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– RESEARCH REPORT –

# Reconstructing Lithic Supply Zones and Procurement Areas: An Example from the Bay of Islands, Northland, New Zealand

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ABSTRACT

While our ability to match lithic artefacts to geological source continues to improve, few explicit techniques exist for the spatial analysis and interpretation of sourced assemblages on the regional level. Obsidian from the Bay of Islands, New Zealand is used here to describe a method of spatial analysis focused on defining intra-regional *procurement areas* where people accessed a common set of sources. The results suggest future analyses of North Island obsidian should take care to account for the natural accessibility of sources and the use of non-local obsidian among coastal populations with greater access to maritime trade and exchange.

*Keywords*: lithic sourcing, supply zone, procurement area

## INTRODUCTION

Obsidian artefact sourcing studies employ spatial and attribute data to reconstruct choices concerning the direct procurement of raw materials and the use of exchange networks. However, despite recent advances in the application of spatial technology (McCoy & Ladefoged 2009) and lithic sourcing (Shackley 1998; Weisler 1997), archaeo logy has remarkably few techniques for the spatial analysis of sourced artefact assemblages. In this paper, we use available data on Northland obsidian (Kaeo, Huruiki) in the Bay of Islands region, New Zealand to describe a method for identifying *procurement areas* defined as geographic regions where people accessed a common set of sources. We make the distinction here between a source used most often in an area, called the 'primary' source, that comprises >50% of an assemblage; and 'secondary' sources which were used less frequently accounting for <50% of assemblages. In this case, the identification of procurement areas helps to confirm that mainland obsidian supply zones were likely small, perhaps within 30–50 km of a source. In addition, the model suggests that the broader natural distribution of Kaeo obsidian may have made it a particularly attractive local source and that there may have been a preference for non-local sources in coastal areas. Overall, the main advantage of defining procurement areas is that they give archaeologists the opportunity to quantify disruptions and continuity in access to local and non-local sources.

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## BACKGROUND

New Zealand obsidian, with 27 geographically distinct sources grouped in four regions of the North Island (Northland, Coromandel/Great Barrier/Hauraki, Taupo, and Mayor Island), has proven especially useful in documenting the circulation of material over long distances (Sheppard 2004: 151). Previous studies based on sites from across the country have documented the shrinking circulation of Mayor Island Obsidian (MIO) from the Archaic to the Classic Period (Seelenfreund & Bollong 1989; Walter *et al.* 2010) and identified locations that may have played centralised roles in exchange (Scott 2007).

However, the supply zone territory of individual sources – defined as the area immediately around a single source where it was directly accessed and beyond which we see a major drop off in the frequency of that source (Renfrew 1972: 465; Renfrew *et al.* 1968: 327–329) – remains poorly defined for New Zealand obsidians. Research to date suggests mainland source territories may have been relatively small. For example, Waihi obsidian has only been found in the Eastern Hauraki Plains and the Western Bay of Plenty within 30 km from the source (Moore 2005). In contrast, MIO has been reported in remarkably high frequencies hundreds of kilometres away from the source.

## Obsidian Sources Used in the Bay of Islands

The Bay of Islands has been the subject of regional scale archaeological surveys but relatively few excavations given the area's high pre-European contact site density (Groube 1964, 1966; Furey 2007; Nevin 1984; Sutton 1990, 1993; Sutton *et al.* 2003). Local sources of obsidian include Kaeo and Weta to the north and Huruiki to the south (Figure 1). While these sources appear as single points in national scale studies, in practice they are better thought of as 'source areas' (Sheppard 2004). While it is difficult to put boundaries on source areas, it is important to note that the Kaeo source area may be two or three times larger than Huruiki. The little that is known about the Weta source which has yet to be identified in artefact sourcing studies, suggests it has a small geographic distribution and may not be a viable source of flake quality material. In this study, we calculated distance to source based on the closest recorded 'obsidian source' in CINZAS (Central Index of New Zealand Archaeological Sites) within each source area.

Urupukapuka Island, the largest island in the Bay of Islands, has been the subject of reconnaissance and intensive survey as well as limited excavations in the course of resource management (Goddard & Blanshard 2010; Leahy & Walsh 1976; McCoy 2008; McCoy & Ladefoged 2010; Roundtree 1983). For this study we chemically characterized obsidian collected from the foreshore of two sites on Urupukapuka Island, Otehei Bay Midden (Q05/1101) and Entico Bay Midden (Q05/1070). Both sites are medium-sized middens composed mainly of cockle, but only Otehei Bay has been archaeologically tested (for recent reviews, see Bruce 2004; Goddard & Blanshard 2010). While moa bone and a few historic artifacts have been recovered from Otehei Bay, the dense population observed by DuFresne in 1772 and the predominance of a single taxon suggests much of the deposit at these two middens dates to the Classic Period (Goddard & Blanshard 2010: 8).

In total, 41 obsidian artefacts were characterized with a Bruker AXS handheld XRF and then classified into four groupings: Mayor Island (n=19), Kaeo (n=11), Huruiki (n=7), and Coromandel (n=4). The identification of the sources of these samples was made using geological samples at the University of Otago as a reference collection (Ward 1972). Assignment to source was conducted by comparing raw XRF spectra of artefacts against geological samples (Figures 2 and 3). Next, samples were either assigned to a specific source (Figure 2) or in the case of the Coromandel, a source region (Figure 3).

