Obsidian sources of the Taupo Volcanic Zone, central North Island, New Zealand

Phillip R. Moore

The Taupo Volcanic Zone (TVZ) includes six geographically discrete sources of artifact-quality obsidian (Taupo, Maraetai, Ongaroto, Rotorua, Rotokawau and Maketu). New information on the nature and extent of these sources (excluding Taupo), and on the visual attributes and geochemistry of the obsidian, is presented. Similarities in visual characteristics, and limited variation in chemical composition of the TVZ obsidians, indicate that it may prove difficult to identify the original source of artifact material derived from this region. At present, only the Taupo and Maketu sources are known to have been exploited in prehistoric times, while use of the Rotorua obsidian remains equivocal.

La Zona Volcánica Taupo (TVZ) contiene seis discretas fuentes de obsidiana de alta calidad para el elaboramiento de artefactos (Taupo, Maraetai, Ongaroto, Rotorua, Rotokawau y Maketu). Se presenta nueva información sobre el origen y el alcance de estas fuentes (excluyendo Taupo), y sobre los atributos visuales y la geoquímica de la obsidiana. Factores como las similitudes en apariencia, y la imperceptible variación de la composición química de las obsidianas de esta zona, indican que puede ser difícil identificar el origen real del material. En este momento, solamente se sabe que las fuentes de Taupo y Maketu han sido explotadas en tiempos prehistóricos, mientras que el uso de la obsidiana Rotorua sigue siendo dudoso.

Introduction

Obsidian was used extensively by pre-European Maori for cutting and scraping purposes, and artifacts of this lithic material are commonly found in New Zealand archaeological sites. By determining the original source of the obsidian through chemical analysis or other means, archaeologists are able to gain some indication of cultural connections, transportation routes and exchange networks, and changes in those over time, although this depends upon a good knowledge of the actual sources and their physical and chemical characteristics.

The Taupo Volcanic Zone (TVZ) is one of three main regions in the North Island of New Zealand from which obsidian was procured in prehistoric times (Sheppard 2004). Significant quantities were also obtained from the Coromandel Volcanic Zone (Moore *in press* a) and Northland (Moore *in press* b), as well as from Mayor Island in the Bay of Plenty (Figure 1). The occurrence of flake quality obsidian in the TVZ was first reported by Green (1962), and Ward (1973) subsequently identified seven geographically discrete sources in the Rotorua, Maraetai, and Taupo areas. Eleven are listed in Sheppard (2004) and Sheppard et al. (2011), though many of these consist of very poor-quality obsidian and are highly unlikely to have yielded material suitable for the production of useable tools.

Little detailed work has been undertaken on the obsidian sources in this region since the 1970s, with the exception of the Taupo source, which was recently re-examined by Moore (2011b). This paper presents new data on the remaining obsidian sources in the Taupo Volcanic Zone, particularly their visual characteristics and chemical composition. It also considers the evidence for exploitation of these sources.

Geological Setting

The Taupo Volcanic Zone (TVZ) is a north-northeast trending belt of Quaternary volcanism extending for >300km across the central North Island (Ewart et al. 1968; Leonard et al. 2010; Figure 1). It includes a number of active volcanic vents, and has a history of major eruptions over the past 1.6 Ma. Many of these eruptions have occurred from a series of eight large calderas (collapse structures) within the zone.

Obsidian is associated with rhyolite domes and lava flows situated around the margins of and within some of the calderas. The main areas of outcropping rhyolite are between Lake Taupo and Tokoroa (Figure 2), and in the Rotorua-Tarawera District (Figure 3). All of the rhyolite lavas within the TVZ were previously included in the Haparangi Rhyolite Formation (Grindley 1960) or Group (Nairn 2002), but are now classified mainly according to the volcanic centre (or caldera) they are

Phillip R. Moore | Peninsula Research, P.O. Box 120, Waihi 3641, New Zealand. peninres@xtra.co.nz

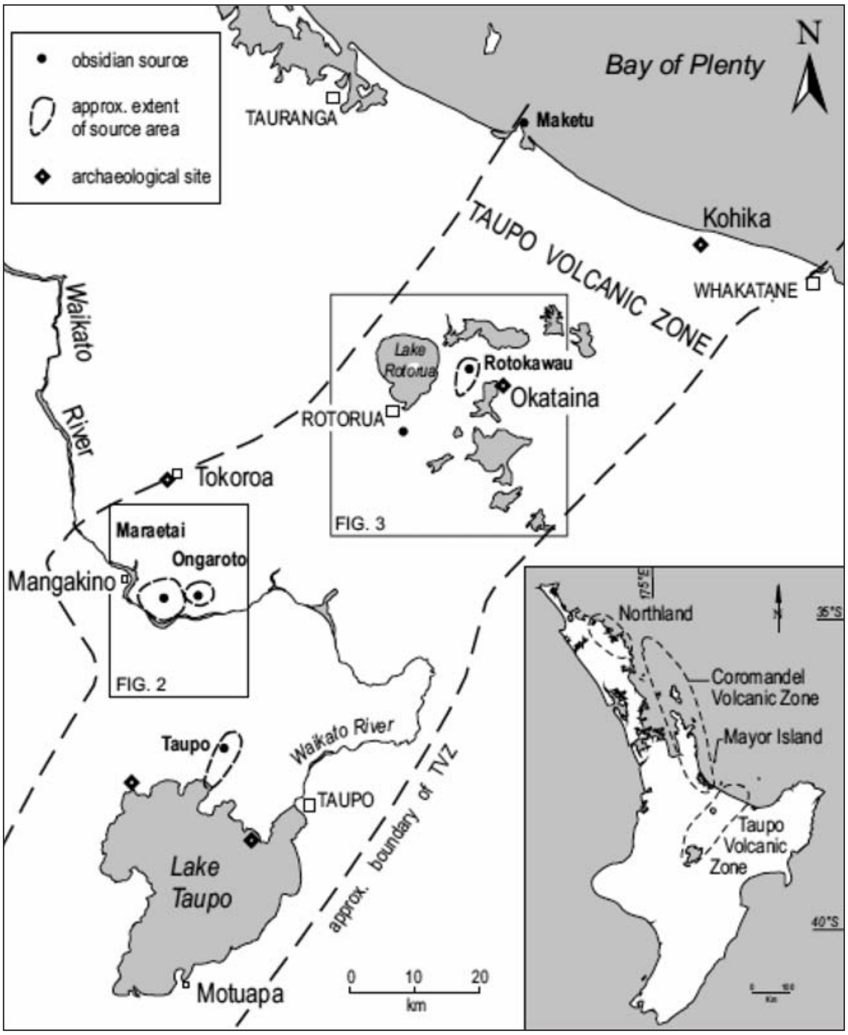

Figure 1. Map of the central North Island, showing the location of obsidian sources, archaeological sites and areas covered by other maps. Inset: Obsidian source regions of New Zealand.

