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The development of compound lava flow fields: insights from the 2008-9 eruption of Mt. Etna, Sicily

NATURAL ENVIRONMENT RESEARCH COUNCIL

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1. Introduction

Lava flow models can predict areas that will be threatened during short-lived effusive volcanic eruptions[1,2], but long-lived activity (>~3 weeks) results in complex flow fields. Multiple ephemeral vents may develop, feeding small flows that undergo processes including breaching and tubing[3-5], which are not fully understood. During the 13/05/2008 – 06/07/2009 eruption of Mt. Etna (Sicily), which emplaced lava flows into the Valle del Bove (VdB), we collected images and topographic data to enable analysis of the role of such processes in flow field evolution.

2. Data collection

By June 2009, effusive activity was limited to the VdB headwall (Fig. 1). A number of ephemeral vents (lifetimes of up to a few days) fed flows reaching up to 1 km in length, with lifetimes of hours to days. At this time we collected topographic data of the active flows using a terrestrial laser scanner[6], and deployed 4 Canon EOS 450D cameras on the VdB rim that captured images at 5-30 minute intervals until the end of the eruption (Fig. 2).

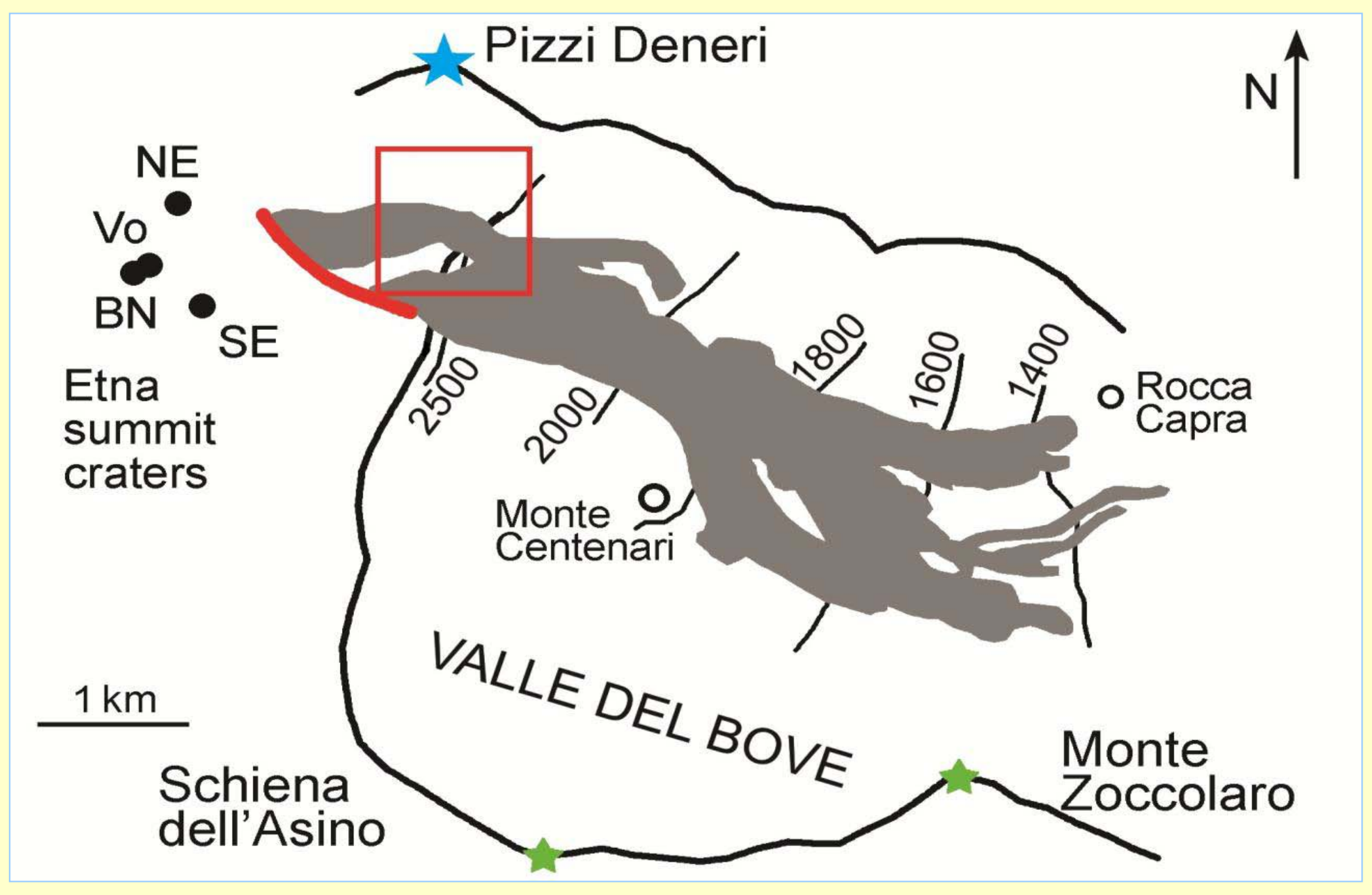
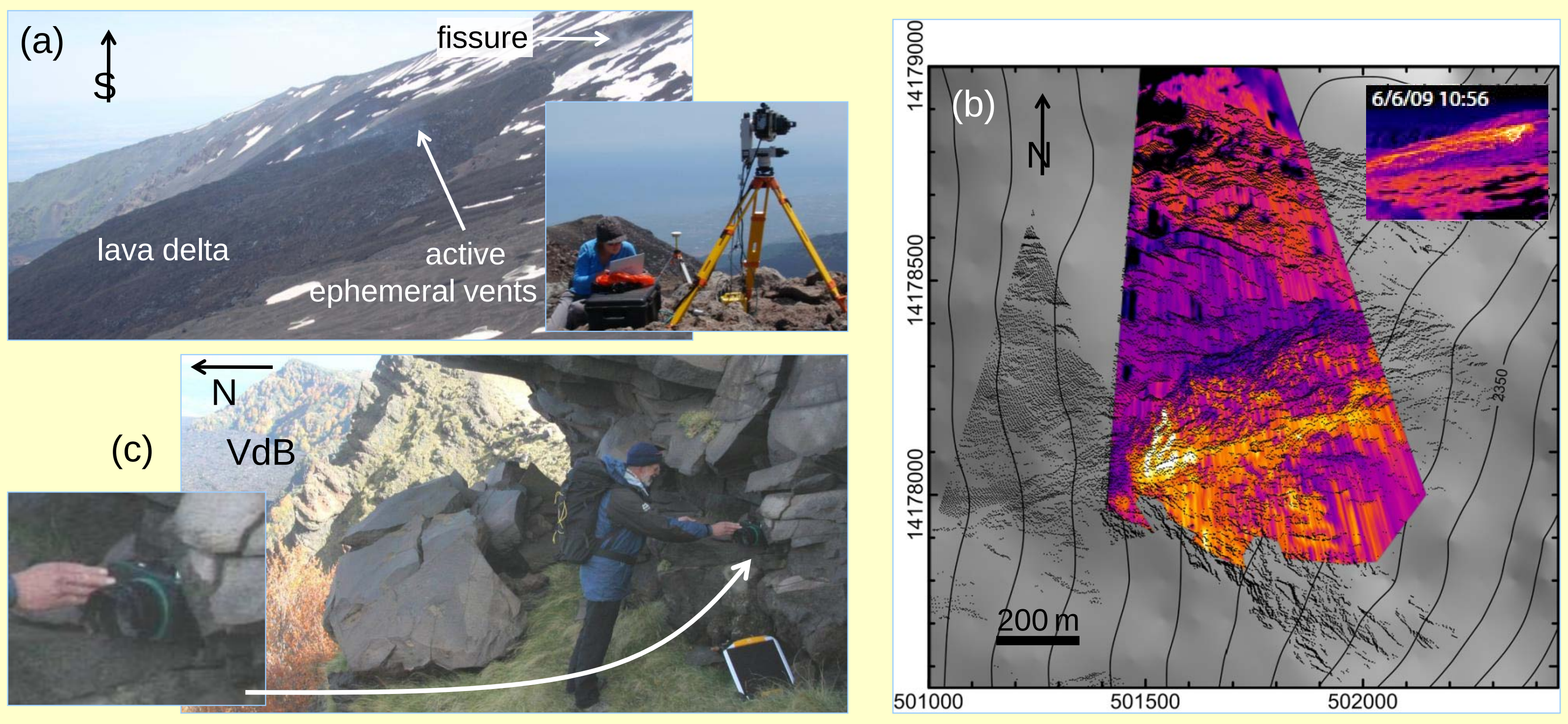