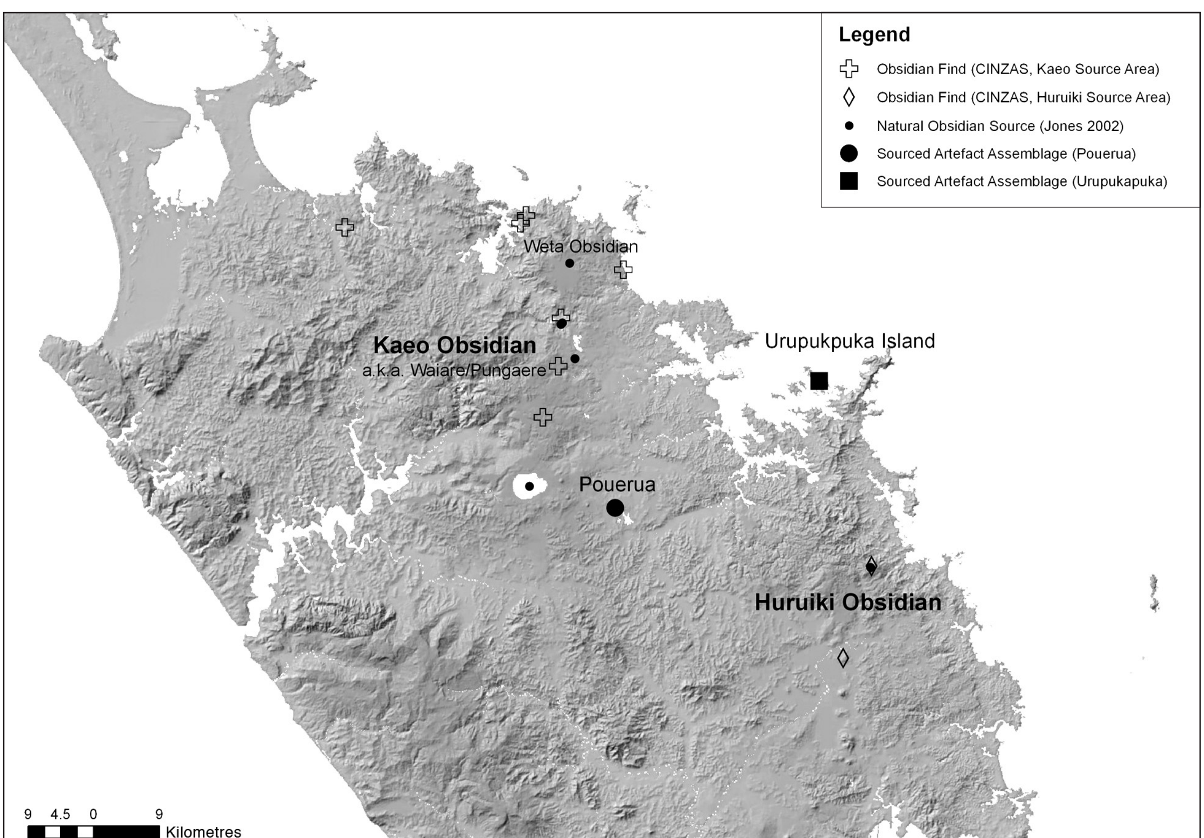


Figure 1. Locations of natural obsidian finds within Kaeo and Huruiki source zones. Note wider geographic distribution of Kaeo obsidian as compared with Huruiki. Source: CINZAS shown as crosses and diamonds; Jones (2002) shown as small dots.

