Source to surface model of monogenetic volcanism: a critical review

I. E. M. SMITH1 & K. NÉMETH2*

1School of Environment, University of Auckland, Auckland, New Zealand
2Volcanic Risk Solutions, Massey University, Palmerston North 4442, New Zealand

*Correspondence: k.nemeth@massey.ac.nz

Abstract: Small-scale volcanic systems are the most widespread type of volcanism on Earth and occur in all of the main tectonic settings. Most commonly, these systems erupt basaltic magmas within a wide compositional range from strongly silica undersaturated to saturated and oversaturated; less commonly, the spectrum includes more siliceous compositions. Small-scale volcanic systems are commonly monogenetic in the sense that they are represented at the Earth’s surface by fields of small volcanoes, each the product of a temporally restricted eruption of a compositionally distinct batch of magma, and this is in contrast to polygenetic systems characterized by relatively large edifices built by multiple eruptions over longer periods of time involving magmas with diverse origins. Eruption styles of small-scale volcanoes range from pyroclastic to effusive, and are strongly controlled by the relative influence of the characteristics of the magmatic system and the surface environment.

Small-scale basaltic magmatic systems characteristically occur at the Earth’s surface as fields of small monogenetic volcanoes. These volcanoes are the landforms produced by explosive and effusive eruptions triggered by the rise of small batches of magma. Their typical occurrence as volcanic fields is the surface expression of a magmatic plumbing system that is spatially dispersed and episodic. Small-scale basaltic volcanic systems are the most widespread form of magmatism on planet Earth (Cañón-Tapia & Walker 2004) (Fig. 1), although they are also the smallest in terms of erupted magma volume. They are often overlooked in the large-scale purview of plate tectonics, although they occur in all of the major tectonic environments, intraplate, extensional and subduction-related (Cañón-Tapia 2016), providing continuous expression of the interaction between the physical–chemical parameters of the rising magma and the external environmental conditions that influence their eruption styles. The temporal record of monogenetic volcano fields is skewed towards younger epochs because their relatively small volumes render them prone to removal from the terrestrial geological record. Further, they are mostly known from the subaerial record because of the relative inaccessibility of small volcano fields in ocean-floor environments.

The last decade has seen a renewed interest in the volcanology, geochemistry, structural and tectonic controls, as well as volcanic hazard and risk studies of small-volume basaltic volcanism. Many studies have been motivated by a need to understand the hazards associated with eruptions, and this is particularly true where volcanic fields are in close proximity to population centres. An example is the Trans-Mexican Volcanic Belt, containing the Chícharo and Michoacán-Guanajuato volcanic fields (Hasenaka & Carmichael 1987; Siebe et al. 2004; Johnson et al. 2008; Erlund et al. 2010; Cebriá et al. 2011), and including the historically active volcanoes Paricutin (1943–52) and Jorullo (1759–74). The Trans-Mexican Volcanic Belt has seen much research, in part due to the opportunity afforded by these historical eruptions, but also because it is an extensive field which poses risks to large population centres including Mexico City (Siebe & Macías 2006). Another area of extensive study is the western USA, where research has been undertaken in the Cima Volcanic Field of California (Dohrenwend et al. 1986; Wilshire et al. 1991; Farmer et al. 1995; Kereszturi & Németh 2016), several small scoria cones and fields in Nevada (Ho 1991; Bradshaw et al. 1993; Bradshaw & Smith 1994; Valentine & Keating 2007; Valentine & Perry 2007; Valentine & Hirano 2010), and the Springerville (Condit et al. 1989; Condit & Connor 1996), San Francisco (Tanaka et al. 1986), Zuni-Bandera (Menzies et al. 1991; Peters et al. 2008) and Geronimo (Menzies et al. 1985) fields of Arizona. Fields in NE China have been the subject of several papers (Hsu & Chen 1998; Zou et al. 2003; McGee et al. 2015), and recently there have been a number of geochemically based studies into the longer-lived Newer Volcanic Province in southern Australia (Jordan et al. 2013, 2015; Boyce et al. 2014, 2015;
Fig. 1. Map of younger than Pliocene monogenetic volcanic fields and other important volcanoes extensively studied in recent years or mentioned in this paper. Please note that this collection is not complete. There are numerous less known monogenetic volcanic fields mostly in Central Asia, along the East African rift systems, Ethiopia, along the Andes (mostly in Chile, Colombia and Argentina) and some in the SW USA not listed in this collection due to incomplete information.
Fig. 1. (Continued) Please note that this map also does not show volcanic fields associated with large island volcanoes of the Azores, Iceland or Hawaii. Yellow stars refer to volcanic fields (VF); red stars show important polygenetic volcanoes associated with numerous small-volume satellite vents commonly cited in monogenetic volcanism literature (mostly from their morphological aspects); and green stars represent iconic monogenetic volcanoes.
Van Otterloo et al. 2014; Blaikie et al. 2015; van Otterloo & Cas 2016).

Studies of small-volume basaltic systems have ranged from covering single centres such as Udo volcano, Jeju Island, Korea (Brenna et al. 2010), Chagwido, Jeju Island, Korea (Brenna et al. 2015), Mt Gambier, Australia (Van Otterloo et al. 2014), and Paricutin, Mexico (Erlund et al. 2010; Cebríá et al. 2011), or several centres in one field such as the two most recent eruptions at the Wudalianchi field in NE China (Zou et al. 2003; Xiao & Wang 2009; Gao et al. 2013; Zhao et al. 2014), and two centres from the Newer Volcanic Province of Australia (Demidjuk et al. 2007), to the scale of a whole field such as, for instance, the west Anatolian Volcanic Field of Turkey (Ersoy et al. 2010, 2012a, b; Ersoy & Palmer 2013), various volcanic fields in Germany (Haase et al. 2004), Hungary (Harangi et al. 2015) and the Czech Republic (Cajz et al. 2009), part of the Central European Volcanic Province (CEVP), and the South Auckland Volcanic Field of New Zealand (Cook et al. 2005), or a whole country or region such as the whole of South Korea (Choi et al. 2006), the whole of New Zealand (Timm et al. 2010) and the whole of NE China (Zhang et al. 1995). Although there are some published theoretical (Takada 1994) and/or experimental studies of monogenetic volcanism (Reiners & Nelson 1998; Hirschmann et al. 2003), they are relatively sparse.

In this paper we review the current state of knowledge of small-scale volcanism from their source in the upper mantle to the eruption characteristics of their surface environment.

The basalt spectrum

Basalts are fundamentally the product of partial melting processes within the Earth, and their compositions are an expression of the temperature and pressure regimes that exist in the outer <150 km of the Earth. Basaltic magmas occur in response to a range of environments within this P–T envelope. Chemical compositions displayed by the basalt spectrum range from strongly Si-undersaturated nepheline (and even more extreme carbonitites) through alkali basalt to silica-saturated tholeiite. The determining parameters of this compositional range are essentially pressure (depth) and temperature (Putirka 2005; Herzberg et al. 2007; Putirka et al. 2007), which in turn constrain the mantle dynamics responsible for melting.

There is a significant positive correlation between the volume of individual magma batches and their position within the basaltic compositional spectrum. Small-volume volcanoes are more alkaline and more Si undersaturated, and larger volume volcanoes are relatively more Si-rich and are less alkaline (McGee et al. 2015). This compositional pattern is readily explained in terms of the ambient parameters within the magma source region, with the nepheline–tholeiite range representing increasing proportions of partial melting (Fig. 2).

Primary magma produced in equilibrium with residual mantle lithologies is identifiable by virtue of its Mg/Fe ratio (usually expressed as the Mg number ([100 × mol MgO]/[mol MgO + mol FeO]) based on the partitioning of Roeder & Emel'ske 1970). However, truly primary magmas are only rarely erupted at the Earth's surface. Overwhelmingly, the chemical composition of basaltic magma reveals that they have experienced some degree of fractionation, mixing and, in some cases, contamination by cognate or exotic (crustal) material.

The compositions of the magmas that leave the melt production zone in the deeper levels of a system are not easily determined due to the effects of multiple shallow-level processes. This is because most volcanic systems are long-lived zones where rising magmas stall, evolve and interact with preceding batches of magma and their solidified or partially solidified equivalents. Relatively primitive magma compositions are more likely to occur in the small-scale basaltic fields of continental environments, which are characterized by sparse infrequent eruptions, rather than in the persistent highly productive systems established at plate margin and intraplate hotspot centres.

Small-scale magmatic systems often erupt basaltic magmas that contain xenoliths of spinel- and garnet-bearing Iherzolite which have equilibrated at pressures and temperatures that lie on the local geotherm (O’Reilly & Griffin 1985; Sutherland et al. 1994). Because the xenoliths are significantly denser than their host magmas, ascent must have been rapid (>10⁻²–10 m s⁻¹) (Spéra 1984; Szabó & Bodnar 1996) and continuous from the depth of xenolith entrapment (Lensky et al. 2006). In these cases, the host magmas have Mg numbers lower than that of primary mantle-derived liquids (Irving & Price 1981; Reay et al. 1991; Camp & Roobol 1992) and so must have undergone some fractionation before entraining their xenoliths. This is consistent with geochemical evidence for magma evolution at high pressures (Smith et al. 2008) and the duplication of evolved magma compositions in crystallization experiments carried out at high pressures (Irving & Green 2008). On the other hand, the petrology and geochemistry of basalts from highly productive systems such as Hawaii, Reunion and Iceland are dominated by the effects of low-pressure fractional crystallization, magma mixing and crystal mush entrainment (Wright 1973; Albarede et al. 1997), together with some deeper crystallization (Putirka et al. 1996; Putirka 1997; Maclean
At the less productive oceanic hotspots of the Azores (Gente et al. 2003) and Canary Islands (Fullea et al. 2015), clinopyroxene–melt barometry and petrographical observations show that magma batches partially crystallize and mix with pre-existing magma batches in a zone of temporary magma storage at near and sub-Moho depths of 15–40 km (Hansteen et al. 1998; Schwarz et al. 2004; Klugel et al. 2005; Galipp et al. 2006; Longpré et al. 2009; Stroncik et al. 2009). Mid-ocean ridges are dominated by fractional crystallization and mixing within shallow (≤7 km) magma chambers or sills (Pan & Batiza 2003), with slower spreading centres fed by dispersed polybaric magma batches that crystallize and evolve at depths of up to 30 km (Herzberg & O’Hara 1998; Herzberg 2004).

These examples serve to illustrate a fundamental aspect of the spectrum of basaltic magmatic systems: that those with relatively high magma production rates evolve by crystallization and mixing at shallow depths, whereas, in less productive systems, magma stalls within a deeper zone of less permanent storage bodies unless ascent rates are sufficient to overcome the gravitational constraints. Clague (1987) and Clague & Dixon (2000) have shown how this spectrum is expressed by the correlated petrogenesis, petrology and volcanic output rates of Hawaiian lavas as the hot centre of the Hawaiian hotspot is approached, over-ridden and then abandoned by the drifting Pacific lithosphere. In summary, the characteristic feature of small-scale basaltic volcanic systems is the relatively simple and dispersed nature of their plumbing systems. The size, depth and longevity of transport, together with the existence of storage areas beneath a volcano, influence the eruptive patterns and the geophysical and geochemical signals associated with volcanic unrest, as well as the complexity of the petrogenetic history that must be revealed in order to constrain the conditions of melt generation that ultimately drive the volcanic system.

**Compositional variations within small-scale volcanoes**

A notable feature of many small-scale volcanic cones is the systematic change in the chemical
compositions of erupting magma during the course of an eruption (Németh et al. 2003; Smith et al. 2008; Brenna et al. 2010, 2011, 2012a; McGee et al. 2012). Rarely, there are examples of volcanic cones that show no compositional variation. Compositional variation has been observed even in very-small-volume cones and in these the systematic variations are often very clearly correlated with stratigraphy. The general pattern is for material erupted early in a sequence to be relatively evolved and for compositions to become progressively more primitive as an eruption progresses. These patterns have been interpreted as due to fractionation of magmas at high pressures close to their source (Smith et al. 2008). In larger volume cones more complicated compositional patterns have been observed (e.g. Brenna et al. 2010) and interpreted as the result of mixing and mingling of discrete melts in the deeper parts of their system. Compositional discontinuities occurring during the course of a monogenetic eruption sequence have also been observed (McGee et al. 2012, 2013) and interpreted as successive partial melting of distinct, but contiguous, source components with differing melting characteristics in a heterogeneous source.

These marked compositional variations displayed within small-volume magma batches are an important feature of small-scale basaltic volcanoes, and are an indication of their close connection with the high-pressure regions of their respective source regions and the rapidity with which magmas rise from these depths.

The monogenetic concept

Small-volume volcanic cones are usefully termed monogenetic and they characteristically occur in volcanic fields. The terms monogenetic and volcano field are to a degree controversial because their defining parameters are imprecise and depend on the perspective of individual researchers. Both terms have been recently reappraised (Németh & Kereszturi 2015; Cañón-Tapia 2016). Here, we discuss the phenomenon of small-scale volcanism in terms of the linked concepts of monogenetic volcanoes, magma batches and volcano fields (Fig. 3).

An established terminology categorizes volcanic systems as monogenetic or polygenetic (Walker 2000). These are useful concepts but suffer from the question of where boundaries that are different in differing areas of investigation may be drawn. In volcanological terms, a monogenetic volcano is one which erupts only once within a defined time period that is recognized as being one in which there is no clear evidence of a temporal break in eruptive activity; the defined time period may be weeks, months, years or, rarely, decades. Observed examples are the scoria cone and associated lava fields of Paricutín (active 1943–52) (Luhr & Simkin 1993; Erlund et al. 2010) or Jorullo (active 1759–74) (Guilbaud et al. 2011) in the central Mexican Volcanic Belt and Mirador, southern Chile (April–May 1979) (Lopez-Escobar & Moreno 1981).