connected with (Leonard et al. 2010). Most are included in the Maroa (Maroa Volcanic Centre), Ongaroto (unassigned centre) and Okataina (Okataina Volcanic Centre) groups. No significant obsidian occurrences have been recorded in the voluminous ignimbrites which cover much of the TVZ and surrounding areas of the Bay of Plenty and Waikato districts.

Obsidian Sources

Taupo Area

The nature and extent of the Taupo source, and visual and chemical characteristics of the obsidian from this area, has recently been documented by Moore (2011b). Information is not repeated here except where it is relevant to discussion on the sources in the TVZ. The Taupo obsidian is the highest quality material in the region.

Jones (2002) also recorded an obsidian source at Motuapa, on the southeast side of Lake Taupo (Figure 1), even though he described samples from this locality as having a "very poor, sub-conchoidal to perlitic fracture" (Jones 2002:144). From my own observations, none of the obsidian is of flake quality.

Whakamaru Area

Geological Context

The obsidian in the Whakamaru area is associated with a complex series of rhyolite domes, referred to as the Western Dome Belt (Wilson et al. 1986; Figure 2). The north-western part of this belt, north of Lake Whakamaru (Waikato River) consists of at least 17 separate lava domes, several of which have remnant obsidian carapaces. South of Lake Whakamaru, rhyolite domes form a 17km long north-south trending complex

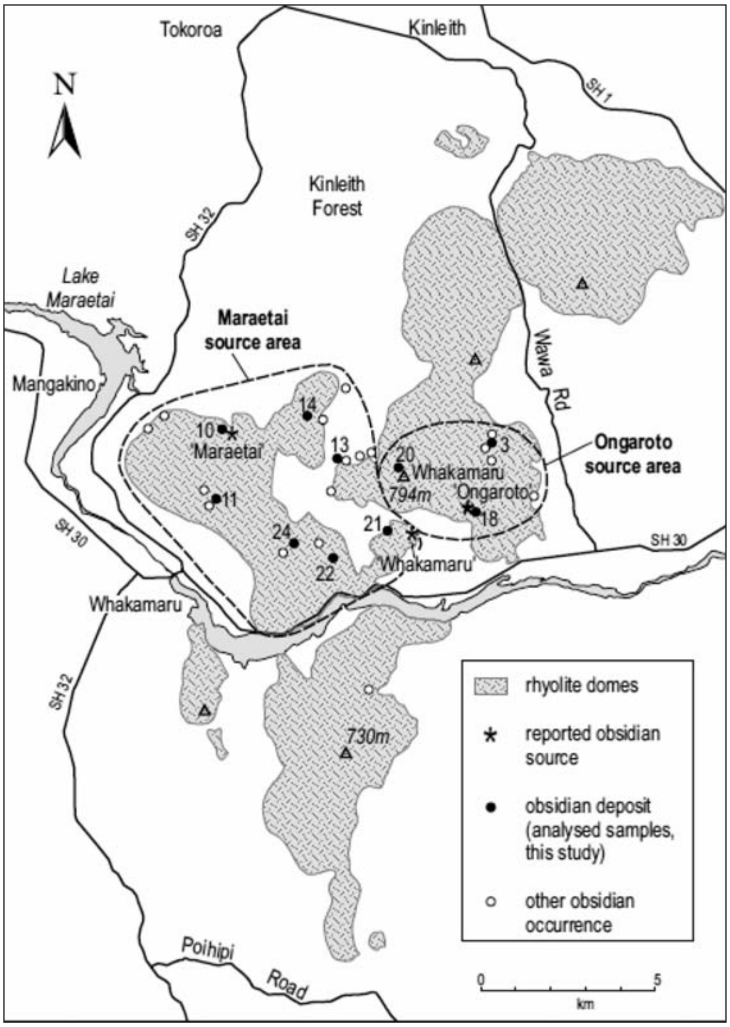

Figure 2. Simplified geological map of the Whakamaru area showing the location of obsidian deposits and approximate extent of the Maraetai and Ongaroto sources. All sample numbers prefixed 'WH'. Geology from Leonard et al. (2010).

(Wilson et al. 1986). Obsidian has not previously been described from this complex, although one sample has been dated (Houghton et al. 1991). All of the rhyolite lavas in the Western Dome Belt are included in the Ongaroto Group (Leonard et al. 2010).

To the west of this complex is a series of four or five small domes forming the Whakaahu Dome Belt (Houghton et al. 1991; Wilson et al. 1986), and mapped as the Whakaahu Formation (Leonard et al. 2010). There are no known obsidian occurrences associated with these domes.

Obsidian Occurrences

The existence of obsidian in this area was originally reported by Green (1962). Three potential sources (Maraetai, Whakamaru, and Ongaroto) were subsequently identified by Ward (1972, 1973) in the southern part of the Whakamaru Forest (Figure 2), though he later regarded the first two as part of the same source group (Maraetai) on the basis of similarities in composition (Ward 1974). During a reconnaissance survey of the forestry area by B. McFadgen and the author in 1978, many other obsidian outcrops were discovered in road cuttings which were collectively treated as a single source (Whakamaru, see Moore n.d.).