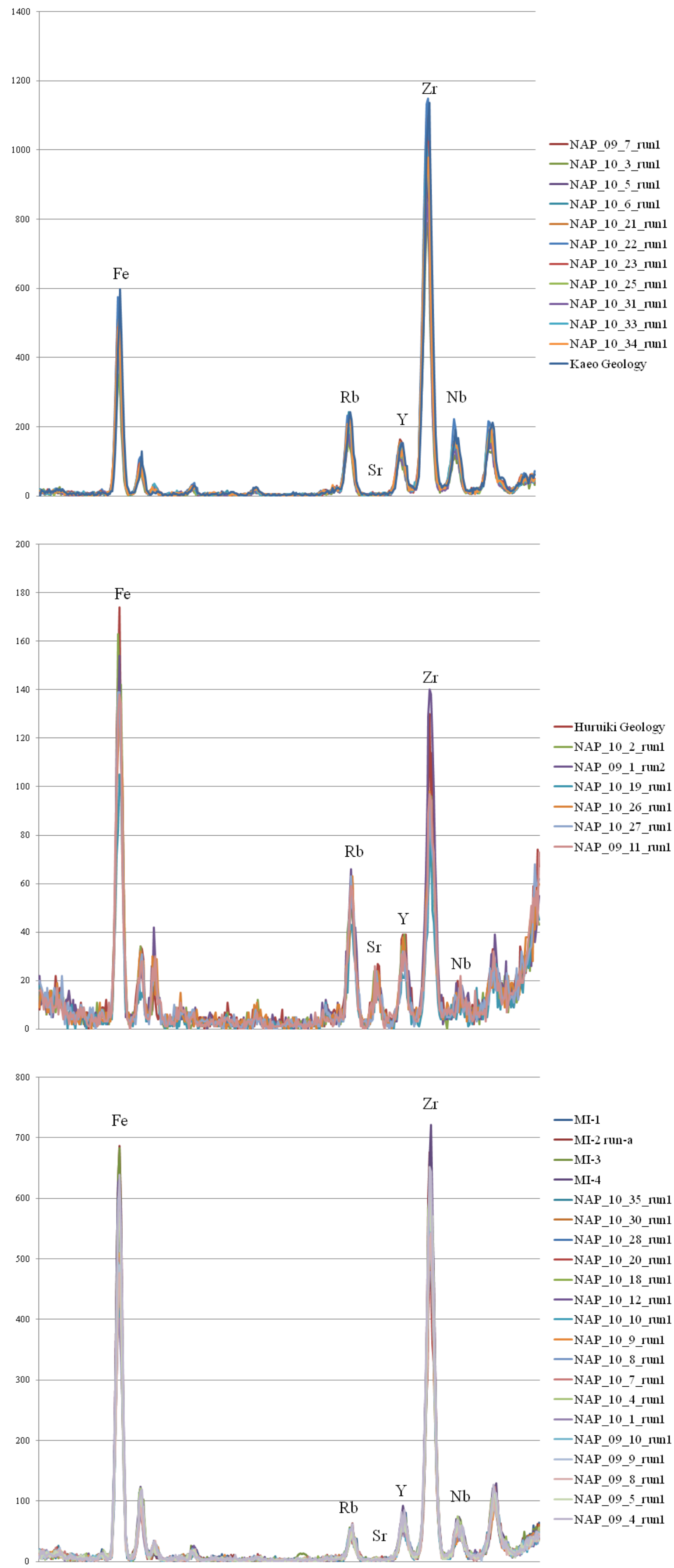


Figure 2. Sourcing obsidian artefacts from Urupukapuka Island, New Zealand: Kaeo, Huruiki and Mayor Island. (Method: Bruker AXS handheld XRF settings: 300 second run time; eV per channel=40; Filament ADC=2.75). Note: spectra of one artefact to Huruiki not shown here.

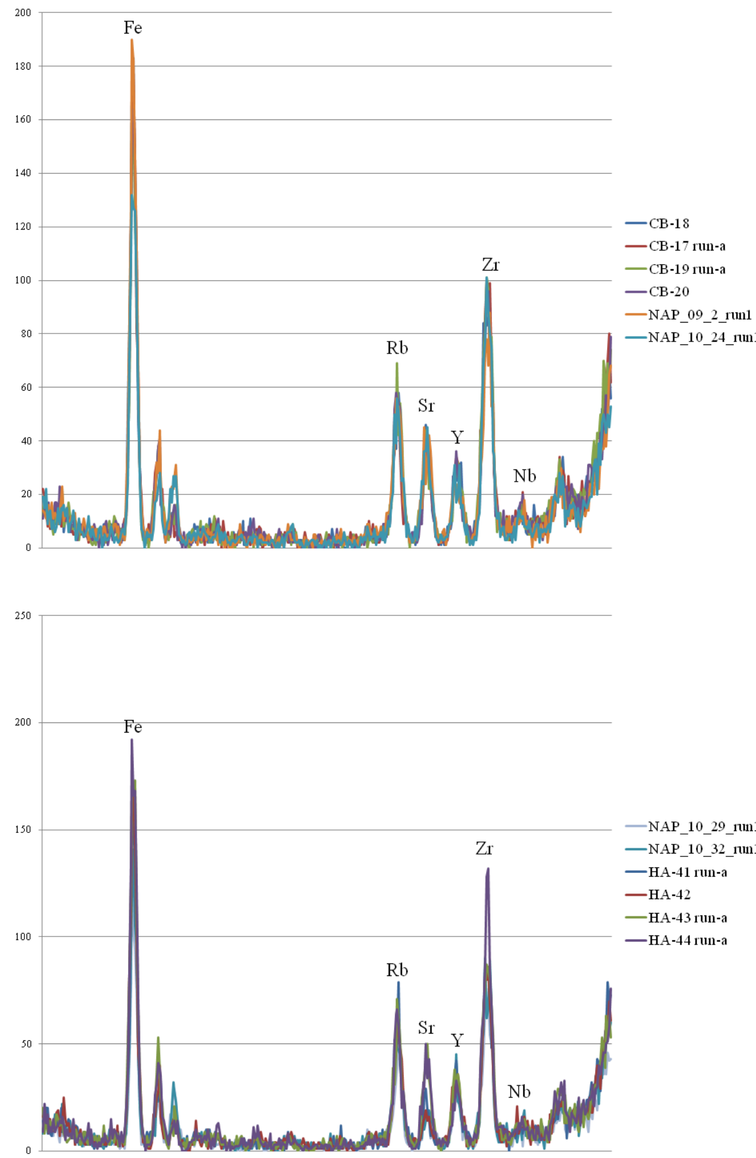


Figure 3. Sourcing obsidian artefacts from Urupukapuka Island, New Zealand: Coromandel Group, Cooks Bay (CB) and Hahei (HA). (Method: Bruker AXS handheld XRF settings: 300 second run time; eV per channel=40; Filament ADC=2.75).