A problem arises because the eruptions of most so-called monogenetic volcanoes were not witnessed, although continuous deposit sequences and the relatively small volumes typical of monogenetic cones strongly support short timescales (Németh 2010; Németh & Kereszturi 2015). In contrast, a polygenetic volcano is one that erupts many times, fed through an established conduit system that has a relatively long lifespan and delivers discrete eruptive phases separated by clear temporal breaks traceable in the erupted sequence (Manville et al. 2009). In concept, the difference between monogenetic and polygenetic volcanoes is one of plumbing (Fig. 3). In monogenetic systems, batches of magma rise quickly to the surface through simple conduit systems with little interaction with the crustal rocks that they encounter on their way. Polygenetic volcanoes result from plumbing systems that involve the development of magma chambers which show complex interactions with surrounding crustal rocks and extensive evolution through crystal fractionation, magma mixing and magma mingling (Fig. 2). One effect of this contrast in plumbing styles is that the magmas of monogenetic systems are relatively primitive (McGee & Smith 2016), reflecting their compositional connection with their mantle sources, whereas magma of polygenetic volcanoes are more commonly chemically evolved through the operation of assimilation and fractional crystallization in crustal reservoirs.

A further concept which is fundamental to monogenetic volcanoes is that of a batch of magma generated in a discrete melting event and with a defined chemical composition (Fig. 3). Typically, monogenetic eruptive sequences show consistent evolutionary development of geochemical trends which can be interpreted as the evolution of a single batch of magma. Less commonly, a magma batch can show little compositional variation. Some eruptive sequences that are clearly monogenetic in terms of their eruptive behaviour can be shown to represent mixing of magmas of consanguineous, but diverse, origin such as documented from Udo Island, South Korea (Brenna et al. 2010). There are also examples of single volcanic structures that have clearly separated eruptive episodes which produced compositionally discrete batches of magma, as revealed from Rangitoto in the Auckland Volcanic Field (Needham et al. 2011). These cases where a more complex plumbing system can be demonstrated mark the transition between geochemically monogenetic volcanoes and geochemically
polygenetic volcanoes, although, from a volcanological perspective, both may be treated as monogenetic (Fig. 3). This is one of the difficulties encountered in applying the term monogenetic.

The distinction between monogenetic and polygenetic is essentially a variable within the spectrum of magmatic systems and one that will have a different definition according to the investigative method.

Further, while individual volcanoes in volcano fields can be described as monogenetic in the sense of representing a temporally restricted period of eruptive activity, the systems of which they are a part may have been active for periods as long as those that develop polygenetic volcanoes (Condit et al. 1989; Connor & Conway 2000; Németh 2010). As an example, the polygenic volcano
Ruapehu in New Zealand evolved to its present state over 300 kyr (Gamble et al. 2003), which is equivalent to the total time span of evolution of the Auckland Volcanic Field (Lindsay et al. 2011) that produced in the same time period at least 53 discrete volcanoes (Kereszturi et al. 2013). Monogenetic volcanic fields in some cases can be long lived and overarch entire geological epochs such as those of the Central European Cenozoic Magmatic System (Ulrchy et al. 2011) or the Western Arabian Cenozoic Volcanic Province (Moufti et al. 2012).

An important aspect of the debate is the rate of magma supply, which can also be thought of in terms of the connection between source and surface (Fig. 3). The volumes of individual magma batches that produce monogenetic volcanic cones are characteristically small (typically <1 km$^3$, commonly <0.1 km$^3$). The compositional features exhibited by monogenetic magma batches commonly show features that relate to source or near-source processes and these indicate rapid rise rates from source to surface. Because of their small volumes, monogenetic magma batches do not retain a connection to their source and essentially represent ‘bubbles’ of rising magma. If they stall in the crust they become un-eruptible with cooling and crystallization. Recent studies have also indicated that the role of magmas that do not reach the surface and represent ‘failed eruptions’ might be important, even in the case of small-volume magmatism (Gudmundsson 2003; Németh & Martin 2007; Taisne et al. 2011; Geshi et al. 2012; Kiyosugi et al. 2012; Friese et al. 2013; Le Corvec et al. 2013a, b; Cañon-Tapia 2014; Re et al. 2015). Growing evidence has also shown that the shallow plumbing system of small-volume volcanoes commonly defined as monogenetic is complex, and magmas exit through an upper conduit linked to various and geometrically complicated networks of pathways (Valentine & Krogh 2006; Valentine et al. 2007, 2011; Geshi et al. 2011; Hintz & Valentine 2012). Such complex plumbing scenarios add complexity to the chemical and architectural evolution of the volcano, even if they are small in volume (Geshi 2000, 2001). Studies of magma-flow movement within the growing small-volume edifice suggest that magma can behave unexpectedly prior to exiting through a vent, leading to the development of complex conduit-crater networks (Petronis et al. 2013; Delcamp et al. 2014).

Over time, a volcanic system that is typically composed of volcanoes that fulfill the monogenetic plumbing criteria and which shows a high magma production rate can gradually produce compositionally more evolved magmas that feed and build architecturally more complex volcanoes that share similarities to polygenetic volcanoes (Fig. 3). There are numerous examples where a long-lived volcanic field (a ‘mature’ field) can, over time, produce more abundant larger volume, geochemically more evolved compositions and architecturally more complex volcanoes. This has been demonstrated in the Trans-Mexican Volcanic Belt (Aguirre-Díaz et al. 2006; Arce et al. 2013), in the western Arabian Cenozoic Volcanic Province (Camp & Roobol 1989; Camp et al. 1991), in several locations in eastern Africa (Franz et al. 1997, 1999) and in the Chaine des Puys in France (Nowell 2008; van Wyk de Vries et al. 2014).

The edifice-building pyroclastic succession of a single monogenetic volcano reflects the changes of eruptive style during the course of an eruption. Such successions are a key to establishing the timing of eruptive events associated with the edifice (Fig. 3). Especially in larger volume volcanoes, these pyroclastic successions are the subject of debates about the monogenetic v. polygenetic origin of the edifice (McKnight & Williams 1997; Sheth 2014). Normally, in a sensu stricto monogenetic volcano, its pyroclastic succession shows a continuous sequence of tephra layers with no evidence to support significant breaks between pyroclastic beds other than normal changes in pyroclastic density current movement, wind-drifted tephra accumulation or erosional surfaces associated with syndepositional remobilization of pyroclasts due to some other non-volcanic sedimentary processes (e.g. sudden mass movement on the wet flank of a growing tephra ring causing syn-eruptive laharc formation) (White 1991; Manville et al. 2009). In either way, such pyroclastic successions show a consistent sequence of pyroclastic beds associated purely with the fluctuation of the relative role of the internal v. external parameters (Fig. 4). In this context, internal parameters are those that are directly associated with the physicochemical nature (e.g. composition, volatile content, its rise speed and rate, and its changes or variations) of the rising magma, while external parameters are those that can affect the magma fragmentation and, hence, the eruption style and the resulting pyroclastic eruptive products (most commonly associated with the availability of external water of any type and its ability to be available in various timescales). Commonly, there is a trend from a typical phreatomagmatic-fragmentation-dominated eruption style towards more magmatic-fragmentation-dominated successions in the course of the eruption of small-volume volcanoes (Lorenz 1987; White 1991), providing late-stage ‘magmatic cap’ (Fig. 5a), intra-crater scoria cone growth in the initial maar/tuff ring crater (Fig. 5b) or gradually filling the maar/tuff ring craters by lava flows (Fig. 5c). The interplay between the internal and external forces acting upon the eruption style of the growing small-volume volcano commonly form eruptive sequences showing
systematic and/or random variations of tephra units associated with the more dominant magma fragmentation styles (Fig. 6). If the eruption takes place as a result of a single eruption of a single magma batch, the pyroclastic successions will show chemical variation patterns associated with either fractionation processes in the tapping magma column en route to the surface or they will show relative compositional homogeneity; such a simple monogenetic volcanic sequence is probably the less common scenario (McGee & Smith 2016).

Most commonly in a small-volume volcanic edifice, the pyroclastic succession shows few distinct horizons commonly marked by ballistic bomb and block layers. These layers can be traced over large areas, and seem to be associated with a volcanic explosive event that was dispersed equally in every direction within a very narrow time period and represent materials that are derived from conduit walls and/or from a degassed magma stalled in the upper conduit or crater. These coarse-grained horizons are typically associated with random

Fig. 4. External v. internal controlling parameters act as ‘competing’ forces to influence magma fragmentation and, hence, the overall architecture of the growing small-volume volcano. On the x-axis of this conceptual diagram, increasing magma volume is shown from right to left and is the fundamental internal force driving volcanic eruptions. On the y-axis, the external forces that influence the magma fragmentation and, hence, the eruption style are marked as the increasing availability (volume) of water to the magmatic system. The external forces can be expressed as a function of external water available, the storage capacity of the aquifers, the hydraulic conductivity, permeability and the surface water availability (a function of climatic conditions). The external forces are heavily dependent on the elevation of the landscape that the magma encounters as higher ground normally has deeper aquifers and/or less potential to capture surface runoff water. In the diagram, two lines separate magmatic-dominated volcanoes (M), mixed-type volcanoes (MIX) and phreatomagmatic-dominated volcanoes (PH). Common types of volcanoes can be distinguished such as: (1) scoria and spatter cones of any size; (2) scoria cones with a thin initial phreatomagmatic base; (3) phreatomagmatic volcanic landform with a thin magmatic cap/infill; (4) well-developed phreatomagmatic landform with a magmatic cap; (5) well-developed phreatomagmatic landform overgrown by a magmatic landform; (6) large well-developed phreatomagmatic landform with a magmatic intra-craterean cone; and (7) various sizes of phreatomagmatic landforms. Note that the red arrows represent a shift of the separating lines of volcano types in the case of high magma flux (mf_high); and orange arrows show the shift of the separating lines of volcano types in the case of low magma flux (mf_low).
Fig. 5. A typical eruption sequence of a small-volume basaltic volcano (Motukorea/Browns Island, Auckland Volcanic Field) (a) that shows some variation of magma rise (juvenile pyroclast volume changes) and the effect of the external water that influences the eruption style (accidental lithic contents). The section is dominated by an initial phreatomagmatic sequence (ph) interbedded with a magmatic-fragmentation-dominated unit (m). In the section, ballistic bombs of accidental lithic fragments caused impact sags (arrows). The entire section is capped by a magmatic capping unit dominated by scoriaceous successions (mc). In addition, random or systematic changes in the upper conduit can trigger vent-clearing events that are commonly associated with some chemical changes as a reflection of the arrival of a new melt batch below (a). A common trend in a small-volume volcanic eruption that finishes with the development of an intra-crater scoria cone (b), such as in Meke Göllü (Meke Lake) in Anatolia’s Karapinar Volcanic Field, or lava spatter cone growth with intra-crater lava infill, such as La Breña maar in the Durango Volcanic Field in Mexico (c).
conduit collapse events but they also can be associated with a systematic movement of the explosion locus along a fissure (Sohn & Chough 1989; White & Ross 2011; Graettinger et al. 2015). In either way, the presence of such horizons can reflect conduit dynamic processes along and across the feeding dyke involved in the eruption (Ross & White 2006; Barnett et al. 2011; Geshi & Oikawa 2014). Commonly, such horizons can also be associated with a slight change in the chemical compositions of the juvenile pyroclasts above such a horizon, reflecting the arrival of a new magma batch that triggered the excavation (Brenna et al. 2011, 2015). In such cases, the initial explosion breccia horizons can contain evidence of syn-eruptive erosion, mud draping or clast rearrangement on the millimetre–decimetre scale, or even erosion events, as in falls of condensed water onto the growing edifice flanks.

Because feeding dykes are commonly blade-like in form and follow fissures (as demonstrated by the presence of a row of craters in many settings), the lithological and, hence, the hydrogeological variations along a fissure (over length scales of hundreds of metres) can cause significant lateral variations of eruption style and strikingly different eruptive products along the fissure, which provides an ‘impression’ that the growing volcanic edifice is complex and has departed from a sensu stricto ‘monogenetic’ nature (Fig. 6). In small magmatic volumes, the relative influence of external parameters on the resulting volcanic edifice structure and their pyroclastic succession can be characteristic (Fig. 7). For larger magma volumes, the effect can be difficult to identify as later eruptive products may completely cover any sign of earlier events (Fig. 7).

Volcano fields
The low rates of magma production that lead to the development of volcano fields rather than single large cones may be due to tectonic setting (Hase-naka & Carmichael 1985; Takada 1994), but this is a complex question. Some volcano fields are found in purely subduction-related, extensional or intraplate settings worldwide (Connor & Conway 2000; Petrone et al. 2003), while others are found in extensional settings near to active arcs, such as in the Cascades of the western USA (Leeman & Bonnichsen 2005; Leeman et al. 2005; Muffler et al. 2011), or in intraplate settings that are gently rift due to the occurrence of plume-like upwelling, such as in the Central European Volcanic Province (Haase & Renno 2008). Volcanic fields can also be found in association with large stratovolcanoes, as in southern Chile (Lopez-Escobar et al. 1995; Cembrano & Lara 2009), across Indonesia (Carn 2000), Changbaishan in NE China (Liu et al. 2009) and Mexico (Siebe et al. 2004; Schaaf et al. 2005;
Sieron et al. (2014), suggesting complex underlying plumbing systems. Large volcanic islands such as Hawaii (Wood 1980), Samoa (Savaii and Upolu) (Németh & Cronin 2009b), Miyakejima (Japan), Ambae (Vanuatu) (Németh & Cronin 2009a), Ambrym (Vanuatu) (Németh & Cronin 2011) or Tenerife (Kereszturi et al. 2012) are commonly associated with rift-aligned zones of small-volume volcanoes grown over the basal lava shields. There are large variations in fundamental parameters such as the size of the area covered by the field, the number of individual volcanoes, and their size and chemical composition. Delineating a volcanic field can be an easy task using statistical methods to define the time and spatial distribution of vents within a field; however, overlapping, amalgamated or long-lived volcanic fields can cause difficulties when describing their areal distribution (Condit et al. 1989; Connor 1990; Bishop 2007; von Veh & Németh 2009; Bohnenstiehl et al. 2012; Howell et al. 2012; Di Traglia et al. 2014; Runge et al. 2015). Many fields have unique characteristics, such as the existence of polygenetic centres preceding the formation of a dispersed network of monogenetic centres, for instance those at Higashi-Izu in Japan (Hasebe et al. 2001), or the presence of flood basalt eruptions preceding the formation of the monogenetic centres in Yemen (Baker et al. 1997). There are some attempts to visualize the spatial distribution of volcanic fields: however, such attempts always run into difficulty when choosing the right selection criteria and the right scale to show volcanic fields (Cañón-Tapia & Walker 2004; Conrad et al. 2011; Kereszturi & Németh 2012a; Cañón-Tapia 2016). As volcanic fields are always evolving and their location follows geotectonic changes (Condit et al. 2011), probably the best way to show their geographical location is to select time slices, such as the younger than Pliocene ages shown on the set of figures in Figure 1.

