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Contribution to the QR Forum

The selective geography of volcanism in oral traditions

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Abstract

Oral traditions describing details of ancient volcanic eruptions and their effects survive throughout the inhabited world. Many such eruptions, especially those having catastrophic environmental and societal consequences, proved sufficiently memorable to form the basis of enduring oral traditions. Using global databases, we identified 2306 such eruptions from 477 inhabited locations that occurred before the start of the Common Era (CE) and are therefore likely to have been the subject of oral traditions. Of these, we selected 20 events ('remembered' Holocene eruptions) for which there are extant oral (-derived) traditions that demonstrate how such traditions can reveal details of past volcanism that often are undetectable by retrodictive geoscientific enquiry. We also selected 20 events ('forgotten' Holocene eruptions) about which no oral traditions are known and discuss the possible reasons for this. Such oral traditions, while often challenging for conventionally trained geoscientists to interpret, are valuable yet largely overlooked sources of information about the nature and effects of Holocene volcanism that can usefully complement geoscientific enquiry. In particular, we identified locations where memories of such volcanism appear 'forgotten' in the hope that scientists might focus their attention on revealing, identifying, and analyzing local traditions.

Keywords: Holocene, eruption, human impact, volcanism, oral tradition, memory, myth, hazard management, orality, risk perception

Introduction

Geoscientists have conventionally paid little attention to non-scientific information sources, especially for their reconstructions of past environments and the changes they underwent. This situation has begun to change, particularly since the publication of Dorothy Vitaliano's trailblazing (1973) volume, *Legends of the Earth: Their Geologic Origins*, that persuasively argued the case for treating 'myth' and 'legend' as potential sources of information about memorable geological events in pre-literate contexts. Also influential was the 2007 compilation on *Myth and Geology*, published by the Geological Society of London, that contained numerous case studies demonstrating the empirical foundations of myth and the knowledge gains obtainable from its re-reading as fact rather than fiction (Piccardi and Masse, 2007).

This study focuses on ancient stories, commonly mythologized, of volcanism and is premised on the idea that pre-literate peoples, being no less risk aware and risk averse than modern peoples, encoded their observations and understanding of a range of volcanic (and other life-threatening) phenomena in their oral traditions, which were passed on from one generation to the next with a high degree of replication fidelity (Makondo and Thomas, 2018; Nunn et al., 2022). The length of time these traditions survived appears to depend firstly on the isolation of the people retaining these memories, the idea being that these are more likely to be 'lost' as a result of cultural syncretism. It seems no coincidence that some of the longest surviving stories/traditions are in places like Australia and the Celtic fringes of Europe where cultures have largely avoided such syncretism (Nunn et al., 2021; Nunn, 2022; Hamacher et al., 2023; Kearney et al., 2023). Secondly, the survival of these traditions depends also on the memorability of the phenomena they recall, specifically their low recurrence (so events are not confused or conflated with one another) and the comparatively high magnitude (a proxy for human impacts).

For the purpose of estimating the longevity of human memory, volcanism traditions are excellent because they are point-in-time phenomena that can generally be dated retrodictively with a high degree of precision. For example, Klamath people's stories about the terminal eruption of Mt Mazama (Oregon, USA), which formed modern Crater Lake about 7600 cal yr BP, must have endured at least this long (Deur, 2002; Egan et al., 2015; Nunn, 2018). And at Kinrara Volcano (Queensland, Australia), which last erupted about 7000 cal yr BP, the Gugu Badhun people's stories about the time when the 'watercourses caught fire' (Cohen et al., 2017) provide an approximate age for the eruption. More recent work on Nabukelevu Volcano (Kadavu, Fiji) demonstrates that local communities retain a diversity of oral traditions recalling the effects of its dome-forming eruption about 2500 cal yr BP (Lancini et al., 2023).

To understand more fully the potential of oral traditions of Holocene volcanism at a global scale, we mapped volcanoes across

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the world that erupted memorably during this period. Then, to illustrate the diverse nature of information that can be gleaned from oral traditions, we selected 20 'eruptions with stories' (i.e., remembered eruptions) from various parts of the world. Then we selected 20 'eruptions apparently without stories' (i.e., forgotten eruptions) that we consider likely to have been witnessed by local people and incorporated into their oral traditions, but which appear not to have survived. In the discussion of this information, we analyzed the ages of remembered and forgotten eruptions to demonstrate that they plausibly come from the same dataset; then we specifically discuss the value of these traditions for reconstructing past geologic histories, the criteria that determine the survival of traditions, and their future value.

Distribution Of Holocene Volcanism in Pre-Literate Contexts

The spatial distribution of active volcanoes across the Earth is explainable by plate tectonics. Around 85% of such volcanoes are associated with convergent or divergent plate boundaries, with the remainder occurring above intraplate hotspots (Cottrell, 2015). While accepting that submarine volcanism may well have informed pre-literate traditions (e.g., Nunn, 2003), this study is confined to subaerial volcanism with the clear potential to be observed by people who at the start of the Holocene numbered around nine million individuals spread across almost all habitable land areas of Earth (Goldewijk et al., 2017).

Our research identified 477 on-land volcanoes that erupted memorably on at least one occasion during the Holocene in preliterate contexts (Siebert and Simkin, 2002; Global Volcanism Program, 2023). For the present study, we define this period as between 11,650 cal yr BP (9700 BCE), which is the start of the Holocene, and 1950 cal yr BP (0 BCE), but include Toomba (Australia), which slightly predates the start of the Holocene, and Pacific Island examples, which come from pre-literate contexts within the past 2000 years. To inform our selection of examples of remembered and forgotten eruptions, we utilized the criteria identified in the previous section as critical to story preservation, namely isolation and memorability (proxied by eruption magnitude). These criteria are plotted in Figure 1.

Isolation is measured in Figure 1 by a nearest-neighbor analysis, in which the more isolated volcanic centers plotted in the upper part of the graph. We assume that the more isolated an eruption, the more likely it is to have persisted in the traditions of the people/s who observed it. Memorability is proxied by eruption magnitude, which was measured using the Volcanic Explosivity Index (VEI). As shown in the key to Figure 1, the largest circles represent the largest eruption magnitude (VEI 7). The age of the (largest) Holocene eruption (> VEI 1) at each of the 477 centers is shown along the horizontal axis.

Favoring larger-magnitude eruptions in more isolated contexts, we selected for discussion 20 remembered eruptions (i.e., those known to have extant traditions) and 20 forgotten eruptions (i.e., those not known to be recalled in extant oral traditions). The distributions of these are shown on Figure 2, listed in Tables 1 and 2, and discussed in the following two sections.

The principal criterion used in the selection of these 40 eruptions was their spatial distribution, the intention being to avoid clustering of examples in particular volcanic parts of the world. Analysis commenced with identification of the major volcanic areas on all continents (except uninhabited Antarctica) and all ocean basins (except the Arctic Ocean). This was followed by mapping of areas occupied by humans for a considerable part of the time slice (11,650–1950 cal yr BP), Pacific Islands and New Zealand excluded. Then in each of the areas of overlap (volcanism and human occupation), oral traditions plausibly linked to volcanism were sought. In this way, 20 remembered eruptions were identified. As a result of this exercise, in each of these overlapping areas, it was then possible to identify 20 apparently forgotten eruptions.

Remembered Eruptions

The term 'remembered eruptions' refers to those Holocene eruptions that are the subjects of extant oral traditions (synonymous in this study with myth/legend) and therefore demonstrate the idea that such eyewitness accounts can extend science-based interpretations of eruptive events in ways that help better understand their nature and impacts. In this section, 20 selected Holocene remembered eruptions (Table 1) are discussed, of which five are examined in detail to illustrate the types of evidence and interpretations such traditions typically contain. This subset represents a variety of styles and scales of eruption, from sudden maar (explosive) events to more prolonged effusive events.

Lake Eacham and nearby maar lakes (Australia)

In northern Queensland (Australia) there are a number of maar lakes about which there are enduring oral traditions, some recently transcribed. Those describing the formation of the maar Lake Eacham (#4 in Table 1), translated and transcribed by linguist Dixon (1972), include a Dyirbal (Aboriginal) story interpreted as describing the formation of this phreatomagmatic maar:

> "…the camping-place began to change, the earth under the camp roaring like thunder. The wind started to blow down, as if a cyclone were coming. The camping-place began to twist and crack. While this was happening there was in the sky a red cloud, of a hue never seen before. The people tried to run from side to side but were swallowed by a crack which opened in the ground" (Dixon, 1972, p. 29).