Pouerua is a massive volcanic cone approximately 32 km inland from Urupukapuka Island. It is one of the most carefully studied landscapes in New Zealand and thus the most complete record of pre-European life documented in the Bay of Islands (Sutton 1990, 1993; Sutton *et al.* 2003). Obsidian from six undefended Classic Period sites at Pouerua has been sourced (P05/ 383 [platform/terraces/pits], P05/ 384 [platform/terrace], P05/ 402 [platform/terraces/pits], P05/ 859 [terraces], P05/ 857[terraces/pits], and P05/ 858 [terraces]). In two studies (Brassey & Seelenfreund 1984; Seelenfreund & Bollong 1989), 123 obsidian artefacts from these sites were sorted into six groupings including: Mayor Island (n=24); Kaeo (n=72); Kaeo or Mayor Island (n=12); Fanal Island (n=10); Fanal Island or Huruiki (n=2); Fanal Island, Huruiki, Great Barrier, Coromandel or Inland (n=1); and Huruiki, Great Barrier, Coromandel or Inland (n=2).

We reclassified the Pouerua and Urupukapuka data into three general groupings: Northern Local Source (Kaeo), Southern Local Source (Huruiki), and Long Distance sources (Table 1). The most difficult aspect of this process was deciding how to assign Pouerua artefacts to Huruiki given the ambiguities in the original studies. The number of possible Huruiki artefacts recovered at Pouerua is clearly small, falling between five and zero samples, so we assigned, conservatively, a single artefact to this grouping. This is not ideal and a re-analysis of this collection would help clarify this point.

Table 1. *General grouping of obsidian artefacts from Bay of Islands sites. Sources: Seelenfreund & Bollong (1989) and present study. Distance to non-local sources measured from Mayor Island.*

| | Urupukapuka Island | | Pouerua | |
|---|---|---|---|---|
| | Obsidian (n, %) | Distance to source | Obsidian (n, %) | Distance to source |
| **Northern Local Source** (Kaeo) | 11 (26%) | 38.3 km | 72 (67%) | 16.8 km |
| **Southern Local Source** (Huruiki) | 7 (17%) | 26.1 km | 1 (1%) | 35.3 km |
| **Long Distance** (Mayor Is. and Coromandel Sources) | 23 (56%) | 293.3 km | 34 (32%) | 297.3 km |
| **Total** | **41** | | **107** | |

## SPATIAL ANALYSES

We analyzed the spatial distribution of obsidian in three ways. First the geographic extents of local obsidian supply zones were defined through a distance decay linear regression model. Next, we diverged from Renfrew's original distance decay model and defined two regions within the supply zone: (1) the immediate *primary source* supply zone, an area created by a distance radius predicted by the linear regression where greater than 50% of an assemblage from a site comes from a particular source; and (2) a *secondary source* supply zone where the linear regression predicts the source should account for a smaller portion of assemblages, between 50% and 0%. To help determine what factors may have been influencing the size of supply zones, we divided the Bay of Islands into four *procurement areas* each with a unique set of predicted primary and secondary sources. Finally, we applied the method outlined here to a larger database concerning the distribution of Waihi obsidian in the Coromandel as an example of how disruptions to lithic supply zones can be identified, quantified, and mapped.

### Distance to Source

Distance-to-source regression models were created for the two local obsidian sources to estimate obsidian supply zones. We used the percentage of obsidian from each source in the Urupukapuka and Pouerua assemblages as the y-axis values of points shown in Figure 4, with the corresponding distance of Urupukapuka and Pouerua to each source on the x-axis. Clearly these regression lines are based on minimal data. However, broken down by source the results further reinforce the assumption that there is a negative linear relationship between access and distance. The models predict that site assemblages at the source should contain between ca. 98% and 63% of artefacts made from that source (Table 2), a prediction that is consistent with previous studies (Renfrew *et al.* 1968, 1972).

