Merapi and Its Dynamic 'Disaster Culture'

3

Karen Holmberg

Abstract

The deep time depth of human life near Merapi volcano in Central Java and complex engagement of residents with a very dynamic and sometimes dangerous environment has produced a rich body of oral traditions linked to geological phenomena. Merapi is both a geophysical entity and a mythical one for those who live near it and plays an important cosmological role as part of a sacred axis that connects the volcano to the seat of power in the Yogyakarta palace (*kraton*) and the Southern Sea. Interdisciplinary research that entwines geosciences with social science considerations is important when considering any volcanic context but in the Merapi context it is requisite. The social importance of volcanism in Javanese contexts became increasingly relevant from the advent of modern scientific assessments beginning in the eighteenth century. These interpretations were at times catastrophism-tinged, however, and reliant upon an eruption date now interpreted as apocryphal. Advances through contemporary scientific studies convey nearly real-time seismic data and webcam imagery to residents and use tomography, drone photogrammetry, and other new ways of visualizing and imaging volcanic processes, events, and structures. Contemporary scientific research is also increasingly explicit in acknowledging the importance of oral traditions as potential artifacts of carefully observed geological events that helped past people understand and mitigate hazards. These oral traditions, still prevalent, can also help convey information to local residents. The stories told about Merapi are not epiphenomenal to scientific understanding of it, but instead, they can aid culturally embedded communication to potentially prevent loss of human life.

Keywords

Merapi · Oral traditions · Social science · Disaster culture

3.1 Introduction

Awareness of the cultural embeddedness of risk has led to a widespread acceptance of the importance of interpretations, negotiations, experience, and creative adaptation to hazards when trying to analyse, intervene in, or mitigate disasters (Krüger et al. 2015). Interdisciplinary

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research that entwines geosciences with social science considerations is important when considering volcanic contexts (e.g. Cronin and Cashman 2007; Cashman and Cronin 2008; Jenkins et al. 2013; Hayes et al. 2020). While this is true in the preparation for, response to, and recovery from any eruption it is especially true in contexts where traditional beliefs can aid culturally embedded communication and potentially prevent loss of human life. In this way, the stories told about a volcano are not epiphenomenal to scientific understanding of it. Merapi volcano, in particular, is both a geological entity and a mythical one for those who live near it. Understanding these components together—rather than separating them as the domain of different disciplines—helps create a more unified understanding of the volcano's important role in the past and future and better convey scientific understandings of risk to the roughly one million people who currently live on Merapi's flanks. Oral histories and ceremonial events can thus be exceptionally important components of risk reduction strategies that contribute to community resilience (Lavigne et al. 2008; Donovan 2010).

While other chapters in this volume very capably focus on specific components of the contemporary scientific understanding of Merapi, this chapter provides an overview of some ways in which Merapi was observed and viewed in traditional Javanese conceptions and how incorporating these understandings with scientific interpretations can benefit contemporary hazards communication. It also examines past and present scientific perceptions of Merapi's role in Java's cultural history—which are their own form of narrative or story—and new ways to 'see' Merapi. Modern descriptions of Merapi eruptions 'have involved descriptions in six languages (Javanese, Indonesian, Dutch, German, French, and English) and have generated an ornate *batik* of terminology' (Voight et al. 2000). The varied descriptions of Merapi also entail exceptionally varied and variegated cultural evocations, meanings, and interpretations that impact to this day the way scientific monitoring data and hazards forecasting are received.

3.2 The Role of the Past in the Present and Future of Merapi

The twenty-first century and its era of environmental changes in the Earth system make an improved understanding of the complex intersections between the geophysical world and human cultures of critical importance (e.g. Florindo and McEntee 2020). Studies of the past perceptions of Merapi as well as the impact the volcano has had on past human life in Central Java are by no means academic or antiquarian questions. Politics and human survival are fraught in any time period, but in early Java 'they were played out in a physical environment that was both more fertile and more unstable that most' (Wisseman Christie 2015). For this extremity alone, Merapi and human occupation in Central Java provide an important topic of study for any insight they may provide. Additionally, however, Merapi provides a remarkable, long-term example of the nature-culture entanglement as human occupation on Java is estimated to extend substantially into the prehistoric deep past (e.g. Kusumayudha et al. 2019).

Volcanoes are geological entities that are deeply incorporated into human social life in far more complex and social ways than the physical impacts of eruption (Holmberg 2007). When modern humans settled Java—roughly 40,000 years ago—they occupied the same territories formerly used by archaic members of the human family, *homo erectus*, who lived on the island from 1.5 million years ago until about 100,000 years ago (Fig. 3.1) and whose genetic material still exists in trace forms (Rizal et al. 2020). Humans and our earlier ancestors have had ample time to witness the various phases of Merapi, though data about them and their intersection with volcanism is fragmentary and only available via archaeology and palaeontology. Merapi has been observed by humans for an exceptionally long time period; Merapi literally 'returned' this gaze and observed (and continues to observe) humans, according to oral tradition (Dove 2008a, 2010).

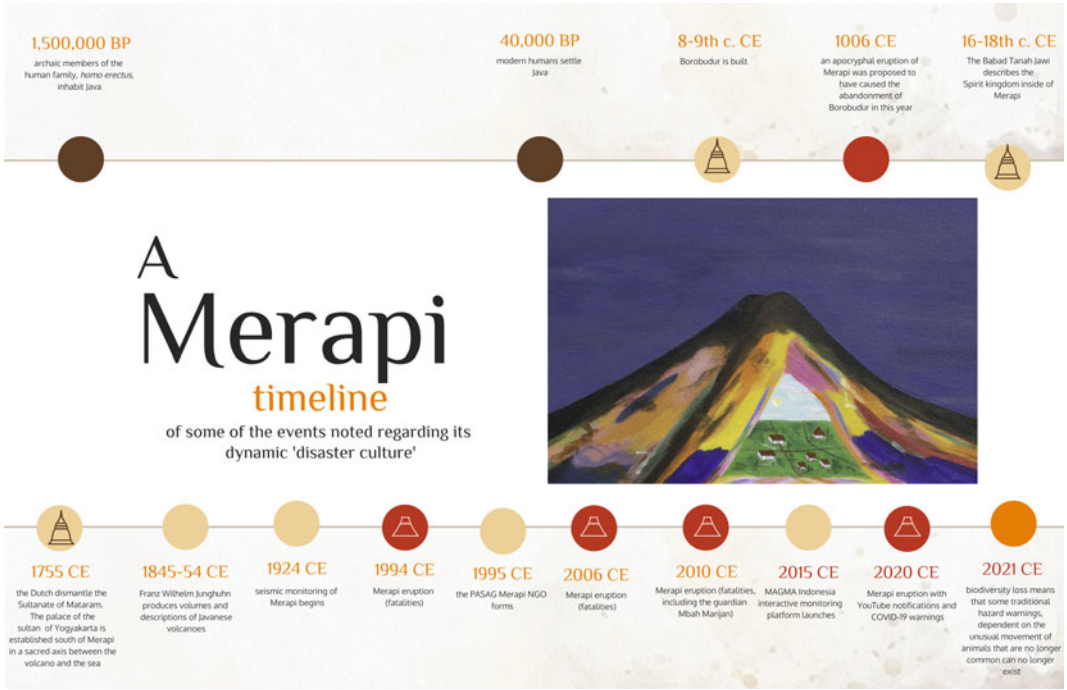

Fig. 3.1 Timeline of Merapi, illustrating some of the events noted in this chapter regarding its dynamic 'disaster culture'

