Introductory Chapter: Updates in Volcanology – From Volcano Modeling to Volcano Geology

Károly Németh

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/64734

The book "*Updates in Volcanology*: *From volcano modelling to volcano geology*" is composed of 13 book chapters provided by authors from a great variety of disciplines. Each of the book chapter genuinely reflects the diversity of volcanological researches in recent years and documents new look at geological problems associated with volcanism and volcanic hazard research. The chapters from this book represent perfectly the current trends in volcanology as a merging research directions from geophysical aspects of volcanology and its traditional field-based methods. The book chapters have been grouped into three sections.

Section 1 is titled "Understanding the volcano system from petrology, geophysics to large-scale experiments" and provides a total of five chapters covering geophysical aspects of volcanic researches including their geochemical perspectives. The section starts with a comprehensive summary on the volcanic plumbing systems we know today and their relevance to understand the volcanic behavior from the magmatic source to a magma fragmentation that provides pyroclasts to be transported and deposited away from their source. Volcanic plumbing systems commonly defined as a network of various magmatic intrusive bodies (sheet- or dyke-like) and diverse size and shape of magmatic storage places (chambers) that located between the primary source and the surface anywhere the geological conditions allow to stall magma migration toward the surface [1–7]. The magmatic plumbing system of a volcano is a complex array of injected melts where various chemical processes take place that are strongly or loosely linked to the primary melt source and/or interact with the wall rocks. This book chapter provides a detailed summary of the methods recently applied to harvest information about these complex system feeding volcanoes on the surface. This chapter provides a summary on the potentials and the limitations of each applied methodology commonly used in magmatic plumbing system studies and highlight the fact that magmatic plumbing systems are complex geo-environments where physical and geochemical processes interact and create a complex 3D array of solidified melts that can then be traced in the geological record as igneous rocks.

Following the detailed summary of the melt generation and migration toward the surface, the next chapter takes the reader to the “surface” and provides a methodological summary on the power of photogrammetric surveys in volcanology. This chapter not only provides an exciting and new read on a traditional method to define volcanic morphology and their temporal changes during volcanic eruptions but it also takes the reader to a very active volcanic zone—Kamchatka—that produced several of the most spectacular volcanic eruptions in the last centuries including the Bezymianny 1955 and other [8, 9], Great Tolbachik 1975 [10–13] and recent 2012 events [14, 15] (**Figure 1**), Karymsky-lake Surtseyan eruption 1996 [16] or the Klyuchevskoy [17], Shiveluch [18], Ksudach [19], Mutnovsky, or Karymsky (**Figure 2**) volcanoes ongoing eruptions. Many of these eruptions not only provided new insight to volcanic eruption processes but also gave new conceptual models for gold recycling beneath volcanoes [20] or let us discover new minerals such as the tolbachite ($CuCl_2$) [21] and other unique minerals [22] or special rock names such as avachites a high-magnesian basalt group documented from the Avachinsky volcano [23]. This chapter looks back 100 years of research history and provides some forgotten images and documents from an area largely unknown for the majority of volcanologists. The chapter through its critical review and global comparison also provides a way forward for the development of the photogrammetric method in volcanology.

Figure 1. Strombolian style explosive eruption through a fissure vent at the Tolbachik volcano in Kamchatka (2012) [Photograph by Dmitry Melnikov, Institute of volcanology and seismology FEB RAS, Petropavlovsk-Kamchatsky, Russia].

Linked to the previous chapter, the third chapter provides a critical review with some original data and research about the role of volcano gravimetry. Volcano gravimetry has developed dramatically in recent years and became a fundamental tool to understand activity changes inside a volcano and hence use collected in situ or near real-time data to estimate volcanic alert status in active volcanoes [24–29]. Gravimetry studies also been used to detect various volcanic structures such as maar-diatreme volcanoes and establish the geological origin of sediment field terrestrial basins, which indeed not as simple process as we might think [30–33]. Similarly, gravimetry has been applied successfully to describe the internal architecture of large volcanoes [34] as well as relatively small-scale features as cavities in lava flows [35]. This chapter provides an easy to understand review of the science behind gravimetry studies then provides an evaluation for the future of gravimetry research on volcanoes.

Figure 2. Summit activity on the Karymsky strato-volcano in Kamchatka [Photo by Dmitry Melnikov, Institute of volcanology and seismology FEB RAS, Petropavlovsk-Kamchatsky, Russia].

The fourth chapter takes the reader to Kyushu in Japan and provides a state-of-art research report with a high-value review of the methods applied to understand the gravity gradient tensor in active volcanic regions in southern Japan. Southern Japan is a home of several post-Pliocene calderas that define the landscape today and the style of expected volcanism in the region [36]. The Kagoshima Bay and its surrounding is in particular one of the region where the highest frequency of silicic caldera-forming eruptions is known on Earth that produced multiple large (10 km<) across calderas and associated ignimbrite and silicic pyroclastic tephra sheets [37]. The large number of volcanoes in these regions alongside with the thick deposits made difficult to see the internal structure of many of these complex volcanoes and their structural relationship to the regional and volcano-tectonic structures; hence, geophysical methods are useful to provide data. This book chapter provides an introduction to the applicability of special gravity gradiometry survey with a new technique to define gravity gradient tensors. The chapter provides clear example to demonstrate that this method capable to locate structural elements such as caldera walls as it has been tested across the Aso caldera [38] hence offer some new avenue to explore for others in other complex volcanic terrains such as the caldera-pitted North Island in New Zealand [39, 40].

