Contemporaneous Ring Fault Activity and Surface Deformation at Subsiding Calderas studied using Analogue Experiments

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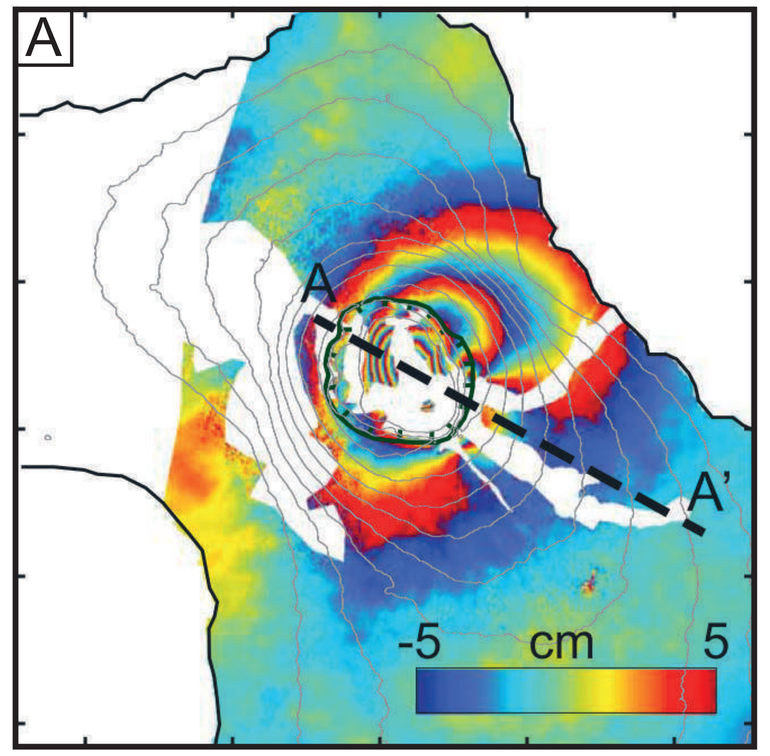
I. Complex Deformation at subsiding Calderas

Motivation:

Overlapping deformation patterns observed by InSAR consisting of:

a. local caldera floor subsidence and

b. broader edifice deflation signal, remain somewhat unexplained.



