Episodic triggering of the rise of resident small-scale basaltic magmas from the mantle

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Small scale basaltic magmatic systems are expressed at the Earth's surface as fields of individual volcanoes, each representing a discrete batch of magma erupted within a defined period of time (weeks to years). Characteristically each volcano shows chemical compositions that are distinct from that of other volcanoes in the field and this can be explained in terms of variation in the parameters of magma generation, specifically depth and proportion of melting. Fundamental to an understanding of the behaviour of such systems is the behaviour of their mantle source. The scale of these systems precludes large scale plume related processes such as those implicated in the origin of large igneous provinces. Rather, adiabatic melting linked to small scale mantle convection can explain both the size and longevity (up to 10 Ma) of these systems. However, the important questions are does each volcano in a field represent a single melting event and what triggers each event? To address these questions we investigate the Quaternary Auckland Volcanic Field (AVF) in northern New Zealand. The field exhibits the common volcanological and chemical behaviour of classic monogenetic volcanic systems. However, a notable feature is the eruption of compositionally discrete magma batches within a very short interval. Paleomagnetic measurements indicate eruption of at least 5 distinct magma batches within a period of about 100 years at about 36 ka. Geochemical modelling shows that these discrete magma batches are not linked by fractionation processes to a single parental composition. The physics of mantle behaviour and melting processes suggest that it is unlikely that each batch represents a separately triggered melting event within a small isolated source volume. We therefore suggest that the origin of compositionally discrete magma batches is not separate melting events but separate extraction events from a source that is partially molten but heterogeneous in terms of melting proportion and therefore melt composition. This is analogous to the model of crustal hot zones invoked to explain variation in magmas within the crust. The final question is what triggers a series of individual extraction events. Here we invoke tectonic forcing from the convergent plate boundary 400 km distant in the central North Island of New Zealand as indicated by correlations between major events on this boundary and flare-ups of volcanic activity in other NZ volcanoes as well as the AVF.

Depth of melt segregation below the Nyos maar-diatreme volcano (Cameroon, West-Africa): major-trace element evidence and their bearing on the origin of CO2 in Lake Nyos

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The Nyos maar-diatreme volcano on the Oku Volcanic Group (OVG) in NW Cameroon carries yet the most infamous maar lake in the world because the lake exploded in 1986 releasing CO2 that killed about 1750 people and over 3000 livestock. A process of safely getting rid of accumulated gas from the lake started in 2001. Even though about 40 per cent of it has been removed, gas continues to seep into the lake from the mantle, so the lake still poses a thread. Available data on basaltic lava from the maar-diatreme volcano and other volcanoes of the OVG are used here to determine the depth and location where the magmas are produced, and to make inferences on the generation of CO2 in the Nyos mantle. Fractionation-corrected major element data agree well with experimental data on mantle peridotite and suggest that Lake Nyos magmas formed at pressures of 2-3 GPa in the garnet stability field. This inference is corroborated by trace element models that indicate small degree (1-2 per cent) partial melting in the presence of residual garnet (2-3 per cent). The basalts have elevated High Field Strength Element (HFSE) ratios (Zr/Hf = 48.5 + 1.2 and Ti/Eu = 5606 + 224) which cannot be explained by any reasonable fractional crystallization model. A viable mechanism would be melting of a mantle that was previously spiked by percolating carbonatitic melts. It is suggested that small degree partial melting of this metasomatised mantle produces the lavas with super chondritic HFSE ratios, and is generating the CO2 that seeps into and accumulates in the lake, and which asphyxiated people and animals during the 1986 gas disaster. This finding requires that current efforts to degas Lake Nyos should take into account the fact that CO2 will continue to seep into the lake for a yet undetermined but long time in the future. A viable solution would be to avoid renewed stratification of the lake, by (somehow) safely and permanently bringing bottom gas-charged waters to the surface to release gas, even after the gas currently stocked in the lake has been completely removed.

Petrology and geochemistry of the New Tolbachik Fissure Eruption volcanic rocks and their evolution during the first two weeks of eruption

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The New Tolbachik Fissure Eruption started on 27.11.2012. Plosky Tolbachik is a stratovolcano, active in Holocene; it is intersected by Tolbachinsky Dol - the monogenetic lava field, formed by numerous cinder cones and lava flows eruptions which repeatedly took place for the last 10 Ka. Most of all cinder cones are concentrated in the narrow axial zone responding to the fault zone location (Fedotov et al., 1984). The last big fissure eruption in this region occurred 37 years ago and lasted for 2 years; the volume of erupted material was 2.2 km3, lava flows covered the area of 45 km2; magnesian, alumina and transitional basalts were erupted. Besides, a new caldera was formed at the summit crater of Plosky Tolbachik (Fedotov et al., 1984).

The New Tolbachik Fissure Eruption began from the effusion and explosion of high-K Ti-rich aluminous trachy-basaltic andesites, black, sub-aphyric, with rare phenocrysts of Pl, Ol and Cpx. Microlites of the groundmass with pilotaxitic and hyalopilitic structures are mainly Pl, dovetail shaped, and, to a lesser extent, Ol and Cpx; Mt is abundant; the areas with hyaline groundmass compositionally similar to the whole rocks are confined to the highly-porous parts of the rock. The petrography of the volcanic rocks of the first days of eruption attests very rapid cooling, high rates of eruption and high mobility of the lava. Composition of Ol varies from Fo64 to 80, Pl is An41 to 62; Cpx are Augites and Salites. The average content (wt.percent) of SiO2 in the whole rock from the first days of eruption is 54.57, Al2O3 16.6, K2O 2.5, MgO 3.36, TiO2 1.8 (for comparison, the eruption in 1975 started from high-Mg medium-K basalts and was continued by high-Al high-K basalts, which are close in composition to the newly erupted basaltic andesites, but have lower content of silica, alkalis and TiO2 at higher MgO and CaO). During the next two weeks bigger plagioclase crystals appeared as phenocrysts (up to 1 cm in diameter); also Ol became more abundant and bigger in size (up to 3 mm in diameter) in comparison to the lavas of the beginning of this eruption. The composition of rocks gradually changed to more mafic: after 10-14 days silica content (wt.percent) dropped to 52.79, while MgO increased to 4.08, TiO2 to 2.03, Al2O3 decreased to 15.8 and K2O remained roughly the same. The trace elements content also changes regularly with the shifting of the main oxides content. Overall, the incompatible trace elements content in lavas of the first portions of new eruption is higher than in all previously studied volcanic rocks of Tolbachinsky Dol; the distribution of trace elements on spidergrams and REE on REE-diagrams forms sub-parallel trends, indicating possible derivation of these rocks through fractional differentiation processes of parent magmas, responsible for the formation of basalts of the North and South Vents of the Great Fissure Tolbachik Eruption in 1975-76.

This work is supported by FED RAS grant 12-III-A-08-165.

Magma ascent and fragmentation in a silica-undersaturated monogenetic volcanic field: evidence from textural analysis of pyroclasts from the Gregory Rift (East African Rift System)

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Pyroclasts formed in eruptions involving high CO_2, silica-undersaturated, magmas in the Gregory Rift of northern Tanzania show distinct textural and morphological characteristics when compared to the more common basaltic equivalents. Overall the shape of all pyroclasts (independent of size) is sub-rounded to near spherical and evidence of broken bubble walls or blocky fragments is extremely rare. This applies to all melilititic eruptions, but do also occur in the eruptions of more primitive nephelinitic magmas erupted in the area. Many of the volcanic landforms within this monogenetic field would classify as maars and tuff rings/cones based on morphology alone, yet the availability of external water required to drive phreatomagmatic fragmentation is scarce as most of these "phreatomagmatic" landforms are located on a horst structure 200-300 meters above the surrounding sedimentary basins and in an arid climate (where evaporation greatly exceeds rainfall on an annual basis). The melilititic pyroclasts are moderately vesiculated (around 30-40%), which is a considerably higher value than what would be expected in phreatomagmatic deposits. Analysis of vesicle size distributions and vesicle number densities also show minor differences between melilititic pyroclasts in scoria cones and those found within tuff rings as well as maar-diatreme volcanoes. From this, in combination with the observed morphologies, it is clear that there is no clear difference between inferred "magmatic" and "phreatomagmatic" pyroclasts of melilititic compositions.

The ascent rate must have been high for the melilititic magmas, and calculations show that these magmas probably ascended with a rate of 8-35 ms^{-1} from an upper-mantle source to the surface (i.e., less than one day), with an absolute minimum speed of <1 ms^{-1} required in order to keep the mantle debris entrained with the rising magma. This essentially excludes any possibility of long-time ponding, and associated degassing, of the melilititic magmas during ascent. Previous studies have shown that melilititic melts can hold >18 wt.% of CO_2 dissolved within the melt structure at upper-mantle pressures, and it is here proposed that the sub-rounded to spherical melilititic pyroclasts form as a result of rapid exsolution of CO_2 during ascent, and that this fragmentation level (controlled by the increasing gas fraction-volume) is located at depth within the conduit. A deep fragmentation level and transport as an aerosol-type gas jet would imply significant cooling of pyroclasts (also within the conduit itself) and this may explain the absence of agglutination/welding even at the crater rim of the melilititic deposits.

Chemical variation in an historical monogenetic eruption (1256 AD Al-Madinah eruption) in the Kingdom of Saudi Arabia: Identifying magma sources

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The study of monogenetic volcanism has become increasingly important over the past decade, particularly in areas where small-scale but frequent volcanism can pose a threat to highly populated or culturally significant areas. Combined physical volcanology and geochemical studies have the potential to provide insights into the occurrence of future eruptions, and the study of well-preserved historical eruptions is particularly useful in this regard. We examined the most recent eruption of the Al-Madinah Volcanic Field in Saudi Arabia, which occurred in 1256 AD, 20 km from the centre of Al-Madinah City. This eruption created seven isolated and nested cones (cones 1-7, from S to N), along a ca.2 km-long fissure associated with a 56 km^2pahoehoe-and-aa lava flow field. Cones 1 to 4 are isolated and cones 5 to 7 are nested and the largest. Cone 1 original edifice was modified by repeated rafting while the others are well-preserved. Volcanological facies variations indicate that the eruptions were most explosive in the nested cones and Strombolian activity was the dominant style. The products generated were alkali basalts and hawaiites (SiO_2 45-47wt%) with some variation in composition, although all show trace element characteristics that lie between typical OIB and MORB. Three compositional groups can be identified: Group 1 has higher abundances of compatible elements (MgO 8-9.4wt%; Mg# 58-63; CaO 10-11wt%; Sc 29-34ppm; V 255-277ppm; Cr 139-329ppm; Ni 118-189ppm), Group 3 has lower abundances of compatible elements (MgO 5.6-6.3wt%; Mg# 46-51; CaO 8-9wt%; Sc 24-29ppm; V 190-217ppm; Cr 69-137ppm; Ni 45-76ppm), and Group 2 lies between these two compositions. Group 1 compositions are from cone 1 and rafted material >1 km from the cone. Group 2 compositions are from cone 2; and Group 3 compositions are from cones 3 to 7. These groups correlate with three groups of lava flows defined as erupting simultaneously in a previous study and described as Low-K, High-K and hybrid basalts. Preliminary results suggest polybaric melting with trace element behaviour indicating a spinel peridotite source for Group 1 (Tb_n/Yb_n=1.62-1.8; $(La/Yb)_n/(Sm/Yb)_n$=1.38-1.71) and a garnet peridotite source for Groups 2 and 3 (Tb_n/Yb_n=1.9-2.1; $(La/Yb)_n/(Sm/Yb)_n$=1.56-1.96) with variations in the degrees of melting: Group 1, La_n/Lu_n=3.1-4.8; La_n/Sm_n=1.5-2; Gd_n/Yb_n=1.8-2.2; Group 3, La_n/Lu_n=4-6.8; La_n/Sm_n=1.3-1.7; Gd_n/Yb_n=2-2.7; and Group 2 compositions lying between these values. This study contributes to the understanding of the temporal evolution of magma compositions and gives new insights into the origin of the magma(s), which is vital information for creating realistic hazard scenarios in this culturally important area.