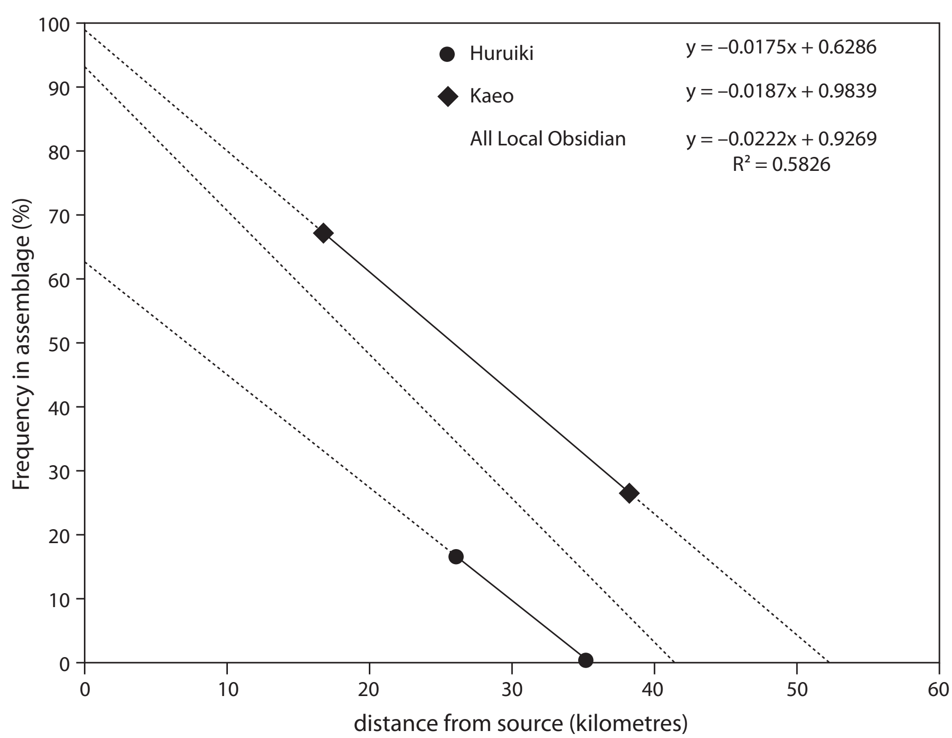


Figure 4. Distance to source models for Kaeo and Huruiki obsidian.

Moreover, the regression suggests that the end of the supply zone, as defined by where frequency of artefacts in an assemblage from that source is 0%, extends 52 km from the northern local source of Kaeo and 36 km from the southern local source of Huruiki.

Table 2. *Estimated source zones based on linear regression model.*

| | Linear Regression (y = %; x = km) | Estimated Use at Source (x = 0 km) | Estimated End of Source Zone (y = 0%) |
|---|---|---|---|
| **Kaeo** | y = -0.0187x + 0.9839 | 98% | 52 km |
| **Huruiki** | y = -0.0175x + 0.6286 | 63% | 36 km |

## Estimated Primary and Secondary Source Zones

Next, we divided the supply zone into regions of primary and secondary supply based on the frequency of a given source. In contrast to Renfrew's distance decay model where access to source is solely a continuous variable, we identified the location within a supply zone where a source drops from being the highest in rank-order importance, or the *primary supply* of obsidian, to being among the sources of lesser importance, or *secondary supplies*. To separate the supply zone in this fashion, we again turned to the regression model to determine at what distance each source ceases to be the majority of obsidian (i.e., y = 50%). The result puts the primary supply zone of Kaeo at 0 to 26 km from that source, and the primary supply zone of Huruiki at 0 to 6 km from that source. Secondary supply zones, defined as areas where the source is predicted to be between 50% and 0%, correspond to distances of 26–52 km and 6–36 km for Kaeo and Huruiki respectively. The geographic boundaries of zones are shown in Figure 5 with primary supply shown as the inner-most buffering rings and secondary supply zones as the larger outer rings.

## Procurement Areas

The intersection of source zones creates four hypothetical intra-regional divisions, or *procurement areas*, defined by access to a common set of primary and secondary obsidian sources (Table 3; Figure 6). In terms of primary sources, Areas A and B are predicted to have relied on the Kaeo obsidian with Area D relying on Huruiki obsidian as the primary supply. Area C lies outside the primary zones of both mainland local sources. However, non-local material is found at the same frequency as one would expect for a primary supply (i.e., 56% non-local artefacts found on Urupukapuka Island, Table 1).