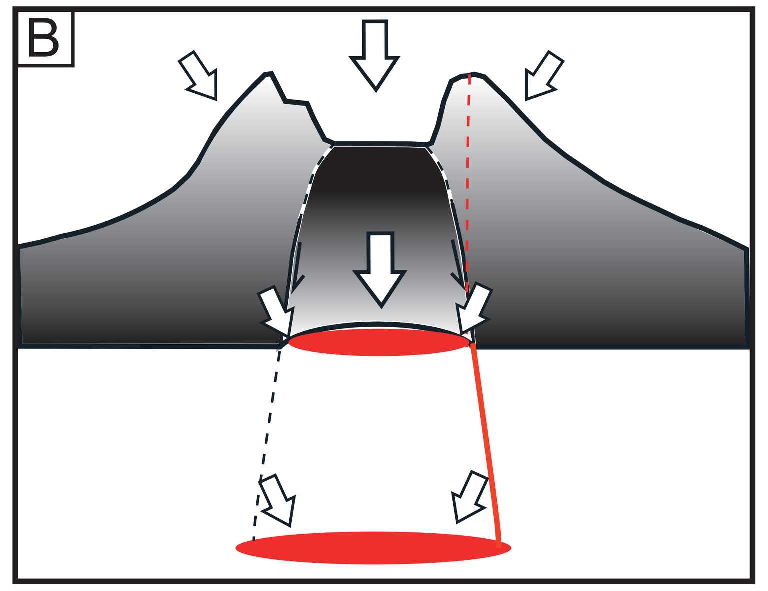


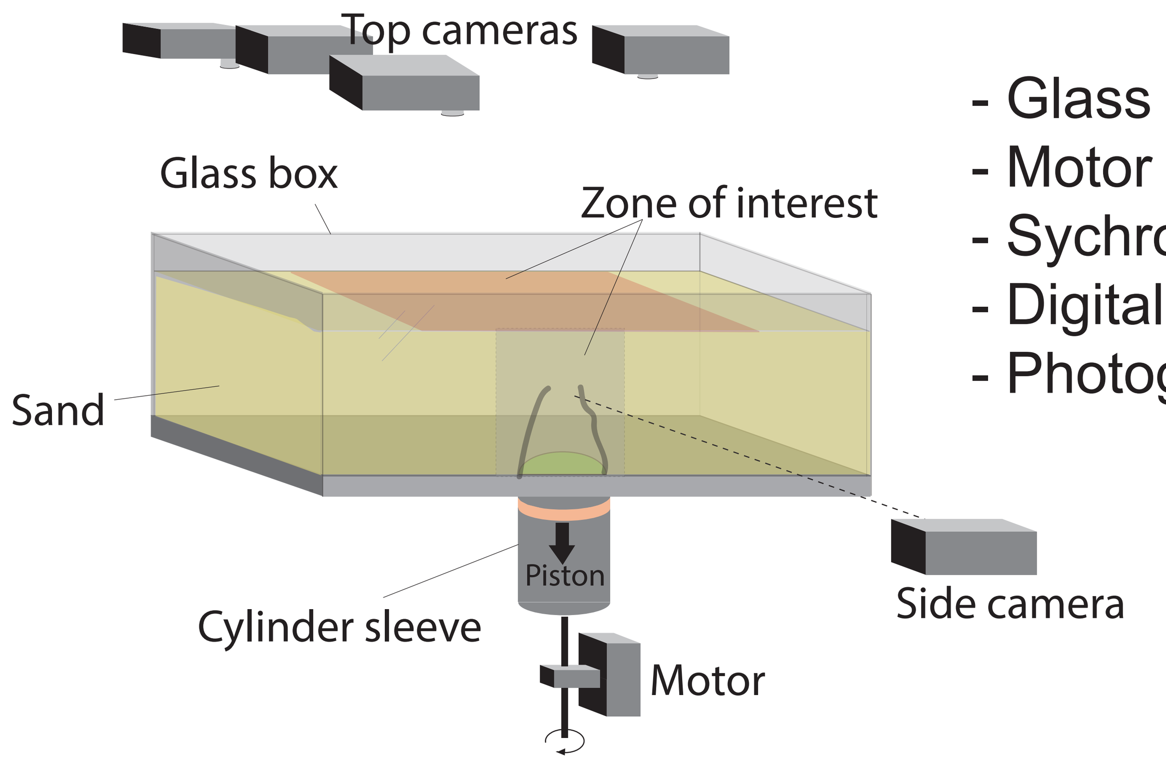
Figure 1. (A) InSAR data of Wolf volcano in western Galápagos showing complex subsidence patterns following the 2015 eruption. (B) Schematic figure of the model used to explain the overlapping deformation, consisting of two magma chambers at different depths. (Xu et al., 2016)

Aim:

- To test if a **single source** and **ring fault** activity can explain the complex pattern
- To monitor changes of **buried ring faults** and **topography** in **2D and 3D at the same time**

II. Sandbox analogue model setup

- Capture from initial to mature stages of a caldera collapse
- Simultaneous observation at depth and at the surface



- Glass box size: 20 x 20 x 20 cm^3
- Motor speed 0.02 ~ 0.04 mm/s
- Sychronized 5 cameras @ 1 fps
- Digital image correlation: PIVLab
- Photogrammetry: Micmac

Figure 2. The sand box analogue model setup design. An engine motor connects to a semi-circle opening beneath the glass box simulates the retreating or depressurization of a sill (magma source). Side view camera observes the rupture processes and map view cameras observe the surface deformation. (After Ruch et al. 2012)

III. Surface Deformation and Ring Fault Development

Model A. Rupture at depth & horizontal deformation (2 cameras = 1 side + 1 top)

