Research

Mapping prehistoric statue roads on Easter Island

Carl P. Lipo[1] & Terry L. Hunt[2]

High resolution satellite photographs offer a new picture of the tracks along which the Easter Island giant statues were hauled from the central quarry to the exhibition sites. The survey traced 32 km of seven major roads, confirmed by features on the ground, where their current condition gives reasons for concern. The authors suggest that the radial pattern implies social division into small groups.

Q1 *Keywords:* ???????

Introduction

Scholars have long debated on how the colossal statues (*moai*) on Easter Island were transported to every corner of the island. The ancient people of Easter Island carved and moved hundreds of multi-ton statues up to 18 km over rugged terrain. While early researchers tracked the course of a few ancient roads leading from the main statue quarry at Rano Raraku, new high-resolution satellite imagery reveals the remains of an extensive pattern of prehistoric roads. Here we report analyses of satellite images and the results of ground-based field surveys that show something of the newly discovered ancient network and its varied components. The distribution and structure of the roads also provide new evidence for evaluating models for how the statues were moved. The pattern of the roads suggests a hypothesis for statue movement by independent groups from across the island, rather than labour controlled by a central chiefdom. Our survey also shows that historic and modern activities have destroyed roads and where protection is urgently needed.

Since the first encounter by the Dutch explorer Jacob Roggeveen in 1722, the giant stone statues (*moai*) of Easter Island (Rapa Nui, Chile) have engendered speculation and debate. With sizes ranging from about 2 to 10 m in height, the distribution of the completed statues meant carving and hauling an estimated 14 000 tons of stone over distances of up to 18 km. Despite many experiments and much debate, just how the massive statues were moved remains a mystery, particularly given the lack of historic or ethnographic evidence. Wild claims of transport by volcanic activity (Wolff 1948) and even extra-terrestrials have been proposed (Von Daniken 1974), and Roggeveen felt that the statues were formed *in situ* by moulding clay or pliable earth (Sharp 1970). However, most archaeologists now agree that the stone statues were moved by some kind of rolling activity (Van Tilburg 1994),

[1] *Department of Anthropology, California State University Long Beach, 1250 Bellflower Blvd., Long Beach, CA 90840, USA (Email: clipo@csulb.edu)*
[2] *Department of Anthropology, University of Hawai'i-Manoa, 2424 Maile Way Honolulu, HI 96822, USA*

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by rocking the figures in an upright fashion (Pavel 1990, 1995; Love 1990) or by levering (Lee 1998, 1999, 2000). Additionally, experimental studies have shown that a relatively small number of individuals could move the statues, rather than the large groups of organised labour once considered necessary (see Lee 1998, 1999, 2000; Love 1990, 2000; Van Tilburg 1996).

Despite the long interest and lively debate on how the statues could have been moved, most scholars have paid only passing attention to the presence of extensive road features stretching from the statue quarry at Rano Raraku in multiple directions across the island. In 1919, Routledge (1919: 194) noted that "the level rays of the sinking sun showed up inequalities of the ground, and, looking towards the sea, along the level plain of the south coast, the old track was clearly seen; it was slightly raised over lower ground and depressed somewhat through higher, and along it every few hundred yards lay a statue". Routledge (1919) outlined the arrangement of roads over the island and sketched a map for segments of a few of them, and while often acknowledged by others, little else was known or made of their significance. In recent years, Love (2000) has undertaken intensive research on the roads and their composite features, including some excavations in the island's southern sector.

Yet despite this recent attention, the roads of Easter Island have never been systematically documented for the island as a whole. Here, we present an extensive analysis of the island's roads as a complement to the intensive studies undertaken recently by Love. Our data have implications for evaluating models for how the statues were moved, and in particular for understanding the scale of labour organisation and investment in monumental statuary and architecture on the island. As we have outlined elsewhere, such investment in monumentality may have played a significant role in the evolution of Easter Island culture (Hunt & Lipo 2001).