Mantle domain boundary beneath the Jicin Volcanic Field, Czech Republic: evidence from isotopic composition of primitive alkaline basaltic rocks

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The Jicin Volcanic Field is situated on the southern shoulder of the Oligocene-Miocene Eger Rift, some 30-60 km from its southern margin and is dominated by scattered erosional remnants of monogenetic volcanoes in NE Bohemia (Czech Republic). The volcanic field mostly consists of scoria- and tuff-cones, a handful of lava flows and lava lakes filling phreatomagmatic craters, and several dykes exposed by selective erosion. Volcanic activity in this area took place in two distinctive periods. Most volcanoes were formed during the Miocene (16-19 Ma) whereas few cones grew up during the Pliocene (4-5 Ma). Primitive members predominate among the erupted magmas of within-plate alkaline character. These are represented by olivine nephelinites and basanites/limburgites with rare picrobasalts. Models of mineral composition suggest that the picrobasalts are derived from basanites through accumulation of ca 15% olivine. Despite relatively uniform major and trace element compositions, significant differences in radiogenic isotopic compositions are observed. The $^{87}Sr/^{86}Sr$ (present-day) ratios for the southern part of the volcanic field are higher than 0.7035 whereas they are strictly limited to lower than 0.7035 in the northern part. In parallel, $^{143}Nd/^{144}Nd$ ratios are higher than 0.51285 for magmas erupted in southern part and lower than this value in the northern part. Collectively, magmas erupted in the northern part of the Jicin Volcanic field are isotopicaly similar to main volcanic complexes of the Eger Rift, whereas the southern part is obviously derived from a more depleted mantle source. Both groups of basaltic rocks erupted in the Jicin volcanic field are also distinguished by their Pb isotopic compositions. Both suites plot in two parallel trends in the $^{208}Pb/^{204}Pb$ vs. $^{206}Pb/^{204}Pb$ diagram, where the northern part is relatively enriched in ^{208}Pb compared to the southern part. We explain more depleted character of the source mantle for the southern part of the Jicin Volcanic field in the context of greater distance from the Eger Rift and, therefore, also from the Variscan suture between Saxothuringian and Bohemian domains, which could modify the mantle composition in the zone of Eger Rift.

Small calc-alkaline volcanoes from the Oas-Gutâi Neogene volcanic area, Eastern Carpathians, Romania; contribution to the controversial monogenetic versus polygenetic classification

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The Oas-Gutâi Neogene volcanic area (OG) belongs to the inner volcanic arc of the Eastern Carpathians built up during complex Miocene subduction processes developed in the Carpathian-Pannonian region. A complex volcanism developed in OG during Miocene (15.4-7.0 Ma). The dominant intermediate calc-alkaline volcanic rocks (predominant medium-K andesites) are overlapping the previous felsic volcanic rocks (rhyolite ignimbrites). The small-sized volcanic forms (200 m to 5 km) related to the intermediate volcanism are mainly represented by solitary volcanoes surrounded by Neogene-Quaternary sedimentary deposits, generally emplaced outside of the main volcanic area, or by small volcanoes spatially associated with the large-sized, complex volcanic structures. These are extrusive domes, dome-coulées and cryptodomes comprised of andesites to rhyolites. The majority of the solitary volcanoes are monogenetic (simple-shape, small volume of magma, single petrographic rock-type) as those from Oas Mts., subaqueously emplaced along certain alignments (possibly tectonically-controlled fissures) oriented parallel with the volcanic arc. Others show petrographic complexity raising questions about the monogenetic or polygenetic genesis. In Oas Mts., the steep conical Jeleznic dome of ca. 4 km diameter, shows a discontinuous composition with pyroxene andesite in the western side and pyroxene hyalodacite in the eastern side. Two very small volcanic forms (ca. 300 m all together) joined in an extrusive dome (Turulung) are comprised of biotite dacite and pyroxene hyalodacite, respectively. In Gutâi Mts., two interconnected extrusive domes (Piatra Rosie-Dănesti), surrounded by Neogene-Quaternary sedimentary deposits, are comprised by pyroxene dacite and biotite dacite/rhyolite, respectively. In the case of the small volcanoes developed inside the volcanic area and classified as "monogenetic", these show a well-defined morphology and specific volcanological and petrological features (e.g. Gutin and Breze extrusive domes). Others raise the question whether these are monogenetic or polygenetic: the Laleaua Albă small-sized (ca. 800 m) dome is comprised of a core of macroporphyric sanidine dacite (8.42 ± 0.33 Ma) surrounded by an envelope of aphyric andesite (8.47 ± 0.42 Ma); the Plesca Mare large-sized (ca. 3.5 km) dome is comprised of a well-developed biotite dacite (68.2 SiO_2) core, bordered by a biotite andesite (58.7 SiO_2). Although these features are the result of magma-mixing and -mingling processes, their eruptive history suggests at least two magmatic pulses/events possibly developed during the same near-continuous, short-lived volcanic activity. The problem of the "monogenetic" volcanoes in OG is aligned with the ongoing discussion about the criteria to be used to separate monogenetic versus polygenetic, as well as to define the size of so called "small monogenetic" volcanoes.

The eruptive history of the small and isolated andesitic Caraci Volcano, developed adjacent to Zărand Basin, South Apuseni Mountains, Romania.

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Caraci Volcano has a slightly asymmetrical buttressed edifice with an ellipsoidal dome structure (D/H ratio 10.7) on top and a total height of 420m, covering a surface estimated at 22km^2. It is located in a small Miocene tectonic basin that has developed adjacent to Zărand Basin, in the South Apuseni Mountains of the Carpathian-Pannonian Region. It was active at around 12.5Ma. Most of the volcanic structure overlies the pre-Neogene basement made of ophiolitic basalts and intruded by younger igneous bodies, while the northern part of the edifice covers Miocene sedimentary deposits (coarse quartz gravel, shales and weakly consolidated sandstone). 3D modeling of the surface of the basement reveals a wedge like basin delimited by normal faults and cut by transversal adjustment normal faults that facilitated volcanic activity. The first volcanic deposits consist of highly fragmented tuffs (sometimes up to 40m thick), covered on the northern slope by a hornblende-plagioclase-phyric andesitic lava flow, and on the southern slope by a highly fragmented breccia of phreatomagmatic origin. The volcanic activity continues with a hornblende-plagioclase-phyric andesitic lava flow sequence that comprises most of the volume generated by Caraci and which spreads over most of the surface covered by the volcanics; flow units juxtapose to a maximum thickness of 100m and slight, but consistent geochemical and petrological variations are observed from bottom to top. Two more, less voluminous andesitic effusions add up to the volcano, one with entirely opacitised hornblende and the latter with almost completely disintegrated opacite and microcrysts of clino- and ortho-pyroxenes. The final effusion consists in the growth of the central dome structure, made of two-pyroxene-plagioclase-phyric basaltic andesites. The southern slope and in less extend the northern, are covered by breccias of pyroclastic origin, made of centimeter-to-meter sized basaltic andesite fragments bounded together in cineritic material; they are interpreted as block-and-ash deposits resulted from dome collapsing events. Meter sized angular basaltic andesite blocks are spread over the eastern, southern and western slopes of the volcano.

From a petrological view, feldspars from each sample show disequilibrium textures and overgrowths that create a variety of patterns, consistent with temperature rise, depressurization or undercooling. These patterns become more complex with each new eruption, until the effusion of the dome-building basaltic andesites that show again simpler patterns. Hornblende also develops thicker reaction rims and more profound opacitisation and resorbtion until it is completely replaced by pyroxenes. This is interpreted as evidence for magma mixing and it is consistent with geochemical modeling that suggests mixing with a more primitive batch of magma. Magnetic susceptibility variations are supporting the petrological assumptions.

Targeting monogenetic volcanoes from different angles to enhance our understanding of the complex eruption dynamics: case study Mt. Gambier, S.E. Australia (VEI 4)

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Monogenetic volcanoes can be very complex requiring a multidisciplinary approach to fully understand their dynamics. Here we present the improved understanding of the eruption dynamics of monogenetic volcanoes based on such an approach, with the 5 ka Mt Gambier Volcanic Complex in the Newer Volcanics Province of south-eastern Australia being the case study. This maar-cone complex is marked by the alternating magmatic and phreatomagmatic deposits reflecting multiple changes in eruption styles.

Detailed mapping was integrated with borehole data into a 3D model, so that the volumes of the different pyroclastic deposits and lava flows related to different eruption styles could be determined. In total a minimum volume of 3.25×10^8 m^3 of material was erupted with a minimum dense-rock equivalent volume of 1.97×10^8 m^3 of magma involved. These volumes are not only indicative for the VEI of this prehistoric eruption, which was 4, but also correspond to the amount of energy for this eruption stored as heat, and using these an estimate can be made of the minimum volume of groundwater necessary in order to produce the phreatomagmatic explosions and deposits.

Based on groundwater models and parameters from the local aquifers these volumes can be tested from a hydrodynamic point of view. This shows that with the aquifer conductivities or flow rates, *K*, ranging from 1.7 - 3.3×10^{-4} m s^{-1}, the available groundwater could not continuously recharge the root zones and diatremes of the maar-diatreme structures of Mt. Gambier, causing the strong alternations in magmatic and phreatomagmatic deposits observed at this volcanic centre. The control of the aquifer dynamics on the eruption dynamics is confirmed by the fact that the magmatic properties (i.e. viscosity, temperature, crystallinity, vesicularity and apparent ascent rate) are not different for the distinct magmatic and phreatomagmatic deposits.