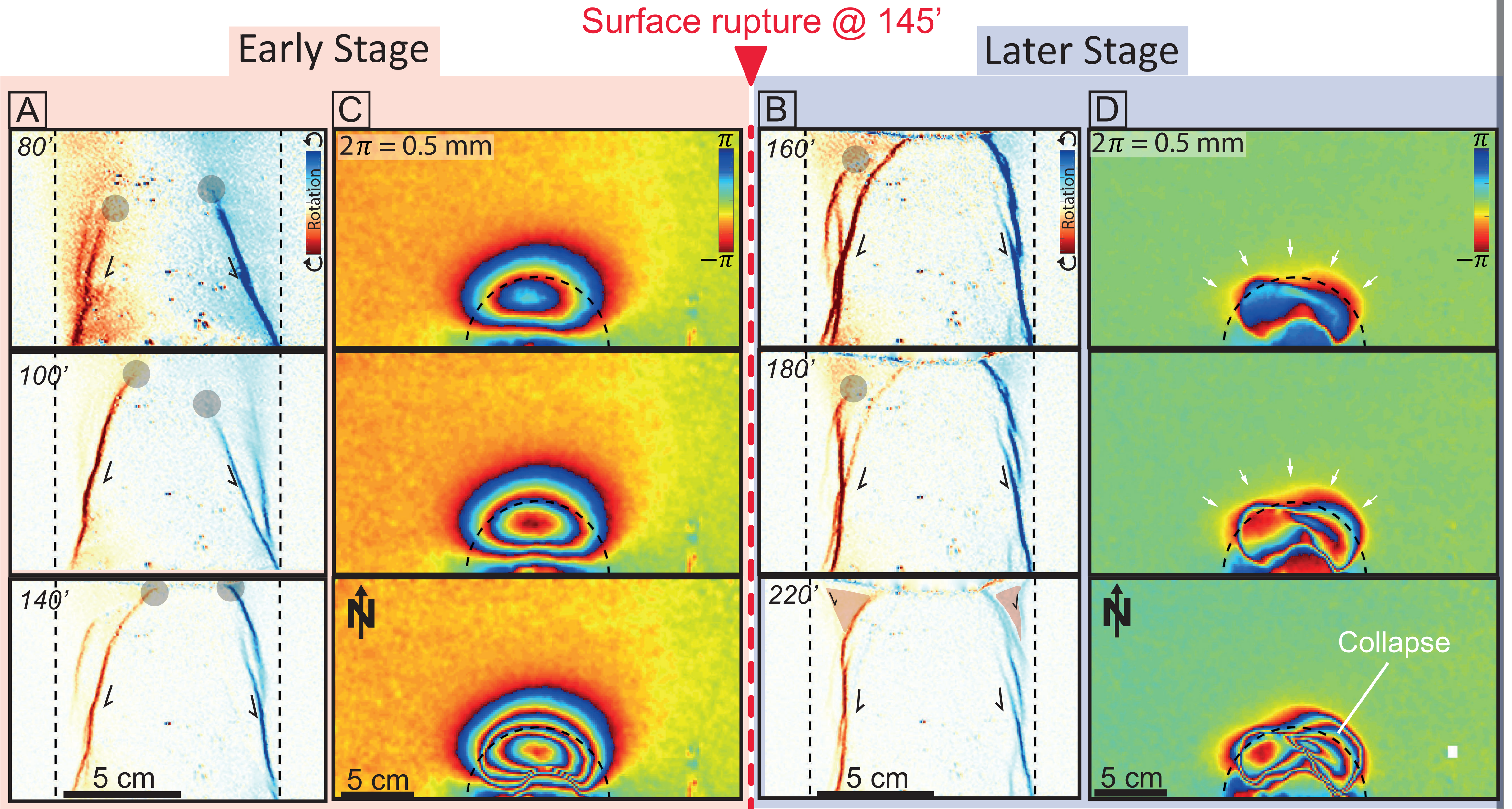
