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Corresponding Author: Dr Jacopo Taddeucci,

Corresponding Author's Institution: Istituto Nazionale di Geofisica e Vulcanologia

First Author: Corrado Cimarelli

Order of Authors: Corrado Cimarelli; Federico Di Traglia; Jacopo Taddeucci

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Abstract: Pyroclast textures document volcanic conduit processes and may be key to hazard forecasting. Here we show that the relative abundance of mingled, variably crystallized domains in pyroclasts from scoria cone eruptions provide a record of magma ascent velocity and can be used to predict the onset of violent Strombolian activity. Scoria clasts from the Croscat Complex Scoria Cone (Spain) ubiquitously show □ m to cm-sized, microlite-rich domains (MRD) intermingled with volumetrically-dominant, microlite-poor ones (MPD). Glass and bulk composition show that MRDs formed by microlite crystallization of MPDs, the former residing longer in a relatively cooler, degassed zone lining the conduit walls, the latter traveling faster in the central, hotter streamline. MPD and MRD magmas intermingled along the interface between the two velocity zones. The proportion of MPD and MRD in different tephra layers reflects the extent of the fast- and slow-flowing zones, thus reflecting the ascent velocity profile of magma during the different phases. At Croscat, the MPD/MRD volume ratio increased rapidly during the early Strombolian activity, peaked around the Strombolian to violent Strombolian shift, and then decreased smoothly irrespective of shifts in eruptive style. We suggest that magma ascent velocity escalated during the Strombolian phase due to the buoyant push of the underlying, volatile-rich magma that was about to drive the following violent Strombolian activity. Monitoring the MPD/MRD ratio of tephra during ongoing scoria cone eruptions may reveal changes in magma flow conditions and could forecast the onset of hazardous violent Strombolian activity.

Response to Reviewers: Dear Editor of Geology,

The present cover letter accompanies the revision of the manuscript "Basaltic scoria textures from a zoned conduit as precursors to violent Strombolian activity" by C. Cimarelli, F. Di Traglia and J. Taddeucci (Ref.: Ms. No. G30120).
The manuscript has been integrated according to all the minor revisions of both reviewers. All of them were constructive and led to significant improvements of the final version of the manuscript.
All suggestions and comments of reviewer #1 have been fully accepted and incorporated in the present version of the manuscript. The reviewer #2 did not suggest any further change in the manuscript and

we wish to thank her for the encouraging suggestions and the detailed review on the previous version of the manuscript.
We also incorporated the few comments of the managing editor and, in particular, the text format used in the figure has been corrected according to the Geology format (see correction of capital letters in all the figures). Also the references cited in the text have been updated according to those reported in the reference list.

Please find below a synthetic list of the reviewer #1 comments to the previous version and the changes we accordingly introduced in the new manuscript.

Reviewer #1
1) Localization of the crystallization and mingling event.

We added a new sentence in lines 140-145, fully accepting the reviewer's view.

2) Timescales of eruption and analytical procedures.

Again, we accepted the suggestion and included a new sentence in lines 169-171.

3) Revision of Figure 3.
Following the recommendation by Reviewer #1, we modified the Fig. 3 omitting the estimated duration scale of the eruption that was previously indicated on the right hand side of the diagram. The information on eruption duration is now included in the caption.

Sincerely yours,

Corrado Cimarelli, Federico Di Traglia, Jacopo Taddeucci.

Supplemental file

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Basaltic scoria textures from a zoned conduit as precursors to violent Strombolian activity

C. Cimarelli[1], F. Di Traglia[2], and J. Taddeucci[3]

[1]*Dip. Scienze Geologiche, Università Roma Tre, L.go S.L. Murialdo 1, 00146 Rome, Italy*

[2]*Dip. Scienze della Terra, Università di Pisa, Via S. Maria 53, 56126 Pisa, Italy*

[3]*Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata 605, 00143 Rome, Italy*

ABSTRACT

Pyroclast textures document volcanic conduit processes and may be key to hazard forecasting. Here we show that the relative abundance of mingled, variably crystallized domains in pyroclasts from scoria cone eruptions provide a record of magma ascent velocity and can be used to predict the onset of violent Strombolian activity. Scoria clasts from the Croscat Complex Scoria Cone (Spain) ubiquitously show μm- to cm-sized, microlite-rich domains (MRD) intermingled with volumetrically-dominant, microlite-poor ones (MPD). Glass and bulk composition show that MRDs formed by microlite crystallization of MPDs, the former residing longer in a relatively cooler, degassed zone lining the conduit walls, the latter traveling faster in the central, hotter streamline. MPD and MRD magmas intermingled along the interface between the two velocity zones. The proportion of MPD and MRD in different tephra layers reflects the extent of the fast- and slow-flowing zones, thus reflecting the ascent velocity profile of magma during the different phases. At Croscat, the MPD/MRD volume ratio increased rapidly during the early Strombolian activity, peaked around the Strombolian to violent Strombolian shift, and then decreased smoothly irrespective of shifts in eruptive style. We suggest that magma ascent velocity escalated during the Strombolian phase due to the buoyant push of the underlying, volatile-rich magma that was about to drive the following violent Strombolian activity. Monitoring the MPD/MRD ratio of tephra during ongoing scoria cone eruptions may reveal changes in magma flow conditions and could forecast the onset of hazardous violent Strombolian activity.

