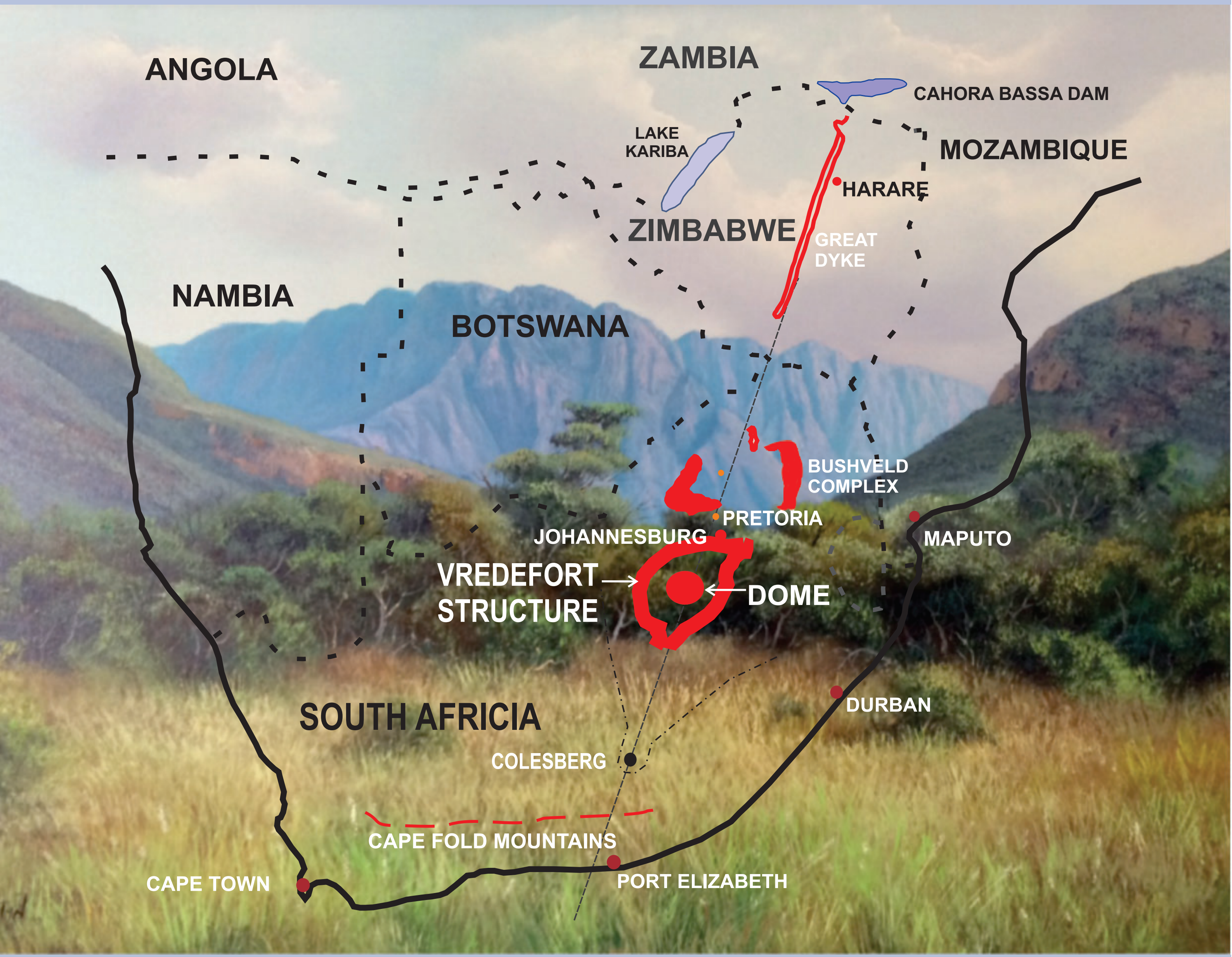
METEORITES, MINERALS AND MERENSKY



David Parkinson Howcroft

METEORITES, MINERALS AND MERENSKY

The Real Story of the Vredefort Impact Structure

Copyright David P. Howcroft South Africa 2018

ISBN: 978-0-620-79365-0

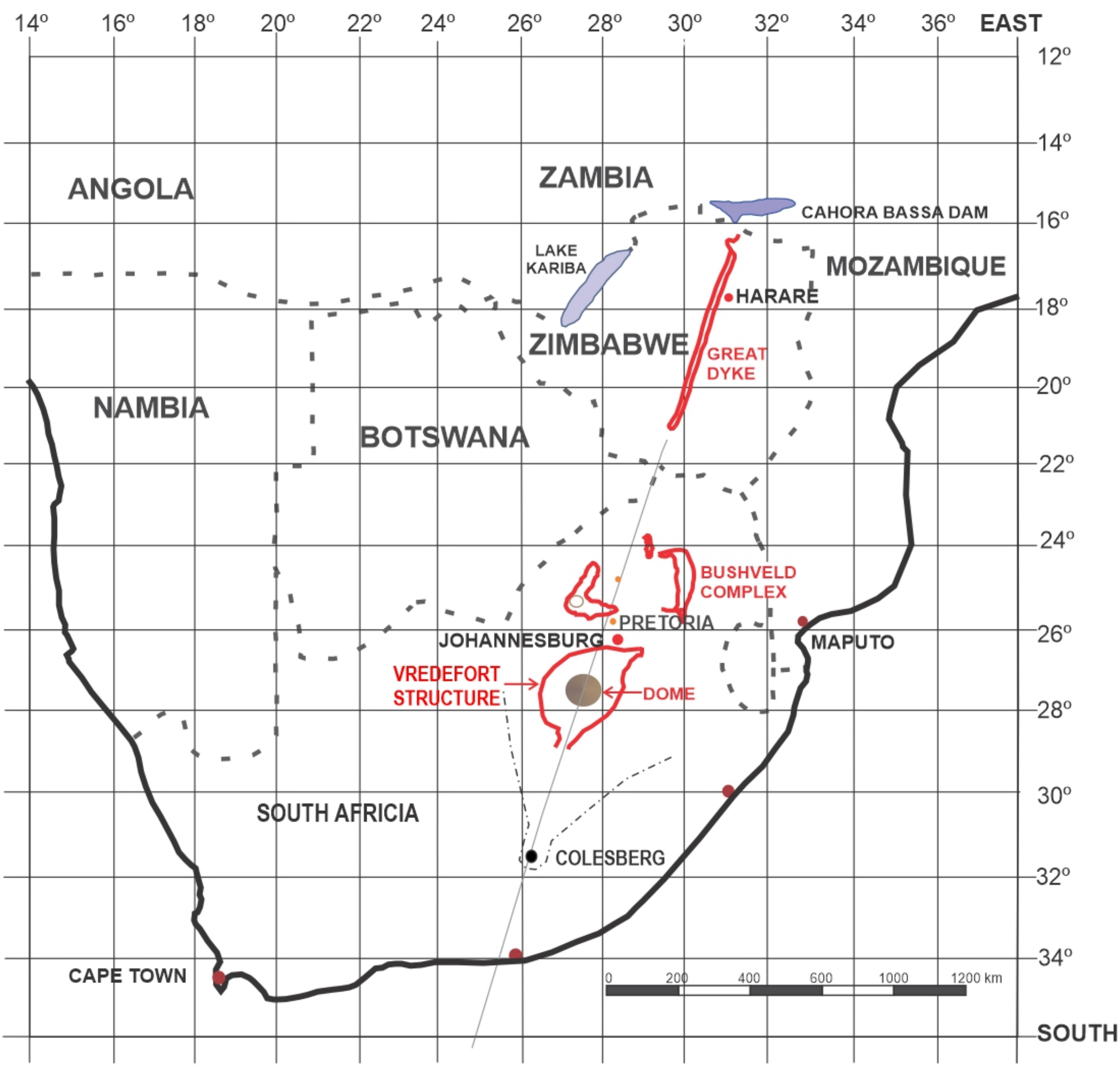
Contents

ABSTRACT

At two hundred and eighty four kilometers in diameter, the Vredefort Meteorite Structure in South Africa, with its central rebound, the Vredefort Dome, is accepted as the largest known impact site on Earth. After 100 years it is still regarded as a mystery.

Enigma: 'A person, thing or situation that is mysterious or puzzling.' (Collins Dictionary)

Radiometric dating in the core has been used to calculate the age at 2023 Ma. The nearby Bushveld Large Igneous Province, world renowned treasure chest of valuable minerals, is dated at 2054 Ma. The chrome and platinum-rich Great Dyke in Zimbabwe is dated as 2575 Ma.



LOCATION OF VREDEFORT METEORITE STRUCTURE, BUSHVELD COMPLEX AND GREAT DYKE

As a result of the multi-million year age differences, members of the geological community do not consider that these three sub-crustal structures are connected, and, with +2000 Ma dates they certainly do not accept that Vredefort, Bushveld and Great Dyke could have had anything to do with the extreme events with worldwide effects from 214 Ma onwards.

Extreme Events from 214 Ma include:

- The 214 Ma Manicouagan cluster of five impacts in northern Pangaea
- The 214 Ma Triassic-Jurassic Mass Extinction where 80% of all species on Earth were wiped out and for which no cause has yet been found
- The 204 Ma beginning of the Karoo Mantle Plume creating the Drakensberg Mountain Range and
- The 185 Ma breakup of Gondwana restarting continental drift.

My main hypotheses contend that the Vredefort Meteorite Impacts were part of a cluster that occurred in 214 Ma and were linked to:

- The 214 Ma Manicouagan Group of five meteorite impacts
- The Bushveld Complex
- The Great Dyke
- The gold lining the Vredefort Structure
- The minerals of the Bushveld Complex and Great Dyke
- The swathe of minerals across southern Africa
- The end Triassic Mass Extinction
- The Karoo Mantle Plume
- The Gondwana breakup
- The explosion of Kimberlite diamond pipes of southern Africa
- The coalfields of the Free State, Highveld, Witbank, Springbok Flats, Ellisras (Lephalale) and Mopane Limpopo.

I accept that the dating methods are accurate but contend that samples came from, or were contaminated by the Vredefort Structure rebound floor rocks and, in the case of the Bushveld Complex and Great Dyke, from the target layer of strata into which the minerals were intruded horizontally. This would account for the three separate 2 Ga ages for the same event and totally overshadow the true age of 214 Ma.

'Any hypothesis must be tested on all points of observational fact. The balance of evidence must be strongly in its favor before it is even tentatively accepted and must always being able to meet the challenge of new observations and experiments' (Patrick Hurley April 1968).

1.0 Vredefort, the world's largest meteorite impact structure (Fig. 1a)

Up until the early nineteen sixties, most believed that the 40 km diameter dome with a 20 km wide surrounding collar of upturned upper-crustal strata surrounding the small village of Vredefort, roughly 120 km south-west of Johannesburg was cryptovolcanic, that is, a 'hidden' volcano with no signs of volcanic material or prior volcanic activity (Bucher 1963)

Early in the twentieth century a geologist from Stellenbosch University had suggested a 'volcanic explosion'. He also predicted that '*When one is dealing with an extraordinary phenomenon, no possibility is too extraordinary to be worthy of consideration'* (Shand 1916). Then in 1936 two geoscientists proposed that this supposed cryptovolcanic structure could be the result of a meteorite crater with a rebound dome in the middle surrounded by rings. This would make the overall crater much larger than the 80 km central rebound. However, Vredefort still puzzled them. They said '*One hardly knew which was better - a meteoritic hypothesis without meteorites or a volcanic hypothesis without volcanics'* (Boon & Albritton 1938).

Eleven years later the well-respected Reginald Daly, Professor of Geology at Harvard backed up Boon and Albritton and added that the energy released by the large, high velocity meteorite would have been great enough to volatilise target and meteorite materials. This event would have been both explosive caused by pressure, and percussive, from the impact (Daly 1947).

Geological and geophysical data gradually began to show support for the meteorite theory. A well-known American planetary scientist wanted to prove that the Vredefort Dome was a crypto-explosive impact structure (Dietz 1961b) and suggested to a Witwatersrand University researcher, Robert Hargraves, that he look for shatter cones, sharp pointed rock chards, which he duly found. He also discovered that all the cones, in their original positions, pointed to the centre of the dome indicating that this was the source of the shockwave (Hargraves 1961). Later others found signs of shock in quartz (Carter 1965). About this time (Dence 1968) from Canada again suggested that the Vredefort Impact Structure looked like it could be a far larger complex crater with the Dome being only the remnant central ring, or rebound. Further proof of the impact structure came when crystals of coesite and stishovite were discovered. These are high pressure and temperature forms of silica that can only be derived from very extreme pressures, too high for volcanic activity (Martini 1978).