In other more complex systems, the presence of a range of basaltic compositions and of intermediate and felsic compositions (e.g. benmoreite, trachyte, phonolite) is evidence of compositional modification during transit to the surface.

The tectonic setting, as well as the local or regional stress field, appear to be important factors in the genesis and form of some volcanic fields (Le Corvec et al. 2013a), and in fact may govern whether polygenetic or monogenetic structures are formed (Takada 1994; Bucchi et al. 2015). The position of the volcanic arc in Mexico is thought to cause the shift from polygenetic to monogenetic volcanism from north to south (Connor 1987). The evolution of some volcanic fields has been linked to tectonic plate movement, such as in the San Francisco Volcanic Field (Arizona) where volcanism is thought to migrate with the westwards movement of the North American Plate (Tanaka et al. 1986). In other cases, small-volume dispersed volcanism shows random distribution with no obvious trend associated with inferred plate motions. However, their occurrence is more likely to be associated with sudden changes in the ‘topography’ of the lithosphere asthenosphere boundary, as has been demonstrated from the Pannonian Basin in central
Europe (Harangi et al. 2015). Tectonic setting and structure has also been implicated as the cause of small-volume magmatism in some volcanic fields, such as the edge-driven convection model of Demidjuk et al. (2007) for the Newer Volcanic Province (SE Australia) where a lithospheric step is thought to cause the upwelling required to stimulate melting. A similar idea to this is invoked for the Zuni-Bandera Volcanic Field of New Mexico, where changes in lithospheric thickness beneath the field are linked to changes in the melting processes (Peters et al. 2008). On a local scale, the distribution of volcanic cones within a field can reflect the orientation of faults (Muffler et al. 2011).

The geochemical character of monogenetic volcano fields is in part related to their specific tectonic setting, and includes intraplate (e.g. eastern Australia, western North America and northern New Zealand), extension (e.g. central Europe and Arabia) and subduction-associated (e.g. Mexico, USA, Argentina) settings. Important underlying factors for the development of monogenetic volcanic systems are small magma volumes, episodic eruption of discrete magma batches and a crustal environment that allows the passage and escape of small magma volumes through the crust.

Volcanic fields can form in a range of surface areas from few tens of square kilometres to over 1000 km² area, within which there may be a few to more than a hundred volcanoes (Connor & Conway 2000). The vent distribution in a dispersed volcanic field has been a common subject of studies intended to establish a temporal–spatial vent evolution concept within a single volcanic field (Le Corvec et al. 2013b). There are volcanic fields in which vents show a marked alignment normally associated with faults such as the Chaîne des Puys in France (Boivin & Thouret 2014; Lutz 2014). The vent alignments can, hence, reflect older underlying structural elements that might have been rejuvenated in the course of the volcanism, as argued for many cases in vent distributions over old continental lithospheric regions (Mazzarini & D’Orazio 2003). There are volcanic fields where vents instead form clusters, and it has been suggested that they represent the surface expressions of narrow ‘mantle fingers’ (Tamura et al. 2009), and there are volcanic fields where vents show random distribution and where any link to structural elements is difficult to establish (Condit et al. 1989).

Monogenetic volcanism in non-basaltic settings

The typical expression of monogenetic magmatism is the development of fields of small volcanoes (pyroclastic cones, maars, lava domes or explosion craters) on widely varying spatial and temporal scales. The range of chemical compositions represented in these fields is most commonly in the basaltic spectrum – nepheline–basanite–alkali basalt–tholeiite (e.g. the Eifel volcanic fields) (Duda & Schmincke 1978; Schmincke et al. 1983; Ali et al. 2013; McGee & Smith 2016), rarely highly alkaline (e.g. along East Africa: the Meidob Hills and the Bayda Volcanic Field) (Rosenthal et al. 2009) and carbonatitic compositions (e.g. the Calatrava Volcanic Field) (Kurszlaukis & Lorenz 1997; Bailey et al. 2005; Stoppa & Schiazzia 2013; Campeny et al. 2014), and, in subduction-related fields, basaltic andesite (Maro & Caffé 2016a; Rasoazanamparany et al. 2016). Less commonly evolved compositions in the phonolite–trachyte–ryholite compositional range occur, usually within spatially limited parts of volcano fields, at later stages in their evolution and where thicker crust is present, such as those fields in the Arabian Peninsula (Fig. 8a) (Camp & Roobol 1989; Camp et al. 1991). Evolved silicic compositions are also found independently of basaltic volcanic fields in some continental settings. Typically evolved silicic compositions occur as dome complexes or pyroclastic cones, such as those across Mexico or central Anatolia (Fig. 8b, c) (Riggs & Carrasco-Núñez 2004; Zimmer et al. 2010; Carrasco-Núñez et al. 2012; Aydin et al. 2014).

There are very few systematic studies which connect the magmatic plumbing system of silicic magmas and their volcanic architecture in a monogenetic context (Brenna et al. 2012b; Ridolfi et al. 2016). This is partially because small and short-lived silicic volcanoes are commonly associated with large and long-lived volcanic systems, and commonly represent a less important fraction of the total system. This concept, however, needs some revision as small monogenetic silicic volcanoes are more common and their eruption occurrence more frequent than is generally appreciated, and they can play an important role in the overall volcanic hazard scape in large and complex volcanic systems. Small silicic volcanoes that form lava domes and/or small explosion craters (maars or just small silicic edifices) are common features in association with large caldera networks, such as those of the Taupo Volcanic Zone in New Zealand (Houghton et al. 1991; Cole et al. 2010, 2014). Among these small volcanoes, some are very young ones and show clear evidence of short eruption durations and are well below the 1 km³ eruptive volume (such as the 14 kyr-old Puketerata tuff ring and dome near Taupo in New Zealand: Fig. 8d) commonly used as a proxy to argue for their monogenetic nature (Brooker et al. 1993; Stevenson et al. 1994; Druitt et al. 1995; Kazanci et al. 1995; Bursik et al. 2014; Dennen et al. 2014; Moufti & Németh 2014).
There are at least two major groups of non-basaltic volcanoes that can be viewed as monogenetic: (1) volcanoes that erupt in continental settings through thick continental crust, such as those in western Arabia (Camp et al. 1991); and (2) volcanoes that, in some degree, show an association with a shallow magma source feeding large-volume, commonly caldera volcanism, such as the Long Valley Caldera (Hildreth 2004) (Fig. 6). A typical scenario for this later group of small volcanoes are those that are fed by a small-volume melts released between major caldera-forming events and inferred to be fed from the same major magmatic sources associated with the main complex and polygenetic volcanic network. Those volcanoes that clearly show an individual feeding network that taps the deeper zones of a magmatic system seem to be associated with volcanic fields that were active over a long time, allowing the capture of magma in the thick crust and its evolution to more silicic compositions. Here, we suggest that in spite of the different magmatic plumbing system associated with these volcanoes, the result on the surface can be very similar in terms of their volcanic architecture. The

Fig. 8. Non-basaltic monogenetic volcanoes: (a) trachytic lava dome (Dabaal Al Shamali) next to a small explosion crater surrounded by a thin tephra ring (Gura 1) from the Harrat Rahat in Saudi Arabia; (b) rhyolitic/rhyodacitic lava dome field near the Erciyes volcano; (c) rhyolitic/rhyodacitic lava dome in a maar/tuff ring of Acigöl in Cappadocia, Turkey; and (d) the 14 kyr-old Puketerata rhyodacitic tuff ring and lava dome.
separation of these volcanoes from other volcanoes with long-lived and stable feeding systems is important not only from a volcanic hazard perspective in young volcanic regions, but also from mineral exploration aspects in older settings where the edifices might be largely removed due to erosion and there is access to their upper conduit zones commonly associated with mineralization. The facies architecture of such exposed plumbing systems of non-basaltic monogenetic volcanism is the key to understanding the overall magma-release processes through individual magma-feeding networks that operate under small supply volume conditions. This situation is clearly different from those systems that have a driving mechanism associated with a larger volume magma supply, and a broader and more interconnected plumbing network that can retain heat long enough to generate heat to drive a geothermal mineralization system.

**Eruption style variation: the ‘competition’ between the magmatic system and the environment**

The style of volcanic eruptions in small-volume monogenetic volcanic fields is strongly dependent on the relative influence of internal magmatic (e.g. magmatic volatiles, chemical composition and viscosity) and environmental factors (e.g. the presence of external water, host sediment physical conditions and fractures) (Németh 2010; Németh & Kereszturi 2015). Essentially, this can be expressed as a ‘competition’ between the magmatic system and the near-surface environment encountered by the rising magma (Fig. 4). In most cases, the volumes of magma batches that feed monogenetic volcanoes are well below 1 km³ (closer to 0.01 km³), and the balance between magmatic and environmental factors can be very sensitive (Kereszturi et al. 2013, 2014).

In a very simplified model, if magmatic volumes are larger (i.e. increasing heat and potential energy ‘stored’ in the rising magma), the system can overwhelm the external environment to produce a dominantly magmatic eruption, and typically Hawaiian–Strombolian eruption styles constructing spatter and scoria cones (Kereszturi & Németh 2012a; Kereszturi et al. 2014). For smaller magma volumes, and potentially lower magmatic flux and therefore eruption rates, external environmental factors will dominate the course of the volcanic eruptions to produce phreatomagmatic eruption styles and associated pyroclastic deposits (Kereszturi et al. 2014). The systematic nature of these processes is commonly observed in the basal pyroclastic succession of monogenetic cones (Fig. 5a). In the initial pyroclastic succession of cones that were produced in an environment where a minimal amount of external water (surface or fracture stored) was available, a thin (metre scale as a maximum) phreatomagmatic pyroclastic deposit always appeared (Murcia et al. 2015) (Fig. 7). Similarly, if the magma supply rate drops, a short-lived phreatomagmatic blast can produce a thin pyroclastic deposit indicating that the eruption style has changed due to changes in the magma rise rate and the access of external water to the rising magma. These processes can leave a dominant textural feature in the pyroclastic succession that may give an impression of major changes in the eruption; however, these changes were caused only by the subtle interaction between the external and internal controlling parameters of the eruption.

Changes in the magma rise rate, magma volume and environmental conditions causes changes in eruption style, leading to cyclical activity patterns. Such trends have recently been documented in a number of volcanic fields (Martin & Németh 2005; van Otterloo et al. 2013; Agustin-Flores et al. 2014, 2015). For example, in the Auckland Volcanic Field in New Zealand, magma volumes vary by orders of magnitude (0.01–1 km³) and there are widely variable conditions of water availability, and as a result there is a wide range of eruption styles in contrast to volcano fields which occur in relatively dry conditions or where magma volumes are larger (Kereszturi et al. 2014). Low magma volumes and the availability of near-surface water in the Auckland Volcanic Field have played a major part in determining eruption styles, and as a consequence about 75% of the volcanic cones were initiated by a significant explosive phreatomagmatic eruptive phase (Kereszturi et al. 2014). Recent studies imply that the relative influence of the magma system and environmental factors can be calculated and integrated into a relatively simple numerical model that can be viewed as the eruption style formula of this specific field (Kereszturi et al. 2017); similar expressions can be derived for other monogenetic magmatic systems.

The environmental influence on a monogenetic volcanic eruption can fundamentally change the potential volcanic hazard from a relatively moderate explosive eruption style that can require a particular type of response to a more violent, phreatomagmatic style that requires a quite different response (Lorenz 2007; Németh et al. 2012). The interplay between the internal v. external parameters that influence the eruption style of small-volume volcanoes can also vary over longer time periods. Typical volcanic fields with more than a dozen volcanic edifices commonly formed over tens of thousands to millions of years, such as the Wudalianchi in NE China which has 14 volcanoes in the past 2.1 myr (Gao et al. 2013). However,
there are also volcanic fields that formed over tens of millions of years but in these there are generally clearly defined periods of eruptive activity: for example, many of the mature volcanic fields in the Arabian Peninsula (Camp & Roobol 1992; Moufti et al. 2012) or in Australia (Boyce 2013).

The consequences of a long lifespan of a monogenetic volcanic field is that the eruption styles preserved in the geological record can carry important information on the environmental conditions that prevailed during the time frame of the field. Climate changes can provoke changes in the surface and subsurface hydrogeology of a region, and this is one of the single most important external factors that can influence the eruptions style. For example, this has been demonstrated in the Bakony–Balaton Highland Volcanic Field in Hungary, a basaltic intraplate field that produced at least 35 volcanic edifices over a nearly 6 myr time period between 8 and 2.3 Ma (Wijbrans et al. 2007); volcanoes dominated by phreatomagmatism are clearly more abundant at a time when palaeoclimatic data indicate more humid and wet periods (Kereszturi et al. 2011). Similar trends have also been suggested from the Trans-Mexican Volcanic Belt (Siebe 1986) and from the Arabian Peninsula (Moufti et al. 2015). While these ideas are logical, so far no systematic studies have been carried out in other fields with longer time spans.

Similarly several studies have demonstrated a potential link between wet periods characterized by saturated subsurface aquifer conditions and more environmentally dominated eruption styles (Siebe & Salinas 2014; Kshirsagar et al. 2015, 2016). Some workers have suggested the influence of large pluvial or inland lakes where basaltic magma rise is ongoing over millions of years. Such a situation has been demonstrated along the western Snake River, where shallow subaqueous volcanoes formed along the margins of a large inland lake (Godchaux & Bonnichsen 2002). With a reduction in the surface area of the lake, the younger Surtseyan volcanoes tend to be confined more towards the present-day axis of the modern western Snake River (Godchaux et al. 1992; Brand & White 2007). Palaeolake-level changes and their influence on the eruption styles of rising magma has also be recorded along Lake Kivu, where the location of Surtseyan and phreatomagmatic volcanoes seems to correlate well with the changing location of the palaeoshoreline of the lake (Capaccioni et al. 2003; Ross et al. 2014, 2015). Similar examples have been reported from Anatolia (Keller 1975) and in several intra-mountain basins in the Basin and Range region of the western USA (White 1990, 1996). It is very likely that the influence of large lacustrine basin evolutions in Central Asia, North Africa and across the Arabian Peninsula influenced the style of volcanism: however, so far, systematic studies have not been performed in this regard.