Using substrate geology to delimit the spectrum of phreatomagmatic eruptive scenarios for the Auckland Volcanic Field (AVF), New Zealand

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Evidence of phreatomagmatic phases is found in 39 of the c. 50 volcanic centres in the AVF. Most of these are located along stream valleys or lowlands especially in the southern part of the field. Phreatomagmatic craters vary from 200 to 1 600 m in diameter and are surrounded by tephra rings up to tens of metres high, comprising pyroclastic surge and subordinated fall successions. Although most of the phreatomagmatic vents have not been studied in detail, the reconstruction of the eruptive histories of few of the volcanoes (Crater Hill, Maungataketake, Motukorea, North Head, Orakei, Pupuke) point to a broad array of distinct eruptive event sucessions. The juvenile fragment content of these deposits range between sites from 30 to 90 vol%. The accidental clasts are made up of fragments from the Miocene Waitemata Group and/or the Plio-Pleistocene Tauranga and Kaawa Formations. The Waitemata Fm is a poorly consolidated, turbiditic sandstone and siltstone succession, uplifted in the Auckland Isthmus area but down-faulted in the Manukau lowlands and capped by 50-100 m-thick sequence of the unconsolidated Plio-Pleistocene sediments. Jointed, low transmissivity, confined aquifers occur in the Waitemata, whereas Kaawa Fm. has good hydraulic conductivity and the impermeable sediments of Tauranga Fm. conform an aquiclude. Maungataketake and Crater Hill tuff rings were excavated mainly within Tauranga and Kaawa. The others were built by explosions through the Waitemata group. Only one example of emergent phreatomagmatic volcanism occurs, the North Head tuff cone (<10 % in vol. of accidental content), which could be an important eruptive style scenario in a near future eruption due to present high sea levels. The most critical factors that control small basaltic phreatomagmatic eruptions are magma flux rates, total erupted volume, substrate rheology, hydrogeological conditions and paleotopography. Assessing quantitative proportions of each factor is difficult. However, a qualitative approach can be developed by associating the stratigraphic, sedimentary and grain/fragmentation characteristics, with the paleo-hydrological/geological conditions of the substrate, as well as sea level. Assuming that substrate and tectonic conditions remain the same in future, as well as considering the high present sea level (1/5 of AVF area is submerged in up to 40 m-depth water) and that the Plio-Pleistocene sediments cover 30 to 40 % of AVF area, future phreatomagmatic eruptions in most parts of the field will have initial phases ranging from emergent-type to base-surge dominated eruptions of brief duration (hours to days). These will produce base surge runouts from several hundreds of meters up to 4 km from the vent. This clearly shows that the substrate conditions play a highly relevant dominant role in guiding the type of phreatomagmatic eruptions in AVF. Shifts of activity to purely magmatic conditions is most likely under eruption scenarios of greater magma volumes

Factors influencing effusive and explosive eruptions of trachytic-phonolitic magmas, an example suite from Harrat Rahat, Saudi Arabia

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The 20,000 km2 intraplate field of Harrat Rahat in Saudi Arabia hosts >1000 volcanic structures erupted between c.10 Ma to 1256AD. Alkali basaltic volcanism dominates, but in the central northern areas of the field (where the lava pile is thickest), more evolved magmas erupted, including benmoreitic, and trachytic compositions. These most evolved products exhibit a range of eruption styles that appear to represent a combination of controlling factors including: eruptive volume, compositional variation, mafic magma intrusion and dissolved gas content. The effusive volcanic suite ranges from simple cryptodome/dome formation, to larger-volume eruptions of large, complex multi-stage domes with temporal variations in magma composition. These produced flank-collapse pyroclastic flows up to 1 km from the flanks. In the parallel explosive sequence, small-volume magma intrusions encountered ground water at depths of 100-300 m and resulting phreatomagmatic explosions formed deep maar craters with minor rings of explosion breccias. In larger volume examples, initial explosions were followed by pyroclastic surges, with further larger volume events producing tephra columns and fountain-collapse pyroclastic flows, deposited up to 4 km from source. In the largest-volume cases, larger pyroclastic flows (>7 km runout), surges and falls were generated in complex eruption sequences that may have lasted several weeks. The most complex eruptive sequences show trends from early near-phonolitic compositions, to later more-primitive compositions. Some sequences were also apparently interrupted by eruption of hotter more mafic magmas. These mafic magmas may be the cause of instability of mid-crustal trachytic magmas, leading to their rise and eruption. Early erupted units are completely crystalline with trachytic textures and no residual glass. Later products contain glass between phenocrysts and vesicles with rounded, but highly deformed margins where they were restricted by the crystalline network. Latest stage eruptives show very small isolated vesicles also restricted by the crystalline mush. Hence, expansion was late-stage, indicating rapid unroofing of very crystal rich magma bodies.

Highly explosive basaltic eruptions: the case of the sunset crater (az, usa)

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Volcanic eruptions involving basaltic magma usually produce low explosivity events characterized by lava flow effusion, lava fountains and/or small Strombolian explosions. However, more explosive eruptions, ranging from violent Strombolian to sub-Plinian and Plinian events, are not uncommon and can represent a serious threat for to nearby populated areas. The study of highly explosive mafic eruptions thus provides an important test of our understanding of eruptive processes. The eruption of Sunset Crater volcano represents an interesting case in that it produced highly explosive eruptions, up to sub-Plinian in scale, that heavily affected the pre-historic communities in the area, and also produced intermittent episodes of lava effusion. Sunset Crater is a >300 m high scoria cone located $\sim$25 km northeast of Flagstaff, AZ (USA), in the San Francisco Volcanic Field. The eruption produced three lava flows that cover $\sim$8 km^2, a scoria-fall blanket up to 12 m thick covering an area of about 500 km^2, and minor spatter cones and ramparts that marked the onset of the eruption. The tephra sequence consists of at least eight fall units associated with major explosive phases, mainly dispersed to the east. The total volume of individual fall units varies between 0.02 and 0.08 km^3 DRE. The maximum is estimated for the Unit 3 deposit (0.08 km^3 DRE) and the total cumulative volume is $\sim$0.3 km^3 DRE. This value is close to the volume calculated based on the total deposit isopach map from Ort et al. (2008, JVGR 176(3): 363-376) ($\sim$0.4 km^3 DRE). Associated column heights, calculated based on the maximum clast-size distribution of Amos (1986, ASU MS Thesis), are between 7 km (Unit 2) and 25 km (Unit 3). Sunset Crater scoria are characterized by a density of 1.2-1.9 x 10^3 kg m^{-3}, which corresponds to 35%-67% vesicularity. The chemical composition is nearly uniform ($\sim$47 wt.% SiO_2) for all eruptive units. Two textural endmembers, intimately intermingled at the mm-scale within a single clast, were identified: one endmember (sideromelane) is characterized by higher vesicularity, with large regular sub-spherical vesicles (modal diameter 0.6 mm), a glass-rich groundmass and evidence of post-fragmentation vesicle expansion; the second endmember texture (tachylite) is characterized by lower vesicularity, with small highly irregular vesicles (modal diameter 0.3 mm) that result in a higher vesicle number density than the sideromelane, and a groundmass rich in microcrysts, mainly Fe-oxides. Scoria compositions and textural characteristics suggest interaction between magmas stored at different depths. The crystalline tachylite texture is interpreted as shallower magma that mixed, in the upper conduit, with more rapidly cooled and decompressed magma (sideromelane) sourced from deeper crustal levels.

Submarine fire-fountaining eruptions: monogenetic scoria cone construction and clast vesicularity (Nishiizu, Izu Peninsula, Japan)

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The Nishiizu Member is a $\sim$12x10^6 m^3, half-dissected coastal remnant of a submarine monogenetic scoria cone in the overall andesitic Matsuzaki Formation (Shirahama Group), on the western side of the Izu Peninsula, Japan. The volcanogenic Shirahama Group is the youngest uplifted section of the Izu-Bonin arc from subduction of the Philippine plate under Japan. The brown scoria cone consists of tens to hundreds of thin to very thick beds of grey scoria lapilli and subordinate water-chilled bombs that are radially dipping (15 to 40 degrees dip) outwards a single area, considered to be the vent source. The beds of brown scoria are massive, ungraded, network-supported and overall monomictic; beds are defined by differences in grain size, and contacts are weak or indistinct. The bombs are fluidal, have thick quenched margins and some are folded and agglutinated. Lapilli and coarse ash chiefly consist of fragments of water-chilled bombs; fine ash is absent. Lithic clasts are extremely rare overall, but common (up to 10 vol.%) in the oldest beds closer to vent. Grading in vesicularity and bubble number density is ubiquitous in bombs, with overall increase in size and abundance of vesicles towards the clast core. This grading in clast vesicularity suggests submarine eruptions by volatile-coupled fire-fountaining, followed by vesicle ripening and moderate coalescence. The very thick, ungraded, poorly defined beds do not match deposition from conventional subaqueous grain flows or density currents, and may reflect a variety of primary and syn-eruptive resedimentation on unstable slopes of the scoria cone, including discrete clast rolling and sliding, and short-lived grain flows.

Variations in eruptive style of mexican basaltic maar volcanoes

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Maars are a special type of volcano that represent extreme conditions of explosivity due to the sudden conversion of thermal to mechanic energy during the interaction of ascending magma with water. Variations in the eruptive style can be attributed to several factors such as magma extrusion rate, explosion depth variation, water/magma ratio, increasing cratering, and viscosity, among others. In Central Mexico, monogenetic volcanism is extensive, and, although scoria cones are dominant, maars form small volcanic fields such as Valle de Santiago (Guanajuato) and Serdan-Oriental Basin (Puebla). In these volcanic fields, maars of basaltic composition are characterized by deep craters that reach the local water table, forming a crater lake; they are by far the most abundant, in comparison with volcanoes of rhyolitic composition, which instead form tephra rings. Based on the stratigraphic fluctuations on their eruptive style, basaltic maars in Central Mexico can be grouped into two main groups: a) Hoya Cintora-Joyuela type volcanoes are characterized by an entirely dry magmatic activity starting from hawaiian lava flows, followed by strombolian scoria and a transitional explosive phase that changes to wet phreatomagmatic maar-forming activity, which includes the periodic injection of juvenile material, particularly at the end of the eruptive phase. b) Atexcac type volcanoes characterized by an evolution from highly fragmented surge-dominated eruptions to coarse brecciated deposits followed by an alternation of wet and dry layers in the upper part of the sequence. This reveals a general drying trend, with the periodic injection of new magma as well as the abrupt fluctuations in water/magma ratios during the construction of the eruptive succession sequence. Perhaps initial magma extrusion rates played an important role in producing these different maar volcanoes, with higher rates for the first type that inhibited phreatomagmatic activity at the beginning. Also, the location of the explosions within the upper unconsolidated granular aquifer (brown tuff) or the deeper highly-fractured bedrock aquifer may control the efficiency of the explosions. Deepening and lateral migration of explosion loci are observed in both maar types, and the lateral migration is strongly controlled by the regional stress regime.