Written records in the Merapi area, including descriptions of its volcanic activity, began a millennia ago. Modern scientific monitoring of Merapi is, comparatively, in its infancy. Understanding how past perceptions of the volcano shape the present has therefore important ramifications for how well scientific interpretations and understandings are communicated to communities at risk from future eruption events.

3.2.1 Misunderstandings of Past Intersections of Culture and Nature at Merapi

The impact of volcanic eruptions formed one of the earliest foci of social science investigation of environmental disasters in the mid-twentieth century and was a precursor of the important shift of scientific focus on equilibria to one that emphasises dynamic, historical, and only partly knowable intersections between the natural world and human life (Dove and Carpenter 2007a). Scientifically, we now believe that a disaster is created through cultural choices, contexts, and information rather than existing as a simply geophysical event (e.g. Oliver-Smith 1996, 2013; Oliver-Smith and Hoffman 1999; Krüger et al. 2015; Kelman 2020). Contemporary studies acknowledge that Merapi eruptions only become 'disasters' through interaction with local social systems that have a temporal and geographic specificity (Muir et al. 2020).

This is apparent when, for instance, looking at the social role of volcanoes in Java in nineteenth and twentieth-century western literature that viewed volcanoes as prominent but in a less nuanced way than current understandings of the lived, experiential view of an animate volcano and its role in human life just noted. In *The History of Java,* British Governor-General Stamford Raffles (1817) cited numerous examples of volcanic eruptions that coincided with dynastic politics on Java and so natural disasters, in these interpretations, were prime movers of social and political change. The presence of

many archaeological sites covered by multiple lahar deposits (Fig. 3.2), still evident in the contemporary period, likely helped inspire these deterministic interpretations.

The overall shift of power and populations from Central Java to the east for several centuries after an unknown catastrophe was a topic of historical debate amongst western scholars of the colonial era. Suggestions of wars or pestilence as the root of the shift in the court's location were replaced by a theory that an eruption of Merapi prompted the depopulation and abandonment of the area (van Hinloopen Labberton 1921). This concept drew upon earlier work (Ijzerman 1891; Scheltema 1912) as well as an inscription in Sanskrit issued in 1041 CE by Airlangga and now referred to as the Pucangan charter. The inscription notes the year 1006 CE (or 1016 CE depending on translation) and a disaster (*pralaya)*. This same artefact was also frequently referred to in colonial literature as the Calcutta Stone, a name that stems from the fact that it was sent from central Java to Calcutta as a gift from Raffles to the British Governor-General of India.

Following examination of Merapi's form and evidence for what he believed was a catastrophic sector collapse and debris avalanche, Dutch volcanologist Reinout van Bemmelen declared that the volcanic *deux ex machina* hypothesis was accurate and that an eruption of Merapi in 1006 CE was one of the world's great 'volcanic outbursts'. This interpretation was part of a large body of work in which van Bemmelen focused on geological events in Indonesia and placed a specific interest in the importance of geological events like volcanic eruptions on societies (van Bemmelen 1949, 1956, 1971). One archaeological site in particular, Borobudur, became entrenched within these interpretations through its monumental architecture and enigmatic state of ruin and abandonment (Fig. 3.1).

Fig. 3.2 Archaeological site covered by multiple lahars. *Photo credit* Frances Deegan

3.2.2 The Colonial View of the Archaeological Site of Borobudur and Its Relationship to Merapi

Merapi and Borobodur are located within fairly close distance to one another (Fig. 3.3), yet their direct, catastrophic linkage a millennia ago is questionable. Archaeological interpretations of the Buddhist monument of Borobudur, built between the eight and mid-ninth centuries, became deeply linked in the colonial imagination of volcanic disaster (Fig. 3.1). Borobudur, like Pompeii, became a physical talisman of the relationship between large-scale geological events and human life.

The city of Pompeii, destroyed in 79 CE by an eruption of Vesuvius and rediscovered some 1500 years after the event, was foundational in shaping western ideas of how environmental events and human life intersect throughout the modern era (Holmberg 2013a). Borobudur became uncritically included within these Romanticism-tinged narratives of volcanic destruction by British and Dutch visitors to the site in the early nineteenth century. The monument, built during a period in which Buddhism was evolving rapidly, merits the attention it has received in hundreds of works, and anyone interested in beginning to study these should begin with the helpful annotated bibliography by Miksic (2012). Some of the best analyses of the monument, described in Javanese chronicles as a mountain with a thousand statues, are compiled by Gómez and Woodward (1981) while Frédéric (1996) provides photographs and descriptions of each of the 1460 reliefs on the monument. The eruption that prompted its abandonment, however, is apocryphal (but see Kusumayudha et al. 2019), and recent studies have argued against the AD 1006 'outburst' theory proposed by van Bemmelen (see Gertisser et al. this 2023, Chap. 6 , for a synthesis).

