

Ripple Effect: Unforeseen Applications of Sand Studies

PAGES 293,297

Sand ripples and their deposits are playing a crucial role in unraveling the history of flowing water on Mars, conducting experimental floods to restore beaches in the Grand Canyon, and improving the ability to detect explosive mines buried beneath the seafloor. Even the visionary geologists who discovered the origins of ripples and ripple stratification could never have imagined these future applications of their work.

Sand ripples formed by blowing wind and flowing water have been studied for almost 150 years. This article briefly reviews some key discoveries in understanding ripples, reviews three studies that are currently utilizing ripples, and illustrates how simple fundamental discoveries have unexpected practical applications.

Anyone who has walked across a sandy creek or windy beach has stepped on ripples. The curious might have wondered what kind of layering or sedimentary structures the ripples leave behind.

Understanding ripple stratification is more complicated than it might seem, because ripples on a riverbed or seafloor include some regions where sand accumulates and other regions where sand erodes. To predict the stratification of a deposit, a geologist must visualize how an evolving three-dimensional bedform moves through space (ignoring all areas undergoing erosion) and then imagine what the structure will look like when the strata are viewed in an irregular outcrop that might be oblique to the original bedding. Many geologists have difficulty visualizing these complex spatial patterns even when guided by three-dimensional computer models [Rubin, 1987].

The first study of ripple stratification was conducted by visionary British geologist

Henry Clifton Sorby [Sorby, 1859], who examined active ripples to learn how flowing water deposited sand 300 million years ago (now preserved as sandstones). More than a century later, Ralph Hunter (U.S. Geological Survey, retired) [Hunter, 1977] discovered that lamination of wind ripples differs from that of subaqueous ripples and that distin-

guishing the two kinds of stratification is one of the best ways to determine whether sand was deposited by wind or water (Figure 1).

Ripples in the Headlines

Today, researchers examining images collected by NASA's Mars Exploration Rovers are using ripple structures to interpret the geologic history of Mars [Grotzinger et al., 2005]. Some of the Martian structures resemble the windblown ripple structures Hunter described, while others resemble Sorby's waterlain ripples. Although the discovery

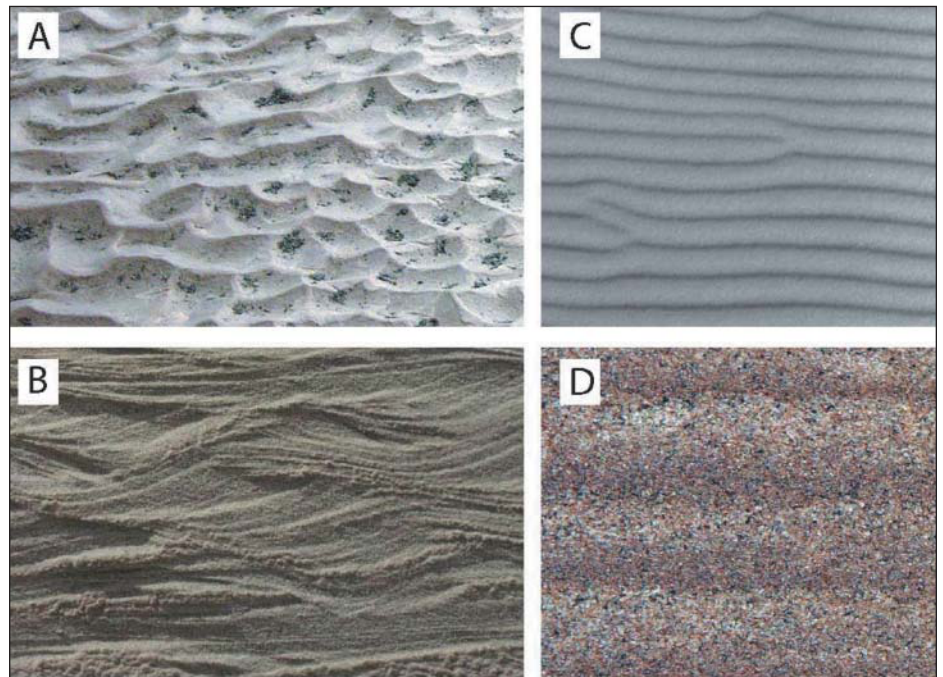


Fig. 1. Ripples and ripple stratification. (a) Ripples formed by flowing water have complicated shapes that change through time. Colorado River, oblique photograph; ripple wavelength is approximately 10 centimeters. (b) Vertical cross section through structures deposited by ripples in the Colorado River; stratification includes curved laminae that preserve the shape of the depositional sites of the original ripples. Thickness of deposit is 10 centimeters. (c) Ripples formed by wind tend to be more regular in space and time than ripples in water. Vertical view from Dillon Beach, Calif.; wavelength is approximately 10 centimeters. (d) Oblique cut through four layers deposited by wind ripples. The four layers were deposited by four ripples that migrated across the bed; each layer gradually coarsens from base to top, reflecting the grading of grain sizes on the lee surface of the original ripple. No evidence of the original ripple shape is preserved. Layers are several millimeters thick; Grand Canyon, Ariz.