A minimum ^{14}C age for the formation of the Lake Eacham maar, the youngest in the area, is 9130 cal yr BP (Whitehead et al., 2007). Other stories likely to recall maar volcanism are known to Aboriginal groups in this area. In 1940, a story describing the creation of Lake Eacham and Lake Barrine was recounted by Emily Russell, a Ngadjon woman, who recalled how 'violent geological disturbances', rapidly rising groundwater levels, and earthquakes were witnessed by her distant ancestors. The rising waters 'swallowed people', although others escaped (Govor, 2000).

Maar lakes, which often remain undisturbed for thousands of years, provide excellent archives of environmental change. In basal sediments from nearby Lake Euramoo, evidence was found of a drier climate in the Early Holocene with sclerophyllous rather than modern rainforest vegetation (Kershaw, 1970), a finding consistent with Aboriginal traditions of 'open country' long ago in this area (Dixon, 1991).

In this example, there is a breadth and depth of oral traditions that might be predicted from the isolated nature of this group of maar volcanoes as well as the seventy millennia or so of isolation that marked Aboriginal occupation of Australia. These factors provide an optimal situation for the repeated intergenerational communication of such traditions (Nunn, 2018).

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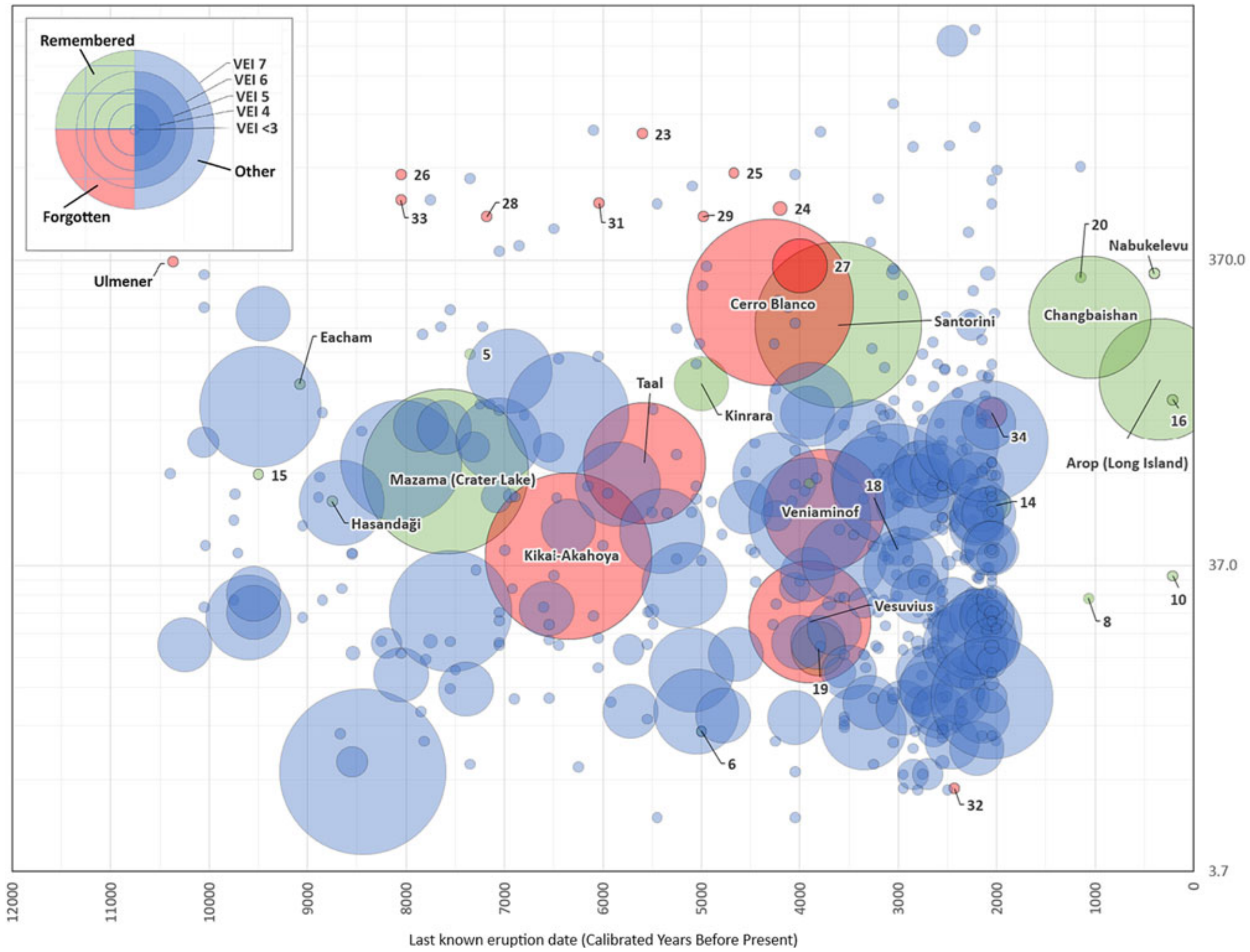

Figure 1. The distribution of 477 Holocene volcanic eruptions (> VEI 1) is represented with increasing isolation of significant eruptive centers from each other plotted on the Y axis (km) and age of the youngest eruption on the X axis. This plot informed the selection of volcanoes considered isolated in time and space, and therefore most clearly identifiable as the subject of nearby (oral) traditions. Circle size represents magnitude of eruption (VEI index). All remembered eruptions (including case studies 1–20) are represented by green circles; all forgotten eruptions (including case studies 21–40) are represented by red circles.

Hasandağı (Turkey/Türkiye)

The oldest volcanic edifice at Hasandağı (Mt Hasan) in southeast Turkey is of Pliocene age, but experienced several phases of activity/growth, the most recent of Holocene age, which was re-dated to about 8970 cal yr BP (6960 BCE) using (U–Th)/He as part of the study of Schmitt et al. (2014) (#7 in Table 1). About 130 km southwest of Hasandağı lie the remains of the Neolithic settlement of Çatalhöyük, founded around 9050 cal yr BP (7100 BCE) (Bayliss et al., 2015), that include a mural interpreted as depicting an erupting volcano (Figure 3) with a plausible resemblance to Hasandağı (Mellaart, 1968). The overlap in ages of this volcano's Holocene eruption and that of the creation of the mural support this interpretation (Schmitt et al., 2014).

Although this eruption of Hasandağı was not visible from Çatalhöyük, it was undoubtedly observed by some of its inhabitants and rendered by the artist on the basis of these observations. Key among the details is the location of the eruption in "the summit region of the taller peak" and "the volcanological interpretation of the painting as showing mild Strombolian activity" (Schmitt et al., 2014, p. 10). Although we know of no parallel oral traditions about this eruption from the published English-language literature, this example shows the importance of visual representations in helping preserve what were undoubtedly once widespread oral traditions recalling this event in this region.

This is consistent with recent ideas that knowledge was communicated orally in pre-literate contexts, often using devices such as poetry and song, dance and performance, but also commonly with the use of visual memory aids such as rock art. Good examples also come from South Africa (Low, 2014), Norway (Nyland and Stebergløkken, 2020), and Australia (McDonald et al., 2018; Ramanaidou and Fonteneau, 2019).

Kinrara (Australia)

Part of the McBride volcanic province in northern Queensland, Australia, the Kinrara Volcano (#9 in Table 1) is today marked by a well-preserved cone rising 30 m above the surrounding plains across which a series of basanite lava flows can be traced as much as 55 km from their source (Cohen et al., 2017). Ages for the most recent eruption, using $^{40}Ar/^{39}Ar$, suggest this occurred 7000 ± 2000 cal yr BP (3000–7000 BCE).