An unexplained disaster or event did occur in Central Java and prompted the site of Borobudur to be abandoned and never re-used. This may have been a political or military disaster, however, and was probably not related exclusively to a volcanic eruption. Recent geological and archaeological data provide no evidence of this occurring because of a single eruption event or debris avalanche in 1006 CE (Murwanto et al. 2004; Purbawinata et al. 2007). Neither is there direct evidence of an eruption in 928 CE, which was the date of the last inscription at the site, though some researchers do still propose an eruption or series of relatively large eruptions at

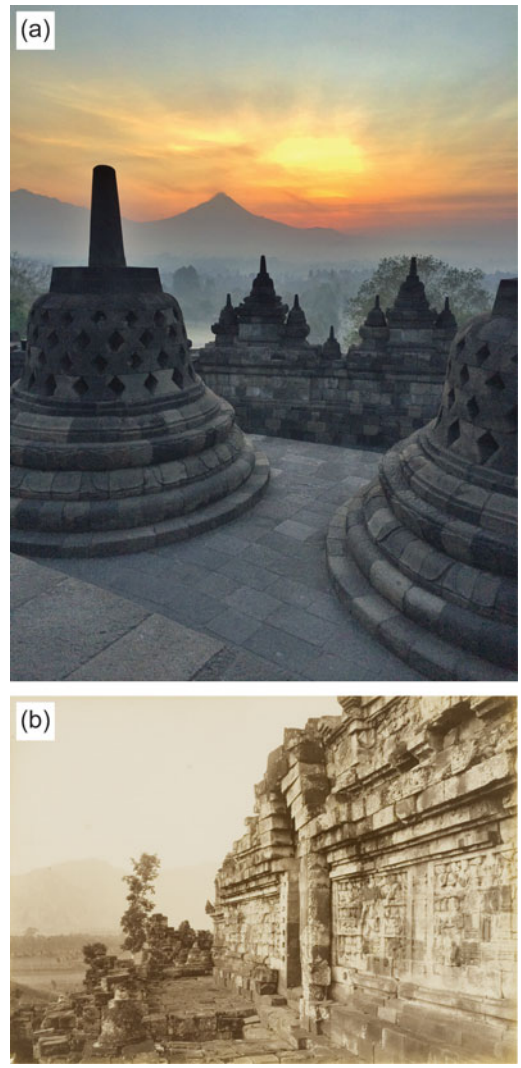

Fig. 3.3 Borobodur, with Merapi volcano in the background, as photographed in **a** 2014 and **b** 1890–91. *Photo credit* **a** K. Holmberg. **b** Kassian Cephas, Leiden University Library, KITLV, image 29,214 Collection page Southeast Asian, Public Domain. https://commons.wikimedia.org/w/index.php?curid=40516381

around that time (Djumarma et al. 1986; Wisseman Christie 2015; Kusumayudha et al. 2019).

Archaeologically, the area around Merapi remained occupied continuously, though there was a shift from a centralised government with a unifying, monumental style of architecture to local government (de Casparis 1950; Dumarçay 1986; Newhall et al. 2000). Gomez et al. (2010) provided locations for 75 structures constructed in this time period, adding to the three well known temples in the Borobudur basin (Borobudur, Mendut, and Pawon). Satellite sites remained in use until the thirteenth century, long after Borobudur's abandonment (Newhall et al. 2000; Murwanto et al. 2004). The shift of the Mataram state is suggested to have been possibly prompted by waterborne diseases from an ancient lake whose existence or non-existence is debated (Murwanto et al. 2004). The often repeated and entrenched scientific mythology of Borobudur as a synecdoche for the destruction of Mataram state power in Central Java through a Merapi eruption, however, is not a unique solution and hence not founded on reliable scientific data.

3.2.3 The Non-Colonial View of Franz Wilhelm Junghuhn on Merapi

The work of Franz Wilhelm Junghuhn provides a notable exception to the colonial focus of early scientific inquiry on Java that viewed science as a means of extracting artefacts, collecting exotic specimens, or imposing Romantic-era interpretations of natural disaster (Fig. 3.4). Junghuhn produced many volumes of descriptions and images of Javanese volcanoes, including Merapi (e.g. Junghuhn 1845a, b, 1853–4) (Fig. 3.1). A humanist who was interested in expanding and sharing geological understanding through his many drawings and paintings of volcanic landscapes, he also sought to understand local communities through their own customs and cosmologies rather than imposing Western ones upon them. Junghuhn's work would today fall within the field of landscape ecology, a term coined by geographer Carl Troll (Troll 1939). It serves as a sub-branch of geography and is already reflected in the German word *Erdkunde*, i.e. the study of the physical properties and contours of the Earth in a way that includes local human activity and action as well as remarkable natural events like volcanic eruptions (see Korintenberg et al. 2020). Junghuhn was prescient in foregrounding local, lived experience of Java's volcanic landscapes.

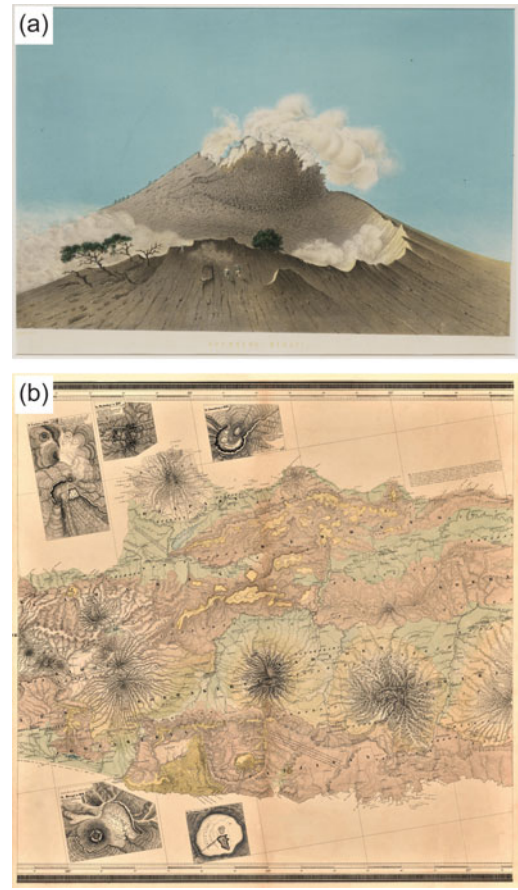

Fig. 3.4 Representations of Merapi by Junghuhn. *Photo credit* **a** Leiden University Library, KITLV, image 50H8 Collection page Southeast Asian, Public Domain, https://commons.wikimedia.org. **b** Nederlands: Kaart van het eiland Java, Public Domain, https://commons.wikimedia.org/w/index.php?curid=48819655

3.3 The Social Life of Merapi

Merapi is personified as *Mbah Merapi* in contemporary Java, using the honorific usually given to a grandparent. The living and lived presence of Merapi, however, is far more deeply embedded than this simple reference to animism or anthropomorphism. Contemporary Java has a complex and syncretic merging of Islamic, Hindu, Christian, Buddhist and earlier spiritualities that importantly temper the responses to volcanic eruptions (Schlehe 1996; Chester 2005). The main monotheistic religions, spirit cults, ancestor worship, spirit healing, shamanism, and mythical traditions all coexist within or despite the main monotheistic structures (Lavigne et al. 2015). In particular, the practice of *Kejawen*, an East Java and Central Java spiritual tradition with a focus on forecasting natural events, is important to understand not as a static religion but as a set of Central and East Javanese beliefs that can be described as 'animist Islamic metaphysics with magic, witchcraft, and shamanic dimensions, in addition to influences from the Hindu-Buddhist Javanese sultanates' (Bobbette 2018). These beliefs co-exist with ritual practices and a cosmological system, the admix of which colours how scientific information about Merapi and its hazards are received and hence they are important to understand (Troll et al. 2015, 2021; Martinez 2017, 2018, 2019; Bobbette 2018, 2020).

