Formation of spikes, crests and scallops in erosion by dissolution

Martin Chaigne[1], Sabrina Carpy[2], Marion Massé[2], Julien Derr[3], Sylvain Courrech du Pont[1], Michael Berhanu[1]

[1] Matière et Systèmes Complexes (MSC), Université Paris Cité, CNRS (UMR 7057), 75013 Paris
[2] Laboratoire de Planétologie et Géosciences (LPG), Nantes Université, CNRS (UMR 6112), 44322 Nantes
[3] Laboratoire Reproduction et Développement des Plantes (RDP), Université de Lyon, ENS de Lyon, UCBL, CNRS (UMR 5667), INRAE, INRIA, 69364 Lyon

martin.chaigne@u-paris.fr

Chemical erosion occurs when a soluble rock like salt, gypsum or limestone is dissolved in contact with a water flow. The coupling between the topography of the rocks, the mass transfer and the flow can lead to the formation of remarkable patterns, like rillenkarrens (parallel channels), tsingys (sharp pinnacles) or scallops (cups-like shapes)[1]. All these patterns display very sharp spikes or crests, despite the diversity of hydrodynamic conditions and nature of the soluble materials. By comparing field measurements, numerical models and experiments, we explain the generic occurrence of these spikes by a geometric approach: singularities at the interface are a direct consequence of the fact that the erosion velocity is directed in the normal direction.

First, we demonstrate the presence of singular structures on the limestone walls, shaped by dissolution, of the Saint-Marcel cave (Ardèche). Then, we propose interface evolution models of increasing complexity allowing us to explain the emergence of spikes and crests as well as the long-term formation of cellular structures. Finally, we perform experiments in which dissolution patterns are carved on the surface of an immersed salt block by a solutal convection instability [2]. We report the emergence of a cellular pattern of concavities surrounded by sharp crests reminiscent of natural scallops, in accordance with our model (cf. Fig. 1). Although the precise prediction of dissolution shapes requires a complete hydrodynamic study, our results show that the characteristic spikes reported ultimately are explained by geometric arguments. These findings can be applied to other ablation patterns, reported for example on melting or sublimating ice and on the surface of meteorites.

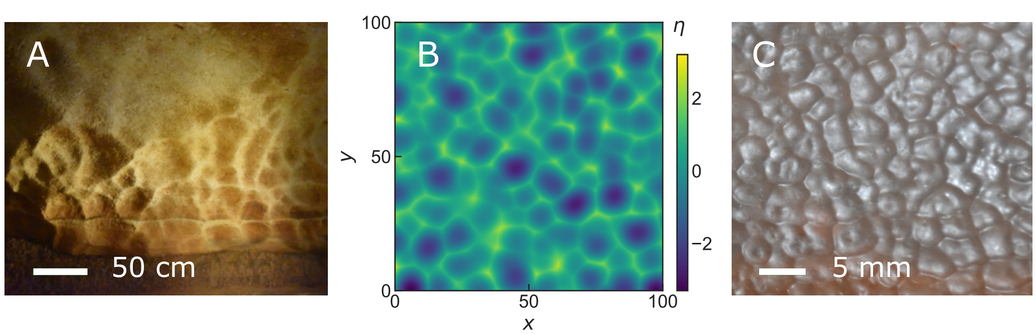

Figure 1. A: Scallops on a wall of the Saint-Marcel cave. B: Scallops obtained numerically with an interface evolution model. C: Scallops obtained experimentally on the bottom surface of an immersed pink salt block.

References

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