INTRODUCTION

Basaltic volcanism, ranging in intensity from effusive to violent explosive, is the prevailing volcanic activity on Earth. Of the variety of explosive styles shown by basaltic eruptions, ranging from Strombolian to Plinian intensities (e.g., Vergniolle and Mangan, 2000), violent Strombolian activity (MacDonald, 1972) is currently under reappraisal. An increasing number of past eruptive successions are being reclassified as violent Strombolian (Arrighi et al., 2001; Valentine et al., 2005, 2007; Di Traglia et al., 2009), as are recently observed events, including the 1943–52 type-eruption of Paricutin (MacDonald, 1972; Luhr and Simkin, 1993; Pioli et al., 2008), the 1995 Cerro Negro eruption (Hill et al., 1998), and the 2002–2003 eruption of Mt. Etna (Andronico et al., 2009). In all the above geological and historical cases, violent Strombolian activity represents the peak-intensity phase of months- to years-lasting eruptions, punctuating other lower-intensity explosive and effusive phases and producing eruptive plumes several kilometers in height with occasional small-scale column collapses, posing severe threats to inhabited areas (Houghton et al., 2006; Andronico et al., 2009).

Similar to other high-intensity explosive phases (Rosi et al., 2006; Sable et al., 2006), the onset of violent Strombolian activity during complex mafic eruptions is inferred to be related to the arrival of volatile-rich magma batches (Andronico et al., 2009; Pioli et al., 2008) and/or to changes in the rheological properties of magma, as related to microlite crystallization within the conduit (Valentine et al., 2005; Andronico et al., 2009), with conduit geometry and branching as additional controlling factors (Keating et al., 2008, Pioli et al., 2009). Violent Strombolian phases require relatively high magma mass flow and ascent velocities (Parfitt, 2004) as well as efficient magma fragmentation, as testified by grain-size and morphology (Andronico et al., 2009; Valentine and Gregg, 2008). Vesicularity of violent Strombolian scoriae, ranging between 50%–70% versus 30%–80% in Strombolian scoriae (Polacci et al., 2008; Pioli et al., 2008; Di Traglia et al., 2009), and bubble number density (BND) values intermediate between Hawaiian and Plinian products, suggest relatively fast decompression of gas-rich magmas compared to lower intensity explosive eruptions

(Houghton and Gonnermann, 2008; Di Traglia et al., 2009). Pyroclasts from violent Strombolian products are typically porphyritic with both glassy and cryptocrystalline groundmasses (e.g., Pioli et al., 2008), interpreted to be the result of different degrees of magma crystallization within different zones of the conduit (Taddeucci et al., 2004). Large microlite contents are expected to change the rheological behavior of basaltic magma both during conduit flow (Lejeune and Richet, 1995) and at fragmentation (Taddeucci et al., 2007), ultimately controlling the eruptive style.

In the present paper, we use textural features of mingled scoriae from the basaltic eruption of the Holocene Croscat Complex Scoria Cone (Spain) to shed light on conduit flow conditions during the transition from Strombolian to violent Strombolian activity, potentially offering a means to forecast the onset of hazardous violent Strombolian events during ongoing eruptions.

The Croscat Complex Scoria Cone

The Croscat Complex Scoria Cone (CCSC) is the youngest volcano of the Garrotxa Volcanic Field and of the whole Iberian Peninsula (11 ka; Guérin et al., 1985), and its volcanic succession provides an excellent example of highly variable activity within a single mafic eruption. The eruption started with fissural Hawaiian activity (LQU; Fig. 1), shifted to Strombolian explosions from a central vent (UQU), and then magma interaction with a shallow aquifer system promoted the first phreatomagmatic phase (CCU). The arrival of a relatively gas-rich, more primitive magma (as testified by trace element variations; Di Traglia et al., 2009), possibly decompressed by the preceding phreatomagmatic activity, drove three violent Strombolian phases, producing widespread tephra blankets (lower, middle and upper CMU). Subsequently, the activity shifted into a second, larger phreatomagmatic phase (CBU). The eruption ended with the emission of a lava flow (CXL) and consequent breaching of the western side of the cone. BND values in CCSC products reveal that ascent rate initially increased at the end of the Strombolian phase, then subsequently became constant during the violent Strombolian phase and finally decreased until the end of the eruption. Stratigraphy and erupted volumes suggest that eruption duration was in the short to average range of scoria cone eruptions (Di Traglia et al., 2009), i.e., several months.