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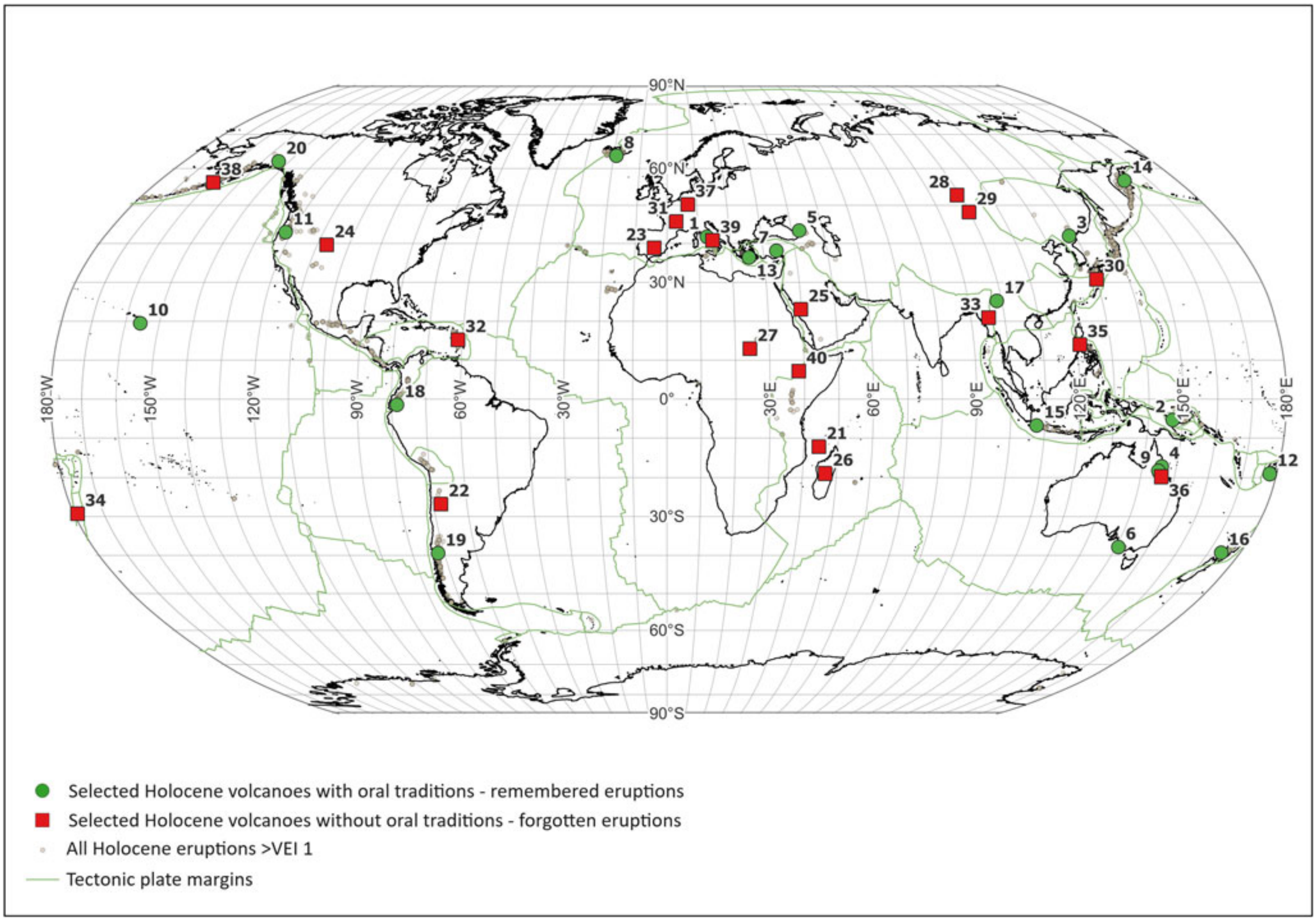

Figure 2. Global distribution of Holocene volcanism with selected volcanoes that have well-documented oral traditions and notable volcanoes that do not. Map compiled with data from Global Volcanism Program (2023).

The Gugu Badhun people, who continue to occupy the Kinrara region, have numerous extant memories of this eruption (Figure 4) and the ways it affected their livelihoods (Hoolihan and Sutton, 1970; Cadet-James et al., 2017). Key among the Gugu Badhun stories are those that recall when 'the earth caught fire along the watercourses', interpreted as observations of lavas from Kinrara flowing along surface declivities. Another story interprets the eruption as the action of a 'witchdoctor' digging a pit in the ground in which he stirred the 'dust' that spread out across the land, making it difficult for people to see where they were and asphyxiating many; 'people got lost in the dust and died'.

Geoscientific research might indeed conclude that lavas from the Holocene eruption of Kinrara favored existing watercourses, reshaping the drainage and topography of the surrounding landscape, and even creating new freshwater springs (around the termini of the lava flows) that became rich in fauna and flora (James, 2009). But additional details in the Gugu Badhun oral traditions could have come only from eyewitnesses. These include the likelihood that this eruption involved the emission of toxic gases from the crater that spread out across the land and had similar effects to other, more recent and better documented events such as the 1986 Lake Nyos (Cameroon) limnic eruption (Kling et al., 1987), suggesting that at one stage during the Kinrara eruption a lake formed in the crater. Such details are not only of historical interest but also relevant to future hazard management in the Kinrara area.

Mt Mazama and Crater Lake (USA)

Mount Mazama is the name given to a complex volcano (#11 in Table 1) more than a kilometer tall that once existed in the southern Cascade Range (Oregon, USA). Its terminal eruption, an ultraplinian event, occurred about 7600 cal yr BP (5650 BCE), a modal age derived from Bayesian analysis of 81 ^{14}C determinations, and resulted in the formation of modern Crater Lake. Eyewitness accounts of this memorable event, which involved the extrusion of more than 100 km^3 of lava and clastic material covering some 2,600,000 km^2 (Bacon and Lanphere, 2006), are the subject of several extant Klamath oral traditions, written down only within the last two hundred years (Deur, 2002).

The most widespread Klamath tradition describes how Llao, the demon who once inhabited the volcano, terrorized the people living around it, shaking the land on which they lived and showering them with hot rocks. So, the people sought the help of the benevolent spirit Skell who battled Llao and eventually pulled down the volcano on top of him, a plausible memory of the terminal eruption and collapse of Mt Mazama and the formation of the modern caldera (Crater Lake). The Klamath stories are rich in ancillary detail, such as when Llao 'spewed fire from his mouth':

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Table 1. Details of selected Remembered Eruptions. VEI = Volcanic Explosivity Index; latitude and longitude are shown in degrees; age is shown in cal yr BP; DPRK = Democratic People's Republic of Korea

No.	Volcano	Country	VEI	Age	Latitude	Longitude
1	Albano	Italy	—	6750	41.73	12.7
2	Arop	Papua New Guinea	VI	290	−5.36	147.12
3	Changbaishan	China/DPRK	VI	1004	41.98	128.08
4	Eacham	Australia	—	9030	−17.3	145.65
5	Elbrus	Russia	—	7300	43.35	42.44
6	Gambier	Australia	IV	5450	−37.85	140.78
7	Hasandağı	Turkey	—	8970	38.13	34.17
8	Katla	Iceland	IV	1016	63.633	−19.083
9	Kinrara	Australia	IV	6950	−18.41	144.92
10	Mauna Loa	USA	—	160	19.48	−155.61
11	Mazama	USA	VII	7630	42.93	−122.12
12	Nabukelevu	Fiji	—	2420	−19.12	177.98
13	Santorini	Greece	VII	3560	36.4	25.396
14	Sheveluch	Russia	V	1960	56.65	161.36
15	Tangkuban Parahu	Indonesia	—	9450	−6.77	107.6
16	Taranaki	New Zealand	—	160	−39.3	174.07
17	Tengchong	China	—	7700	25.23	98.5
18	Tungurahua	Ecuador	V	2960	−1.47	−78.44
19	Villarrica	Chile	—	3760	−39.42	−71.93
20	Wrangell	USA	—	1147	62.01	−144.02

> "Red-hot rocks as large as the hills hurtled through the skies. Burning ashes fell like rain … Like an ocean of flame it devoured the forests on the mountains and in the valleys … until it reached the homes of the people. Fleeing in terror before it, the people found refuge in the waters of Klamath Lake" (Deur, 2002, p. 20).

This case study therefore illustrates the additional information that can be acquired through such detailed 'legends'. For instance, geoscientists can certainly map the extent of large pieces of clastic material, but they cannot easily know how much forest was destroyed during this eruption (Long et al., 2014). And while the extract above notes some of the responses by local residents to the eruption, one wonders whether some of that inferred since, such as the effects of the eruption of Mt Mazama on the resource base that forced the development of new methods of food preparation (Oetelaar and Beaudoin, 2016), could have been understood far sooner had the Klamath 'stories' been treated more seriously and transcribed more assiduously earlier than they were.

Nabukelevu (Fiji)

Part of a volcanic island arc associated with proximal lithospheric plate underthrusting, Kadavu Island in southern Fiji exhibits a progression of active volcanism from northeast to southwest (Verbeeten et al., 1995). The only active volcano today is Nabukelevu (Mt Washington) (#12 in Table 1), where three eruptive episodes occurred within the past three millennia (Cronin et al., 2004a). This marks the approximate time span of human occupation of the Fiji archipelago so there is an expectation that people would have witnessed these events.

