Agricultural Biotechnology Support Project, part of the USAID Collaborative Agriculture Biotechnology Initiative.

Paarlberg's claim that external, anti-GM views have been the main influence on decision-making by national governments in Africa is not substantiated. Instead, international players on both sides of the GM debate have fought a fierce tug-of-war over policy, with African regulators and policy-makers often left as unwilling bystanders.

> "Blue-skies research into future agricultural techniques is essential."

Meanwhile, on the ground, detailed, site-specific evidence on the performance of GM technologies indicates that a farmer's ability to reap the potential benefits depends on a range of technical, agronomic and institutional factors (see http://tinyurl.com/ksbfxo and http://tinyurl.com/krmzxu). For instance, the transgenic trait needs to be available in crop varieties that can perform in constrained environments. A good yield depends heavily on favourable soils and irrigation, which the poorest farmers typically lack. As the experiences of smallholder Bt-cotton farmers in South Africa have demonstrated, GM crop technology also needs to be supported by infrastructure and institutions if it is to benefit the poorest people.

These findings are in contrast to the triumphalism of reports that show the spread of GM crops around the world, such as that released annually by the International Service for the Acquisition of Agri-biotech Applications. Studied closely, the 2008 report shows that only 8 of the 25 countries that grew GM crops planted more than a million hectares. Almost 80% of the global GM crop of 125 million hectares was grown in just three countries: 62.5 million hectares in the United States, 21 million hectares in Argentina and almost 16 million hectares in Brazil. Moreover, the GM crops that have been commercialized to date are mostly insect-resistant Bt varieties of maize and cotton and herbicide-tolerant varieties of soya bean, designed for and mainly used by large-scale commercial farmers.

African agricultural policy-makers have some difficult decisions to make. Biotechnology will surely be part of the mix of approaches required for the future, as indicated both in the World Bank's 2008 World Development Report on agriculture and in the 2008 International Assessment of Agricultural Knowledge, Science and Technology for Development. But big uncertainties remain — including how farmers will gain access to markets where GM products are currently restricted and the potential risks of GM technologies to the environment or health. An informed 'wait-and-see' stance thus makes sense.

What of the future? One of the pivotal arguments in *Starved for Science* is that promising pipeline technologies and longer-term research are also being held back. To make his case, Paarlberg cites the effort to develop drought-tolerant GM maize, a major programme of the African Agricultural Technology Foundation. Supported by the Bill & Melinda Gates Foundation, it is working with a range of public and private research and development organizations. This broad initiative involves conventional breeding, genomics applications and genetic-marker-based selection as well as genetic modification. Yet Paarlberg zeroes in on the GM solution, maintaining that this is where the necessary breakthroughs will happen.

Blue-skies research into future agricultural techniques is essential. But inflating expectations has major downsides. As occurred with medical biotechnology, hype can distort innovation. It diverts funds from other research and narrows the focus of study to genetics rather than taking into account the wider environmental, behavioural and synergistic dynamics (P. Nightingale and P. Martin *Trends Biotechnol.* **22**, 546–569; 2004). A similar process will occur in agricultural science unless we retain a balanced perspective of the options available.

A dogmatic and unscientific stance on GM crops — whether for or against — helps no one, least of all African farmers. A more evidence-based approach than Paarlberg's is needed — one that should foster diverse development pathways for agriculture underpinned by high-quality scientific research and attuned to particular circumstances. ■

**Ian Scoones** is a professorial fellow at the Institute of Development Studies and co-director of the ESRC STEPS Centre, University of Sussex, Brighton BN1 9RE, UK. **Dominic Glover** is a postdoctoral researcher in the Technology and Agrarian Development Group, Wageningen University, 6706 KN Wageningen, the Netherlands.
e-mail: i.scoones@ids.ac.uk

**For additional references, see http://tinyurl.com/lfp2x3.**

# The world in a grain of sand

**Sand: A Journey through Science and the Imagination**
by Michael Welland
Oxford University Press: 2009. 352 pp. £18.99

On an island off the southwestern coast of Turkey, called Sedir Adasi, lies a stunning stretch of white sand known as Cleopatra's Beach. According to legend, Cleopatra's lover Mark Antony made the beach for her as a lavish gift by shipping bargeloads of sand from Egypt to the island some 2,000 years ago. There may be a grain of truth in this story, writes Michael Welland in *Sand* — the "exotic creamy white oolith" granules occur nowhere else on the island but match those on Egyptian coastal beaches west of Alexandria.

A modern mystery of sand is the origin of the silica used in making silicon for the electronics industry. After much research, Welland drew a blank. The handful of technology companies who dominate this crucial market would not disclose the source of their raw material; all the author could deduce was that silicon chips are made from "sand that has already been ultrapurified by nature: quartzite".

A popular book by a long-time professional geologist could easily have been worthy but dry. Yet *Sand* is serious and entertaining; it is the work of someone who has been in love with the stuff since he built sandcastles as a child. Nothing like it has been published before, even by the larger-than-life pioneer of sand studies, Ralph Bagnold, who serves as Welland's inspiration.

Bagnold was a British army officer who saw the Sphinx excavated in the 1920s from tonnes of preservative sand laid down over millennia. He became a desert explorer in Egypt and a formidable adversary behind enemy lines in the Second World War. He was also a scientist, and built a wind tunnel at Imperial College London to investigate the behaviour of sand grains under controlled conditions. In 1941 he published *The Physics of Blown Sand and Desert Dunes*, a classic study (see *Nature* **457**, 1084–1085; 2009) that was later used by NASA to plan how its rovers should deal with Martian sand.