While the names originally introduced by Ward (1973) have continued to be widely used by archaeologists (e.g., Jones 2002; Neve et al. 1994; Sheppard 2004; Sheppard et al. 2011), some workers have referred only to Maraetai and Ongaroto (Seelenfreund & Bollong 1989, following Ward 1974), resulting in uncertainty over the exact number of sources in the area. Neve et al. (1994) also made reference to samples from 'Mangakino', but provided

Figure 3. Simplified geological map of the Rotorua-Tarawera area showing the location of obsidian sources and other occurrences. Locality numbers for the Rotokawau source are prefixed 'RK'. Geology from Nairn (2002) and Leonard et al. (2010).

no details. New chemical analyses obtained as part of the present study indicate that there are two main sources in the area – Maraetai and Ongaroto, here referred to collectively as 'Whakamaru'.

Green (1962) also reported the occurrence of alluvial boulders of obsidian just below the confluence of the Waikato and Waipapa rivers, about 12km northwest of Mangakino. It is likely these were derived from the Whakamaru area.

Visual Characteristics

The Whakamaru obsidian is predominantly black to very dark grey, but some is dark grey and red-brown. It has an imperfect, sub-conchoidal fracture, but does produce useable flakes. Translucency ranges from good to poor, and flow banding from weak to strong, with some samples showing distinct color banding (black/dark grey). Phenocrysts of quartz and feldspar are common and up to 3mm in size, and many samples contain black pyroxene, hornblende or biotite crystals. Spherulites are absent to very common, light grey, and up to 5mm in diameter, while glassy globules (up to 1mm) are rare to common. There are no obvious differences in visual characteristics of obsidian from the Maraetai and Ongaroto sources.

Rotorua Area

Three separate sources were recorded by Ward (1973) on the outskirts of Rotorua City – Ngongotaha, Whakarewarewa and Hemo Gorge (Figure 3), which he subsequently combined into a single source group ('Rotorua', Ward 1974). A further three potential sources east of Lake Rotorua (Rotoiti, Lake Rotokawau and Lake Okataina) were identified by Moore (n.d.). Sheppard (2004:Figure 7.1) and Sheppard et al. (2011) also list 'Tarawera' as a source, as do Neve et al. (1994) and Jones (2002), though no details are provided by these authors.

A large part of the Rotorua District has now been mapped by geologists in considerable detail, particularly the Okataina Volcanic Centre to the east of Lake Rotorua (Nairn 2002). Although obsidian is widespread in the area, sample descriptions make it clear that most is highly fractured or perlitic in texture (Bowyer 2002) and not of flake quality. Observations by the author confirm this view.

Ngongotaha

Ward's (1973) 'source' consisted of outcrops in the vicinity of a modern quarry on the eastern side of the mountain (Figure 3), which he described as being composed of black obsidian with a vitreous lustre, but not of flake quality. Recent examination of outcrops and road cuttings on and around Ngongotaha has indicated that all of the obsidian is highly fractured and perlitic, and is very unlikely to yield useable flakes.

Whakarewarewa

Ward (1973) obtained fragmentary samples of semi-flake quality black and red obsidian from an active quarry near Whakarewarewa, but also noted that obsidian had apparently outcropped in the vicinity (1973:99). Sampling of the same locality by B. McFadgen and the author in 1978 yielded only a few small pieces. Observations made in 2011 suggest the obsidian occurs mainly in the form of thin lenses within the parent rhyolite. No new chemical (XRF) analyses of the obsidian have been obtained because of the very limited material available.

The quarry (since abandoned) is situated on the steep northern margin of an elongate dome or flow of Rotorua Rhyolite (Nairn 2002) which extends westward to the Hemo Gorge, regarded as a separate potential source by Ward (1973; Figure 3). The road cutting in the gorge exposes a coarse glassy breccia containing large blocks of black, perlitic obsidian of non-flake quality (pers. obs. 1978). Considering the geological context, and the fact that obsidian from the two locations appears to have a fairly similar chemical composition (Ward 1972), they can probably be treated as a single source area. The name 'Rotorua' is retained for the source, in preference to 'Whakarewarewa' or 'Hemo Gorge'.

Rotoiti

Outcrops and road cuttings along the south side of Lake Rotoiti and in the forestry area to the southeast expose poor quality obsidian, and a number of localities were recorded in 1978 and 1983. Others have been documented by Bowyer (2002). Much of the obsidian occurs as blocks or fragments within glassy rhyolite flows, or as clasts in breccia deposits. All of the obsidian is black or dark grey, contains common to abundant phenocrysts, is generally spherulitic, and has a perlitic texture and very poor fracture. None is of flake quality.

Okataina

An obsidian source (Site V16/24) was recorded at the northern end of Lake Okataina in 1980 (Figure 3). It was described as consisting of scattered boulders of glassy rhyolite extending for several hundred meters along the hillside above the lake shore, which apparently included fragments of black, flake quality obsidian. Some of the rocks also contained flecks of red obsidian.

This locality was revisited in 2011. Abundant cobble to boulder sized blocks of obsidian were found along the lower slopes of the hillside, but all consisted of poor quality, perlitic and spherulitic material. No flake quality obsidian was seen.

Rotokawau

The presence of obsidian clasts (up to 10cm) in coarse breccias exposed around the northern side of Lake Rotokawau was noted by the author in 1983 (Figure 3). More recently, a literature search revealed a reference to 'outcrops of obsidian' on nearby Whakapoungakau (Grange 1937:65), along with a brief petrographic description and chemical analysis of one sample. Examination of a piece of the original sample (P6113) collected by Grange, now held in the Petrology Collection at GNS Science, indicated that it is of flake quality, and the sample has been re-analyzed (Table 3).

Grange (1937) did not record exactly where his obsidian sample was collected. However, one of the streams draining the north-western side of Whakapoungakau is named the Waimata, implying that it might contain obsidian (*matā*). In a brief survey of this area in 2008 only a few cobbles and boulders of obsidian were found in Waimata Stream, but abundant cobbles and some boulders (up to 60cm in diameter) of flake quality material were discovered in the adjacent streams to the west (Ohaunui Stream) and east (Te Toroa Stream). Color varies from dark grey to black but is typically very dark grey, and most pieces have an imperfect conchoidal fracture. Translucency is generally moderate to poor (rarely very poor), and flow banding ranges from weak to strong with common color banding. The obsidian typically contains sparse to common phenocrysts, mainly of quartz and feldspar, light grey spherulites up to 3mm in diameter, and rare glassy globules (up to 0.5mm). Some samples also include tiny black needle-like crystals.