The first written accounts of Merapi's incorporation into the social world is from the Sultanate of Mataram, dating to the sixteenth through eighteenth centuries, which was the last major independent Javanese kingdom prior to Dutch colonisation. The *Babad Tanah Jawi* (Fig. 3.1) chronicles Javanese legends, including descriptions of a spirit world within Merapi's crater that formed when the arrival of humans caused the spirits to retreat into the volcanoes and other marginal places on Java (Geertz 1960). This powerful spirit kingdom (*kerajaan makhluk halus*) within Merapi mirrors that of the human world. It is populated by rulers, soldiers, farmers, and herders, and it draws humans into it through their deaths when they are required as servants (Schlehe 1996, 2008; Zeilinga de Boer and Sanders 2002; Donovan 2010). Merapi's eruptions are sometimes interpreted as the procession of spirit court members while lahars, ash, and gas clouds are sometimes interpreted as evidence of courtly house construction or cleaning (Schlehe 2008; Dove 2010). The spirit kingdom and physical landscape all exist within physical interaction of one another (Fig. 3.5).

When the Dutch dismantled the Sultanate of the Mataram in 1755, the palace (*kraton)* of the Sultan of Yogyakarta was established twenty kilometres south of Merapi (Fig. 3.1). The *kraton*, Merapi, and the sea are connected in a sacred axis (Karsono and Wahid 2008; Troll et al. 2015,

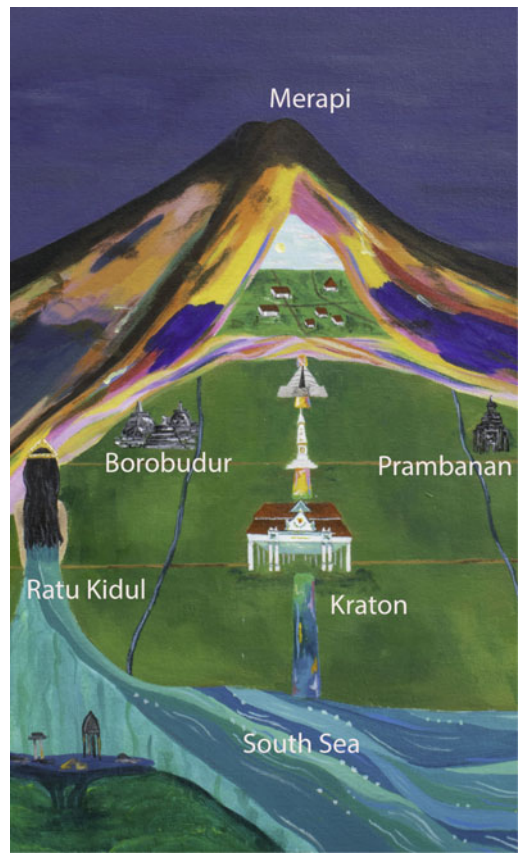

Fig. 3.5 The sacred axis between Merapi and the sea. *Illustration credit* Taylor Burkhead; adapted from Troll et al. (2015)

2021). In this axis, Merapi is literally the spike at the centre of the universe (*paku alam*) and hence extremely important (Dove 2007). Despite the volcano's importance, however, it is the goddess or Queen of the Southern Sea (the Indian Ocean), Ratu Kidul, who is the ruler of all of the spirits of Java (Wessing 1997). It is Ratu Kidul and her interaction with the other bookend of the sacred axis, Merapi, who play the key roles in creating balance (Fig. 3.6).

Ratu Kidul promised the sixteenth-century founder of the Mataram II kingdom, Senopati, protection from Merapi eruptions (Schlehe 1998, 2010). The present Sultan of Yogyakarata and the spiritual guardian (*Juru Kunci)* of Merapi perform rituals to this day that are connected to this mythical legacy. In particular, an elaborate annual ceremony called *Labuhan* (Fig. 3.7) occurs simultaneously at the south coast at Parangkusumo beach (near Parangtritis) where Ratu Kidul and Senopati first met as well as at Merapi to revitalise the relationship between the palace, the villages, the mountains, and the sea (Schlehe 1998, 2008). Ritually prepared offerings include textiles, perfume, incense, money, and every eight years a saddle for a horse (Triyoga 1991). The spirits of people who were good in their lifetime enter the realm of Ratu Kidul in the South Sea or the Merapi kingdom before moving to paradise; 'like the spirits of the volcano, the spirits of the dead still maintain connections to the living' (Schlehe 1996). Ratu Kidul supports the Javanese sultans, and it is through her power that they hold state power (Jordaan 1984; Resink 1997). The full mythology and role of Ratu Kidul is rich and worthy of discussion far beyond the scope of this chapter (see Wessing 1997; Troll et al. 2015).

3.3.1 A 'Disaster Culture'

Volcanoes and their eruptions are generally viewed through a lens of destruction and risk in western, scientific vantages that is antithetical to the traditional Javanese focus on lived