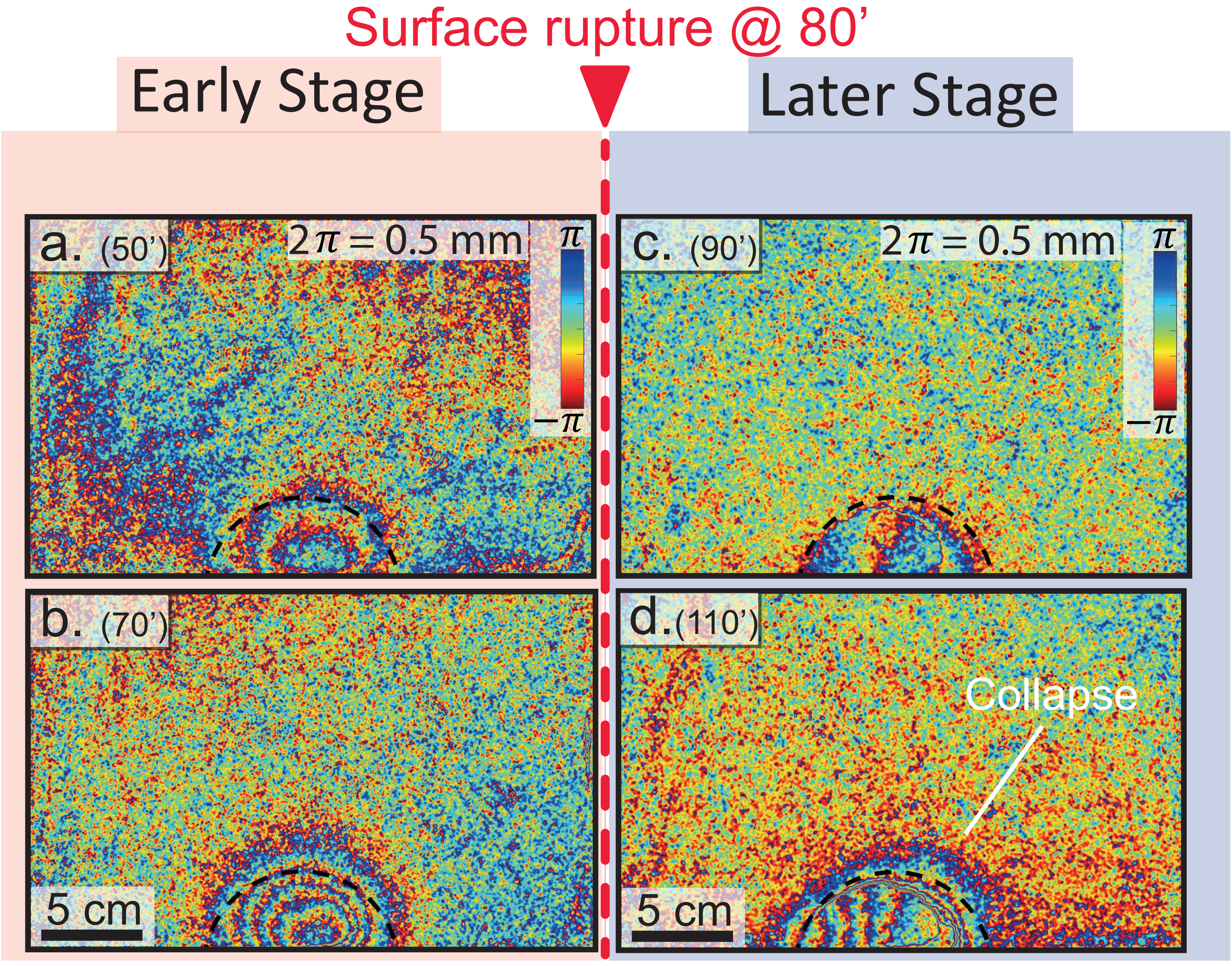