The fifth and closing chapter of this section of the book provides a summary of large-scale experiments to understand the source conditions and controlling parameters of explosive eruptions. This chapter is a valuable summary of the methods applied for large-scale experiments written by a group of researchers pioneered experimental volcanology through large-scale experiments; hence, the reader can get a very genuine view of such researches limitations and extent [41, 42]. In addition, the author group is also strongly linked to field-based research on pyroclastic deposits of pyroclastic density currents; therefore, this chapter provides well-established ideas and concepts [43]. In general, large-scale experiment to model various types of explosive processes, magma fragmentations, crater formation, and their numerical modeling is probably one of the most dynamic parts of volcanology in recent years [44–56]. In this chapter, different methodologies for investigating eruptive source conditions and the subsequent evolution of the eruptive plumes are presented. The methodologies range from observational techniques to large-scale experiments and numerical models. The chapter also poses fundamental research questions that can only be answered if we follow the proposed techniques to define the effect of unsteady flow conditions at the source on the eruptive column dynamics and the interaction between a convective plume and wind.

The second section of the book "volcanic eruptions and their impact to the environment" consists of five chapters. Each of these chapters provides various aspects of volcanism from their hazard and consequence perspective. The opening chapter of this section sum up the volcanological information associated with one of the less known volcano that produced one of the largest set of eruptions in the past 10 ka. Baekdusan volcano that is located in the frontier between China and North Korea is a volcano that has a basaltic shield capped by a trachyte-dominated sequence and a large caldera [57]. This chapter highlights the fact that Baekdusan volcano is an active and very complex volcano as its volcanic seismicity, ground deformation, and volcanic gas geochemistry yields indicate that a magmatic unrest takes place in the period between 2002 and 2006. The geological record and the recent volcano monitoring data suggest that the Mt. Baekdusan is an active volcano [58]; hence, proper volcanic hazard studies are needed to estimate the potential volcanic eruption scenarios a new eruption would follow.

The second chapter in this section takes the reader to Japan where an analysis of the magnitude-frequency distribution of slope failures was studied. The statistical data provided in this chapter are based on many years of research, and this chapter gives a very useful summary to the readers how to apply similar method to their fields. Interestingly, this chapter provides a relatively simple equation for the magnitude-frequency distribution of slope failures for larger than 10^7 m^3 volumes. The chapter concludes that this magnitude-frequency may applicable over several thousands of years of record making possible for future large-scale volcanic failure predictions. It is an alarming conclusion however, that larger than 10^9 m^3 mega collapses can occur in every 1000–2000 years period; hence, such mega events cannot be looked at as a rare events in Japan. Volcanic debris avalanches are common volcanic processes that generate a specific volcanic sedimentary successions and geomorphological disturbances; hence, their study is important [59, 60]. Such large-scale failures of volcanic edifices need to be studied in similar way as this chapter demonstrated to be able to provide magnitude-frequency distribution relationships in volcanic terrains prone to collapse.

The third chapter of this section deals with a research area of volcanic aerosol behavior developing dynamically in recent years to provide functioning models to volcanic aerosol effect to radiation in the Arctic. This chapter claims that despite the suspected perturbance of volcanic aerosols to the Arctic radiation balance, we know very little about their radiative impacts in the Arctic. It is also poorly understood partially due to the limited attention, this process has received what the effects of other aerosol types that are often present in the region [61], both natural and anthropogenic [62–64]. The link between volcanic events and their potential climatic impact is one of the subjects reach beyond the limits of volcano sciences and commonly connected to social studies, history, and art [65–69]. Research activity to understand volcanic aerosol behavior over the Arctic has also increased in recent years [70–72]; hence, this chapter provides a very useful summary of the current state of knowledge. The chapter points out that the Arctic environment is both unique and complicated, and the perturbations caused by volcanic aerosol need to be examined in a regional context. Due to the harsh environment, more data are derived from remote sensing; hence, this chapter provides a comprehensive summary of remotely sensed data collection techniques. The numerous models presented in this chapter show the strengths and shortcomings of volcanic ash transport and dispersion models in general [73–75] and calling future targeted research specifically designed for Arctic conditions. Among many, the authors claim that the effect of ash aggregation such as accretionary lapilli formation [76, 77] not many cases considered in ash transport and deposition models in spite their huge effect on the potential distribution pattern their deposition can show [78].

The fourth chapter in this section takes a reader to a fairly new research area that studies the link between corrosion effects on various alloys in a volcano-polluted seawater. Corrosion damage in human-built environment caused by volcanic processes can cause significant economic loss especially in marine steel infrastructures such as bridges, wharfs, platforms, and pipeline systems. While understanding the corrosion in general relatively well documented in subaerial conditions such as volcanic ash and acid rain effect on man-made structures [79–81]. Similar studies in a subaqueous environment are relatively rare [82]. This chapter provides an interesting overview of the world of corrosion including the description of techniques that can measure their rates. The results of the study of corrosion in volcanic-polluted waters can contribute to understanding of the volcanic hazards and associated risks of such processes that can act on human-built environments.

The final chapter in this section deals with the mineral assemblages recorded in various fumarolic systems across the most famous fumarole fields in Europe. This chapter provides a descriptive overview of the mineral phases recorded from various fumarolic systems focusing on examples from Italy and Greece. Fumarolic systems viewed as important environments where rare elements can concentrate even in economically significant amount [20]. The mineral variations associated with fumarolic systems are great, and such systems often act as harvesting ground to identify previously unknown minerals [10, 83]. Fumarolic systems are also viewed as a window to the magmatic system; hence, they commonly studied with an aim to understand the magma behavior provides the heat beneath such systems [84–86]. This chapter takes examples from well-known fumarolic systems such as those at Vulcano Island in Italy to raise some awareness among researchers on the significance of fumarolic systems in volcanic regions.

