– ARTICLE –

A Locational Analysis of Rock Art in the North Island, Aotearoa New Zealand

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ABSTRACT

Māori rock art is widely distributed across Aotearoa New Zealand. It has been extensively studied in the South Island where a strong correlation between rock art and limestone outcrops in the South Island has been identified. However, few studies have investigated the distribution and preservation of petroglyphs and pictographs in the North Island. Previous studies suggest preliminary correlations between the distribution of North Island rock art and availability of suitable rock surfaces. As they are based on broad regional observations of the distribution of sites and geological formations, the observations of correlations of art with rock type is limited. Here we adopt a landscape approach to quantitatively test previous correlations through applications of GIS to conduct a spatial analysis using a 25 m digital elevation model of the North Island. A disproportionate presence of rock art on ignimbrite rock formations is shown. This preliminary analysis provides a foundation for more detailed regional studies to understand if the correlation reflects a deliberate selection of certain geological rock surfaces by North Island Māori, and how differential weathering and preservation processes may contribute to the present-day spatial distribution of rock art.

Keywords: Māori rock art; geological distribution; preservation; locational analysis

INTRODUCTION

Firmly embedded within its environment and landscape, the immovability of rock art is a central strength for its archaeological enquiry (Chippindale & Nash 2004). Various forms of Māori rock art are found widely but unevenly distributed on both main islands of New Zealand, with a greater number of sites identified in the South Island (Trotter & McCulloch 1981). As with studies of rock art in other Polynesian archipelagos (e.g. Lee 1992, 2002; Lee & Stasack 2005; Millerstrom 2006), an understanding of landscape context has been central to explanations of when and why Māori rock art was made (e.g. Trotter & McCulloch 1981, Anderson 1990). Historically research attention has focused on the South Island where the largest concentrations of known Māori rock art are found in limestone formations in Canterbury and Otago. In comparison to South Island studies, there has been little published research on rock art in the North Island where the archival and archaeological site records provide inconsistent and scant detail of the sites and surrounding environments (O'Regan 2016). This contributes to uncertainty of the extent to which the North Island record reflects differential rock art preservation and regional bias in historic surveys. As a result, there is ambiguity about the few observations that have been made on the spatial distribution of rock art in the North Island (e.g. Trotter & McCulloch 1981: 45; Anderson 1990: 5–6; Pick 2010: 149–150). Key questions that arise from previous work include the extent to which rock art sites are dispersed across suitable geology, whether the artists had a selective preference for a particular rock canvas, and what correlations exist with different environmental and social variables that may inform on the archaeological context of the rock art.

The formation and weathering of the New Zealand landmass has resulted in highly variable regional geology. In the North Island, however, there have yet to be detailed examinations of what rock formations provide suitable surfaces for art production and the relative stability of those surfaces in relation to the preservation of different types of markings. The implications of the regionally variable geology on the spatial distribution of North Island rock art remains poorly understood. Such issues constrain archaeological research and establishing conservation priorities for rock art in that island (O'Regan 2018). We argue that adopting a landscape approach to visualise and analyse the distribution of Māori rock art in relation to the underlying geological canvas will further our understanding of the variable location of rock art and its likely preservation. Here, we assess that relationship for currently documented North Island Māori rock art sites.

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Submitted 19/12/19, accepted 28/4/20.

LANDSCAPE ARCHAEOLOGY, SPATIAL ANALYSIS, AND ROCK ART

Landscape approaches are well established in rock art studies where spatial analyses of how tangible figures are placed in Indigenous peoples' landscapes offer potential to explore cultural values and intangible aspects of behaviour in past societies (Wienhold & Robinson 2017, Horn *et al.* 2019). There has been a shift from restricted deterministic explanations towards alternative perspectives of how rock art distribution can be interpreted through spatial analyses using GIS software (Cruz Berrocal *et al.* 2014). The strength of landscapes studies, however, still hinges on understandings of the character of the environment at the time period being investigated rather than assuming the conditions now reflect those in the past. For example, the results of early viewshed analysis of rock art in Kilmartin Glen, Scotland that related the degrees of visibility of locations to the potential cultural significance of an area (Gaffney *et al.* 1996) was latter rebuffed by analysis that accounted for the vegetation that was contemporaneous with the manufacture of the rock art and monuments examined (Winterbottom & Long 2006).

This issue is relevant for rock art research in New Zealand where massive environmental change has occurred over the approximately 700 years of human occupation (Holdaway *et al.* 2018) but is compounded by uncertainty regarding when different Māori rock art was created (O'Regan 2016). Overcoming these issues in New Zealand requires a departure from investigations based mostly on the 'site' scale to applying multi-scalar approaches that investigate changing topographic environments from the individual rock and site levels up to regional scales of analysis (O'Regan 2016, see also Chippindale 2004; Hyder 2004; Wienhold 2014; Lock & Pouncett 2017).

GIS APPLICATIONS TO ROCK ART

Geographic information systems (GIS) and associated quantitative and spatial analytical tools are increasingly applied at multiple spatial and temporal scales in archaeology. This provides a strong toolkit to investigate location-based questions in rock art research (Robinson 2010; Wienhold & Robinson 2017). In rock art studies GIS has been used for data capture, as well as for quantitative and spatial assessments of rock art distribution and placement for preservation, conservation, prospection, and public education (e.g. Cruz Berrocal & Vicent Garcia 2007; Rogerio-Candelera *et al.* 2011). Rapid advances in GIS software have been integral in predictive modelling of areas likely to contain archaeological features and can be applied in the management of archaeological heritage (Banerjee *et al.* 2018; Nsanziyera *et al.* 2018).