**Volcanosedimentary response and preservation potential**

Monogenetic volcanic fields are composed of individual small-volume volcanic edifices, each with a relatively simple upper conduit–crater–vent system, that are normally spaced from each other at distances longer than their edifice base diameter. The small volume of magma involved and the variable external conditions influence the style of eruption and determine the variety of associated eruptive deposits. Where magma volumes are low and environmental conditions wet, phreatomagmatic eruption styles may prevail over the entire duration of the growth of a single volcano. Such explosive eruptions are expected to produce tephra deposits extending over several tens of kilometres from their source. In spite of the low magma volume, such volcanoes can produce reasonable-sized volcanic edifices because of the relatively large volume of country rock that is ‘recycled’ as non-volcanic pyroclasts (Németh et al. 2012). In such environmentally controlled eruptions, the ‘footprint’ of each cone is relatively large and tephra deposits relatively extensive (Németh et al. 2012). While these tephra blankets are normally thin and their preservation potential low, the volcanic field will be dominated by large numbers of depressions (craters) that then can act as small sedimentary basins to ‘harvest’ ash from other sources (White 1991). Such volcanic fields can quickly lose their volcanic appearance due to vegetation cover and extensive erosion of the relatively small volcanic edifices. If a volcanic field is active over a long time and the magma production rate large, the sedimentary contribution to the terrestrial record can be significant and may be preserved for a longer time as part of the continental sedimentary successions (Manville et al. 2009; Martin-Serrano et al. 2009).

The preservation potential of the volcanic eruptive products of phreatomagmatic-dominated volcanic fields is unknown in the long term. While craters are excellent sites to host tephra records, commonly the only record of the existence of such volcanic fields in the geological past is the exposed diatreme associated with maar volcanoes. The information that can be gained from diatremes is, however, restricted to the understanding of the individual volcano and cannot be used for correlative purposes to refine the eruption history of the volcanic field as a whole (White & Ross 2011). In addition, because diatremes are pyroclast-accumulation zones where individual explosive events excavated and recycled pyroclasts, it is a significant challenge to establish...
the original eruptive volume of the volcano and, hence, establish its fundamentally monogenetic origin (White & Ross 2011). This problem has recently been demonstrated through careful examination of some kimberlite-bearing diatremes and other mafic diatremes (Kurszlaukis & Fulop 2013; Fulop & Kurszlaukis 2014). In eastern Germany, some diatremes recorded eruptive products found to be millions of years apart, apparently hosted in the same narrow and well-defined pipe-like features normally interpreted to be the result of a single monogenetic volcanic eruption under wet—environmentally controlled—conditions (Suhr & Goth 2009; Buechner et al. 2015). A similar scenario has also been recorded in several kimberlite pipes, where clear geochemical, age and textural evidence showed that a single pipe can host multiple ‘zones’ formed in separate events in a kind of a compound monogenetic scenario (Kurszlaukis & Barnett 2003; Barnett 2008). It seems that, for some reason, these pipes functioned as volcanic conduits for successive monogenetic eruptive events separated by long time periods, commonly reaching the range of the total lifespan of the entire volcanic field they belong to.

It appears that there are a large number of phreatomagmatic-dominant monogenetic volcanic fields, especially in coastal areas, large intracontinental lacustrine basins or just in well-drained areas with a good groundwater network. Although such conditions favour phreatomagmatism in the evolution of the volcanic field, it is rare that there is no variation in the eruption style from volcano to volcano across the field. If the volcanic field operates with elevated magma output rates and potentially higher magma flux rates, most of the volcanoes of the field, even if they have dominantly phreatomagmatic early phases, reach purely magmatic explosive and/or effusive conditions in their later stages. Such cases have recently been demonstrated from the Auckland Volcanic Field in New Zealand (Kereszturi et al. 2014).

Volcanic fields where the eruptions are dominated by magmatic (dry) conditions are composed of numerous scoria and spatter cones, and lava flows and fields. The pyroclast-preservation potential of such fields can be long in arid conditions; however, in humid climates, such cones can vanish over tens of thousands of years. It is inferred that degradation of scoria cones follows a regular pattern: hence, such cones can be used for relative age dating (Wood 1980; Fornaciai et al. 2012). However, recent studies demonstrated that such methods need to be treated carefully as the syn-eruptive processes might have a larger impact on the cone architecture and their degradation than it is commonly thought (Kereszturi et al. 2012; Kereszturi & Németh 2012b).

**Conclusion**

The concept of monogenetic and polygenetic volcanoes is usefully applied to the spectrum of volcanic systems from small to large. Monogenetic volcanoes are defined by small magma volumes, short eruptive periods and dispersed plumbing, although the magmatic systems to which they belong may be long lived. The characteristic expression of monogenetic volcanic systems is as fields of small volcanic cones.

An important feature of basaltic monogenetic volcanic systems is that observed patterns of compositional variation are commonly linked to differentiation processes that have occurred at high pressures close to their sources or to differential partial melting in their mantle sources. This illustrates the close link between magma sources and the eruption of magma at the Earth’s surface, which points to rapid rise rates and little interaction with the rocks through which the magma rises – an important distinction from polygenetic systems.

There is a clear separation of monogenetic systems from the basalt-dominated volcano fields which are linked to deep hot mantle sources and fields where there are significant amounts of evolved compositions that are related to processes operating at crustal depths. Small-volume volcanoes with a significant proportion of evolved compositions are related to systems which have a high magma supply rate where magmas have stalled within the crust and fractionation processes have led to the evolved compositions. These volcanoes represent a transition towards the complex edifices that characterize polygenetic volcanic systems.

An important concept that links the nature of the magmatic system to the environment in which magmas erupt at the Earth’s surface is one of a competition between the rising magma and the nature of the eruptive environment. Where the system dominates, magmatic eruption styles (Hawaiian, Strombolian, effusive) create scoria cones and lava flows in what can be termed ‘dry’ conditions. In contrast, where the environment dominates and the availability of water profoundly influences the behaviour of erupting magma, eruption styles are dominated by phreatomagmatism, and the production of tuff cones, tuff rings and maars.

Small-scale magmatic systems, commonly expressed at the surface of the Earth, represent the rise of small-volume batches of magma into spatially restricted domains. Although individual magma batches are small, this is the most widespread form of volcanism on Earth. The monogenetic volcanoes which are a feature of such systems provide a unique window into processes in the upper mantle that give rise to magmas. Further understanding their behaviour underpins hazard
scenarios where human activities impinge on their existence.

A snapshot of current advances in research on monogenetic volcanism

Small-scale volcanic systems expressed at the Earth’s surface as fields of small volcanoes are the most widespread form of volcanic activity on the planet. Because individual volcanoes in these fields are typically formed during a temporally restricted period of time, the term monogenetic has become a useful descriptor for this type of volcanism, although it is not one that is universally accepted. Monogenetic volcanism has received a lot of attention in recent years, partly because the small scale of their associated magmatic systems enables the preservation of unique petrological features and provides a ‘window’ into the processes that produce their magmas, because the details of their volcanic processes are readily interpreted and also because, despite their small scale, there is a realization that many communities worldwide are vulnerable to the effects of future volcanic activity.

This Special Publication has arisen from the activities and discussions at workshops and conferences during recent years, including the International Maar Conferences, the commemorative 250 year anniversary on the Jorullo scoria cone eruption, various thematic sessions on monogenetic volcanism offered in major volcanological congresses such as the International Association of Volcanology and Chemistry of the Earth’s Interior Scientific Assembly, the General Assemblies of the International Union of Geodesy and Geophysics, the Geomorphological World Congresses, the American Geophysical Union meetings, and several regional workshops. This volume is not intended as a comprehensive volume on the nature of monogenetic volcanism but, rather, is a snapshot of the current state of research into this important type of volcanic activity. The diverse nature of research into monogenetic volcanism during the past decade, together with the far-reaching outcomes that have resulted, demonstrates that a unified definition and understanding of the processes that drive monogenetic volcanism is not yet available.

In this introductory chapter we have reviewed the current state of understanding of the chemistry and volcanology of monogenetic volcanic fields. The following chapters deal mainly with the volcanological aspects of monogenetic volcanism, the way that volcanic cones grow through various eruptive processes (Bemis & Ferencz 2017; Lorenz et al. 2016) and the relationships that these have to the immediate underlying conduit (Kurszlaukis & Lorenz 2016).

An important aspect of the study of monogenetic volcanic systems has been the way that an understanding of their behaviour has been built on detailed studies of systems in widely dispersed localities and in a wide variety of geological and tectonic environments. Much of this volume has been devoted to presenting the current perspective of volcanism in different parts of the world. Cas et al. (2016) and Murcia et al. (2016) describe regional-scale studies of the western Victorian (Australia) province and the northern part of Harrat Rahat in Saudi Arabia. Fulop & Kurszlaukis (2016) present the results of a study of a kimberlite pipe in Ontario, highlighting the complexity of a kimberlite pipe reflecting the potential rejuvenation of volcanism in the exact same location and producing texturally and chemically complex diatremes. There follows chapters on several small-scale monogenetic fields in Mexico (Alvarez et al. 2017a, b; Aranda-Gómez et al. 2016; Saucedo et al. 2017), Argentina (Báez et al. 2016: Maro & Caffe 2016b) and Colombia (Borrero et al. 2016). These serve as an illustration of the importance of individual studies in different settings from around the world.

This paper is result of discussions with many colleagues across the globe. Discussion sessions during the past and recent International Maar conferences were particularly stimulating. Many aspects of the researches resulted in this review were funded by various agencies such as the Massey University Research Funds (2016), and New Zealand National Hazard Platform Project. Reviewers’ comments by Xavier Bolos and Philip T. Leat were greatly appreciated.

References

Aguirre-Diaz, G.J., Jaimes-Viera, M.D.C. & Nieto-Obregon, J. 2006. The Valle de Bravo volcanic field: geology and geomorphometric parameters of a quaternary monogenetic field at the front of the Mexican volcanic belt. In: Siebe, C., Macias, J.L. & Aguirre-Diaz, G.J. (eds) Neogene–Quaternary Continental Margin Volcanism: A Perspective from Mexico. Geological Society of America, Special Papers, 402, 139–154.

Agustin-Flores, J., Németh, K., Cronin, S.J., Lindsay, J.M., Kereszturi, G., Brand, B.D. & Smith, I.E.M. 2014. Phreatomagmatic eruptions through unconsolidated coastal plain sequences, Maungataketake, Auckland Volcanic Field (New Zealand). Journal of Volcanology and Geothermal Research, 276, 46–63.

Agustin-Flores, J., Németh, K., Cronin, S.J., Lindsay, J.M. & Kereszturi, G. 2015. Shallow-seated explosions in the construction of the Motukorea tuff ring (Auckland, New Zealand): evidence from lithic and sedimentary characteristics. Journal of Volcanology and Geothermal Research, 304, 272–286.
ALBAREDE, F., LUITIS, B. *et al.* 1997. The geochemical regimes of Piton de la Fournaise volcano (Reunion) during the last 530 000 years. *Journal of Petrology*, **38**, 171–201.

ALL, S., NTAFLOS, T. & UPTON, B.G.J. 2013. Petrogenesis and mantle source characteristics of Quaternary alkali mafic lavas in the western Carpathian–Pannonian Region, Slovakia, Austria. *Chemical Geology*, **337**, 99–113.

ALVAREZ, R., CORBO CAMARGO, F. & YUTSIS, V.V. 2017a. Geophysical modelling of Isla Isabel: a volcanic island on the Mexican continental margin. In: NÉMET, K., CARRASCO-NÚÑEZ, G., ARANDA-GÓMEZ, J.J. & SMITH, I.E.M. (eds) Monogenetic Volcanism. Geological Society, London, Special Publications, **446**. First published online March 3, 2017, https://doi.org/10.1144/SP446.13

ALVAREZ, R., CORBO CAMARGO, F., YUTSIS, V.V. & ARZATE, J.A. 2017b. A volcanic centre in Mexico’s Pacific continental shelf. In: NÉMET, K., CARRASCO-NÚÑEZ, G., ARANDA-GÓMEZ, J.J. & SMITH, I.E.M. (eds) Monogenetic Volcanism. Geological Society, London, Special Publications, **446**. First published online September 29, 2016, https://doi.org/10.1144/SP446.1

ARANDA-GÓMEZ, J.J., CÉRCA, M. *et al.* 2016. Structural evidence of enhanced active subsidence at the bottom of a maar: Rincón de Parangueo, México. In: NÉMET, K., CARRASCO-NÚÑEZ, G., ARANDA-GÓMEZ, J.J. & SMITH, I.E.M. (eds) Monogenetic Volcanism. Geological Society, London, Special Publications, **446**. First published online December 15, 2016, https://doi.org/10.1144/SP446.10

BOYCE, J. 2013. The Newer Volcanic Province of southeastern Australia: a new classification scheme and distribution map for eruption centres. *Australian Journal of Earth Sciences*, **60**, 449–462.

BOYCE, J.A., KEAYS, R.R., NICHOLLS, I.A. & HAYMAN, P. 2014. Eruption centres of the Hamilton area of the Newer Volcanics Province, Victoria, Australia: pin-pointing volcanoes from a multifaceted approach to landform mapping. *Australian Journal of Earth Sciences*, **61**, 735–754.

BOYCE, J.A., NICHOLLS, I.A., KEAYS, R.R. & HAYMAN, P.C. 2015. Variation in parental magmas of Mt Rouse, a complex polymagmatic monogenetic volcano in the basaltic intraplutonic Newer Volcanics Province, southeast Australia. *Contributions to Mineralogy and Petrology*, **169**, 11.

BRADSHAW, T.K. & SMITH, E.I. 1994. Polygenetic quaternary volcanism at Crater Flat, Nevada. *Journal of Volcanology and Geothermal Research*, **63**, 165–182.