Fig. 1. Location map. **Heavy black line**: rim of the VdB. **Red line**: eruptive fissure. **Grey area**: maximum extent of the 2008-9 flows. **Red box**: area of active flows in June 2009, enlarged in Fig. 2. **Green stars**: camera positions. **Blue star**: laser scanning and camera position. Contours in m.

Fig. 2. (a) Flow field from P. Deneri. Inset: scanner in use at this location. **(b)** Data (black dots) collected with the scanner plotted on SRTM topography. Draping a thermal image taken from P. Deneri (inset) over the topography identifies currently active flows. **(c)** Checking cameras at Schiena dell-Àsino. Cameras were anchored in sheltered spots and powered by solar panels.



3. Flow field development

More than one ephemeral vent could be active at any time, each feeding more than one flow. Flows experienced breakouts, due to cooling induced stagnation, pulses in effusion rate (Fig. 3), or accidental breaches resulting from transient channel blockages[5]. Pulses were observed to reactivate ephemeral vents and flows, initiate breakouts from stalled fronts, and cause flow fronts to accelerate (Fig. 3).

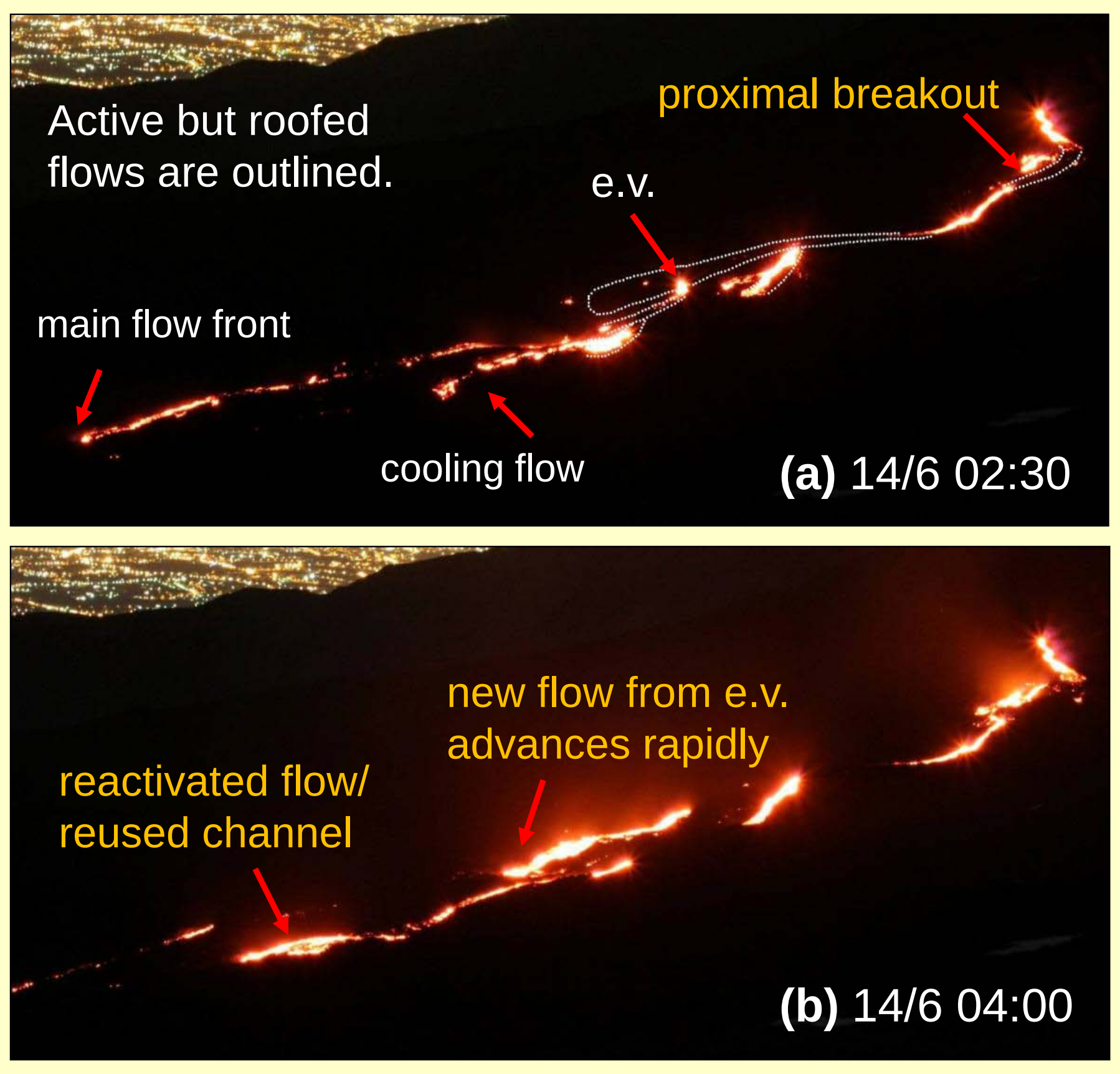


Fig. 3. (a) The main flow, (vent top right corner), is partly roofed. A stagnant lobe in the medial flow field contains an ephemeral vent (e.v.) The main front is incandescent. Proximal breakouts indicate the initiation of a pulse. **(b)** As the pulse advances downflow, it generates a new flow from the e.v., which advances rapidly. Renewed incandescence along the path of the cooling flow in (a), may indicate reactivation of the earlier flow, or reuse of the channel. In contrast, comparing (a) and (b), the main flow front has not advanced far in this interval.

4. Flow front tracking

The fronts of some larger flows (and associated breakouts) have been tracked through the image sequence. Using knowledge of the camera imaging geometry, the pixel tracks can be reprojected onto the topographic surface to determine flow advance in 3-D geographic coordinates (Fig. 4). Integration of the imagery and topography allows flow lengths, hence velocities, to be extracted (Fig. 5).