A landscape approach as that described by Cruz Berrocal and colleagues (2014) has potential for application in the North Island. They use GIS and statistical analysis of landscape variables to investigate possible geographic patterns that have influenced the distribution of 370 Levantine rock art sites in the Spanish Mediterranean basin. To begin, an equal-size random sample of point locations was generated as a control group within a 50 kilometre buffer around the rock art sites excluding the sea. This buffer represented a two-day-walking hinterland. The random point locations were defined by the general representation of landscape features (e.g., mountain ranges, topography, and seasonal streams) that characterise the Spanish Mediterranean basin. Next, the randomness of the Levantine rock art sample was tested by an average nearest neighbour analysis that indicated a less than 1% likelihood that the Levantine rock art spatial pattern could be a result of random processes. A perimeter surrounding each rock art site and random point was defined by a 1 km circular buffer around their XY coordinate points. The landscape variables tested included quantitative features; slope, elevation, aspect, annual rainfall, and average climatic temperatures. Qualitative layers (bioclimatic levels, soil types and land uses) were measured by calculating their area percentage in each of the 1 km buffers to create a landscape factor model in which to analyse the variables that characterise the local rock art environmental context. Each buffer was developed through a series of geographical layers that related to the structural factors of the landscape, allowing consideration of associations of rock art places with particular landscape structures, and their preservation and formational history over time.

THE NORTH ISLAND ROCK ART RECORD

At the time of this study there were 156 rock art sites known in the North Island with recorded geographical coordinates. A summary visualisation shows that the sites are unevenly distributed across the North Island (Figure 1). Anderson (1990: 6) suggested that rock art placement in the North Island may correlate with the availability of suitable surfaces such as siltstone and volcanic ash. However, further assessment is required to investigate whether rock suitability is the main factor explaining the placement of rock art or if other regional factors may also be influencing rock art distribution.

Pick's (2010) review of the New Zealand Archaeological Association (NZAA) archaeological site records identified 127 rock art sites across the North Island and confirmed these were concentrated in small regional clusters in the Taupō Volcanic Zone (TVZ) and on the Taranaki coast. Pick identified regional homogeneity in manufacture techniques, but the environmental details of sites were not compared other than to note the general geological characteristics where these were described in reports. Based on these and correspondence with Taranaki archaeologist Kelvin Day, a broad correlation of rock art to volcanic rocks in the TVZ and to andesite boulders in Taranaki was suggested (Pick 2010).

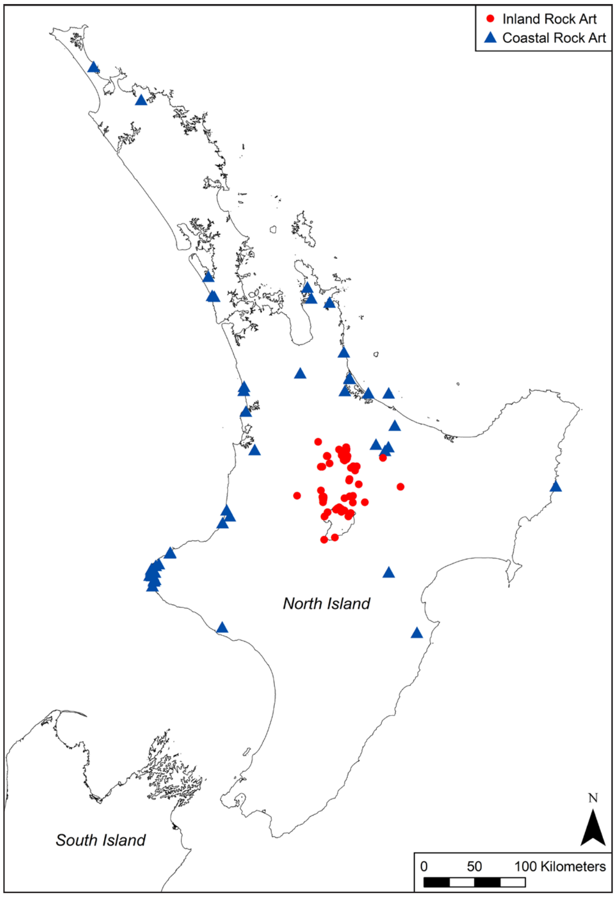

Figure 1. Distribution of known North Island coastal and inland rock art sites at 2018. Coastal sites are defined as those within 20 km from the coast. Data source: University of Auckland research project 'Initiating a Māori archaeology of threatened North Island rock art'.

A more detailed and multi-scalar investigation of rock art locations near Taupō examined the impact of various formational processes, including land use histories and preservation conditions, and their association with environmental and cultural variables related to surviving Māori rock art (O'Regan 2016). Beyond the immediate Taupō study area, however, the environmental characteristics of sites across the North Island have not yet been systematically identified. These limitations in the understanding of rock art placement across the island constrain the scope to predictively target rock art surveys, as well as determine conservation management strategies for known sites (O'Regan 2018). To address this O'Regan is currently undertaking a major review of North Island Māori rock art records. As part of that research an up-to-date data set of the distribution of North Island rock art sites has been compiled.