Texture and Composition of Mingled Scoria Clasts

From the best exposed proximal section of the cone we collected 14 samples representative of all tephra units and analyzed thin sections of scoria lapilli under binocular, petrographic, and Field-Emission Scanning Electron Microscope (FE-SEM) (see Methodological Appendix in the GSA Data Repository[1]). Scoriae from all stratigraphic units, irrespectively of the eruptive mechanism, show intermingling of two distinct textural domains that we term microlite-poor (MPD) and microlite-rich domains (MRD), respectively (Fig. 2). MPDs are made up of sideromelane glass (pale yellow to brown in thin section) with abundant spherical vesicles down to a few μm in diameter, and include up to 1–2 vol.% of 1–50 μm-sized microlites of plagioclase (Pl), clinopyroxene (Cpx), oxides (Ox), and occasional olivine (Ol). With respect to MPDs, MRDs (dark-opaque and tachylite-like in thin section) are less vesicular, include larger and more irregular vesicles, and contain a significantly larger fraction (15–43 vol.%) of the same microlites. Microlites are mostly euhedral, with evidence of zonation in the Cpx, subordinate skeletal habits occurring in Ol and Plg. Phenocrysts of Ol and Cpx equally occur in both domains. The two domains are commonly found intermingled in the same scoria clast, with individual domains ranging in size from ~30 μm to the size of the whole clast. Domain boundaries, defined by a sharp (mostly <1 μm-thick) transition of glass composition (highlighted by the gray tone of BSE images), are mostly convoluted and show fluidal re-orientation of prolate microlites in MRDs, independent of clast or vesicle preferential orientations.

Electron Microprobe (EMPA) and FE-SEM spot and bulk chemical analyses (see Appendix) of MPDs and MRDs show that interstitial glasses in MRDs follow a clear differentiation trend, with the MPD counterparts representing the most primitive extremity. Notably, MRDs bulk composition is comparable (within analytical error) to that of adjoined MPD glass (Fig. 2).

In order to obtain a fast and accurate measure of the relative abundance of MPDs and MRDs up-section in the Croscat deposits, we classified 2–4 mm particles as “MR” or “MP” on the basis of their prevailing groundmass texture under petrographic microscope (see Appendix). The results

(Fig. 3) show a smooth trend, with a rapid increase of the MPD/MRD vol. ratio within the Strombolian deposit, a peak around the transition to violent Strombolian ones, and a gradual decrease up-section, with no major changes corresponding to shifts in eruptive style (e.g, the magmatic-phreatomagmatic transition).

INTERPRETATION AND CONCLUSIONS

Conduit Flow Dynamics During Complex Explosive Basaltic Eruptions

The clear differentiation trend of interstitial MRD glasses, the chemical homogeneity of MRD bulk and MPD interstitial glass compositions, and the occurrence of an identical phenocrysts assemblage, all together reveal that MPDs and MRDs represent portions of the same magma that experienced different degrees of microlite crystallization. Microlite abundance and vesicle abundance and shape (e.g., Mangan and Cashman, 1996) suggest a longer conduit residence time of MRDs with respect to MPDs. Horizontal velocity gradients within conduits were already postulated to generate magma zoning during mafic explosive activity with respect to both vesicularity (Lautze and Houghton, 2005) and microlite crystallization patterns (Taddeucci et al., 2004). We hypothesize that MRDs resided longer in a relatively cooler zone lining the conduit margins, where degassing was also favored, while MPDs traveled faster in a hotter environment along the central streamline of the conduit. Groundmass textures thus would outline horizontal velocity gradients, averaged over the length of the MRD-forming zone of the conduit. We note that, in the CCSC case, such gradients persisted throughout the eruption.

The mingling of MPDs and MRDs may illuminate flow dynamics of the velocity-zoned CCSC conduit. In our scenario, the two domains mingle at the boundary between the two zones of the conduit with different ascent velocities. This boundary, given the lack of domains texturally and compositionally intermediate between MPD and MRD, was relatively sharp and hosted, at least locally, turbulent flow conditions, as testified by the convoluted morphology of the domains. Physical mingling was driven by the velocity gradient occurring between the two domains and controlled by their strong rheological contrast, as related to the high solid fraction of MRDs (Fig. 4).

The MPD/MRD volume ratio of erupted products reflects the extent of the two domains at fragmentation as related to variable magma flow conditions, and is expected to be mainly controlled by conduit geometry (specifically the volume/surface ratio) and magma ascent velocity. In the CCSC case, the dispersal and country-rock content of erupted products, which are proxies to changes in conduit size or shape, do not correlate with MPD/MRD. Conversely, MPD/MRD broadly correlates positively with another, independent measure of magma ascent velocity, i.e., BND (Toramaru, 2006; Di Traglia et al., 2009), supporting the notion that velocity changes during the eruption caused the observed up-section variations in MPD/MRD, which, in this case, acts as a magma flow speedometer.

The smooth variation of MPD/MRD in the eruption products points out equally smooth changes in magma flow conditions over the time scale represented by each of our samples, likely days to weeks. The fact that MPD/MRD varied smoothly irrespective of abrupt changes in eruptive style implies that the formation and mingling of the two domains occurred below the fragmentation zone, at a level deep enough not to be affected by external factors (e.g., contact with external water) but shallow enough to preserve the domains from mixing.