Figure 3. Analysis after digital image correlation. (A) Cross-section view of the early stage ring fault development through time captured by the side-view camera. Rotation field of pixels shows the location of the ring fault (dashed lines indicate the source width). (B) Ring fault development after the rupture reaches the surface. At time 220 sec. we can see both the reverse and the normal faulting. (C) Early stage N-S horizontal surface displacements (wrapped at 0.5 mm per fringe) shows that the deformation extends well beyond the source edge (dashed lines). (D) Later stage horizontal displacements appear more localized after the rupture has reached the surface. Here the displacement from previous stage (before 140 second) has been removed to emphasize only the later stage features.

Model B. Vertical displacements from DEM time series (5 cameras = 1 side + 4 tops)



- Wide and smooth deflation extends beyond the caldera edge early on (a, b)
- Subsidence concentrates in the caldera after ring fault ruptures the surface (c, d)

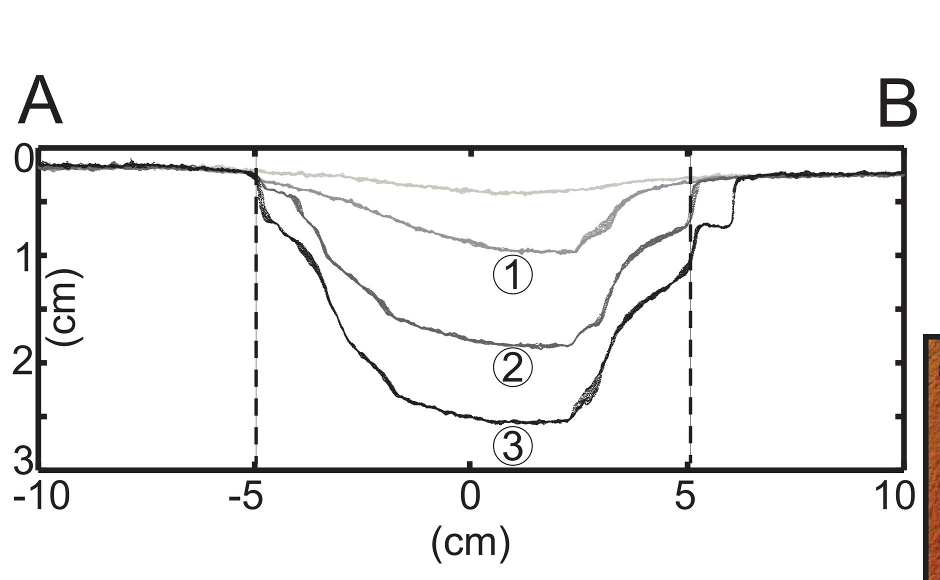
Limitation:

- Features are more sensitive in horizontal field than vertical field

Figure 4. Vertical displacements (wrapped at 0.5 mm per fringe) display similar deformation patterns as the horizontal displacements above. In later stage, the displacement from previous stage (before 80 second) has been removed to emphasize only the later stage features.

IV. 3D topography model

- Retrieving DEMs from different collapse stages
- Time series of topographic profiles



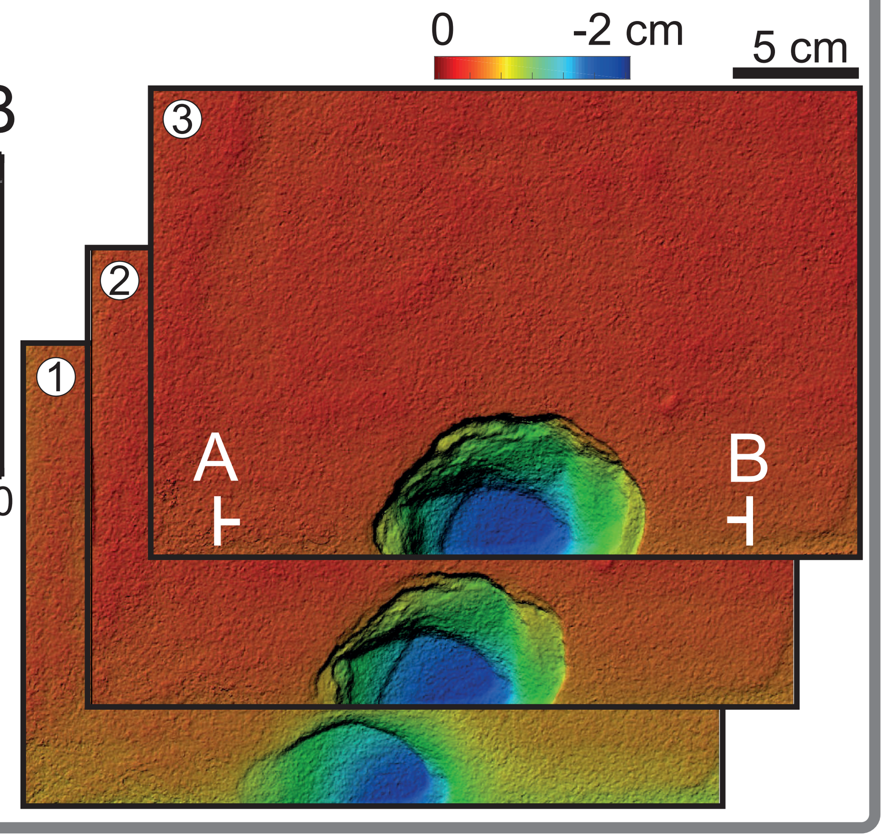


Figure 5. (Left) The topographic profiles through time (dashed lines indicate the source width). (Right) DEM at corresponding time of the topographic profiles.