The final, third section of the book consists of three chapters dealing with volcanic geology problems that can be applied to older volcanic successions. The section starts with an exhaustive summary of the recent results on the study of subaqueous explosive and effusive volcanism in the Cabo de Gata region in SE Spain. Subaqueous volcanism in recent years became the center of volcanic researches [87] partially due to the racing to identify reliable evidences of presence of water or ice on extra-terrestrial regions commonly associated with volcanism [88, 89] and understand ore-forming processes in volcanic regions located or closely linked to subaqueous environments [90, 91]. It is just an addition to the increase of research activity that in the geological record, volcanic rocks are commonly associated with subaqueous sedimentary rocks; hence, there is a need to understand well the limitations of identification of various eruptive environment hence using volcanic rocks for paleoenvironmental (eruptive environment) reconstructions. Identification of peperites [92] for instance became a trademark to contribute to the eruptive environment discussions such as establishing subaqueous versus subaerial conditions [93]. Similarly, new researches on distinguishing explosive versus effusive non-explosive fragmentation of magma to feed large volume of hyaloclastite piles provided useful tools to use these deposits for paleoenvironmental reconstruction of rock units in the geological record [94, 95]. As a result of these research activities, a new commission called Commission of Subaqueous Volcanism of the International Association of Volcanology and Chemistry of the Earth's Interior was established in 2016. Cabo de Gata is probably one of the most perfectly exposed regions where the eruptive products (effusive and explosive) of subaqueous volcanism can be accessed along coastal sections [96]. This chapter provides a very detailed summary for the research results of the study of the Cabo de Gata volcanic rocks based on many previous research works [97].

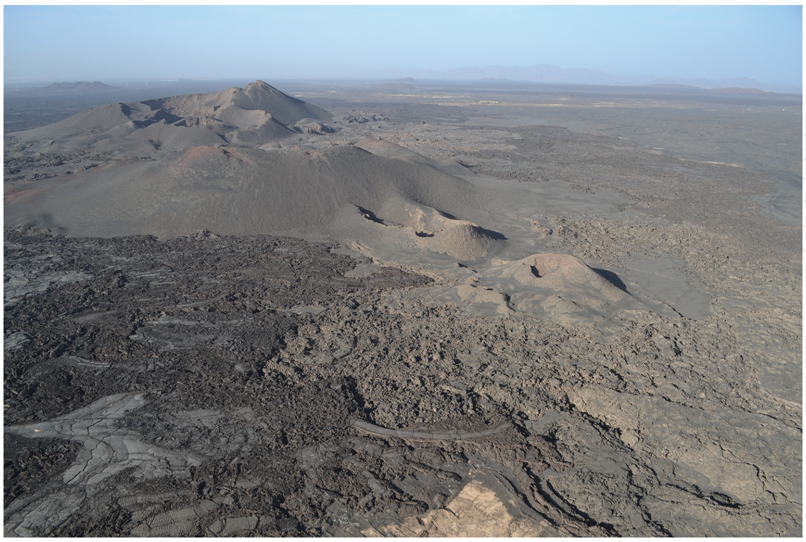

Figure 3. The AD 1256 fissure eruption site near the city of Al Madinah in Saudi Arabia, a potential geosite in the proposed Al Madinah Volcanic Geopark.

The second chapter in this section addresses a question: how polygenetic are monogenetic volcanoes? This question sounds strange as the two word, monogenetic versus polygenetic are opposing and negating each other. The authors take the reader to a journey to demonstrate the difficulty to define monogenetic volcanism especially if we are looking at volcanic successions preserved in a geological record. Such problem has been addressed recently in many places arguing that in old but partially preserved and eroded successions, the distinction between volcanic rock units formed in a single and short volcanic process can look very similar to those that formed over longer time without significant evidence of erosional surfaces in the rock units. This chapter draws again the attention to view small-volume volcanoes as a system that functions as a source to surface model [98]. *In such model, the timing, longevity, and the total eruptive volume of individual eruptive episodes and the total volcanic activity can produce complex volcanic facies architecture composed of multiple eruptive units commonly forming such small-volume volcanoes* [99, 100]. This chapter explores the volcanic facies architecture of small-volume volcanoes that carry obvious signs of complex eruptive history that commonly can be translated to relatively long eruptive history and an elevated volume of magma involvement [101–103]. This chapter is useful to understand the gradual transition of small to large volcanoes, hence to see the link between monogenetic and polygenetic volcanism [104].

The final chapter of this section and the entire book takes the reader to a volcanic region in Inner Mongolia, China, where volcanic rocks help to understand the evolution of the Central Asian Orogenic Belt [105–108]. While this region is not directly considered as a locality of volcanological studies, its geological history documents significant magmatological processes associated with terrane accretion and associated volcanic processes [109]. The region is also a home of advanced studies of adakite magmas, and hence, it is inferred that magmatism resulted from intermediate to felsic magmas that carry geochemical characteristics indicative for the melt to be sourced by partial melting of the altered basalt that is subducted below volcanic arcs [110]. This chapter also highlights the methods need to be applied to recognize various stages of terrain accretion and petrogenetic processes associated with a complex plate margin process.