Strombolian to Violent Strombolian Transition and Eruption Monitoring Implications

The observed MPD/MRD trend indicates a rapid increase of magma ascent velocity during the Strombolian activity, peak velocity during the violent Strombolian phase, and a gradual velocity decrease until the end of the eruption.

Focusing on the Strombolian to violent Strombolian transition, we note that, despite the large difference in their intensity and style, peak magma ascent velocity, as recorded by MPD/MRD, was similar during the two phases, and also during the intervening phreatomagmatic activity. Violent Strombolian activity was driven by a batch of magma slightly less evolved and more volatile-rich in comparison to that driving the earlier Strombolian one (Di Traglia et al., 2009). This volatile-rich magma exerted a strong buoyancy lift on the overlying, relatively gas-poor magma filling the conduit. The increasing magma ascent velocity during Strombolian activity could reflect a combination of two factors: 1) the increasing buoyancy of the gas-charged magma as it ascended, magmastatic pressure decreased, and bubbles expanded; and 2) the progressive reduction of viscous resistance as the gas-poor magma column was evacuated, also favored by the decrease in the thickness of the microlite-rich, more viscous conduit lining (see Lautze and Houghton, 2007). Even if accelerated to similar ascent velocities, the overlying magma drove moderate Strombolian activity due to its relatively low volatile content, in contrast with the underlying, volatile-rich magma that, reaching the surface, fueled violent Strombolian activity (Fig. 4).

Mingled textures occur in other violent Strombolian eruption products (Andronico et al., 2009; Pioli et al., 2008), suggesting that the processes active during the CCSC eruption may be common in complex basaltic explosive eruptions. Textural monitoring of pyroclasts during ongoing basaltic eruptions already proved to be capable of identifying, and to some extent anticipate, increasing intensity of basaltic explosive activity (Taddeucci et al., 2002). The CCSC case provides an interpretative framework for previous cases. Moreover, our methodology allows MPD/MRD to be measured within a few hours after sample collection (see Appendix) and may be included in textural monitoring of basaltic volcanoes. Daily MPD/MRD measures could reveal fluctuations in the magma ascent rate of ongoing eruptions, eventually heralding the arrival of gas-charged magma and the onset of more violent activity.

ACKNOWLEDGMENTS

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REFERENCES CITED

Andronico, D., Cristaldi, A., Del Carlo, P., and Taddeucci, J., 2009, Shifting styles of basaltic explosive activity during the 2002–03 eruption of Mt. Etna, Italy: Journal of Volcanology and Geothermal Research, v. 180, p. 110–122, doi: 10.1016/j.jvolgeores.2008.07.026.

Arrighi, S., Principe, C., and Rosi, M., 2001, Violent Strombolian and Subplinian eruptions at Vesuvius during post-1631 activity: Bulletin of Volcanology, v. 63, p. 126–150, doi: 10.1007/s004450100130.

Di Traglia, F., Cimarelli, C., De Rita, D., and Gimeno Torrente, D., 2009, Changing eruptive styles in basaltic explosive volcanism: Examples from Croscat complex scoria cone, Garrotxa Volcanic Field (NE Iberian Peninsula): Journal of Volcanology and Geothermal Research, v. 180, p. 89–109, doi: 10.1016/j.jvolgeores.2008.10.020.

Guérin, G., Behamoun, G., and Mallarach, J.M., 1985, Un exemple de fusió parcial en medi continental. El vulcanisme quaternari de la Garrotxa: Vitrina - Museu Comarcal de la Garrotxa, v. 1, p 19–26.

Hill, B.E., Connor, C.B., Jarzemba, M.S., La Femina, P.C., Navarro, M., and Strauch, W., 1998, 1995 eruptions of Cerro Negro Volcano, Nicaragua, and risk assessment for future eruptions: Geological Society of America Bulletin, v. 110, p. 1231–1241, doi: 10.1130/0016-7606(1998)110<1231:EOCNVN>2.3.CO;2.

Houghton, B.F., Bonadonna, C., Gregg, C.E., Johnston, D.M., Cousins, W.J., Cole, J.W., and Del Carlo, P., 2006, Proximal tephra hazards: recent eruption studies applied to volcanic risk in the Auckland volcanic field, New Zealand: Journal of Volcanology and Geothermal Research, v. 155, no. 1–2, p. 138–149, doi: 10.1016/j.jvolgeores.2006.02.006.

Houghton, B.F., and Gonnermann, H.M., 2008, Basaltic explosive volcanism: Constraints from deposits and models: Chemie der Erde - Geochemistry, v. 68 (2), p. 117–140.

Keating, G.N., Valentine, G.V., Krier, D.J., and Perry, F.V., 2008, Shallow plumbing systems for small-volume basaltic volcanoes: Bulletin of Volcanology, v. 70, p. 563–582, doi: 10.1007/s00445-007-0154-1.

Lautze, N.C., and Houghton, B.F., 2007, Linking variable explosion style and magma textures during 2002 at Stromboli volcano, Italy: Bulletin of Volcanology, v. 69, p. 445–460, doi: 10.1007/s00445-006-0086-1.