In 2011, additional obsidian occurrences were discovered along the western and southern margins of the Whakapoungakau 'dome'. Abundant pebble to cobble sized pieces (up to 30cm in diameter) were found in a gully near the end of Hawthornden Drive (locality RK4), and also further south in Te Rereoterangi Stream (locality RK5; Figure 3). Banded and red-brown material is relatively common at the former location. Only a few small pebbles of obsidian have been seen in streams draining the north-eastern side of Whakapoungakau, and no pieces were located on or near the track to the top of the mountain. Thus the source area appears to be restricted to the western part of the rhyolite 'dome'.

FEATURE	Taupo	Whakamaru	Rotorua	Rotokawau	Maketu
Color (reflected)	Black, minor grey and red-brown	Black to dark grey, rare red-brown	Black, red-brown	Dark grey to black, some red-brown	Black to dark grey
Color (transmitted)	Grey	Grey	Grey	Grey	Grey, some brown
Translucency	Moderate to good, some poor	Good to poor (mostly moderate)	Moderate to good	Moderate to poor	Good to very poor
Flow banding	Generally weak	Weak to strong	Weak	Weak to strong	Generally weak (wispy)
Color banding	Common	Common	Minor?	Common	Minor
Fracture	Conchoidal	Sub-conchoidal	Sub-conchoidal	Mostly sub-conchoidal	Conchoidal
Spherulites	Absent to common	Absent to very common	Sparse?	Common	Rare to abundant
Phenocrysts	Rare to sparse	Common	Common	Sparse to common	Sparse
Globules	Absent to very rare	Rare to common	Sparse to common	Rare	Very rare
Cortex	None or water-worn	None	?	Water-worn	Water-worn (smooth)

Table 1. Summary of visual characteristics of obsidian from TVZ sources

Maketu

The Maketu source was identified in 1987 (Moore n.d.; Figure 1). It consists entirely of obsidian pebbles, which are sparsely distributed along the shoreline around the Maketu Peninsula (Okurei Point). The pebbles are derived from coarse to fine gravels forming the adjacent cliffs, which are of Pleistocene age and interpreted as old lahar (volcanic mud flow) deposits (Briggs et al. 2006). Although the source of the lahar is unknown, it most likely originated from the TVZ. A few small pebbles have also been found along the coast to the south, at Otamarakau (Moore 2004).

The pebbles are up to 6cm in diameter, generally rounded to well rounded, and typically have a smooth, waterworn cortex. The obsidian has good conchoidal fracture, vitreous lustre, and is predominantly black to very dark grey (rarely dark grey). Translucency ranges from good to very poor, and some pieces are brown in transmitted light. Flow banding is mostly weak and 'wispy'. Spherulites are very rare to abundant (up to 4mm diameter), and phenocrysts are generally sparse. Globules are very rare.

Discriminating Between Sources

Visual Characteristics

The general features of obsidian from the various source areas in the TVZ (including Taupo) are summarized in Table 1. It is evident from this that many of the characteristics are quite similar, and hence there could be considerable difficulty in distinguishing between material from the Whakamaru, Rotorua and Rotokawau areas in particular. However, a distinction between Whakamaru and Rotokawau material may be possible on the basis of translucency, which is generally moderate to good in Whakamaru obsidian. Taupo obsidian is of higher quality and contains fewer phenocrysts than that from other sources in the TVZ. It is also mainly black, and usually lacks cortex. The Maketu obsidian, which is more likely to be found in sites along or near the Bay of Plenty coast, is distinguished by its generally wispy flow banding and the presence of smooth waterworn cortex.

Chemical Analysis

Very few complete chemical analyses of TVZ obsidians have previously been published, apart from those reported by Stevenson (1990) and Moore (2011b) for the Taupo source. The composition of the Taupo obsidian is remarkably consistent, and only an average value is used here. A further 21 XRF analyses were obtained for other sources as part of the present study, and these are presented in Tables 2 and 3. All samples were analyzed using the Siemens SRS 3000 sequential X-ray spectrometer at the School of Environment, University of Auckland. Samples were crushed using a Tungsten Carbide ring grinder. H_2O content was estimated by heating weighed sample aliquots to 100^oC,