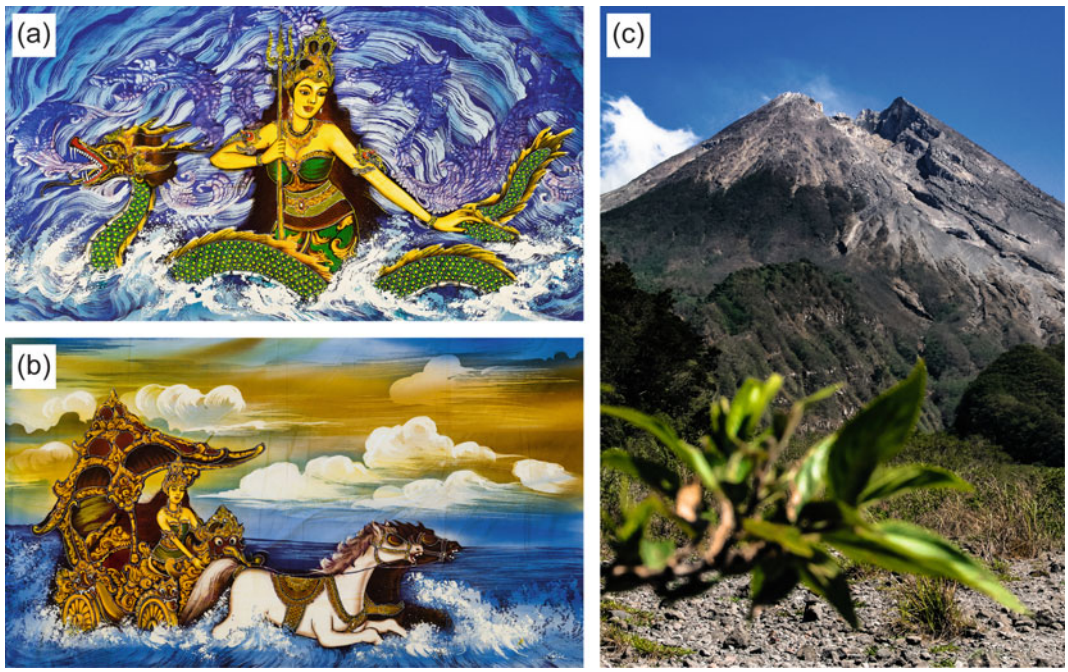

Fig. 3.6 Ratu Kidul and Merapi are the two end-members of the sacred balance. *Photo credit* **a, b** Valentin Troll, images of Ratu Kidul in batik from his personal collection. **c** Merapi by Hildaniar Novitasari, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=90747666

Fig. 3.7 Images of the annual Labuhan ceremony. *Photo credit* **a** Tri Hand, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=88221800. **b** Arfani M, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=88155355. **c–d** Flickr Commons

interactions with Merapi. In addition to the intercession that Ratu Kidul and the *Labuhan* ceremony allow to everyone, not just the sultan or guardian, residents acknowledge numerous benefits of Merapi's presence. The 1994 eruption of Merapi (Fig. 3.1) killed several dozen people (Voight et al. 2000). Following this tragedy, however, a balance resumed through an 'untroubled age' (*jaman aiyem)* for people in the village of Turgo (Dove 2008b). This new age included changes in the agro-ecology that improved the villagers' livelihoods through a shift from subsistence to market-oriented economy, particularly through the sale of milk produced by cows utilising grasslands. The high-elevation grasslands, where fodder for the cattle is retrieved during the dry season, benefit from the periodic ash fall and the extensive below-ground root systems of the predominant grass there (*Imperata cylindrica*) permits it an adaptive advantage following pyroclastic flows (Dove 2007, 2008a; Dove and Carpenter 2007b). Block and sand mining of pyroclastic deposits and lahar-filled river beds (Fig. 3.8) also provide materials for construction and sculpture workshops (Lavigne et al. 2008, 2015). This mining, which removes sand and rock for cement in Singapore, mainland China, Bali, or Jakarta is linked into a complex political ecology of regional geopolitics and material flows. For those

Fig. 3.8 Example of block and sand mining of Merapi volcanic deposits taken at Kali Gendol and showing the mining of block-and-ash flow deposits from the 2006 eruption. *Photo credit* Sylvain Charbonnier

who believe in the Javanese spiritual tradition of K*ejawen*, treating the volcano as a resource for extraction is a cause of future disasters (Bobbette 2018, 2020).

The deep intersection of volcanic activity within social life near Merapi is sometimes referred to in the English-language literature as a 'disaster culture' (e.g. Troll et al. 2015) or 'volcanic culture' that requires social volcanology (e.g. Donovan 2010) to adequately address. This vantage refers to the very complex and phenomenological realities of living near active volcanoes (Blong 1984; Schlehe 1996, 2010; Chester 1998; Donovan 2010). Rather than a feeling of distinct threat, what scientists refer to as 'hazard' is perceived in the Merapi area as something quite different. This sense is instead described frequently in terms of being confused (*bingung)* or lost (*kesasar)* and while in this state of loss a female spirit (*wewe)* sometimes appears in the guise of relatives or close friends to lead them into the crater (Dove 2007, 2008a). The stories of such states of confusion are described in ways that indicate both a familiarity and an 'otherness' to the volcano through stories of going to the market to buy rice cakes, for example, and realising that you actually bought flat rocks. When you are led to the crater in your confusion, you feel as though you are going to your own home. The ability to intercede in geological events through Ratu Kidul and ritual behaviour allows residents a sense that when disasters do occur—such as the eruption in 1994—the loss of life and property would have been higher without the ritual behaviour or that the losses will be compensated in some way in the long term (Dove 2007; Lavigne et al. 2008).

It is important to note that local cosmologies can have their own epistemological differences and peculiarities (Schlehe 2010). The same beliefs and perceptions are not shared universally even within the local area of Merapi, as Donovan (2010) points out in a discussion of the 2006 eruption (Fig. 3.1). What is commonly shared,

however, is the very personified idea of Merapi and the ability of the spiritual guardian (*Juru Kunci*) to communicate with the volcano. For this reason, the death of the guardian known as Mbah Marijan during the eruption in 2010 was a highly significant event (Fig. 3.1). Mbah Marijan was killed on 26 October 2010 when an explosive eruption began 35 h after an alert was issued that one was imminent. Remarkably, Mbah Marijan remained in the village of Kinahrejo, roughly six kilometres from the summit, along with 34 others who also refused to evacuate (Surono et al. 2012; Subandriyo et al. 2023, Chap. 12).

Mbah Marijan was a symbol of traditional Javanese beliefs, masculinity, defiance of modern Muslim political power, and even an energy drink was using him through advertisements (Schlehe 2010). Despite the highest warning levels of volcanic activity, he refused to evacuate, prompting other villagers to follow his lead. This helped create a stark, exaggerated, and ultimately artificial division between traditional beliefs and modern science. It also exacerbated the frustrations of predominantly Muslim volunteers from West Java with local residents' behaviour, as it seemed counter to scientific understanding and their own safety. Local volcano mythology regarding eruption precursors likely contributed to the reluctance to evacuate, although the socio-economic impact of losing livestock and hence livelihood as well as a lack of trust in the governmental disaster response may be the more important factors (Triyoga 1991; Schlehe 1996; Dove 2008a; Lavigne et al. 2008, 2015; Donovan 2010; Donovan et al. 2012; Mei and Lavigne 2012, 2013; Troll et al. 2015). As recent studies show (e.g. Mei et al. 2016), issues of livelihood and the adjustments required by resettlement are significant even for villagers who have positive responses to leaving their villages and recommendations on the basis of ancient legends or traditional beliefs that encourage not to evacuate may thus fall on fruitful ground, although being frequently counterproductive in respect to civil protection matters.