In spite of all the extraterrestrial meteorite impact validation coming through, most South African geologists still believed that the structure was volcanic in the form of a cryptoexplosion. In July 1987 the International Conference on Catastrophes in the Geological Record and Cryptoexplosion Structures was convened in Parys, a town within the dome. After many papers were presented and arguments put forward, it was voted that, based on the evidence, what was then known as the Vredefort Crater was a large complex impact structure with the Vredefort Dome being the rebound central core.

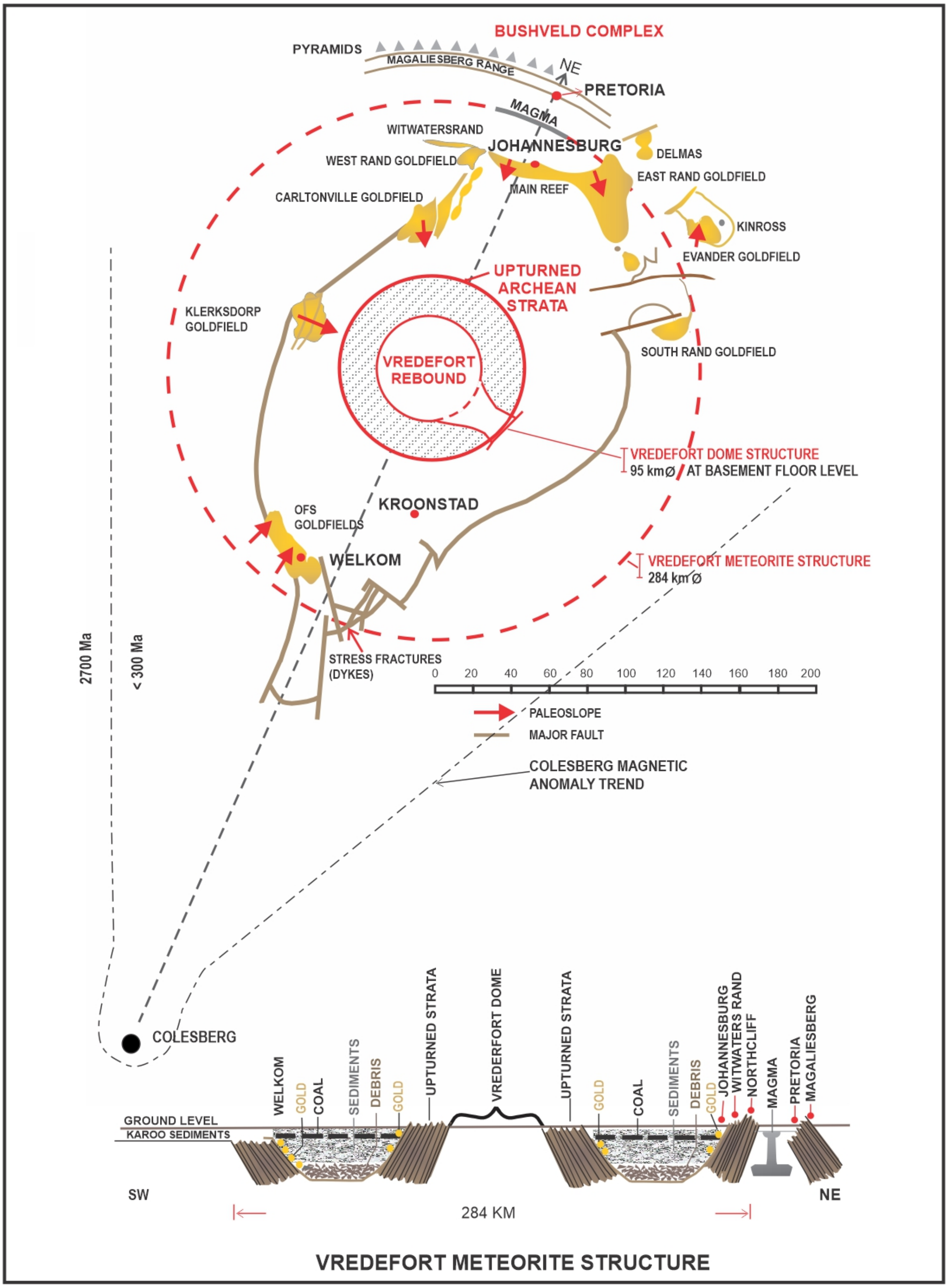
The term *Structure* in place of *Crater* was coined by two University of Witwatersrand researchers (Reimold & Gibson 1996) and I agree. This terminology is used throughout these hypotheses.

During the 1990's teams of geoscientists using various modern radiometric techniques set an age in the order of 2020 Ma for the Vredefort structure from samples taken within the Vredefort Dome (Allsop, Fitch, Miller & Reimold 1991, Kamo, Reimold, Krogh & Colliston 1996, Spray, Kelley & Reimold 1995).

Scientists had measured the present depth of the structure's floor below present sediment and debris at 15 km using seismic technology (Friese, Charlesworth & McCarthy 1995). From this others calculated that the highest point the dome reached before collapsing was 29 km (Henkel & Reimold 1996). From shatter cones the transient cavity diameter was estimated to be about 124-140 km. Making use of these values in relation to other exposed Earth and Moon craters, the outer rim was calculated to be about 270-300 km. The latest method involved estimating the diameter of the base of the rebound at floor level as 95 km and then calculating a final rim diameter of about 284 km. This would make the Vredefort Meteorite Structure the largest known meteorite impact site in the world (Therriault, Grieve & Reimold 1996).

The final crater diameter is based on the assumption that the original structure was round. However, if the gold reef lining the impact crater is linked, as I propose, then it is possible to follow a map of the Witwatersrand gold mines (Vorster 2001). The *jelly bowl* shaped crater is roughly oval in shape, 330 km long on its current south-west to north-east axis and about half that width across. At the time of the impact proposed in this article the direction of travel would have been from west to east due to Gondwana's rotational position and Earth's obliquity (Fig. 3b).

My hypothesis is that the oval shape is due to a group of three large, fractured metallic, meteorite bodies, from a larger group, impacting Earth at a very shallow angle from the current south-west (Dietz 1961) and north-east trending (Kinnaird 2005). At the meteorite's entry point, seventy kilometers south of Welkom, the outer crater rim is not visible, the fractured reefs more than a kilometre below ground (Lehmann 1959) are covered with 200 Ma Karoo sedimentation (Fig 1a). To the north-east the high, upturned, old sedimentary Pretoria Group, including Witwatersrand, Magaliesberg and Waterberg, are piled into 40-100 km wide concentric anticlines and synclines, ridges and troughs, or 'ripples'. Further, the richest reef, 41,700 tonnes of gold and 146,000 tonnes of uranium mined from 1886 to 1987 in the Central Rand Group (Pretorius 1991) through Johannesburg, is robust, exposed and unbroken. Currently the total gold mined in the Witwatersrand by 2016 was 56,000 tonnes (Chamber of Mines 2017).



The approach of a string of mountain sized fragments, equivalent to a 28 km diameter meteorite, would have been soundless and barely visible to any lifeforms until the final moments. Their entry speed, about 25 km/s, compressed the atmosphere ahead in brilliant flashes of 5000°C (Struve 1950) seconds before impacting with Earth, one behind the other, at a very shallow angle of about 5-8 degrees (see Fig. 1b & 10c). They penetrated the young overlying, 300-214 Ma strata of Karoo, Ecca and Dwyka then into the old 2700-1800 Ma strata of the Transvaal Group in the Witwatersrand Craton.

The explosions from vapourised rock pushed the floor down and lifted the roof of the gigantic chamber until it split in a ring at the 146 km transient diameter releasing a fireball of incandescent gas, containing ejecta and vapourised gold, upwards forming a 1000 km diameter superheated mushroom cloud that lasted for over two hours (Chapter 2, Table 1).

The multi-billion tonne chrome fragments, with iron and other dense metallic particles, penetrated the chamber sidewall below the Witwatersrand Ridge, melting as they went, and continued hydro-dynamically subsurface at hypervelocity >3 km/s (Dietz 1961a). In this case the entry speed was 25 km/s reducing to 3 km/s after another two hundred kilometers, forming the Bushveld Complex (Chapter 8).

Within the main Vredefort Structure chamber, this was followed several tens of seconds later (Melosh 1989) by the centre of the floor rebounding upwards and piercing the roof of remaining central sedimentary layers to form the Vredefort Dome surrounded by an upturned, and some overturned, 20 km thick collar of Pre-Cambrian rock (Dietz 1961).

Where the thick, old Transvaal Supergroup strata had been blasted off in a neat ring around the 146 km diameter transient chamber, the vertical chamber walls below began to collapse inwards then ejecting out at ballistic velocity. Slowly the remaining outer strata sheared off from the Magaliesberg in a wider ring and slumped (Turtle 2005) at 60 degrees into the crater (Whiteside, Hiemstra, Glasspool, Pretorius & Antrobus 1976) which doubled the transient diameter, the jagged north-facing rim forming a 56 km wide cliff rising 200 metres above the torn plain. Today, from the Johannesburg suburb of Northcliff there is a wonderful view where one can look 30 km northwards to the Magaliesberg Range passing across Pretoria and see the next of a row of matching, south-facing, upturned strata that I will call the first of the ripples (Fig. 6).

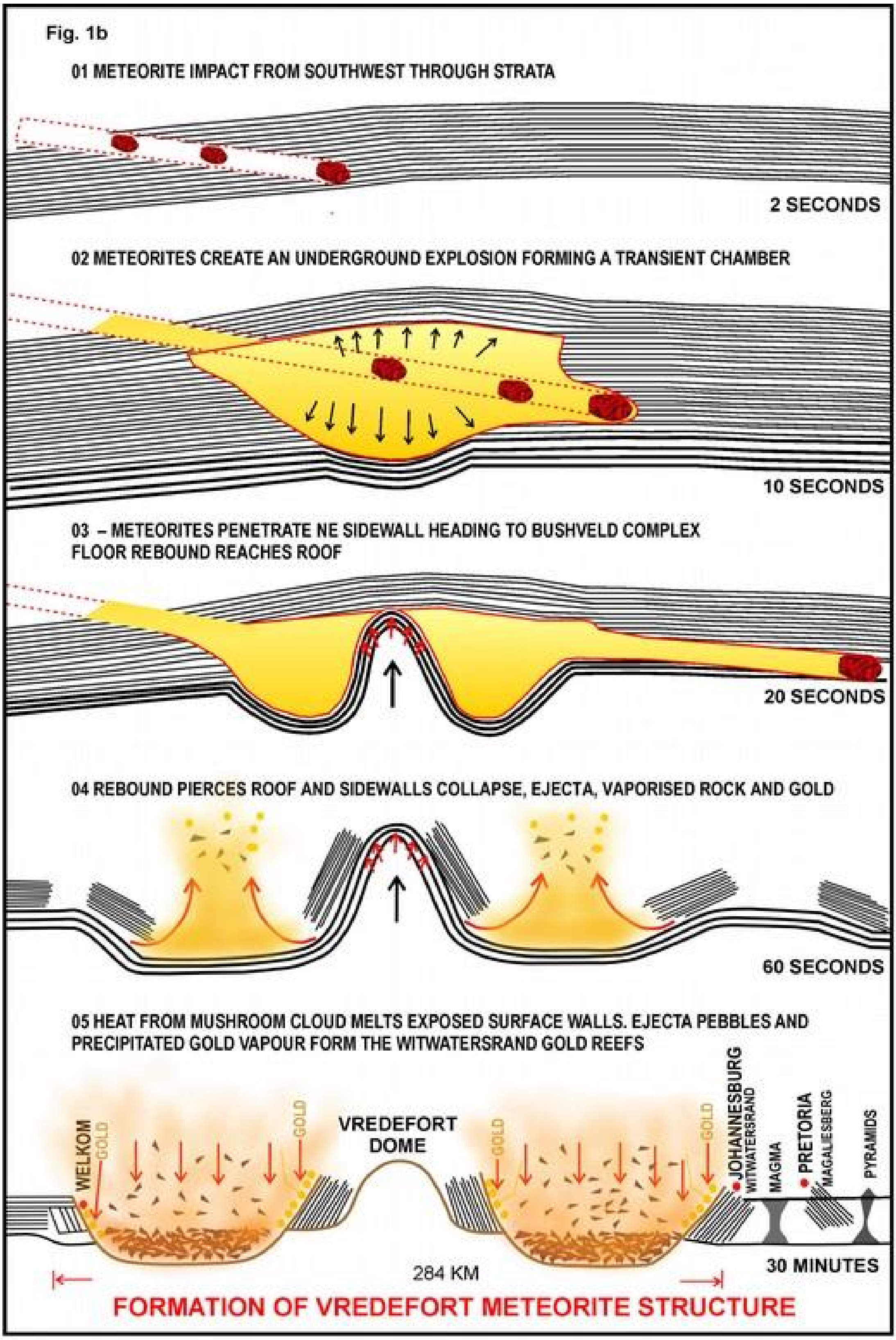


Fig. 1b
01 METEORITE IMPACT FROM SOUTHWEST THROUGH STRATA
2 SECONDS
02 METEORITES CREATE AN UNDERGROUND EXPLOSION FORMING A TRANSIENT CHAMBER
10 SECONDS
03 – METEORITES PENETRATE NE SIDEWALL HEADING TO BUSHVELD COMPLEX
FLOOR REBOUND REACHES ROOF
20 SECONDS
04 REBOUND PIERCES ROOF AND SIDEWALLS COLLAPSE, EJECTA, VAPORISED ROCK AND GOLD
60 SECONDS
05 HEAT FROM MUSHROOM CLOUD MELTS EXPOSED SURFACE WALLS. EJECTA PEBBLES AND
PRECIPITATED GOLD VAPOUR FORM THE WITWATERSRAND GOLD REEFS
WELKOM
GOLD
GOLD
VREDEFORT
DOME
GOLD
GOLD
JOHANNESBURG
WITWATERSRAND
MAGMA
PRETORIA
MAGALIESBERG
PYRAMIDS
30 MINUTES
284 KM
FORMATION OF VREDEFORT METEORITE STRUCTURE

2.0 Earth impact effects, power and forces involved

Purdue University has published an interesting Earth Impact Effects Program (Marcus, Melosh & Collins 2018). This simulator is used to calculate the size, speed and other effects of a meteorite strike (Table 1).