The book overall provides a great diversity of subjects relevant to volcanic researches. While the book purely a result of "blue sky" attempt to collect new research outputs reflecting the current trends in volcanic researches, the selection of chapters reflects well the dynamic nature of volcanological researches. The book naturally cannot provide a balanced summary of the current advances in volcanology. Large and dynamically developing segments of current volcanological research are not covered in this book. Reports on the advances of crater formation based on analog experiments [47, 50], experimental volcanological studies [76, 111–113], lava flow dynamic modeling through experiments and numerical codes [114, 115], developing new methods for eruption forecasting especially the eruptions' economic impact [116–119], experimental and field-based studies of maar-diatreme volcanism [48] or new advances in understanding magma fragmentation, vesiculation, and their internal and external controlling parameters are among many new research fields this book has not provided overviews. Also, recently, IAVCEI has established a new commission called Commission on Volcano Geoheritage and Protected Volcanic Landscape, which is a clear sign that geoeducation, geoconservation, and geotouristic researches and programs associated with volcanism claiming their own place among volcanic sciences [120] (**Figure 3**). It is hoped that in a future "volcanology" book, reports on these field's research results will be incorporated. Until that please enjoy this book!

Author details

Károly Németh

Address all correspondence to: k.nemeth@massey.ac.nz

Volcanic Risk Solutions, Massey University, Palmerston North, New Zealand

References

[1] Allard, P., et al., Mount Etna 1993–2005: Anatomy of an evolving eruptive cycle. Earth-Science Reviews, 2006. 78(1–2): p. 85–114.

[2] Cartwright, J. and D.M. Hansen, Magma transport through the crust via interconnected sill complexes. Geology, 2006. 34(11): p. 929–932.

[3] Holt, S.J., S.P. Holford, and J. Foden, New insights into the magmatic plumbing system of the South Australian Quaternary Basalt province from 3D seismic and geochemical data. Australian Journal of Earth Sciences, 2013. 60(8): p. 797–816.

[4] Kavanagh, J.L., D. Boutelier, and A.R. Cruden, The mechanics of sill inception, propagation and growth: Experimental evidence for rapid reduction in magmatic overpressure. Earth and Planetary Science Letters, 2015. 421: p. 117–128.

[5] Gudmundsson, A., Strengths and strain energies of volcanic edifices: Implications for eruptions, collapse calderas, and landslides. Natural Hazards and Earth System Sciences, 2012. 12(7): p. 2241–2258.

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

[7] Geshi, N., K. Németh, and T. Oikawa, Growth of phreatomagmatic explosion craters: A model inferred from Suoana crater in Miyakejima Volcano, Japan. Journal of Volcanology and Geothermal Research, 2011. 201(1–4): p. 30–38.

[8] Belousov, A., Deposits of the 30 March 1956 directed blast at Bezymianny volcano, Kamchatka, Russia. Bulletin of Volcanology, 1996. 57(8): p. 649–662.

[9] Belousov, A., et al., Pyroclastic surges and flows from the 8-10 May 1997 explosive eruption of Bezymianny volcano, Kamchatka, Russia. Bulletin of Volcanology, 2002. 64(7): p. 455–471.

[10] Chaplygin, I., et al., Native gold from volcanic gases at Tolbachik 1975–76 and 2012–13 Fissure Eruptions, Kamchatka. Journal of Volcanology and Geothermal Research, 2015. 307: p. 200–209.

[11] Fedotov, S.A., A.P. Khrenov, and A.M. Chirkov, Tolbachik Great Fissure Eruption of 1975, kamchatka. Doklady Akademii Nauk Sssr, 1976. 228(5): p. 1193–1196.

[12] Fedotov, S.A., et al., Major Tolbachik Fissure Eruption in Kamchatka, South Break of 1975–1976. Doklady Akademii Nauk Sssr, 1977. 237(5): p. 1155–1158.

[13] Budmikov, V.A., Y.K. Markhinin, and A.A. Ovsyannikov, The quantity, distribution and petrochemical features of pyroclastics of the Great Tolbachik Fissure Eruption., in The Great Tolbachik Fissure Eruption, S.A. Fedotov and Y.K. Markhinin, Editors. 1983, Cambridge University Press: Cambridge. p. 41–56.

[14] Lundgren, P., et al., Dike model for the 2012–2013 Tolbachik eruption constrained by satellite radar interferometry observations. Journal of Volcanology and Geothermal Research, 2015. 307: p. 79–88.

[15] Volynets, A.O., et al., Monitoring of the volcanic rock compositions during the 2012–2013 fissure eruption at Tolbachik volcano, Kamchatka. Journal of Volcanology and Geothermal Research, 2015. 307: p. 120–132.

[16] Belousov, A. and M. Belousova, Eruptive process, effects and deposits of the 1996 and the ancient basaltic phreatomagmatic eruptions in Karymskoye Lake, Kamchatka, Russia. Special Publication of the International Association of Sedimentologists, 2001. 30: p. 35–60.

[17] Koulakov, I.Y., et al., Magma sources in the mantle wedge beneath the volcanoes of the Klyuchevskoy group and Kizimen based on seismic tomography modeling. Russian Geology and Geophysics, 2016. 57(1): p. 82–94.

[18] Belousov, A.B., The Shiveluch volcanic-eruption of 12 November 1964—Explosive eruption provoked by failure of the edifice. Journal of Volcanology and Geothermal Research, 1995. 66(1–4): p. 357–365.

[19] Braitseva, O.A., et al., The caldera-forming eruption of Ksudach volcano about cal AD 240: The greatest explosive event of our era in Kamchatka, Russia. Journal of Volcanology and Geothermal Research, 1996. 70(1–2): p. 49–65.

[20] Zelenski, M., V.S. Kamenetsky, and J. Hedenquist, Gold recycling and enrichment beneath volcanoes: A case study of Tolbachik, Kamchatka. Earth and Planetary Science Letters, 2016. 437: p. 35–46.

[21] Vergasova, L.P. and S.K. Filatov, A new mineral Tolbachite, CuCl2. Doklady Akademii Nauk Sssr, 1983. 270(2): p. 415–417.