Easter Island is small (17 km^2) and among the most isolated inhabited islands on earth. The island lies just outside the tropics (27°9′S) and lacks the biodiversity, abundant rainfall, permanent streams and rich reef ecosystems common elsewhere in Polynesia. Multiple lines of evidence document settlement from Eastern Polynesia no later than AD 600-700. In its extreme windward location to Polynesia, the island likely remained well isolated following colonisation (Finney 1993). Scholars estimate that over at least 500 years (*c.* AD 1000-1500) islanders carved more than 700 multi-ton *moai*, with at least 300 transported from the quarry at Rano Raraku and traversing distances up to 18 km over a rugged landscape. In addition to statues, the ancient islanders constructed more than 313 monumental religious structures (*ahu*) (Martinsson-Wallin 1994), comprising with the statue industry large investments in cultural elaboration (Hunt & Lipo 2001). In sum, despite a remote location and limited resources, the *per capita* investment in monument construction on Easter Island is among the highest anywhere in the ancient world.

Methods

Over the past several decades, satellite imagery has become a powerful and efficient means for generating information about the structure of the earth's surface over large areas. The potential of satellite images in archaeological research, however, is only beginning to be recognised. Part of the slow adoption of satellite-based research in archaeology has been the relatively low resolution of images that was available from early satellites. Satellites such as those in the Landsat series, for example, are only able to resolve features larger than 80 m in size. Thus, the earliest uses of satellite images were limited mostly to the study of landscapes or very large archaeological features (e.g., Allan & Richards 1983; Custer 1986; Ebert & Lyons 1980; Findlow & Confeld 1980; Schalk & Lyons 1976). In the past several years, this situation has radically changed with the availability of declassified military imagery and the establishment of commercial firms who have launched their own satellites. A new generation of satellites such as Corona, SPIN-2, Orbview-3/4, SPOT, EROS and Ikonos provide high-resolution images that are well below 10 m and at low costs. Here we take 'high resolution' to mean imagery that represents the earth's surface at a resolution of less than 10 m across (Forte 2001:132). It is possible in such images to recognise archaeological features (e.g., structures, monuments, deposits); their use has spawned a wide variety of applications in archaeological research (e.g., Failmezger 2001; Fowler, 1996, 2002; Kennedy 1998, Kouchoukos 2001; Mumford & Parcak 2002; Philip *et al.* 2002).

Significantly, the resolution of recent satellite images has proven to be sufficient to trace linear prehistoric features such as roads (e.g., Ur 2003; Sever & Wagner 1991) and even footpaths (McKee *et al.* 1994; Sheets & Sever 1991; Sheets 2003). The success of these studies suggests that it should be possible to detect roads used to move Easter Island statues (*moai*) which can be *c.* 2-5 m across provided views are not obstructed by vegetation or other kinds of ground cover.

We acquired images from DigitalGlobe's QuickBird satellite (http://www.DigitalGlobe.com), a commercial satellite launched in 2001, which orbits the earth every 93.5 min and revisits its path every 1-3.5 days depending on the latitude. Remarkably, the QuickBird satellite is capable of generating panchromatic images with resolutions of 61-72 cm and multispectral images with resolutions of 244-288 cm. Differences in resolution depend on the degree to which the satellite is off from the nadir (overhead position) when the image is taken. Data in the DigitalGlobe images are geo-processed so that points and features can be located with an accuracy of 23 m at 90 per cent circular error.

The QuickBird satellite provides images that are comparable with most aerial photographs, and is of sufficient resolution to provide a base for mapping between $1' = 200'$ and $1'' = 400'$ scale (Nale 2002). One of the advantages of QuickBird is that it is able to collect data at near nadir and that the corresponding digital imagery may be considered true overheads. An additional advantage that QuickBird has over aerial photographs is that images are available in colour, panchroma and 4-band multispectra ranging from blue to near-infrared (400 nm-900 nm). This multispectral information, though at a lower resolution (*c.* 2.4 m), is of sufficient quality to provide for a broad range of vegetation and environmental information. Natural colour imagery can provide for crop, forest and wetland information. Remarkably, all of these datasets are available for areas across most of the earth for about US $30 per square kilometre.