3.4 The Scientific Vision of Merapi

3.4.1 Modern Scientific Study of Merapi

Modern scientific observations and descriptions of Merapi began in the mid-eighteenth century. These include Dutch and German publications prior to World War II (e.g. Junghuhn 1853–1854; Verbeek and Fennema 1896) and more systematic observations in the first half of the twentieth century (see Voight et al. 2000 and references therein). The compiled genealogy of volcano science on Merapi by Voight et al. (2000) joins prior historical summaries (e.g. van Bemmelen 1949; Neumann van Padang 1951, 1983; Berthommier 1991). A shifting array of governmental organisations—often with multiple acronyms or names depending on the translations—have monitored, managed, or communicated information about Indonesian volcanoes throughout the twentieth century. Seismic monitoring of Merapi began in 1924 with one station located on the western slope roughly nine kilometres from the summit (VSI-ESDM 2020) and new forms of monitoring and new ways of disseminating data are continually evolving through new technologies (see Budi-Santoso et al. 2023, Chap. 13).

Merapi is currently monitored through five observation posts (Jrakah, Babadan, Selo, Kaliurang, and Ngepos; Fig. 3.9) which are located at distances of 5–10 km from the summit and operate under the supervision of the Research Development Center for Geological Disaster Technology (BPPTKG) in Yogyakarta (VSI-ESDM 2020; Lavigne et al. 2015). Current techniques for monitoring include: visual analyses (morphological changes and meteorological measurements using CCTV cameras, stereograph and thermal cameras); geological analyses of the summit and stratigraphic record, seismic (including four local short-period analog and five local broadband digital stations as well as a reference station some 40 km away for regional reference data); deformation (Electronic Distance Measurement reflector units, tiltmeter, real-time

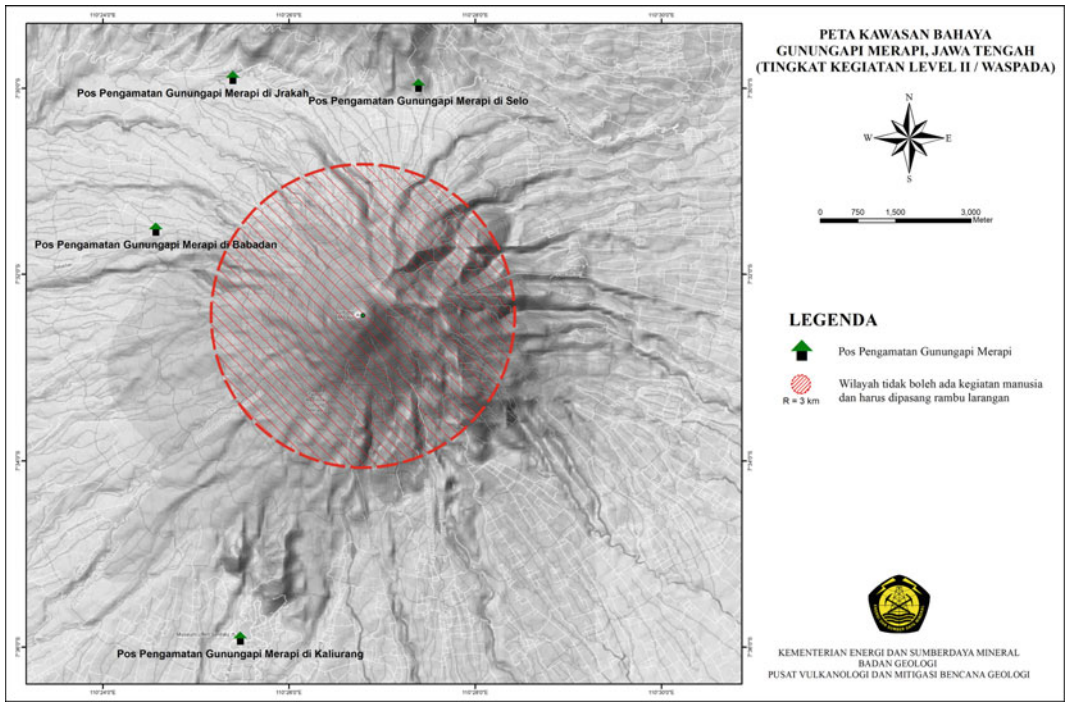

Fig. 3.9 Current volcano observation posts at Merapi. Note that the map only shows four of the observation posts as Ngepos is outside of the map view

GPS); and geochemical analyses of fumaroles using chromatography, spectrophotometry, and volumetry (VSI-ESDM 2020; Lavigne et al. 2015). Further information regarding volcano monitoring at Merapi, with particular reference to the 2010 eruption, can be found in Subandriyo et al. (2023, Chap. 12).

3.4.2 Collecting and Disseminating Data and Interpretations in the Twenty-First Century

The BPPTKG, a part of the Geological Agency (VSI), reports to the Center for Volcanology and Geological Disaster Mitigation (PVMBG). The BPPTKG is charged with Merapi disaster mitigation and monitoring and provides a website with current alert notifications, monitoring data, general information, and webcams from the monitoring stations (BPPTKG [access date: 8 June 2020]). When an eruption event occurs, as it did, for example, on 10 April 2020, the website records data such as the seismogram reading, duration, and height of the eruption column. A two-minute video of the event was immediately posted on YouTube and local residents were warned to watch for ash fall. Residents were told of the health problems the ashfall can cause (breathing difficulty, eye and skin irritation). Significantly, this information was placed within the context of the ongoing coronavirus pandemic and residents were informed that there is no evidence that ashfall can kill the virus that causes COVID-19 (Fig. 3.1). In addition to the website, the BPPTKG uses community radio stations, SMS updates, and Twitter to disseminate information during crises.

A new online and mobile phone platform launched in 2015, MAGMA Indonesia (Fig. 3.1), provides quasi-real time and interactive geological data, including live seismograph data (v2 Beta), via a dynamic digital map and

open-source technology (VSI-PVMBG 2020). MAGMA Indonesia (v0.1.3 Alpha) uses graphic indicators of different activities and risk levels for each volcano and other geological hazards such as tsunamis, earthquakes, and landslides. Users can zoom in to a three-metre resolution in the satellite imagery. The mobile application was last updated October 2019 and is available for phones with Android operating systems.