Lautze, N.C., and Houghton, B.F., 2005, Physical mingling of magma and complex eruption dynamics in the shallow conduit at Stromboli volcano, Italy: Geology, v. 33, no. 5, p. 425–428, doi: 10.1130/G21325.1.

Lejeune, A.M., and Richet, P., 1995, Rheology of crystal-bearing silicate melts: an experimental study at high viscosities: Journal of Geophysical Research, v. 100, B3, p. 4215–4229, doi: 10.1029/94JB02985.

Luhr, J.F., and Simkin, T., 1993, Paricutín: The Volcano Born in a Mexican Cornfield: Geoscience Press Inc., Phoenix, Arizona, 427 p.

MacDonald, G.A., 1972, Volcanoes: Prentice-Hall Inc., Englewood Cliffs, New Jersey. 510 p.

Mangan, M.T., and Cashman, K.V., 1996, The structure of basaltic scoria and reticulite and inferences for vesiculation, foam formation, and fragmentation in lava fountains: Journal of Volcanology and Geothermal Research, v. 73, p. 1–18, doi: 10.1016/0377-0273(96)00018-2.

Parfitt, E.A., 2004, A discussion of the mechanisms of explosive basaltic eruptions: Journal of Volcanology and Geothermal Research, v. 134, no. 1–2, p. 77–107, doi: 10.1016/j.jvolgeores.2004.01.002.

Pioli, L., Erlund, E., Johnson, E., Cashman, K., Wallace, P., Rosi, M., and Delgado Granados, H., 2008, Explosive dynamics of violent Strombolian eruptions: The eruption of Parícutin Volcano 1943–1952 (Mexico): Earth and Planetary Science Letters, v. 271, p. 359–368, doi: 10.1016/j.epsl.2008.04.026.

Pioli, L., Azzopardi, B.J., and Cashman, K.V., 2009, Controls on the explosivity of scoria cone eruptions: Magma segregation at conduit junctions: Journal of Volcanology and Geothermal Research, v. 186, p. 407–415, doi: 10.1016/j.jvolgeores.2009.07.014.

Polacci, M., Baker, D.R., Bai, L., and Mancini, L., 2008, Large vesicles record pathways of degassing at basaltic volcanoes: Bulletin of Volcanology, v. 70, no. 9, p. 1023–1029, doi: 10.1007/s00445-007-0184-8.

Rosi, M., Bertagnini, A., Harris, A.J.L., Pioli, L., Pistolesi, M., and Ripepe, M., 2006, A case history of paroxysmal explosion at Stromboli: Timing and dynamics of the April 5, 2003 event: Earth and Planetary Science Letters, v. 243, p. 594–606, doi: 10.1016/j.epsl.2006.01.035.

Sable, J.E., Houghton, B.F., Del Carlo, P., and Coltelli, M., 2006, Changing conditions of magma ascent and fragmentation during the Etna 122 BC basaltic Plinian eruption: Evidence from clast microtextures: Journal of Volcanology and Geothermal Research, v. 158, p. 333–354, doi: 10.1016/j.jvolgeores.2006.07.006.

Taddeucci, J., Pompilio, M., and Scarlato, P., 2002, Monitoring the explosive activity of the July-August 2001 eruption of Mt. Etna (Italy) by ash characterization: Geophysical Research Letters, v. 29, p. X1–X4, doi: 10.1029/2001GL014372.

Taddeucci, J., Pompilio, M., and Scarlato, P., 2004, Conduit processes during the July-August 2001 explosive activity of Mt. Etna (Italy): inferences from glass chemistry and crystal size distribution of ash particles: Journal of Volcanology and Geothermal Research, v. 137, p. 33–54, doi: 10.1016/j.jvolgeores.2004.05.011.

Taddeucci, J., Scarlato, P., Andronico, D., Cristaldi, A., Zimanowski, B., Büttner, R., and Küppers, U., 2007, Advances in the study of volcanic ash: Eos, Transactions, American Geophysical Union, v. 88, no. 24, p. 253–260, doi: 10.1029/2007EO240001.

Toramaru, A., 2006, BND (Bubble-Number Density) decompression rate meter for explosive volcanic eruptions: Journal of Volcanology and Geothermal Research, v. 154, p. 303–316, doi: 10.1016/j.jvolgeores.2006.03.027.

Valentine, G.A., Krier, D., Perry, F.V., and Heiken, G., 2005, Scoria cone construction mechanisms, Lathrop Wells volcano, southern Nevada, USA: Geology, v. 33, p. 629–632, doi: 10.1130/G21459.1.

Valentine, G.A., Krier, D.J., Perry, F.V., Heiken, G. 2007, Eruptive and geomorphic processes at Lathrop Wells scoria cone volcano. Journal of Volcanology and Geothermal Research,v. 161, p. 57–80, doi:10.1016/j.jvolgeores.2006.11.003

Valentine, G.A., and Gregg, T.K.P., 2008, Continental basaltic volcanoes - Processes and problems: Journal of Volcanology and Geothermal Research, v. 177, p. 857–873, doi: 10.1016/j.jvolgeores.2008.01.050.