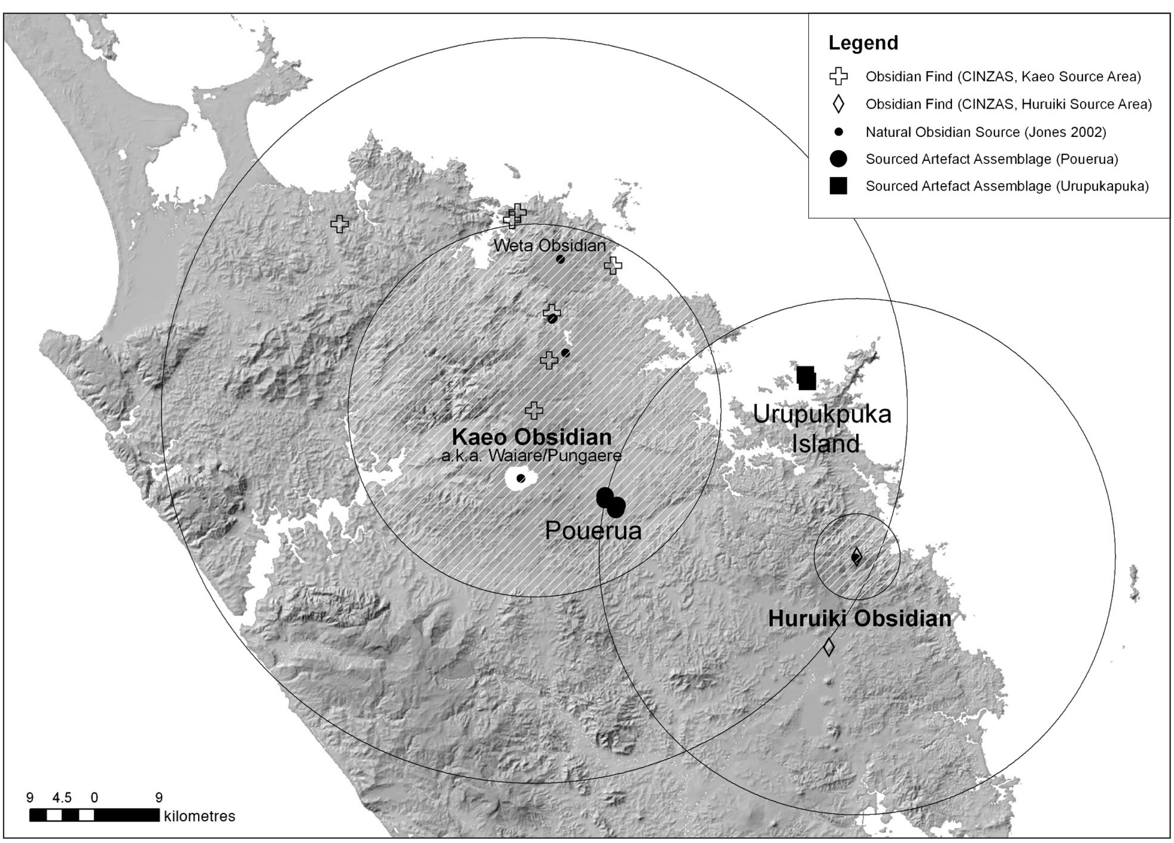


Figure 5. Hypothetical supply zones of Kaeo and Huruiki obsidian.

Table 3. *Procurement areas defined by estimated primary and secondary obsidian supplies.*

| | Primary Supply Source (>50%) | Secondary Supply Sources (<50%) | Environments |
|---|---|---|---|
| Area A | Kaeo | Non-local sources | Inland |
| Area B | Kaeo | Huruiki, Non-local sources | Inland, Coast |
| Area C | Non-local sources | Kaeo, Huruiki | Coast |
| Area D | Huruiki | Kaeo, Non-local sources | Inland |

The use of secondary sources is the major distinction between those areas that share a common primary source, with different mixes of secondary choices predicted depending upon where each area lies relative to local sources. In addition, since the area closest to the Kaeo source (Area A) lies beyond the predicted supply zone of the neighbouring source, only non-local sources are listed as a potential secondary source.

## IDENTIFYING AND QUANTIFYING DISRUPTIONS TO SUPPLY ZONES: WAIHI OBSIDIAN

In larger and more developed datasets, the methodology presented here gives archaeologists a spatial tool for identifying and quantifying disruptions to expected lithic procurement patterns. These disruptions might be attributable to an undocumented neighbouring source, or sources, influencing frequencies, or they could be the result of a disruption to access from increased territoriality. To demonstrate how this might apply to a case in New Zealand we examined the distribution of Waihi obsidian (Moore 2005). Waihi obsidian is ideal for this purpose, first, because it has a total cultural distribution similar in size to Northland obsidians and the current regional dataset includes 15 sites and >5,000 obsidian artefacts (Table 4); and second, because we expect that the distribution of Waihi obsidian was heavily influenced by the availablity of Mayor Island obsidian, located only 39 km away. However, without data on the distribution of Mayor Island and other sources of obsidian it is unclear if Waihi was completely overshadowed as the primary source across its entire cultural distribution or only in a localized region of the coast.

To model disruptions in the distribution of Waihi obsidian we began by creating a simple linear distance-to-source model based on the known maximum distribution of Waihi obsidian (i.e., at 30 km, frequency is 0%) and a maximum expected frequency at the source (i.e., if at 0 km, frequency is 99%; then $y=-0.33x+0.99$). Next, we used the difference between the actual frequency of Waihi obsidian and the expected amount based on a site's distance from the source (Table 4; Figure 7) to create a contour map that shows where, and to what degree, Waihi

