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Big theories from little pebbles grow

(Filed: 01/08/2006)

Their shape could reveal millennia of geology, says Roger Highfield

'I was like a boy playing on the sea-shore, and diverting myself now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."

Sir Isaac Newton came up with this evocative quote some three centuries ago, and would have been fascinated by a paper on pebble-smoothing that has just appeared in the journal Physical Review Letters - one that answers a question that dates back to the days of Aristotle: what shape is a pebble?

The paper by Douglas Durian of the University of Pennsylvania and Carlos Marques of the University of Strasbourg focuses on a puzzling feature of pebbles. Why is it that random erosion down the ages makes them pebble-shaped and not nicely round, like little pucks, or even ball-shaped?

To work out why, Durian and Marques started out with idealised proto-pebbles - flat, 5mm thick pieces of clay that had been moulded into squares, triangles and other polygons. They tumbled these shapes in a spinning metal pan to simulate erosion in two dimensions.

Once the corners had been worn away, the pebbles became smaller and rounded but, impotantly, never circular. Even when the original shape is moulded as a circle, the erosion process leads to the characteristic roundish-but-not-circular shape typical of a pebble.

Like any good science, this raised a new question. How do you describe the resulting shapes, other than the usual circular argument that they are, er, shaped like pebbles? Most attempts have involved measuring the "aspect ratios"

- that is, the ratio of the longest to the shortest axis.

Instead, the team worked out the distribution of curvatures around the circumference of each eroded pebble, plotted it on a graph and found that it followed a nearly Gaussian - bell-shaped - curve. Thus, they concluded, a pebble is, of course, "a nearly round object with a near-Gaussian distribution of curvatures".

But that, of course, only goes for two-dimensional idealised pebbles. Why is is that millions of years of erosion do not usually turn rocks into neat spheres but into flat, round pebble shapes? (Pebble experts will already know that almost spherical pebbles can be found in "witches' holes", the round depressions carved by water and pebbles on some beaches and rivers.)

Geologists think that the reason most pebbles are flat is that they originate from flat, sedimentary deposits, or have been worn flat by the passage of water. The team is now recreating three-dimensional erosion to see if this really is why so many pebbles are flat.

Eventually, said Marques, they hope to develop a mathematical tool that can "decode" the shapes of pebbles in sediments and link these to the erosion process that the pebbles underwent - regardless of what shape they originally had. From the shape of a pebble, geologists would be able to figure out millions of years of history.

This issue also has deep practical significance. Without flattish pebbles, children would have been denied the pleasure of playing ducks and drakes, a satisfyingly simple pursuit which dates back to ancient times. Here, once again, French science has led the way.

Stone-skimming involves four factors - the pebble's speed and spin velocity, the attack angle of the stone with respect to the water's surface, and the impact angle.

Using a specially built machine, Christophe Clanet of the Institute of Research on Non-Equilibrium Phenomenon, Marseille, and Prof Lydéric Bocquet of the University of Lyon could alter the speed, spin and angle of an idealised stone (an aluminium disc) as they recorded the impacts with a high-speed video camera.

In this way, they found the "magic angle" between the stone and the water's surface must be about 20 degrees to get the most bounces: no fewer than 40, in the case of the record set four years ago in Pennsylvania by an American, Kurt Steiner.