Vergniolle, S., and Mangan, M., 2000, Hawaiian and Strombolian eruptions, in Sigurdsson, H., Houghton, B., McNutt, S., Rymer, H., Stix, J. eds., Encyclopedia of Volcanoes. Academic Press, San Diego, CA, pp. 447–461.

FIGURE CAPTIONS

Figure 1. Location (a), integrated stratigraphy and sampled levels (b), and square root of area versus thickness plot for violent Strombolian deposits of the CCSC, also showing the fields of violent Strombolian and Subplinian deposits (after Arrighi et al. 2001) (c).

Figure 2. a) Dark-gray, tachylite-like microlite-rich domains (MRD) and light-gray, sideromelane-like microlite-poor (MPD) ones in mingled scoriae of the CCSC (polarized light). b, c) BSE image of the two domains. Note microlite-rich MRD groundmass (darker gray, silica-enriched interstitial glass) and MPD (lighter gray, silica-poor glass with higher vesicularity). Microlites are black, elongated Plg, gray, zoned Cpx, light gray Ol, and white Ox. d, e, f) fluidal morphologies of MRD (white outlines) with Ol phenocrysts (dark gray) occurring in both domains. g) CaO versus MgO plot of the interstitial glass (MPD and MRD) and bulk (MRD only) compositions from all samples (in the inset, an example of FE-SEM spot and raster areas for the chemical analysis of interstitial glass and bulk composition, respectively).

Figure 3. Relative abundance (vol.%; ± 1σ error bar) of MP clasts up-section in the Croscat deposits. Eruption duration is estimated to be several months. Dashed line (third order polynomial best fit) highlights the sharp increase in the MP clasts abundance in the UQU Strombolian deposits anticipating the CMU violent Strombolian ones.

Figure 4. Interpretative scheme of the Croscat eruptive conduit. a) Mingling interface between the MR and MP magmas (conduit margin and central flow line are toward the left and right hand sides of the figure, respectively). Grey arrows represent flow velocity. b) During the Strombolian phase, magma flow velocity is relatively low and the MR zone is well developed. c) The buoyant lift from the underlying, volatile-rich magma increases flow velocity and reduces the MR zone. d) Flow velocity escalates as volatile-rich magma vesiculates and the more viscous, volatile-poor magma is evacuated. e) Flow velocity decreases after the first arrival of the gas-charged magma and the onset of violent Strombolian activity. Similar ascent velocities in c) and e) result in very different activity at the vent due to the different volatile content of the erupting magma.

[1]GSA Data Repository item 2009xxx, xxxxxxxx, is available online at www.geosociety.org/pubs/ft2008.htm, or on request from editing@geosociety.org or Documents Secretary, GSA, P.O. Box 9140, Boulder, CO 80301, USA.

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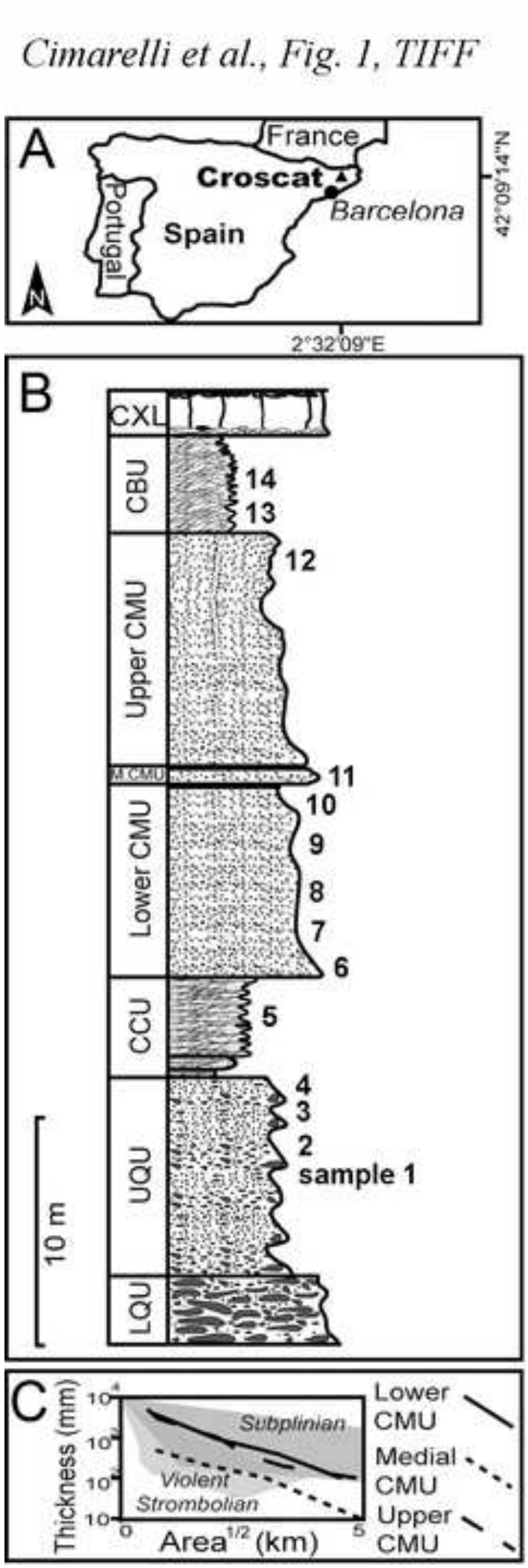