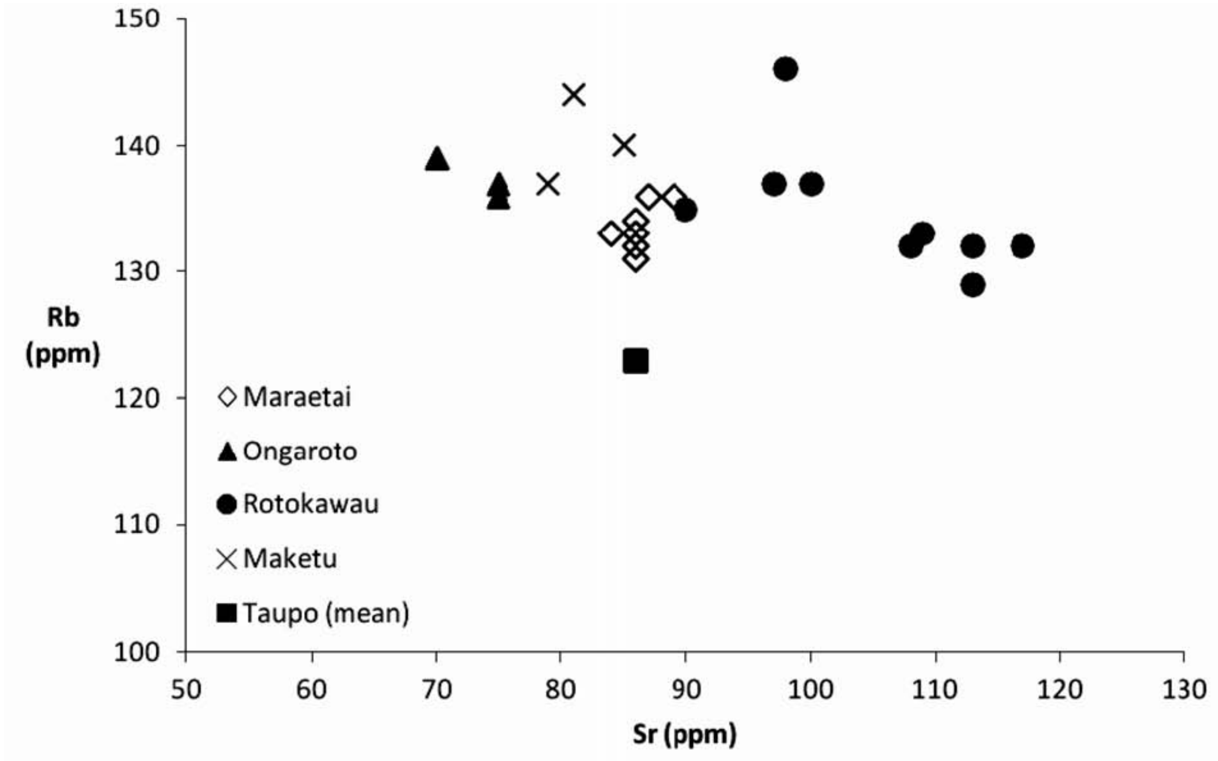

Figure 4. Rb-Sr scatter plot for TVZ obsidian sources. Additional data for the Maketu source from Moore (2004); mean value for the Taupo source from Moore (2011b).