[22] Pekov, I.V., et al., New zinc and potassium chlorides from fumaroles of the Tolbachik volcano, Kamchatka, Russia: Mineral data and crystal chemistry. III. Cryobostryxite, $KZnCl_3 \bullet 2H_2O$. European Journal of Mineralogy, 2015. 27(6): p. 805–812.

[23] Portnyagin, M.V., et al., Petrology of avachites, high-magnesian basalts of Avachinsky volcano, Kamchatka: I. General characteristics and composition of rocks and minerals. Petrology, 2005. 13(2): p. 99–121.

[24] Delgado, F. and A. Pavez, New insights into La Pacana caldera inner structure based on a gravimetric study (central Andes, Chile). Andean Geology, 2015. 42(3): p. 313–328.

[25] Crossley, D., J. Hinderer, and U. Riccardi, The measurement of surface gravity. Reports on Progress in Physics, 2013. 76(4):046101. doi: 10.1088/0034-4885/76/4/046101.

[26] Battaglia, M., et al., 4D volcano gravimetry. Geophysics, 2008. 73(6): p. WA3–WA18.

[27] Behncke, B., et al., Ground deformation and gravity changes on the island of Pantelleria in the geodynamic framework of the Sicily Channel. Journal of Volcanology and Geothermal Research, 2006. 150(1–3): p. 146–162.

[28] Pingue, F., et al., Ground deformation and gravimetric monitoring at Somma-Vesuvius and in the Campanian volcanic area (Italy). Physics and Chemistry of the Earth Part A: Solid Earth and Geodesy, 2000. 25(9–11): p. 747–754.

[29] Saibi, H., J. Gottsmann, and S. Ehara, Post-eruptive gravity changes from 1999 to 2004 at Unzen volcano (Japan): A window into shallow aquifer and hydrothermal dynamics. Journal of Volcanology and Geothermal Research, 2010. 191(1–2): p. 137–147.

[30] Sesulka, V., et al., Identification of a buried Late Cenozoic maar-diatreme structure (North Moravia, Czech Republic). Geologica Carpathica, 2014. 65(6): p. 471–479.

[31] Nickschick, T., H. Kaempf, and T. Jahr, The “Triasscholle” near Greiz, Germany-a volcanic origin? Bulletin of Volcanology, 2014. 76:806. DOI 10.1007/s00445-014-0806-x.

[32] Valenta, J.J., et al., Problems and challenges in detection of pre-Mesozoic maar volcanoes: Example from the Principalek Volcano in the Permian Krkonose Piedmont Basin. Journal of Geosciences, 2014. 59(3): p. 169–181.

[33] Flechsig, C., et al., Integrated geophysical and geological methods to investigate the inner and outer structures of the Quaternary Mytina maar (W-Bohemia, Czech Republic). International Journal of Earth Sciences, 2015. 104(8): p. 2087–2105.

[34] La Delfa, S., G. Patane, and J.C. Tanguy, Kilometer-scale heterogeneities inside volcanoes revealed by using a set of geophysical methods: Variable stress field at Mount Etna, Sicily. Physics of the Earth and Planetary Interiors, 2000. 121(1–2): p. 157–173.

[35] Deroussi, S., et al., Localization of cavities in a thick lava flow by microgravimetry. Journal of Volcanology and Geothermal Research, 2009. 184(1–2): p. 193–198.

[36] Suzukikamata, K. and H. Kamata, The proximal facies of the Tosu Pyroclastic-flow deposit erupted from Aso Caldera, Japan. Bulletin of Volcanology, 1990. 52(5): p. 325–333.

[37] Aramaki, S., Formation of the Aira caldera, southern Kyushu, approximately 22,000 years ago. Journal of Geophysical Research, 1984. 89(NB10): p. 8485–8501.

[38] Miyabuchi, Y., Post-caldera explosive activity inferred from improved 67–30 ka tephrostratigraphy at Aso Volcano, Japan. Journal of Volcanology and Geothermal Research, 2011. 205(3–4): p. 94–113.

[39] Wilson, C.J.N. and J.V. Rowland, The volcanic, magmatic and tectonic setting of the Taupo Volcanic Zone, New Zealand, reviewed from a geothermal perspective. Geothermics, 2016. 59: p. 168–187.

[40] Cole, J.W., et al., Okataina Volcanic Centre, Taupo Volcanic Zone, New Zealand: A review of volcanism and synchronous pluton development in an active, dominantly silicic caldera system. Earth-Science Reviews, 2014. 128: p. 1–17.

[41] Dioguardi, F. and P. Dellino, PYFLOW: A computer code for the calculation of the impact parameters of Dilute Pyroclastic Density Currents (DPDC) based on field data. Computers and Geosciences, 2014. 66: p. 200–210.

[42] Duerig, T., et al., A new method for the determination of the specific kinetic energy (SKE) released to pyroclastic particles at magmatic fragmentation: Theory and first experimental results. Bulletin of Volcanology, 2012. 74(4): p. 895–902.

[43] Mele, D., et al., Hazard of pyroclastic density currents at the Campi Flegrei Caldera (Southern Italy) as deduced from the combined use of facies architecture, physical modeling and statistics of the impact parameters. Journal of Volcanology and Geothermal Research, 2015. 299: p. 35–53.

[44] Ross, P.S., et al., Experimental birth of a maar-diatreme volcano. Journal of Volcanology and Geothermal Research, 2013. 260: p. 1–12.

[45] Mader, H.M., et al., Dynamics of explosive degassing of magma: Observations of fragmenting two-phase flows. Journal of Geophysical Research-Solid Earth, 1996. 101(B3): p. 5547–5560.