Here we perform a locational analysis to identify variation in North Island rock art distributions relative to topographical and geological factors that may influence its location and preservation. A locational analysis using exploratory spatial analysis techniques moves beyond a 'site-based' analysis and also investigates the topographic environment of rock art at broader regional scales (Hyder 2004). The unit of analysis in this study is an archaeological site, an immovable and proximate remnant of human behaviour recorded in the NZAA Site Recording Scheme (SRS) as having rock art present. A site may consist of different archaeological phenomena but the one we refer to here is rock art. The effects of uneven survey data on examining the distribution of rock art sites is also acknowledged, as the locational data used here are limited to the records available in the NZAA SRS database. Hence, the 'boundary' of the site is defined as an arbitrary 1 km buffer. This buffer was chosen to encapsulate the relevant area while being coarse enough to mitigate the resolution of environmental data and potential errors in the placement of these rock-art sites from the NZAA database, which we discuss below. Addressing the lack of confidence in the overall record to date, this study will then support the further documentation of North Island rock art by providing insights based on quantitative data to can help identify other locations where rock art surveys may be usefully targeted.

LOCATIONAL ANALYSIS METHODS

The spatial analysis methods used in this study were developed from those employed by Cruz Berrocal *et al.* (2014) and undertaken with ESRI ArcGIS 10.6.1. The locational analysis was conducted in two parts: first at an island-wide scale considering all North Island sites in unison; and second at a regional scale examining differences between coastal and inland rock art locations. A preliminary overview of the distribution indicated that the rock art locations clustered at the coast in some regions. Within the digital elevation model (DEM) used the measurement of slope and related variables was typically different between coastal and inland locations so the two topographical zones were separated.

The 25 m DEM of the North Island was sourced from Land Information New Zealand (LINZ), as was topographic river data (LINZ Data Service 2018). Geological rock type data was obtained from Geological and Nuclear Sciences (GNS) (GNS Science 2009). Both the geological and river data were analysed at a 1:250,000 scale.

The list of 156 rock art sites was sourced from a current University of Auckland research project database compiled from a comprehensive 2018 review of North Island rock art listings in the NZAA SRS, New Zealand's official inventory of archaeological sites. A search of the SRS database using multiple ascriptions applied to rock art (e.g. petroglyph, engraving, incision, carving, pictograph, drawing, painting, ochre, kōkōwai) produced a draft list of sites that was then manually checked by O'Regan to remove those not confirmed as rock art localities. This is the most thorough inventory of North Island rock art currently available.

However, the character of the site location data limits the spatial detail that can applied in this study. The SRS, from which the site coordinates are mostly sourced, provides location data of differing accuracy: recently visited sites mostly have coordinates recorded handheld GPS (n 48); some site coordinates are developed from other mapping information (n 3); and coordinates for earlier site recording are taken from the Central Index of New Zealand Archaeological Sites (CINZAS) and are those of the south-west corner of a 100 m × 100 m square in which the archaeological feature is located (n 102). Coordinates were also generated for three further sites known from other literature but not yet recorded in the SRS.

At an island-wide scale the density of rock art sites across different geological deposits was calculated to identify the range of rock types on which rock art was located. The clustering of the sites on particular types of geology was statistically tested to confirm if the clustering pattern was non-random. The percentage of rock art occurring on different geological rock surfaces and topographical settings were also examined to consider if distributional patterns are a function of differential rock art preservation.

For this study, 156 random points were generated as a control group. The plotting of the random sample was constrained to geology types on which rock art sites are known (Table 1). This avoided including rock formations, such conglomerate, that are unlikely to support manufacture or survival of Māori rock art. Both the control group points, and site locations were constrained by a 20 km buffer to compare the distributions of coastal and inland rock art features on a regional scale. Given New Zealand's topography, this is an arbitrary identification of a location within 20 km of the coastline as being 'coastal'. To analyse associated environmental variables 1 km buffers were generated around each of the rock art sites and random points (after Cruz-Berrocal *et al.* 2014). This buffer size was chosen to account for both the relevant structural features that surround the sites and the resolution of the location and topographical data.

The DEM was used in raster format (with a pixel size of 25 m × 25 m) to derive several environmental variables and assess their influence on the preservation of rock art features and its susceptibility to weathering. These are slope gradient (slope), down slope direction (aspect), elevation, and distance to water courses. Slope (measured in degrees) (Tables 1 and 2) has a strong influence on the exposure and preservation of rock art features on the available rock surface due to its association with the positioning of the rock (Aubry & Dimuccio 2012; Cruz Berrocal *et al.* 2014). Aspect levels (measured in degrees) influence slope temperature and humidity, which can affect the kind of surface weathering on rock types where rock art has been found (Aubry & Dimuccio 2012) (Tables 1 and 2). Elevation (metres above sea level) is also relevant in terrain analysis and shown to be associated with slope in archaeological site mapping and rock art distribution (e.g. Nsanziyera *et al.* 2018). As with some rock art studies elsewhere (e.g. Arsenault 2004; Cruz Berrocal *et al.* 2014), previous research indicates associations of Māori rock art locations with rivers and lakes (Allen *et al.* 2013; O'Regan 2016). As a variable the distance to watercourses is measured in metres from the 1km buffer edge. Measuring from the buffer edge accounts for resolution of some site coordinate data. An average nearest neighbour test was performed in ArcGIS to assess the randomness of the North Island rock art sample distribution (S1).