We used a composite of three sets of recent high-resolution (60 cm) panchromatic and multispectral images in the analysis of Easter Island. These images were taken on 2 April 2003, 2 December 2002 and 3 February 2003 and at angles less than 15 degrees off of nadir. Though the images were georeferenced by DigitalGlobe, we conducted additional georectification by matching points on the images with GPS coordinates collected on the ground. This rectification allowed us to travel to points identified on the images to within the precision of our hand-held GPS units, or about 20 m. The image data were processed using a nearest-neighbour resampling kernel that produced a pixel size of 70 cm for the panchromatic images and 240 cm for the multispectral images. While portions of the island are not visible due to cloud coverage, as a composite set the images provide a view of *c.* 85 per cent of the island's ground surface.

The minimal vegetation and the nature of the archaeological record on the island made features easily visible in the images. The environment of the Easter Island predominately comprises various grasses and other weedy plants. Much of the island is under grazing by cattle and horses, with some small-scale farming. Areas of the island have been planted with eucalyptus trees, but these groves are limited. As a result, archaeological features such as platforms (*ahu*), house foundations (*hare paenga*), agricultural features (*manavai*) and in some cases, statues (*moai*), were easily identified. We recognised road features as linear forms on several criteria, often found in combinations, such as vegetation differences, depressions filled with cobble scree, banks, trails between statues, erosion patterns and shadow marks. Vegetation differences appear to have been caused by compressed sediment that retains greater moisture. The same compressed, U-shaped roadbeds naturally filled with surface rocks (cobbles) as scree or eroded into troughs with surface water flow, particularly on slopes. Some roads have curbstones and other structural features, including earthworks that create shadows in angled light, or are associated with multiple statues.

We first identified alignments and linear features of stone, soil and/or vegetation anomalies measuring to approximately 5 m in width (Figures 1 and 2). Roads appeared on the images as extensive, dark lines in the case of the panchromatic images or with colour and intensity differences in the case of the multispectral images. The panchromatic images were the most useful since the resolution of these images is an order of magnitude greater than the average width of the road features. For the most part, the multispectral data were too low in resolution, given the average width of the roads. However, the multispectral images often provided information about potential vegetation differences used to corroborate potential ancient roads first recognised in the panchromatic data.

Extensive historic sheep ranching in the late nineteenth and early twentieth centuries by Williamson-Balfour and Company and modern farming activities have led to the construction of roads, stone walls (*pirca*) and fences. Since the linear features identified on the satellite images included a combination of prehistoric, historic and modern roads, we initially mapped as many linear features as possible and used ground survey to eliminate roads clearly attributed to more recent activity. Survey teams travelled to all areas identified as potential roads on the satellite images. The presence of statues (*moai*) along roadbeds as well as constructed linear features such as curbstones with U-shaped depressions served as a primary means to confirm the prehistoric age of roads. Such features were not always continuous, but linear aggregations of features could be traced across the landscape. Use of these criteria means that our map delineates the *minimum* number of statue roads, but ensures that the patterns we observed are related to prehistoric activity, and not ranching or other kinds of later historic activities.

To distinguish the ancient roads from historic and modern ones as well as other linear features on the landscape, we paid particular attention to linear features crossed by historic