But Welland stretches beyond Bagnold and his deserts. *Sand* begins on the small scale, with the counter-intuitive physics of granular behaviour. Strangely, dry sand behaves like a liquid, whereas damp sand is more like a solid, provided that it is not too wet. Welland explains the stability and collapse of sand piles, and the forensic study of sand to solve murders. This leads to a discussion of the weird and wonderful microscopic life forms — such as rotifers, tardigrades, gastrotrichs, turbellarians and others — that have evolved to flourish in the spaces between shifting, abrasive sand grains. Such an environment may become the last refuge for life in the event of catastrophic climate change. Welland then addresses sand on a progressively larger scale: along the course of meandering rivers, in the formation of beaches, in deserts and mid-ocean sandbanks, in the formation of Old Red Sandstone rocks found extensively from the Arctic to the Gulf of Mexico and, finally, in sand found beyond Earth.

Welland asks how sand grains have helped humans to conceive the Universe and the infinite. He begins with Archimedes who, in the third century BC, calculated that $10^{63}$ grains of sand would fill the Universe to the outermost sphere of the fixed stars. The author also discusses, and attractively illustrates, how sand has been used artistically in many cultures — from sand painting by Australian aboriginal communities and the North American Navajo, to Zen sand gardens in Japan and the sand sculptures created by digital methods at the Media Lab at the Massachusetts Institute of Technology in Cambridge. One fascinating photograph shows the 'Earthquake Rose', the pattern made by a desktop toy, a sand-tracing pendulum, during a strong earthquake in Washington state in 2001.

PHOTO SCALA, FLORENCE/EGYPTIAN MUS., CAIRO

**Green desert glass from Libya was carved into a scarab beetle for Tutankhamun's necklace — but how did the silica glass form?**

A personal epilogue provides the reader with a genuine mystery. In 1922, the discovery of Tutankhamun's tomb in Egypt yielded a famous necklace with a scarab beetle carved from a glowing, yellow-green, gem-like material, which its discoverer Howard Carter did not recognize. In the 1990s, the material was shown to be a unique silica glass, 28 million years old and 98% pure, from a particular part of the Libyan desert.

Welland travels to this desolate spot and cherishes the glassy samples he finds glittering on the dunes. But, he muses, what could have produced heat that was intense enough to fuse silica? A strike from a meteorite or lightning can be ruled out because of the lack of visible impact craters or hollow fulgurite tubes, respectively. He speculates that the cause might have been an air burst from the impact of an asteroid with the atmosphere, similar to that at Tunguska in Siberia, Russia, in 1908.

With irresistible ideas such as this, Welland provides an appealing blend of science and the imagination, worthy of the famous vision of the poet William Blake: "To see a world in a grain of sand". ■

**Andrew Robinson** is the author of *Earthshock* and *The Story of Measurement*. He is a visiting fellow of Wolfson College, Cambridge CB3 9BB, UK.
e-mail: ar471@cam.ac.uk

# D-Day forecast fictionalized

**Turbulence**
by Giles Foden
Faber and Faber: 2009. 368 pp. £16.99

Fluid dynamics and weather prediction seem unpromising material for a gripping story. But Giles Foden has ingeniously dramatized what is perhaps the most important weather forecast ever made: that for the D-Day landings, the invasion of continental Europe at Normandy by the Allied forces towards the end of the Second World War. The result is a compelling tale, with meteorologists as the unlikely heroes and the turbulence of the title providing the central metaphor.

General Dwight D. Eisenhower, in command of the operation, had to be sure that the crossing of the English Channel would not be disrupted by bad weather. And he needed that assurance five days in advance — a length of time that stretches today's forecasting techniques to their limit, and which was beyond the capability of meteorologists in 1944. Add to that the need for a low tide to evade the German sea defences, the task confronting the Allies' weather experts seemed insurmountable.

In *Turbulence,* Foden tells this story through the eyes of a fictional character, Henry Meadows, a young academic attached to the forecasting team that is led, as it was in reality, by the British meteorologist James Stagg. The decision-making process of Stagg and his fractious colleagues, including the brash American entrepreneur Irving Krick and the arrogant but astute Norwegian Sverre Petterssen, occupies the last third of the book. Stagg and Petterssen each published their own accounts in the 1970s. Although Foden's tale is steeped in that history, he allows Meadows to make the crucial, unrecognized contribution.

The story begins with Meadows being sent to rural Scotland to glean clues about forecasting from the leading authority of the day, the difficult genius Wallace Ryman. Ryman is a fictionalized version of Lewis Fry Richardson, known for his work on fractal coastlines, who Foden rightly calls "one of the unsung heroes of British science". Like Richardson, Ryman is a Quaker whose experiences in the Friends' Ambulance Unit during the First World War convinced him that war must be avoided. He shuns collaboration with the military, so Meadows must pursue his mission by stealth — an attempt that he mostly bungles.

In Scotland, Meadows runs into the second wayward genius in the book, this time without a pseudonymous disguise: Geoffrey Pyke, the man behind the Habbakuk project to build aircraft carriers out of ice reinforced with wood pulp. This 'Pykrete' is extraordinarily resistant to impacts and melting. Also making a fleeting appearance is Julius Brecher, a doppelgänger for biochemist Max Perutz, who assisted Pyke during the war. This part of the plot would seem far-fetched if you didn't know that it is true.