[46] Roche, O., D.C. Buesch, and G.A. Valentine, Slow-moving and far-travelled dense pyroclastic flows during the Peach Spring super-eruption. Nature Communications, 2016. 7.

[47] Macorps, E., et al., The effects of the host-substrate properties on maar-diatreme volcanoes: Experimental evidence. Bulletin of Volcanology, 2016. 78:26. DOI 10.1007/s00445-016-1013-8.

[48] Valentine, G.A., et al., Experiments with vertically and laterally migrating subsurface explosions with applications to the geology of phreatomagmatic and hydrothermal explosion craters and diatremes. Bulletin of Volcanology, 2015. 76:15. DOI 10.1007/s00445-015-0901-7.

[49] Sweeney, M.R. and G.A. Valentine, Transport and mixing dynamics from explosions in debris-filled volcanic conduits: Numerical results and implications for maar-diatreme volcanoes. Earth and Planetary Science Letters, 2015. 425: p. 64–76.

[50] Sonder, I., A.H. Graettinger, and G.A. Valentine, Scaling multiblast craters: General approach and application to volcanic craters. Journal of Geophysical Research-Solid Earth, 2015. 120(9): p. 6141–6158.

[51] Graettinger, A.H., et al., Facies distribution of ejecta in analog tephra rings from experiments with single and multiple subsurface explosions. Bulletin of Volcanology, 2015. 77:8. DOI 10.1007/s00445-015-0951-x.

[52] Valentine, G.A., et al., Experimental craters formed by single and multiple buried explosions and implications for volcanic craters with emphasis on maars. Geophysical Research Letters, 2012. Vol. 39, L20301, doi:10.1029/2012GL053716.

[53] Doronzo, D.M., et al., Numerical analysis of the effect of topography on deposition from dilute pyroclastic density currents. Earth and Planetary Science Letters, 2010. 300(1–2): p. 164–173.

[54] Doronzo, D.M., et al., Dust storms, volcanic ash hurricanes, and turbidity currents: Physical similarities and differences with emphasis on flow temperature. Arabian Journal of Geosciences, 2016. 9:290. DOI 10.1007/s12517-016-2351-8.

[55] Roche, O., Nature and velocity of pyroclastic density currents inferred from models of entrainment of substrate lithic clasts. Earth and Planetary Science Letters, 2015. 418: p. 115–125.

[56] Lube, G., et al., Synthesizing large-scale pyroclastic flows: Experimental design, scaling, and first results from PELE. Journal of Geophysical Research-Solid Earth, 2015. 120(3): p. 1487–1502.

[57] Yun, S.-H. and J. Koh, Petrochemical characteristics of volcanic rocks of historic era at Mt. Baekdusan. Journal of the Geological Society of Korea, 2014. 50(6): p. 753–769.

[58] Park, K., Research Trends on Mt. Baekdu Volcano - Is She Dormant or Active? Journal of The Korean Geomorphological Association, 2013. 20(4): p. 117–131.

[59] Tost, M., S.J. Cronin, and J.N. Procter, Transport and emplacement mechanisms of channelised long-runout debris avalanches, Ruapehu volcano, New Zealand. Bulletin of Volcanology, 2014. 76(12).

[60] Procter, J.N., S.J. Cronin, and A.V. Zernack, Landscape and sedimentary response to catastrophic debris avalanches, western Taranaki, New Zealand. Sedimentary Geology, 2009. 220(3–4): p. 271–287.

[61] Iwi, A.M., et al., Mechanisms linking volcanic aerosols to the atlantic meridional overturning circulation. Journal of Climate, 2012. 25(8): p. 3039–3051.

[62] VanCuren, R.A., et al., Aerosols and their sources at Summit Greenland – First results of continuous size- and time-resolved sampling. Atmospheric Environment, 2012. 52: p. 82–97.

[63] Scalabrin, E., et al., Amino acids in Arctic aerosols. Atmospheric Chemistry and Physics, 2012. 12(21): p. 10453–10463.

[64] Allen, R.J. and S.C. Sherwood, The impact of natural versus anthropogenic aerosols on atmospheric circulation in the Community Atmosphere Model. Climate Dynamics, 2011. 36(9–10): p. 1959–1978.

[65] Toohey, M., et al., Climatic and societal impacts of a volcanic double event at the dawn of the Middle Ages. Climatic Change, 2016. 136(3–4): p. 401–412.

[66] Miller, G.H., et al., Abrupt onset of the Little Ice Age triggered by volcanism and sustained by sea-ice/ocean feedbacks. Geophysical Research Letters, 2012. Vol. 39, L02708,doi:10.1029/2011GL050168.

[67] Timmreck, C., Modeling the climatic effects of large explosive volcanic eruptions. Wiley Interdisciplinary Reviews-Climate Change, 2012. 3(6): p. 545–564.

[68] Meronen, H., et al., Climate effects of northern hemisphere volcanic eruptions in an Earth System Model. Atmospheric Research, 2012. 114: p. 107–118.

[69] Zhong, Y., et al., Centennial-scale climate change from decadally-paced explosive volcanism: A coupled sea ice-ocean mechanism. Climate Dynamics, 2011. 37(11–12): p. 2373–2387.

[70] Kravitz, B. and A. Robock, Climate effects of high-latitude volcanic eruptions: Role of the time of year. Journal of Geophysical Research-Atmospheres, 2011. Vol. 116, D01105, doi:10.1029/2010JD014448.

[71] Harris, B.M. and E.J. Highwood, A simple relationship between volcanic sulfate aerosol optical depth and surface temperature change simulated in an atmosphere-ocean general circulation model. Journal of Geophysical Research-Atmospheres, 2011. Vol. 116, D05109, doi:10.1029/2010JD014581.