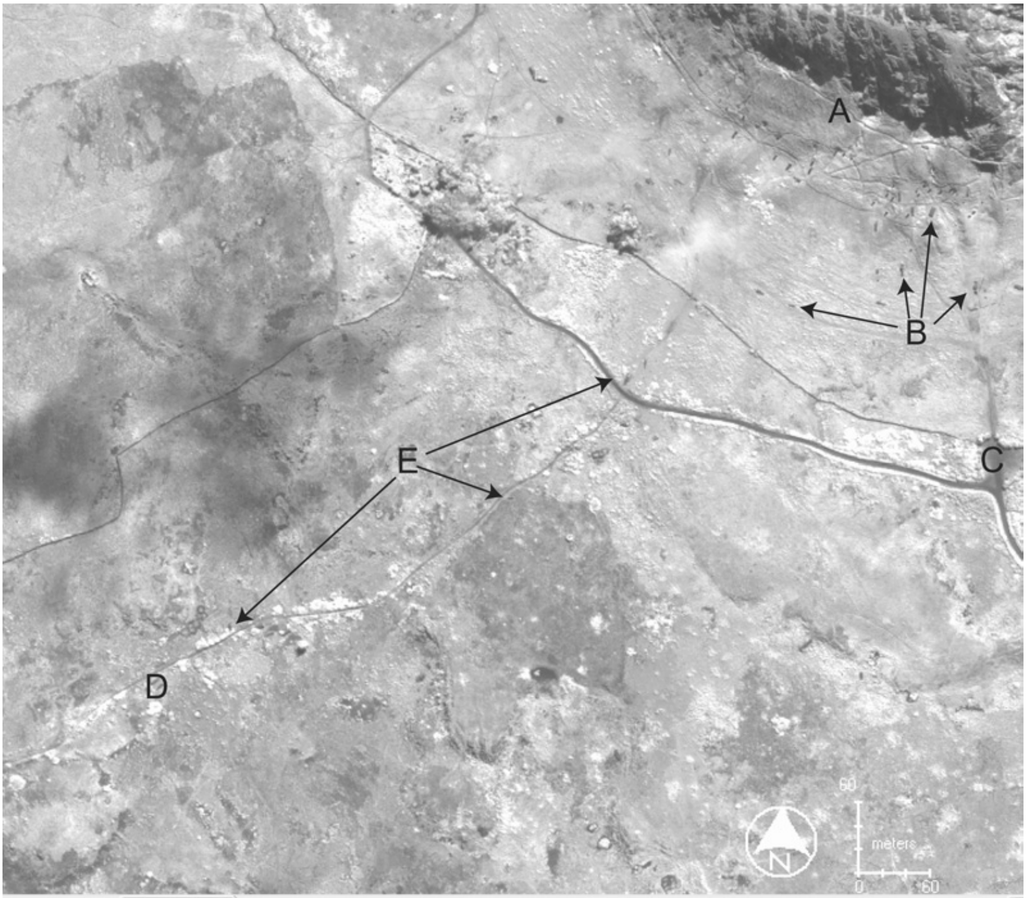

Figure 1. A panchromatic 70 cm resolution QuickBird satellite image showing an ancient road section leading west-southwest from the Rano Raraku statue quarry (A). Statues that surround the quarry are easily visible in this image (B) as is the modern parking lot (C). The ancient road (D) is visible primarily as a horse trail and as a line of vegetation that runs from the northeast to the southwest corner of the image. This feature likely reflects sediment compaction with greater water retention and subsequent vegetation growth. Multiple large statues (moai) line this road near the quarry (E). The satellite image was provided by RADARSAT, Inc and DigitalGlobe, Inc.

features such as ranch roads and walls to estimate relative ordering. We also plotted the island-wide distribution of 702 statues and 87 statue topknots (*pukao*) of red volcanic cinder from Puna Pau Crater (Figure 3). Finally, we conducted extensive ground survey, covering approximately 70 km of potential roads. The field survey consisted of walking the length of the areas identified as potential roads (ancient, historic or modern) and recording evidence of prehistoric modifications, linear patterns of erosion, and particularly the presence of statues. Indeed, investigations of the alignments plotted from the satellite images led to the discovery of several statues previously undocumented.

Results

Our analysis and field survey have identified approximately 32 km of ancient statue roads emanating like spokes from the Rano Raraku quarry across the island (Figure 3). These