This is a good starting point because we have our calculated diameter of 284 km for the outer rim. Meteorite speed has been selected as 25 km/sec as '*Asteroids strike the earth at an average speed of about 25 km/second*' (Grieve 1990).

Table 1 Data calculated using the Earth Impact Effects Simulator from Purdue University.

Value	Parameter	Comment
25 km/sec	Speed Min 17-Max 40 km/s	(Grieve 1990)
28 km	Meteor (equivalent) Diameter	Adjust to get 284 km Diameter
284 km	Structure Rim Diameter	(Therriault, Grieve & Reimold 1996)
8000 kg/m^3	Meteor density	For Iron meteorite
Sedimentary	Target rock	Karoo and Transvaal Group
5 Degrees	Angle of approach	Great Dyke Figs. 1b & 10c
146 km	Transient Diameter	Earth Impact Effects Program
52 km	Transient depth	Earth Impact Effects Program
2 km	Final depth	Floor 15 km + melt & debris
44,000 km^3	Volume target vapourised	Earth Impact Effects Program
1068 km	Fireball diameter	Earth Impact Effects Program
1440 more	Radiant Energy than Sun	Earth Impact Effects Program
2.2 hours	Duration of Radiant Energy	Earth Impacts Effect Program
11.2	Earthquake Richter scale	Earth Impact Effects Program

During impact this meteorite cluster dissipated energy equivalent of 6.86 billion Megatons of TNT (Earth Impact Effects Program). By calculation this is 180 billion times greater than the combined atomic bombs dropped on Hiroshima, 15 kt, and Nagasaki, 21 kt, (Malik 1985) and 137 million times greater than the largest man-made nuclear explosion on Earth, Russia's Tsar Bomba 50 Megaton (Adamsky & Smirnov 1994).

The meteorite fragments shot through the crater in a few seconds causing a shock wave travelling at 5 km/second to compress the target rock. As the shock wave passed, the rock rebounded with a residual velocity of about one-fifth moving the target material at 1 km/second (Melosh 1989). This created the transient crater 146 km in diameter in just 73 seconds blasting high temperature ejecta out of the crater at ballistic speed.

Material below the fragmented meteorite was driven downwards and radially outwards (Dence 1968). As the transient crater reached maximum depth the floor came to a standstill and then started to rebound. The target floor rock was released from high pressure and, helped by gravity effects from fluid forces below, driving the crater floor upwards to a height of 29 km (Henkel & Reimold 1996).

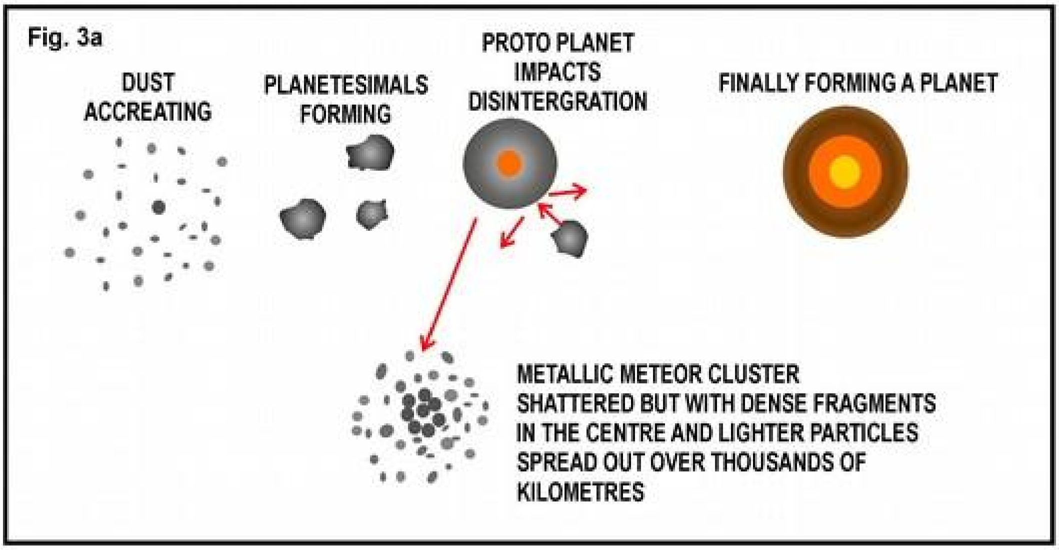
The impacts would have vapourised 44,000 cubic kilometres of the sedimentary rock and created a fireball 1068 km in diameter. If you were standing 1000 km away, where Port Elizabeth, South Africa, is today, the Thermal Radiation, 1440 times more intense than the Sun, would have incinerated you. This was followed three and a half minutes later by a seismic shock wave, with a force of 11.2 reading on the Richter scale with the resultant earthquake damaging or flattening every single structure. The air blast would arrive 50 minutes later at the speed of sound and a pressure of 50 atmospheres which would blast away any structures left standing as well as all trees (Earth Impact Effects Program).

3.0 Asteroid belt, metallic meteorites and multiple impacts (Fig. 3a)

3.1 Asteroid belt

Every day hundreds of thousands of meteors burn up in the Earth’s atmosphere, most millimetres in size (Parkes 2018). About every 100 years, one that is metres in diameter almost reaches the ground resulting in serious local damage such as that in Russia in 1947 (Struve 1950). Apollo objects, asteroids or comets whose orbits pass through the Asteroid Belt, average 1 km in diameter. They reach Earth about once in every 250,000 years leaving a 20 km diameter crater (Wetherill 1979). About every 100 million years a meteorite of more than ten kilometres in size will cause worldwide damage that could cause mass extinction. The Vredefort Meteorite cluster of planetary core material that impacted earth should be a once in Earth’s lifetime event (Marcus, Melosh & Collins 2018) and should theoretically only have occurred during planetary formation 4500-4000 Ma (Elkins-Tanton 2016).

Planetary formation started some four and a half billion years ago. Not, as has long been accepted, a gentle accumulation of dust and gasses, but a far more violent formation, with planetoids forming and then crashing together. These planetoids have even been shown to have generated enough internal heat to melt and form metallic cores as the denser materials sink to the centre. Gradually fewer and larger planetoids form, crash together and reform until one is left large enough to survive and sweep the orbit clear, absorbing the debris. This then becomes *the* planet (Fig 3a) (Elkins-Tanton 2016).



Planetary formation in the solar system was successful except for that unstable area between Mars and Jupiter where today there are more than 400,000 objects of more than one kilometre in diameter (Wetherill 1979). This is the Asteroid Belt which is left with a relatively small amount of material, the remnants of planetesimals or the remains of one or more successful planets that were later smashed to smaller particles. About 85% of the remains are chondrites, stony objects (Wetherill 1979), but some are rich in minerals which would have originated from a core. An example of this is the 226 km diameter nickel-iron asteroid known as Psyche which is expected to be visited by a NASA mission in 2021 (Elkins-Tanton 2016, Schroeder 2018).

3.2 Metallic meteorites

The relationship between meteorites and minerals is well established. For example, it is always possible to find out which rocks come from meteorites by the abnormal amounts of metal in them, such as nickel. These high density metals would not be on the surface of the newly formed, still molten Earth. Rather they would sink through the melt and travel downwards to the centre of the planet. Once there they would not return to the surface as a dropped stone would not return to the surface of a pond. After the Earth cooled and a crust formed, metals found on or near the surface have come from space as the crust prevents them from sinking to the core. Deep volcanoes or mantle plumes only have trace amounts of minerals and are mainly made up of lava, molten rock, from the Earth's mantle.

The high density metals are called siderophiles (iron lovers), as they like to join the high density iron at the core of a planet. For this reason an elevated concentration of siderophilic metals in melt rock is a good indication of meteorite activity (Alvarez & Asaro 1990). Most of the metallic elements in and around the Vredefort Structure, Bushveld Complex and the Great Dyke, including gold, chrome, platinum, PGMs, cobalt, manganese, vanadium, nickel and iron, are siderophilic.

I propose that the cluster of metal-rich meteorites which left a legacy of the world's greatest deposits of minerals could only have come from remnant core material of some long-ago shattered planet, the remains of which are now likely to form the Asteroid Belt. (Struve 1950).

3.3 Multiple impacts

It now appears that many of these asteroids are not alone on their long journeys through space. Besides the multiple Shoemaker-Levy-9 Comet impact with Jupiter in 1994, and the twin craters at Clearwater Lakes in Canada (Alvarez & Asaro 1990), geophysicists John Spray, Simon Kelley and David Rowley have discovered that five known craters stretching from Canada and the USA to France and Ukraine all have exactly the same age of 214 Ma. Three of the five craters, Manicouagan and Saint Martin in Canada and Rochechouart in France were at the same latitude, 22.8 degrees north, now forming a nearly 5000 km chain. The other two, Obolon in Ukraine and Red Wing in Minnesota lay on identical declination paths with Rochechouart and Saint Martin. This was not obvious at first but when the continental positions of North America and Europe joined together, with the position of Pangaea taken into consideration and the rotation of the Earth at that time, then it all fitted. The three main meteorite craters lined up exactly west to east and the distance between them was short enough to allow for impacts in a short space of time, within hours (Spray, Kelley & Rowley 1998, Steele 1998), or even minutes.

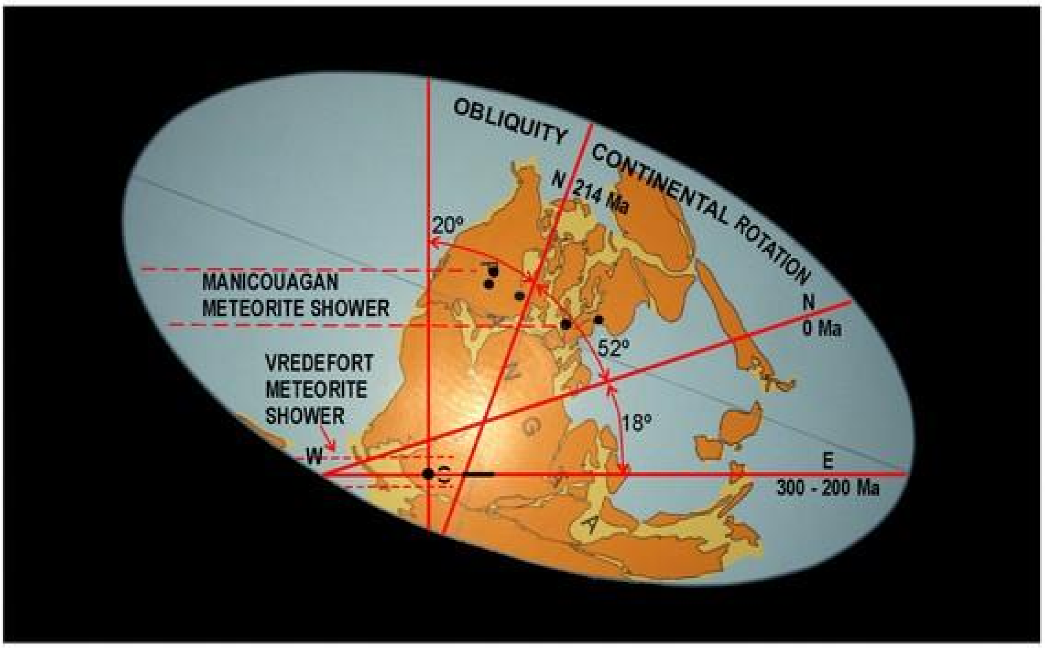
I hypothesise that the Vredefort Structure, Bushveld Complex and the Great Dyke are also the same age, created within minutes, of each other and of the Manicouagan cluster.