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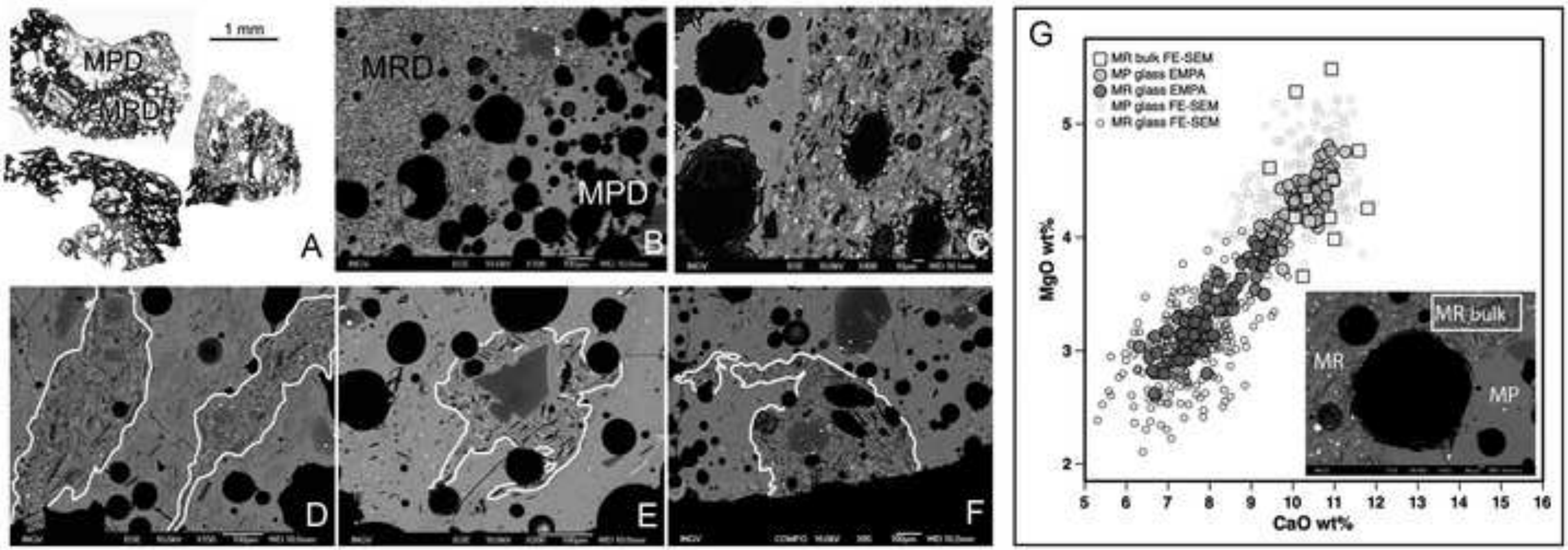