V. Conclusions and Future work

1. **Track** deformation **2D at depth** and **3D on the surface** simultaneously
2. **Analogue models** of caldera collapse show **ring fault** development and propagation
3. **Ring faulting** tends to **concentrate deformation** within the caldera

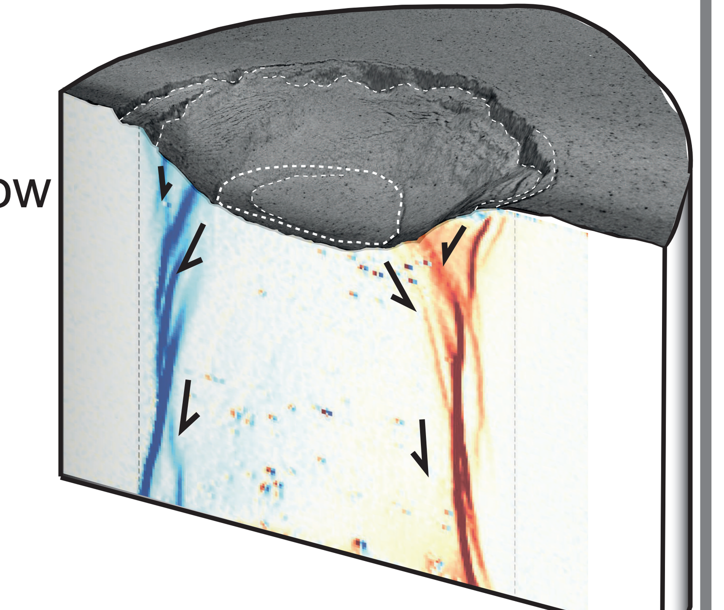


Figure 6. Schematic figure showing the ring fault activity and the surface topography change.

Future work:

1. Integration of **topography**
2. Comparison with **numerical modeling** (sill + ring fault)

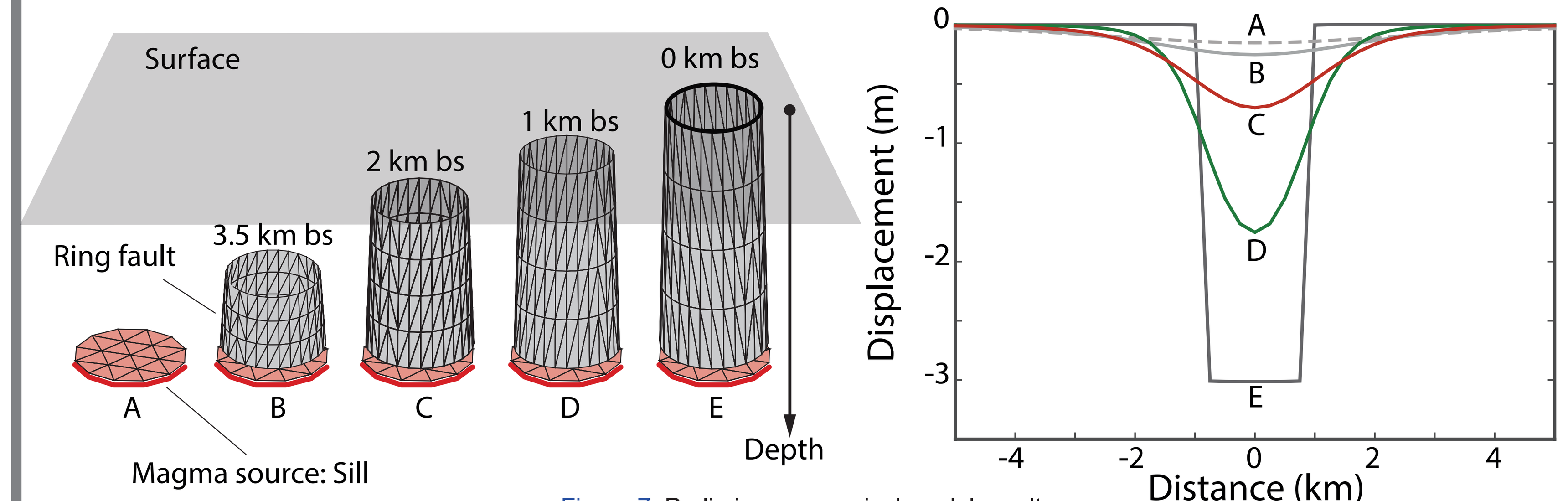


Figure 7. Preliminary numerical model results.