Videos on YouTube are important components of the MAGMA Indonesia outreach (Fig. 3.10). An animated introduction to MAGMA Indonesia, volcanic hazards, monitoring, and communication methods on its YouTube channel posted in September 2016 had over 18,000 views as of June 2020. Another representative video, titled 'Top 40' (posted in August 2017) uses computer-generated imagery to show magma rising through conduits to the surface and a nighttime eruption while villagers run from houses before a pyroclastic density current inundates it. The video includes images of the monitoring stations and discussions with John Pallister from the Volcano Disaster Assistance Program of the United States Geological Survey.

It is worth noting that the dynamism of the Earth, which is what necessitates rapid sharing of information about volcanic hazards, is currently accompanied by the rapid transformation and dynamism of the technologies which we use to examine a volcano like Merapi. Seismology and deformation (Lühr et al. 2023, Chap. 5), gas emissions (Nadeau et al. 2023, Chap. 11), and petrology (Troll and Deegan 2023, Chap. 8) have long been used as ways of monitoring Merapi's activity. The 'hundred-year eruption' in 2010 was the latest major eruption of Merapi to be

Fig. 3.10 MAGMA Indonesia screen captures from YouTube of its 'Top 40' video, https://www.youtube.com/watch?v=P_SXl9Coefo, accessed 6 June 2021

forecast by those precursory signals as well as near-real-time satellite radar imagery (Surono et al. 2012). The 2010 pyroclastic deposits were mapped using dual-polarisation Synthetic Aperture Radar (Solikhin et al. 2015). Recent work provides new ways to 'see' Merapi through resistivity tomography (Byrdina et al. 2017), seismic tomography (Widiyantoro et al. 2018), drone photogrammetry (Darmawan et al. 2018), and numerical models to better understand its recent eruptive behaviour (Carr et al. 2020).

Simultaneously, while monitoring benefits from innovative technologies, new risks arise from our increasingly globalised and technological world and need to be considered. The wide-ranging effects of the Eyjafjallajökull eruption in Iceland in 2010 on the global economy through flight and commerce cancellations were striking. Flight disruptions such as those that occurred from Merapi's relatively brief eruption in 2010 prompted the cancellation of roughly 2000 flights, paralysis of much activity in the city, the bankruptcy of one airline, and thwarted the Mecca pilgrimages of thousands of Muslims (Surono et al. 2012; Picquout et al. 2013). A much larger eruption could be a serious future threat (Newhall et al. 2000; Lavigne et al. 2015; Troll et al. 2015).

3.5 The Nature and Culture of Merapi in the Anthropocene

Volcanoes provide an important way to query how we as humans perceive the planet and the intersection of human life with the Earth system (Holmberg 2020). Merapi is one of the world's most hazardous and one of the most important volcanoes for careful scientific research due to its frequent activity, long time depth of cultural resonance, and high population density. Additionally, Merapi is crucial through its inclusion in the Deep Earth Carbon Degassing Project (DECADE) as an initiative within the Deep Carbon Observatory. Study of Merapi is part of the study of a sustainable future globally and directly contributes to our understanding of how anthropogenic carbon emissions relate to the overall carbon cycle (Deep Carbon Observatory 2019; Whitley et al. 2019, 2020).

The contemporary Merapi context is striking in its relationship to the past and to the volcanic landscape. Even with all of the technology available for communication, traditional means of alerting villagers are still used and important in times of crisis; these include the beating of a traditional gong (*kentongan*) as warning that a volcanic event is imminent and the community is in danger (Lavigne et al. 2015). A communication code in the pattern of sounds can convey messages such as 'safe', 'major event', 'disaster,' or 'death' in a way that to a westerner is discernible as a communication form similar to Morse code.

In this context, the sacred axis and the guardian's intercession provide an ability to communicate with the spirit realm that Merapi is a part of according to traditional beliefs. In an extension of *Kejawen* to the contemporary era and scientific monitoring, some people now provide offerings to the seismic stations and meditate in the Babadan monitoring station at Merapi (Martinez 2017). Offerings of cooked rice grown on the volcano, shaped into a cone like the volcano (*tumpeng)*, and left at sand mining sites accentuate the link between the sustenance of the human body and the land that produces that sustenance, symbolising that both are deeply linked to the volcano with a deep appreciation for the gifts provided being expressed this way (Bobbette 2018, 2020). After the guardian of Merapi, Mbah Marijan, was killed in 2010, his son—Asih Lurah Surakso Sihono—became the new spirit guardian. He has expressed willingness to avert future disasters by serving as a liaison for the local volcano observatory (Troll et al. 2015). This willingness to merge traditional and scientific ways of understanding Merapi and the ability of different forms of knowledge to coexist is something to which the scientific community is also increasingly open (e.g. Schwartz-Marin et al. 2020).

3.5.1 Oral Traditions and Participatory Hazards Communication as a Bridge to Scientific Communication

Neither scientific understanding nor traditional beliefs are static narratives, however. Like all narratives, they are in constant revision, negotiation, and transformation. Computational methods of examining volcanic hazards in quantified terms are one important way to consider risk and social vulnerability and convey it to scientists (e.g. Maharani et al. 2016), yet a more qualitative engagement in which scientific interpretations are made understandable within an already existing cultural framework can be a better way to communicate with residents near the actual risk. Incorporating oral traditions within the Merapi context as a way to understand the actions of people who may distrust scientists or civil protection authorities is part of a growing body of important work that seeks to create a communication bridge (Dove 2008a; Lavigne et al. 2008; Donovan 2010; Schlehe 2010; Troll et al. 2015, 2021; Bobbette 2018, 2020).

These studies join a body of literature from other geographical regions that take the integration of local traditions into crisis management seriously (e.g. Cashman and Cronin 2008; Swanson 2008). Oral traditions may provide a means of understanding and communicating hazards but also ways of mitigating future harm by providing understanding of early warning signs. Examples of this include a lullaby created after a tsunami in 1907 that provided early warning and is credited with saving the lives of 78,000 people on Indonesia's Simeulue Island by prompting them to run to higher ground when the sea receded (McAdoo et al. 2006; Syafwina 2014). Local tradition near Pinatubo volcano in the Philippines described a spirit of the sea who hid in the mountain and showered the land with rock, mud, dust and fire for three days while the earth shook (Rodolfo and Umbal 2008; Donovan and Suharyanto 2011). A Chamula story from pre-Columbian Mexico described a 'boiling rain' that poured out of El Chichón volcano; it rose to the sky as clouds then poured down as fatal rain that helped make sense of a boiling mud flow produced by water trapped behind hot pyroclastic debris filled the valleys and villages below (Duffield 2001). In pre-Columbian Panamá, a Bribrí story describes how the sea was a pregnant woman who was bitten by a poisonous snake and how her belly rumbled and swelled until a tree exploded from it and rose toward the sun, a story thought to incorporate observed eruptions of the Barú volcano (Holmberg 2013b).

