COMET Event Response

Area of Interest: Fentale Volcano, Ethiopia
Date Covered: 8-22th October 2024
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Data Used:

- InSAR images collected by the European Sentinel-1 satellite and processed using the COMET LICSAR system;
- InSAR images acquired by the CosmoSkyMed satellite, provides through the CEOS GVEWERS programme and processed at the University of Bristol using ISCE2.
- USGS Earthquake Catalogue.

Recent Activity:

The latest Sentinel-1 InSAR image (6th-18th Oct) shows that the rate of deformation has decreased to ~6cm from ~17cm in the previous image (24th Sept-6th Oct), with a slight shift to the north (~3 km). The pattern of deformation is consistent with further opening of the dyke and slip along two inward dipping faults which ruptured the surface.

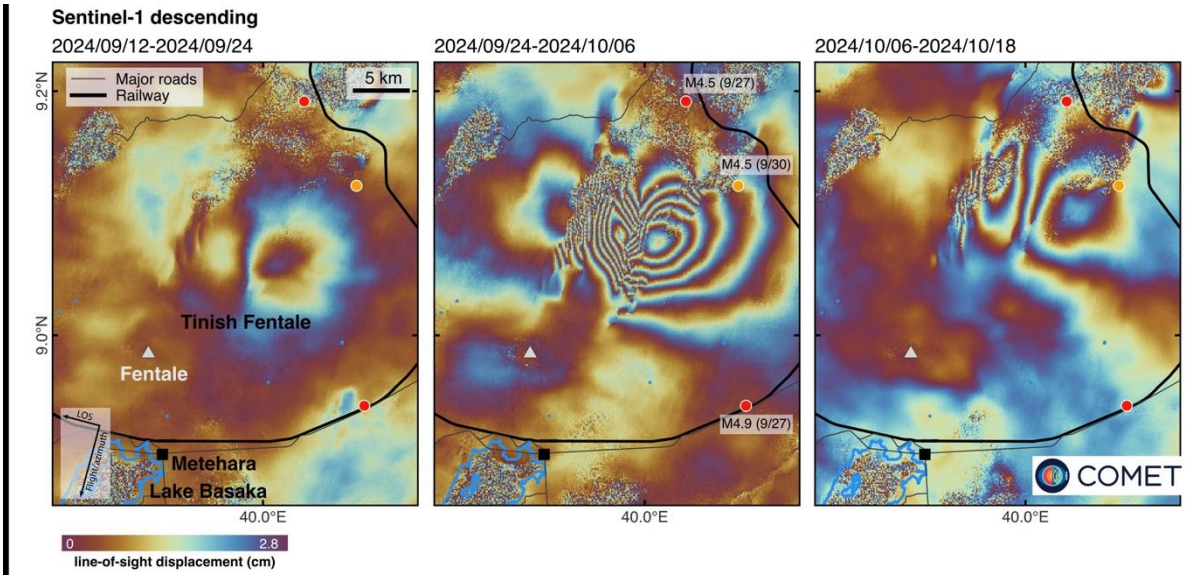

Fig 1. Sentinel-1 time series from Sept-Oct 2024. The most recent image shows a decrease and northward shift in the deformation.

CosmoSkyMed images provide additional constraints on the timing of deformation and indicate that little deformation took place between 3-12th October. The USGS reported 3 additional M4+ earthquakes in this time period, on 6th, 13th and 16th October.