Comparison of the volcanic geology of the Tacambaro-Puruaran (arc front) and the Zacapu (arc inland) areas in the Michoacan Guanajuato volcanic field, Mexico

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The highest concentration of monogenetic volcanoes in the subduction related Mexican Volcanic Belt (MVB) occurs in its western-central part, where the arc reaches a maximum width of 150 km. This 40,000 km2 area, the Michoacan-Guanajuato Volcanic Field (MGVF), hosts more than 1000 monogenetic volcanoes and vents, and the only two of the MVB born in historical times: Jorullo and Paricutin. The 690 km2 Tacambaro-Puruaran area (TAC) is located at the volcanic front while the 2310 km2 Zacapu area (ZAC) lies more inland, 60 km to the N, in a direction parallel to the subduction vector. The systematic comparison of the two areas allows for inferences regarding to the subduction process and associated magma genesis, and might help explain the unusual number of vents that comprise the MGVF.

Based on detailed mapping, volumes of erupted products were estimated with the aid of a Digital Elevation Model. Compositional and new 40Ar-39Ar and 14C data allowed us to estimate magma eruption rates and to determine variations in the relative proportion of different magma types erupted during the course of time. Our results indicate that MVB volcanism has been present in both areas since 5 Ma, but eruptions have become more frequent at the arc front. In the Holocene, at least 13 eruptions occurred in the TAC (average recurrence interval of 800 years, one of the highest monogenetic eruption frequencies detected within such a small area in a subduction-setting) while only 10 eruptions occurred in the much larger ZAC. Thus, volcanism has not migrated southward in this region, as often postulated, but rather has become more intense at the arc front. Compositions of erupted products are distinctly more diverse and less evolved at the arc front (high proportion of basaltic andesites and occurrence of exotic alkaline compositions in the TAC) than at greater distances from the trench (mostly andesites, but also dacites and rhyolites in the ZAC). Volcanic centers are preferentially aligned along SW-NE directions in the TAC compared to WSW-ENE in the ZAC, consitent with local fault strikes. A higher rate of lithospheric extension in the south during the Quaternary seems to have allowed a larger number of small, poorly evolved, and compositionally diverse dikes to reach the surface during this period.

Experimental craters formed by single and multiple buried explosions and implications for volcanic craters with emphasis on maars

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Craters at many volcanoes, including most maars, are formed by multiple subsurface explosions. Experiments compared the crater formed by a single large, buried explosion, with craters formed by multiple explosions with the same cumulative energy. Explosive charges were detonated in pads composed of layered aggregates, in three configurations: (1) a single large charge buried near its optimal crater excavation depth; (2) three charges, each with 1/3 the energy of the first one, buried at approximately the same depth with respect to the original pad surface; (3) the same three charges buried successively deeper. Final crater size in the multiple explosion cases is not a good indicator of the energy of individual explosions. However, crater morphology, and ejecta volume and distribution can be good indicators of explosion energy and depth. The experimental explosions also demonstrate a mechanism for formation of dilute, fine-grained pyroclastic density currents driven by the collapse of a coarse mixture and lateral expulsion of dusty gas. These results directly impact the estimate of the energy released by past maar eruptions and future hazard assessments.

Magma withdrawal below ground-water table as a trigger to form large maars over high magma discharge rate fissure-fed lava spatter/scoria cones: the Al Wahbah Crater (Harrat Kishb, Saudi Arabia)

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Al Wahbah Crater is one of the largest and deepest Quaternary maar crater (NW-SE-elongated, appx.2.3-km wide and 250-m deep with an irregular near-perpendicular crater wall) not only in the Arabian Peninsula but also among other craters of volcanic fields on Earth. It is located in the SW edge of the bimodal (alkali olivine basalt/phonolite) Harrat Kishb (2Ma-Recent) that formed lava flows over 6000-km2. Al Wahbah Crater cuts deeply into the pre-eruptive surface exposing the Proterozoic diorite basement that is covered by at least two basanitic lava sheets and a lava spatter/scoria cone defining the crater as a maar. The half-sectioned pre-maar cone in the NW demonstrate that the maar collapse post-date the lava schield and cone formation. The lack of evidences to support significant time break between the pre-maar cone-building pyroclastic beds and the dune-bedded accidental lithic-rich pyroclastic beds that form the tuff ring suggests that the pre-maar cone (and its lava flow) and the tuff ring formation is in a time-continuum and they formed in the same eruptive episode. In this respect Al Wahbah's eruption is unique and differs from maar formation that implies initial magma-water interaction-driven explosions near surface followed by gradual explosion locus down-migration as a result of gradual exhaustion of ground-water sources (Lorenz's model). Al Wahbah seems to have been followed an opposite eruption path started with an initial lava shield and cone-building phase that have been intervened by phreatomagmatic explosive eruptions that have been culminated in a maar collapse and tuff ring formation. This scenario can be best explained by the drop of the magma discharge rate causing magma withdrawal below regional ground-water table. The drop in the magmatic pressure in the conduit due to the decrease in magma rise speed enhanced ground-water to enter to the top of the withdrawn magma column through cracks along the unsupported solidified mnargin of the conduit wall. As a result, effective thermohydraulic explosion took place initially in the time when the same volcanic system still emitted lava flows that rafted cone material and damping tuff breaccia on top of the still moving lava flows allowing protrusions of lava into the freshly deposited wet pyroclastic blanket. In the main phase of the maar-forming event the reduced magma discharge rate shifted the efficiency of the explosive phreatomagmatic magma fragmentation to its maximum to produce base surges that were travelled radially at least 2-km from their source leaving behind a quickly thinning blanket of dune-bedded pyroclastic deposit that covered, plastered and engulfed everything around the newly formed maar. It seems Al Wahbah represents a rare but potentially one of the most hazardous volcanic phenomena documented in the Harrat Kishb that is essential to understand to develop accurate volcanic hazard scenarios at the Harrat Kishb and elsewhere.

Submarine monogenetic volcanism

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Monogenetic volcanism is a widespread phenomenon recognized to occur in a range of terrestrial settings. By comparison, very few observations of submarine volcanism have been interpreted as monogenetic, particularly in the vast expanse of the deep sea, which forms Earth's volumetrically dominant volcanic province. The purpose of this presentation is to consider the types of landforms, eruption products and vent geometries one might anticipate for deep sea monogenetic fields in the context of what is known from direct and remote observations of deep sea volcanism. We discuss several settings in which submarine monogenetic volcanism is likely to be common and explore examples using a generic definition (small magma batches, small volume eruptions, isolated/dispersed magmatic systems, and no link of eruption deposits to pre-existing polygenetic volcanic structures but structural control on the locus of volcanism is permissible). These settings include extensional basins (particularly in back arcs), near-spreading-center seamount fields, and mid-plate settings. Examples will be compared to subaerial settings (e.g., Michoacan-Guanajuato and Auckland volcanic fields). For example, apparently short-lived volcanism at discrete, closely spaced elongate volcanic cones and low lying lava flows in the NE Lau backarc basin shares many characteristics with subaerial monogenetic fields, including the size and spacing of volcanic vents and edifices. Geological, morphological, petrological, and geochemical observations made over six research expeditions since 2008 have been used to characterize this volcanic field and to test for a monogenetic or polygenetic classification. Volcanoes in the group are as close as 1.5 km apart (summit to summit) and 450-1400m tall. They are formed predominantly of low effusion rate pillow lavas with variable amounts of pyroclastic deposits, suggesting relatively long-lived volcanism (ca 100-200 yrs) at each edifice, similar to large lava shields in Iceland (e.g., skjaldbreidur). ROV and near-bottom photographic surveys do not indicate the types of structures expected for a protracted, many-eruption volcanic history at a single volcano, although there is some evidence for syn or post eruptive tectonism. At least three of the (the now inactive) volcanoes support black smoker hydrothermal chimneys, suggesting relatively recent volcanism and a crustal magma body remains to generate these high temp systems. Terrestrial monogenetic fields can also support robust geothermal systems. All but one of the cones are built of broadly boninitic volcanic products yet major and trace element compositions are distinct enough to imply that each is fed by separate, poorly mixed, small magma batches. Rapid extension combined with thin lithosphere and episodic and dispersed magma supply from the nearby subduction system appears to promote conditions favoring dispersed monogenetic volcanism over longer lived volcanic edifices or ridges at this site.

The complex geometries of maar-diatremes determined from geophysical modelling techniques. Examples from the Newer Volcanics Province of south-eastern Australia

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The Cainozoic Newer Volcanics Province (NVP) of south-eastern Australia is an intraplate, basaltic volcanic province comprised of over 400 monogenetic eruptive centres. Approximately 40 maar volcanoes have been identified, typically displaying well preserved edifices with no exposure of the underlying diatreme, so geophysical modelling techniques are applied to understand the morphology of their subsurface structures.

High resolution gravity and magnetic surveys were conducted across several maar volcanoes located within the NVP, including the Ecklin maar, Red Rock Volcanic Complex (RRVC), Mount Leura Volcanic Complex (MLVC) and the Anakie maar. The maar volcanoes surveyed display simple (Ecklin and Anakie) and complex (RRVC, MLVC) morphologies and eruption styles, representing a range of the different sizes and eruption styles observed within maar volcanoes of the NVP. Within this region, volcanic rocks tend to have a high petrophysical contrast (higher magnetic susceptibility, lower density pyroclastic deposits and higher density lava flows) with the surrounding host rock (carbonates, siliciclastics and granite (Anakie)), making maar volcanoes ideal for geophysical modelling. The depth, geometry and petrophysical property distributions of the volcanoes diatreme and feeder dykes were determined by 2D forward and 3D inverse modelling techniques.

The Ecklin and Anakie maars display relatively simple geophysical signatures. Long wavelength gravity lows with corresponding magnetic highs are observed across the craters and were reproduced during modelling with the presence of a shallow maar-diatreme structure at Anakie and two coalesced diatreme structures containing a denser central vent at Ecklin. The RRVC and MLVC have more complex geophysical signatures, consisting of short wavelength gravity and magnetic highs superimposed on longer wavelength gravity lows. These anomalies are reproduced during modelling with multiple shallow coalesced diatremes containing dykes and magma ponds.