Between 280 Ma and 200 Ma, southern Africa was lying on its side, rotated clockwise relative to now (Hurley 1968, Veevers 2004, Moorbath 1977 & a series of graphics from the Senckenberg Museum). This positioning, combined with up to 23 degrees of obliquity (angle at which the celestial equator intercepts the ecliptic), would allow meteorites from other parts of the solar system to impact southern Africa from west to east (Fig. 3b).

At 214 Ma, Pangaea would have had North America and Eurasia joined together at the top of the continent. From west to east is exactly the same direction that the Manicouagan cluster impacted with northern Pangaea 214 Ma. In addition to this latitudinal alignment the continental maps of 300 Ma to 200 Ma indicate that Manicouagan/Rochechouart and Vredefort/Bushveld/Great Dyke were on approximately the same longitude north to south which would mean that they could all have been impacted by the same spread out cluster.

The perfect alignment for all these events in time and direction would be highly unlikely to have ever occurred before or after this period of 300 Ma to 200 Ma.

Fig. 3b



VREDEFORT METEOR PATH FROM WEST TO EAST
BETWEEN 300 AND 200 Ma

To get back to the unlikely proposition that three separate meteorites had collided with Vredefort 2020 Ma, Bushveld Complex 2055 Ma and the Great Dyke 2575 Ma then there would have been a 70% chance for each of them to have landed in the ocean, the remains never to be seen again, and very little chance that they would be metallic as 85% of meteorites are stony (Wetherill 1979). This means that of all meteorites that collide with Earth only 3.75% are terrestrial metallic impacts.

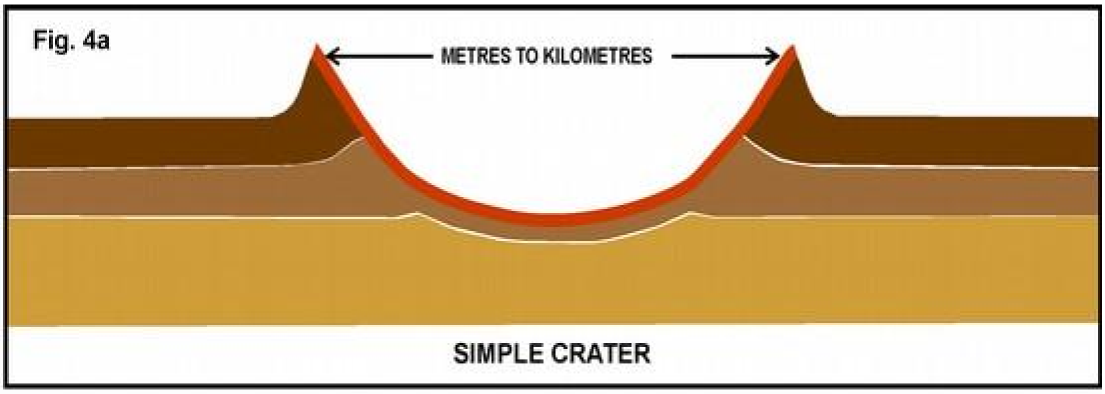
It is also unlikely that southern Africa would have been in a location and rotation on Earth to create three separate, once in a solar lifetime, events, perfectly aligned west to east as they were in 214 Ma with each other and the planetary plane.

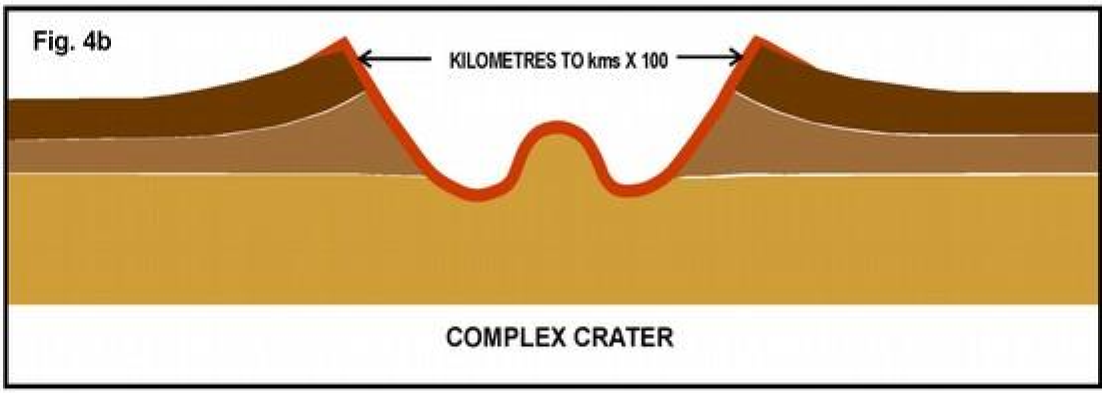
4.0 Simple, complex and 'penetrative' craters

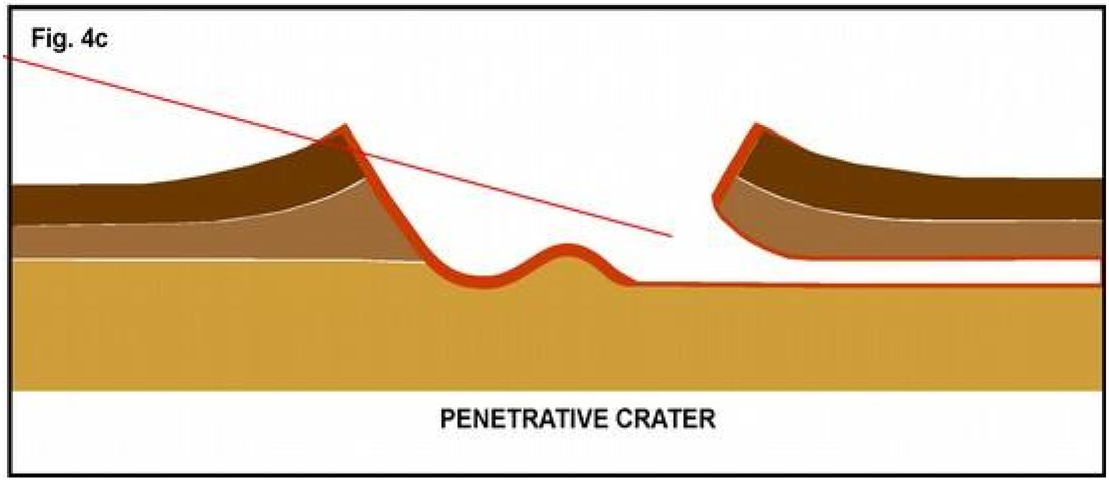
4.1 Simple meteorite crater (Fig. 4a)

If the meteorite is less than about one hundred metres across, it forms a simple crater when it collides with Earth. This impact makes a crater in the form of a bowl. The shock waves compress the target rock then the release wave melts, vaporises and blasts out ejecta; molten rock as well as debris from the meteorite itself. On Earth these craters can reach a maximum diameter of about 5 km and depth of about 1 km (Grieve 1990). The immediate or transient diameter of the crater is smaller than the final size as the steep walls slide into the cavity but the transient depth is greater as the final cavity is partially filled with debris and melt.

A well-known example of a large simple crater is the Meteor Crater (formally Barringer) in the Arizona desert in the USA. The iron meteorite was estimated to be about 60 metres in diameter, weighing a million tons and leaving a crater 1.2 km in diameter and 170 metres deep. The age of Meteor Crater is 25-50 ka and the meteor dissipated energy of about 5 mega ton TNT.







4.2 Complex meteorite crater (Fig. 4b)

When meteorites are larger than about 100 metres in diameter and travelling in excess of 20 km/sec the impact compression followed by reflected rarefaction of the shock wave excavates a transient cavity, deep enough for gravity to help rebound the centre like a stone dropped in water (Grieve 1990). With large complex craters the transient depth is deep enough to penetrate the Earth's brittle crust to an area in which plastic deformation takes place. The reflected rarefaction wave with hydraulic and gravitational effects can raise the central rebound core to great heights in seconds before it partially collapses.

After the ejecta is blasted out, the crater walls collapse and debris slides down into the newly formed jelly-bowl shaped crater. Examples of complex craters on Earth are Sudbury, Ontario, Canada, 250 km diameter, 1849 Ma and Manicouagan, Quebec, 75 km diameter, 214 Ma.

4.3 Penetrative meteorite crater (Fig. 4c)

My hypothesis is that there is a third category that should be considered. This type of crater would result from a meteorite impacting Earth at a shallow angle. If we look at the cross-section of Meteor Crater, it is seen that the meteorite impacted at an angle estimated to be about 30 degrees. One side has a higher rim and from borings made here this is found to have a deep pocket of shattered rock (Beals 1958). This profile is similar to that which we have from the Vredefort Structure with the rim 1.2 km below ground level where an asteroid plunged into the earth from the current south-west (Dietz 1961) seventy kilometers south of Welkom and a 300 metre high rim in the current north-east, Johannesburg (Fig. 1b).

Now we need to consider how it is possible for a meteorite, or fragments thereof, to penetrate 599 km below ground. The signs are that they travelled underground through the sedimentary strata from south of Welkom to beyond Polokwane and 550 km across Zimbabwe.

Firstly, they need to be metallic. Chondrites, stony meteorites, would disintegrate close to the impact zone. As the Bushveld Complex has contained nearly 6 billion tonnes of chrome, as well as all the iron and other minerals (Vorster 2001), this would make an excellent projectile. It also makes no difference that the 6 billion tonnes of chrome would become molten at some point in its journey as it has been shown that most projectiles become fluid above 3 km/second but continue to penetrate in a hydrodynamic manner (Charters 1960).

Secondly, there needs to be sufficient energy to drive this projectile for hundreds of kilometres through old, sedimentary rock. This would require mass and speed. Einstein came up with Energy is Mass times Speed squared. Think about an anti-tank projectile, roughly 700 mm x 25 mm, weighing about 6 kg. This is travelling at about 1500 m/second which can penetrate 700 mm hardened steel armour (M829A3 2016), about 28 times its diameter.

Our Vredefort projectile cluster has a mass 1000 billion times more and a speed 16 times higher. This makes the energy 256,000 billion times greater! This is certainly sufficient to drive the projectiles through the sedimentary strata for 599 kilometres. Note also that the ratio of diameter to penetration is similar, by taking the equivalent diameter of 28 km then the penetration is about 20 times its diameter. Probably more as the target material is sedimentary rock and not hardened steel. It is important to note that the distance travelled below ground for the Vredefort-Bushveld event is similar to the Great Dyke.

Examples of penetrative meteorite craters are the Vredefort Structure, 284 km diameter which is complex and penetrates a total distance of 599 km, and the Great Dyke in Zimbabwe, 550 km long, which is purely penetrative.

5.0 Continental drift, Pangaea, glaciers, coal and sedimentation (Fig 5a-e)

From 650 Ma to 500 Ma separate old continents on the Earth's crust, floating over the heavier mantle, were moving together to eventually amalgamate by 320 Ma (Veevers 2004). This supercontinent, Pangaea, with northern America, Europe and Asia to the north and Gondwana (southern Pangaea) comprising southern Africa, South America, India, Australia and Antarctica in the south. The whole supercontinent of Pangaea floated southwards positioning Gondwana within the Antarctic Circle for fourteen million years from about 302 Ma to 288 Ma (Bangert, Stollhofen, Lorenz & Armstrong 1999). During this time snow and ice built up to 4 km thick (Horton, Poulsen & Pollard 2010; Montanez & Poulsen 2013).

As Pangaea drifted north the huge expanse of ice began melting from below causing glaciers to gouge out huge areas in present day South Africa (Karoo Supergroup), South America (Parana, Argentina), Antarctica (Beacon) and eastern Australia (South Australia to Queensland) (Dineen, Fraiser & Isbell 2013). This formed a huge inland lake covering Gondwana, about six thousand kilometres in diameter. The bed of this lake was filled with glacial debris; now known in South Africa as the Dwyka Group (Hancox & Goetz 2014).