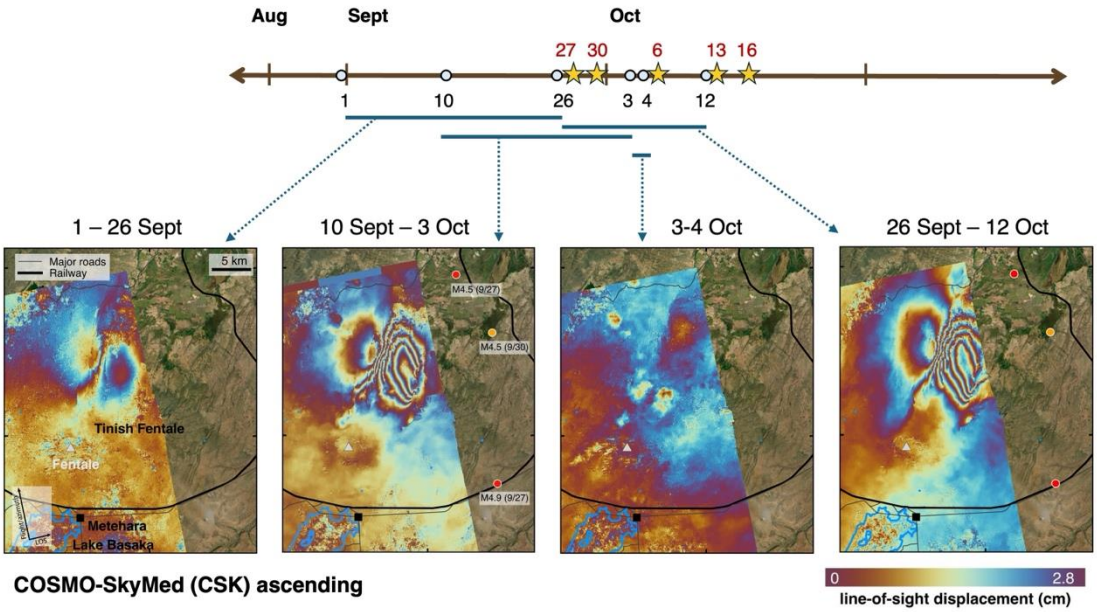

Fig. 2. CosmoSkyMed images of Fentale and Tinish Fentale from 1 Sept-12th Oct 2024. Note, the 10 Sept -3 Oct image is almost identical to the 26 Sept-12 Oct image, suggestion little deformation took place between 3-12 Oct.

Modelling

The Sentinel-1 data can be modelled using a dyke intrusion beneath two inward dipping normal faults. We fix the location of the faults based on mapping the images. Using a fault dip of 60°, places the top of the dyke at 4 km. We fix the bottom of the dyke to 8 km based on previous estimates of the brittle-ductile transition (Keir et al, 2006), but note that this trades off against dyke opening. The sequence shows an overall northward progression, with the dyke centre moving NNE by a total of 5 km. Average fault slip is small (10-20 cm), but surface displacements on individual fault scarps may be much larger.

	12-24 Sept	**24 Sep-6 Oct**	**6-18 Oct**
Dyke Length	6.1 km	7.0 km	7.0 km
Dyke Centre	9.06N 39.97E	9.08N 39.98E	9.11N 39.98E
Relative Location	-2.0 km	0 m	+3.3 km
Dyke Opening	0.4 m	1.1 m	0.7 m
Dyke Volume	9.7 million m^3	30 million m^3	28 million m^3
Average Fault Slip	~ 1cm.	10-20 cm	~1 cm

Long-term perspective.

The area has experienced previous seismic swarms, including a dyke intrusion in 2015, that caused about 5 cm of deformation and an earthquake swarm with magnitudes up to 4.3, but did not result in an eruption (Temtime et al, 2020; Ayele et al, 2024). Processing of the entire Sentinel-1 archive shows: the 2015 dyke intrusion (Fig 3a), slow uplift in 2017-2023 located between Fentale and Tinish Fentale (Fig 3b) and the 2024 dyke, which is located north along strike of the 2015 dyke intrusion (Fig 3d).