The complex diatreme geometries revealed from forward and inverse modelling suggest that the eruption histories of these volcanoes are more complex than their relatively simple morphology would suggest. Multiple coalesced diatreme structures indicate complex eruption histories involving vent migration, while preserved dykes within the diatreme suggest short-lived fluctuations between phreatomagmatic and magmatic eruption styles. The shallow diatreme structures observed suggest that soft-substrate behaviour influenced the geometry of the diatreme, and likely contributed to the migration of vents observed at Ecklin, RRVC, and MLVC. The shallow diatreme observed within the Anakie maar is attributed to a short-lived eruption and low water content within the granitic host rock.

Fly By Numbers: Using Mercury-DPM to explore the in-flight particle-particle interactions of 'ballistic' volcanic blocks

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Particles ejected in Strombolian-type eruptions typically follow ballistic trajectories through the atmosphere before coming to rest at the Earth's surface. However, Vanderkluysen et al. (2012) have observed particles colliding mid-air, resulting in deviations from standard ballistic trajectories that, in some instances, allow particles to exceed the maximum distances attainable by their previously assumed ballistic trajectories.

Mercury-DPM, a code for discrete element simulations, is here used to investigate the prevalence and effects of particle collisions numerically. Once particle parameters (e.g. size, density), exit conditions (e.g. ejection angle, ejection speed), external body forces (e.g. gravity, air drag), and particle-particle interactions (elastic, plastic, viscous, frictional) are defined, Mercury computes the translational and rotational evolution of particles by solving Newton's second law. Thus it is an ideal tool for exploring the reltionships between the exit conditions of particles, including the concentrations of particles within eruptive bursts and the time periods between bursts, and how these factors affect both the prevalence of particle collisions and the resultant translations of the particles involved. By exploring the range of scenarios documented for actual eruptions, we are able to quantify the anticipated effects of particle-particle interactions due to Strombolian-type volcanic activity.

Space–time evolution of monogenetic basaltic volcanism in the Garrotxa Volcanic Field, NE Iberian Peninsula.

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We reconstructed the space-time evolution of the central Garrotxa monogenetic Volcanic Field (GVF), the youngest volcanic area of the Iberian Peninsula, by integrating stratigraphy, petrography, geomorphology, and well-log stratigraphy of the volcanic products. The mapping and the study of the volcanic succession has been conducted following the Unconformity Bounded Stratigraphic Units criteria applied to volcanic terrains. The detailed stratigraphy of the volcanic successions shows that the central GVF evolved through four main periods of volcanic activity (Synthems) represented by the eruptive products of the mafic monogenetic volcanoes (Eruptive Units) and by their reworked syn- and inter-eruptive (epiclastic) deposits. The morphology and the architecture of the monogenetic eruptive centres suggest that feeder dykes emplaced responding to the orientation of local structural lineaments according to the present stress tensor, which determines the strike-slip tectonic regime active in the region since the Pliocene-Pleistocene. The facies analysis of the deposits and their distribution show that migration of volcanism toward the center of the basin coincided with a trend of increasing explosivity. Episodic hydromagmatism in the central Garrotxa occurred without a specific neither geographic nor temporal correlation. Basic lava flow units in this sector have been systematically sampled and petrographically and geochemically studied in order to obtain a complete dataset useful for correlation purposes. Finally, integrating field data with the stratigraphy of water wells, we determined the volume of the volcanic deposits. The low average volume of products emitted during each eruptive period and the long quiescence separating them allows classifying the GVF as a low output rate volcanic field.

Structural controls of monogenetic volcanism

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The factors controlling the precursory activity in monogenetic volcanic fields are still poorly understood, which means that eruption forecasts in these systems are not very accurate. The fact that in monogenetic volcanism each eruption has a different vent suggests that volcanic susceptibility has a high degree of randomness, so that accurate forecasting is subjected to a very high uncertainty. Recent studies on monogenetic volcanism reveal how sensitive magma migration may be to the existence of changes in the regional and/or local stress field produced by tectonics or lithological contrasts (i.e., intrusion of magma bodies), which may induce variations in the pattern of further movements of magma, thus changing the location of future eruptions. This implies that a precise knowledge of the stress configuration and distribution of rheological and structural discontinuities in such regions is crucial to forecast monogenetic volcanism.

We use the Garrotxa Volcanic Field (NE Spain) as a case study to improve our understanding of the local 3D geology of monogenetic volcanic fields. We have used a combination of high precision geophysical techniques, including gravimetry, self-potential and electrical resistivity tomography, in order to investigate the relationship between local tectonics and the spatial distribution of monogenetic volcanoes in the Garrotxa. Our results show that this volcanic field is underlain by low-density material, which partly can be interpreted as the roots of surface manifestations of volcanic activity. They also show that most of the eruptive fissures which have controlled the volcanic activity in this area for more than 300 ka correspond to NE-SW and NW-SE oriented tectonic structures. This suggest that ascent and eruption of magmas in this volcanic field has been controlled by the same regional normal faults bounding the horsts and grabens of the area and which seems to be related to the origin of magmas at the base of the lithosphere. This explains the high magma ascent velocities (0.2- 2m/s) found in these volcanoes, which together with the presence of mantle xenoliths and lower crust cumulates, suggest that some of the eruptive fissures and faults reached quite deep in the lithosphere. The occasional diversification of magma at the upper part of the crust towards secondary fractures of the same structural system seems due to stress barriers caused by the presence of intrusive bodies from previous eruptions and stratigraphic discontinuities in the substrate.

Integrating temporal and spatial patterns of Quaternary Cascades eruptions with geochemistry, tomography and heat flow

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Volcanism in the Cascades arc, USA, is episodic in both space and time. The modulation of time-varying mantle melt influx by crustal magmatic plumbing drives much of this unsteadiness. However the relative contributions of source time-variation versus crustal control are poorly constrained. Here we synthesize a number of datasets relevant to Holocene and Quaternary Cascades magmatism, to identify patterns in preserved eruptions and validate models for crustal magma transport.

Our database contains >2200 published Quaternary Cascades volcanic vent locations, vent types, ages, and major element geochemistry of erupted lavas. Major element geochemistry is obtained from USGS professional papers and the American Volcanic and Intrusive Rock Database (NAVDAT). We also include arc-wide heat flow data, modeled seismic tomography and crust thickness beneath vents. Eruption ages are less well constrained than other parameters, and we focus on variation between major geologic Epochs and their subdivisions.

We perform Spectral Clustering on vent locations to define volcanic centers for each Epoch and for the entire Quaternary. Centers found through Spectral Clustering reproduce the major loci of volcanism in the cascades, and identify time-varying structure in the number and distribution of monogenetic eruptions. Concentric zonation of SiO_2 content within many clusters reflects a bimodal distribution of eruptions, between compositionally evolved central vent eruptions and mafic regional monogenetic vents. There is significant North-South structure in vent type and distribution that correlates with variations in heat flow and average crustal shear velocity.

Although precise eruption ages for the complete dataset are not currently available, certain volcanic centers are quite well constrained and allow further analysis. The time history of eruptions <400 ka at Mazama, OR, shows that the spatial distribution of eruptions does not follow a Poisson distribution when well-resolved in time, but rather clusters around an evolved center. Monogenetic eruptions preceding the 7.8 ka Crater Lake eruption define a spatial and temporal pattern that is consistent with stress focusing of rising dikes by a growing and pressurizing magma chamber over 20-25 kyr.

Spatial and temporal variations in volcanism younger than 4.5 ka in the Campi Flegrei active volcanic field

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The Campi Flegrei caldera is an active volcanic field in one of the most densely populated and high-risk volcanic areas in the world. Volcanological, structural and geochemical research documents an intense volcanism with a series of 15 explosive and effusive eruptions over a 200-300 years period following less than 2 centuries of repose after the Agnano-Monte Spina Plinian eruption (about 4.5 ka). The renewal of volcanism was preceded by an uplift of a few tens of meters, triggered by mafic refilling of reservoirs at depths of 3 km or less. The repose was ended by a sequence of about 15 eruptions, twelve of the events were of low magnitude and involved some combination of phreatomagmatic, strombolian and effusive activity. All but one of the eruptions occurred in the eastern-central part of Campi Flegrei, which coincided with the area of maximum deformation and seismic and hydrothermal energy release inside the caldera.

The activity began with the SMG explosive event which erupted latites and include a sequence of ash surge layers beneath a strombolian scoria fallout deposit that formed a small scoria cone with a feeder conduit exposed south of the Solfatara crater. Subsequently close to SMG scoria cone growth the Olibano lava dome which was overlain by a sequence of volcanic breccias and fine-ashes generated by phreatic explosions from the southeastern corner of the present Solfatara crater. Later a lava dome forming eruption laid down several layers of scoria breccias at the base of the Accademia lava dome which shortly preceded the vulcanian activity of the Solfatara maar. The SMG, Olibano, Accademia and Solfatara eruptions were clustered along NW-SE-trending faults at the boundary of the minor Agnano Monte Spina caldera. Similar trending faults were also activated during the seven eruptions of Astroni followed by the Fossa Lupara event which was erupted from a vent along the same NW-SE eruptive fissure as Astroni. The exception to the clustering was the Averno event, in the western sector of the caldera, located along an old NNW-SSE structure, outlined by several eruptive centres active from ca. 14 to ca. 4 ka. Tephra from the Averno eruption was deposited while Solfatara was still active and provides the first direct evidence that concurrent explosive activity has occurred in two different sectors of the caldera.

The presented data show that eruptions may cluster at intervals of a few years to decades and also occurred simultaneously in the eastern and western sectors of the caldera, providing insight into future eruption scenarios in CF for hazard-mitigation plans.