As the lake silted up from rivers, fluvial, and windswept dust, aeolian, it eventually became a huge fertile swamp with dense forests of the famous Glossopteris trees. These proliferated from 298 Ma until 252 Ma (Prevec 2011). This was a water loving tree with tongue shaped leaves that grew to thirty metres high. For roughly fifty million years these swampy jungles laid down the organic debris that became the future Natal Vryheid coalfields in South Africa as well as those in India, South America and Eastern Australia. The protected Antarctic fields are buried under thick ice once again. In South Africa these deposits became the Pietermaritzburg shale, and Vryheid Formations coal.

By 252 Ma the giant lake with its swampy jungle had silted and become dryer as Gondwana drifted northwards towards hotter climates and all the vast forests of Glossopteris died out. Intermittent floods and windborne dust buried the Natal coal under kilometres of sediments, the Ecca Group. This situation had stabilized by 214 Ma (Table 2).

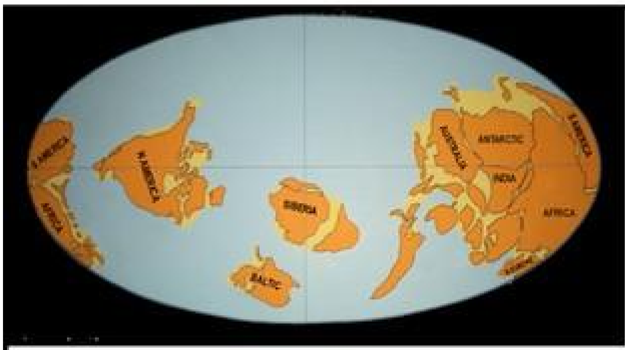


Fig. 5a

650 - 500 Ma

Continents separated and drifting.

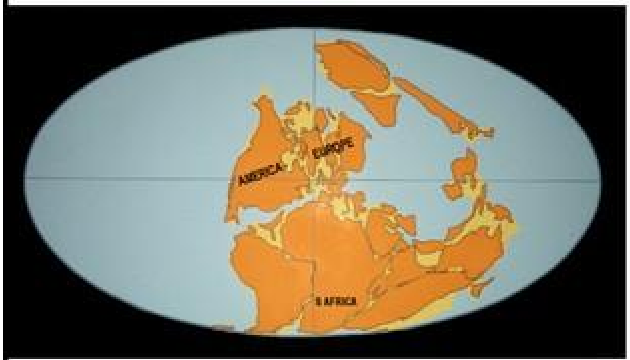


Fig. 5b

320 Ma

Continents assembling. 302 - 288 Ma Southern Gondwana frozen under 4 kms of ice.

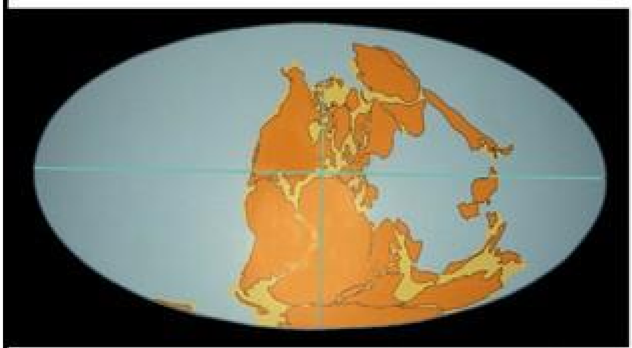


Fig. 5c

280 Ma

Pangaea drifting northwards.

Southern Africa rotated clockwise.

Fig. 5d

298 - 252 Ma

Glossopteris trees form coalfields.

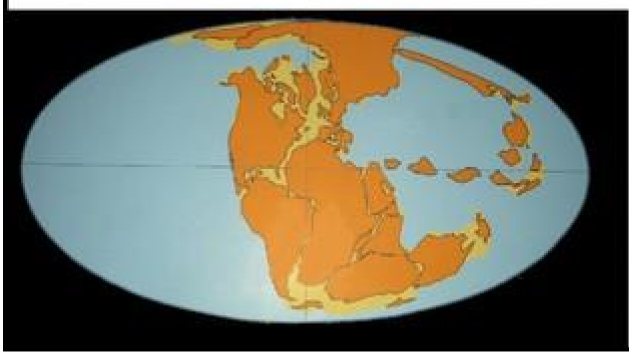


Fig. 5e

250 - 214 Ma

Coalfields buried under Ecca sedimentation prior to impacts.

Table 2 From 650 Ma until now - Continental drift, glaciation, coal & sedimentation

Age	Event	Description
650 Ma	Continental drift	Continents separate groups
500 Ma	Continental drift	Continents separate, approaching
320 Ma	Continental drift	Pangaea Supercontinent forms
302 Ma	Continental drift	Gondwana in Antarctic Circle, 4 km ice
288 Ma	Continental drift	Moving north, glaciers, Dwyka debris
298 Ma	Gondwana coal	Glossopteris forests in giant lake/swamp
252 Ma	Glossopteris extinction	Natal coal ends, Ecca sediments cover
214 Ma	Vredefort-Bushveld-Great Dyke	Catastrophic damage, mass extinctions
210 Ma	Coal Highveld-Limpopo	Crater and ripple valleys coal formation
204 Ma	Karoo Mantle Plume	Rising at 5 cm/year, spread 3000 km wide
200 Ma	Continental drift	Breakup following Karoo Mantle Plume
180 Ma	Drakensberg Mountains	Karoo area 1.5 km uplift, magma cap
145 Ma	Karoo Mantle Plume	Continents drifting away
100 Ma	Kimberlite diamonds	80 pipes surround Vredefort Structure
0 Ma	Karoo Mantle Plume	Remnant now under Marion Island

The above table shows the ages for Continental Drifting accretion, a stable Pangaea for 140 million years, the Gondwana polar excursion, glaciation, and Gondwana coal fields of South Africa, India, South America, Australia and Antarctic. Ecca sedimentation in South Africa, Vredefort-Bushveld-Great Dyke impact event, the second coal creation period in cavity and ripple valleys (Chapter 15), the Karoo Mantle Plume, uplift of Karoo and Drakensberg formation, the start of Continental breakup and current location of the Karoo Plume.

It was at 214 Ma that large parts of the platinum-rich chrome core fragments of the Vredefort meteorite created the cavity into which the sedimentary Ecca and Transvaal Group strata tilted and slumped.

We know that the glaciation event took place about 288 Ma in which 4 km thick ice would have scraped off the centre cone and outer rims of the Vredefort Structure including the ‘ripples’ if they had been there. This would also prove that the Vredefort impact took place after glaciation about 214 Ma and not 2020/2054 Ma.

6.0 The 'ripples' of upturned strata, magma dykes and caves (Fig. 6)

6.1 The ripples of upturned strata

The chrome and other minerals in the meteorite fragments did not disintegrate on impact or in the explosion under the Vredefort area. Because of their size, metallic content and the shallow angle, they penetrated parallel to the Earth's surface and travelled hundreds of kilometres underground towards the north-east in minutes. These hypervelocity penetrations would have converted some of their immense kinetic energy into heat, melting themselves and the target sedimentary rocks in seconds as pressure was converted to heat. The metal-rich fluid then ploughed on through the sub-surface creating wide waves of uplifted old strata, hundreds of metres high, in the form of *ripples*, alternating with west-east dykes of newly erupted doleritic magma (molten rock) as they went (Fig.6).

Eventually the molten projectiles lost energy, slowing down to hydraulically intrude horizontally between layers of sedimentary rock to form the basis of the Bushveld Large Igneous Province. Some of the molten mineral fragments continued past the Bushveld Complex to come to a squiggly stop north-west of Pietersburg. However, the ripples did not stop there as the tsunami-like shock waves and magma below the hard crust radiated outwards to the north thrusting up more mountain ranges as they went.

The first ripple is the north-eastern outer rim of the meteorite crater. This is the Witwatersrand Ridge, stretching 56 km from Krugersdorp in the west through Johannesburg (Northcliff) to Bedfordview in the east with sedimentary slabs, jagged on edge, facing north and sloping steeply back. The additional 100 km wide ripples that spread outwards through the crust to the north left us with the south facing Magaliesberg, Waterberg, Strydpoortberge, Soutpansberg and Lebombo mountain ranges. The distance from Vredefort to the Witwatersrand Ridge is roughly 120 km, then 65km to Magaliesberg, 105 km to Waterberg, 120 km to Strydpoortberg, 175 km to Soutpansberg and 350 km to Lebombo Mountains.

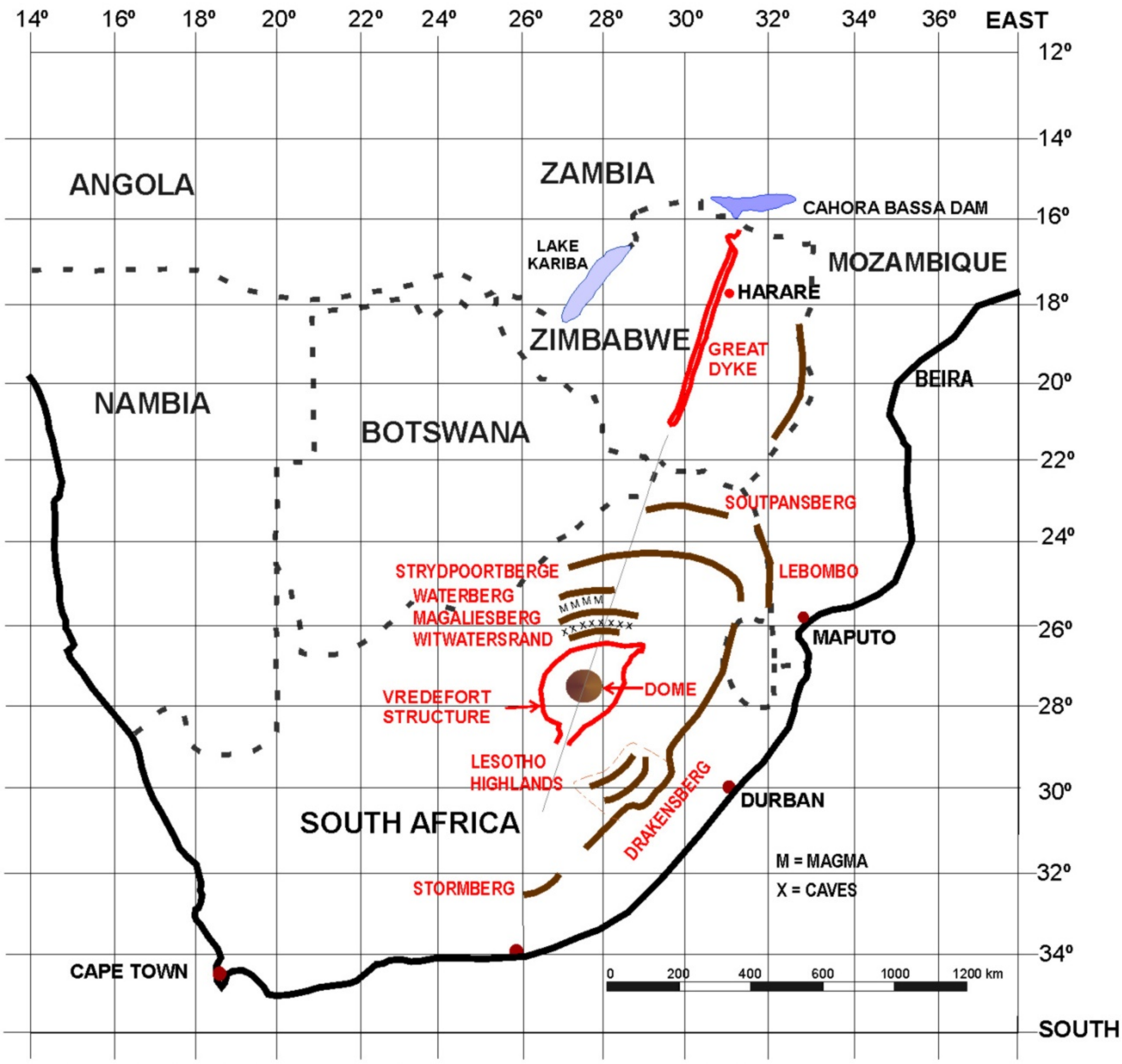
6.2 Magma dykes

Midway from Johannesburg to Pretoria, between the Witwatersrand and Magaliesberg ranges is a twenty kilometre wide west-east seam of hard, blue, igneous, dolerite rock which is mined in huge quarries at Diepsloot and Midrand for crusher stone to make concrete or surface roads.