Recent research focused on several traditional communities on the islands of the Kadavu group and identified 13 extant stories about Nabukelevu volcanism (Lancini et al., 2023), all considered likely to recall the largest event: the dome-forming eruption that occurred more than 2420 ± 90 cal yr BP (470 BCE). Most of these stories recalled how the 'god' of Ono Island, finding his view of the sunset obscured by dome formation, 'flew' to Nabukelevu to confront the god living there. The two fought, considered a memory of the eruption, then one pursued the other through the sky, dropping 'soil' to create islands, the names and formation sequence of which feature in several versions of the story. It is proposed that this sequence is a memory of the movement of the ash cloud across the region. Another detail in some versions explains that one god 'drank' up the ocean to reveal the hiding place of his rival, a detail interpreted as a memory of a tsunami.

This case study is instructive in two ways. Firstly, for most of the time that stories about the warring gods on Kadavu was written down, around the mid-nineteenth century, it was treated as a myth (i.e., a made-up culture-defining story with no basis in fact). This interpretation was supported by the assumption that the youngest eruption at Nabukelevu had been tens of thousands of years ago, long before people arrived in Fiji. This assumption was nullified when pottery fragments were discovered in a paleosol beneath several meters of scoria, which led to the 'myth' being treated more seriously and eventually being found to be a memory of an eruption at Nabukelevu. Secondly, as the research of Lancini et al. (2023) demonstrates, in places where oral traditions continue to be related, it is possible to identify geological details from oral (and recently transcribed) accounts, implying that this would be a worthwhile project in situations similar to that of Nabukelevu.

Table 2. Details of selected Forgotten Eruptions. VEI = Volcanic Explosivity Index; latitude and longitude are shown in degrees; age is shown in cal yr BP

No.	Volcano	Country	VEI	Age	Latitude	Longitude
21	Anjouan	Comoros	—	9300	−12.22	44.42
22	Cerro Blanco	Argentina	VII	4250	−26.79	−67.77
23	Columba	Spain	—	6270	38.87	−4.02
24	Dotsero	USA	—	4150	39.66	−107.04
25	Harrat Al-Madinah	Jordan	—	694	23.08	39.78
26	Itasy	Madagascar	—	8000	−19.03	46.7
27	Jebel Marra	Sudan	IV	3950	12.95	24.27
28	Jom–Bolok	Russia	—	1200	52.713	99.021
29	Khorgo	Mongolia	—	7710	48.19	99.86
30	Kikai–Akahoya	Japan	VII	7300	30.793	130.305
31	La Vache and Lassolas	France	—	8600	45.71	2.96
32	Morne Patates	Dominica	—	685	15.25	−61.35
33	Popa	Myanmar	III	8000	20.92	95.25
34	Raoul	New Zealand	—	150	−29.27	−177.92
35	Taal Caldera	Indonesia	VI	5530	14	120.99
36	Toomba	Australia	—	20180	−19.86	146.14
37	Ulmener	Germany	—	11000	50.21	6.98
38	Veniaminof	USA	VI	3700	56.17	−159.38
39	Vesuvius	Italy	VI	3850	40.82	14.43
40	Wendo Koshe	Ethiopia	—	2346	7.19	38.39

Memories of other remembered eruptions

In addition to the five case studies detailed above, a further 15 Holocene eruptions, plausibly recalled in extant oral traditions and therefore ‘remembered’, are described more briefly below.

Albano Maar (Italy) (#1 in Table 1) is Europe’s deepest lake and has exhibited volcanic activity for at least 5900 years (De Benedetti et al., 2008), posing a continuing threat to the southern fringes of Rome. In 394 BCE, an aqueduct was built through the crater wall and acted as a spill over for any unexpected rise in maar lake levels, implying that the Roman engineers knew the history of the area, probably through local oral traditions (Nunn et al., 2019).

Also known as Long Island, Arop (Papua New Guinea) (#2 in Table 1) is the site of a VEI-6 eruption that occurred 1651-1671 CE and brought the ‘taim tudak’ (time of darkness) to people across an area of almost 100,000 km^2, an event well remembered in oral traditions (Blong, 1982; Blong et al., 2018).

The location of several Holocene ultraplinian eruptions, Changbaishan (China–North Korea) (#3 in Table 1) is the subject of several Chinese traditions explaining the formation of maars and caldera lakes, hot springs, fire, and flood that plausibly recall its millennium eruption 946–947 CE (Wei et al., 2002; Zhang et al., 2022).

Mount Elbrus (Russia) (#5 in Table 1) is the highest volcano in the Caucasus Mountains. One of its satellite cones, Lesser Tkarsheti (Georgia), erupted around 6500 years ago (4188–4740 BCE) (Bogatikov et al., 2003; Vashakidze et al., 2019). Given that people lived throughout this area at this time (Golovanova et al., 2020), it has been proposed that this lava-dominated event helped inform the basis of the Greek classical myth of Prometheus and his punishment by Zeus for stealing fire from the gods and gifting this to humanity (Barber and Barber, 2004).

Maar formation at Mount Gambier (#6 in Table 1), in the Newer Volcanics Province of South Australia, occurred around 5450 cal yr BP and is one of the most recent eruptions in Australia. Two groups of Aboriginal stories likely refer to this event. One references ‘a growling old man’ living at Mount Gambier who periodically ‘threw fire into the sky’ (Wilkie et al., 2020). The other is the story of a family of giants that settled here, having fled eruptions at other volcanoes in the area, until one day water rose up in the maar and flooded their cooking ovens, forcing them to move again (Smith, 1880), which has been interpreted as a memory of maar development (Nunn et al., 2019).

The first inhabitants of Iceland arrived 870–930 CE and missed the massive subglacial eruption 822–823 CE of Katla (Büntgen et al., 2017) (#8 in Table 1), yet soon developed oral traditions about its subsequent activity, especially the lava, pyroclastic flows, and the associated flooding that affected nearby communities (Einarsson, 2019).

The volcanic edifice of Mauna Loa (USA) (#10 in Table 1) dominates the island of Hawai’i and, together with its more active flank volcano Kilauea, is the subject of many Hawaiian stories (Westervelt, 1916; Coombs et al., 2006). Many recall the activities of the deity, Pele, who is said to have made her home on Kilauea and to have been responsible for its activity for most of the ca. 800 years that people have lived in the Hawaii group (Rieth et al.,

