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VREDEFORT DOME

Target Earth

by Graeme Addison

The paddles dip and drip, the canoe pushes out concentric rings of ripples across the still surface of the Inlandsee. This shallow lake, or pan, surrounded by undulating grassland, is Ground Zero of a blast that shook the world two billion years ago. It is the centre of the Vredefort Dome. From here can be glimpsed a semi-circle of mountains known as the Bergland, marking the collar of the crater about 20 kilometres away.

Beyond lie the distant heights of the Witwatersrand, the outermost ring of the crater. Despite its age and the erosion that has scoured it down to its roots, the 300km wide crater remains the largest visible feature of its kind on the Earth's surface, stretching from the gold metropolis of Johannesburg in a great south-westerly sweep through Klerksdorp to Welkom – the Arc of Gold – from which has come some 40 percent of all the gold ever mined.

To the southeast the crater disappears under the Karoo Supergroup system – the dour platteland with its endless flat horizons and luminous blue skies. The Inlandsee itself is not really related to the crater: it just happens to be where it

is as a result of much later Karoo geomorphology in which new layers of sediment were laid down and then removed by glaciers and rivers.

The Vredefort Dome is a Whodunit at the centre of an astrophysical detective story. Is it the product of an asteroid impact or a volcanic explosion – a blast or a belch? For more than 100 years, geologists have puzzled over the strange curvature of the mountains and plains surrounding the towns of Parys and Vredefort, with the sombre Vaal River cutting its way through radial cracks in the structure.

In 2005 the Vredefort Dome was declared a World Heritage Site (WHS). The official area covers 30 000 hectares and lies mainly in the Bergland, situated along both banks of the Vaal River, a little over an hour's drive from Johannesburg. Although the prime reason for declaring the WHS is geological, there is more to it.

Human habitation of the area goes back to the time that our species originated, more than 3 million years ago. About an hour's drive northwards from Parys is the Cradle of Humankind at Sterkfontein. The Australopithecus – a short-legged, small-brained and big-toothed ape-like creature walking on two legs – probably lived throughout the area including the Dome although the remains have been found in dolomite caves around Sterkfontein.

Evidence of early, middle and late Stone Age occupation goes back some 150 000 years. There is a Stone Age cave at Thabela Thabeng near the quaint village of Venterskroon, and a “workshop” for stone tools near the Schoemansdrift Bridge over the Vaal. In the present era, between the 12th and 19th centuries, Iron Age communities of Tswanas built stone-walled villages whose ruins are found everywhere in the Bergland. One of these communities at Askoppies was home to many thousands who piled their ash in mounds on the rocky slopes behind their dwellings.

The region lies at the centre of modern South African history. In July 1836, the first violent confrontation between the Matabele and the Voortrekkers took place at a small koppie overlooking the Vaal. Liebenbergkop – named after the family that died amongst its rocky outcrops – symbolises the beginning of a century and a half of racial conflict that finally culminated in the democratic settlement of the 1990s.

During two Anglo-Boer wars, in 1880-1 and 1899-1902, British armies and Boer commandos skirmished across these hilltops and kloofs. A stone fort at Boplaas marks the spot where British Tommies kept watch on Boer forces stealthily riding through the tortured and broken landscape of the Dome.

Gold was mined here, though not in rich quantities. The little village of Venterskroon was founded in 1887 after the discovery that the same gold-bearing strata from which Johannesburg drew its wealth cropped out in the Bergland too. Small-scale mining has left several tunnels in the hard quartzite but in the 1920s the effort was abandoned for lack of paydirt.

The first geologist to make a thorough study the Dome was the government surveyor Louis Taylor Nel, who took three years to compile the first geological map of the area in the 1920s. The consensus then was for a volcanic eruption rather than a meteorite impact. By the 1990s, however, scientists were convinced that widespread traces of shock in altered stone and melt seams, combined with the multi-ringed crater formation, proved that an enormous asteroid had wreaked havoc on our planet.

A chunk of space rock roared through the early atmosphere and struck our planet like a mighty cannonball. Travelling at around 20 kilometres a second, the foreign body larger than Table Mountain and measuring some 10-15km

across, punched a cavity between 30-50km deep in the Earth's crust, melting or vaporising it in a split second.

This was the largest single energy release ever to occur on the planet (at least that we can identify). It probably generated a force equal to a 100 million megaton nuclear explosion, or 100,000,000,000,000 tons of TNT, though the figure is something of a guesstimate. The blast hurled 70 000 cubic kilometres of material into the sky as so-called ejecta, some of which doubtless headed for other planets as meteorites. The rest fell back to Earth as a layer of debris while dust clouds choked the upper atmosphere for years to come.

Earthquakes, tsunamis, landslides and volcanic eruptions followed as the shockwaves travelled around the globe. The crater itself went through a rapid series of transitions in a matter of about four minutes to reach an estimated final diameter of 360km. All of this happened about 2.023 billion years ago, so long ago in fact that the original crater has been eroded to its foundations and appears smaller today. What we look at today is the deep core of the structure, at least 8km below where the original crater must have lain.

