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Aeolian Ridge

► Megaripple

Aeolian Ripple

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Definition

Small (centimeter to meter wavelength) aeolian bedforms, commonly occurring in trains, created by the mobilization and accumulation of sand-sized grains into roughly parallel ridges that are typically oriented transverse to the direction of the wind.

Category

A type of ► ripple; A type of ► aeolian deposit; A type of ► bedform

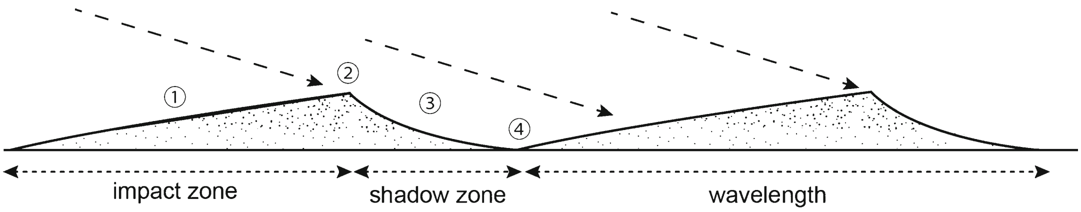
Description

Ripples are small, regularly repeated depositional bedforms consisting of sand-sized grains that develop almost anywhere that sand and wind occur together (Greeley and Iversen 1985). Ripples generally form transverse to the wind direction and their straight to slightly sinuous crests generally end or bifurcate within a few meters (Greeley and Iversen 1985, p. 149). Aeolian ripples have wavelengths from 0.01 to 20 m, heights from a few mm to 1 m, and indices between 12 and 50 (Leeder 1982). Unlike dunes, ripples lack slip faces (Thomas 1989; Greeley and Iversen 1985). The coarsest and finest grains are concentrated at the crests and troughs, respectively (Bagnold 1941, p. 145), and they are typically less than tens of saltation path length long (Bagnold 1941; White 1979). Ripples can form on free-standing surfaces as well as on larger aeolian bedforms such as dunes.

Normal ripples on Mars have been observed by landed missions, but megaripples, termed ► transverse aeolian ridges, are large enough to study with orbital data. While ripples and dunes on Earth are morphologically distinct, the increased saltation path length of sand-sized material on Mars due to the thinner atmosphere (White 1979) may cause overlap between the dimensions of large ripples and small dunes despite their unique formation mechanisms (Wilson et al. 2003).

Morphometry

The windward-facing (stoss) slopes of the ripple tend to be 8–10° and are eroded by saltating grains, whereas leeward slopes, protected from impacting grains, are 20–30° and are steepest near the ripple crest (Greeley and Iversen 1985). Ripple wavelength is either controlled by the saltation path length (Bagnold 1941) or the ripple height, which may act as a barrier to saltating particles (Sharp 1963; Fig. 1).



Aeolian Ripple, Fig. 1 Aeolian ripple development: (*1*) stoss slope, (*2*) ripple crest (coarse grains), (*3*) lee slope, (*4*) ripple trough (sheltered fine grains); *dashed lines* show paths of saltating grains (After Pye and Tsoar 1990; Fig. 6.4, Sharp 1963)

Ripple Wavelength

It is the horizontal distance between the deepest points of two troughs or the horizontal distance between two crests in a rippled sand surface (Glenn 1979).

Ripple Height

It is the vertical distance from the base of the ripple to the crest.

Ripple Index

It is the ratio of ripple wavelength to ripple height, which generally varies inversely with grain size and directly with wind velocity (Greeley and Iversen 1985).

Subtypes

(1) Normal ripples (also known as sand ripples, ballistic ripples, and impact ripples) have wavelengths of 1–25 cm and heights of 0.5–1.0 cm (Sharp 1963) and are asymmetric in profile with windward and lee slopes of 10° and 30°, respectively (Mabbutt 1977). Crests are generally straight or slightly sinuous and form transverse to wind direction in well-sorted sand (0.3–2.55 mm).

(2) ► Megaripples (also known as giant ripples, granule ripples, erosion ripples, sand ridges, and pebble ridges) have wavelengths of ~3 m up to 25 m (Greeley and Iversen 1985) and form in bimodal sands transverse to the wind direction. The wind is sufficient to mobilize the fine material but coarser grains become concentrated on the ripple crest, resulting in a more symmetric profile relative to normal ripples.

(3) Fluid drag ripples (Bagnold 1941), also known as aerodynamic ripples (Wilson 1972), can form either longitudinally or transversely (Thomas 1989) to the high velocity wind direction in well-sorted fine sand and are characterized by very long, flat ripple forms.