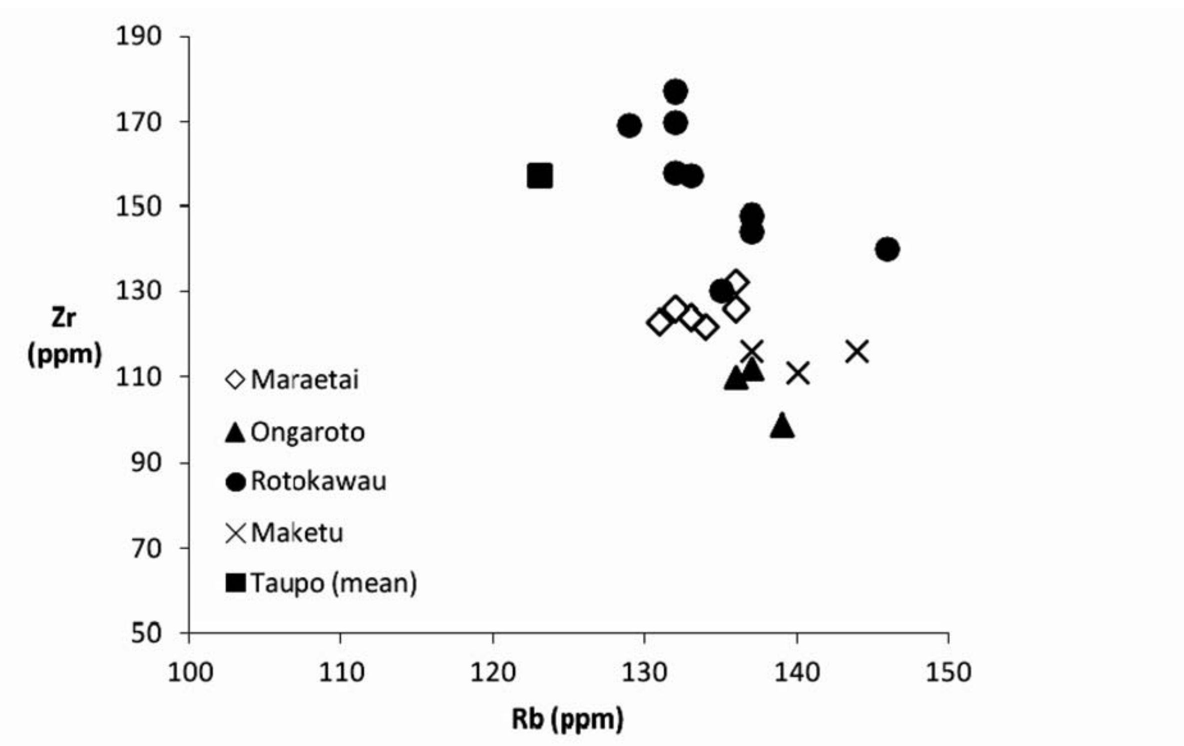

Figure 5. Zr-Rb scatter plot for TVZ obsidian sources

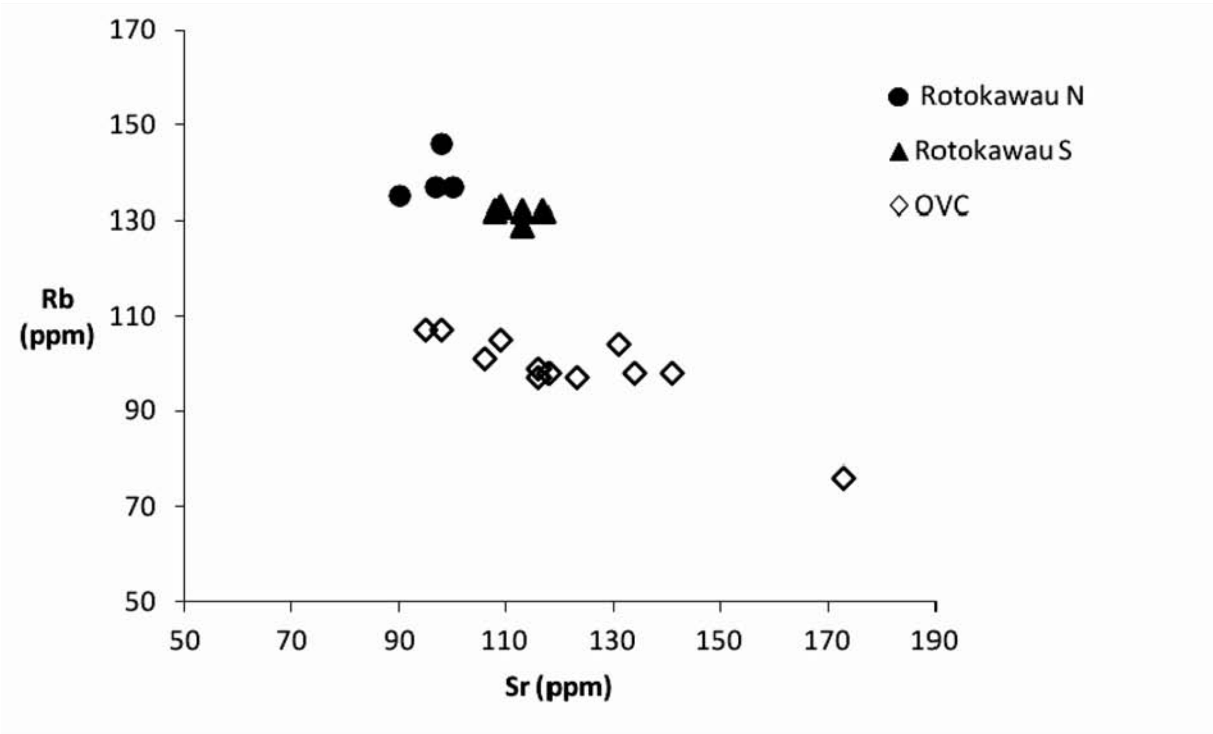

Figure 6. Rb-Sr scatter plot for obsidians from the Rotorua-Okataina area (OVC = Okataina Volcanic Centre). Data for OVC obsidians from Bowyer (2002), except sample RO-6 (see Table 3).

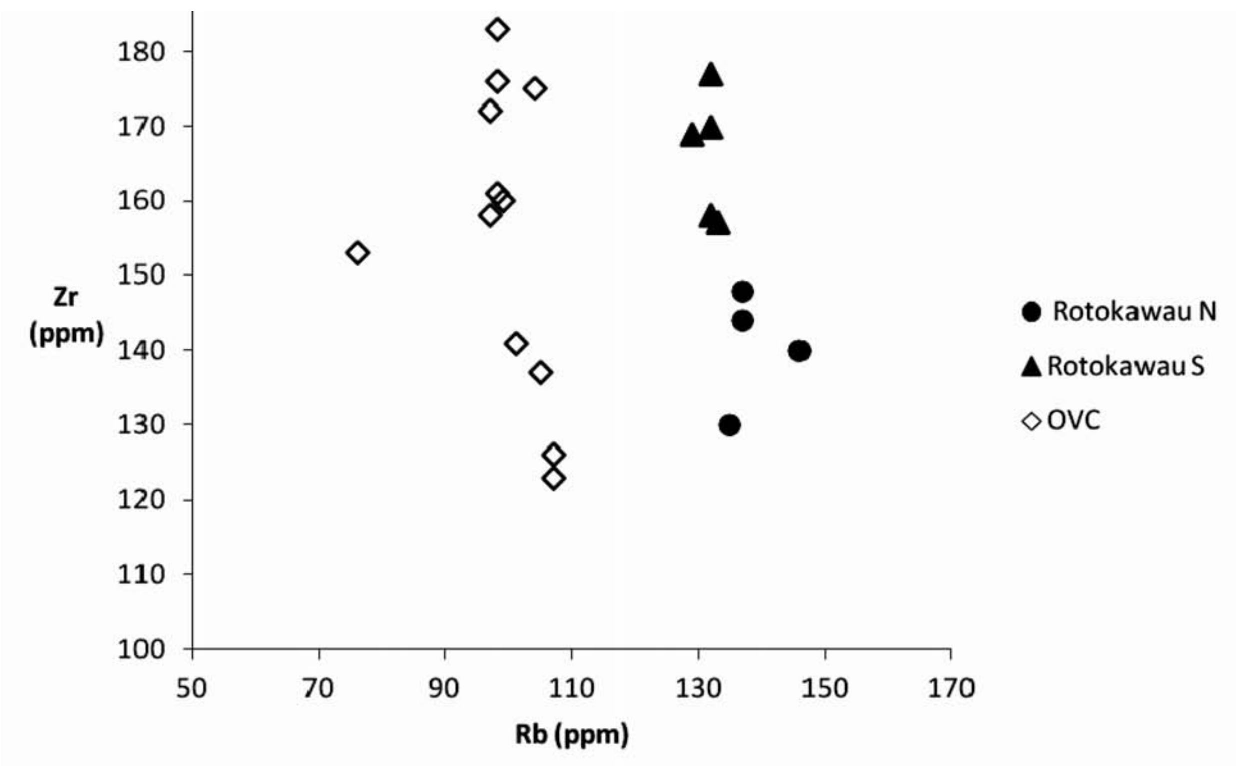

Figure 7. Zr-Rb scatter plot for obsidians from the Rotorua-Okataina area.