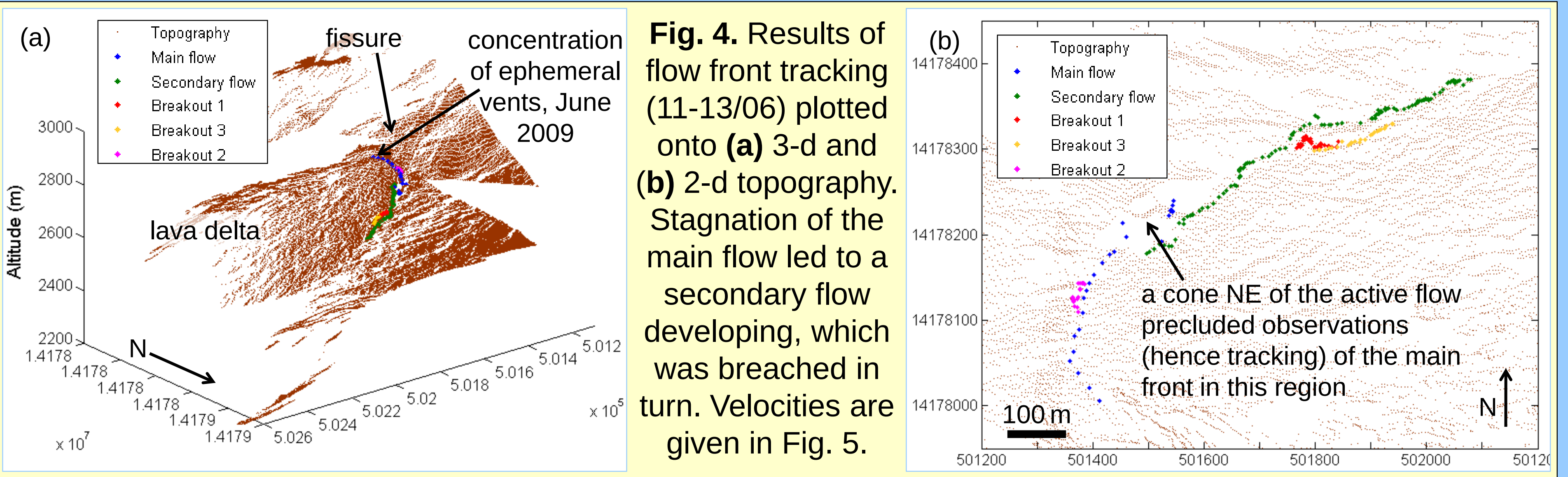


Fig. 4. Results of flow front tracking (11-13/06) plotted onto **(a)** 3-d and **(b)** 2-d topography. Stagnation of the main flow led to a secondary flow developing, which was breached in turn. Velocities are given in Fig. 5.