[72] Robock, A., L. Oman, and G.L. Stenchikov, Regional climate responses to geoengineering with tropical and Arctic SO_2 injections. Journal of Geophysical Research-Atmospheres, 2008. Vol. 113, D16101, doi:10.1029/2008JD010050.

[73] Wilkins, K.L., et al., Using data insertion with the NAME model to simulate the 8 May 2010 Eyjafjallajokull volcanic ash cloud. Journal of Geophysical Research-Atmospheres, 2016. 121(1): p. 306–323.

[74] Mulena, G.C., et al., Examining the influence of meteorological simulations forced by different initial and boundary conditions in volcanic ash dispersion modelling. Atmospheric Research, 2016. 176: p. 29–42.

[75] Stevenson, J.A., et al., Big grains go far: Understanding the discrepancy between tephrochronology and satellite infrared measurements of volcanic ash. Atmospheric Measurement Techniques, 2015. 8(5): p. 2069–2091.

[76] Mueller, S.B., et al., Experimental volcanic ash aggregation: Internal structuring of accretionary lapilli and the role of liquid bonding. Earth and Planetary Science Letters, 2016. 433: p. 232–240.

[77] Van Eaton, A.R., et al., Hail formation triggers rapid ash aggregation in volcanic plumes. Nature Communications, 2015. 6:7860. DOI: 10.1038/ncomms8860.

[78] Folch, A., A. Costa, and G. Macedonio, FPLUME-1.0: An integral volcanic plume model accounting for ash aggregation. Geoscientific Model Development, 2016. 9(1): p. 431–450.

[79] Wilson, G., et al., Vulnerability of laptop computers to volcanic ash and gas. Natural Hazards, 2012. 63(2): p. 711–736.

[80] Watanabe, M., et al., Corrosion of copper and silver plates by volcanic gases. Corrosion Science, 2006. 48(11): p. 3759–3766.

[81] Kelestemur, O. and B. Demirel, Corrosion behavior of reinforcing steel embedded in concrete produced with finely ground pumice and silica fume. Construction and Building Materials, 2010. 24(10): p. 1898–1905.

[82] Morinaga, Y., et al., Comparative Study of Corrosion Resistance and Corrosion Products in Hot Spring, Seaside, and Other Environments Between Zn and Zn-7Al Alloy-Coated Steel. Corrosion, 2008. 64(12): p. 929–938.

[83] Jacobsen, M.J., et al., Oskarssonite, AlF3, a new fumarolic mineral from Eldfell volcano, Heimaey, Iceland. Mineralogical Magazine, 2014. 78(1): p. 215–222.

[84] Caliro, S., G. Chiodini, and A. Paonita, Geochemical evidences of magma dynamics at Campi Flegrei (Italy). Geochimica Et Cosmochimica Acta, 2014. 132: p. 1–15.

[85] Tassi, F., et al., Geochemical and isotopic changes in the fumarolic and submerged gas discharges during the 2011-2012 unrest at Santorini caldera (Greece). Bulletin of Volcanology, 2013. 75:711. DOI: 10.1007/s00445-013-0711-8.

[86] Paonita, A., et al., The episodic and abrupt geochemical changes at La Fossa fumaroles (Vulcano Island, Italy) and related constraints on the dynamics, structure, and compo-

sitions of the magmatic system. Geochimica Et Cosmochimica Acta, 2013. 120: p. 158–178.

[87] Cas, R.A.F. and G. Giordano, Submarine Volcanism: A review of the constraints, processes and products, and relevance to the Cabo de Gata volcanic succession. Italian Journal of Geosciences, 2014. 133(3): p. 362–377.

[88] Bernhardt, H., et al., Photogeologic mapping and the geologic history of the Hellas basin floor, Mars. Icarus, 2016. 264: p. 407–442.

[89] Zealey, W.J., Glacial, periglacial and glacio-volcanic structures on the Echus Plateau, upper Kasei Valles. Planetary and Space Science, 2009. 57(5–6): p. 699–710.

[90] Large, R.R., Australian volcanic-hosted massive sulfide deposits—features, styles, and genetic models. Economic Geology and the Bulletin of the Society of Economic Geologists, 1992. 87(3): p. 471–510.

[91] McPhie, J., et al., Origin of the supergiant Olympic Dam Cu-U-Au-Ag deposit, South Australia: Was a sedimentary basin involved? Geology, 2011. 39(8): p. 795–798.

[92] Skilling, I.P., J.D.L. White, and J. McPhie, Peperite: A review of magma-sediment mingling. Journal of Volcanology and Geothermal Research, 2002. 114(1–2): p. 1–17.

[93] Rosa, C.J.P., J. McPhie, and J.M.R.S. Relvas, Distinguishing peperite from other sediment-matrix igneous breccias: Lessons from the Iberian Pyrite Belt. Journal of Volcanology and Geothermal Research, 2016. 315: p. 28–39.

[94] Jutzeler, M., J. McPhie, and S.R. Allen, Explosive destruction of a Pliocene hot lava dome underwater: Dogashima (Japan). Journal of Volcanology and Geothermal Research, 2015. 304: p. 75–81.

[95] Allen, S.R. and J. McPhie, Products of neptunian eruptions. Geology, 2009. 37(7): p. 639–642.

[96] Biber, J.L. and T. McCann, Peperite development in a Miocene-age carbonate succession, Cabo de Gata volcanic area (Agua Amarga/Carboneras basins), SE Spain - The Breche Rouge revisited. Zeitschrift Der Deutschen Gesellschaft Fur Geowissenschaften, 2014. 165(2): p. 229–245.