	Maraetai							Ongaroto		
Sample	WH10/1	WH11/1	WH13/1	WH14/2	WH21/1	WH22/1	WH24/1	WH3/1	WH18/1	WH20/1
AU no.	-	-	62497	62498	62501	62502	62503	-	62499	62500
wt %										
SiO2	76.86	76.96	77.13	77.11	77.01	76.95	77.10	76.96	77.16	77.33
TiO2	0.15	0.15	0.15	0.14	0.15	0.16	0.15	0.11	0.12	0.12
Al2O3	12.26	12.31	12.35	12.38	12.39	12.34	12.38	12.26	12.37	12.32
Fe2O3*	1.21	1.20	1.23	1.24	1.25	1.28	1.24	1.09	1.18	1.16
MnO	0.04	0.04	0.04	0.04	0.05	0.05	0.04	0.04	0.04	0.04
MgO	0.11	0.10	0.23	0.24	0.24	0.24	1.01	0.06	0.20	0.20
CaO	0.99	0.98	1.00	1.00	1.01	1.04	1.01	0.79	0.86	0.86
Na2O	3.81	3.80	3.90	3.90	3.91	3.90	3.89	3.86	3.98	3.97
K2O	3.76	3.75	3.82	3.81	3.85	3.88	3.81	3.91	3.94	3.86
P2O5	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
LOI	0.39	0.29	0.27	0.18	0.30	0.22	0.30	0.45	0.83	0.42
Total	99.62	99.60	99.87	99.88	99.87	99.86	99.88	99.55	99.87	99.88
ppm										
Ba	636	662	780	783	795	827	785	682	812	795
V	6	5	5	6	9	8	7	3	4	6
Cr	-	1	3	1	1	2	2	-	2	1
Cu	-	-	2	4	3	1	-	-	3	2
Zn	29	28	27	29	29	31	29	28	30	30
Rb	134	131	133	133	136	136	132	139	137	136
Sr	86	86	86	84	87	89	86	70	75	75
Y	21	20	21	20	21	22	21	21	22	22
Zr	122	123	124	124	126	132	126	99	112	110
Nb	8	8	7	7	8	8	8	8	8	7
Pb	15	14	17	16	16	17	16	15	19	17
Rb/Sr	1.56	1.52	1.55	1.58	1.56	1.53	1.53	1.99	1.83	1.81
Zr/Rb	0.91	0.94	0.93	0.93	0.93	0.97	0.95	0.71	0.82	0.81

Table 2. Chemical (XRF) analyses of obsidians from the Maraetai and Ongaroto sources, Whakamaru area. Analyses by J. Wilmshurst, University of Auckland. * Total Fe expressed as Fe_2O_3

and loss on ignition (LOI) obtained by further heating to 1000^{o}C. For analysis, sample beads (diameter = 40mm) were prepared in a ratio of two grams of ignited sample mixed with six grams of SPECTRACHEM 12:22 flux. Thirty-five international standards were used for major and trace element calibration employing the method of variable alphas (Bruker SPECTRAplus software). Most analyzed samples have been lodged in the Petrology Collection, School of Environment, University of Auckland.

It is evident from Tables 2 and 3 that the variation in composition of obsidians in the region is relatively small, particularly for the key elements of Rb, Sr and Zr. Nevertheless there are important differences in Rb/Sr and Zr/Rb ratios, and in the concentrations of several major elements (e.g., CaO). Scatter plots of Rb-Sr and Zr-Rb (Figures 4 & 5) confirm the limited variation in composition of the TVZ obsidians, most notably in Rb content which generally ranges from 130-140ppm. Although sources can probably be distinguished on the basis of Sr and Zr concentrations, there is a slight overlap in the compositional fields for Rotokawau and Maraetai. The Maketu obsidian is also similar to that from Maraetai and Ongaroto, and it is likely that additional analyses would result in some overlap of fields. However, the Maraetai and Ongaroto sources are well separated in terms of Sr content in particular. The Taupo obsidian can be distinguished from all other TVZ sources on its lower Rb value.

The greater variation in Zr and Sr content of the Rotokawau obsidian reflects the fact that northern and western parts of the source area have a slightly different composition, as illustrated in Figures 6 and 7. The northern samples (RK 1-3) have lower Sr and Zr values, and a slightly higher Rb concentration, than those from the western deposits (RK4-5, and probably

	Rotokawau									Rotoiti	Maketu
Sample	P6113	RK1/1	RK1/7	RK2/1	RK3/2	RK4/1	RK4A/1	RK5/1	RK5/2	RO6	MK1/1
AU no.	-	62489	62490	62491	62492	62493	62494	62495	62496	-	-
wt %											
SiO2	75.58	75.93	76.38	76.22	76.31	75.65	75.47	75.90	75.69	75.03	75.49
TiO2	0.19	0.18	0.16	0.15	0.17	0.2	0.2	0.19	0.19	0.24	0.09
Al2O3	12.71	12.70	12.64	12.46	12.65	12.94	12.95	12.81	12.94	12.67	12.63
Fe2O3*	1.56	1.48	1.39	1.33	1.44	1.62	1.67	1.55	1.62	1.71	1.42
MnO	0.04	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.05	0.07	0.04
MgO	0.15	0.21	0.18	0.18	0.26	0.29	0.30	0.28	0.29	0.28	0.04
CaO	1.29	1.20	1.10	1.10	1.16	1.34	1.37	1.28	1.32	1.40	0.95
Na2O	3.92	3.91	3.91	3.84	3.99	4.08	4.10	4.03	4.08	4.17	3.83
K2O	3.72	3.75	3.89	3.79	3.80	3.67	3.72	3.75	3.65	2.98	4.04
P2O5	0.03	0.03	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.05	0.02
LOI	0.16	0.29	0.51	0.40	0.21	0.23	0.26	0.27	0.21	0.96	0.60
Total	99.60	99.57	99.86	99.26	99.85	99.87	99.86	99.86	99.86	99.55	99.14
ppm											
Ba	625	763	794	765	790	766	802	783	751	671	625
V	7	9	6	4	5	9	9	10	11	10	4
Cr	8	17	1	5	3	4	1	4	3	0	0
Cu	4	1	5	3	4	3	1	3	4	0	0
Zn	31	30	29	23	30	33	33	32	32	41	36
Rb	133	137	146	135	137	129	132	132	132	97	140
Sr	109	100	98	90	97	113	117	108	113	123	85
Y	20	21	21	19	20	22	22	22	22	23	29
Zr	157	148	140	130	144	169	177	158	170	172	111
Nb	8	8	8	8	8	8	8	8	8	9	10
Pb	12	16	15	14	16	16	16	15	17	13	17
Rb/Sr	1.22	1.37	1.49	1.5	1.41	1.14	1.13	1.22	1.17	0.79	1.65
Zr/Rb	1.18	1.08	0.96	0.96	1.05	1.31	1.34	1.2	1.29	1.77	0.79

Table 3. Chemical (XRF) analyses of obsidians from the Rotokawau and Maketu sources, and Rotoiti area. Analyses by J. Wilmshurst, University of Auckland. * Total Fe expressed as Fe_2O_3

P6113), resulting in different Rb/Sr and Zr/Rb ratios (Table 3). There are also minor differences in Al_2O_3, Fe_2O_3, CaO and Na_2O concentrations, which suggests that Whakapoungakau is probably a composite dome formed during two or more closely-spaced eruptive phases. While this could be considered grounds for the recognition of separate sources, there is no obvious difference in visual characteristics of the obsidian apart from the occurrence of red-brown material only in western deposits.