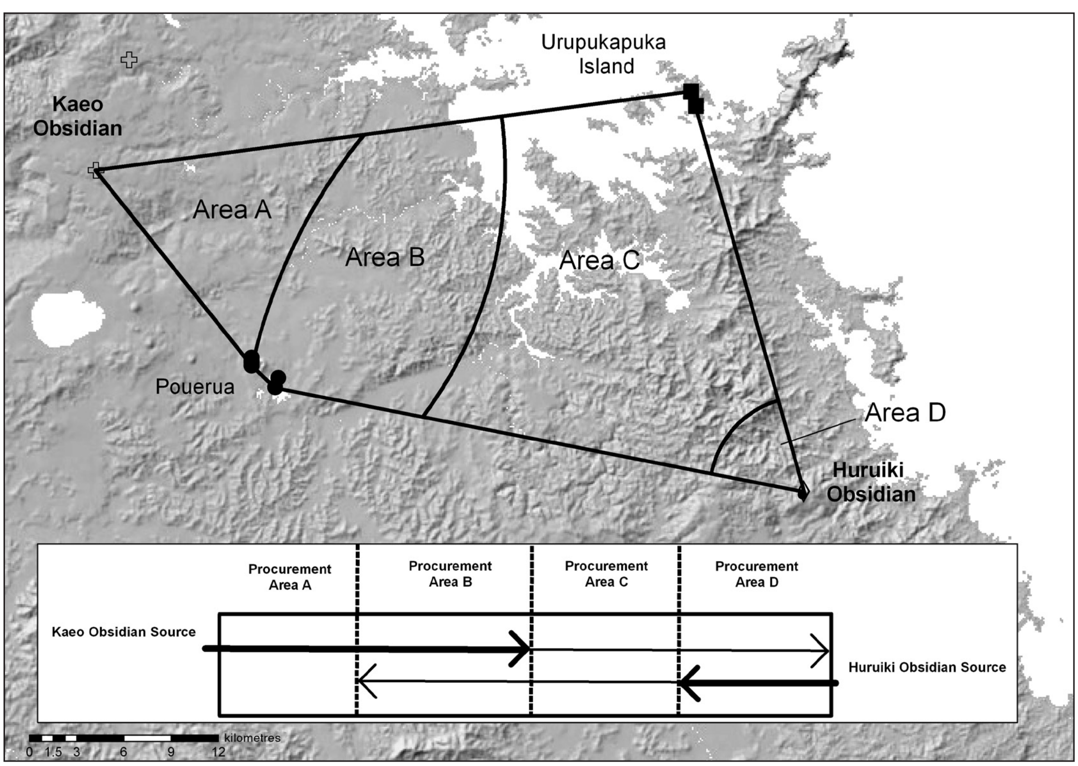


Figure 6. Obsidian procurement areas, Bay of Islands, New Zealand. The region is divided into four procurement areas (A–D). The study area's boundary was defined by location of sites and sources while interior divisions were created by intersecting buffer areas around local sources.

Table 4. *Distance to Source for Waihi Obsidian, Coromandel (adapted from Moore 2005).*

| Site | Distance from Source (km) | Waihi in Assemblage | Predicted Amount of Waihi | Difference (Actual–Predicted) | Assessment |
|---|---|---|---|---|---|
| Opito (T13/788) | 19.59 | 60.0% | 34% | 25.6% | Higher than expected |
| Opito (T13/324) | 19.59 | 35.5% (N=76) | 34% | 1.1% | Within expected range |
| Opito (T13/789) | 19.59 | 30.0% | 34% | −4.4% | Within expected range |
| U13/89 | 10.74 | 16.4% (N=460) | 64% | −47.2% | Lower than expected |
| U13/46 | 10.34 | 13.0% (N=240) | 65% | −51.9% | Lower than expected |
| Raupa (T13/13) | 19.59 | 2.0% (N=3,588) | 34% | −32.4% | Lower than expected |
| Waiwhau (T13/756) | 19.59 | 2.0% (N=590) | 34% | −32.4% | Lower than expected |
| Orokawa Bay | 10.9 | 0.0% | 63% | −63.0% | Lower than expected |
| Kauri Point | 12 | 0.0% | 59% | −59.4% | Lower than expected |
| Whiritoa (T12/2) | 29.2 | 0.0% | 3% | −2.6% | Within expected range |
| Otumoetai pa | 30.5 | 0.0% | 0% | 0.0% | Within expected range |
| Onemana (T12/16) | 34.7 | 0.0% | 0% | 0.0% | Within expected range |
| Oruarangi (T12/192) | 36 | 0.0% | 0% | 0.0% | Within expected range |
| Paterangi (T12/17) | 36 | 0.0% | 0% | 0.0% | Within expected range |
| Hurumoimoi (T12/347) | 38.5 | 0.0% | 0% | 0.0% | Within expected range |

was overshadowed by Mayor Island obsidian (Figure 8). As one might expect, the greatest impact is on coastal assemblages (−40%), but this impact continues somewhat inland. It appears that Waihi was used as a primary source, and significant secondary source in some areas, despite the dominance of Mayor Island.

## CONCLUSIONS

The analysis of obsidian supply zones and procurement areas raises several issues relevant to how archaeologists approach reconstruction of resource access and exchange in the past. First, while these results from the Bay of Is-

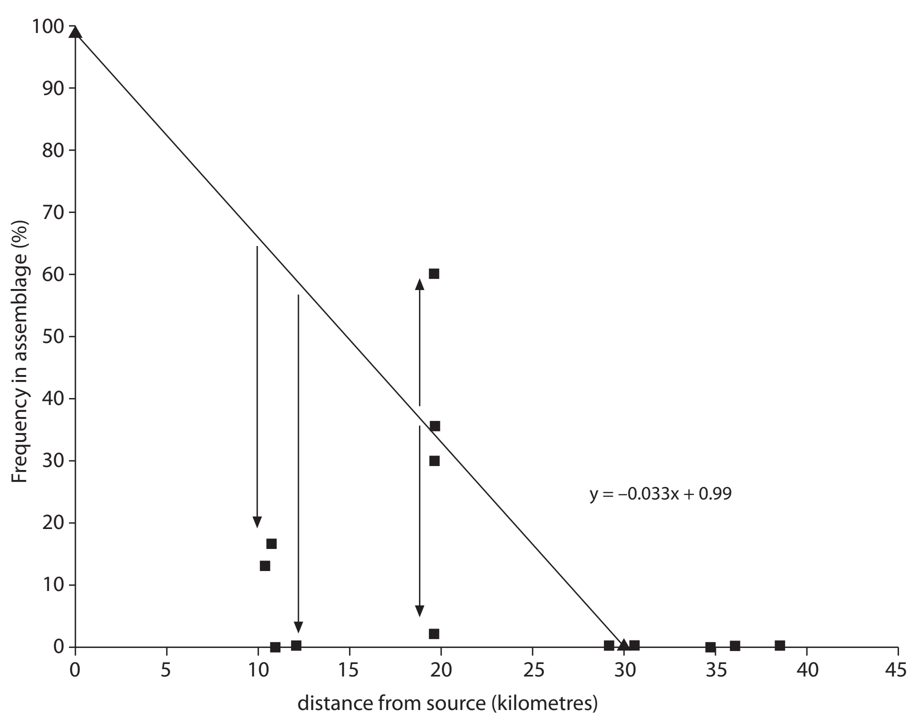


Figure 7. Distance to source model for Waihi obsidian. Linear regression based on maximum cultural distribution (30km) and maximum frequency at source (99%). Source: Moore (2005).