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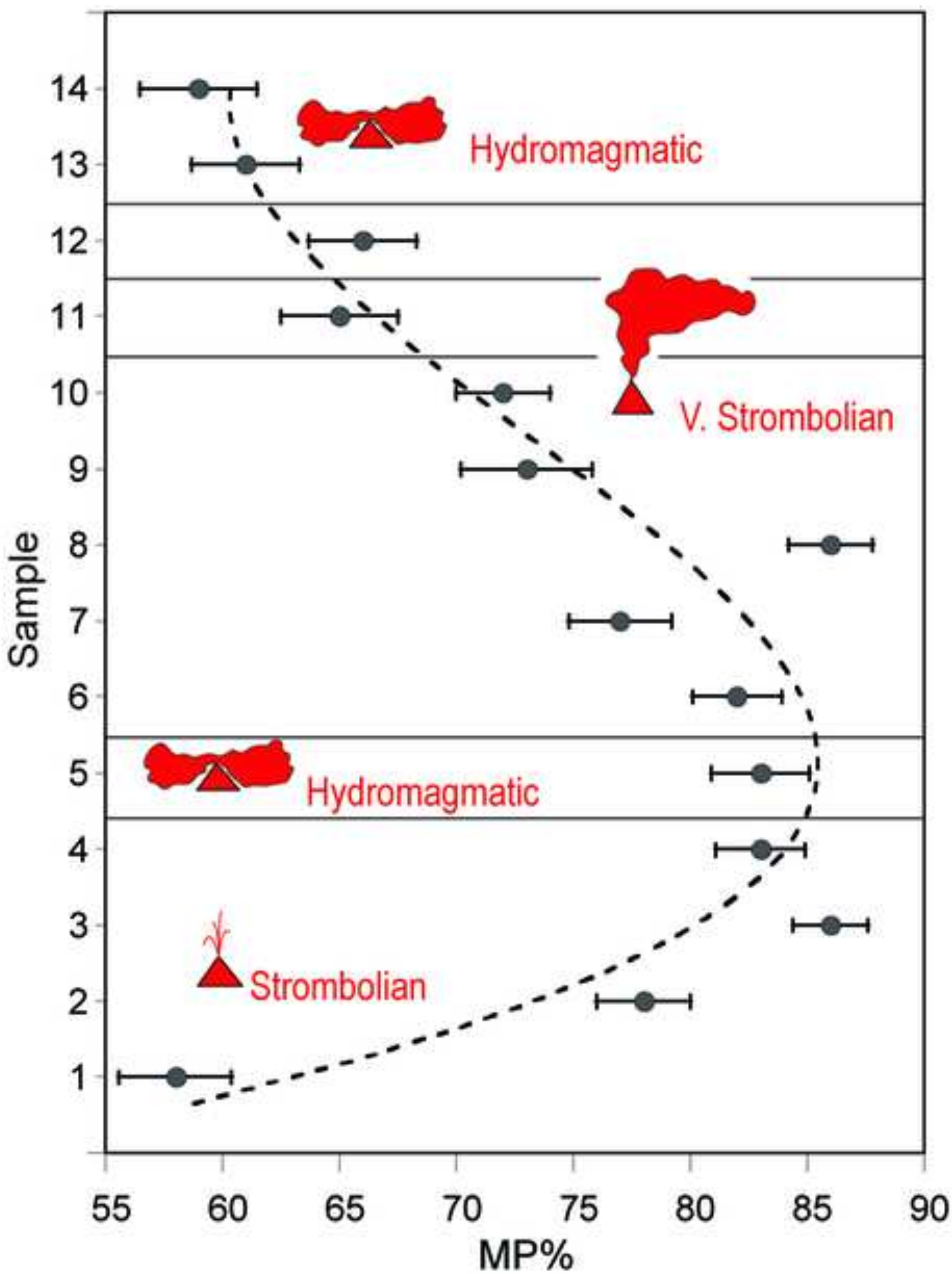

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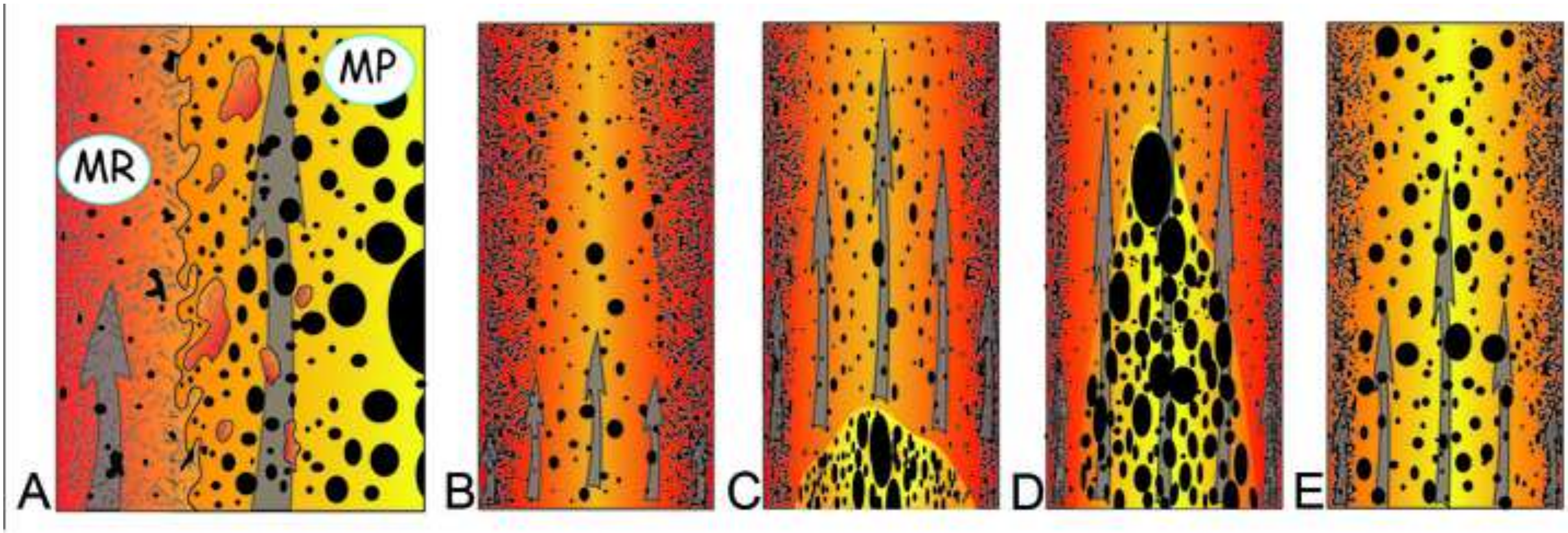

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