Figures 6 and 7 also show data for obsidian samples from the Okataina Volcanic Centre (OVC) obtained by Bowyer (2002). These samples were collected from a variety of locations, including outcrops at Lake Rotoiti, Lake Okataina and Lake Tarawera (Figure 3). The obsidians from this volcanic centre form a distinctly different geochemical group from the Rotokawau source, and in fact all TVZ sources. They are characterized by lower Rb values and Rb/Sr ratios, but generally higher Zr/Rb ratios.

Overall, the available analyses indicate that there may be some difficulty in distinguishing between the different TVZ obsidian sources unless a wider range of elements are employed.

Evidence of Exploitation

One of the difficulties in assessing the exploitation of obsidian sources in the TVZ is that so few archaeological sites in the central North Island have been excavated. Only the Whakamoenga and Waihora cave shelters at Lake Taupo, and the early 'moa-hunter' site at Tokoroa have yielded significant obsidian assemblages (Figure 1). Material from the former two sites appears to be derived entirely from the Taupo source (Moore 2011b).

The recent analysis of obsidian collections from a number of early sites along the Waikato-King Country coastline suggests that Taupo obsidian was widely utilized in the western North Island, at least as far north as the Waikato River mouth (Moore 2011a). A few artifacts of Taupo obsidian have also been recorded at some sites in the Bay of Plenty, at Kohika (Moore 2004) and Mt. Maunganui, Tauranga (unpublished data). However, none of the >4000 flakes analyzed by Seelenfreund and Bollong (1989) in their New Zealand-wide study were able to be specifically assigned to any of the TVZ sources, because of the inability to distinguish between 'grey' obsidians from the 'Inland', Coromandel, Great Barrier and Northland regions.

At present there is very limited evidence for the exploitation of sources in the Rotorua area. There are no collections of obsidian artifacts from the district lodged with the Rotorua Museum, and none have been recorded from local sites. Only a few artifacts from distant locations have been sourced to either the Rotorua or Whakamaru areas. In an early analysis of 210 pieces of obsidian from various sites at Palliser Bay, using conventional XRF, five (from three different sites) were attributed to 'Rotorua' and one to Ongaroto, though all with <95% probability (Leach & Anderson 1978). A recent analysis of 121 artifacts from Maungarei in Auckland indicated that at least 6 originated from 'Rotorua' (Davidson 2011). These were sourced by EDXRF, based on the visual comparison of x-ray spectra with those obtained for reference samples. It is assumed that the actual source was Whakarewarewa, since none of the others within Ward's (1973, 1974) Rotorua group contain flake quality obsidian. The physical characteristics of the obsidian were not recorded. One flake from Maungarei was also attributed to an unknown central North Island source, possibly Maraetai.

The early 'moa-hunter' site of Tokoroa (T16/1) is situated <20km from the Whakamaru sources and about 35km from Rotorua (Figure 1), and therefore might be expected to contain some obsidian from one or both of these areas. Excavation of part of the site in 1961-62 yielded 510 flakes, pieces and cores of obsidian, of which 94% were green in transmitted light and attributed on that basis to Mayor Island (Law 1973). Interestingly, all of the 29 cores were of Mayor Island obsidian. Of this collection, 270 pieces were subsequently analyzed by Seelenfreund and Bollong (1989) using EDXRF, which indicated that at least 86% were probably from Mayor Island and 5% (14) were 'grey'; a further 5% were classified as 'unknown'. Unfortunately, a significant proportion of the Tokoroa collection is now missing, including all except two of the estimated 30 'grey' flakes, thus preventing a proper re-assessment of the assemblage. However, my re-examination of the remaining part of the collection (383 pieces held at Auckland Museum) suggests that >90% of the obsidian came from Mayor Island and at least some of the 'grey' flakes were derived from the Taupo source.

The only definite evidence for local use of the Maketu obsidian has come from a detailed study of the artifact assemblage from the Kohika site, a swamp *pa* located about 35km to the southeast (Moore 2004; Figure 1). Approximately 60% by weight of the 'grey' obsidian (about 250g) was identified from visual characteristics and XRF analysis as being from Maketu. This is equivalent to 10-12 average-sized pebbles. So far, no culturally-derived flakes of the obsidian have been identified from any sites at Maketu itself. One pebble has been collected from a relatively early site (U14/363) at Mt. Maunganui, but there is no indication it was worked. Beyond the Bay of Plenty, recent EDXRF analysis of a large obsidian assemblage from an early site on Ponui Island (S11/20) near Auckland indicated that about 5% (31 pieces) originated from Maketu (Sheppard et al. 2011). Given the nature of the source, this is a rather surprising result, and probably warrants re-assessment.

Discussion

Recognition of the Rotokawau source raises the issue of whether obsidian artifacts previously attributed to 'Rotorua' did in fact originate from Whakarewarewa, or may have come from Rotokawau. Obviously the situation is complicated by not knowing for certain if there was a significant outcrop of flake-quality obsidian at Whakarewarewa prior to modern quarrying which had the potential to be exploited by pre-European Maori. Nor do we have any reliable information on its chemical composition. Thus, for now, all source allocations to 'Rotorua' should probably be treated as tentative rather than definite.

At present, the case for exploitation of obsidian occurrences in both the Rotorua and Whakamaru areas is dependent on very limited sourcing data, of uncertain reliability. None of the studies that have assigned artifacts to sources in these areas have presented any quantitative analyses that are able to be re-evaluated. The main concern here is that obsidian from the Hahei source on the Coromandel Peninsula (Moore *in press* a) has very similar Rb, Sr and Zr values to that from the Rotokawau (North) and Maraetai sources, and therefore it is possible that the artifacts concerned originated from Hahei rather than the TVZ. Clearly, this could make a significant difference to the identification of former distribution networks.

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