The results of the analyses are compared to examine potential patterns in North Island rock art distribution. We apply descriptive and inferential statistics through significance testing in RStudio (2015) to investigate whether the distributions depart from the expectations based on the random sample. These statistical tests were performed at 95% confidence intervals, and results were considered significant at $p \leq 0.05$ (S2).

RESULTS

North Island Rock Art Distribution

The kernel density distribution and cluster and outlier analysis show that the highest concentration of rock art localities is around the central region of the North Island within the TVZ, mostly on rhyolitic and ignimbrite rock surfaces (Figure 2). The next highest density and clustering occurs on the west coast of the North Island in Taranaki where the rock formations are predominantly debris and gravel. Approximately 51.92% of rock art sites fall on ignimbrite rock, which has the highest percentage out of all the geological rock types with rock art sites present (Figure 3). Of the sites 22.44% are located on other rock categories that are individually too small to be factored into the analyses (Table 1). Metamorphic and sedimentary rock formations had the lowest percentages of rock art sites present (Table 1). In stark contrast to the South Island, where over 98% of known sites are found on limestone, only 1.12% of known North Island sites are found on this rock type (Table 1). Approximately 30% of coastal rock art features occurred on debris and 40% occurred on gravel whereas for inland rock art features 90% occurred on ignimbrite surfaces. The average nearest neighbour analysis of the North Island rock art sample, indicates that the clustering of rock art sites significantly departs from a random pattern (nearest neighbour ratio = 0.328; z score = –16.196, $p = 0.000$).

The central tendency was inferentially compared through significance testing using the Welch two-sampled *t* test for variables with numeric mean values (Table 2). The Mann Whitney U test was used to complement the t-tests by determining whether there were differences in the medians of each variable tested between the two independent samples. This non-parametric test was used by treating the variables with numeric values as rank-order outcome variables as some of the data were slightly skewed and