Subsurface geology is by its very nature difficult to visualise, so the Vredefort ring or structure is a kind of window into the crust. Elsewhere on Earth other large craters are either too recent or too distorted to show much of how complex craters form deep down.

The term "Dome" refers to the broad central upheaval zone, some 40km across, where the Earth's crust rebounded to fill the hole made by the explosion. The Dome is certainly not the 200 metre wide humpbacked rock that perches over the small town of Vredefort, one of many such prominent granite outcroppings that speckle the map.

Many specialists would rather use the term “Vredefort structure” to describe the whole complex of the Dome and the surrounding Witwatersrand Supergroup system. It comprises not just the upheaval feature but also a great deal of faulting, folding and fracturing arising from movements that happened before, during and after the blast.

Long before impact, the Witwatersrand system formed as lake with sedimentary strata lying evenly across a vast flat basin. The asteroid shattered the strata, upending and capsizing them in the collar zone around the crater core, and bending them down under the Earth's surface. The same sequence of strata that make up the distant ridges of the Witwatersrand are found in the Bergland, except that here they are overturned in reverse order and show all the markings of impact shock.

Today one can pick up *shattercones* (polygonal rocks streaked with fine horsetail and fir-leaf patterns) and view rock walls embedded with grey or black streaks known as *pseudotachylites* (“as if volcanic”) caused by friction and melting. *Shock deformation* of quartz crystals can be seen at microscopic level.

Until the late 1980s, most thought that a cataclysmic “cryptoexplosion” from within the Earth was the origin of Vredefort, and there is still some support for this hypothesis. Telltale clues, however, strongly favour the view that this was an exogenic event (from without) rather than an endogenic one (from within). The presence of minerals known as stishovite and coesite, which form only when quartz-rich rocks are suddenly shocked, is taken as persuasive evidence of an impact.

The Earth and other planets have always been impact targets, and during the Era of Bombardment some 3.9 billion years ago, both Earth its Moon were resurfaced by salvos of space bodies, or bolides. Comets, dusty snowballs,

splashed down in their multitudes, delivering much of the water in the seas. Flaming meteorites released colossal dust clouds and vapour plumes causing a rain of atmospheric chemicals, leading to global cooling.

The Vredefort asteroid was a relative latecomer in this scenario, but because all signs of earlier blasts have been obliterated by crustal changes and erosion, this crater remains the largest we know of. The laws of probability make it likely that large-scale impacts will occur every 50 to 100 million years.

A slightly smaller impact occurred at Chicxulub, Yucatan, much more recently, some 65 million years ago, and is thought to have wiped out the dinosaurs. Near the Dome, the presence of ancient fossilised bacterial mats, called stromatolites, shows that life was developing and it certainly survived (or we would not be here), but opinions differ about whether the Vredefort blast prodded evolution in a new direction.

The most primitive signs of life on Earth are dated around 3.7 billion years ago. Vredefort occurred just as life was undergoing transition from prokaryotic form (organisms without a cell nucleus) to eukaryotic form (single-celled or multicelled organisms). During the 1990 Meteoritic Society world congress held in Johannesburg, Professor Philip Tobias, world famous for work done on fossils, read a paper on the possibility that the energy released by Vredefort may have contributed to the transition from bacteria to more complex creatures.

While some biologists have dismissed this suggestion, the fact the blast happened during one of life's critical evolutionary phases 2 billion years ago, has ensured that the controversy remains one of many surrounding the crater.

Even the question of the crater's origins shows signs of reviving. Recently Earth scientists at Kiel University in Germany claimed that huge eruptions of

gas can take place from beneath the crust, shooting matter outwards in a “Verneshot” (named after the writer Jules Verne who suggested using a cannon to blast rockets into space).

There are divergent ideas about how and why gold is found in such fabulous quantities around the fringes of the Vredefort structure. The arguments hinge on highly technical points about rock mechanics and hydrothermal processes; suffice to say that the gold was originally laid down by ancient rivers in alluvial fans or deltas at the edge of the Witwatersrand basin, and became much more concentrated underground in later times.

What the Vredefort blast did was tilt and bury the gold ore at exceptional depths and over an enormous range. Later erosion partially revealed the strata on the glittering quartzite crests of the Witwatersrand where prospectors discovered it in 1886. The deepest mine in the world is at Tau Tona – the name means “great lion” in Sesotho – where the series of main shafts plunges more than 3.6km vertically down in one of humanity’s greatest feats of engineering.

One of the most astonishing features of the Dome is the magnetic anomaly that causes compasses to malfunction near its centre, prompting *Scientific American* to nickname it the “Bermuda Triangle” of Africa. According to nuclear geologist Rodger Hart, of the iThemba Laboratory for Accelerator Based Science in South Africa, the intense heat of the blast caused thermal remagnetisation corresponding to the palaeomagnetic pole position at the time.

For the visitor the key difficulty is actually to “see” the Dome because it is only visible as a whole from space. It takes an effort of the imagination to grasp its totality and understand its unique planetary nature. Here Earth and Space intersected for a few catastrophic moments. Quiet reflection at the Inland See

or a trip to one of the viewsites in the Bergland to gaze over the broken landscape will fill any visitor with a sense of profound awe.

Further readings

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