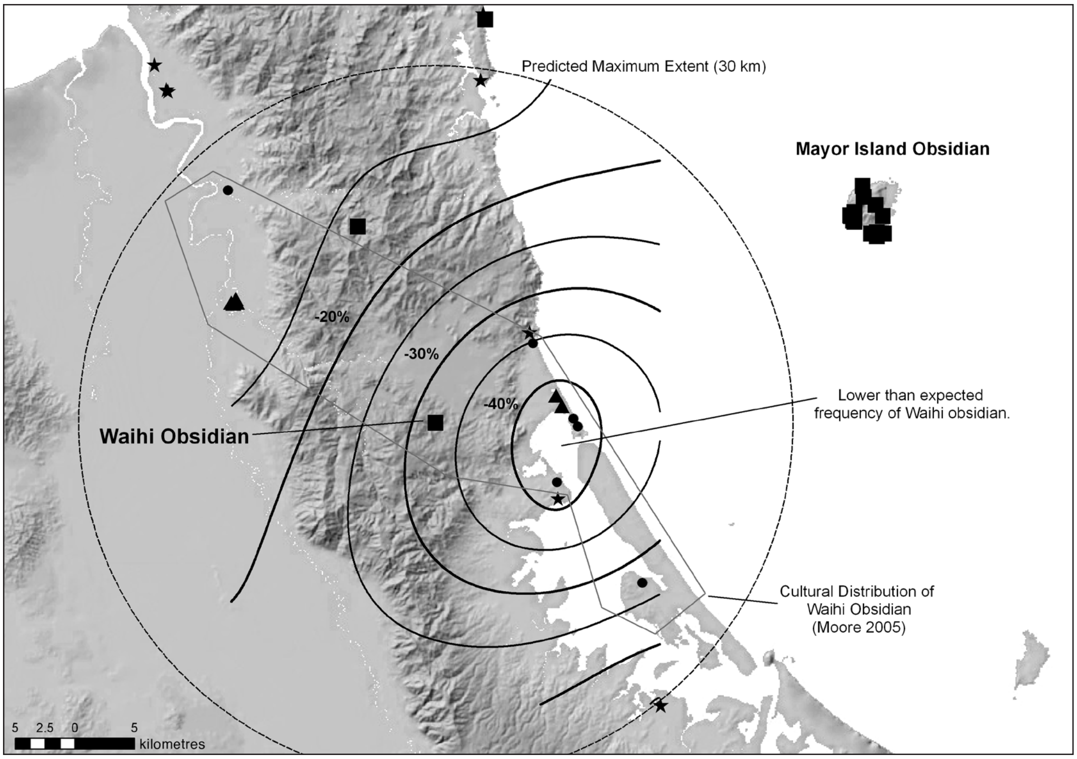


Figure 8. Disruption of Waihi obsidian lithic supply zones, Coromandel. The area of lower than expected frequency of Waihi obsidian is attributable to an unmapped coastal procurement area associated with Mayor Island obsidian. Sites with reported frequency of Waihi obsidian (triangles); sites with Waihi present, frequency unknown (circles) or no Waihi obsidian found in sourcing studies (stars); and known sources of obsidian (squares). Sources: Jones (2002); Moore (2005).

lands and the Coromandel are encouraging, detecting and quantifying lithic procurement disruptions in terms of their relative severity and spatial extent is something best approached with a large sourced database, preferably with information additional to frequency, such as artefact weight, stage of reduction, and detailed information on archaeological context. Nonetheless, the models presented here conform to the expectation that mainland obsidian source supply zones were remarkably small, perhaps including an area just 30–50 km from the source. Further, the wider geographic distribution of Kaeo – as shown by the distribution of source finds reported in CINZAS – appears to influence the size of the supply zone. This is not surprising because given the choice between sources of relatively equal quality, people will turn more often to stone that is easier to access. Clearly, more sampling within the study area, and across the North Island, will help determine how supply zones operated in practice.

Second, the large proportion of long-distance sourced artefacts in coastal areas may indicate that a source hundreds of kilometres away was accessed with similar frequency to local sources. This may be due to the lower transport costs of material from distant sources to coastal sites as opposed to the transport of that material to inland sites. Furthermore, MIO may have been sought after on the grounds of higher quality, compared with local sources. Alternatively, the high proportion of MIO may be a result of the longer time depth of occupation of this area as compared with the inland sites. Only greater chronological control can help determine the better explanation and how supply zones changed over time.

Finally, as previous researchers have found (Leach 1978; Prickett 1975), study of supply and exchange patterns at a regional scale is an important first step to giving archaeologists the ability to track key social changes in the past. In the example presented here, the creation of procurement areas gives the researcher the opportunity to document disruptions and continuity in access to local and non-local sources. In this case we focused on a single material type, but this method could certainly be expanded to study how different raw materials, such as chert, were used as substitutions for obsidian. Given the right samples and chronological controls, the focus of future research should be not only on documenting this aspect of life in pre-contact New Zealand but also on what it can tell us about the evolution of territoriality in general.

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