Role of discontinuities in the spatial pattern of sea cliff erosion: case of a seaward dipping flysch cliff (Socoa, Basque Country, France)

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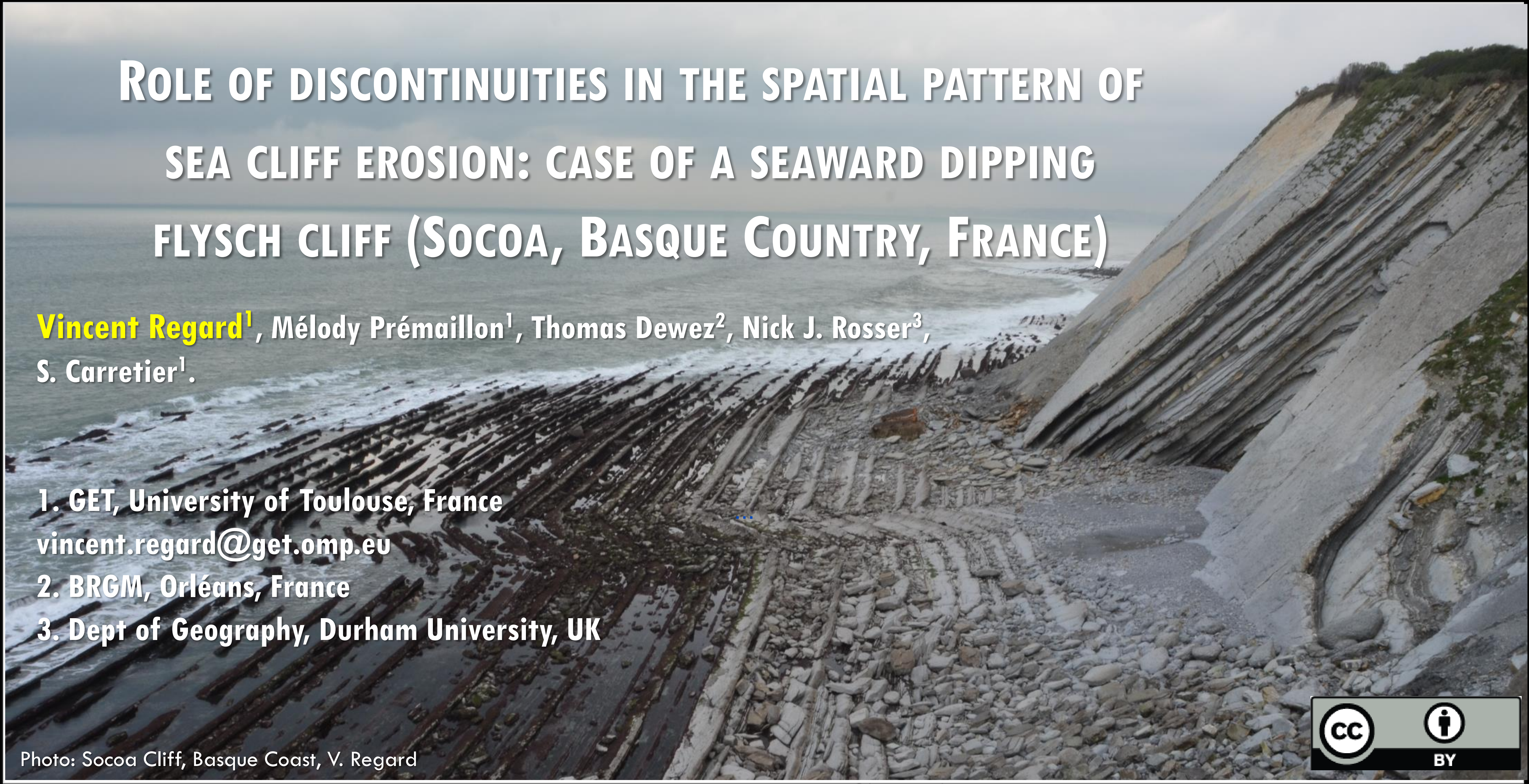


Photo: Socoa Cliff, Basque Coast, V. Regard

Rationale

The **way sea cliffs** erode and collapse has been mainly at sites with horizontal bedding conditions (e.g., Rosser et al. 2013). Here we study a cliff constituted by a 45°-dipping sedimentary layers (Socoa, SW France).

