equine travel could include cell values that account for pasturage and paddocking of animals. For example, small alluvial valleys with low hydrological aspect (slow drainage), appropriate plant communities (grasses), and appropriate aspect (good agricultural growth) would be good places to stop to feed and keep herds close along far-flung routes.

Conclusion

GIS-aided modeling has the potential to account for equestrian movement across landscapes that once existed in the past. Beginning in the 16th century, the colonial introduction of horses radically transformed the lives of those who inhabited a vast and arid landscape,

lives of both the colonized and the colonizers. Frontier situations were even more affected by considerations manifest in equestrian lifestyles and by subsequent relationships to the landscape. The presence of equestrians affected everything from the most mundane activities to the most critical: food and fuel gathering, communication, trade, transportation, and warfare. This preliminary look at the dynamics of horse travel over challenging, mountainous terrain suggests that a GIS-aided model can provide finer-grained approximations of the kinds of travel times experienced in the colonial past. Some of the research questions that might be addressed include those evaluating the degree of communities' isolation (or freedom from invigilation) from administrative centers, tactical positioning of villages at landscape scales relevant to mounted combatants, and effective striking ranges related to temporary encampments. These models hold the promise of better understandings of a dynamic and horse-connected landscape through the lenses of those who crafted the frontier from the backs of their mounts.

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