BRADSHAW, T.K., HAWKESWORTH, C.J. & GALLAGHER, K. 1993. Basaltic volcanism in the Southern Basin and Range – no role for a mantle plume. *Earth and Planetary Science Letters*, **116**, 45–62.
tapping vertically separated mantle source regions, genetic eruptions similar to 200 kyr apart driven by Smith. Lithos. cano growth, Jeju Island Volcanic Field, Korea. persed magmatic system and its implications for vol-

ting. California: description, interpretation and implications for the most recent eruption in the Southern Mono Craters, Earth Sciences Journal of Volcanology and Geothermal Research with coeval and nearby polygenetic volcanism in an Carran-Los Venados volcanic field and its relationship the Lausitz Volcanic Field. International Journal of dome-building eruption – Puketarata tuff ring, Taupo .

activity at a monogenetic volcano, Udo, Jeju Island, Research Journal of Volcanology and Geothermal Idaho. phy of phreatomagmatic deposits at the Pleistocene Arabian continental alkali basalt province; Part II. 104, 2057–2083. Bursik, M., Sieh, K. & Melztner, A. 2014. Deposits of the most recent eruption in the Southern Mono Craters, California: description, interpretation and implications for regional marker tephas. Journal of Volcanology and Geothermal Research, 275, 114–131. Caju, V., Rapprich, V., Erban, V., Pecskay, Z. & Radon, M. 2009. Late Miocene volcanic activity in the Ceske stredohori Mountains (Ohre/Eger Graben, northern Bohemia). Geologica Carpathica, 60, 519–533. Camp, V.E. & Roobol, M.J. 1989. The Arabian continental alkali basalt province; Part I. Evolution of Harrat Rahat, Kingdom of Saudi Arabia; with Suppl. Data 91-06. Geological Society of America Bulletin, 103, 363–391. Campeny, M., Mangas, J., Melgarejo, J.C., Bambo, A., Alfonso, P., Geron, T. & Manuel, J. 2014. The Catanda extrusive carbonatites (Kwanza Sulf, Angola): an example of explosive carbonatic volcanism. Bulletin of Volcanology, 76, 818. Caño-Tapia, E. 2014. Volcanic eruption triggers: a hierarchical classification. Earth-Science Reviews, 129, 100–119. Caño-Tapia, E. 2016. Reappraisal of the significance of volcanic fields. Journal of Volcanology and Geothermal Research, 310, 26–38. Caño-Tapia, E. & Walker, G.P.L. 2004. Global aspects of volcanism: the perspectives of ‘plate tectonics’ and ‘volcanic systems’. Earth-Science Reviews, 66, 163–182. Capaccioni, B., Vaselli, O., Santo, A. & Yalire, M. 2003. Monogenic and polygenetic volcanoes in the area between the Nyiragongo summit crater and the Lake Kivu shoreline. Acta Volcanologica, 14, 129–136. Carn, S.A. 2000. The Lamongan volcanic field, East Java, Indonesia: physical volcanology, historic activity and hazards. Journal of Volcanology and Geothermal Research, 95, 81–108. Carrasco-Núñez, G., Davidson-Harris, P., Riggs, N.R., Ort, M.H., Zimmer, B.W., Willcox, C.P. & Branchey, M.J. 2012. Recent explosive volcanism at the eastern Trans-Mexican volcanic belt. In: Aranda-Gómez, J.J., Tolson, G. & Molina-Garza, R.S. (eds) The Southern Cordillera and Beyond. GSA Field Guides, 25, 83–113. Cas, R.A.F., van Otterlooo, J., Blaikie, T.N. & Van den Hove, J. 2016. The dynamics of a very large intra-plate continental basaltic volcanic province, the Newer Volcanics Province, SE Australia, and implications for other provinces. In: Németh, K., Carrasco-Núñez, G., Aranda-Gómez, J.J. & Smith, I.E.M. (eds) Monogenetic Volcanism. Geological Society, London, Special Publications, 446. First published online November 7, 2016, https://doi.org/10.1144/SP446.8 Cebriá, J.M., Martín, B.M., López-Ruiz, J. & Moran-Zenteno, D.J. 2011. The Paricutin calc-alkaline lavas: new geochemical and petrogenic modelling constraints on the crustal assimilation process. Journal of Volcanology and Geothermal Research, 201, 113–125. Cembrano, J. & Lara, L. 2009. The link between volcanism and tectonics in the southern volcanic zone of the Chilean Andes: a review. Tectonophysics, 471, 96–113. Choi, S.H., Mukasa, S.B., Kwon, S.T. & Andronikov, A.V. 2006. Sr, Nd, Pb and Hf isotopic compositions of late Cenozoic alkali basalts in South Korea: evidence for mixing between the two dominant asthenospheric mantle domains beneath East Asia. Chemical Geology, 232, 134–151. Clague, D. 1987. Hawaiian xenolith population, magma supply rates, and development of magma chambers. Bulletin of Volcanology, 49, 577–587. Clague, D.A. & Dixon, J.E. 2000. Extrusive controls on the evolution of Hawaiian ocean island volcanoes. Geochemistry, Geophysics, Geosystems, 1, 1010.
MONOGENETIC VOLCANISM: INTRODUCTION

Cole, J.W., Spinks, K.D., Deering, C.D., Nairn, I.A. & Leonard, G.S. 2010. Volcanic and structural evolution of the Okataina Volcanic Centre; dominantly silicic volcano associated with the Taupo Rift, New Zealand. Journal of Volcanology and Geothermal Research, 190, 123–135.

Cole, J.W., Deering, C.D., Burt, R.M., Sewell, S., Shane, P.A.R. & Matthews, N.E. 2014. Okataina Volcanic Centre, Taupo Volcanic Zone, New Zealand: a view of volcanism and synchronous pluton development in an active, dominantly silicic caldera system. Earth-Science Reviews, 128, 1–17.

Condit, C.D. & Connors, C.B. 1996. Recurrence rates of volcanism in basaltic volcanic fields: an example from the Springerville volcanic field, Arizona. Geological Society of America Bulletin, 108, 1225–1241.

Condit, C.D., Crumpler, L.S., Aubele, J.C. & Elston, W.E. 1989. Patterns of volcanism along the southeastern margin of the Colorado Plateau: the Springerville Field. Journal of Geophysical Research, 94, 7975–7986.

Connor, C.B. 1987. Structure of the Michoacan–Guanajuato Volcanic Field, Mexico. Journal of Volcanology and Geothermal Research, 33, 191–200.

Connor, C.B. 1990. Cinder cone clustering in the TransMexican volcanic belt: Implications for structural and petrologic models. Journal of Geophysical Research: Solid Earth, 95, 19,395–19,405.

Connor, C.B. & Conway, F.M. 2000. Basaltic volcanic fields. In: Sigurdsson, H. (ed.) Encyclopedia of Volcanoes. Academic Press, San Diego, CA, 331–343.

Conrad, C.P., Blanco, T.A., Smith, E.I. & Wessel, P. 2011. Patterns of intraplate volcanism controlled by asthenospheric shear. Nature Geoscience, 4, 317–321.

Cook, C., Briggs, R.M., Smith, I.E.M. & Maas, R. 2005. Petrology and geochemistry of intraplate basalts in the South Auckland Volcanic Field, New Zealand: evidence for two coeval magma suites from distinct sources. Journal of Petrology, 46, 473–503.

Delcamp, A., van Wyk de Vries, B., Stephane, P. & Kervyn, M. 2014. Endogenous and exogenous growth of the monogenetic Lemptegy volcano, Chaine des Puys, France. Geosphere, 10, 998–1019.

Demiduk, Z., Turner, S., Sandiford, M., George, R., Foden, J. & Etheridge, M. 2007. U-series isotopic and geodynamic constraints on mantle melting processes beneath the Newer Volcanic Province in South Australia. Earth and Planetary Science Letters, 261, 517–533.

Dennen, R.L., Bursik, M.J. & Roche, O. 2014. Dome collapse mechanisms and block-and-ash flow emplacement dynamics inferred from deposit and impact mark analysis, Mono Craters, CA. Journal of Volcanology and Geothermal Research, 276, 1–9.

Di Traglia, F., Morelli, S., Casagli, N. & Garduno Monroy, V.H. 2014. Semi-automatic delineation of volcanic edifice boundaries: validation and application to the cinder cones of the Tancitaro–Nueva Italia region (Michoacán–Guanajuato Volcanic Field, Mexico). Geomorphology, 219, 152–160.

Dohrenwend, J.C., Wells, S.G. & Turkin, B.D. 1986. Degradation of quaternary cinder cones in the Cima volcanic field, Mojave Desert, California. Geological Society of America Bulletin, 97, 421–427.

Druiitt, T.H., Brenchley, P.J., Göktén, Y.E. & Franca, V. 1995. Late Quaternary rhyolitic eruptions from the Aciqol Complex, central Turkey. Journal of the Geological Society, London, 152, 655–667, https://doi.org/10.1144/gsjgs.152.4.0655.

Duda, A. & Schmincke, H.U. 1978. Quaternary basanites, melilit nephelinites and tephrites from the Laacher See area (Germany). Neues Jahrbuch fuer Mineralogie Abhandlungen, 132, 1–33.

Erlund, E.J., Cashman, K.V., Wallace, P.J., Proll, L., Rosi, M., Johnson, E. & Granados, H.D. 2010. Compositional evolution of magma from Paricutin Volcano, Mexico: the tephra record. Journal of Volcanology and Geothermal Research, 197, 167–187.

Ersøy, E.Y. & Palmer, M.R. 2013. Eocene–Quaternary magmatic activity in the Aegean: implications for mantle metasomatism and magma genesis in an evolving orogeny. Lithos, 180, 5–24.

Ersøy, E.Y., Helvaci, C. & Palmer, M.R. 2010. Mantle source characteristics and melting models for the early-middle Miocene mafic volcanism in Western Anatolia Implications for enrichment processes of mantle lithosphere and origin of K-rich volcanism in post-collisional settings. Journal of Volcanology and Geothermal Research, 198, 112–128.

Ersøy, Y.E., Helvaci, C. & Palmer, M.R. 2012a. Petrogenesis of the Neogene volcanic units in the NE–SW-trending basins in western Anatolia, Turkey. Contributions to Mineralogy and Petrology, 163, 379–401.

Ersøy, Y.E., Helvaci, C., Uysal, I., Karamoglou, O., Palmer, M.R. & Dendi, F. 2012b. Petrogenesis of the Miocene volcanism along the Izmır-Bahcesir Transfer Zone in western Anatolia, Turkey: implications for origin and evolution of potassic volcanism in post-collisional areas. Journal of Volcanology and Geothermal Research, 241, 21–38.

Farmer, G.L., Glazner, A.F., Wilshire, H.G., Wooden, J.L., Pickthorn, W.J. & Katz, M. 1995. Origin of late Cenozoic basalts at the Cima volcanic field, Mojave Desert, California. Journal of Geophysical Research: Solid Earth, 100, 8399–8415.

Fornaciari, A., Favalli, M., Karatson, D., Tarquinii, S. & Boschi, E. 2012. Morphometry of scoria cones, and their relation to geodynamic setting: a DEM-based analysis. Journal of Volcanology and Geothermal Research, 217, 56–72.

Franz, G., Breitkreuz, C. et al. 1997. The alkaline Meidob volcanic field (Late Cenozoic, northwest Sudan). Journal of African Earth Sciences, 25, 263–291.

Franz, G., Steiner, G., Volk, F., Pudlo, D. & Hammerschmidt, K. 1999. Plume related alkaline magmatism in central Africa – the Meidob Hills (W Sudan). Chemical Geology, 157, 27–47.

Friese, N., Bene, F.A., Tanner, D.C., Gustafsson, L.E. & Siegsmund, S. 2013. From feeder dykes to scoria cones: the tectonically controlled plumbing system of the Rauoholar volcanic chain, Northern Volcanic Zone, Iceland. Bulletin of Volcanology, 75, 11.

Fullea, J., Camacho, A.G., Negreño, A.M. & Fernandez, J. 2015. The Canary Islands hot spot: new insights from 3D coupled geophysical–petrological modelling of the lithosphere and uppermost mantle. Earth and Planetary Science Letters, 409, 71–88.
Fulop, A. & KURSZLAUKIS, S. 2014. It takes two to tango. Or: how polygenetic is a monogenetic volcano? In: CARRASCO-NÚÑEZ, G., ARANDA-GÓMEZ, J.J., ORT, M.H. & SILVA-CORONA, J.J. (eds) 5th International Maar Conference, Abstracts Volume. Universidad Nacional Autónoma de México, Centro de Geociencias, Juriquilla, Mexico, 149–150.

Fulop, A. & KURSZLAUKIS, S. 2016. Monogenetic v. polygenetic kimberlite volcanism: in-depth examination of the Tango Extension Super Structure, Atapawiskat kimberlite field, Ontario, Canada. In: NÉMETH, K., CARRASCO-NÚÑEZ, G., ARANDA-GÓMEZ, J.J. & SMITH, I.E.M. (eds) Monogenetic Volcanism. Geological Society, London, Special Publications, 446. First published online September 23, 2016, updated November 4, 2016, https://doi.org/10.1144/SP446.7

Galipp, K., KLUGEL, A. & HANSTEN, T.H. 2006. Changing depths of magma fractionation and stagnation during the evolution of an oceanic island volcano: La Palma (Canary Islands). Journal of Volcanology and Geothermal Research, 155, 285–306.

Gamble, J.A., Price, R.C., Smith, I.E.M., McIntosh, W.C. & Dunbar, N.W. 2003. 40Ar/39Ar geochronology of magmatic activity, magma flux and hazards at Ruapehu volcano, Taupo Volcanic Zone, New Zealand. Journal of Volcanology and Geothermal Research, 120, 271–287.

Gao, W., Li, J., Mao, X. & Li, H. 2013. Geological and geometrical value of the monogenetic volcanoes in Wudalianchi National Park, NE China. Geochronology, 5, 73–85.

Gente, P., Dyment, J., Maia, M. & Goslin, J. 2003. Interaction between the Mid-Atlantic Ridge and the Azores hot spot during the last 85 Myr: emplacement and rifting of the hot spot-derived plateaus. Geochemistry, Geophysics, Geosystems, 4, 8514.

Geshi, N. 2000. Fractionation and magma mixing within intruding dike swarms: evidence from the Miocene Shi-tara–Otoge igneous complex, central Japan. Journal of Volcanology and Geothermal Research, 98, 127–152.

Geshi, N. 2001. Melt segregation by localized shear deformation and fracturing during crystallization of magma in shallow intrusions of the Otoge volcanic complex, central Japan. Journal of Volcanology and Geothermal Research, 106, 285–300.