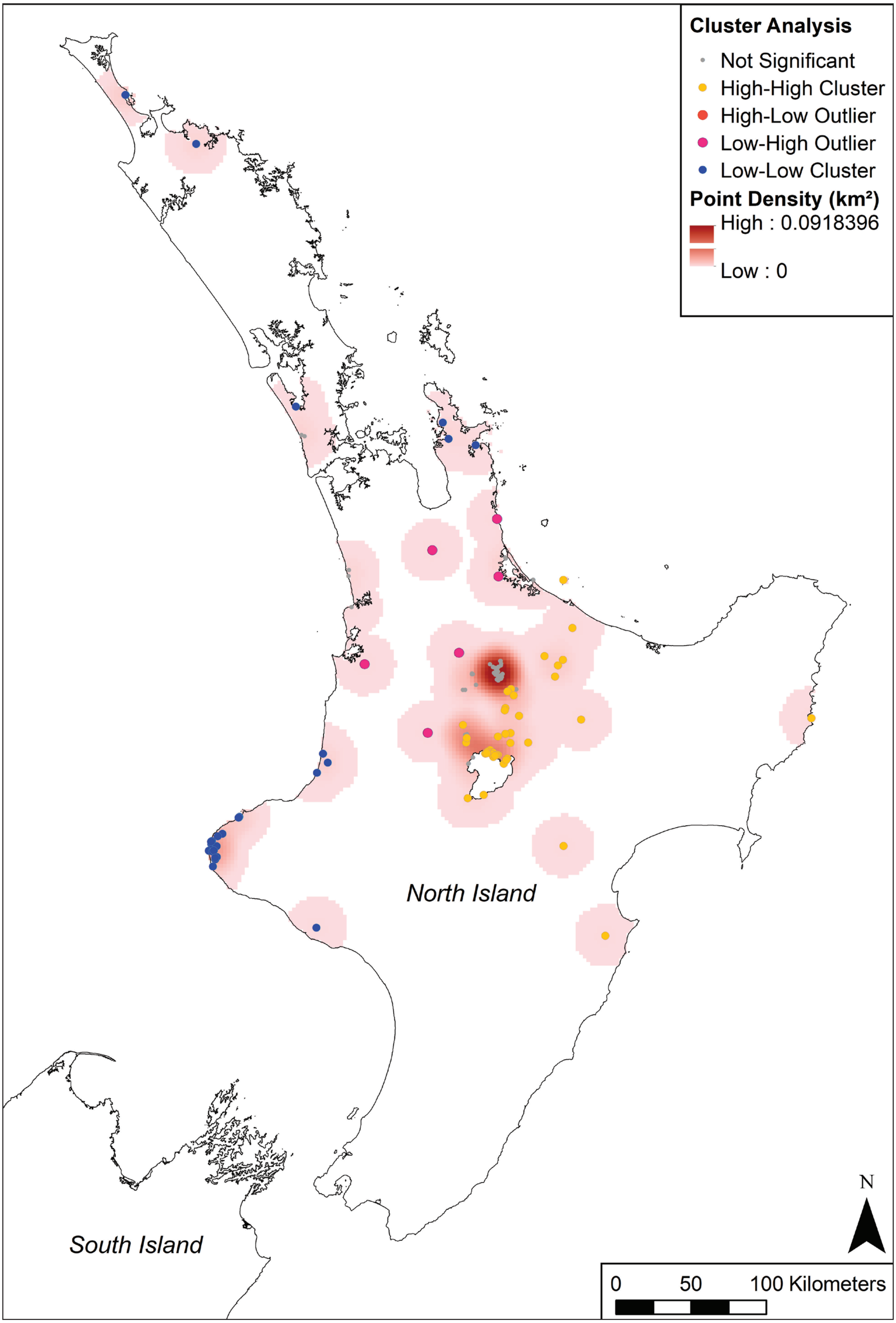

Figure 2. Kernel density distribution and cluster and outlier analysis of rock art in the North Island.

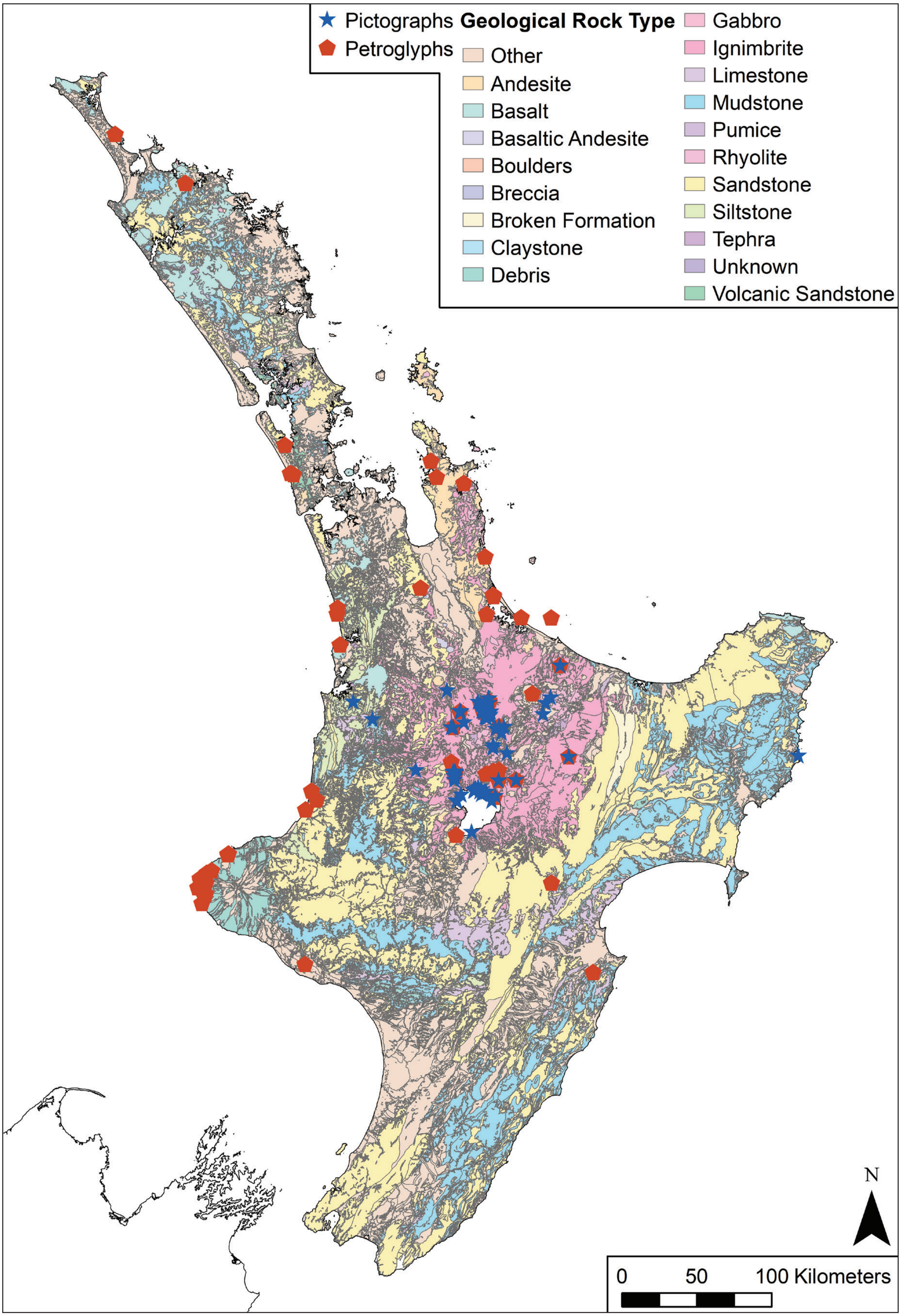

Figure 3. Map of the North Island showing the various geological rock surfaces.