Volcanic hazard mapping based on eruptive histories and eruptive volumes - A case study from the Auckland Volcanic Field (New Zealand)

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Volcanic field-scale spatial and temporal magma fluxes are often used to express the long-term volcanic hazard associated with monogenetic volcanic fields. In addition, the temporally ordered eruptive volumes are key information to assess the field's long-term eruptive behaviour (i.e. ascribe time or volume predictability). However, these descriptions of volcanic hazard and volcanic field evolution provide only limited information about the edifice-scale volcanic hazard related to a future vent opening. The eruptive volume, as an important parameter for long-term volcanic hazard assessment, is also essential for the edifice-scale hazard classification. However, the accuracy of this parameter is hampered by the high susceptibility of volcanic edifices to significant erosion in a relatively short time (e.g. 1 000 to 100 000 yr) after their eruption. The remobilization of tephra after an eruption also creates uncertainty in eruptive volume calculations. Determination of eruption style is also important for better understanding of area will be area affected by future volcanism (e.g. difference in distribution of phreatomagmatic pyroclastic density current deposits versus scoria fall deposits). All these input data should be applied when quantifying likely eruptive scenarios and describing the spatial context of volcanic hazards in monogenetic volcanic fields. In this study, an edifice-scale investigation of eruptive volumes and eruption histories was performed on the Quaternary Auckland Volcanic Field with the aim of constructing volcanic hazard maps. The eruptive volumes, which were corrected to Dense Rock Equivalents (DREs), were interpreted and assigned to dominant eruption styles recorded for the specific edifices such as phreatomagmatic and magmatic. These volumes (genetic-unit-based eruptive volumes) were used subsequently to understand the proportion of magma fragmented by a certain eruption style. Four eruptive scenario types were distinguished: (1) pure magmatic volcanoes (e.g. scoria cones with lava flows), (2) volcanoes with short-lived phreatomagmatic eruptions and long-lived magmatic phases, (3) volcanoes with long-lived phreatomagmatic, and short-lived magmatic, stages (e.g. tuff rings with an intra-crater lava lake and scoria cone), and (4) pure phreatomagmatic volcanoes (e.g. maars). These groups form a gradual transition from one to another that reflects the variable influences of climate, topography, and substrate geology, across different spatial locations and over time during the life of the field. Within each of these groups, there is a wide range of volumetric variability from 0.001 to 0.6 cubic km, with an average of 0.03 cubic km. This approach can be adapted to improve the volcanic hazard mapping of monogenetic volcanic fields worldwide, which ideally could be further developed by building a database of individual eruption properties from a range of similar fields in other areas.

Multidisciplinary approach to the hazard assessment for the Holocenic Tenerife flank eruptions

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A multidisciplinary approach has been applied to assess the hazard related to the eruptive fissures on the slopes of the main volcanic edifices in Tenerife. We concentrated on the historical eruptions and on the whole framework of the NW rift. Tenerife is a complex volcanic area in which long-lived volcanic centers coexist with a number of different-age scoriae and spatter cones. Our work concentrated on the youngest portion of these cones, their age, and distribution. In order to achieve this goal, a detailed fieldwork has been carried out by means of a 1:5,000 scale cartography of volcanic deposits and structural feature. An area of about 10 sq km has been surveyed up to now. Archaeomagnetic method has been used to elucidate age relations of the main recent volcanic record (last 8.000 yrs BP) and a suitable field work was done. Chronostratigraphic characterization of 42 different localities (i.e. 590 archaeomagnetic measurements) was performed. In addition, petrochemical and rheological analyses are in progress. The present data set allows us to point out some important findings that depict a new scenario for the flank activity in Tenerife with strong implication for hazard assessment. At present, we are able to produce the complete cartographic and chronostratigraphic sequence of two famous and distinct areas, Fasnia-Siete Fuentes-Arafo and Chinyero volcanic fields, that probably represent the "general behavior" of the up to known monogenetic activity on Tenerife. Polygenetic cones, instead of monogenetic scoriae cones, seem to be the main character of the Holocene activity in Tenerife. No previous investigations have ever evidenced this aspect. In the Fasnia area we recognized the effect of at least two volcano-tectonic trends (one 120N oriented and the other one 50N) resulting in three different lava flows outpouring, in stratigraphic order, from two dismantled scoriae cones and from an eruptive fissure oriented 30N. Three orders of lava levees are well exposed in the southern portion of the lava field. Only the 1km long and last emitted lava flow belongs to the 1704-05 eruptive episode. Scoriae ramparts, pit craters and a small cover of lapilli fallout complete the deposits associated to 1704-05 eruption. The contemporaneous presence of big scoriae cones and small scoriae ramparts has been frequently recognized elsewhere in Tenerife and is a characteristic of the Chinyero volcanic field too, where the 1909 volcanics are mantling two previous scoriae cones. These observations have implications on the hazard assessment for opening of eruptive fissures in Tenerife and hazard maps have to be deeply revised taking into account that large older scoriae cones are related to a vigorous Strombolian activity, characterized by high explosivity (highly vesicular lapilli and bombs) and long lasting lava flows, while the real historical activity expressed only scoriae ramparts along eruptive fissures and moderate lava flows.

Mathematical Coupling of Geological Data as an Approach to Volcanic Hazard Analysis; Harrat Rahat, Saudi Arabia

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The monogenetic volcanic field of Harrat Rahat in Saudi Arabia is a highly complex volcanic system with 1000+ volcanic cones or craters distributed over 20,000 km2 and with evidence of volcanic activity spanning from >10 Ma to eruptions in 641AD and 1256AD. This record, and a possible recent stalled eruption in 1999, drives a need to quantify the likelihood and magnitude of future eruptions. This has stimulated research about the controlling subsurface processes essential for estimating eruption frequency, magnitude, and style of distributed alkali-basaltic intraplate volcanism, as well as the probable location of a future event.

Observable data for this field include: vent locations, volumes and spatial distributions of past eruptive products, aeromagnetic and seismic interpretations of sub-surface structure, regional tectonic models, along with petrographic and geochemical analyses of some the erupted products.

To obtain spatio-temporal recurrence rate estimates for volcanic fields that exhibit both natural variability and highly complex dynamics, a method is presented which determines probable relationships between data sets. The ultimate goal is to determine which, if any, of the currently observable data and geophysical/geological models are related to the locations and timings of eruptive events.

Data sets are arranged as spatially (and if applicable, temporally) constrained layers and training and validation procedures used to determine the most probable relationships between data sets and consequently which geophysical properties best explain the surface expression of volcanism

Using a Monte Carlo event-order model to compare spatio-temporal eruption forecasts in a monogenetic volcanic field

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Many spatio-temporal models have been proposed for forecasting the location and timing of the next eruption in a monogenetic volcanic field. These have almost invariably been fitted retrospectively. That is, the model has been tuned to all of the data, and hence an assessment of the goodness of fit has not been carried out on independent data. The low rate of eruptions in monogenetic fields means that there is not the opportunity to carry out a purely prospective test, as thousands of years would be required to accumulate the necessary data. This leaves open the possibility of a retrospective sequential test, where the parameters are calculated only on the basis of prior events and the resulting forecast compared statistically with the location and time of the next eruption. In general, events in volcanic fields are not dated with sufficient accuracy and precision to pursue this line of investigation; An exception is the Auckland Volcanic Field (New Zealand), consisting of c. 50 centers formed during the last c. 250,000 years, for which an age-order model exists in the form of a Monte Carlo sampling algorithm, facilitating repeated sequential testing. I examine a suite of spatial, temporal and spatio-temporal hazard models, comparing the degree of fit, and attempt to draw lessons from how and where each model is particularly successful or unsuccessful. It is found that a relatively simple (independent) combination of a renewal model (temporal term) and a spatially uniform ellipse (spatial term) performs as well as any other model. Both avoid over fitting the data, and hence large errors, when the spatiotemporal occurrence pattern changes.

Petrology of the melilititic and nephelinitic rock suites in the Lake Natron-Engaruka monogenetic volcanic field, northern Tanzania

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The Lake Natron - Engaruka Monogenetic Volcanic Field (LNE-MVF) in northern Tanzania consists of more than 150 vents of Upper Pleistocene to Holocene age that are scattered over an area of 2500 km^2. Here we describe the petrological characteristics of these eruptions in detail and link the magma chemistry to eruptive behaviour when the magmas reach the surface. Erupted magmas are predominantly of melilititic or nephelinitic compositions (70 and 25%, respectively), together with minor amounts of basanites (5%). The melilititic magmas form by small degrees (1-2%) of partial melting of a metasomatized upper mantle source (containing 1-4% garnet together with both amphibole and phlogopite). The melilitites ascend very rapidly through the lithosphere prior to eruption minimizing the effect of fractional crystallization and/or crustal contamination. These eruptions also frequently carry relatively large amounts of mantle debris to the surface. The nephelinitic rock suite, on the other hand, form by larger degrees of melting (2-4%) at higher levels of the sub-continental lithosphere containing less garnet (<1%). The scarcity of mantle debris in the nephelinitic eruption deposits, combined with the more evolved magma chemistry indicates ponding in crustal reservoirs en-route to the surface. For many of the nephelinitic magmas this ponding resulted in fractional crystallization of predominantly olivine, which is also one of the main phenocryst phases in these rocks. However, these periods of ponding in the crust must have been short as none of the investigated rocks show any clear evidence of being affected by crustal contamination.

Within the LNE-MVF there is a rough correlation between magma chemistry and the resulting volcanic landforms. Large maar volcanoes and tuff cones/rings are predominantly of melilititic composition, whereas the nephelinites typically form scoria cones. This is attributed to the fact that melilititic magmas can hold more CO_2 dissolved in the melt structure compared to nephelinites, in combination with a rapid ascent from the upper mantle to the surface for the melilitites (<1-2 days). We interpret violent exsolution of CO_2 (in response to rapid decompression) to be responsible for the higher explosivity of the melilititic eruptions compared to the nephelinitic magmas within the LNE-MVF.

Seismological evidences o a potential birth of a monogenetic volcano

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Some monogenetic volcano fields are very close to cities, such as in New Zealand or in Mexico. A new monogenetic volcano may appear at any place and at any time, which could be potentially hazardous for nearby regions. The ability to detect a new one in advance is obviously very important and challenging. The existence of nearby seismometers may help for such detection. Magma sometimes reaches the surface with the birth of a volcano which can be monogenetic, but in other cases the magma does not reach the surface How to detect such movements? How to be sure the magma will reach the surface? Some observations may detect them, such as seismicity which is distributed as a swarm, with a very peculiar distribution in time and magnitudes. In particular, it is important to distinguish between a tectonic swarm and a volcanic swarm. Scaling laws of seismicity in magnitude and time help to perform such a distinction. We show three cases: a seismic swarm in Chile, in the 2007 Aysen crisis, corresponding to an aborted birth of a monogenetic volcano; a seismic swarm triggered after the 2004 great Mw 9.2 Sumatra-Andaman earthquake over an old monogenetic volcano; and a spatial study of monogenetic volcanoes in Mexico (Michoacan) showing the difficulty to forecast the place and time of the birth of a monogenetic cone without seismological records.

Eruptive Event Determination; Harrat Rahat, Saudi Arabia

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The monogenetic volcanic field of Harrat Rahat in Saudi Arabia is a highly complex volcanic system with 1000+ volcanic cones and craters distributed over 20,000 km2 and with evidence of volcanic activity spanning from >10 Ma to eruptions in 641AD and 1256AD. This record, and a possible recent stalled eruption in 1999, drives a need to quantify the likelihood and possible location and magnitude of future eruptions. This has stimulated research about the controlling subsurface processes influencing distributed alkali-basaltic intraplate volcanism.