Beyond Pretoria, on the N1 you can turn west on the N4 route along the valley floor north of the Magaliesberg Range. Here you will follow a 100 km long string of pyramid shaped hills stretching all the way past Rustenburg. These pointed hills contain the sought after Pyramid Gabbronorite; a dark-coloured inverted pigeonite bearing gabbronorite. This is commonly known as Impala black marble. The Reserve Bank building in Pretoria is clad with this product.

In the village of Pyramid on the R101 route you can see a hundred metre high cross-section in a rock quarry showing slabs of sedimentary rock that were lifted up by the magma.

Fig. 6 THE 'RIPPLES'



MOUNTAIN RANGES RADIATING OUT FROM THE VREDEFORT STRUCTURE

6.3 Caves

The shock wave from the meteorite impact radiated outward, compressing the underground sedimentary strata. This was followed by a rebound that can tear rock apart to form massive cave systems. Signs of these remain in long valleys alongside the Witwatersrand Ridge, most of them now flooded. This aquifer stretches from the town of Springs, east of Johannesburg to Botswana in the west. The water stored is about the same as contained in Lake Kariba (Turton 2012), an amount of 181 cubic kilometres (World Bank 2018).

Until 1938 when the Vaal Dam was built, Rand Water pumped its utility supply for Johannesburg out of this aquifer at Zuurbekom, near Lenasia. Mines to the west of Johannesburg could only sink shafts after the development of cementation in 1925 to get through these flooded caves and others have had to pump hundreds of thousands of tons of a cement-minedump-sand mix into the caves to control flooding.

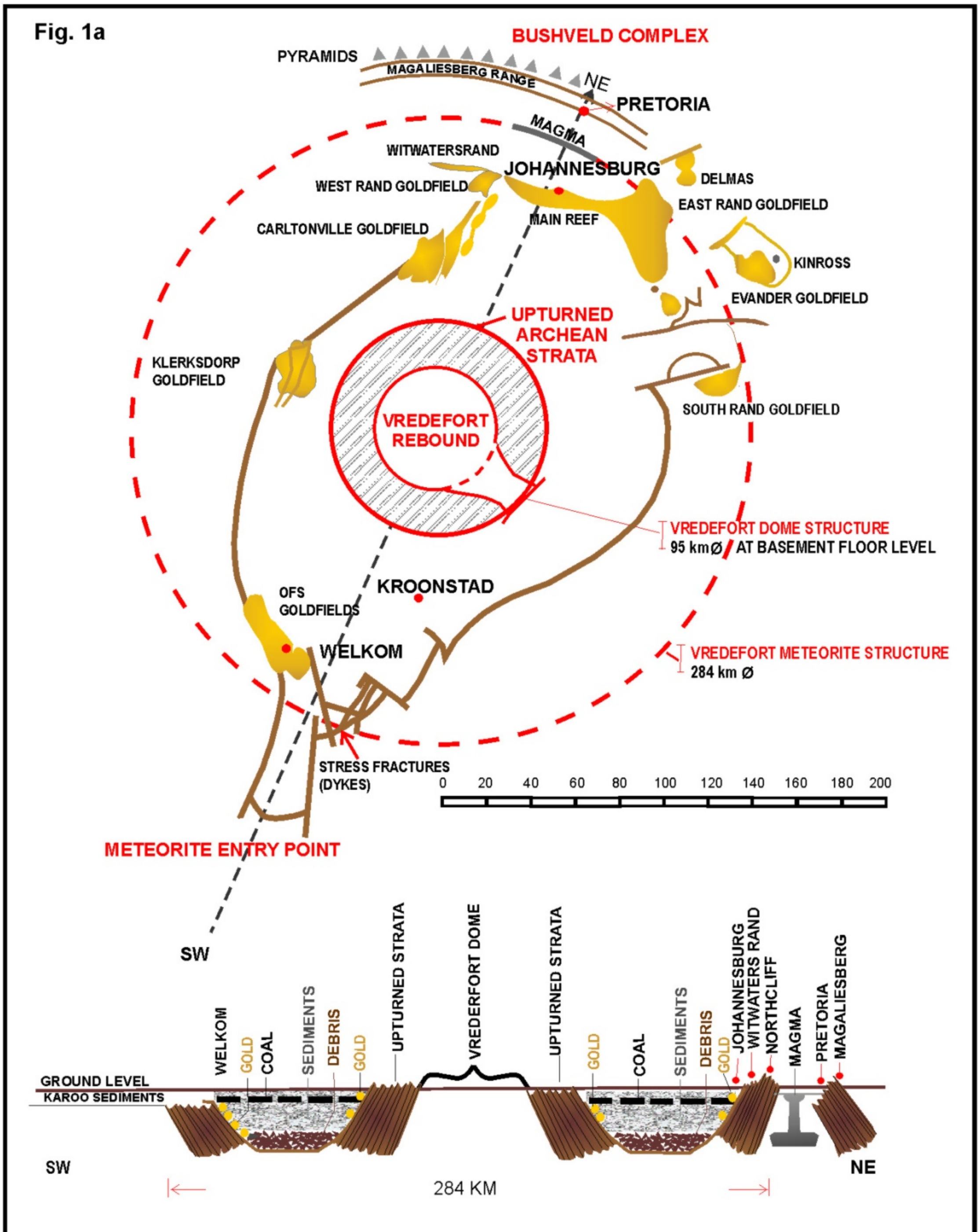
To the west, sinkholes are a huge problem, even swallowing an entire mine reduction plant in 1962 at West Driefontein with the loss of 29 lives and a house with the entire Oosthuizen family at Blyvooruitzig in 1964.

A team from the University of Johannesburg has now examined the recently discovered Armageddon Cave, 4 km long, 50 m wide and 260 m deep in the West Rand area, that has not flooded. Researcher, Pedro Boshoff says that the shock waves would have compressed the strata along the Witwatersrand and then suddenly released causing low angle slip faults with rock layers shearing past each other. He has made the connection with the Vredefort impact and therefore concludes that this giant cave is 2023 million years old which would make it the oldest cave on Earth by far (Tucker 2015). The previous oldest is the Jenolan Caves in the Blue Mountains to the west of Sydney, Australia, which is dated at 340 Ma (Armstrong and Osborne 2007).

The problem with Armageddon being dated at 2023 Ma is that the area where all these caves occur was below 4 km of ice during the period 302-288 Ma (Bangert 1999) when Gondwana was over the South Pole. If this did not collapse the caves, the following glaciers that scraped off the surface and left the Dwyka debris would have. This would mean that the caves have to be younger than 288 Ma. . If the Vredefort Meteorite struck the ground after the glaciers and the Ecca strata had been formed, then the age of 214 Ma makes more sense.

7.0 Witwatersrand basin, worlds' largest deposits of gold (Fig. 1a)

The almost 300 km diameter Vredefort Structure rim is surrounded on all sides except the south-east by the world's largest accumulation of gold mines. This can be seen on the Geoscience Gold map (Vorster 2001). One hundred and thirty years of mining from the Witwatersrand goldfields has produced more than half of the worlds' gold, over 56,000 tons (Chamber of Mines 2017). They still have the largest reserves in the world although current levels of newly mined gold accounts for only 5% of worldwide production. Now that the deepest mines are below 4 kilometres, the costs of mining limit the depth of gold extraction.



VREDEFORT METEORITE STRUCTURE

Within the Vredefort Impact Structure, gold, mainly as fine particles less than 0.5 mm, is found embedded with 25 mm round translucent pebbles in a matrix of quartz (Whiteside, et al. 1976). This is associated with the entire structure cavity excluding the interior of the rebound at Vredefort itself. The gold reef lies on the inside of the Vredefort Structure cavity, sloping at about 60 degrees to the south at the surface of the Main Reef in the vicinity of Johannesburg, decreasing to about 15 degrees at a depth of three kilometres (Whiteside, et al. 1976). The walls of the entire original 'jelly bowl' from Welkom to Klerksdorp to Johannesburg and Springs are lined with fine gold It is probable that the original floor at 15 km deep is also lined with gold as this metal occurs on some of the outside wall of the remnant rebound core (Vorster 2001).

When the meteor cluster penetrated the Earth's atmosphere at a shallow angle from the current south-east, the smaller fragments of gold were already heated from friction. After penetrating the Earth with other larger, higher melting point minerals they melted first and were vapourised with the underlying strata forming a huge underground chamber as described above. When the roof of this chamber collapsed in a ring at the edge of the transient cavity the vapourised gold was blasted out with other shattered rock and ejecta. The rebound lifted the supracrustal strata forming an upturned collar around the dome and, as the transient wall collapsed, the outer ring of strata slumped into the newly formed crater (Fig. 1b).

Minutes after the crater formation, the ring of fire, with its mushroom cloud and radiant energy, 1400 times greater than received from the sun, melted all the exposed, steeply angled strata surfaces lining the crater, turning silica rock into molten quartz. A shower of hot ejecta pebbles rolled into this melt combined with fine grains of precipitated gold to become imbedded, forming the Witwatersrand Gold Reef, the richest in the world.

An example of metals precipitating after impact is Meteor Crater in Arizona where an engineer, Daniel M. Barringer, searched for nickel and iron under the crater floor without success (Barringer 1964). However, a geologist, Harvey Nininger, discovered fine particles, less than one millimetre in diameter, of nickel and iron in the surrounding area that had precipitated out of a cloud of vapourised metal (Nininger 1949). This was estimated to total between 10,000 to 15,000 tonne.

In South Africa some of the vapourised gold was deflected to the north and north-east by the remains of the surge wave from the initial explosion causing fine particles to rain down in the Mpumalanga and Limpopo provinces as well as north into Zimbabwe. To this day you can still find Zimbabweans panning for those small specks of gold in the streams. It is well known historically that this area was a great source of surface and alluvial gold that was exported via the Mozambique coast by Arab and then Portuguese traders. Hans Merensky's missionary/mapmaker father located the area of the lost city, Great Zimbabwe, by reading tales passed on to early Portuguese Captains (Lehmann 1959). This great stone complex was known as a gold trading centre from 700 to 1100 AD (Gayre of Gayre 1972).

Geologists still write about gold that was placed in reefs on the walls of the Witwatersrand Basin Lake by age old river deltas as paleoplacer deposits or welled up out of the crust as hydrothermal deposits (Pretorius 1991; Therriault, Grieve & Reimold 1996). Pretorius also said that the long held belief that the source of gold and uranium from the very old greenstone granite was not possible as the mineral composition was not the same and there was just not enough to be a source of the rich Witwatersrand Gold Reef.

I believe that the reason for overlooking a meteoritic source of gold was that until about 1960 the Vredefort Dome was considered to be the full size of the meteorite crater. Such a simple crater did not match up with the Witwatersrand Gold Reef and therefore could not be considered. No one has returned to the enlarged complex crater to examine why the gold coats the inner walls of the rim as well as the outer walls of the rebound in such a rich, uniform manner.