Geshi, N. & Oikawa, T. 2014. The spectrum of basaltic feeder systems from effusive lava eruption to explosive eruption at Miyakejima volcano, Japan. Bulletin of Volcanology, 76, 797.

Geshi, N., NÉMETH, K. & Oikawa, T. 2011. Growth of phreatomagmatic explosion craters: a model inferred from Suoana crater in Miyakejima volcano, Japan. Journal of Volcanology and Geothermal Research, 201, 30–38.

Geshi, N., Kusumoto, S. & Gudmundsson, A. 2012. Effects of mechanical layering of host rocks on dike growth and arrest. Journal of Volcanology and Geothermal Research, 223, 74–82.

Godchaux, M. & Bonnichsen, B. 2002. Syneruptive magma–water and posteruptive lava–water interactions in the Western Snake River Plain, Idaho, during the past 12 million years. In: Bonnichsen, B., White, C.M. & McCurry, M. (eds) Tectonic and Magmatic Evolution of the Snake River Plain Volcanic Province. Idaho Geological Survey Bulletin, 30, 387–435.

Godchaux, M.M., Bonnichsen, B. & Jenks, M.D. 1992. Types of phreatomagmatic volcanoes in the western Snake River plain, Idaho, USA. Journal of Volcanology and Geothermal Research, 52, 1–25.

Graettinger, A.H., Valentine, G.A. & Sonder, I. 2015. Circum-crater variability of deposits from discrete, laterally and vertically migrating volcanic explosions: experimental evidence and field implications. Journal of Volcanology and Geothermal Research, 308, 61–69.

Gudmundsson, A. 2003. Surface stresses associated with arrested dykes in rift zones. Bulletin of Volcanology, 65, 606–619.

Guilbaud, M.N., Siebe, C., Layer, P., Salinas, S., Castro-Govea, R., Garduno-Monroy, V.H. & Le Corvec, N. 2011. Geology, geochronology, and tectonic setting of the Jorullo Volcano region, Michoacan, Mexico. Journal of Volcanology and Geothermal Research, 201, 97–112.

Haase, K.M. & Renno, A.D. 2008. Variation of magma generation and mantle sources during continental rifting observed in Cenozoic lavas from the Eger Rift, Central Europe. Chemical Geology, 257, 195–205.

Haase, K.M., Worthington, T.J. & Stoffers, P. 2004. Variation of the slab input and its effects on partial melting along the Kermadec arc. Geochimica et Cosmochimica Acta, 68, A615–A615.

Hansteen, T.H., Klugel, A. & Schmincke, H.U. 1998. Multi-stage magma ascent beneath the Canary Islands: evidence from fluid inclusions. Contributions to Mineralogy and Petrology, 132, 48–64.

Harangi, S., Jankovics, M.E., Sagi, T., Kiss, B., Lukacs, R. & Soos, I. 2015. Origin and geodynamic relationships of the Late Miocene to Quaternary alkaline basalt volcanism in the Pannonian basin, eastern-central Europe. International Journal of Earth Sciences, 104, 2007–2032.

Hasebe, N., Fukutani, A., Sudo, M. & Tagami, T. 2001. Transition of eruptive style in an arc-arc collision zone: K–Ar dating of Quaternary monogenetic and polygenetic volcanoes in the Higashi-Izu region, Izu peninsula, Japan. Bulletin of Volcanology, 63, 377–386.

Hasenaka, T. & Carmichael, I.S.E. 1985. A compilation of location, size, and geomorphological parameters of volcanoes of the Michoacan–Guanaajuato volcanic field, central Mexico. Geofisica Internacional, 24, 577–608.

Hasenaka, T. & Carmichael, I.S.E. 1987. The cinder cones of Michoacan–Guanaajuato, central Mexico: petrology and chemistry. Journal of Petrology, 28, 241–269.

Herzberg, C. 2004. Partial crystallization of mid-ocean ridge basalts in the crust and mantle. Journal of Petrology, 45, 2389–2405.

Herzberg, C. & O’Hara, M.J. 1998. Phase equilibrium constraints on the origin of basalts, picrites, and komatiites. Earth-Science Reviews, 44, 39–79.

Herzberg, C., Asimow, P.D. & et al. 2007. Temperatures in ambient mantle and plumes: constraints from basalts, picrites, and komatiites. Geochemistry, Geophysics, Geosystems, 8, Q02006.
HILDRETH, W. 2004. Volcanological perspectives on Long Valley, Mammoth Mountain, and Mono Craters: several contiguous but discrete systems. Journal of Volcanology and Geothermal Research, 136, 169–198.

HINTZ, A.R. & VALENTINE, G.A. 2012. Complex plumbing of monogenetic scoria cones: new insights from the Lunar Crater Volcanic Field (Nevada, USA). Journal of Volcanology and Geothermal Research, 239, 19–32.

HIRSCHMANN, M.M., KOGISO, T., BAKER, M.B. & STOLPER, E.M. 2003. Alkaline magmas generated by partial melting of garnet pyroxenite. Geology, 31, 481–484.

Ho, C.H. 1991. Time trend analysis of basaltic volcanism for the Yucca Mountain site. Journal of Volcanology and Geothermal Research, 46, 61–72.

HOUGHTON, B.F., LLOYD, E.F., WILSON, C.J.N. & LANPHERE, M.A. 1991. K–Ar ages from the Western Dome Belt and associated rhyolitic lavas in the Maroa Taupo area, Taupo Volcanic Zone, New Zealand. New Zealand Journal of Geology and Geophysics, 34, 99–101.

HOWELL, J.K., WHITE, S.M. & BOHNNENSTEHL, D.R. 2012. A modified basal outlining algorithm for identifying topographic highs in gridded elevation data, part 2: application to Springfield Volcanic Field. Computers & Geosciences, 49, 315–322.

HSU, C.N. & CHEN, J.C. 1998. Geochemistry of late Cenozoic basaltic from Wudalianchi and Jingphu areas, Heilongjiang province, northeast China. Journal of Asian Earth Sciences, 16, 385–405.

IRVING, A.J. & GREEN, D.H. 2008. Phase relationships of hydrous alkaline magmas at high pressures: production of nepheline-hawaiitic to mugearitic liquids by amphibole-dominated fractional crystallization within the lithospheric mantle. Journal of Petrology, 49, 741–756.

IRVING, A.J. & PRICE, R.C. 1981. Geochemistry and evolution of lherzolite-bearing phonolitic lavas from Nigeria, Australia, East Germany and New Zealand. Geochimica et Cosmochimica Acta, 45, 1309–1320.

JOHNSON, E., WALLACE, P., CHASHMAN, K., GRANADOS, H.D. & KENT, A. 2008. Magma volatile contents and degassing-induced crystallization at Volcán Jorullo, Mexico: implications for melt evolution and the plumbing systems of monogenetic volcanoes. Earth and Planetary Science Letters, 269, 478–487.

JORDAN, S.C., CAS, R.A.F. & HAYMAN, P.C. 2013. The origin of a large (>3 km) maar volcano by coalescence of multiple shallow craters: Lake Purrumbete maar, southeastern Australia. Journal of Volcanology and Geothermal Research, 254, 5–22.

JORDAN, S.C., JOWITT, S.M. & CAS, R.A.F. 2015. Origin of temporal–compositional variations during the eruption of Lake Purrumbete Maar, Newer Volcanics Province, southeastern Australia. Bulletin of Volcanology, 77, 833.

KAZANCI, N., GEVREK, A.I. & VAROL, B. 1995. Facies changes and high calorific peat formation in a Quaternary maar lake, Central Anatolia, Turkey – the possible role of geothermal processes in a closed lacustrine basin. Sedimentary Geology, 94, 255–266.

KELLER, J. 1975. Quaternary maar volcanism near Karapinar in central Anatolia. Bulletin Volcanologique, 38, 378–396.

KÉRÉSZTURI, G. & NÉMETH, K. 2012a. Monogenetic basaltic volcanoes: genetic classification, growth, geomorphology and degradation. In: NÉMETH, K. (ed.) Updates in Volcanology – New Advances in Understanding Volcanic Systems. InTech Open, Rijeka, Croatia, 3–88. https://doi.org/10.5772/51387

KÉRÉSZTURI, G. & NÉMETH, K. 2012b. Structural and morphometric irregularities of eroded Pliocene scoria cones at the Bakony–Balaton Highland Volcanic Field, Hungary. Geomorphology, 136, 45–58.

KÉRÉSZTURI, G. & NÉMETH, K. 2016. Post-eruptive sediment transport and surface processes on unvegetated volcanic hills – a case study of Black Tank scoria cone, Cima Volcanic Field, California. Geomorphology, 267, 59–75.

KÉRÉSZTURI, G., NÉMETH, K., CSILLAG, G., BALOGH, K. & KOVÁCS, J. 2011. The role of external environmental factors in changing eruption styles of monogenetic volcanoes in a Mio–Pleistocene continental volcanic field in western Hungary. Journal of Volcanology and Geothermal Research, 201, 227–240.

KÉRÉSZTURI, G., JORDAN, G., NÉMETH, K. & DONIZPAEZ, J.F. 2012. Syn-eruptive morphometric variability of monogenetic scoria cones. Bulletin of Volcanology, 74, 2171–2185.

KÉRÉSZTURI, G., NÉMETH, K., CRONIN, S.J., AGUSTIN–FLORES, J., SMITH, I.E.M. & LINDSAY, J. 2013. A model for calculating eruptive volumes for monogenetic volcanoes – implication for the Quaternary Auckland Volcanic Field, New Zealand. Journal of Volcanology and Geothermal Research, 266, 16–33.

KÉRÉSZTURI, G., NÉMETH, K., CRONIN, S.J., PROCTOR, J. & AGUSTIN–FLORES, J. 2014. Influences on the variability of eruption sequences and style transitions in the Auckland Volcanic Field, New Zealand. Journal of Volcanology and Geothermal Research, 286, 101–115.

KÉRÉSZTURI, G., BEBBINGTON, M. & NÉMETH, K. 2017. Forecasting transitions in monogenetic eruptions using the geologic record. Geology, first published online January 2017, https://doi.org/10.1130/G38596.1

KIOUSI, K., CONNOR, C.B., WETMORE, P.H., FERWERDA, B.P., GERMA, A.M., CONNOR, L.J. & HINTZ, A.R. 2012. Relationship between dike and volcanic conduit distribution in a highly eroded monogenetic volcanic field: San Rafael, Utah, USA. Geology, 40, 695–698.

KLUGEL, A., HANSTEEN, T.H. & GALIPPE, K. 2005. Magma storage and underplating beneath Cumbre Vieja Volcano, La Palma (Canary Islands). Earth and Planetary Science Letters, 236, 211–226.

KÖSZIK, S., NÉMETH, K., KÉRÉSZTURI, G., PROCTOR, J.N., ZELLMER, G.F. & GESHI, N. 2016. Phreatomagmatic and water-influenced Strombolian eruptions of a small-volume parasitic cone complex on the southern ringplain of Mt. Ruapehu, New Zealand: facies architecture and eruption mechanisms of the Ohakune Volcanic Complex controlled by an unstable fissure eruption. Journal of Volcanology and Geothermal Research, 327, 99–115. https://doi.org/10.1016/j.jvolgeores.2016.07.005

KSHIRSAHAG, P., SIEBE, C., NOELLE GUILBAUD, M., SALINAS, S. & LAYER, P.W. 2015. Late Pleistocene Alberca de Guadalupe maar volcano (Zacapu basin, Michoacan): stratigraphy, tectonic setting, and
paleo-hydrogeological environment. Journal of Volcanology and Geothermal Research, 304, 214–236.

KSHIRSGAR, P., SIEBE, C., NOELLE GUILBAUD, M. & SALINAS, S. 2016. Geological and environmental controls on the change of eruptive style (phreatomagmatic to Strombolian-effusive) of Late Pleistocene El Caracol tuff cone and its comparison with adjacent volcanoes around the Zacapu basin (Michoacan, Mexico). Journal of Volcanology and Geothermal Research, 318, 114–133.

KURSZLAUKIS, S. & BARNETT, W.P. 2003. Volcanological and structural aspects of the Venetia kimberlite cluster – a case study of South African kimberlite-maasdiatreme volcanoes. South African Journal of Geology, 106, 165–192.

KURSZLAUKIS, S. & FULOP, A. 2013. Factors controlling the internal facies architecture of maasdiatreme volcanoes. Bulletin of Volcanology, 75, 761.

KURSZLAUKIS, S. & LORENZ, V. 1997. Volcanological features of a low-viscosity melt: the carbonatitic gross Brukharos Volcanic Field, Namibia. Bulletin of Volcanology, 58, 421–431.

KURSZLAUKIS, S. & LORENZ, V. 2016. Differences and similarities between emplacement models of kimberlite and basaltic maasdiatreme volcanoes. In: NÉMETH, K., CARRASCO-NÚÑEZ, G., ARANDA-GÓMEZ, J.J. & SMITH, I.E.M. (eds) Monogenetic Volcanism. Geological Society, London, Special Publications, 446. First published online October 5, 2016, updated 10 November 2016, https://doi.org/10.1144/SP446.5

LE CORVEC, N., MENAND, T. & LINDSAY, J. 2013a. Interaction of ascending magma with pre-existing crustal fractures in monogenetic basaltic volcanism: an experimental approach. Journal of Geophysical Research: Solid Earth, 118, 968–984.

LE CORVEC, N., SPORLI, K.B., ROWLAND, J. & LINDSAY, J. 2013b. Spatial distribution and alignments of volcanic centers: clues to the formation of monogenetic volcanic fields. Earth-Science Reviews, 124, 96–114.

LEEMAN, W.P. & BONNIKENB, B. 2005. Overview of silicic volcanism of the Snake River Plain – Yellowstone (SRPY) province. Geochimica et Cosmochimica Acta, 69, A237–A237.

LEEMAN, W.P., LEWIS, J.F., EVARTS, R.C., CONREY, R.M. & STRECK, M.J. 2005. Petrologic constraints on the thermal structure of the Cascades arc. Journal of Volcanology and Geothermal Research, 140, 67–105.

LENESKY, N.G., NIEBO, R.W., HOLLOWAY, J.R., LYAKHOVSKY, V. & NAVON, O. 2006. Bubble nucleation as a trigger for xenolith entrapment in mantle melts. Earth and Planetary Science Letters, 245, 278–288.