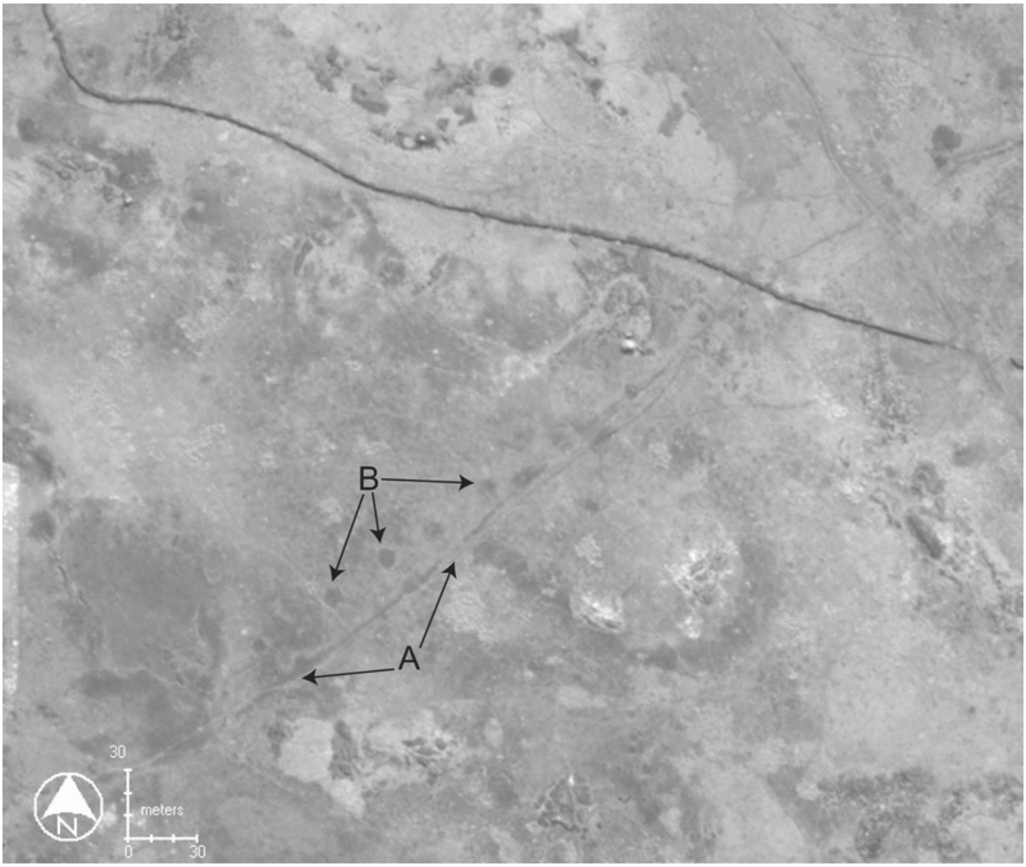

Figure 2. Satellite image of ancient road section (A) identified in Akahanga sector, southern coastal road, with multiple stone-circular features (6-8 m) visible on north side (B). This QuickBird satellite image was provided by RADARSAT, Inc and DigitalGlobe, Inc.

roads comprise a minimum of four major roads leading north-northwest, northwest, west-southwest and southwest. A fifth major road may head directly north from the quarry, but historic and modern modification and use leave this identification ambiguous without further research. Major roads are also found along the west and north side of the island and on the lower (northern) edge of Rano Kao Crater. Minor roads or remnants lead from Rano Raraku to the monumental site (*ahu*) of Tongariki, and along the northeast coast. Some of these roads conform to those sketched by Routledge in 1919, but overall our research shows a greater extent of roads. Field survey confirms that ancient road alignments are formed by linear depressions and/or eroded beds commonly filled with cobbles, as soil erosion (particularly on slopes), as stone constructed features (e.g., single and double alignments of curbstones lining the edge of roadbeds), as earthen/rock modifications, as clearings of surface rock and/or as vegetation differences (Figures 4 and 5). Along the southern road in Akahanga we also identified circular stone clusters (6-8 m in diameter) placed roughly parallel to the road (Figure 2). These features may have played a role in statue transport;