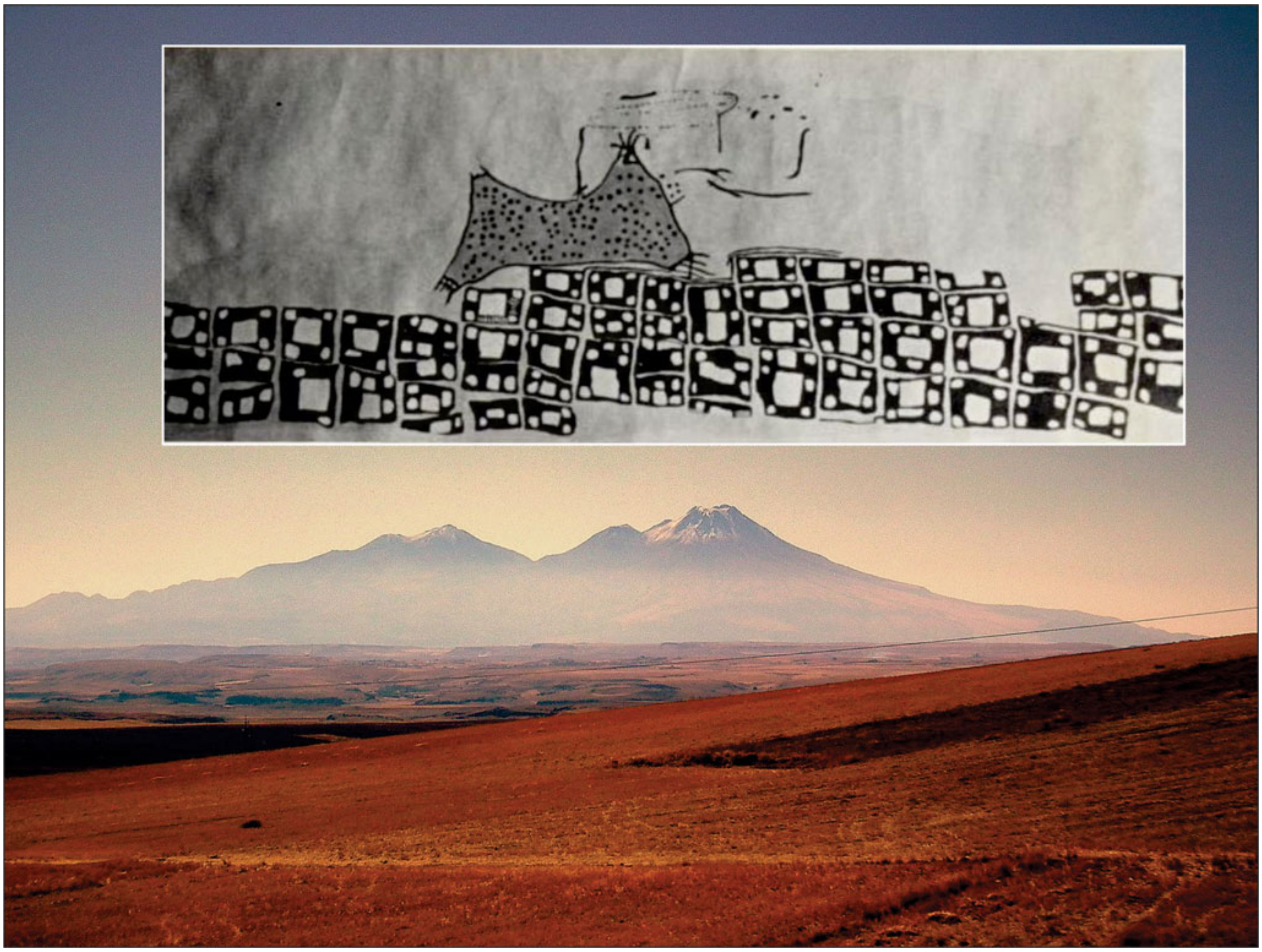

Figure 3. The twin peaks of the Hasandağı volcano (Turkey) showing (inset) the mural from Shrine VII at Çatalhöyük, 130 km distant, that has been interpreted as depicting the latest eruption of Hasandağı about 8970 cal yr BP (6960 BCE). Main image from Wikimedia Commons (Stephen Mason), inset from Mellaart (1968).

2011). The various Pele stories show such a close correlation with last-millennium volcanic chronology that there is little doubt they encode eyewitness accounts of various events (Swanson, 2008).

The partly submerged caldera of Santorini or Thera (Greece) (#13 in Table 1) is one of several islands that remain after the ultraplinian eruption here around 3500 cal yr BP (1562–1538 BCE) (Pearson et al., 2023), which likely contributed to the collapse of the Minoan civilization (Driessen and MacDonald, 1997) and had such an effect further afield that monuments such as the Tempest Stele in Egypt (Ritner and Moeller, 2014) were erected to complement the telling of oral traditions. Oral traditions preserve memories of the eruption of Santorini, recorded in Hesiod's *Theogony* as a clash between the god Zeus and the Titans (Greene, 1992) and plausibly also in the Book of Exodus in the Christian Bible (Periáñez and Abril, 2014).

One of a group of active volcanoes in northern Kamchatka (Ozerov et al., 2020), Sheveluch (Russia) (#14 in Table 1), is also the subject of several Itelmen oral histories that report how it has moved around the landscape (Degai, 2009), something interpreted as observations of the shift of the center of eruptive activity over possibly several hundred years or more. One set of Itelmen stories recalls that the Kronotskoe Lake was the original location of the volcano but that, after it rose and wandered off in search of a better resting place, both Kainach and Kul'hkolyangin lakes formed in its footprints (Russian sources quoted in Degai, 2009, p 40).

One of the most active volcanoes in western Java (Indonesia), Tangkuban Parahu (#15 in Table 1), erupted several times during the Holocene, but there are Sundanese stories that likely explain its memorable phreatic eruptive activity 9445–9980 cal yr BP, which is remembered as a consequence of a folk hero named Sangkuriang kicking over a boat he had built and creating a dome/mountain (Vitaliano, 1973; Kartadinata et al., 2002).

Located in the west of North Island (New Zealand), Mount Taranaki (#16 in Table 1) is a stratovolcano that erupted frequently during the Holocene, including the ca. 700 years of human occupation of New Zealand (Hogg et al., 2003; Cronin et al., 2021). The most recent confirmed eruption occurred 1790 CE (Cronin et al., 2021) and may be recalled in Māori oral traditions of a battle between the giants (volcanoes) Taranaki and Tongariro for the love of Pihanga, which were recorded in writing by early European (Pākehā) settlers (Ngāwhare-Pounamu, 2014).

The Tengchong volcanic field in southwest China (#17 in Table 1) exhibited explosive activity from at least three centers during the Holocene (Li et al., 2020). Many of these centers

Figure 4. This mural depicts a modern interpretation of the Gugu Badhun creation story, telling of the conflict between Numalnali (bronze-winged pigeon) and Bubunba (pheasant) that resulted in the appearance of Baganbara (Kinrara Volcano) and the associated lava flows, which are at the center of Gugu Badhun territory. This oral tradition speaks of the pheasant's futile pursuit of the faster pigeon which melted rocks forming the lava fields flowing from the Kinrara volcanic edifice. Surrounding the birds is the Rainbow Serpent, a supernatural being said to have emerged from one of the many springs that subsequently appeared from Kinrara's lava flows. ©Harry Gertz, Shannon Gertz, and Vanessa Gertz; used with permission.

were identified from local informants, exemplifying "a custom in some Chinese geological survey work that geologists look for stories or tales from natives" (Chen and Zheng, 2021, p. 283). These researchers give the example of local stories about how Tengchong used to be a 'sea of water' but then the goddess Nuwa threw three of her giant sewing needles into it, allowing land to grow and volcanoes to form.

The active volcano of Tungurahua (Ecuador) (#18 in Table 1) comprises three volcanic edifices, the youngest of which began forming around 2300 cal yr BP, since which time it has exhibited eruptive episodes every century or so (Hall et al., 1999). Since Spanish arrival in the area in 1533 CE, there has been documentary evidence of these but observations of the eruption that occurred about 623 ± 13 cal yr BP, around 200 years earlier, were well established in the traditions of the Puruhás Indians living in the area at the time of contact (Le Pennec et al., 2008). Earlier massive eruptions such as the VEI 5 event of 2990 cal yr BP plausibly could be the earliest inspirations of such traditions. Memories of the activity of Tungurahua are also implicit in the story reporting the beliefs of local residents that this volcano was the wife of Chimborazo Volcano, 40 km to the west, and that the two had occasional intercourse with eruptive consequences (Bandelier, 1906).

The basaltic-andesitic stratovolcano Villarrica (Chile) (#19 in Table 1) has been active throughout the Holocene and remains so today (Costantini et al., 2011). The Mapuche people have stories about the spirits trapped in a cave (*reñü*) within this volcano who periodically harm Mapuche livelihoods through (eruption-associated?) floods and drought, something preventable by an annual 'ñillatun' ceremony (Faron, 1964).

The Alaskan volcano of Wrangell (USA) (#20 in Table 1), erupted in 1147 and 1830 cal yr BP, in both instances spreading ash across a vast area and forcing the migrations of Athabascan peoples who encoded stories of these eruptions in their oral traditions, typically using a metaphor of the kidnap of 'prize women' to recall their conflicts that arose from migration into others' territory (Fast, 2008; Mullen, 2012). They also have stories of how their migrations led them to mountains that subsequently 'melted', sparking a fire that spread across the land ('Dogrib Tale' in Fast, 2008), and to places where a mountain 'surged up in front of them' before destroying itself and becoming 'a vast plain' ('Hare Tale' in Fast, 2008).

Forgotten Eruptions

The term 'forgotten eruptions' refers to those Holocene eruptions that occurred in places where human populations were long established and almost certainly would have been memorable enough to have been incorporated into oral traditions. The difference with those described in the preceding section is that no such

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traditions have been identified by the authors as extant, implying either that they were never formally recorded or that they truly have been forgotten. In this section, 20 selected Holocene forgotten eruptions (Table 2) of this kind are discussed, of which five are examined in detail to illustrate the range of likely reasons for them having become forgotten. It is possible that while 'remembered eruptions' are more likely in English-speaking and/or well-studied contexts, 'forgotten eruptions' appear more likely to be found in non-English-speaking and/or less well-studied contexts.

Cerro Blanco (Argentina)

The caldera-forming eruption at Cerro Blanco (Argentina) (#22 in Table 2), about 4200 cal yr BP, was possibly one of the largest on Earth during the Holocene, producing more than 110 km^3 of eruptive products, those most voluminous locally being pyroclastic flows (Báez et al., 2020). The magnitude of this eruption and the profundity of the changes it wrought to the surrounding landscape may have obliterated its human population, which at the time was low density and dominated by hunter-gatherers, thereby perhaps explaining why no memories of it are found in later oral traditions. A comparable situation has been invoked for the depopulation of the prehistoric population of La Payunia District, which was affected by volcanism earlier in the Holocene (Durán et al., 2017).