LINDSAY, J.M., LEONARD, G.S., SMID, E.R. & HAYWARD, B.W. 2011. Age of the Auckland volcanic field: a review of existing data. New Zealand Journal of Geology and Geophysics, 54, 379–401.

LIU, J.Q., CHU, G.Q., HAN, J.T., RIQUAL, P., JIAO, W.Y. & WANG, K.J. 2009. Volcanic eruptions in the Longgang volcanic field, northeastern China, during the past 15 000 years. Journal of Asian Earth Sciences, 34, 645–654.

LONGRÉ, M.-A., TROLL, V.R., WALTER, T.R. & HANSTEEN, T.H. 2009. Volcanic and geochemical evolution of the Teno massif, Tenerife, Canary Islands: some repercussions of giant landslides on ocean island magmatism. Geochemistry, Geophysics, Geosystems, 10, Q12017.

LOPEZ-ESCOBAR, L. & MORENO, H. 1981. Erupción de 1979 del Volcán Mirador, Andes del Sur, 40°21’S: características geoquímicas de las lavas y xenolitos graníticos. Revista Geológica de Chile, 13–14, 17–33.

LOPEZ-ESCOBAR, L., CEMBRANO, J. & MORENO, H. 1995. Geochemistry and tectonics of the Chilean Southern Andes basaltic Quaternary volcanism (37–46’S). Revista Geológica de Chile, 22, 219–234.

LORENZ, V. 1987. Phreatomagmatism and its relevance. Chemical Geology, 62, 149–156.

LORENZ, V. 2007. Syn- and posteruptive hazards of maasdiatreme volcanoes. Journal of Volcanology and Geothermal Research, 159, 285–312.

LORENZ, V., SUHR, P. & SUHR, S. 2016. Phreatomagmatic maas–diatreme volcanoes and their incremental growth: a model. In: NÉMETH, K., CARRASCO-NÚÑEZ, G., ARANDA-GÓMEZ, J.J. & SMITH, I.E.M. (eds) Monogenetic Volcanism. Geological Society, London, Special Publications, 446. First published online September 27, 2016, https://doi.org/10.1144/SP446.4

LUHR, J.F. & SIMKIN, T. 1993. Paricutin. The Volcano Born in a Mexican Cornfield. Geosciences Press, Phoenix, AZ.

LUTZ, H. 2014. The ancient volcanoes of Central France – Nicolas Desmarest’s famous volano-geomorphological map in an unrecorded print from 1811. Zeitschrift der Deutschen Gesellschaft für Geowissenschaften, 165, 395–406.

MACLENNAN, J. 2008. Short length-scale compositional heterogeneity in basalts and their mantle sources. Geochimica et Cosmochimica Acta, 72, A582–A582.

MANVILLE, V., NÉMETH, K. & KANO, K. 2009. Source to sink: a review of three decades of progress in the understanding of volcanioclastic processes, deposits, and hazards. Sedimentary Geology, 220, 136–161.

MARO, G. & CAFFE, P.J. 2016a. The Cerro Bitiche Andesitic Field: petrological diversity and implications for magmatic evolution of maafic volcanic centers from the northern Puna. Bulletin of Volcanology, 78, 51.

MARO, G. & CAFFE, P.J. 2016b. Neogene monogenetic volcanism from the Northern Puna region: products and eruptive styles. In: NÉMETH, K., CARRASCO-NÚÑEZ, G., ARANDA-GÓMEZ, J.J. & SMITH, I.E.M. (eds) Monogenetic Volcanism. Geological Society, London, Special Publications, 446. First published online September 26, 2016, https://doi.org/10.1144/SP446.6

MARTIN, U. & NÉMETH, K. 2005. Eruptive and depositional history of a Pleocene tuff ring that developed in a fluviolacustrine basin: Kissomlyo volcano (western Hungary). Journal of Volcanology and Geothermal Research, 147, 342–356.

MARTIN-SERRANO, A., VEGAS, J. et al. 2009. Morphotectonic setting of maaf lakes in the Campo de Calatrava Volcanic Field, (Central Spain, SW Europe). Sedimentary Geology, 222, 52–63.

MAZZARINI, F. & D’ORAZIO, M. 2003. Spatial distribution of cones and satellite-detected lineaments in the Pali Aike Volcanic Field (southernmost Patagonia): insights into the tectonic setting of a Neogene rift system. Journal of Volcanology and Geothermal Research, 125, 291–305.
McGee, L.E. & Smith, I.E.M. 2016. Interpreting chemical compositions of small scale basaltic systems: a review. *Journal of Volcanology and Geothermal Research*, 325, 45–60.

McGee, L.E., Millet, M.-A., Smith, I.E.M., Németh, K. & Lindsay, J.M. 2012. The inception and progression of melting in a monogenetic eruption: Motukorea Volcano, the Auckland Volcanic Field, New Zealand. *Lithos*, 155, 360–374.

McGee, L.E., Smith, I.E.M., Millet, M.-A., Handley, H.K. & Lindsay, A.M. 2013. Asthenospheric control of melting processes in a monogenetic basaltic system: a case study of the Auckland Volcanic Field, New Zealand. *Journal of Petrology*, 54, 2125–2153.

McGee, L.E., Millet, M.-A., Beer, C., Smith, I.E.M. & Lindsay, J.M. 2015. Mantle heterogeneity controls on small-volume basaltic volcanism. *Geology*, 43, 551–554.

McKnight, S.B. & Williams, S.N. 1997. Old cinder cone or young composite volcano?: the nature of Cerro Negro, Nicaragua. *Geology*, 25, 339–342.

Menziez, M., Kempton, P. & Duncan, M. 1985. Interaction of Continental Lithosphere and Astrophemospheric Melts Below the Geronimo Volcanic Field, Arizona, USA. *Journal of Petrology*, 26, 663–693.

Menziez, M.A., Kyle, P.R., Jones, M. & Ingram, G. 1991. Enriched and depleted source components for tholeiitic and alkaline lavas from Zuni- Bandera, New-Mexico — inferences about intraplate processes and stratified lithosphere. *Journal of Geophysical Research: Solid Earth and Planets*, 96, 13,645–13,671.

Moufti, M.R. & Németh, K. 2014. The White Mountains of Harrat Khaybar, Kingdom of Saudi Arabia. *International Journal of Earth Sciences*, 103, 1641–1643.

Moufti, M.R., Moghazl, A.M. & Ali, K.A. 2012. Ar/39Ar geochronology of the Neogene–Quaternary Harrat Al-Madinah intercontinental Volcanic Field, Saudi Arabia: implications for duration and migration of volcanic activity. *Journal of Asian Earth Sciences*, 62, 253–268.

Moufti, M.R., Németh, K., El-Masry, N. & Qaddah, A. 2015. Volcanic geotopes and their geosites preserved in an arid climate related to landscape and climate changes since the Neogene in Northern Saudi Arabia: Harrat Huta Hayom (Hai’il Region). *Geoheritage*, 7, 103–118.

Muffler, L.J.P., Clyne, M.A., Calvert, A.T. & Champion, D.E. 2011. Diverse, discrete, mantle-derived batches of basalt erupted along a short normal fault zone: the Poisson Lake chain, southernmost Cascades. *Geological Society of America Bulletin*, 123, 2177–2200.

Murcia, H., Németh, K. et al. 2015. The Al-Du’aybah volcanic cones, Al-Madinah City: implications for volcanic hazards in northern Harrat Rahat, Kingdom of Saudi Arabia. *Bulletin of Volcanology*, 77, 54.

Murcia, H., Lindsay, J.M. et al. 2016. Geology and geochemistry of Late Quaternary volcanism in northern Harrat Rahat, Kingdom of Saudi Arabia: implications for eruption dynamics, regional stratigraphy and magma evolution. In: Németh, K., Carrasco-Núñez, G., Aranda-Gómez, J.J. & Smith, I.E.M. (eds) *Monogenetic Volcanism*. Geological Society, London, Special Publications, 446. First published online September 30, 2016, https://doi.org/10.1144/SP446.2

Needham, A.J., Lindsay, J.M., Smith, I.E.M., Augustinus, P. & Shaine, P.A. 2011. Sequential eruption of alkaline and sub-alkaline magmas from a small monogenetic volcano in the Auckland Volcanic Field, New Zealand. *Journal of Volcanology and Geothermal Research*, 201, 126–142.

Németh, K. 2010. Monogenetic volcanic fields: Origin, sedimentary record, and relationship with polygenetic volcanism. In: Cañón-Tapia, E. & Száczik, A. (eds) *What is a Volcano?* Geological Society of America, Special Papers, 470, 43–60.

Németh, K. & Cronin, S.J. 2009a. Phreatomagmatic volcanic hazards where rift-systems meet the sea, a study from Ambae Island, Vanuatu. *Journal of Volcanology and Geothermal Research*, 180, 246–258.

Németh, K. & Cronin, S.J. 2009b. Volcanic structures and oral traditions of volcanism of Western Samoa (SW Pacific) and their implications for hazard education. *Journal of Volcanology and Geothermal Research*, 186, 223–237.

Németh, K. & Kereszturi, G. 2015. Monogenetic volcanism: personal views and discussion. *International Journal of Earth Sciences*, 104, 2131–2146.

Németh, K. & Martin, U. 2007. Shallow sill and dyke complex in western Hungary as a possible feeding system of phreatomagmatic volcanoes in ‘soft-rock’ environment. *Journal of Volcanology and Geothermal Research*, 159, 138–152.

Németh, K., White, J.D.L., Ray, A. & Martin, U. 2003. Compositional variation during monogenetic volcano growth and its implications for magma supply to continental volcanic fields. *Journal of the Geological Society, London*, 160, 523–530, https://doi.org/10.1144/0016-749021-131.

Németh, K., Cronin, S.J., Smith, I.E.M. & Flores, J.A. 2012. Amplified hazard of small-volume monogenetic eruptions due to environmental controls, Orakei Basin, Auckland Volcanic Field, New Zealand. *Bulletin of Volcanology*, 74, 2121–2137.

Nowell, D. 2008. The Chaine des Puys volcanoes of the Auvergne, France. *Geology Today*, 24, 231–238.

O’Reilly, S. & Griffin, W.L. 1985. A xenolith-derived getherm for southeastern Australia and its geophysical implications. *Tectonophysics*, 111, 41–63.

Pan, Y.C. & Batiza, R. 2003. Magmatic processes under mid-ocean ridges: a detailed mineralogic study of lavas from East Pacific Rise 9°30’N, 10°30’N, and 11°20’N. *Geochemistry, Geophysics, Geosystems*, 4, 8623.

Peters, T.J., Menziez, M., Thrillwall, M. & Kyle, P.R. 2008. Zuni-Bandera volcanism, Rio Grande, USA – Melt formation in garnet- and spinel-facies mantle straddling the asthenosphere-lithosphere boundary. *Lithos*, 102, 295–315.

Petrone, C.M., Franchalanci, L., Carlson, R.W., Ferrari, L. & Conticelli, S. 2003. Unusual coexistence of subduction-related and intraplate-type magmatism: Sr, Nd and Pb isotope and trace element data
from the magmatism of the San-Pedro-Ceboruco graben (Nayarit, Mexico). Chemical Geology, 193, 1–24.

PETRONIS, M.S., DELCAMP, A. & DE VRIES, B.W. 2013. Magma emplacement into the Lemptég scoria cone (Chaîne Des Puys, France) explored with structural, anisotropy of magnetic susceptibility, and paleomagnetic data. Bulletin of Volcanology, 75, 753.

PUTIRKA, K. 1997. Magma transport at Hawaii: inferences based on igneous thermobarometry. Geology, 25, 69–72.

PUTIRKA, K., JOHNSON, M., KINZLER, R., LONGHI, J. & WALKER, D. 1996. Thermobarometry of maﬁc igneous rocks based on clinopyroxene–liquid equilibria, 0–30 kbar. Contributions to Mineralogy and Petrology, 123, 92–108.

PUTIRKA, K.D. 2005. Mantle potential temperatures at Hawaii, Iceland, and the mid-ocean ridge system, as inferred from olivine phenocrysts: evidence for thermally driven mantle plumes. Geochemistry, Geophysics, Geosystems, 6, Q05L08.

PUTIRKA, K.D., PERFITT, M., RYERSON, F.J. & JACKSON, M.G. 2007. Ambient and excess mantle temperatures, olivine thermometry, and active v. passive upwelling. Chemical Geology, 241, 177–206.

RASOAZANAMPARANY, C., WIDOM, E. ET AL. 2016. Temporal and compositional evolution of Jorullo volcano, Mexico: implications for magmatic processes associated with a monogenic eruption. Chemical Geology, 434, 62–80.

RE, G., WHITE, J.D.L. & ORT, M.H. 2015. Dikes, sills, and stress-regime evolution during emplacement of the Jagged Rocks Complex, Hupi Buttes Volcanic Field, Navajo Nation, USA. Journal of Volcanology and Geothermal Research, 295, 65–79.

REAY, A., MCINTOSH, P.E. & GIBSON, L.L. 1991. Lherzolite xenolith bearing ﬂows from the east Otago province: crystal fractionation of upper mantle magmas. New Zealand Journal of Geology and Geophysics, 34, 317–327.

REINERS, P.W. & NELSON, B.K. 1998. Temporal-compositional-isotopic trends in rejuvenated-stage magmas of Kauai, Hawaii, and implications for mantle melting processes. Geochemica et Cosmochimica Acta, 62, 2347–2368.

RIDOLFI, F., RENZULLI, A., PERUGINI, D., CESARE, B., BRAGA, R. & DEL MORO, S. 2016. Unravelling the complex interaction between mantle and crustal magmas encoded in the lavas of San Vincenzo (Tuscany, Italy). Part II: geochemical overview and modelling. Lithos, 244, 233–249.

RIGGS, N. & CARRASCO-NÚÑEZ, G. 2004. Evolution of a complex isolated dome system, Cerro Pizarro, central Mexico. Bulletin of Volcanology, 66, 322–335.

ROEDER, P.L. & EMSLIE, R.F. 1970. Olivine-Liquid Equilibrium. Contributions to Mineralogy and Petrology, 29, 275–289.