The Socoa cliff has been monitored for 6 years by photographic campaigns carried out on foot from the intertidal platform.

The **3D point clouds** of the cliff are calculated using SfM and change is calculated by differencing the point clouds.

The **analysis of the difference** point clouds allows to investigate the global evolution of the cliff, as well as the modes of evolution. **Cavities are generally the most active areas**, eroding by block detachment at the edges.

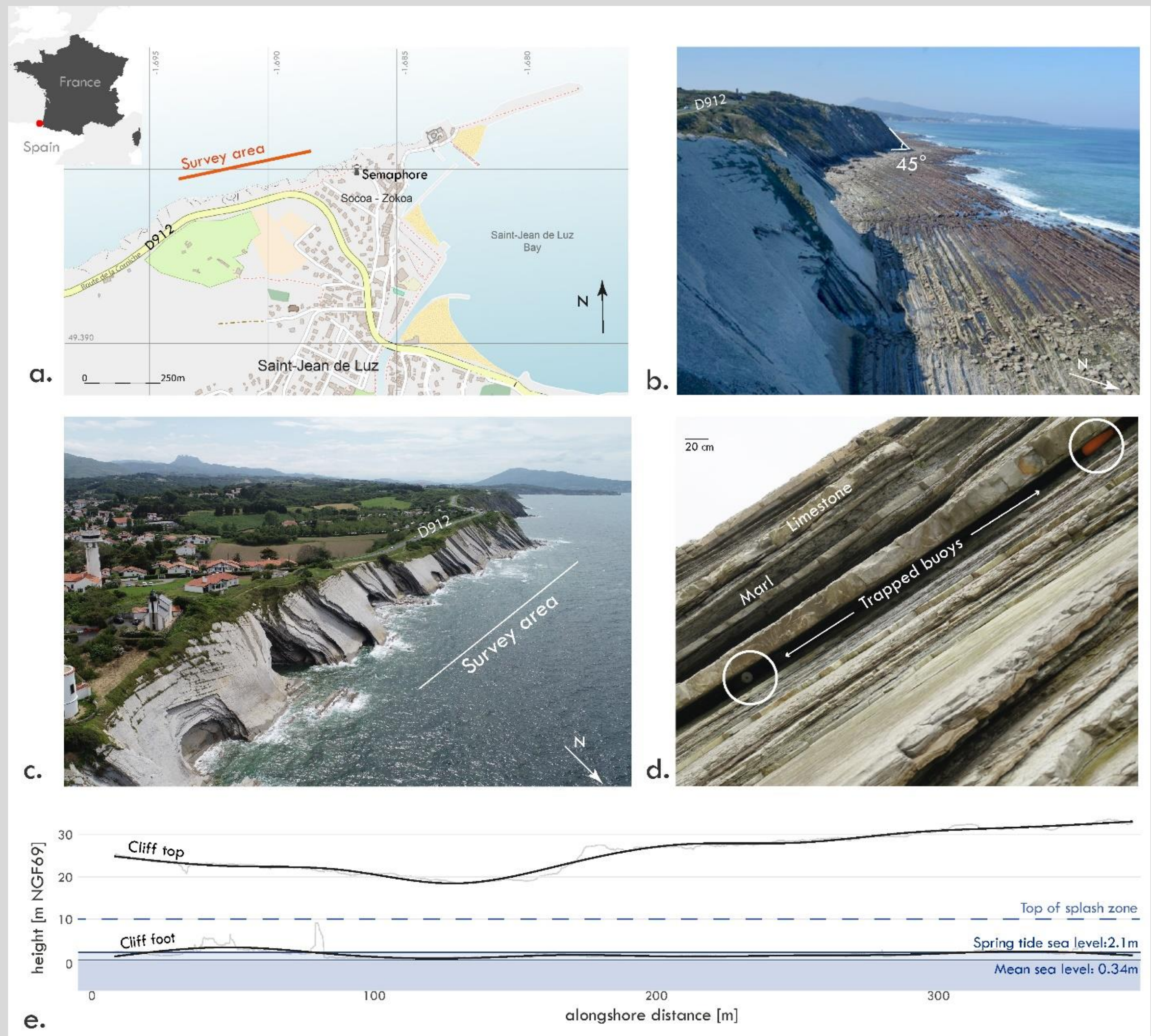
1-Location ⇧ 2-Material ⇧ 3-Methods ⇧ 4-Global signal (1) ⇨ 5-Global signal (2) ⇩ 6-Local signal ⇩