Formation

Ripples form when unidirectional winds are strong enough to initiate saltation of sand grains that exploit chance irregularities in the surface (Bagnold 1941). The windward (stoss) side is bombarded by wind-transported grains, each moving downwind at a distance defined by the average saltation path length of the grain. The subsequent erosion on the stoss side of the ripple creates a zone of accumulation on the leeward side, moving the entire system forward.

In general, ripple wavelength increases with ripple height (Thomas 1989, p. 238). Sharp (1963) observed that wavelength increases with time and suggested ripple wavelength is a function of ripple height and the angle that saltating grains impact the bed. Therefore, Sharp (1963) proposed that ripple wavelength is controlled by wind velocity and the length of the impact-shadowed zone.

Bagnold argued that ripple wavelength is a function of the saltation and reptation path length of the sand grains, which is controlled by wind speed (Bagnold 1941). However, recent studies show that saltation trajectories are many times longer than ripple wavelength. Ripple spacing is about six times the mean reptation path length (Thomas 1989). In the new model, ripples are controlled by reptation flux. Particles are entrained into reptation not directly by the wind, but by the nearly unidirectional bombardment of saltating particles (Prigozhin 1999). Saltating grains that impact coarser material cause reptation or creep or low-velocity movement along a short path length (Anderson 1987). These low-energy particles outnumber high-energy trajectories by about 9:1 (Thomas 1989). Coarse grains that move by creep processes accumulate on the lee side of the ripple and limit the height of the ripple (Bagnold 1941) until equilibrium is reached and the bedform migrates in the direction of sand transport (Thomas 1989, p. 238).

Distribution

Ripples can occur on any large-scale aeolian bedform (Thomas 1989). On Mars, they commonly occur in topographic depressions (e.g., craters, troughs, valleys, channels) and are widespread throughout the equatorial and midlatitude regions of both hemispheres (e.g., Wilson and Zimbelman 2004; Figs. 2, 3, and 4).

Ripple Patterns

► Reticulate ridge. In Hellespontus, Mars, transverse ridges show straight, bifurcating, sinuous, and catenary-to-lunate ripple patterns, oriented parallel and also orthogonal to dune migration direction, with a primary component (parallel) and a secondary component (orthogonal), indicating bimodal winds (Fig. 4). A reticulate or network arrangement is formed as interference patterns. Different ripple sets have different albedos that may result from grain size sorting or mineral separation (Bishop and Wheeler 2010).

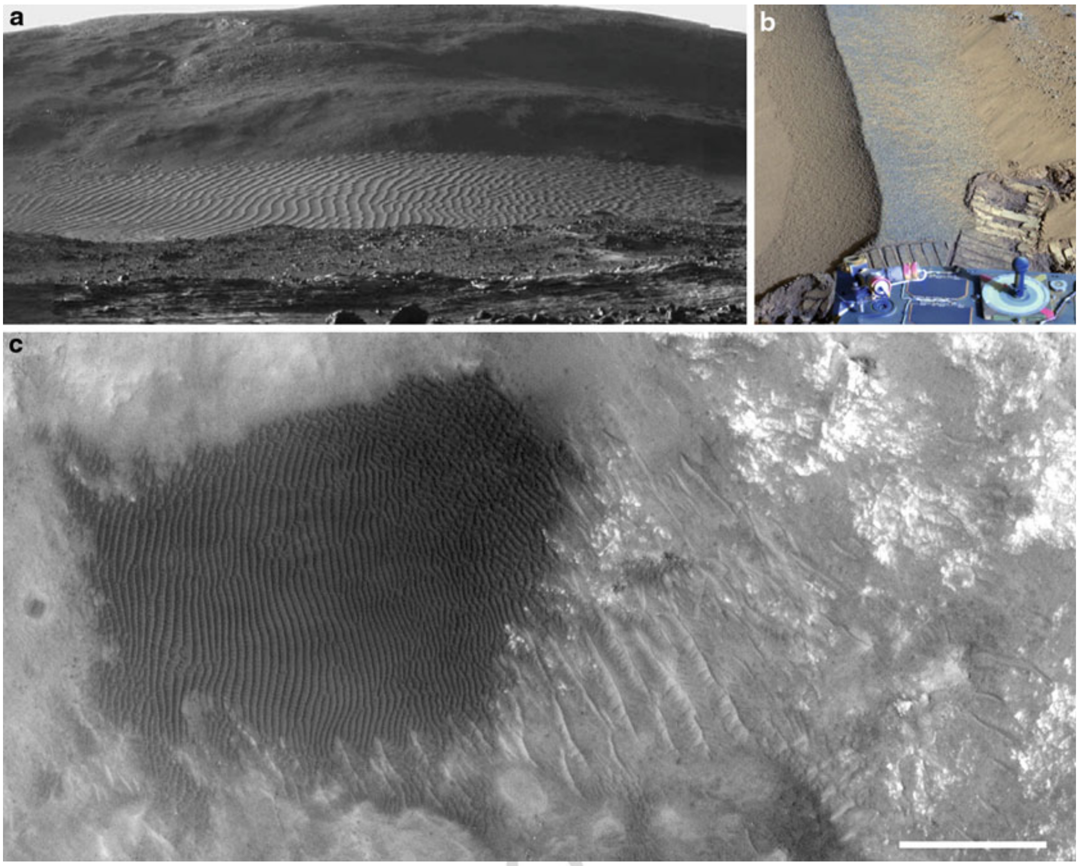
Aeolian Ripple, Fig. 2 View of ripple crests (covered with very small hematite spherules) and troughs (scattered with larger spherules) on the plains between Eagle and Endurance craters. Field of view is ~52 cm. (Fig. 13.35 from Bell et al. 2008). Meridiani Planum, Mars. Opportunity Mini-TES Reduced Data Record 1T 134662794 RDR 10 00 P3575 N0 A1. Color view from 482 (B), 535 (G), 673 (R) nm images. Sol 73 sequence P2589 (NASA/JPL/Washington University St. Louis)