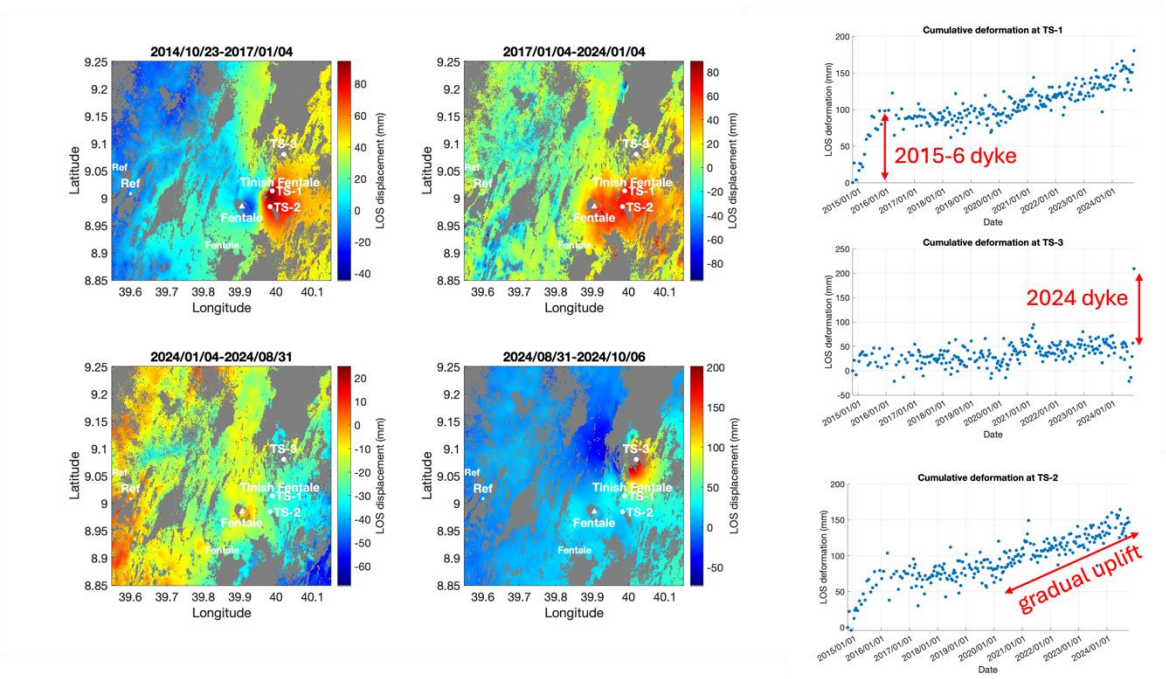

Fig 3. Sentinel-1 Time-series from 2014-2024.

Forward Look:

For now, activity is decreasing. However, there are many examples where eruptions have occurred several months after a dyke intrusion, including the 2021 Fagradalsfjall eruption (Sigmundsson et al, 2022), the 2017 eruption of Agung, Indonesia (Albino et al, 2019) and the 2007 eruption of Oldoinyo Lengai, Tanzania (Biggs et al, 2009). At Agung and Oldoinyo Lengai, the eruption occurred from a volcanic edifice > 10 km from the dyke intrusion. We envisage 3 possible scenarios:

- Scenario 1: Activity continues to decrease and this intrusion episode ends.
- Scenario 2: An eruption close to the dyke location.
- Scenario 3: An eruption from Fentale volcano.

Ongoing monitoring is therefore critical. Ground-based information such as GNSS deformation and earthquake catalogues (regional or local) can provide higher temporal resolution than satellite data. Of particular importance is understanding the deformation in the area of past uplift (Fig 3b): if uplift continues there we might expect more activity and eventually this might lead to eruption in places where the tectonic extensional stresses have been taken up by the dyke intrusions.

References

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Ayele, A., Luckett, R., Baptie, B., & Whaler, K. (2024). The 2015 earthquake swarm in the Fentale volcanic complex (FVC): A geohazard risk for Ethiopia's commercial route to the Djibouti port. *Journal of African Earth Sciences*, *213*, 105236.

Biggs, J., Amelung, F., Gourmelen, N., Dixon, T. H., & Kim, S. W. (2009). InSAR observations of 2007 Tanzania rifting episode reveal mixed fault and dyke extension in an immature continental rift. *Geophysical Journal International*, *179*(1), 549-558.

Keir, D., Ebinger, C. J., Stuart, G. W., Daly, E., & Ayele, A. (2006). Strain accommodation by magmatism and faulting as rifting proceeds to breakup: Seismicity of the northern Ethiopian rift. *Journal of Geophysical Research: Solid Earth*, *111*(B5).

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