1-Location

- **Monoclinal Flysch**: alternating beds of contrasting mechanical resistance (average thickness ~50 cm-1m)
- **Bedding** parallel to the shore (direction N 70°E)
- 45° dip towards the sea
- 20-30 m high cliff

- **Swell** from the W-NW (25° oblique to the shore)
- Mean significant **wave height**: 1.5 m; peak period: 9.6 s (Abadie et al., 2005)
- Mesotidal: spring tidal range ~4m

- Temperate **Oceanic Climate** (~1500 mm/a rainfall, average monthly temperature between 11 and 19°C)

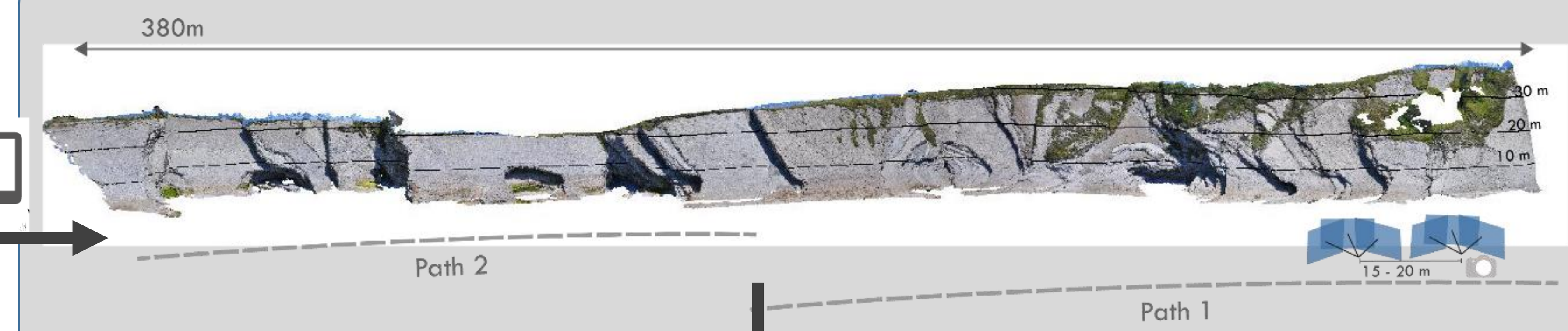


2-Material:

Photos of the cliff from the platform

Campaign
2011/06/15
2012/05/06
2014/06/17
2015/07/30
2016/04/06
2017/02/13

3-Photogrammetry



Differences from single epoch 3D clouds

Single clouds

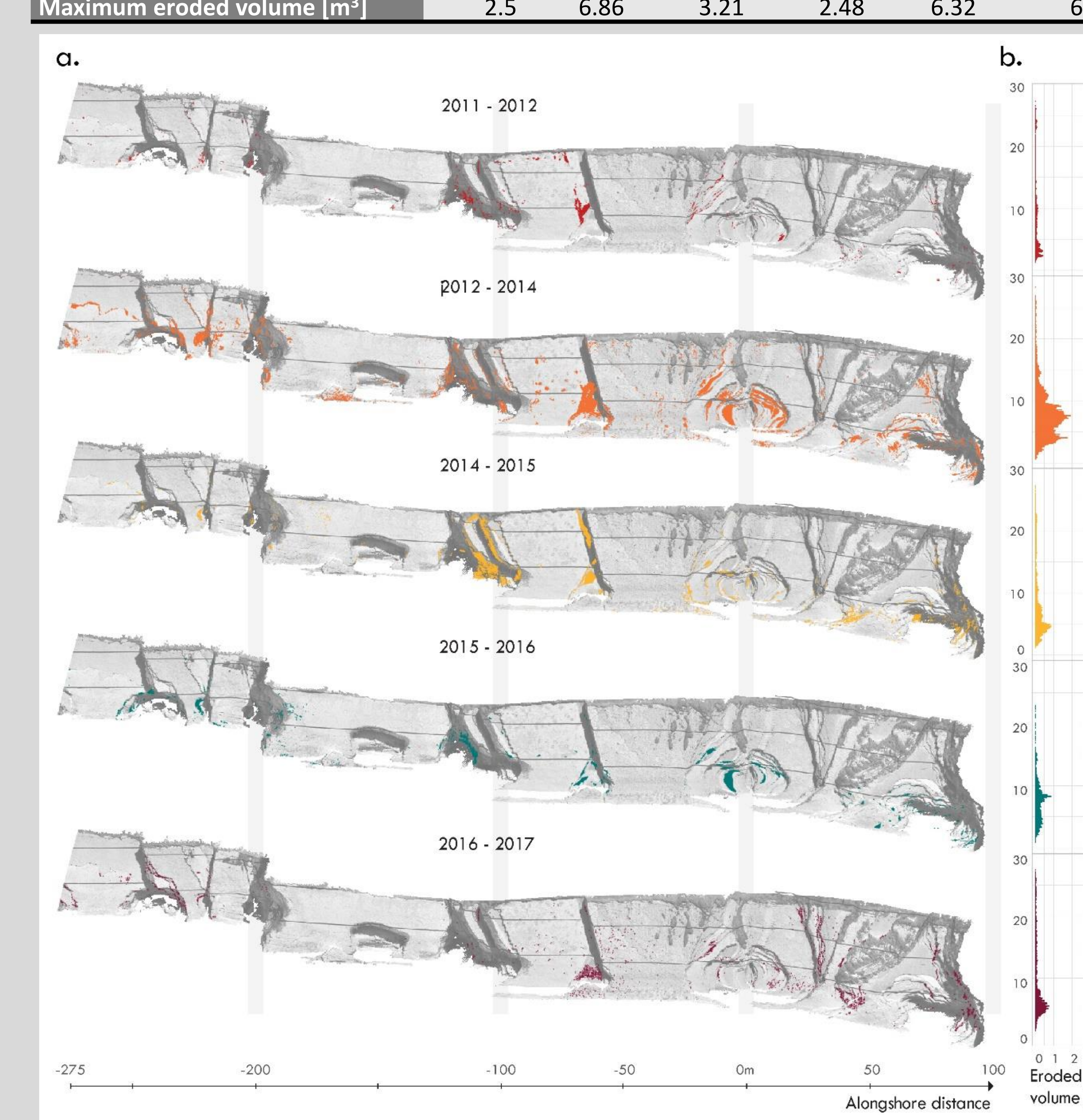
- **Cloud calculation**: Sfm (Photoscan)
- **Cleaning** (manual)
- **Coregistration** with other single clouds

Difference clouds

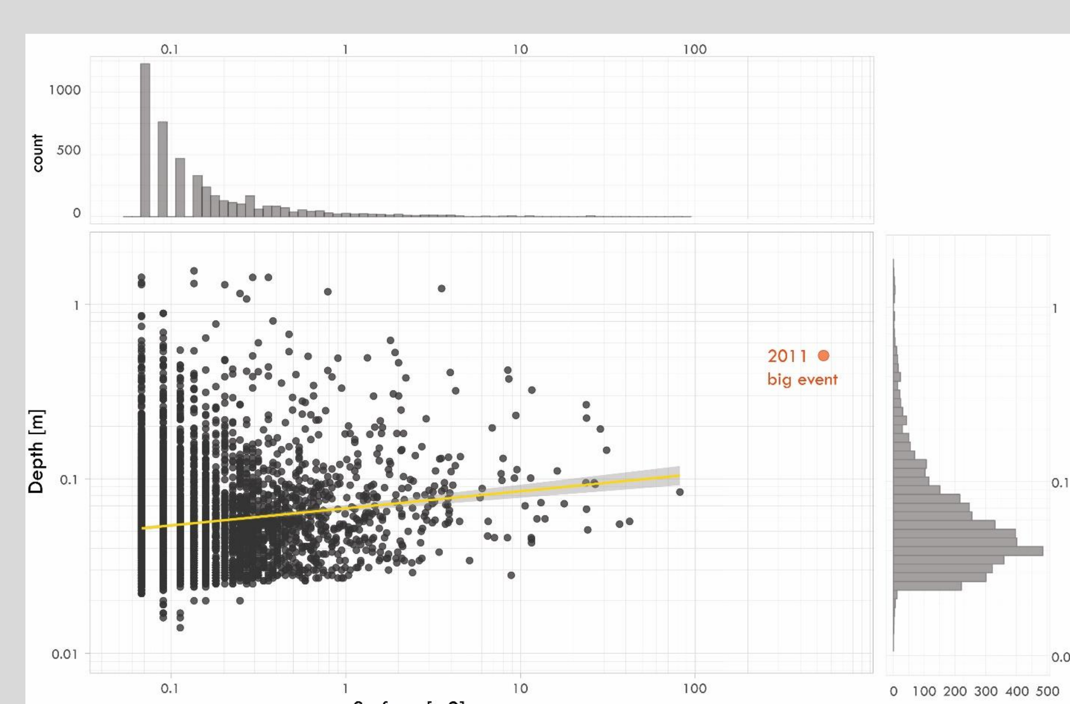
- **Difference clouds** calculated with M3C2 (Lague et al. 2013)
- Noise removal and registration misfit correction (M3C2)
- Fake erosion scars selected and removed using a random forest analysis (trained on a manually selected data point set, cf figure)