Table 1. *Summary of variables tested against the random sample generated on geological rock types that have known rock art localities. Percentage (%) of rock art sites and random points on geological rock types were analysed for both the North Island rock art and random samples.*

Geographic Layer	Variable		Mean Value	
			North Island Rock Art	Random Sample
Slope	Slope (degrees)	Mean	13.16	0.63
		Std. dev.	12.42	1.33
Aspect	Aspect (degrees)	Mean	175.31	170.87
		Std. dev.	120.92	113.86
Elevation	Elevation (m)	Mean	294.95	251.25
		Std. dev.	189.54	283.93
Geographic Layer	**Variable (1 km buffer)**		**Mean Value**	
			North Island Rock Art	**Random Sample**
Near Distance from Rivers	Near Distance from Rivers (m)	Mean	238.04	1339.80
		Std. dev.	255.07	1736.52

Geological Rock Types	North Island Rock Art (%) of sites	Random Sample (%) of points
Andesite	1.92	1.28
Basalt	0.64	1.92
Gravel	5.77	10.90
Ignimbrite	51.92	13.46
Limestone	1.12	0.64
Pumice	1.28	0.64
Rhyolite	7.05	2.56
Sandstone	4.49	15.38
Tephra	1.92	0
Volcanic sandstone	0.64	0.64
Other	22.44	72.27

non-normal in distribution, particularly for slope (Table 2). This method of comparing a parametric t-test and non-parametric test follows the analysis of Cruz Berrocal *et al.* (2014). The non-parametric Fisher's exact test was used for the categorical variables (i.e. geological rock types and geographic regions) as cell count for more than 20% of the data analysed was less than 5 (Table 3 and Table 5). A Cramer's V statistic was calculated to examine the strength of the association between the two categorical variables.

All results for the North Island rock art sample were significantly different when compared to the random sample using a t-test or Mann Whitney U test (Table 2). However, at a regional scale differences in mean slope and aspect values for inland rock art are not statistically significant compared to the random sample. In contrast, all mean variables from coastal rock art samples were different compared to the random population (Table 2). Other analyses showed that where rock art is located there was no significant association between the geological rock types compared to the random sample tested by the Fisher's exact test and Cramer's V statistic (Table 3). This was the same for coastal rock art when tested against the random sample. However, there was a significant relationship between the geological rock types compared to the random sample for inland rock art.

ROCK ART TYPES

North Island Māori rock art includes both pictographs made by adding a pigment to the rock surface and petroglyphs, images made by removing rock from the surface by pecking, incising or engraving (Figure 3). Most known pictographs in the North Island are kōkōwai (red ochre) applications, although a few examples of black images made with a carbon-based pigment are recorded. The total counts of rock art types and their geographic location are presented in Table 4. In 24 cases both pictographs and petroglyphs are found together but are counted as separate occurrences for this study. Rock art types were tested against the geographical region where they are located and the geological rock type (Table 4, Table 5).

A Fisher's exact statistical test and Cramer's V test presented no significant differences between the pictograph sites and their geographic location in comparison with the randomly generated points (Table 6). A non-significant relationship was also true for petroglyph sites and their geo-

Table 2. *Welch two-sampled t-test and Wilcox Mann-Whitney U statistics for quantitative variables for North Island, coastal, and inland rock art in comparison to the random sample.*

Variable (mean)	Group	Mean	Sig. (t)	Df	Mann-Whitney U	W
Slope	NI Rock Art	13.16	5.61E-08	162.780	2.09E-01	11199
	Random Sample	0.63				
Aspect	NI Rock Art	175.31	2.01E-10	308.110	7.84E-13	6579.5
	Random Sample	170.87				
Elevation	NI Rock Art	294.95	0.083	268.800	1.68E-04	15165.0
	Random Sample	251.25				
Near Distance	NI Rock Art	238.04	6.49E-13	161.690	2.20E-16	5299.0
	Random	1339.80				
Slope	Rock Art Coastal	5.85	4.13E-06	53.121	5.92E-09	147.0
	Random Coastal	0.04				
Aspect	Rock Art Coastal	174.86	5.29E-02	53.023	2.20E-02	459.5
	Random Coastal	115.46				
Elevation	Rock Art Coastal	75.61	2.64E-05	63.838	2.84E-05	719.0
	Random Coastal	40.51				
Near Distance	Rock Art Coastal	242.59	0.006	24.456	3.07E-05	1069.0
	Random Coastal	1448.28				
Slope	Rock Art Inland	5.85	2.20E-16	104.530	0.050	1060.0
	Random Inland	0.63				
Aspect	Rock Art Inland	175.55	0.7451	221.490	0.7193	8326.0
	Random Inland	170.87				
Elevation	Rock Art Inland	75.61	1.01E-09	203.440	2.20E-16	13196.0
	Random Inland	251.25				
Near Distance	Rock Art Inland	242.59	0.063	38.123	0.028	1790.0
	Random Inland	1339.80				

Table 3. *Fisher's exact test results and Cramer's V testing the association between the geological rock type of the North Island, coastal, and inland rock art to the randomly generated sample.*

	Fisher's Exact	Cramer's V
North Island – Random Sample	0.365	0.727
Inland – Random Sample	0.002	0.894
Coastal – Random Sample	0.075	0.891

Table 4. *Regional counts of known rock art types.*

Geographic Region	Petroglyphs	Pictographs
Auckland Region	3	0
Bay of Plenty Region	9	5
Gisborne Region	0	1
Hawke's Bay Region	2	1
Northland Region	5	0
Taranaki Region	20	0
Waikato Region	41	93

Table 5. *Counts of known rock art types and the geological rock types they were found on.*

Geological Rock Type	Petroglyphs	Pictographs
Andesite	2	0
Basalt	0	1
Boulder	3	0
Debris	13	1
Gravel	9	0
Ignimbrite	30	75
Limestone	0	1
Mudstone	3	0
Olivine Basalt	1	0
Pumice	1	2
Rhyolite	4	8
Sandstone	9	2
Silt	1	0
Tephra	0	3
Volcanic Sandstone	1	0
Unknown	0	7

graphic location (Table 6). Although there were more rock art sites observed in the Waikato region, the distribution of both types of rock art and their associated geographical location do not appear to be influenced by the geographic region in which they are located. Thus, there are factors other than location to consider.