Ripple Migration

Ripples show evidence of migration in several locations on Mars including the North Polar Erg, Nili Patera, Kaiser, Herschel, Rabe, and Matara craters but are immobile on several intracrater dunes in the southern highlands (Bridges et al. 2011).

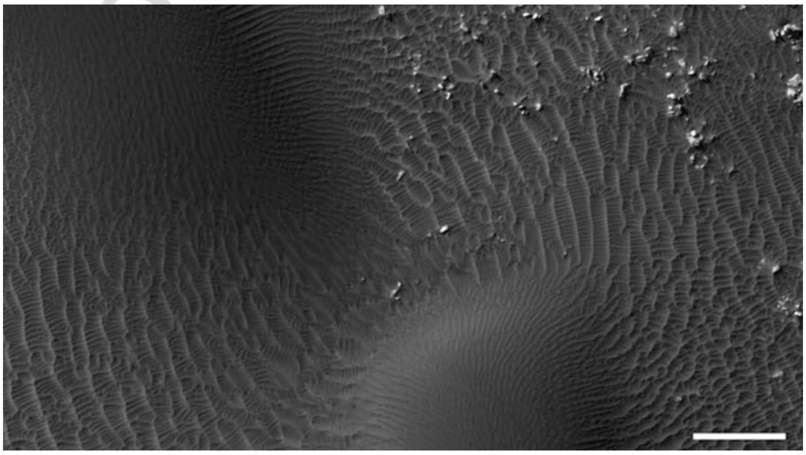
History of Investigation

Misconceptions regarding the formation of aeolian ripples are as follows: (1) they form as a result of a special wave motion, analogous to water waves, generated by the shear (different speed) of two adjacent fluids (sand and wind), and (2) they are microdunes that failed to grow into regular dunes. Modern conceptions were developed by Bagnold (1941) and Wilson (1972). Wilson established the hierarchic system of aeolian features realizing that ripples and dunes are not gradational stages, but rather



Aeolian Ripple, Fig. 3 The active, dark, mafic El Dorado ripple field with interfingering inactive, light-toned coarse-grained ripples on the flanks of Husband Hill on Mars (Sullivan et al. 2008). (**a**) Spirit Pancam R1 (436 nm) sol 813; (**b**) coarse-grained ripple very near the summit of Husband Hill. Wheel track in right center is 16 cm wide. Spirit Pancam L247 (mosaic of 753, 601, 432 nm), sol 607 (NASA/JPL/Cornell); (**c**) view from orbit, scale bar 50 m. HiRISE PSP_003900_1650 (NASA/JPL/University of Arizona)

Aeolian Ripple, Fig. 4 Three scales and different orientations of sand patterns in Hellespontus/Noachis Terra, Mars. Portion of a dark transverse ridge is to the *upper left*. Scale bar 50 m. HiRISE ESP_016036_1370 at 42.68°S, 38.02°E (NASA/JPL/University of Arizona)



represent different mechanisms of formation (Greeley and Iversen 1985, p. 148 and references therein).

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Aeolian Sand Deposits

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Definition

Windblown and deposited granular material with particle sizes of 0.0625–2 mm.

Category

A type of ► aeolian deposit.

Note

This entry discusses sand deposits in general; details on bedforms and other aeolian deposits can be found in the appropriate entries.

Subtypes

Subtypes by organization:

(1) ► Bedforms
  (1.1) ► Dune
  (1.2) ► Ripple
  (1.3) ► Megaripple
(2) ► Sand sheet
(3) ► Drift deposits (Greeley et al. 2002)