4-Differences at site scale

<	2011-2012	2012-2014	2014-2015	2015-2016	2016-2017	Sum of differences (2011-2017)
Monitored time [days]	326	773	408	251	321	2070
Detection threshold	0.064	0.023	0.034	0.045	0.029	-
Equivalent erosion rate of cliff head [mm/yr]	1.1	3	1.9	2.5	2	2.3
Total eroded volume [m^3]	13	83.24	27.9	22.8	23	170
Maximum eroded volume [m^3]	2.5	6.86	3.21	2.48	6.32	6.86



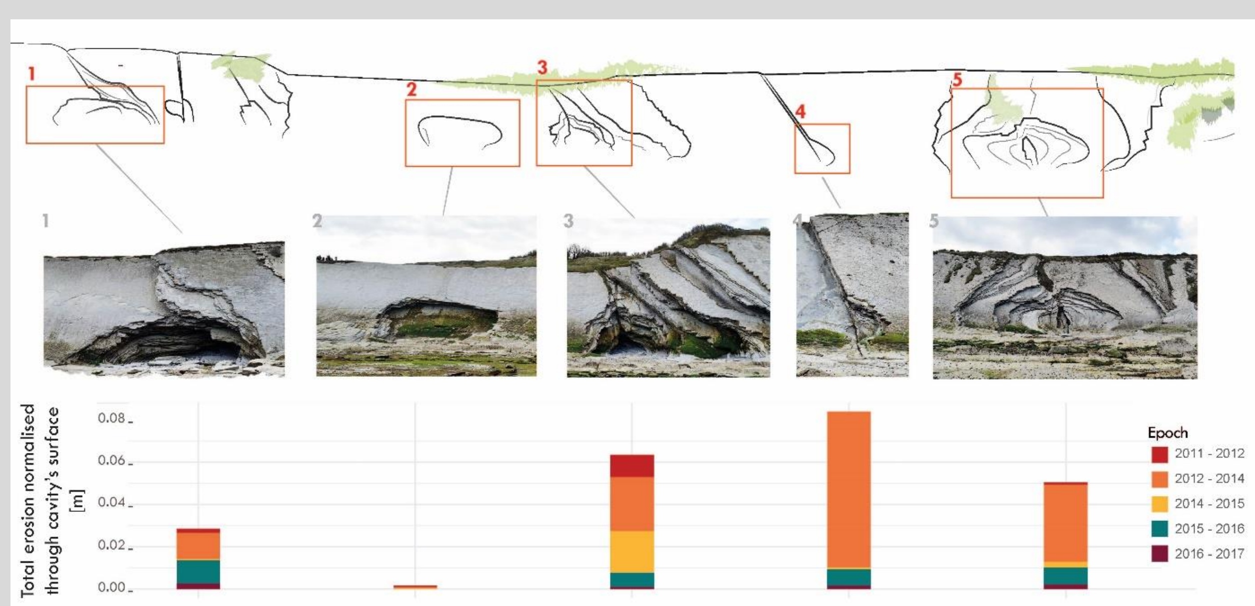
5-Global scar inventory



Line figures the linear regression