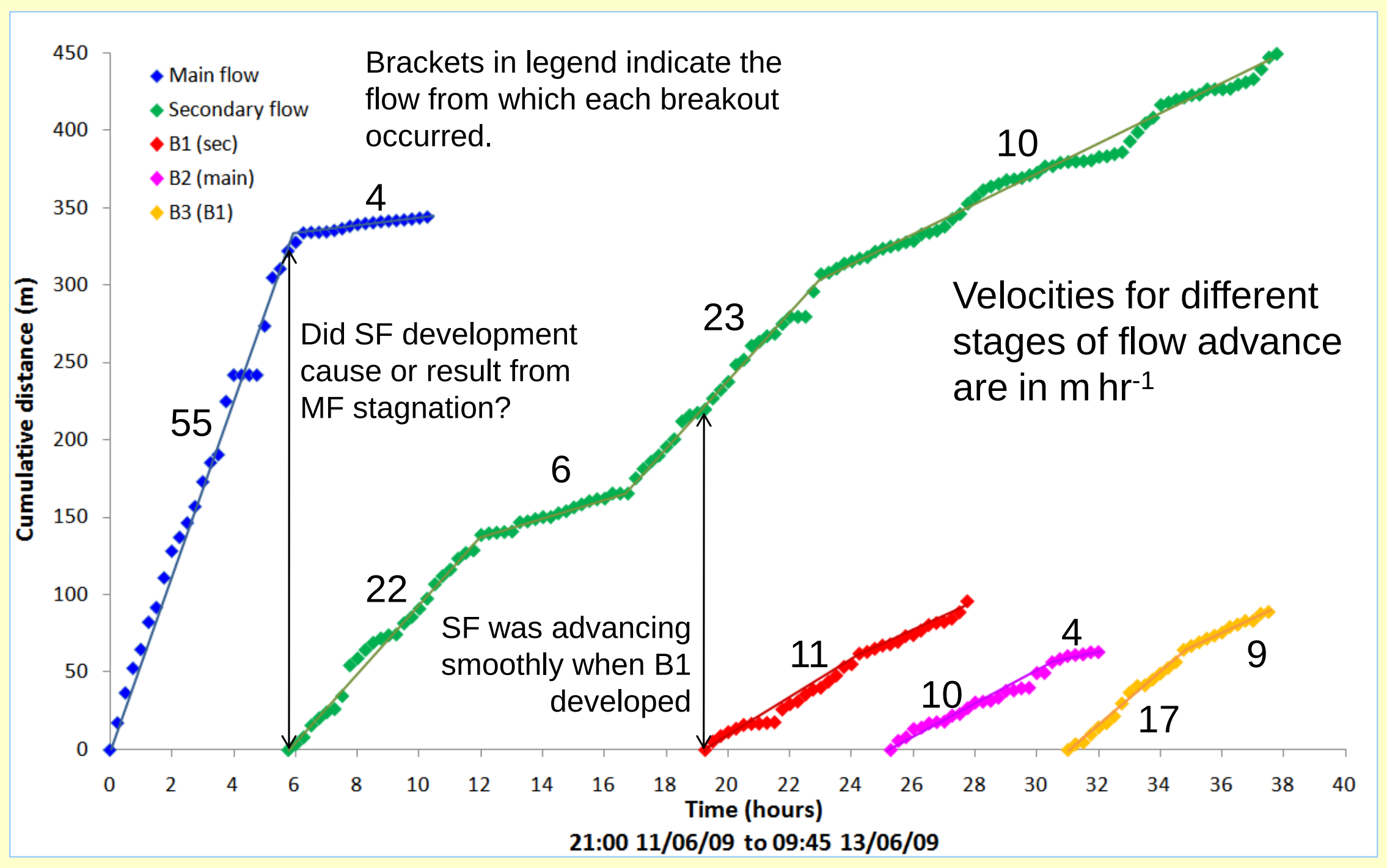