ROSENTHAL, A., FOLEY, S.F., PEARSON, D.G., NOWELL, G.M. & TAPPE, S. 2009. Petrogenesis of strongly alkaline primitive volcanic rocks at the propagating tip of the western branch of the East African Rift. Earth and Planetary Science Letters, 284, 236–248.

ROSS, K.A., SMETS, B., DE BATIST, M., HILBE, M., SCHMID, M. & ANSELMETTI, F.S. 2014. Lake-level rise in the late Pleistocene and active subaquaic volcanism since the Holocene in Lake Kivu, East African Rift. Geomorphology, 221, 274–285.

ROSS, K.A., SCHMID, M., OGORKA, S., MUVUNDA, F.A. & ANSELMETTI, F.S. 2015. The history of subaqueous volcano recorded in the sediments of Lake Kivu; East Africa. Journal of Paleolimnology, 54, 137–152.

ROSS, P.-S. & WHITE, J.D.L. 2006. Debris jets in continental phreatomagmatic volcanoes; a ﬁeld study of their subaeraneous deposits in the Coombs Hills vent complex, Antarctica. Journal of Volcanology and Geothermal Research, 149, 62–84.

RUNGE, M.G., BEEBINGTON, M.S., CRONIN, S.J., LINDSAY, J.M. & MOUFTI, M.R. 2015. Sensitivity to volcanic ﬁeld boundary. Journal of Applied Volcanology, 4, 1–18.

SAUCEDO, R., MACIAS, J.L. ET AL. 2017. Mixed magmatic–phreatomagmatic explosions during the formation of the Joya Honda maar, San Luis Potosi, Mexico. In: NÉMETH, K., CARRASCO-NÚÑEZ, G., ARANDA-GÓMEZ, J.J. & SMITH, I.E.M. (eds) Monogenetic Volcanism. Geological Society, London, Special Publications, 446. First published online February 28, 2017, https://doi.org/10.1144/SP446.11

SCHAFF, P., STIMAC, J., SIEBE, C. & MACIAS, J.L. 2005. Geochemical evidence for mantle origin and crustal processes in volcanic rocks from Popocatepetl and surrounding monogenetic volcanoes, central Mexico. Journal of Volcanology, 1243–1282.

SCHMINCKE, H.U., LORENZ, V. ET AL. 1983. The Quaternary Eifel Volcanic Fields. Springer, Berlin.

SIEBE, C. & MACIAS, J.L. 2006. Volcanic hazards in the Mexico City metropolitan area from eruptions at Popocatepetl, Nevado de Toluca, and Jocotitlan stratovolcanoes and monogenetic scoria cones in the Sierra Chichinautzin volcanic ﬁeld. In: SIEBE, C., MACIAS, J.L. & AGUIRRE-DIAZ, G.J. (eds) Neogene–Quaternary Continental Margin Volcanism: A Perspective from México. Geological Society of America, Special Papers, 402, 253–329.

SIEBE, C. & SALINAS, S. 2014. Distribution of monogenetic phreatomagmatic volcanoes (maars, tuff-cones and tuff-rings) in the Mexican Volcanic Belt and their tectonic and hydrogeologic environment. In: CARRASCO-NÚÑEZ, G., ARANDA-GÓMEZ, J.J.,
ORT, M.H. & SILVA-CORONA, J.J. (eds) 5th International Maar Conference, Abstracts Volume. Universidad Nacional Autónoma de México, Centro de Geociencias, Juriquilla, Mexico, 183–184.

SIEBE, C., RODRIGUEZ-LARA, V., SCHAFF, P. & ABRAMS, M. 2004. Geochemistry, Sr–Nd isotope composition, and tectonic setting of Holocene Pelado, Guespalapa and Chichinautzin scoria cones, south of Mexico City. Journal of Volcanology and Geothermal Research, 130, 197–226.

SIERON, K., CAPRA, L. & RODRIGUEZ-ELIZARRRAS, S. 2014. Hazard assessment at San Martin volcano based on geological record, numerical modeling, and spatial analysis. Natural Hazards, 70, 275–297.

SMITH, I.E.M., BLAKE, S., WILSON, C.J.N. & HOUTHON, B.F. 2008. Deep-seated fractionation during the rise of a small-volume basalt magma batch: Crater Hill, Auckland, New Zealand. Contributions to Mineralogy and Petrology, 155, 511–527.

SMITH, V.C., SHANE, P. & NAIRN, I.A. 2005. Trends in rhyolite geochemistry, mineralogy, and magma storage during the last 50 kyr at Okataina and Taupo volcanic centres, Taupo Volcanic Zone, New Zealand. Journal of Volcanology and Geothermal Research, 148, 372–406.

SMITH, V.C., SHANE, P. & NAIRN, I. 2010. Insights into silicic melt generation using plagioclase, quartz and melt inclusions from the caldera-forming Rototoi eruption, Taupo volcanic zone, New Zealand. Contributions to Mineralogy and Petrology, 160, 951–971.

SOHN, Y.K. & CHOUGI, S.K. 1989. Depositional processes of the Suwolbong Tuff Ring, Cheju Island (Korea). Sedimentology, 36, 837–855.

SPERA, F.J. 1984. Carbon dioxide in petrogenesis III: role of volatiles in the ascent of alkaline magma with special reference to xenolith-bearing mafic lavas. Contributions to Mineralogy and Petrology, 88, 217–232.

STEVENS0N, R.J., BRIGGS, R.M. & HODDER, A.P.W. 1994. Physical volcanology and emplacement history of the Ben-Lomond rhyolite lava flow, Taupo Volcanic Zone, New Zealand. New Zealand Journal of Geology and Geophysics, 37, 345–358.

STOPPA, F. & SCHIAZZA, M. 2013. An overview of monogenetic carbonatitic magmatism from Uganda, Italy, China and Spain: volcanologic and geochemical features. Journal of South American Earth Sciences, 41, 140–159.

STRONCZK, N.A., KLUGE, A. & HANSTEEN, T.H. 2009. The magmatic plumbing system beneath El Hierro (Canary Islands): constraints from phenocrysts and naturally quenched basaltic glasses in submarine rocks. Contributions to Mineralogy and Petrology, 157, 593–607.

SUHR, P. & GOTH, K. 2009. Three times at the same place with different stuff. In: HALLER, M.J. & MASSAFERO, G.I. (eds) Third International Maar Conference – Abstract Volume. Asociacion Geologica Argentina, Publicaciones Especiales, Resumes y Eventos, Serie D, 12, 120–121.

SUTHERLAND, F.L., RAYNOR, L.R. & POGSON, R.E. 1994. Spinel to garnet lherzolite transition in relation to high-temperature paleogeotherms, Eastern Australia. Australian Journal of Earth Sciences, 41, 205–220.

SZABÓ, C. & BODNAR, R.J. 1996. Changing magma ascent rates in the Nograd-Gomor volcanic field northern Hungary/southern Slovakia; evidence from CO2-rich fluid inclusions in metasomatized upper mantle xenoliths. Petrologiya, 4, 240–249.

TAISNE, B., TAIT, S. & JAUJART, C. 2011. Conditions for the arrest of a vertical propagating dyke. Bulletin of Volcanology, 73, 191–204.

TAKADA, A. 1994. The influence of regional stress and magmatic input on styles of monogenetic and polygenetic volcanism. Journal of Geophysical Research, 99, 13,563–13,573.

TAMURA, Y., NAKAJIMA, J., KODAIRA, S. & HASEGAWA, A. 2009. Tectonic setting of volcanic centers in subduction zones: three-dimensional structure of mantle wedge and arc crust. In: CONNOR, C.B., CHAPMAN, N.A. & CONNOR, L.J. (eds) Volcanic and Tectonic Hazard Assessment for Nuclear Facilities. Cambridge University Press, Cambridge, 176–195.

TANAKA, K.L., SHOEMAKER, E.M., ULRICH, G.E. & WOLFE, E.W. 1986. Migration of Volcanism in the San-Francisco Volcanic Field, Arizona. Geological Society of America Bulletin, 97, 129–141.

TIMM, C., HOERNLE, K. ET AL. 2010. Temporal and geochemical evolution of the Cenozoic intraplate volcanism of Zealandia. Earth-Science Reviews, 98, 38–64.

ULRYCH, J., DOSTAL, J., ADAMOVIC, J., JELINEK, E., SPACEK, P., HEGNER, E. & BALOGH, K. 2011. Recurrent Cenozoic volcanic activity in the Bohemian Massif (Czech Republic). Lithos, 123, 133–144.

VALENTE, G.A. & HIRANO, N. 2010. Mechanisms of low-flux intraplate volcanic fields-Basin and Range (North America) and northwest Pacific Ocean. Geol., 38, 55–58.

VALENTE, G.A. & KEATING, G.N. 2007. Eruptive styles and inferences about plumbing systems at Hidden Cone and Little Black Peak scoria cone volcanoes (Nevada, USA). Bulletin of Volcanology, 70, 105–113.

VALENTE, G.A. & KROGH, K.E.C. 2006. Emplacement of shallow dikes and sills beneath a small basaltic volcanic center – the role of pre-existing structure (Paiute Ridge, southern Nevada, USA). Earth and Planetary Science Letters, 246, 217–230.

VALENTE, G.A. & PERRY, F.V. 2007. Tectonically controlled, time-predictable basaltic volcanism from a lithospheric mantle source (central Basin and Range Province, USA). Earth and Planetary Science Letters, 261, 201–216.

VALENTE, G.A., GAFFNEY, E.S., DAMIANAC, B. & KROGH, K.E. 2007. Saucer-shaped sills at shallow depths beneath a scoria cone volcano (Paiute Ridge, Nevada, USA). Eos, Transactions of the American Geophysical Union, 88, (52, Suppl.), Abstract V11A-0370.

VALENTE, G.A., SHUEFT, N.L. & HINTZ, A.R.L. 2011. Models of maar volcanoes, Lunar Crater (Nevada, USA). Bulletin of Volcanology, 73, 753–765.

VAN OTTERLOO, J. & CAS, R.A.F. 2016. Low-temperature emplacement of phreatomagmatic pyroclastic flow deposits at the monogenetic Mt Gambier Volcanic Complex, South Australia, and their relevance for understanding some deposits in diatremes. Journal of the Geological Society, London, 173, 701–710, https://doi.org/10.1144/jgs2015-122
van Otterloo, J., Cas, R.A.F. & Sheard, M.J. 2013. Eruption processes and deposit characteristics at the monogenetic Mt. Gambier Volcanic Complex, SE Australia: implications for alternating magmatic and phreatomagmatic activity. Bulletin of Volcanology, 75, 737.

van Otterloo, J., Raveggi, M., Cas, R.A.F. & Maas, R. 2014. Polymagmatic activity at the monogenetic Mt Gambier Volcanic Complex in the Newer Volcanics Province, SE Australia: new insights into the occurrence of intraplate volcanic activity in Australia. Journal of Petrology, 55, 1317–1351.

van Wyk de Vries, B., Marquez, A., Herrera, R., Granja Bruna, J.L., Llanes, P. & Delcamp, A. 2014. Craters of elevation revisited: forced-folds, bulging and uplift of volcanoes. Bulletin of Volcanology, 76, 875.

von Veh, M.W. & Németh, K. 2009. An assessment of the alignments of vents on geostatistical analysis in the Auckland Volcanic Field, New Zealand. Geomorphologie: relief, processus, environnement, 15, 175–186.

Walker, G.P.L. 2000. Basaltic volcanoes and volcanic systems. In: Sigurdsson, H., Houghton, B.F., McNutt, S.R., Rymer, H. & Stix, J. (eds) Encyclopedia of Volcanoes. Academic Press, San Diego, CA, 283–290.

White, J.D.L. 1990. Depositional architecture of a maar-pitted playa: sedimentation in the Hopi Buttes volcanic field, northeastern Arizona, U.S.A. Sedimentary Geology, 67, 55–84.

White, J.D.L. 1991. The depositional record of small, monogenetic volcanoes within terrestrial basins. In: Fisher, R.V. & Smith, G.A. (eds) Sedimentation in Volcanic Settings. SEMP (Society for Sedimentary Geology), Special Publications, 45, 155–171.

White, J.D.L. 1996. Pre-emergent construction of a lacustrine basaltic volcano, Pahvant Butte, Utah (USA). Bulletin of Volcanology, 58, 249–262.

White, J.D.L. & Ross, P.S. 2011. Maar-diatreme volcanoes: a review. Journal of Volcanology and Geothermal Research, 201, 1–29.

Wijbrans, J., Németh, K., Martin, U. & Balogh, K. 2007. 40Ar/39Ar geochronology of Neogene phreatomagmatic volcanism in the western Pannonian Basin, Hungary. Journal of Volcanology and Geothermal Research, 164, 193–204.

Wilshire, H.G., McGuire, A.V., Noller, J.S. & Turrin, B.D. 1991. Petrology of lower crustal and upper mantle xenoliths from the Cima Volcanic Field, California. Journal of Petrology, 32, 169–200.

Wood, C.A. 1980. Morphometric evolution of cinder cones. Journal of Volcanology and Geothermal Research, 7, 387–413.

Wright, J.B. 1973. Continental drift, magmatic provinces and mantle plumes. Nature, 244, 565–567.

Xiao, L. & Wang, C.Z. 2009. Geologic features of Wudalianchi volcanic field, northeastern China: implications for Martian volcanology. Planetary and Space Science, 57, 685–698.

Zhang, M., Suddaby, P., Thompson, R.N., Thirlwall, M.F. & Menzies, M.A. 1995. Potassic volcanic-rocks in NE China – geochemical constraints on mantle source and magma genesis. Journal of Petrology, 36, 1275–1303.

Zhao, Y.-W., Fan, Q.-C., Zou, H. & Li, N. 2014. Geochemistry of Quaternary basaltic lavas from the Nuomin volcanic field, Inner Mongolia: implications for the origin of potassic volcanic rocks in Northeastern China. Lithos, 196, 169–180.

Zimmer, B.W., Riggs, N.R. & Carrasco-Nuñez, G. 2010. Evolution of tuff ring-dome complex: the case study of Cerro Pinto, eastern Trans-Mexican Volcanic Belt. Bulletin of Volcanology, 72, 1223–1240.

Zou, H., Reida, M.R., Liub, Y., Yacob, Y., Xud, X. & Fa, Q. 2003. Constraints on the origin of historic potassic basalts from northeast China by U–Th disequilibrium data. Chemical Geology, 200, 189–201.