[97] Soriano, C., et al., Facies architecture, emplacement mechanisms and eruption style of the submarine andesite El Barronal complex, Cabo de Gata, SE Spain. Journal of Volcanology and Geothermal Research, 2013. 264: p. 210–222.

[98] Canon-Tapia, E., Reappraisal of the significance of volcanic fields. Journal of Volcanology and Geothermal Research, 2016. 310: p. 26–38.

[99] Muirhead, J.D., et al., Monogenetic volcanoes fed by interconnected dikes and sills in the Hopi Buttes volcanic field, Navajo Nation, USA. Bulletin of Volcanology, 2016. 78:11. DOI: 10.1007/s00445-016-1005-8.

[100] Lefebvre, N.S., J.D.L. White, and B.A. Kjarsgaard, Arrested diatreme development: Standing Rocks East, Hopi Buttes, Navajo Nation, USA. Journal of Volcanology and Geothermal Research, 2016. 310: p. 186–208.

[101] Sheth, H.C. and E. Canon-Tapia, Are flood basalt eruptions monogenetic or polygenetic? International Journal of Earth Sciences, 2015. 104(8): p. 2147–2162.

[102] Jankovics, M.E., et al., A complex magmatic system beneath the Kissomlyo monogenetic volcano (western Pannonian Basin): Evidence from mineral textures, zoning and chemistry. Journal of Volcanology and Geothermal Research, 2015. 301: p. 38–55.

[103] Brenna, M., et al., Co-located monogenetic eruptions similar to 200 kyr apart driven by tapping vertically separated mantle source regions, Chagwido, Jeju Island, Republic of Korea. Bulletin of Volcanology, 2015. 77:43. DOI: 10.1007/s00445-015-0928-9.

[104] Nemeth, K. and G. Kereszturi, Monogenetic volcanism: Personal views and discussion. International Journal of Earth Sciences, 2015. 104(8): p. 2131–2146.

[105] Zhao, Y., et al., The Dunhuang block is a Paleozoic orogenic belt and part of the Central Asian Orogenic Belt (CAOB), NW China. Gondwana Research, 2016. 30: p. 207–223.

[106] Shi, Y., et al., Zircon ages and Hf isotopic compositions of Ordovician and Carboniferous granitoids from central Inner Mongolia and their significance for early and late Paleozoic evolution of the Central Asian Orogenic Belt. Journal of Asian Earth Sciences, 2016. 117: p. 153–169.

[107] Li, H., et al., Ordovician intrusive rocks from the eastern Central Asian Orogenic Belt in Northeast China: Chronology and implications for bidirectional subduction of the early Palaeozoic Palaeo-Asian Ocean. International Geology Review, 2016. 58(10): p. 1175–1195.

[108] Xiao, W. and M. Santosh, The western Central Asian Orogenic Belt: A window to accretionary orogenesis and continental growth. Gondwana Research, 2014. 25(4): p. 1429–1444.

[109] Liu, J., et al., The tectonic setting of early Permian bimodal volcanism in central Inner Mongolia: Continental rift, post-collisional extension, or active continental margin? International Geology Review, 2016. 58(6): p. 737–755.

[110] Castillo, P.R., Adakite petrogenesis. Lithos, 2012. 134: p. 304–316.

[111] Kueppers, U., et al., Fragmentation efficiency of explosive volcanic eruptions: A study of experimentally generated pyroclasts. Journal of Volcanology and Geothermal Research, 2006. 153(1–2): p. 125–135.

[112] Daniels, K.A. and T. Menand, An experimental investigation of dyke injection under regional extensional stress. Journal of Geophysical Research-Solid Earth, 2015. 120(3): p. 2014–2035.

[113] Dioguardi, F., P. Dellino, and S. de Lorenzo, Integration of large-scale experiments and numerical simulations for the calibration of friction laws in volcanic conduit flows. Journal of Volcanology and Geothermal Research, 2013. 250: p. 75–90.

[114] Kereszturi, G., et al., Emplacement conditions of the 1256 AD Al-Madinah lava flow field in Harrat Rahat, Kingdom of Saudi Arabia - Insights from surface morphology and lava flow simulations. Journal of Volcanology and Geothermal Research, 2016. 309: p. 14–30.

[115] Del Negro, C., A. Cappello, and G. Ganci, Quantifying lava flow hazards in response to effusive eruption. Geological Society of America Bulletin, 2016. 128(5–6): p. 752–763.

[116] Bebbington, M. and R. Zitikis, Dynamic Uncertainty in Cost-Benefit Analysis of Evacuation Prior to a Volcanic Eruption. Mathematical Geosciences, 2016. 48(2): p. 123–148.

[117] Sobradelo, R., et al., Probabilistic approach to decision-making under uncertainty during volcanic crises: Retrospective application to the El Hierro (Spain) 2011 volcanic crisis. Natural Hazards, 2015. 76(2): p. 979–998.

[118] Kereszturi, G., et al., Influences on the variability of eruption sequences and style transitions in the Auckland Volcanic Field, New Zealand. Journal of Volcanology and Geothermal Research, 2014. 286: p. 101–115.

[119] Runge, M.G., et al., Integrating geological and geophysical data to improve probabilistic hazard forecasting of Arabian Shield volcanism. Journal of Volcanology and Geothermal Research, 2016. 311: p. 41–59.

[120] Moufti, M.R. and K. Nemeth, The intra-continental Al Madinah volcanic field, Western Saudi Arabia: A proposal to establish Harrat Al Madinah as the first volcanic Geopark in the Kingdom of Saudi Arabia. Geoheritage, 2013. 5(3): p. 185–206.