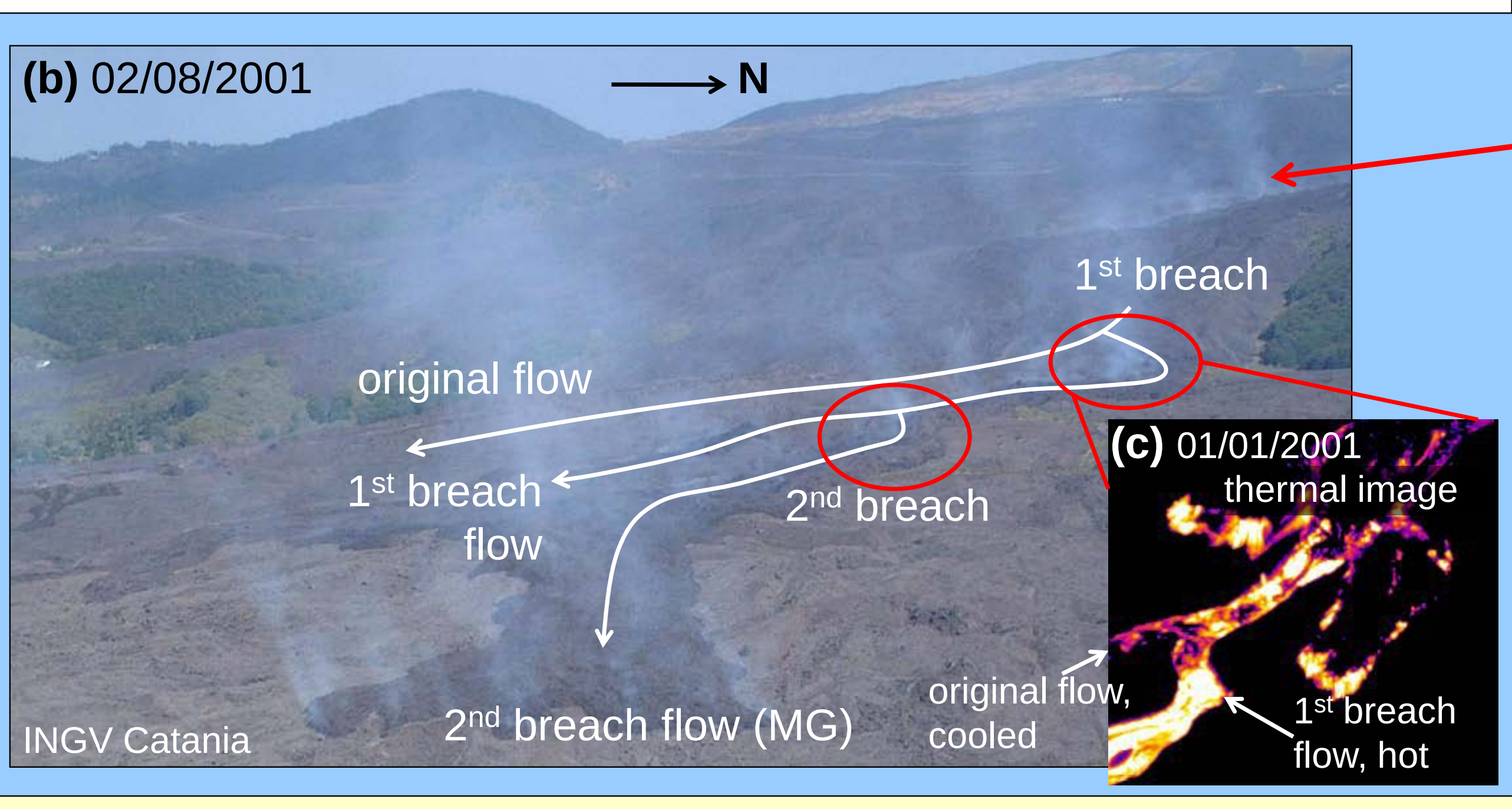