Incorporating local communities in hazards observation, communication, and disaster prevention can have remarkably positive results. The long-term intersection of the scientific community and local communities near Tungurahua volcano in Ecuador is exemplary of what such integrated communication can accomplish (see Mothes et al. 2015). In the Merapi region, a non-governmental organisation, PASAG Merapi (PASAG is an abbreviation for *Paguyuban Sabuk Gunung*, or mountain chain association; this organisation formed in 1995; Fig. 3.1), has led communities in the creation of two-dimensional maps or models since the early 2000s (Lavigne et al. 2015). Following the 2010 Merapi eruption, a French non-governmental organisation, CCFD-Terre Solidaire, created a three-dimensional scale relief model for participatory community mapping of the eruption damage as well as the roads and routes utilised by residents to evacuate (Lavigne et al. 2015). For the scientific community, this would translate as a physical model of what a Geographical Information System represents, which is a layering of data. That same digital layering is not familiar necessarily to those in the Ngarmomulyo municipality on the western flank of Merapi, though, and hence the physical model is of far more utility in both obtaining and conveying information with local residents.

3.5.2 The Sacred Axis as Pre-Modern Observation

Data from pre-modern observation of Merapi's behaviour is potentially reflected in the concept

of the sacred axis that connects Merapi to the *kraton* and the Southern Sea. Examination of the volcano-earthquake interaction along the Opak River fault line indicates that the geological phenomena is increasingly frequent in the contemporary context (Walter et al. 2007; Surono et al. 2012). The concept of the sacred axis between Merapi and the sea could be accrued knowledge of local seismic and eruptive events in the past, such as the volcano-earthquake interactions, that are renewing and cyclical (Troll et al. 2015, 2021). Use of this local tradition could help communicate hazards in ways that are understandable and memorable and alleviate a small portion of the friction that can often exist worldwide between government organisations, scientific institutions, and local communities.

A study by Atmojo et al. (2018) of primary school students near Merapi indicates that the inclusion of traditional stories in the educational process can result in quantifiably improved hazards awareness and ability to mitigate simulated volcanic hazards. The study draws upon recent Indonesian educational research focused on incorporating traditional knowledge within science studies (Rusilowati et al. 2015; Andriana et al. 2017; Setiawan et al. 2017). It also adds to recent investigations of how belief systems can aid disaster response and preparedness in Indonesia (e.g. Joakim and White 2015).

Another finding of the Atmojo et al. (2018) study worth highlighting is that some traditional hazard warnings of seismic or volcanic unrest at Merapi—such as the unusual movement of tigers, monkeys, lions, and deer—no longer exist in our current era of biodiversity loss (Fig. 3.1). The acknowledgement of anthropogenic destruction near Merapi requires 'an ethics of dialogue and engagement' (per Schlehe 2010) based not only on local understanding but the global transformations in which they are contextualised. Engaged scholarship should privilege constructions of the world that promote a just, accountable, egalitarian and democratic environmental future (Blaikie 1999; Dove 2008b). Scientific monitoring is very important, but social justice in the face of corruption—particularly in the context of disaster assistance funds that feel more ephemeral than the spirits that live in Merapi's crater for marginal residents—is as well (Dove 2007). In this sense, no less so now as in the past, geological disasters in the Merapi area are highly cultural events and not exclusively natural ones.

3.6 Engagement with Dynamic Pasts and Futures

> The ritual forms that have developed possess deep roots in regional cultures across Indonesia; yet their contemporary importance shows not their timeless authenticity but, rather, their centrality in national projects and their local renegotiations (Tsing 1993).

Traditional beliefs regarding volcanic eruption cannot be seen only as remnants of the past as they are very much entwined in the contemporary world and future interactions. Javanese traditional conceptions, past and present, show a sense of dynamism as opposed to catastrophism. Eruptions were incorporated into Javanese cosmology as opposed to being something unusual or anomalous. An inscription from 824 CE prays for a king's ascent to spiritual merit 'so long as the underground fire breathing hot remains, as the wise see, unsuppressed through the openings which are in its control, so long as the earth remains also, and the Meru inhabited by the gods remains, also, so long as Vrta (Sun) of the sky scatters his own rays' (Sarkar 1971; Newhall et al. 2000). The endemic instability of the Javan environment contributes to a complete inappropriateness of 'environmental management policies based on assumptions of steady-state equilibria' (Lavigne and Gunnell 2006; Dove 2008a). In fact, 'the "normal" state of nature on Java is to be recovering from the last disaster, not equilibrium and repose' (Lavigne and Gunnell 2006). To assume a generalised ecological harmony in the Javanese cosmology is a romanticised western construct of the manifold meanings and experiences that adhere to the volcanic landscape (Schlehe 2008).

A newspaper account of a visit to the new guardian of Merapi describes him in a context of

hawkers selling 'a Pompeiian collection of geological mementoes' such as mini-volcano keychains or postcards of smoking volcanoes (Hodal 2012). The association of Pompeii and Merapi is pertinent to the western perception of the site of Borobudur as a site of nature overwhelming a vulnerable culture. The Merapi area, however, provides a far more complex study area for the intersection of human life and volcanism than this simplistic binary. The same newspaper article cites the new volcano guardian as saying, 'Merapi is really a special mountain with its own special character…. It's difficult to predict even using scientific methods. There are a few natural signs we can look out for, and I can use those, but I'm still quite new at this' (Hodal 2012). Modern volcanology is also a relatively new science, and this rightly prompts caveats such as 'there is currently no reliable method to anticipate whether Merapi will have an explosive event' (Newhall et al. 2000). There is a humility inherent in both of these statements, one from a traditional vantage and one from a scientific vantage, that is healthy. For those who live on Merapi's slopes, the ghosts, spirits, and shamans of *Kejawen* are important for predicting the future behaviour of the volcano but so are technology and scientific data (Bobbette 2018). New studies using samples from Merapi indicate that hydrothermal alteration of andesitic lava domes can lead to explosive behaviour and provide an important addition to real-time hazard assessment (Heap et al. 2019). With continued scientific research and innovative technologies available in the future we will hopefully continue to refine our capacity to forewarn residents on Merapi's flanks of eruption events. Overall, though, it is important to remember that we monitor Merapi, but the volcano simultaneously monitors and watches us (Dove 2010). Study of Merapi is a way of studying human culture and how we interact with the volcano as much as it is the geological world of natural phenomena that occur at Merapi.

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