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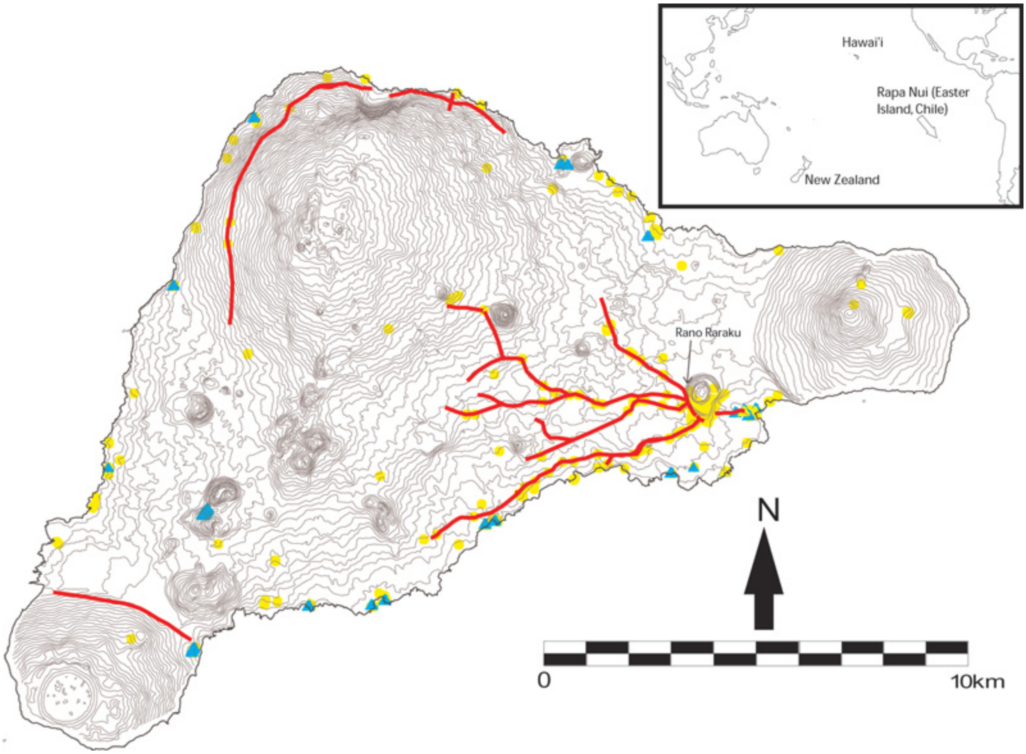

Figure 3. An island-wide distribution of 702 statues (moai, yellow circles), 87 topknots (pukao, blue triangles) and confirmed ancient statue roads (red lines) made on a mosaic of satellite images. About 32 km of roads are shown. The north-northwest road extends 2.7 km; the west-northwest road, 4.5 km, with a western branch an additional 2.6 km; the west-southwest road (discontinuous) 4.0 km; the main southernmost road 8.6 km; Rano Kao Crater road 3.6 km; and the westnorth coast road, 13.0 km. A possible road leads directly north from the quarry at Rano Raraku (4.4 km), but additional field evaluation is necessary to confirm an ancient road given historic and modern activities on the same route.

a few are found on other roads. In the field survey we also documented and distinguished historic horse trails, ranch roads and zones of modern grading or other machine work.

The course of the statue roads also reveals their independence from areas of high-density occupation. The paths do not connect areas of habitation together. Rather, the roads appear to have been primarily constructed for statue transport, and not for other primary purposes, such as travel and communication. This may distinguish, to some degree, the roads of Easter Island from general economic transportation systems elsewhere (e.g., Sheets 2003; Trombold 1991).

Some ancient statue roads had been modified and reused in historic and modern times. In many cases, ancient statue roads appear to have offered ideal paths for historic horse trails, ox carts, or more recently for motor vehicles. Recent use of the ancient roads appears to have followed a 'path of least resistance' as they are relatively free of rock or other barriers and traverse minimal topography and distances from one point to another. The termination of at least the three major west and northwest bound roads end in recently ploughed fields. Such historic and modern use makes the presence of some ancient roads difficult to confirm without further intensive study, such as the excavations conducted by Charles Love on

Figure 4. Photograph of roadbed depression, curbstones and cobble talus, southern coastal road, Akahanga sector, looking west-southwest.

Figure 5. Photograph of southern coastal road leading from Rano Raraku statue quarry; road alignment is visible as a line of vegetation (compare with Figure 1, from satellite image).

road segments in 2001 (see Flenley & Bahn 2002). Reports from Love's excavations will provide important details on their construction, form, use and a basis for establishing an absolute chronology through dating. Tracing ancient roads across the landscape provides a vivid picture of where recent activities have destroyed archaeological evidence. The roads are a clear reminder of the urgent need for a comprehensive management plan for historic preservation on the island.