Within volcanic fields around the world, particularly in rifting or extensional environments, magma reaches the surface through dykes that may erupt through multiple vents within a brief period (hours to months). This is observed at the surface as temporal and spatial clustering of vents, on a variety of scales as seen by chains of cones/craters, overlapping cones and/or closely clustered structures. From a long term hazards perspective, these multiple vent eruptions should be considered as single eruptive events to avoid overestimation of temporal recurrence rates and/or bias of the hazard, and hence the consequent risk. This definition of an eruptive event, with varying spatial and temporal components, also allows model validation to a greater extent. It is simpler to model the area where a dyke may reach the surface than an exact location at which a vent may appear.

In the absence of detailed site-by-site mapping, few have attempted to disentangle multiple-vent eruptions to develop a field-wide volcanic event/episode record. Here, eruptive events are determined using expert elicitation to obtain a priori event dimension distributions. These were adapted via Bayes to well-informed distributions with the likelihood function based on observed eruptive events in Harrat Rahat.

Probabilities for each vent grouping across the volcanic field were then obtained by comparison of the potential event dimensions with this a posteriori distribution. Results were validated by field mapping and petrographic study for several of the identified events.

Karioi volcano, western North Island, New Zealand: a behind arc polygenetic intraplate-convergent margin volcanic complex

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Karioi is a 756 m high Late Pliocene to Early Pleistocene basaltic shield volcano surmounted by a low-angle composite cone. It is situated 130 km behind the active Taupo Volcanic Zone (TVZ) and 250 km above the subducted Pacific slab, at the northwestern end of a 65-km long chain of volcanoes on the Tasman Sea coast of western North Island, New Zealand. Karioi volcano is constructed of lavas derived from two contrasting basalt magma series: an arc magma series, and an alkalic intraplate series. Both series of lavas are stratigraphically intercalated, with no evidence of any significant time break between them. The alkalic basalts have geochemical compositions typical of other intraplate basalt volcanic fields of western and northern North Island, i.e. steep REE patterns indicating derivation from a garnet peridotite source, low LIL/HFS element ratios, and Sr, Nd and Pb isotopic compositions with a HIMU-OIB source. The arc lavas are primitive low SiO2 ankaramites with compositions typical of subduction-derived convergent margin magmas, i.e. high LIL/LREE and LIL/HFS element ratios, and Sr, Nd, and Pb isotopic compositions derived from a depleted mantle component, a component from subducted oceanic lithosphere, and possibly a minor component from subducted sediments. Some stratigraphically younger lavas on the summit cone of Karioi have more evolved high-K andesitic compositions, but others are basaltic and have transitional compositions, possibly representing mixing of intraplate and arc type magmas. Although Karioi volcano is surrounded by a contemporaneous monogenetic volcanic field, the intraplate lavas of Karioi have constructed a basal polygenetic lava shield sequence. Also, since they are intercalated and contemporaneous with arc lavas, they cannot be derived from a recent deep mantle plume source because of the existence of the underlying subducted slab.

Insights into volcanic fissure eruption dynamics based on detailed field mapping and geochemical analysis: A case study of the Mt. Eccles Volcanic Complex, south-eastern Australia

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The Mt. Eccles Volcanic Complex (MEVC; 38° 3.66'S, 141° 55.34'E) forms part of the Newer Volcanics province (NVP) of south-eastern Australia, which is the site of Australia's most recent volcanic activity. The MEVC is the only known exposed fissure vent system in Australia and represents a 'snap-shot' into the intermediate stages of shield volcano development. The MEVC has been dated as young as 7 ka, and comprises a spectacular NW-SE trending fissure vent system that is aligned with several small cinder and spatter cones to the south, forming a ~2 km long array. The strong alignment of the MEVC fissure vent and cone array suggests dykes utilized pre-existing structures during magma ascent, a hypothesis supported by co-alignment with large-scale Paleozoic basement faults in the area. Partial collapse of the vent walls reveals excellent exposure of the internal structure of the fissure, which comprises alternating horizons of lava and spatter sequences. The fissure vent is breached to the north by a substantial lava field, the longest of these lavas extends over 50 km in length reaching the current coastline to the south. These sizable flows indicate a sustained high effusive phase in the MEVC eruption that allowed the development of an extensive lava tube network, which is preserved as numerous lava caves, channels and tumuli. Quarrying of scoria cones to the south of the array has provided excellent exposure of their internal structure, down to the lava flows on which the cones were built. Stratigraphic logging of the quarry walls and detailed mapping of the quarry floor provides insights into the growth of cinder cones and the nature of the shallow feeder system. Field relations suggest the volcanism started in the north of the area and moved progressively southwards. Hawaiian fire-fountaining was a dominant eruptive style at the MEVC, with minor Strombolian and phreatomagmatic behaviour to the south. XRF analyses of stratigraphically constrained samples show the erupted products comprise hawaiite, nepheline-hawaiite, basanite and alkali-olivine basalt, with a strong Ocean Island Basalt character that is consistent with other erupted products in the NVP. The MEVC eruptive period was likely short-lived, with punctuated events lasting in total several weeks to months.

Understanding geomorphic data of monogenetic scoria cones

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The definition of a scoria (or cinder) cone traditionally refers to any kind of volcanic landform that has conical geometry, is dominantly composed of fragmented rocks (coarse ash to lapilli) of low silica content of any type (e.g. basalt) and that is small in edifice volume (e.g. 0.1 to 0.00001 cubic km). Geomorphic data of scoria cones are often used for understanding eruptive and degradation processes quantitatively and as discrimination factors for relative age dating. One of the most common interpretations of scoria cones' geomorphic data is that these geomorphic parameters gradually decrease with age as the erosion processes smooth the cone morphology away from the Earth surface. Recently, an increasing number of studies have found evidence for a significant eruptive-control on the morphology of scoria cones. This study aims to give a summary of the possible interpretations of the geomorphic data of scoria cones in the light of the findings of new studies. Morphometric data extracted from any source (e.g. Digital Elevation Models) carry information about both syn-eruptive and post-eruptive processes. Therefore, the traditional morphology-based discrimination of edifice degradation stages and relative age groupings of volcanic cones should be avoided; a distinction should be made between the syn-eruptive contribution and the post-eruptive contribution before any further interpretation is carried out. For discrimination purposes, known absolute ages should be used, thus the likely effect of erosion on the primary, syn-eruptive morphology can be quantified. Here we suggest that prior to any detailed morphological study on a cone-dominated field, a preliminary assessment of the cone (e.g. eruption history) needs to be performed and cones grouped following their genetic (syn-eruptive) origin. If the grouping of edifices is based on eruptive similarities, then the initial morphologies should be similar to each other and their subsequent degradation will likely follow the same pattern over time. Here we provide numerous examples to support the syn-eruptive controls on scoria cone morphology and their long-term effect on degradation rates and patterns under different climatic settings. A theoretical degradation model, by the combination of long-term (e.g. rain splash erosion) and short-term (e.g. debris flow) mass wasting processes, is established to help the interpretation of geomorphic data. Due to the coupling mechanism between the eruptive diversity and the degradation path of individual volcanoes, it is proposed that volcano degradation is not only the consequence of age and climate, but of many other processes, such as number of 'event' degradations and the erosion-resistance of pyroclastic materials exposed to the environment.

Uranium series - size correlations in intraplate basaltic volcanic fields: source control on physical parameters

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Small volume basaltic eruptions within volcanic fields have the potential to reveal subtle features of magmatic processes which are overwhelmed in larger systems such as central continental volcanoes, ocean island basalts and large igneous provinces. One of the major findings of recent research has been that such volcanic fields can reveal the fine detail of source heterogeneity both on whole field and single volcano scales. Because small volume centres often display almost complete volcanic sequences within a range of eruptive styles and sizes, opportunities are presented whereby correlations between physical features and chemical compositions can be investigated in detail. The Auckland Volcanic Field (AVF) in northern New Zealand is one of the best-sampled cases of a basaltic volcanic field; the volcanoes comprising the field show a spectrum of sizes and compositions from small volume nephelinitic maars and tuff dominated centres, through medium sized alkalic basanitic and basaltic scoria cones, to larger volume subalkalic basalt scoria and lava dominated centres. We focus on four eruptions which display a size and compositional spectrum: Purchas Hill (11ka, the smallest sampled volcanic centre in the AVF, nephelinitic in composition), Mt Wellington (10ka, medium sized, alkalic basalt) and the two eruptions of Rangitoto (Rangitoto 1: 552yrs BP, medium sized, alkalic basalt, and Rangitoto 2: 502yrs BP, the largest volcanic centre in the AVF, subalkalic basalt). U series and other isotopic data for the largest, smallest and two medium sized volcanic centres in the field show strong correlations between eruptive volume and isotopic composition. Preliminary data show that the volcanic centres display a spectrum of compositions in U-Th isotopic, Pb isotopic and SiO2 vs. Total Alkali space, with the smallest centre (Purchas Hill) displaying the highest (230Th/232Th) (1.38), the most radiogenic 206Pb/204Pb (19.416) and 208Pb/204Pb (39.009), the lowest SiO2 (39 wt%) and highest total alkalis (6 wt%). The largest centre displays the lowest (230Th/232Th) (1.14), the least radiogenic 206Pb/204Pb (19.039) and 208Pb/204Pb (38.781), the highest SiO2 (49.5 wt%) and lowest total alkalis (3 wt%). Other isotopic and trace element parameters tentatively show similar correlations. The observed differences in the chemical parameters can be attributed to melting of a heterogeneous source, where the heterogeneity results in varying magmatic processes. These results suggest that physical parameters of individual centres in intraplate volcanic fields may dominantly be dictated by processes in the deep asthenosphere.

Unraveling the eruption dynamics of the complex volcanology at the 5 ka Mt. Gambier Volcanic Complex, south-eastern Australia

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The 5 ka, basaltic, multi-vent and polymagmatic Mt. Gambier Volcanic Complex (MGVC) is a complex of maars, tuff, scoria and spatter cones. It occurs within the late Cainozoic basaltic intraplate Newer Volcanics Province of south-eastern Australia. Field mapping, stratigraphy and facies analysis, component analysis, whole rock geochemistry and electron microprobe and Fourier Transform IR analyses were used to constrain the eruption dynamics of the MGVC. The eruption styles range from magmatic to phreatomagmatic with varying intensities in explosivity. The analyses indicate that the highly variable eruption styles in this complex monogenetic system resulted from a combination of magmatic variables (magmatic effusive vs. magmatic explosive styles) and the dynamics of interaction between the rising magma and the two underlying aquifers (one confined and one unconfined).