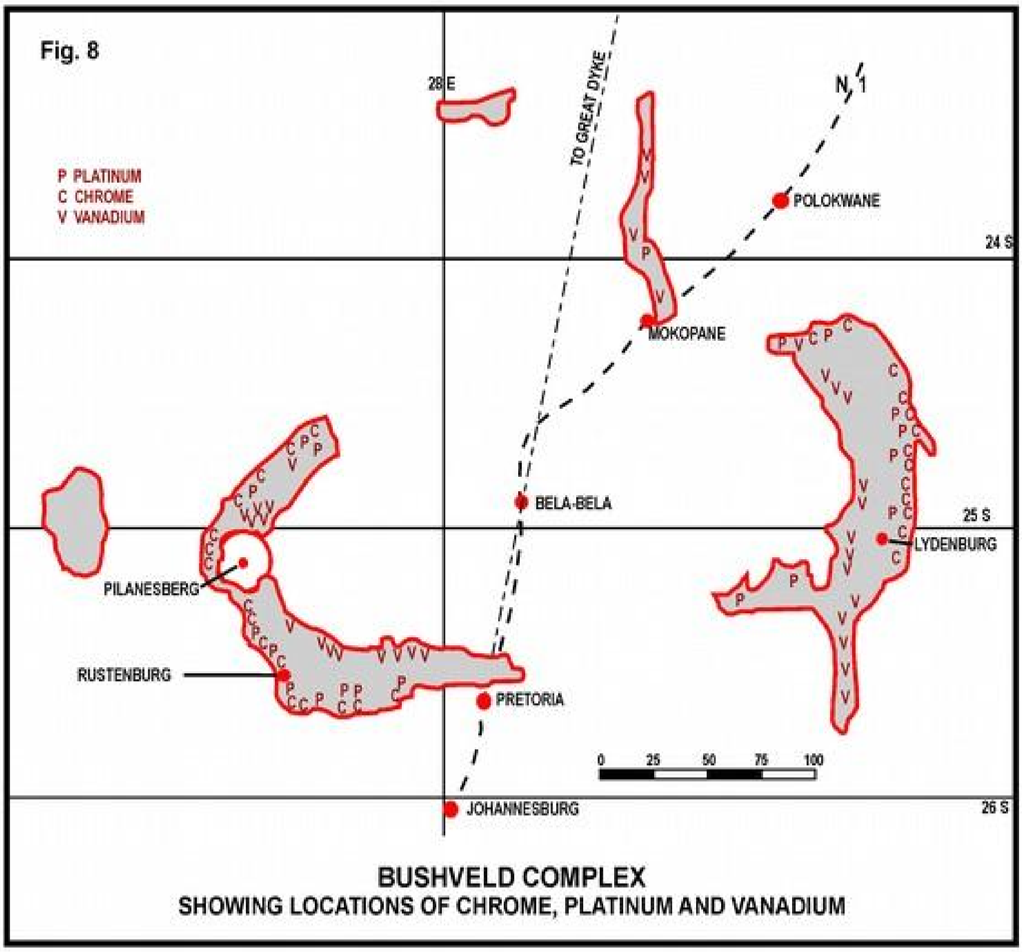
I propose that the gold came from core particles of the Vredefort Meteor cluster. This gold came with the chrome-platinum-mineral rich meteorite fragments that had penetrated under Vredefort. The kilometer's thick Transvaal Group strata slumped into the crater at 60 degrees, forming a new wall, the surface of which melted in the extreme heat from the fireball. Some of the quartz ejecta pebbles tumbled down the steep sides until they became imbedded in the molten walls with minute particles of precipitation from vapourised gold. Millions of years of sedimentation followed by coal formation and then more sedimentation topped up the remnant crater (Chapter 15).

8.0 Bushveld Complex, world's largest deposits, chrome, platinum, PGMs, vanadium, vermiculite & andalusite (Fig. 8)

The Bushveld Large Igneous Province (LIP) begins about 200 km north-east of the Vredefort Dome and is the largest layered igneous intrusion in the world. This comprises massive crustal emplacements of intrusive rock with high levels of magnesium and iron (Coffin & Eldholm 1994) which solidified without erupting through the Earth's surface. It is more than 60,000 square kilometers in size and is estimated to contain over one million cubic kilometers of intruded rock. There are two crescent-shaped 'brackets' of dark, mineral-rich mafic rock, to the west and east, which lie on either side of the current north-east trending line from the centre of the Vredefort Structure to the Great Dyke in Zimbabwe.

Geologists suggested that during the Bushveld event the old craton was extended and then compressed in a south-west to north-east direction (Gibson & Stevens 1998). This would correspond to a meteoritic projectile penetrating through this area, one tongue shaped extension continued before coming to a squiggly stop past Potgietersrus Platinum Mine north-west of Polokwane.

The Bushveld Complex is not the result of a direct meteorite strike from above as no signs of shock-metamorphic effects associated with this type of event have been found. No shatter cones, no planer deformation features (PDFs) in quartz or zircon, no impact melt and no melt-rich fragmented breccia. There is also no deformation of the floor strata below the Rooiberg Group that would be associated with a direct impact (French 1990).



It has been suggested that the source of minerals in the Bushveld Complex could be plume related following a large meteorite impact (Rhodes 1975). This is unlikely as mantle materials do not contain large concentrated amounts of siderophilic minerals (Alvarez & Asaro, 1990) such as six billion tonnes of chromite plus large quantities of iron, manganese and other minerals. It is more likely that the large volume of high temperature magma which arrived after the minerals, accumulated in the centre of the ring-shaped complex, splitting it. This could convert the dark, mafic rock into lighter coloured felsic (Tackley 2017). This later intrusion, which could also have come many millions of years later directly from the Karoo Mantle Plume as felsic magma, would split the initial ring shape, spreading the Complex apart into its present form.

My hypothesis here is that as the mineral-rich Bushveld Complex is not volcanic (Kinnaird 2005) or the result of direct meteorite impacts (Reimold & Koeberl 2014) and it was intruded horizontally (Kinnaird 2005), we need to look at a side penetration of a hydrodynamic nature. The intrusion would have come from molten particles of the Vredefort Meteorite. The initial multi-kilometre sized meteorite fragments, containing about 6 billion tonnes of chrome (Vorster 2001) and other minerals travelling at 25 km/second before impact, slowed down progressively over a few minutes.

In this time, even though these projectiles became fluid, they forced their way, hydrodynamically, one behind the other at hypervelocity, not less than 3 km/second, in enormous, pulses of hydraulic shock (Charters 1960). They parted the layers of horizontal strata for hundreds of kilometres, creating waves of mountain ridges, before coming to a stop. These would have been at a lower energy level by the time they reached the Bushveld Complex and would have resulted in the absence of meteorite impact indications (French 1990, Reimold & Koeberl 2014) but still allowed hot magma high in chrome, iron, magnetite and other minerals to intrude.

As this horizontal intrusion slowed down under the middle of the Bushveld Complex, most of the mineral-rich molten magma would begin to spread out pushing into existing 2054 Ma layers within the Pretoria Group, raising younger layers and the Rooiberg strata above that. The high density, high pressure fluid would lift layers from the bottom and intrude to about 75 kilometres out from this central point. As each layer was filling so another layer of sedimentary rock above would part and the next intrusion would begin. As the intrusion was relatively thin, heat could be dissipated in the enveloping layers of strata causing it to cool quickly and end abruptly. The formation of pigeonite, Impala Black Marble, at about 900 degrees Celsius confirms that the magma had cooled quickly during the side intrusion process.

Regarding the age of the Bushveld complex it is said that in spite of being about 2055 Ma it is undeformed (Kinnaird 2005). In other words, it does not look its' age.

When the geoscientists wanted to get this date, they determined the age of rocks in layers of strata pre and post-dating the intrusions of the Bushveld Complex. This indicated a date of 2054 Ma (Scoates & Friedman 2008). Minerals cannot be dated so they dated the rocks below and above the Merensky Reef at 2054 Ma.

If, however the Merensky Reef was intruded from the side horizontally at a depth that matched a layer of 2054 million year old existing rocks in the Pretoria Group strata then Scoates & Friedman and all the others were measuring the age of the local rock in the layers of the strata that existed before the meteorite strike. There is no reason that the minerals in the Merensky and other reefs could not have been intruded there 214 Ma or any time from 2054 Ma until now. It is simply by chance that the physical depth of the horizontal Bushveld Complex intrusions matches the age of the existing strata at that depth (see Table 3).

Table 3 Bushveld complex sedimentary strata (Walraven & Martini 1994)

Age of existing strata	Name of strata
2000-1800 Ma	Rooiberg Group
2054-2000 Ma	Pretoria Group
2054 Ma:	←←←← 214 Ma Bushveld side intrusion
2230-2054 Ma	Pretoria Group
2500-2100 Ma:	Transvaal Supergroup
2700-2500 Ma	Kaapvaal Craton
3000-2700 Ma:	Swazian

There is another point to make in the measurement of age for the Bushveld Complex. By dating the layers of strata to infer the age of the intrusion, various dates have been calculated depending on the site locality. Hence we see in two articles on the Bushveld Complex (Walraven & Martini 1994 and Kinnaird 2005) a spread of ages listed of up to ±48 million years. This is not possible for an event that took place in a short period of geological time (Harmer & Armstrong, 2000) and 'a time span of a few million years' (Kinnaird 2005).

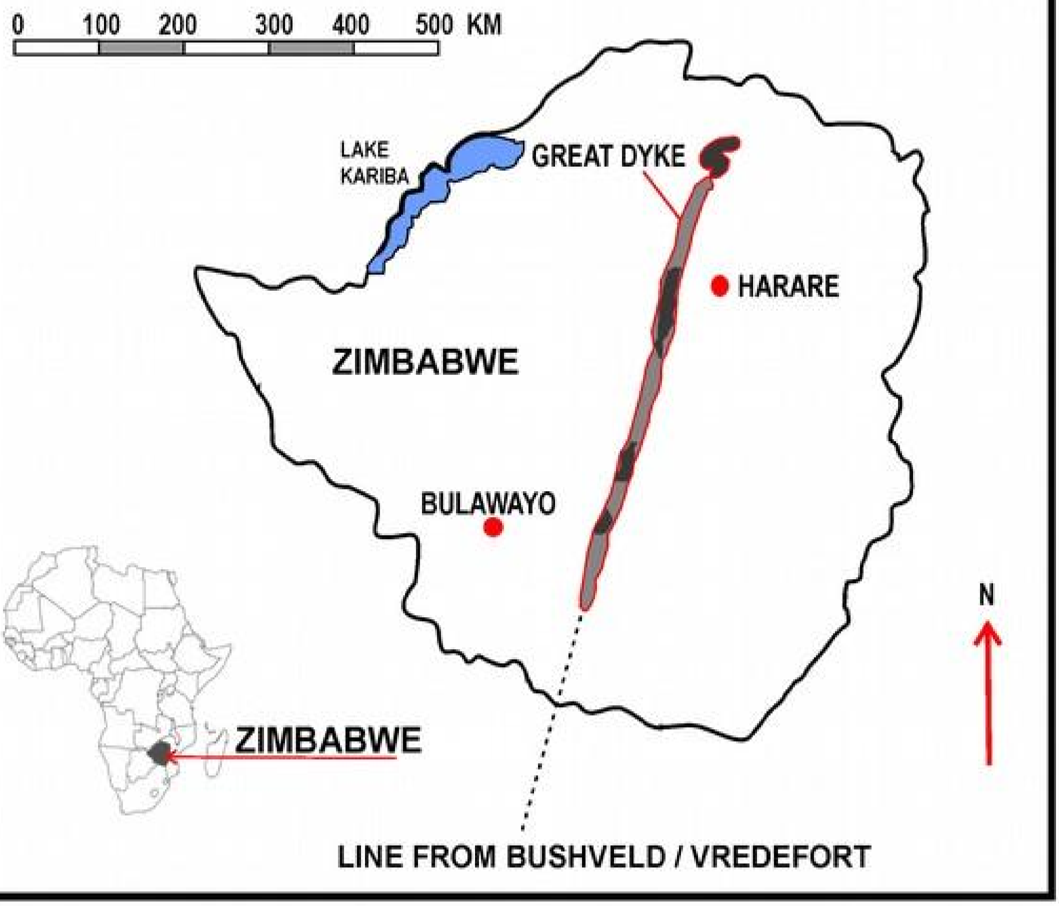
I contend that 214 million years ago, large semi-continuous pulses of mineral-rich chrome core material from Vredefort Meteorite particles, travelling hundreds of kilometres a few kilometres below the surface, came to rest in the Pretoria Group (of the Transvaal Supergroup) at a depth that corresponded to an age of 2054 Ma. Incorrectly the layer of strata is being dated and not the projectile that penetrated the strata from the side.

9.0 The Great Dyke of Zimbabwe (Fig. 9)

I hypothesise that the Great Dyke is an anachronism for a straight, 550 km long astrobleme, the word coined by Robert Dietz for an ancient scar left in the Earth's crust by a huge meteorite (Dietz 1961a) and that it was caused by an independent mineral fragment of the Vredefort Meteor Shower.

Its lopolithic, Y-shaped cross section, gouge scars the top of the old Zimbabwe Craton. Satellite pictures and terrain maps of the Great Dyke show that the direction started in a straight line from the current southwest and ended in a swirly question mark at the higher north-eastern end as it ran out of directional speed. Imagine a single large underground nuclear explosion that could make a cavity that looks like the Kimberley Big Hole. Then imagine a multi-million tonne high-chrome projectile with the energy of millions of nuclear-sized explosions ploughing through the layered crust about a kilometer or so below the surface at an entry speed of 25 km/second. The Y-shaped cross-section is from the hypervelocity, subterranean penetration that 'zipped' through the existing rock strata horizontally, the whole process was over in less than a minute.

Fig. 9



How could the meteorite travel 550 km and maintain the same level below ground? Consider that the sedimentary target layers were relatively undisturbed, still lying horizontally. The large meteorite fragment entering almost parallel to the ground (Fig.10c), near Tod's Guesthouse on the Beit Bridge-Bulawayo Road, would hydrodynamically follow the weaker joints between the layers of strata, blasting off the roof explosively. This would result in the continuous Y-profile, and shedding off its own mineral layers, staying at that level until eventually coming to a stop. The un-deformed structure of the Great Dyke shows that the thick, old Zimbabwe Craton was stable when the intrusion occurred.