Our analysis also confirmed a weak statistical difference between the distribution of pictographs occurring on different types of geology in comparison to the randomly generated points (Table 6). The Cramer's V test indicates that the strength of association is relatively weak. While the distribution of petroglyphs on particular rock types was not statistically significant compared to that of the random sample, the Cramer's V statistic indicates that the strength of association was strong. This difference suggests that there is a weak relationship between type of rock art (pictographs or petroglyphs) and the different underlying geological formations.

Table 6. *Fisher's exact test and Cramer's V results: association between rock art type (petroglyph or pictograph) with geographic region and geological rock type compared to the random generated sample.*

	Fisher's Exact	Cramer's V
Regions w/ pictographs	0.999	0.882
Regions w/ petroglyphs	0.129	1.000
Rock types w/ pictographs	0.121	0.861
Rock types w/ petroglyphs	0.047	0.791

DISCUSSION

The results of this study suggest that North Island Māori rock art sites are in part distributed with respect to environmental variables. The location of some rock art correlates by type with certain geological formations, and some topographical factors that may influence rock art preservation also appear to correlate with the distribution of the sites. A high proportion of rock art sites in ignimbrite rock areas contrasts with the distribution of known South Island Māori rock art that occurs disproportionately in limestone landscapes. However, the weak association between rock art sites and geological rock types suggests that geological rock surfaces may not be significantly influencing rock art presence and further testing is required. As the highest density and clustering of North Island rock art sites occurs in the TVZ, an association with ignimbrite is not surprising. The southern area of the TVZ is composed of volcanic formations rich in rhyolitic and silica-based rocks. Eruptions over the last two million years have produced pyroclastic flows from at least eight calderas that have deposited ignimbrites across much of the central and eastern North Island (Beresford and Cole 2000; Leonard *et al.* 2010:vi). The high occurrence of rock art sites could, then, potentially reflect the availability of ignimbrite outcrops for marking and the characteristics of those rocks for rock art preservation. Ignimbrite is composed of hard rhyolitic rock and provides suitable surfaces for rock art that are relatively stable over time compared to softer more easily eroded rocks. However, the weak association observed does not support the idea that local character of the geology influences the presence of petroglyphs and pictographs and further analysis is needed to investigate the weak relationship observed.

Overall, the distribution of North Island rock art sites appears to occur at lower elevations on moderately low slope terrain at gradual incline levels. This may relate to ease of access to these areas compared to steeper mountainous terrain. However, relative survey coverage could have also influenced this pattern and should be taken into consideration. Accessibility may also be a factor in the significant association measured by near distance to main water courses, as with South Island rock art sites where river valleys are understood to have been pathways across tribal landscapes (O'Regan 2016). Although this study did not have data detailed enough to evaluate aspect of rock art bearing panels within sites at least at the broader location scale in relation to the 1km buffers, site aspect levels do not appear to have a significant influence on the placement of rock art. Therefore, the data suggests that it is unlikely that weathering processes based on aspect of the site slope are influencing the present-day preservation of North Island rock art. The distributions of sites with respect to the given environmental variables examined, did not differ between coastal and inland areas. This result suggests that the regional differences of coastal and inland locations do not influence the distribution of rock art with respect to the tested environmental variables and there are other selection factors that require further investigation.

Rock art is evident in the archaeological record as a cumulative palimpsest, with a restricted level of resolution and interpretation that becomes apparent when information is extracted from it (Bailey 2007: 205, 209). Consideration of the temporal scale is important when considering behavioural questions such as whether site distribution reflects rock surfaces having been selected for particular cultural reasons as opposed to other formational events that shape the archaeological record (Aubry & Dimuccio 2012). A localised absence of rock art today may result from the loss of previously existing figures, and it may be uncertain of how much of the rock surfaces provided a useful canvas when the rock art was made. These factors can obscure possible indications of cultural selection. For example, some figures recorded in the 1980s in a central North Island site are no longer readily visible, confounding intra-site analyses of rock art placement (O'Regan 2016). This also highlights the issue that rates of deterioration of rock art bearing surfaces in New Zealand are not yet understood and so able to be factored into modelling of Māori rock art distributions.

Preservation of rock art and the presence of different rock art types on certain geological rock surfaces are likely subjected to a range of selection factors not just based on location, as indicated by the statistical analysis of other environmental variables such as slope angles, rock type, and possible cultural preference. One challenge is investigating whether rock art was present on rock surfaces from various geographic areas around the North Island but are no longer visible due to a range of equifinal processes such as weathering over time. The challenge is to discern whether rock art would have survived to present-day on these potentially suitable rock surfaces and how to elucidate its absence.