Yet the possibility of there being formally unrecorded memories of this event remains because areas peripheral to those most affected by the eruption were occupied both before and after it. For example, the Abra del Toro rock shelter, 177 km to the east of Cerro Blanco, was occupied by hunter-gatherers both before and after this eruption, which blanketed the site with a 1-m-thick ash layer (Carbonelli et al., 2022). It may have been the return several years post-eruption of the herds of camelids, attracted by the new growth of vegas pasture, that saw the return of humans to the area (the post-eruption sediment fill of this rock shelter contains an abundance of camelid scapulae). As argued for comparable sites (Torrence, 2016), the location of this rock shelter may have been preserved in oral traditions, enabling it to be found once more. This suggests that such traditions were an essential part of people's culture at this time, implying that memories of the Cerro Blanco caldera-forming eruption may have become 'lost' only comparatively recently.

Kikai-Akahoya (Japan)

The caldera-forming super-eruption named Kikai-Akahoya (Japan) (#30 in Table 2) occurred 7300 cal yr BP on the ocean floor 50 km south of Kyushu Island and produced 70–80 km^3 of magma, making it one of the largest of all Holocene eruptions (Hamada et al., 2023). Pyroclastic flows and tsunamis ran across the land in several places while ash was deposited as far as 1000 km away throughout most of the Japanese archipelago. There is evidence that these phenomena reduced food availability for Jomon hunter-gatherers and forced the migration of affected groups, leading to the emergence of new cultural traits that came to define the early Jomon period. While largely conjectural, it is possible that the apparent absence of extant oral traditions of this eruption is attributable to human mobility, namely the focus of displaced populations on reconfiguring their livelihoods in unfamiliar environments rather than on remembering what had happened to those they had left; an example of people moving from western to eastern Tokai in the aftermath of the eruption was discussed by Ikeya (2017).

About 70 km from the center of the Kikai-Akahoya caldera, Tanegashima Island was one of the worst affected areas and, to judge from the absence of continuity of the distinctive Nishinosono pottery tradition there, had its population wholly obliterated (Uchiyama et al., 2023). There followed 'several centuries' before a series of small ephemeral settlements were re-established on Tanegashima Island. These were probably focused on marine-food acquisition because they lack many arrowheads, interpreted as an absence of terrestrial animals to hunt, which is a contrast to the island's pre-eruption occupation. The absence of oral traditions about the eruption on Tanegashima (and in similar places) may therefore be due to the comprehensive depopulation of the island during the eruption and its resettlement much later by groups of people with no knowledge about it.

Taal Caldera (Philippines)

Numerous eruptions from Taal Volcano on Luzon Island in the Philippines have been recorded since at least 1562 CE (Delos Reyes et al., 2018), but no traditions are known about the formation of the caldera from which this volcano rises. Taal Caldera (#35 in Table 2) is estimated to have formed during the Middle Holocene, between 5310 and 6910 cal yr BP, and to have been marked by the extrusion of 50 km^3 of basalt–andesite scoria (Martinez and Williams, 1999). That people were living on Luzon Island at the time of this memorable caldera-forming eruption is indisputable, so the absence of extant oral traditions (which must have once existed) is best explained by the cultural syncretism, driven by in-migration from adjoining lands, that characterizes the Late Holocene human history of the Philippines (Miranda et al., 2003). Cultural mixing of this kind generally leads to the loss of pre-existing place-based stories as the people who developed them are either displaced or have their traditions intercalated with those of new sets of migrants.

Toomba (Australia)

While there are many Aboriginal stories of volcanic eruptions within the ca. 70,000 years of human settlement in Australia, most of these recall Holocene activity (Wilkie et al., 2020). Of the Holocene volcanoes for which no such stories are known, that of Toomba in northern Queensland (#36 in Table 2) is a conspicuous example, not least because stories are known for the separate volcanic center of Kinrara (see above), 180 km northwest, which last erupted 7000 ± 2000 cal yr BP (Cohen et al., 2017). The same authors estimated the age of the youngest eruption at Toomba as being 21,000 ± 3000 cal yr BP, meaning that any associated oral traditions may not have survived because they occur beyond 'the edge of memory' (Nunn, 2018). That said, it has been suggested that Aboriginal memories may exist of an eruption in southern Australia more than 30,000 cal yr BP (Matchan et al., 2020). People are likely to have been living in the Toomba area at the time of its last eruption, so the absence of surviving oral traditions might also be due to a lack of cultural continuity.

Ulmener (Germany)

Modern humans occupied the area of West Eifel in modern Germany long before the last glacial maximum and would have witnessed a number of maar-forming eruptions subsequently,

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including that around 11,000 cal yr BP, which formed Ulmener Maar (#37 in Table 2) and the youngest in the region (Sirocko et al., 2013). Although other culturally grounded stories are known from here, none that might conceivably reference maar formation is known. While this may be because the memorable events lie beyond 'the edge of memory' (see Toomba above), few deep-time stories exist from this part of Europe, probably because it experienced regular cultural turnover, associated with the loss of place-linked stories, during the last few millennia, unlike its Celtic fringes, for instance (Nunn et al., 2021).

Other forgotten eruptions

In addition to the five case studies detailed above, a further 15 Holocene eruptions, considered memorable and yet not the subject of any known oral traditions, are deemed 'forgotten' and are described more briefly below.

Anjouan Island volcano (Comoros) (#21 in Table 2), in the western Indian Ocean, about equidistant between the island of Madagascar and the African mainland, exhibited volcano activity on at least three occasions within the Holocene. Strombolian activity occurred ca. 9300 cal yr BP (7513–7089 BCE) in the upper Pomoni Valley with a more recent eruption "in the central part of Anjouan during the last thousand years" (Quidelleur et al., 2022, p. 9), well within the period of known human settlement of the island (Crowther et al., 2016). No (oral) accounts of this volcanic activity from within or beyond the Comoros are known.

The Columba Volcano within the Calatrava Volcanic Field (Spain) (#23 in Table 2) erupted spectacularly during the postglacial period (13,500–6270 cal yr BP), damming the Jabalón River and creating a sizeable lagoon/wetland for several thousand years (Piedrabuena et al., 2019). People had occupied the area throughout this time but no stories about this event appear to have survived, plausibly because of subsequent cultural turnover.

Holocene volcanism at Dotsero (Colorado, USA) (#24 in Table 2), "…began with effusive activity, transitioned to maar-forming phreatomagmatic explosions, and then ended with a violent Strombolian phase" about 4150 cal yr BP (Sweeney et al., 2018, p. 78). While the popular idea that the name Dotsero means 'something new' in the Ute language can be traced to a 1934 newspaper article (*The Steamboat Pilot*, June 8), this seems unauthenticated and not part of any more detailed traditions.

Holocene eruptions have characterized the Harrat Al-Madinah volcanic field in Saudi Arabia (#25 in Table 2). While the two youngest eruptions, 641 CE and 1256 CE, are described in historical records, the 'post-Neolithic' eruptions (Qm6 in Moufti et al., 2013) that produced thick lava flows in the area, which would have affected local peoples, do not appear to feature in extant oral traditions.

Although several authors claim that volcanism at the Itasy Volcanic Field (Madagascar) (#26 in Table 2) lasted from Pliocene to Holocene times, a robust geochronology is currently lacking (Melluso et al., 2018). Yet given that Madagascar was occupied for the entire Holocene (Hansford et al., 2018), it is reasonable to suppose some of the most recent events were witnessed by people and may remain in oral traditions that have not been transcribed.

The circular volcanic massif of Jebel Marra (Sudan) (#27 in Table 2) is the highest point in the country, which is why it has a comparatively lush vegetation and plentiful water, attractive for human settlement, compared to the surrounding desert. Increased mobility of the region's inhabitants, particularly within the last few hundred years, may explain the absence of surviving traditions about volcanism, especially the formation of the Deriba Caldera 3500 cal yr BP (Rouwet et al., 2021).

Located within southern Siberia, the Jom–Bolok basalt field (Russia) (#28 in Table 2) was active throughout the latest Pleistocene and Holocene, with the largest eruptions occurring within the period 1600–800 cal yr BP (Shchetnikov et al., 2019). Just a few hundred kilometers west of Lake Baikal, where there is abundant evidence for Holocene human settlement (Losey et al., 2016), it seems likely that people would have witnessed the activity of Jom-Bolok even though no extant accounts are known.