Fig. 5. Cumulative distance advanced by the flows in Fig. 4. The sudden decrease in velocity of the main flow (MF) coincides with the initiation of the secondary flow (SF). Stagnation of MF may have occurred due to a break in slope, thus causing SF to develop. Alternatively, initiation of SF may have cut supply to the MF front. A pulse, which produced proximal breakouts, may have contributed to the development of the short-lived B2. B1 may have developed for the same reason, but began during daylight, when pulse identification is more difficult. No disruption of the advance of SF was noted at this time.

5. Analogues in larger (km-scale) flows

Repeated levée breaching events were observed during the 2001 and 2004 Etna eruptions[7-9]. In 2001, breaching led to two major new flows, one of which advanced at 40 to the original flow direction (Fig. 6). In 2004, breach flows advanced slightly further than the original flow front. Such processes may potentially increase or renew the hazard posed by a flow.



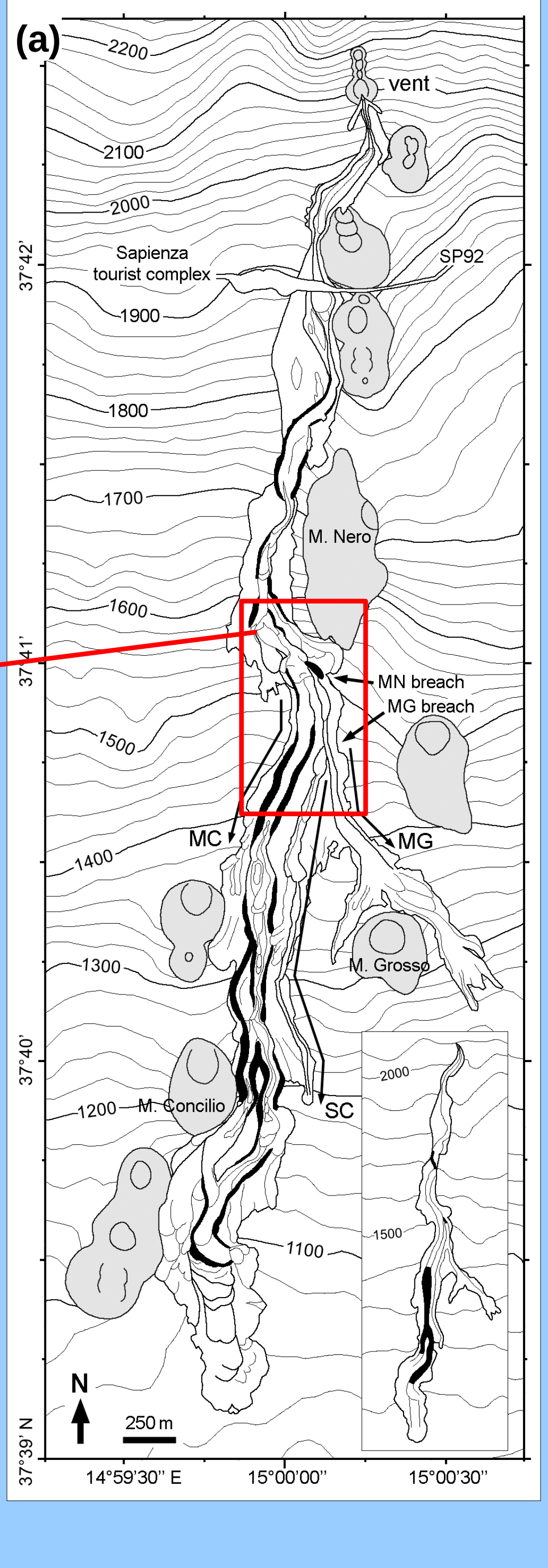


Fig. 6. (a) The 2001 flow field. 8 days of activity emplaced a 6.4 km long flow[9], then two breaches in the medial flow field (box) produced substantial new flows. **(b)** The second of these (MG) advanced in a different direction. Published data[9] suggest an effusion rate pulse occurred at a similar time to the breach, which may have contributed to its development, though stagnation of earlier flows **(c)** also played a significant role.

6. Conclusions and Future Work