The results of this preliminary investigation are indicative rather conclusive. The spatial scale at which the analysis was conducted reflects the character of the existing spatial data for the North Island rock art sites and resolution of the models for the surrounding topographic landscape. The relationship between rock art site distribution and ignimbrite could be the result of historical surveyor bias that drew on experience to target areas close to waterways in the central North Island, and the absence of comparable surveys in other regions (O'Regan 2016). The results may not only reflect the overall geology that characterises the area, but also how that provides particular rock surfaces appropriate for rock art. The TVZ is largely composed of pyroclastic volcanic rock with the erosion of surrounding landscape leaving ignimbrite bluffs and rock shelters that have been the focus of Māori marking. In contrast Taranaki is largely characterized as debris and gravel areas in which more 'open air' rock art is found on the outfall of lahars and andesite boulders on the coast.

A DEM at a higher resolution than 25m would enhance terrain analysis of the influence of slope, elevation and aspect at a region-specific scale. However, the utility of that would be limited by the inconsistent accuracy of the location data and contemporary geographic regional boundaries currently available from the SRS. There are also other recognised limitations in the quality of rock art data in the NZAA site record forms and from historical surveys (Trotter & McCulloch 1981: 39–40; Anderson 1990; Pick 2010; Law 2008: 57; O'Regan 2016: 15–18). For example, over the past 30 years areas around the Taupō and southern Waikato have been intensively surveyed by local archeologist Perry Fletcher whereas archaeological attention to some other areas of North Island has not yet had the same specific regard for the identification of rock art (O'Regan 2016).

Analysis of associations with other archaeological features in the surrounding landscape may provide important information about related land use (Robinson 2006, 2010), so providing additional insights on rock art placement, especially if multi-scalar approaches are employed such as O'Regan's (2016) multi-scalar analysis of rock art around Taupō and South Canterbury. The land use may also be influenced by particular geological characteristics which may explain the presence of people in the past and correlations of sites with the different rock formations.

It is also important to note that the distribution of rock art on particular geological rock surfaces such as ignimbrite maybe coincidental to other cultural factors influencing the placement of the figures. For example, an alternative explanation for North Island rock art site distribution may be an association to areas where Western Māori dialects are spoken (Anderson 1990: 6–7). Associations between geological rock surfaces and rock art may not be the only factor influencing the site distribution.

One way of testing the results from this study, and the limitations of the historical data, is to survey the various sub-types of ignimbrite from the available geological data and look at areas of ignimbrite rock surfaces where rock art has not yet been recorded. The results of this study could be tested at a smaller regional scale targeting the high density and clustered areas of rock art. This can increase the resolution of analysis on the distribution of rock art across the North Island and the potential factors shaping its present-day occurrence. Future investigations further testing the extent to which the present-day North Island rock art distribution is shaped by geological processes could employ predictive modelling. A predictive model may shed light on the taphonomic and preservation issues regarding potential rock surfaces where rock art may potentially occur and areas where it is no longer identifiable (Fernandes 2010; Aubry & Dimuccio 2012; Cruz Berrocal *et al.* 2014). The results from our study form a foundation to re-assess the existing records and propose survey of areas where rock art may be present but has not been identified.

CONCLUSIONS

This study adopted a quantitative locational analysis approach using spatial techniques to investigate preliminary correlations made between the distribution of North Island rock art and selection of geological rock surfaces. The results indicate that there is a disproportionate presence of rock art placed on ignimbrites, possibly reflecting a preservation bias on those rock surfaces. However, further research will be required to determine the reasons behind these results. The findings can be further explored by developing a predictive model to assess if rock art is occurring on ignimbrite rock surfaces where rock art has previously not been recorded. The rock art sites appear to be non-randomly associated with slope, elevation and distance to water at an island-wide scale. Further investigation of factors such as formational and weathering processes should also be taken into consideration to explain whether this apparent preservation bias is a result of cultural activity, survey bias, or a combination of factors. Intra-site data for rock panels slope, aspect and climatic exposure would strengthen factoring surface weathering into models. Although the research findings here are only indicative, this study contributes initial quantitative consideration considerations which will help inform more detailed data gathering and investigation of the geological canvases of North Island rock art and the likely location of these sites, potentially through predictive modelling. Our study highlights the importance of assessing rock art distribution at both an island-wide and regional scales, as well as clarifying issues in the character of existing data that impact such assessments. It will help inform efforts to further survey and record the rock art before it disappears from those places, thus, contributing to further management and documentation of North Island rock art. Rather than being limited to anecdotal observations as in the past, this first investigation of North Island rock art sites using GIS provides a starting point for future modelling of site distribution and surveys informed by a systematic evaluation of the relationship between rock art sites and the underlying geological canvas.

Acknowledgements

The rock art site data used for this study was provided by a Royal Society of New Zealand Marsden Fast Start project 'Initiating a Māori archaeology of threatened North Island rock art' (RSNZ project number 3713836) undertaken by Gerard O'Regan, University of Auckland. That site data had been compiled from a search of the New Zealand Archaeological Association Site Recording Scheme by Dr Simon Bickler and reviewed by O'Regan with research assistance by Darcy Cullen and India Logan-Riley. A special thanks to Dr Bruce Floyd for providing statistical advice and insightful suggestions. Ngā mihi ki a rātou.

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