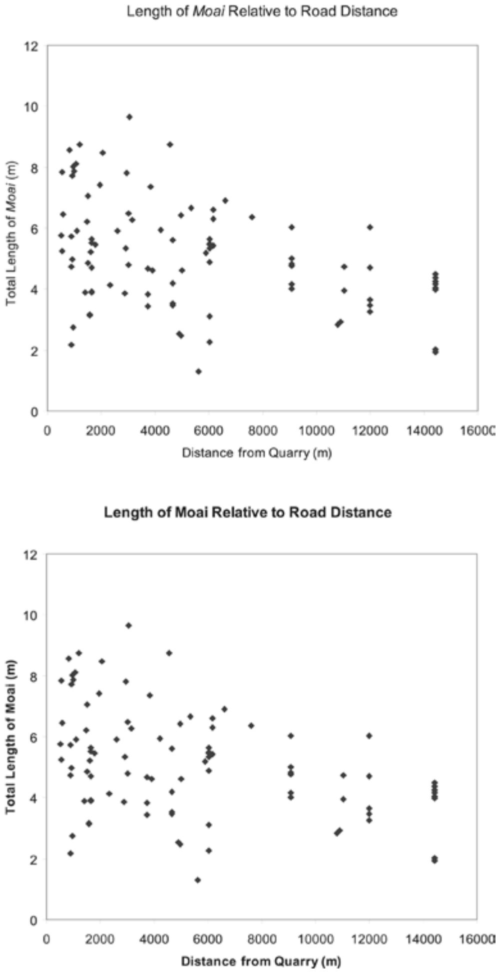

Figure 6. Length of complete moai and their distance from the quarry at Rano Raraku measured on the roads for the southern portion of Easter Island (mean = 5.13 ± 1.75 m, n = 95, data provided by B. Shepardson). The distance calculation includes moai that are 'in transit' found along roads and those associated with monumental religious structures (ahu). The size and variability in statue size decline as the distance from the quarry increases. Mean statue size in the quarry is 5.63 ± 2.02 m, n = 99); statues outside the quarry are smaller (mean = 4.54 ± 1.75 m, n = 145). This distribution suggests that the transport of statues required the greatest investment in energy, failure occurring more often with larger statues.

Discussion

The systematic documentation of the ancient roads of Easter Island is essential to evaluate the competing models for how the statues were moved. Data on statue size and distribution suggest that their movement required the greatest investment in energy (Figure 6), and that transport failure occurred more often with larger statues. Documenting the roads provides data on the actual minimal distances that the statues were transported, rather than hypothetical or optimal paths used in some models (Van Tilburg 1994). Direct study of the roads will also inform on the nature of the surfaces and the slopes the statues traversed in the movement over the island.

Mapping the paths of these stone giants also provides some clues for the social, economic and political organisation of the ancient islanders. The roads emanate from the quarry in a spoke-like pattern to the south, west and north coasts. Field survey confirmed the distribution of at least seven major roads/road segments, extending some 32 km. Their arrangement suggests that roads were not necessarily shared, but each region (potentially related to individual social groups) had their own road for delivery of statues from Rano Raraku. The apparent independence of the roads argues against a centralised authority regulating statue production and transport. Instead, the evidence favours a model of smaller, competing groups engaged in the labour-intensive investments of statue making and transport. We suggest such a hypothesis for relatively autonomous competing groups over much of the island's prehistory should be tested against multiple lines of evidence.

The remains of the ancient roads provide a new context in which to evaluate models for the movement of the statues from the quarry at Rano Raraku to every part of the island.

If the pattern of road construction and use support a hypothesis for the movement of statues by smaller independent and competitive groups, then social and political organisation was not centralised for the island, as some have inferred (Diamond 1995). Indeed, much of the story told for Easter Island's ancient past is in need of critical re-evaluation (Hunt & Lipo 2001; Rainbird 2002). Meanwhile our survey also suggests that the ancient roads themselves are fast disappearing as ploughing and other farming activities spread across the island.

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