The combination of time-lapse imagery and topographic data allows short-term changes in lava flow field configurations to be tracked, and flow velocities to be estimated. Short-term changes in effusion rate can be observed in the form of pulses that result in new flow units, which may or may not be sustained, but care must be taken in distinguishing pulses that result from true changes in supply from those arising due to transient blockages. The calculation of flow advance velocities is the first step towards extracting quantitative estimates of rheological properties from the images[10]. Processes similar to those observed here have been documented in larger (km-scale) flows during several eruptions on Etna[7,8] (Fig. 6) though with poorer time resolution. Smaller-scale flows, which can serve as analogues for larger flows, are easier to monitor using remote imaging, and can be used to validate existing lava flow models.

References: 1. Vicari, A., Herault, A., Del Negro, C., Coltelli, M., Marsella, M., Proietti, C. (2007) *Env. Model. Softw.* 22, 1465-71. **2. Hidaka, M.**, Goto, A., Umino, S., Fujita, E. (2005) *Geochem., Geophys., Geosyst.* 6(7) Q07008. **3. Calvari, S.**, Pinkerton, H. (1998) *J. Geophys. Res.* 103, 27291-301. **4. Polacci, M.**, Papale, P. (1999) *Phys. Chem. Earth (A)* 11-12, 949-52. **5. Pinkerton, H.**, Wilson, L. (1994) *Bull. Volcanol.* 56, 65-80. **6. James, M.R.**, Pinkerton, H., Applegarth, L.J. (2009) *Geophys. Res. Lett.* 36, L22305. **7. James, M.R.**, Pinkerton, H., Robson, S. (2007) *Geochem., Geophys., Geosyst.* 8(3) Q03006. **8. Applegarth, L.J.**, Pinkerton, H., James, M.R., Calvari, S. (2010) *Bull. Volcanol.* 72, 641-656. **9. Behncke, B.**, and Neri, M., (2003) *Bull. Volcanol.* 65, 461-76. **10. Ellis, B.**, Wilson, L., Pinkerton, H. (2004) *Lunar. Planet. Sci. Abst.* XXXV 1550.