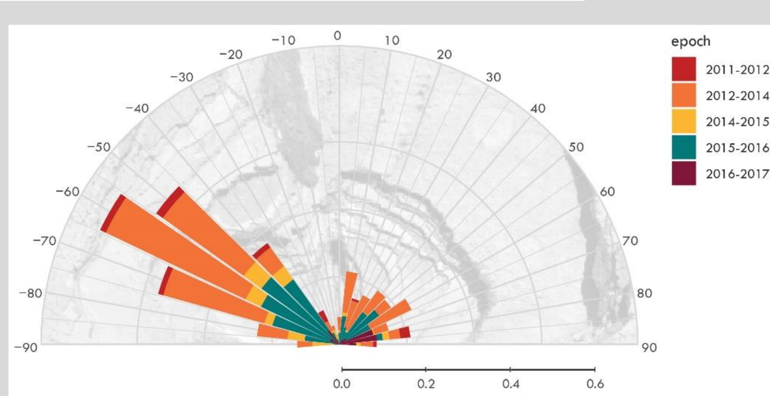
6-Block detachment from the cliff

Lessons from local evolution at edges



Analysis of cavities

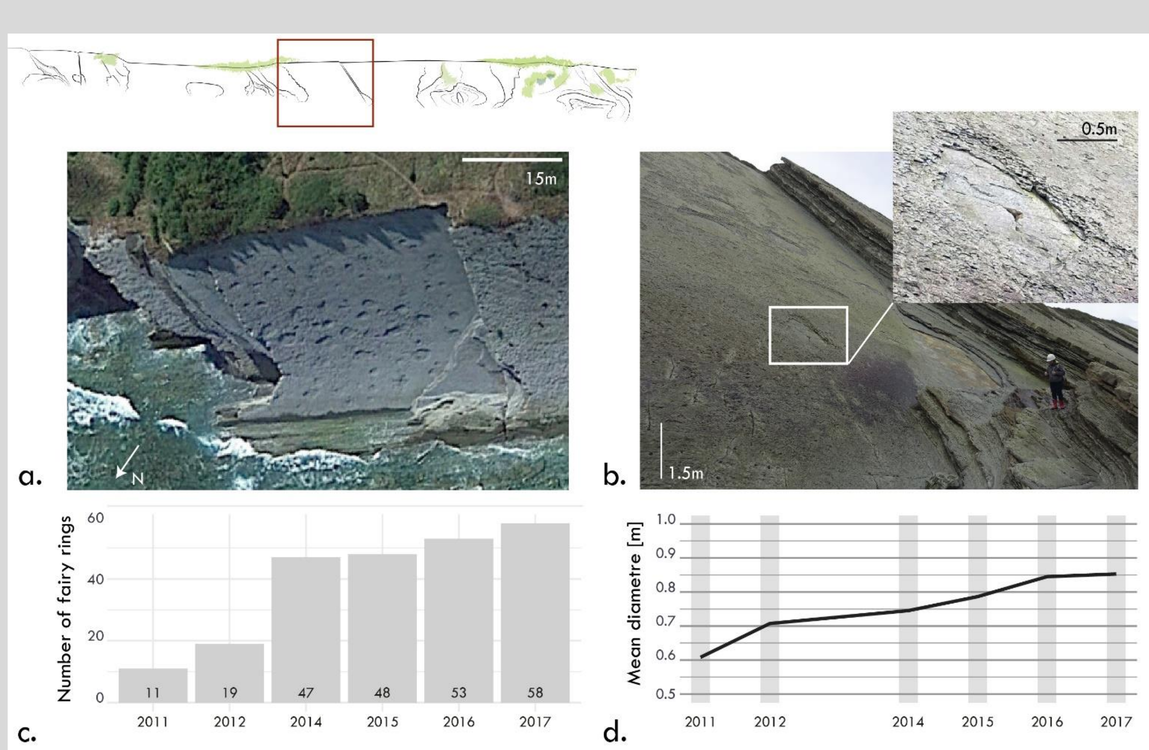
- Either located where fault outcrops or not
- **Block detachment** preferentially occurs at edges
- Cavities with faults are evolving more quickly
- Block detachment progresses upwards and laterally from a point source located at the bottom of the cliff



Lessons from local evolution of marly surface edges

"fairy rings"