The latest eruptions of the Khorgo Volcano (Mongolia) (#29 in Table 2) occurred 8780–7710 cal yr BP (Chuvashova et al., 2007) and were dominated by lava flows that dammed the Suman River valley to create the Terkhiin–Tsagaan Lake (Enkhbold et al., 2022). Despite the major landscape changes resulting from these events, there seem to be no extant memories of these eruptions, perhaps because the people who occupied the area during the Early Holocene were nomadic and did not retain place-based memories as long as their sedentary counterparts.

The violent Strombolian Holocene eruption of the La Vache and Lassolas scoria cones (#31 in Table 2), within the Chaine des Puys (France), around 8600 cal yr BP (Jordan et al., 2016), does not appear to feature in cultural traditions, possibly because those people who observed the eruption were later supplanted by other inhabitants.

In the Caribbean, eruptions occurred at Morne Patates (Dominica) (#32 in Table 2) on at least three occasions during the Late Holocene, approximately 2380 cal yr BP, 1560 cal yr BP, and 685 cal yr BP (Lindsay et al., 2003). These events are probably all later than the time of known human arrival on Dominica, 2470–2340 cal yr BP (520–390 BCE) at Delices (Shearn, 2018) but are not known to feature in any extant pre-Columbian traditions, perhaps because of the overprint of later arrivals.

Still having a potential to erupt again, the last eruption of Mt Popa (Myanmar) (#33 in Table 2) included collapse of the volcanic edifice about 8000 cal yr BP and associated pyroclastic flows and ash deposition (Belousov et al., 2018). It is likely that memories of this eruption remained in oral traditions here for a long time, although none appear to be remembered today, because stories about a more recent earthquake event (2392 cal yr BP [442 BCE]) have been recorded (Bell, 1907).

Voluminous ash-producing eruptions occurred on Raoul Island in the Kermadec group (New Zealand) (#34 in Table 2) within the period 1650–1800 CE (Worthington et al., 1999; Bourne et al., 2023), a time when Māori voyagers were travelling between New Zealand and the islands of central Polynesia. For this reason, it might be expected that stories about these and other eruptions (see Nunn, 2003) would be part of the impressive body of Māori oral traditions, but this appears not to be the case.

The Alaskan volcano of Veniaminof (USA) (#38 in Table 2) has been active repeatedly in historical times, particularly the past hundred years, but the sizes of these events are dwarfed by the colossal caldera-forming eruption about 4100–3900 cal yr BP (Miller and Smith, 1987) that changed the shape of the Alaskan Peninsula and the lives of its inhabitants (Barton et al., 2018). While numerous oral traditions have been recorded for this region, none appear to refer specifically to this eruption, possibly because the memories of it became conflated with observations of younger eruptions.

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A similar reason may explain why extant memories of the eruptions of Vesuvius (Italy) (#39 in Table 2) focus on the famed event 1871 cal yr BP (79 CE) that entombed Pompeii and Herculaneum and its successors rather than the earlier and more powerful Plinian eruption, the Pomici di Avellino event, 3945 cal yr BP (1995 BCE) (Sevink et al., 2011), in which "… the pyroclastic density currents generated during the final phreatomagmatic phase are among the most widespread and voluminous in the entire history of the volcano" (Sulpizio et al., 2010, p. 539). The burial of a pre-eruption village (Di Vito et al., 2009), the existence of human footprints created during eruptive pauses (Mastrolorenzo et al., 2006), and the post-eruption establishment of a Bronze Age village (Croce del Papa) all demonstrate that humans witnessed this eruption even though no oral memories of it are known to have survived (Passariello et al., 2009).

The Wendo Koshe volcano (#40 in Table 2) rises from within the Corbetti Caldera in southern Ethiopia. The modern volcano formed during a Plinian eruption around 2346 cal yr BP that spread pumice lapilli across an area exceeding 1000 km^2 (Rapprich et al., 2016), an event that would have been witnessed by people who would have incorporated their observations in oral traditions, none of which appear to be known today. This situation contrasts with that in northern Ethiopia where written records chronicle eruptions dating from the fifth century CE.

Discussion

The goals of this study are (1) to identify places where extant oral traditions of Holocene volcanism have survived (remembered eruptions) and are likely to have informed the understandings and responses of pre-literate peoples in particular places, and (2) to identify places where such traditions are not known (forgotten eruptions) but are likely to have existed once, given the demonstrable presence of people in the area at the time of a memorable eruption. The latter places represent potential sites for further research seeking to uncover and analyze possible (oral) memories of Holocene volcanism. Eruption ages are plotted in Figure 5 for both remembered and forgotten events, illustrating the likelihood that the data collected probably are drawn from the same dataset and thereby allowing the inference that the reason why memories of the former have survived, and the latter have not is for human not geological causes.

This discussion is in three parts. With reference to these 40 eruptions, the first part reviews the value of oral traditions, explaining for remembered eruptions how these traditions helped local people anticipate, rationalize, and cope with these events. The second part discusses how oral traditions of volcanism have survived in the case of remembered eruptions and how they are likely to have become lost in the case of forgotten eruptions. The third part of this discussion is focused on the future, highlighting the value of culturally grounded oral traditions of volcanism to the survival of people in particular places, typically non-western contexts, who may experience volcanism in the future.

Value of oral traditions about volcanism

Discussions of risk management at societal (national/global) level often implicitly assume that this is something that was enabled by literacy, specifically the ability to write explanations and instructions that could be learned by key people who can then design and drive localized responses to phenomena such as volcanic eruptions. The implications of this position are that our pre-literate ancestors had no appreciation of the value of risk management, something that recent research has shown clearly to be false (Johnson et al., 2018; Nunn et al., 2022; Parsons and Fisher, 2022). Oral traditions about remembered eruptions (see above) represent memories of past volcanism but they also inform knowledge-holders about how to recognize and interpret precursors as well as how to respond to eruptions – all of which we might label 'risk management'.

Traditional precursors include unusual levels of seismicity (as at Eacham) and rising water tables and lake levels (as at Gambier). In addition, a well-studied example is that of Savo Island (Solomon Islands) where the central volcano erupts spectacularly about every 150 years. Oral traditions note eruption precursors include vegetation die-off, increased hydrothermal activity, and the filling of the usually dry summit crater with water. Local residents also know that when the loosely consolidated volcanic sediments produced during the last eruption that fringe the island are eroded back to the foot of the volcano slopes, an eruption is due (Petterson et al., 2003).

Knowledge of how to respond to imminent or recent eruptions is also inferred to have been common in many pre-literate societies. The principal response was to move away from the danger zone and then to return to it when the danger was past. Examples of remembered eruptions that explicitly talk about migration are Mazama and Villarrica. Other traditions recall the back-and-forth mobility forced by periodic eruptions, such as those of Athabascan peoples linked to eruptions of Wrangell and possibly those of hunter-gatherers before and after the eruption of Cerro Blanco.

It can also be inferred from the lack of human remains and/or the survival of eyewitness accounts of eruptions that people in the area recognized the signs of imminent eruption and moved away before the eruption occurred. For instance, archaeological excavations of pre-eruption (Minoan) Akrotiri on Santorini Island (Greece) have not found any human remains, suggesting the city was abandoned long before the memorable island-destroying eruption 3563 cal yr BP (1613 BCE) (Friedrich et al., 2006). The survival of numerous oral traditions of people living on and around Kuwae Island (Vanuatu) before its spectacular island-destroying eruption 498 cal yr BP (1452 CE) suggest they also moved out of the area well before this occurred (Witter and Self, 2007; Ballard, 2020).

Oral traditions of remembered eruptions also detail the understandings of pre-literate people about why eruptions occurred and what might be done to prevent them. While the worldviews of people in the past differed from those of modern scientific rationalists, the desire to affect the causes of disaster – what is today labelled 'mitigation' – was as strong. Pre-modern understandings of natural disasters, including volcanism, often involved the actions of supernatural beings who nevertheless shared many of the characteristics of fallible humans. Examples of this include the remembered eruptions of Mazama and Nabukelevu where in each case a fight between a pair of 'gods' explained various phenomena including ash/rock falls, ground shaking, collapse-caldera formation (burying the evil god at Mazama), and tsunami incidence (where one god drank the sea at Nabukelevu to expose his rival). Many humans believe gods can be appeased through supplicatory practices, which explains why many active volcanoes continue to be places for sacrifice and offerings today; examples include Kilauea (USA) and Mt Bromo (Indonesia). Such practices were undoubtedly more widespread in the past.

