KINNEYIA: A FOSSIL HYDRODYNAMIC INSTABILITY

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Microbial mats are complex colonies of single-celled organisms, existing in a mass of extracellular polymeric substances (EPS, or, slime). Usually, these mats are roughly flat, but fossils can sometimes be found with intriguing ripple patterns covering them, featuring regular wrinkles a few millimetres wide, as in Fig. 1(a). These trace fossils (microbially mediated sedimentary fossils) are known as Kinneyia, and have been found from around the globe, at sites covering billions of years. Their appearance, however, gradually declined with the rise of multicellular life, and they finally disappeared from the fossil record during the Jurassic.

Characterized by clearly defined ripple structures, Kinneyia are generally found in areas that were formally littoral habitats (near shorlines) and covered by microbial mats. To date, there has been no conclusive explanation of the processes involved in the formation of these fossils, but the fossil evidence shows that they formed immediately after major storm events. Composed mainly of EPS, microbial mats behave like viscoelastic fluids. We have proposed [1,2] that the key mechanism involved in the formation of Kinneyia is a Kelvin–Helmholtz-type instability of the surface in a viscoelastic film under flowing water [Fig. 1(b,c)]. A ripple corrugation is spontaneously induced in the film and grows in amplitude over time. Theoretical predictions show that the ripple instability has a wavelength proportional to the thickness of the film. Experiments carried out using viscoelastic films confirm this prediction: the ripple pattern that forms has a wavelength roughly three times the thickness of the film. This behaviour is independent of the viscosity of the film and the flow conditions. Laboratory-analogue Kinneyia were also formed via the sedimentation of glass beads, which preferentially deposit in the troughs of the ripples. Well-ordered patterns form, with both honeycomb-like and parallel ridges being observed, depending on the flow speed. These patterns, and their scaling, correspond well with those found in Precambrian Kinneyia samples collected from Namibia, with similar morphologies, wavelengths and amplitudes being observed.

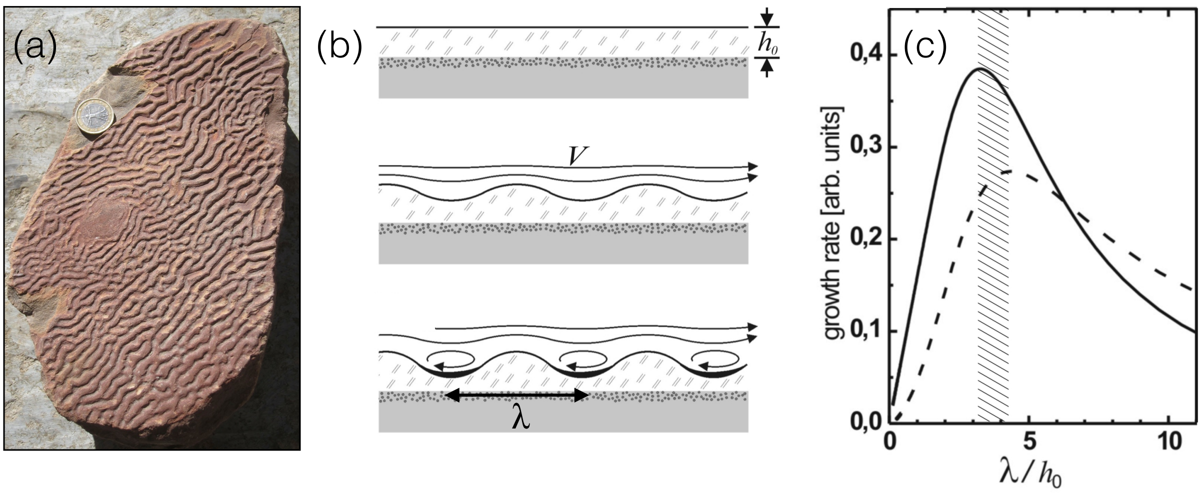

Figure 1. (a) Kinneyia fossil from Namibia. (b) We model the conditions of Kinneyia formation by a biomat of thickness h_0 under a superficial flow V. The surface is unstable to wrinkles, with a most unstable wavelength λ that (c) is proportional to h. This model is tested rigorously against analogue experiments and field data, and appears to also match the wavelength of the saturated pattern.

References

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