Magmatic variables are crystallinity, vesicularity, temperature, density, viscosity, rise rate, pre-eruptive volatile contents and degassing. The aquifer dynamics are related to the aquifer properties - grainsize distributions, permeability, recharge rates, hydraulic conductivity (i.e. horizontal flow rate) - as well as the behaviour of the water itself and how these properties rheologies change with the introduction of rising hot magma. Also the conduit properties related to the aquifers are important (i.e. sealing of the conduit walls and liquifaction). The rising magma, at each eruption point, first interacted with the upper unconfined aquifer and then later with the deeper confined aquifer as the diatreme was progressively excavated deeper.

This poster provides insight in how these variables and dynamics are constrained and what the results are to date of the different methods. It should trigger a discussion about the way hydrodynamics are perceived when studying eruption dynamics.

New insight into the timing of volcanism at Salton Buttes, California from $^{40}Ar/^{39}Ar$ dating and paleomagnetism

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Five Quaternary rhyolite domes lie along the southern margin of the Salton Sea, California. The domes are aligned parallel to the axis of spreading along the boundary between the Pacific and North American plates in the Salton Trough pull apart basin. These volcanic domes are spatially associated with a broad area of high heat flow (tens of kilometers wide) and active geothermal energy production in the Salton Sea Geothermal Field. Magmatic rocks in the Salton Trough are bimodal in composition, including rhyolites and subsurface diabase dikes. Volcanism at the Salton Buttes is characterized by both magmatic and phreatomagmatic activity, where explosive activity preceded an effusive phase in at least two cases.

Given the surface expression of the low profile domes in an area of rapid sedimentation and subsidence (~0.2-2 cm/yr; Schmitt and Hulen 2008; Brothers et al. 2009) and <15 ka U-Th ages for the rims of zircon crystals from two of the domes (Schmitt and Vazquez 2006; Schmitt et al. 2013), the domes are likely all latest Pleistocene to Holocene in age. Here, we add U-Th zircon rim ages for all of the domes and a new $^{40}Ar/^{39}Ar$ age for anorthoclase from Obsidian Butte, confirming latest Pleistocene to Holocene eruption ages. Further, by comparing independent paleomagnetic remanent directions from sites drilled in the domes with geomagnetic secular variation, we find that there were at least three distinct eruption periods. These distinct eruption dates are coincident with small variations in glass and whole-rock composition of domes.

Finally, over a longer timespan, volcanism in the Salton Trough apparently is markedly sporadic. The most recent known volcanism (small volume rhyolite domes akin to surface domes discovered by geothermal exploration drilling) occurred >420 ka (now at >1.6 km depth beneath the ground surface, Schmitt and Hulen 2008). We speculate that volcanism is reserved to periods when magma production rate outpaces extension rate.

Brothers, Driscoll, Kent, Harding, Babcock, Baskin (2009) Tectonic evolution of the Salton Sea inferred from seismic reflection data, Nature Geoscience 2: 581-584.

Schmitt and Hulen (2008) Buried rhyolites within the active, high-temperature Salton Sea geothermal system, Journal of Volcanology and Geothermal Research 178: 708-718.

Schmitt and Vazquez (2006) Alteration and remelting of nascent oceanic crust during continental rupture: Evidence from zircon geochemistry of rhyolites and xenoliths from the Salton Trough, California, Earth and Planetary Science Letters 252: 260-274.

Schmitt, Martin, Stockli, Farley, Lovera (2013) (U-Th)/He zircon and archaeological ages for a late prehistoric eruption in the Salton Trough (California, USA), Geology 41: 7-10.

Abu monogenetic volcano group in SW Japan Arc: its characteristic landforms, eruption types, and magma genesis

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Late Cenozoic Abu monogenetic volcano group (AMVG) consists of 56 volcanoes and is distributed over an area of 400km^2 in SW Japan Arc. Some of the 56 volcanoes are located within the sea. The volcanic activity is classified into an alkaline basalt-dominated early period (2-1.6Ma), and a calc-alkaline andesite to dacite dominated late period (<0.8Ma). The early activity took place about 0.4 mys, during which time 0.3 km^3 of alkaline basalt alone was erupted to form lava flow with scoria cone and small lava plateaus. The late activity produced alkaline basalt consisting of small lava plateau and lava flows with scoria cone. Smallest basaltic lava plateau, Nakanodai volcano (0.19Ma), is 600m x 450m in basal distance and 50m in height. Dominant calc-alkaline andesite to dacite also flooded from the fissure to build lava plateaus or flat lava domes. Largest lava plateau, Ooshima volcano (0.19Ma), is 2400m x 1500m in basal distance and 170m in height. The andesite to dacite lavas formed the lava plateaus might be higher temperatures and effusive rates. The largest basaltic monogenetic volcano, Iraoyama volcano (0.4-0.32Ma), erupted thick fallout deposits (<30m in thickness) from central vent and simultaneous scoria cone formation. Then large volume of lava flows oozed out two directions from the base of the scoria cone. The east lava flow formed the lava plateau surrounding country rock. The northern lava flow followed a former river valley to reach the lowland 14km away. The solidified long lava flow (<100m in depth) is eroded and exhibits spectacular columnar jointing along cliffs in valleys. These landmarks are named Dragon's Causeway related to the tradition of this area. These suggest that Iraoyama volcano might be constructed by violent strombolian eruption such as production of large amount of fallout deposit, simultaneous scoria cone formation and large volume of lava effusion from the base of the scoria cone. The basalts in early activity show the OIB type signature. On the other hand, basalts in late activity have the OIB- and island-arc type signatures. They might be derived from heterogeneous mantle diapir. The calc-alkaline andesite and dacite might be produced by magma mixing between primitive basaltic and felsic magmas. Magmatism of AMVG suggests that heating induced by intrusion of basalt magma resulted in partial melting of the crust, thus producing felsic calc-alkaline magmas.

Petrography and Ar isotopic information of nosean in the phonolite in East Eifel volcanic field, Germany: investigation of the source of excess ^{40}Ar

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Since the reports of the ^{40}Ar/^{39}Ar analyses and excess ^{40}Ar on Quaternary Eifel monogenetic volcano field in Germany from 1985 to 1990 by the group of Lippolt of the University of Heidelberg, hauyne and nosean in certain phonolites from the northwest of East Eifel volcanic field were known to contain significant amounts of excess ^{40}Ar and show apparent older ages. However, its petrographic meaning was not well known. The group of Sumino of the University of Tokyo has clarified the source for excess ^{40}Ar in plagioclase phenocrysts from the historic Unzen dacitic lava flows as the melt inclusions shown as zones in plagioclase by in-situ laser Ar isotope analysis.

In order to investigate the source of excess ^{40}Ar in hauyne/nosean from the phonolite in the East Eifel by in-situ Ar isotope analysis with UV pulse laser (wavelength 266 nm) and ^{40}Ar/^{39}Ar dating system at the University of Potsdam, we collected phonolites from the East Eifel and investigated their petrography, mineral composition and Ar isotopes. The rock collected from Olbrueck contains nosean, leucite and sanidine phenocrysts. Nosean contained fine inclusions with a size of less than 5 micrometer which are distributed linearly, but not as zones. For many nosean grains resorbtion occurred, although no inclusions or resorption are shown from the leucite and sanidine phenocrysts. The analysis by SEM-EDS showed that the resorbtion was caused by carbonates or carbonate melts. The chemistry at inclusions or in holes where the inclusions probably located showed higher Cl and S content, which could be derived from volcanic volatile elements. The in-situ Ar isotopic analyses were performed on the polished surface of small rock plates (less than 1cm size and less than 1mm thickness) with UV pulse laser by 100 or 200 micrometer beam size. Obtained results are: (1) carbonate in/around the nosean only show nearly the atmospheric Ar isotope ratios, (2) the in-situ analyses of nosean and leucites showed clearly higher ^{40}Ar/^{36}Ar ratios up to 460 (nosean) or 600 (leucite), (3) the correlation of the ^{40}Ar/^{36}Ar ratios with or without apparent involvement of linear distribution of inclusions in the spot areas was not clear. It was mostly difficult to analyze inclusion-free areas. (4) From the K-Ar isochron plots of the results considering potassium contents for nosean and leucites, nosean clearly shows the older age than leucite. This data set implies that the nosean surely has the apparent older ages than leucite as the previous reports by the group of Lippolt. Therefore presently the influences to the Ar isotope from the inclusions are not yet clear. As other rock plates were also irradiated by the fast neutron in the reactor at Petten, Netherlands, the discussion will continue with the results by in-situ ^{40}Ar/^{39}Ar analyses of those samples.

Complex interaction between Strombolian and phreatomagmatic eruptions in the Miocene monogenetic volcanism of the Harrat Shama Volcanic Field (SW of Sauda Arabia)

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The Harrat Shama volcanic Field (HSVF) is a well-exposed, intra-continental extensional basin during the opening of the Red Sea, containing 5 km of Miocene preserved and uplifted bimodal volcanics and interbedded volcaniclastic rocks. The HSVF comprises proximal wall deposits with a well defined crater wall unconformity and crater-fill deposits. The style of volcanic activity was mainly explosive and was reinforced by hydrovolcanic processes. The Shama deposits can be divided into two sequences depending on the field observations and the main depositional characteristics: lower sequence represents volcanic aggradational processes that constructed the crater, and is composed of hyaloclastites, zeolite-bearing bedded tuffs, and explosively fragmented accretionary bedded lapillituffs of wet surge facies and an upper sequence, made up of ash flow deposits and peperitic breccias that are capped by basaltic lava flows. The differences between the two sequences are reflected in both eruption dynamics and fragmentation mechanisms as well as the overall characteristics of the deposits. Fluvial erosion and deposition completed the evolution of the emerged marginal part of the basin.

The two complex volcanic successions that show evidence of several eruptive episodes, were built by magmatic and hydrovolcanic explosions of different styles (Strombolian, sub-Plinian and phreato-Strombolian) generated from a common source. They formed a dynamic closed intra-continental sedimentary system that experienced a successive subsidence. The initial eruptions are interpreted to have been dominated by discrete, highly efficient, phreatomagmatic fall deposits, which are attributed to an overall high eruption rate in a deep lacustrine setting (lower sequence), followed by a transition to dominantly subaerial ash-flow deposits and volcaniclastic sediments sited in the upper part of the basin. The Phreatomagmatism has contributed to the construction of more than a half of this volcanic edifice, frequently associated with the Strombolian activity but also independently, giving rise to a large variety of eruptive sequences. Dome growth occurred at the end of the eruption, but subsequent retrogressive explosions triggered by external water destroyed all trace of the original dome morphology. We find that the main cause of such complex eruptive behaviour resides in the stratigraphic, structural and hydrogeological characteristics of the substrate above which the volcanoes were emplaced, rather than on the compositional characteristics of the erupting magma, as they do not show significant variations among the different deposits studied.