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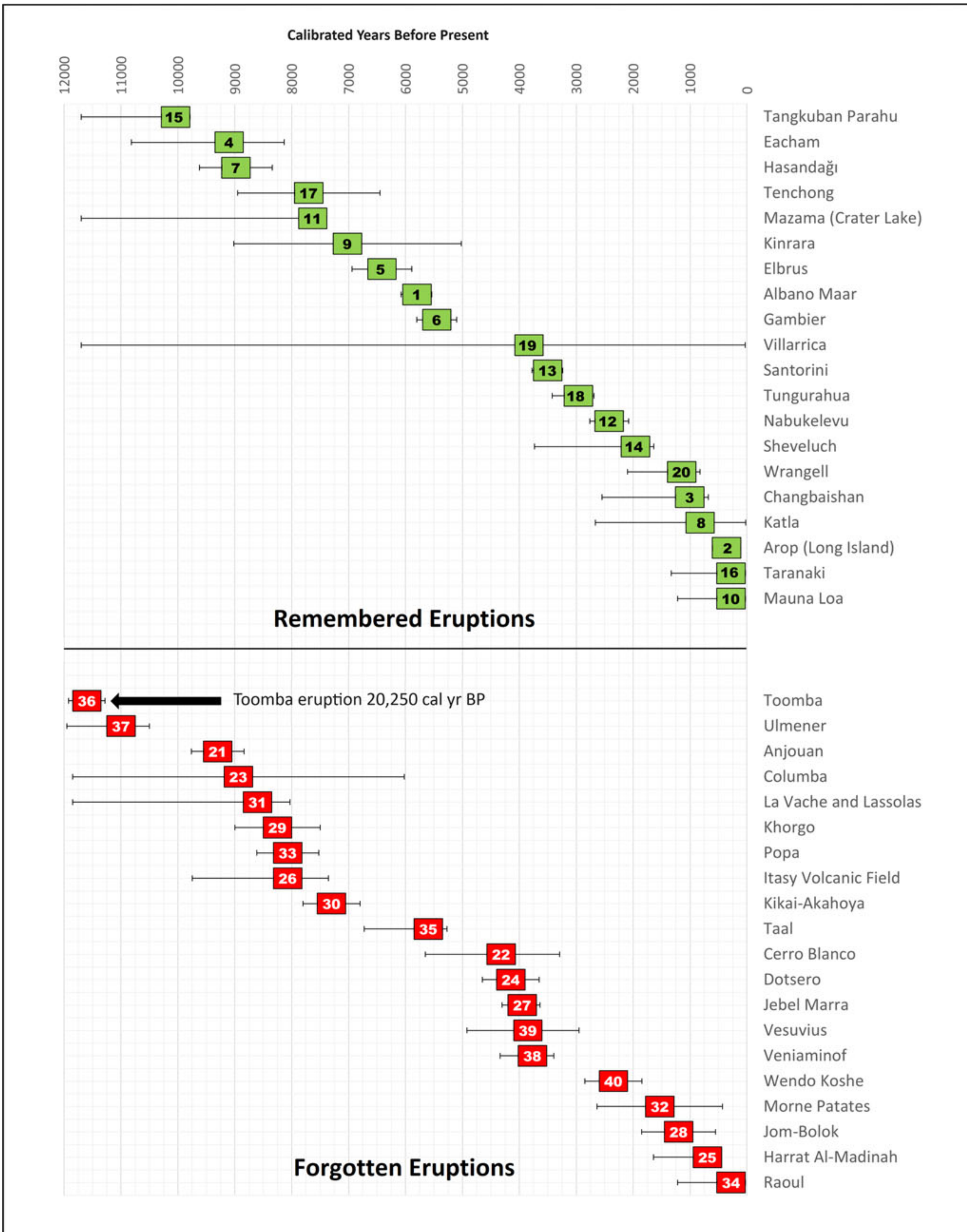

Figure 5. Selected Holocene eruptions with likely eruption duration (bars) or occurrence coinciding with probable human occupation. Remembered eruptions (1–20) have associated oral traditions whereas forgotten eruptions (21–40) have either ambiguous references in pre-literate traditions or no known memories.

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Survival and loss of oral traditions about volcanic eruptions

Pre-literate societies encoded their observations of memorable (eruptive) events into their oral traditions so these memories might be passed on to future generations, plausibly as part of a system of risk awareness intended to optimize the chances of people surviving in a particular place. Examples are documented for diverse phenomena, including meteorite falls, coastal-land loss, tsunamis, and volcanism (Masse and Masse, 2007; Nunn and Reid, 2016; Nunn et al., 2019; Lavigne et al., 2021; Hamacher et al., 2023). Such documented instances require oral traditions to have survived the spread of literacy in particular places as well as the cultural turnover that invariably preceded it. This section discusses how some traditions survived, and some have apparently been lost.

For oral traditions to endure, passed on repeatedly from one generation to the next, there needs to be minimal disruption to the contexts in which these traditions are communicated. In practical terms, this means that tradition-owning people remain anchored to place so that place-based information can be communicated easily and its importance understood readily by local residents. Good examples come from Australian contexts (such as Eacham, Gambier, and Kinrara) where people practiced circumscribed nomadism for most of the past ca. 70,000 years, and in island contexts (such as Mauna Loa, Nabukelevu, Tangkuban, Parahu, and Taranaki) where moving elsewhere was often more difficult than in continental ones. It also means that there remains a will to communicate this information, perhaps because of the magnitude/effects of the remembered event (as with maar formation at Eacham, or collapse-caldera formation at Mazama and Santorini), perhaps because there remain signs within the environment that such events may reoccur (as at Arop, Changbaishan, and Tungurahua).

Several authorities have averred that massive amounts of oral knowledge were lost with the transition to literacy (Ong, 1982; Vansina, 1985). Survival seems to have been an exception rather than the norm. Within the 477 memorable Holocene eruptions reviewed for this paper, there are far fewer remembered eruptions than forgotten eruptions. Two common reasons for loss of oral traditions are identifiable within the database for forgotten eruptions (Table 2). First is the detachment from place, specifically places to which particular traditions are linked. Once tradition-owning peoples leave such places, traditions are likely to disappear after a few generations, as in Cerro Blanco, Kikai–Akahoya, and Toomba. Second is the arrival in such places of new groups of people, who have their own traditions and worldviews that invariably become blended with (or even displace) those of the original inhabitants; this kind of cultural syncretism may be implicit in Columba, La Vache and Lassolas, and Taal Caldera.

Future value of oral traditions about volcanism

Many oral traditions about volcanism are framed by non-western communities within local worldviews, communicated using local languages by trusted communicators. In contrast, 'global' risk management is invariably communicated to such communities utilizing a foreign worldview, privileging ideas and language that many local stakeholders adjudge to be alien. This explains why volcano risk management strategies that are designed and communicated by outsiders often have far less effect in non-western contexts than anticipated (examples come from Indonesia [Donovan, 2010; Nazaruddin, 2022] and elsewhere [Cashman and Cronin, 2008]).

For this reason, the use of place-based culturally grounded (oral) traditions about volcanic hazards are key to effective hazard planning and mitigation in such places: an argument demonstrated for volcanoes in Vanuatu (Cronin et al., 2004b) and in Indonesia (Troll et al., 2015) where traditions can "…help improve hazard mitigation and foster dialogues with the communities … especially in cases where scientific approaches alone appear insufficient" (Troll et al., 2015, p 163).

This also applies to non-traditional contexts where knowledge in (oral) traditions about volcanic pasts can also provide unique information about the nature of volcanism, the recurrence of particular phenomena, and their effects, all of which is helpful for future hazard planning. For example, at Albano, the importance to the future of "classic studies on volcanic hazards" has been explicitly acknowledged (De Benedetti et al., 2008, p. 404). In the Newer Volcanics Province (NVP) in southern Australia, where Gambier is located, "…oral traditions … offer enhanced awareness of the NVP's volcanic pasts and futures" (Wilkie et al., 2020, p. 10). And at Kilauea, a parasitic vent on Mauna Loa, Hawaiian traditions allow us "…to know that Kilauea erupts explosively more often than once thought" (Swanson, 2008, p. 431).

Conclusion

Volcanic hazards present diverse threats to human society. Geologists reveal patterns of volcanism while archaeologists reveal patterns of occupation. Where these overlap, in pre-literate (ancient) contexts, memory is the great intangible artefact whose unique ability to humanize the past and inform the nature of future hazards has been underestimated. Through an account of remembered eruptions, this paper has shown that oral traditions about past volcanic eruptions provide rich sources of information that cannot be obtained any other way. Through an account of forgotten eruptions, this paper shows that such information is likely to have been lost; yet it implicitly questions whether science has searched hard enough for this information. In non-western contexts where oral traditions have been incompletely documented, it seems likely that there is information about past volcanism that could one day be uncovered. This requires scientists to put aside prejudices about 'myth' and 'legend' as cultural inventions and interrogate oral traditions more closely.

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