- Similar evolution from a point source



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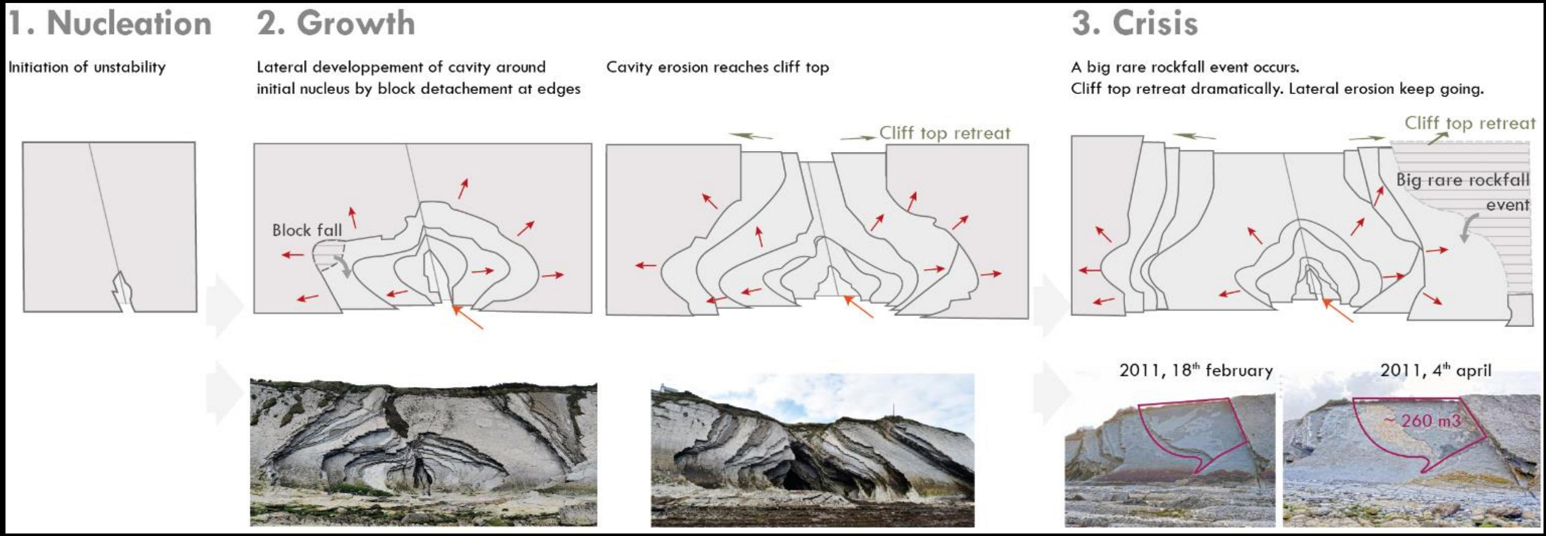
- **Average cliff retreat** in Socoa: between 3 mm/a and 11 mm/a (not shown, 3D comparison from point clouds computed from 1954 and 2008 aerial photographs).
- **Model of evolution** in Socoa:

  1- **instability nucleation** at the bottom of the cliff, preferentially where a fault outcrops

  2- **growth**, both laterally, upwards, and in depth

  3- **crisis**, the cliff in between cavities may collapse during crisis events.

  Important: the average cliff retreat rate is similar at the cavities and in between; crisis recurrence is ~100 a



Further reading

Prémaillon, M., 2018, Hiérarchisation des facteurs d'érosion des falaises côtières du site au globe [PhD Thesis]: Université de Toulouse. https://hal.archives-ouvertes.fr/tel-02414918v1

Abadie, S., Butel, R., Dupuis, H., and Brière, C., 2005, Paramètres statistiques de la houle au large de la côte sud-aquitaine: Comptes Rendus Geoscience, v. 337, p. 769–776, doi:10.1016/j.crte.2005.03.012.

Lague, D., Brodu, N., Leroux, J., 2013. Accurate 3D comparison of complex topography with terrestrial laser scanner: Application to the Rangitikei canyon (N-Z). ISPRS Journal of Photogrammetry and Remote Sensing 82, 10–26. https://doi.org/10.1016/j.isprsjprs.2013.04.009

Rosser, N.J., Brain, M.J., Petley, D.N., Lim, M., and Norman, E.C., 2013, Coastline retreat via progressive failure of rocky coastal cliffs: Geology, v. 41, p. 939–942, doi:10.1130/G34371.1.

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