

NEWS & VIEWS

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Figure 1 | Desert storm — Wadi Mur, Yemen, 2003.

GRANULAR MATTER

Static in motion

Troy Shinbrot and Hans J. Herrmann

Wind-blown desert sands can charge up spontaneously. But although sand flow and the forces on charged bodies are well studied separately, surprisingly little is known of what happens when the two combine.

The strange things that happen when granular media and electrostatic charge mix have long exercised the minds of both scientists and engineers. In the latest episode in this saga, Kok and Renno, writing in *Physical Review Letters*¹, focus on how static charges affect the aeolian — wind-borne — transport of sand. As the basic ingredient of sand encroachment and dune motion (Fig. 1), this is a process of more than academic interest, with implications for desertification and coastal management.

But first some history. As long ago as 1867, William Thomson, better known as Lord Kelvin, studied the charging of both falling grains and water droplets in his attempts to understand the origin of atmospheric lightning². Eighty years on from that, physicist E. W. B. Gill drew on his observations of sparking and radio interference on the Macedonian front during the First World War to produce a similar effect in the laboratory³.

Grains in an electric field are also known to self-assemble into complex patterns⁴. Other poorly understood, but bothersome, phenomena can be traced back to particle charging, too. Clouds of charged dust regularly produce

devastating explosions in grain and coal plants⁵. On the Moon, charged grit attaches itself to spacesuits and works its way into suit joints, causing them to leak air and so cut exploration time. The problem was such that Apollo 16 commander John Young considered dust the number one concern in returning there. That sentiment was echoed in NASA's most recent study on Mars exploration⁶.

Back on Earth, aeolian flows have been measured in both field⁷ and laboratory⁸ experiments. These investigations showed that charges acquired by wind-blown sand can be sufficient to levitate the grains, and even to violently eject them (Fig. 2, overleaf). Despite experimental data demonstrating that grains readily acquire substantial charges, with few notable exceptions⁸, surprisingly little fundamental analysis has been done on how charge affects granular flow, and several essential questions remain to be answered.

First, it has been established that even carefully prepared, identical materials charge one another^{9,10}. But how exactly does this work? In a desert environment, where wind-blown sand grains have little but other, similar grains to

rub against, yet still manage to acquire charge, this is a significant puzzle. Kok and Renno¹ go some way to finding an answer, constructing an effective charging relation, for pairs of particles of the same composition but different sizes, that describes the empirical fact that smaller sand grains tend to charge negatively, and larger grains positively.

Even so, the mechanism for the underlying charge transfer remains at best tenuously understood. One proposal is that smaller particles rise to the top of a sand cloud, where they encounter more highly mobile, negative ions in the air, and so themselves become negatively charged¹. Another theory holds that asymmetric particle collisions heat the smaller particles more effectively than the larger ones, possibly leading to a transfer of charge between them¹⁰.

A second unanswered question is how the charge that is measured on sand grains affects aeolian flow. Kok and Renno produce a model for the motion of wind-blown sand ('saltation') that takes electrostatic interactions into account by assuming charged sand grains to be attracted to Earth, which acts as an infinitely large, oppositely charged particle. This causes

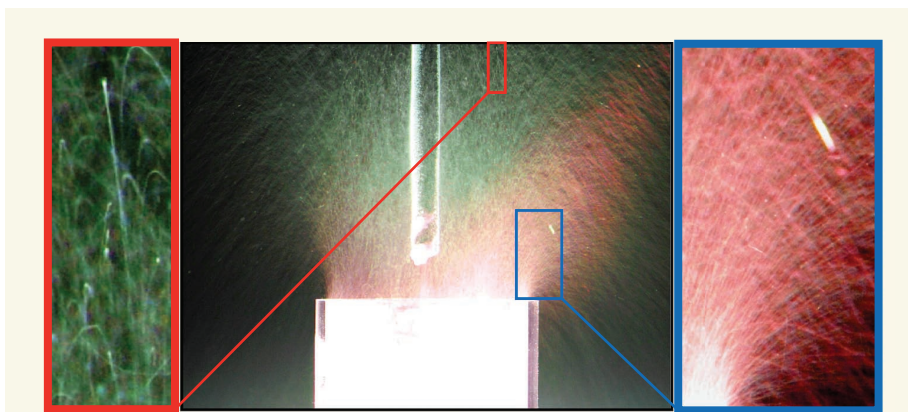


Figure 2 | Granular fountain. In this laboratory demonstration (centre) of the explosive potential of charged grains, glass beads 500 micrometres in diameter are charged by repeatedly pouring them through a vertical acrylic tube into an acrylic container. The charges on the grains become so large that the beads cannot remain at rest, and they spontaneously form a fountain that erupts from the container, even after the inflow has ceased. If the tube is electrically grounded, these ejections do not occur. Left inset, trajectories of individual grains; right inset, an apparent example of a granular aggregate coexisting alongside individual grains. Kok and Renno¹ produced a model of the development of such charge on sand. (Colours are digitally enhanced; image and experiment courtesy of F. K. Wittel, ETH-Zürich.)

charged sand grains to fall back down faster than they would do otherwise. At the same time, the authors note that charged grains tend to levitate (or even jump considerable distances, as seen in Figure 2), and so should become more easily airborne than neutral grains. Both of these apparently contradictory propositions seem sound, but their combined effect on sand flow, and the effect of charges of both signs on a saltating bed, remain to be fully understood. Further progress will require

a concerted combination of careful measurements and simulations rarely attempted to date⁸.

One final, extremely basic, question is: will charged sand grains attract or repel each other? Both phenomena are observed. If grains simply acquire a uniform charge, they will of course repel each other according to Coulomb's law. But dipole moments — a result of an uneven distribution of electric charge — on single particles have also been observed, and local

assemblies of charge are known to form at points of contact between grains¹¹. Consequently, similarly treated grains are seen to both repel each other and to adhere in clusters³ in the same system (Fig. 2). How a collection of grains in, say, a desert sandstorm will behave will ultimately depend on the charge distributions on individual grains, which are poorly understood.

It is remarkable that, since Kelvin's time, so basic a question as how a common material such as sand becomes charged and flows remains unresolved. Work such as that of Kok and Renno¹ demonstrates how complex the research challenges are. The simple combination of grains and charge will no doubt be generating more surprises in the years to come. ■

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