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that water has flowed on Mars is not completely a surprise—because channel-like landforms have been observed by remote imaging—the key role of ripple structures in documenting that water once flowed on Mars is the first time ripples attained a cosmic importance.

Additional evidence of water on Mars was provided by the rover Opportunity's microscopic imager, a device for which Sorby is owed at least partial credit. He pioneered the use of microscopy in geology, for which he was roundly criticized by his contemporaries. He wrote, "In those early days people laughed at me. They quoted [Swiss scientist Honorace Bénédict de] Saussure who had said that it was not a proper thing to examine mountains with microscopes, and ridiculed my action in every way. Most luckily I took no notice of them" (see <http://www.sorby.org.uk/hcsorby.shtml>). Imagine Sorby's surprise if he learned that microscopy was essential to examining mountains on other planets.

Ripples and ripple stratification also play a role in restoration of sandbars along the Colorado River in the Grand Canyon. The sandbars are an essential part of the natural ecosystem; they supply sediment to the river to increase turbidity, and they provide campsites, substrate for vegetation, and backwater habitat for juvenile native fish [Rubin *et al.*, 2002].

Beginning in 1963, Glen Canyon Dam blocked the transport of sand down the Colorado River, causing erosion of downstream sandbars. Over subsequent decades, native fish populations declined, and archaeological sites along the river eroded at what seemed to be an accelerating rate. Archaeologists and geomorphologists suspected that as the river-deposited sandbars were eroded by the river and colonized by vegetation, the bars supplied less windblown sand to the nearby archaeological sites. To determine whether the pre-dam and post-dam deposits and landforms were deposited by wind or water, geologists rely on the characteristic structures deposited by these two kinds of ripples [Draut *et al.*, 2005].

In November 2004, the U.S. Department of the Interior's Glen Canyon Dam Adaptive Management Program implemented a restoration flood experiment [Wright *et al.*, 2005] using geologic quantities of water and sand (almost a cubic kilometer of water that redistributed one million metric tons of sand

that over the previous few months had been delivered to the main stem Colorado River by tributaries downstream from the dam).

Ripples are also playing a role in national defense. The U.S. Navy discovered that the presence of ripples allows sonar signals to penetrate the seafloor in areas where the sound would otherwise be reflected; the ripples enable sonar to detect mines buried beneath the seafloor. This capability depends on ripple size, shape, and orientation relative to sonar properties, so the Navy wants to know how ripples form, how waves and currents influence ripple orientation [Rubin and Hunter, 1987], morphology, and the rate at which biologic processes cause ripples to degrade.

The use of ripples by the Navy and NASA is not the first application of sand bedforms to both military operations and planetary geology. The British explorer and scientist Ralph A. Bagnold conducted expeditions into the dune fields of the Sahara desert (for which he was awarded the Royal Geographical Society's Founder's Medal in 1935). Bagnold's work [1931, 1941] not only advanced the fundamental understanding of dunes and sand transport, but also was crucial to desert military operations during World War II. In 1978, the route of his 1938 expedition in Egypt was retraced, and the observations were used to interpret desert landforms on Mars [El-Baz *et al.*, 1980]; that same year Bagnold was awarded the Sorby Medal by the International Association of Sedimentologists.

Unforeseen Applications

Even scientists who make breakthrough discoveries may not be able to imagine future applications of their work. Sorby was unsure of the value of his own work on ripples. In his 1859 paper he wrote, "I must now have, in my note-books, not less than twenty thousand recorded observations, many of which I have not been able to make use of hitherto..." Similarly, Hunter was surprised to learn that his work had been used to interpret the origin of sandstones on Mars.

For one and a half centuries, research on ripples was directed largely at understanding the relations between flowing fluids, transport of grains, and resulting sediment stratification. Knowledge about ripples is

now being applied to other planets, restoration of Grand Canyon beaches, and national defense. The fact that ripples are central to three such notable research projects simultaneously is coincidental, but the fact that pure research is later applied to unforeseen practical problems is to be expected—even when the topic is as commonplace as sand ripples.

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