One might wonder why the Great Dyke is a gouge of approximately the same depth parallel to the Earth for 550 km whilst the fragments from the Vredefort Meteorite penetrated much deeper, causing an underground explosion, before continuing on to the Bushveld Complex. The reason for that is the curvature of the Earth. Before impact the shattered fragments were spread out across many thousands of kilometres even though they all came from the same direction. Some of the chrome particles located lower in the group relative to the target would impact south of Welkom whilst others, higher up, would be 'over the horizon' and only just skim the ground. The difference in inclination is about 5-8 degrees depending on where the Vredefort Meteorites first penetrated (Figs. 10b, c & d).

This Great Dyke 3–12 km wide gouge has near horizontal sills of igneous ultramafic layers. The ferromagnesian rock includes large amounts of chrome and platinum and also contains economic amounts of nickel, copper, gold and platinum group metals. In fact the mineral composition and grades match the Merensky Reef in the Bushveld Complex closely except for large quantities of asbestos which make mineral recovery difficult.

The similarity of the Great Dyke with the Bushveld Igneous Complex is striking.

- Firstly, the horizontal intrusive layering of sills is indicative of a formation that was not volcanic
- Secondly, the minerals contained in the magma are similar to those of the Merensky Reef which means it is likely that they were derived from similar chrome and platinum-rich metallic particles of the same extra-terrestrial source
- The third similarity is the distance that the platinum-rich chrome fragments travelled below ground level. The Great Dyke is 550 km long across Zimbabwe and the Vredefort/Bushveld fragments penetrated from south of Welkom to north-west of Polokwane, about 599 km.
- Both trails end with a 'squiggle' which one would expect from a projectile slowing down and losing forward momentum
- The fifth interesting observation that connects the three events is that the straight–line scar of the Great Dyke is in the same direction and path as the current southwest–northeast trending impact of the Vredefort Meteorite. In fact, on a large-scale map you can draw a straight line from the meteorite entry scar 70 km south of Welkom, through the centre of the Vredefort Dome, through the highest point of the Witwatersrand Ridge at Northcliff, through the middle of the Bushveld Complex near Bela-Bela, pass over the South African border at Pontdrif, and line up precisely with the Great Dyke! Maps for Southern Africa and the latest for Zimbabwe, which shows background terrain, are useful for seeing the Great Dyke and above alignment (Map Studio 2015).

On maps of today's era we see this line from the Vredefort Dome to the Bushveld Complex to the Great Dyke in a southwest to northeast direction. If the Vredefort Meteor shower was the remains of a shattered planet or forming planetoid, possibly from the asteroid belt, we would expect it to approach on the planetary plane, from west to east. As explained in Chapter 3.0 the direction of this line in 214 Ma would have been west to east due to the rotational position of Gondwana and the obliquity of our planet Earth.

Now, let us look at the age estimation of the Great Dyke. The Dyke lies within the Zimbabwe Craton and has been dated at 2.575 billion years old (Oberthuer, Davis, Blenkinsop & Hoehndorf 2002). However the target rock of Zimbabwe Craton is aged from 2.8 to 2.5 Ga (Dirks & Jesma 2002). This means that the age given for the dyke is about the same as 25% down into the craton strata.

If the core material of a metallic meteorite consists of elements that cannot be aged, the age measurement will come from material in the magma derived from the target rock. It is presumed that the age measurement will be reset to zero during the melting or solidifying process. This does not always happen as a result of meteorite strikes (Taylor 2018). Therefore, for the same reason that the age of the Bushveld Complex was aged by the strata layer in which the projectile is imbedded, so it is with the Great Dyke. As the meteorite fragment entered from the side into a strata layer of 2575 Ma its age could be anything from that till now. I believe that it was 214 Ma.

10.0 The swathe of minerals south-west to north-east (Fig. 10a & 10b,c,d)

Not only do we have Vredefort Meteorite Structure with its gold lining, the Bushveld Complex and Great Dyke in an exact line with chrome, platinum, PGMs, gold, nickel, vanadium and asbestos, but there are large mineral deposits from 1000 km to the south-west and 1000 km to the north-east of the Vredefort Structure. This 800 km wide swathe of world leading economically viable minerals stretches from O'Okiep Copper District in the Northern Cape to the Copperbelt in Zambia.

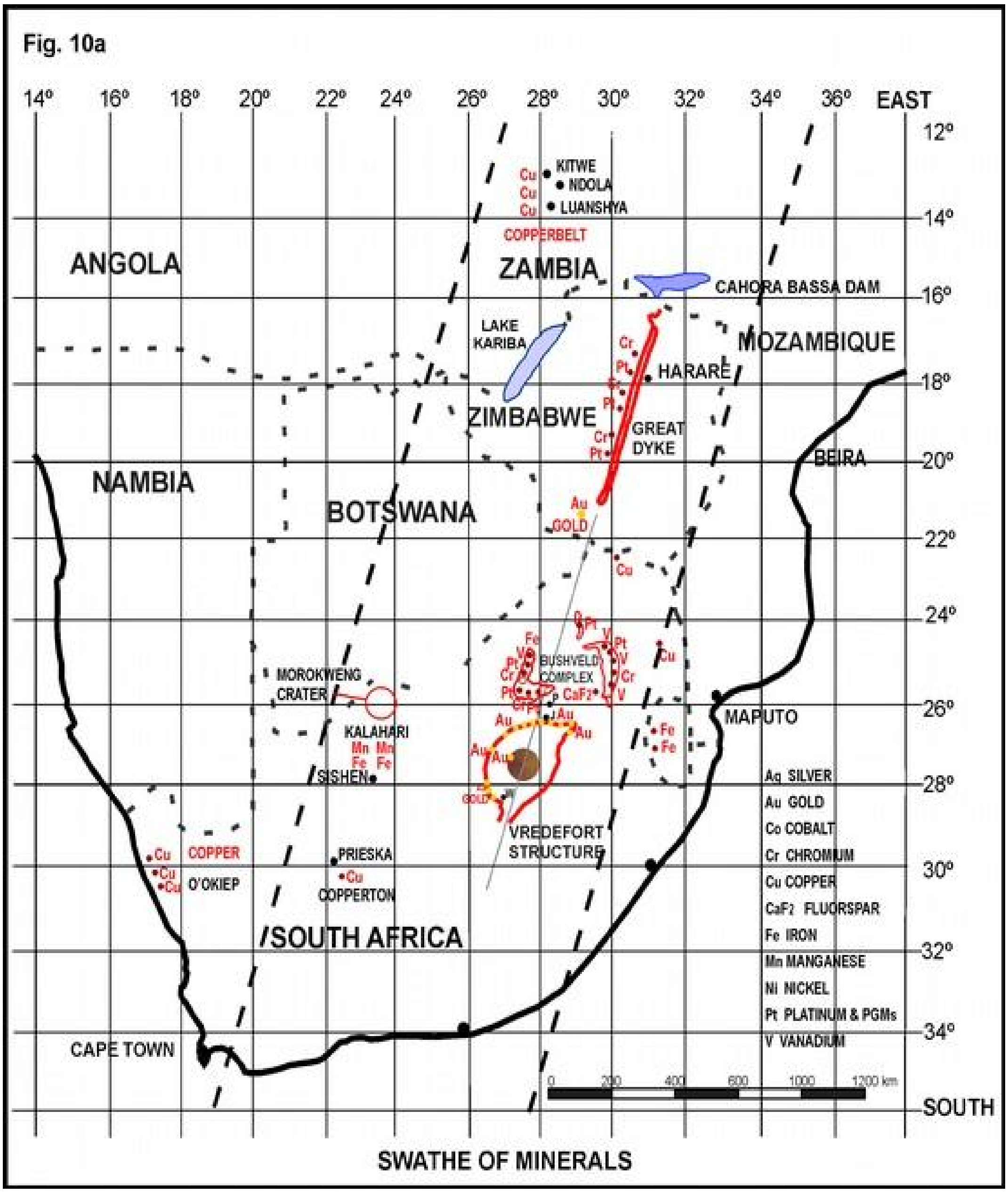
The Council for Geoscience has produced downloadable maps of all the minerals of South Africa showing where they are mined. The 25 minerals (precious, metallic and industrial) that fall into the swathe above are, in alphabetical order: Andalusite, Antimony, Asbestos, Barytes, Chromite, Cobalt, Copper, Fluorspar, Gold, Iron, Lead, Manganese, Molybdenum, Nickel, Phosphate, Platinum, PGMs, Rare Earths, Silver, Tin, Titanium, Uranium, Vanadium, Vermiculite, Zinc and Zirconium (Vorster 2001).

Table 4 The Swathe of Minerals of southern Africa

Symbol	*Name (Use)*	*SG*	*Melt Deg C*	*Latest pa*	*Reserves*	*World*
Ag	Silver	10.5	960 Deg C	145 t	10 kt	15
Au	Gold	19.3	1062 Deg C	428 t	40 kt	1
Co	Cobalt Inc DRC	8.6	1490 Deg C	64kt	N/A	1
Cr	Chromite (Exc Zim)	6.5	1510 Deg C	6.6 Mt	5 500 Mt	1
Cu	Copper (Inc Zambia)	8.9	1083 Deg C	1.2 Mt	SA13 Mt	1
Fe	Iron (Steel)	7.86	1525 Deg C	73 Mt	1 500 Mt	6
CaF2	Fluorspar	3.1	N/A	213 kt	41 Mt	1
Mn	Manganese (Steel)	7.4	1220 Deg C	3.6 Mt	4 000 Mt	1
Ni	Nickel	8.9	1452 Deg C	37 kt	12 Mt	3
Pb	Lead	11.4	327 Deg C			
Pt	Platinum (& PGMs)	21.5	1755 Deg C	207 t	63 kt	1
Sb	Antimony	6.62	629 Deg C	3.7 kt	250 kt	4
Sn	Tin	7.3	232 Deg C	nil	20 kt	
Ti	Titanium	4.54	1850 Deg C	1 Mt	146 Mt	2
U	Uranium	18.7	1132 Deg C	861 t	284 kt	4
V	Vanadium	5.5	1710 Deg C	18 kt	1.2 Mt	1
Zn	Zinc	7.12	418 Deg C	63 kt	15 Mt	5
Zr	Zirconium	4.15	2130 Deg C	253 kt	14 Mt	2
	Andalusite (Ceramics)			23 kt	51 Mt	1
	Asbestos		Ex Insulation	28 kt	N/A	N/A
	Coal (Power/Fuel)		Local/Export	224 Mt	5.5 Gt	5
	Diamond (Kimberlite plus Alluvial)		Not Botswana, Namib, Lesotho	10.8k carats	N/A	5
	Phosphate		Fertilisor	2.8 kt	2.5 Mt	3
	Vermiculite		Insulation	209 kt	80 Mt	1

This vast array of minerals, many of which form the largest deposits in the world, could not have seeped up through the Earth's crust from the mantle as they have a higher density. Most of them are siderophiles that would have sunk to the Earth's core if they had been there during the formation of this planet. After the crust was formed they could only have come from meteorites.

Fig. 10a



SWATHE OF MINERALS

These were all minerals that would typically have been separated out with a density and temperature in the molten core of some long past planetary formation. After cooling down over hundreds of millions of years and solidifying, with different materials in neat layers, like the segments of an onion, a serious smashup occurred throwing off the mantle and leaving the shattered core to be held together by its own reduced gravity. It is likely that this fragmented core had mostly separated into the various minerals of similar densities before colliding with Earth as most of the minerals are accumulated in individual deposits with the densest in the centre of the swathe.

As the shattered core approached Pangaea from the west in 214 Ma, at a very shallow angle, the dense individual fragments of gold, platinum, and PGMs as well as a large amount of chrome gathered in the core surrounded by iron and manganese, then copper and lastly rocky remnants of the mantle spread out over tens of thousands of kilometres (Fig. 10b).

Looking at the swathe of mineral deposits, the bottom of the outer core, rich in copper, collided with Earth first in the O'Okiep Copper Region of the Western Cape, followed by mountain sized chunks of iron and manganese in the 160 km long ore body that includes Sishen and Hotazel (Boardman 1977). Note the recently discovered subsurface Morokweng Crater, possibly the world's second largest, 80 km north-east of these deposits (Fig.10a)

The centre of the core containing the dense minerals, chrome, vanadium, gold and platinum, then impacted into the ground from south of Welkom, below Vredefort and under Johannesburg/Pretoria to the Bushveld Complex. Most of the high density gold, vapourising first due to its lower melting point and the long horizontal distance through the atmosphere, remained behind in the cavity before being ejected and then precipitating to line the strata that slumped into the crater.

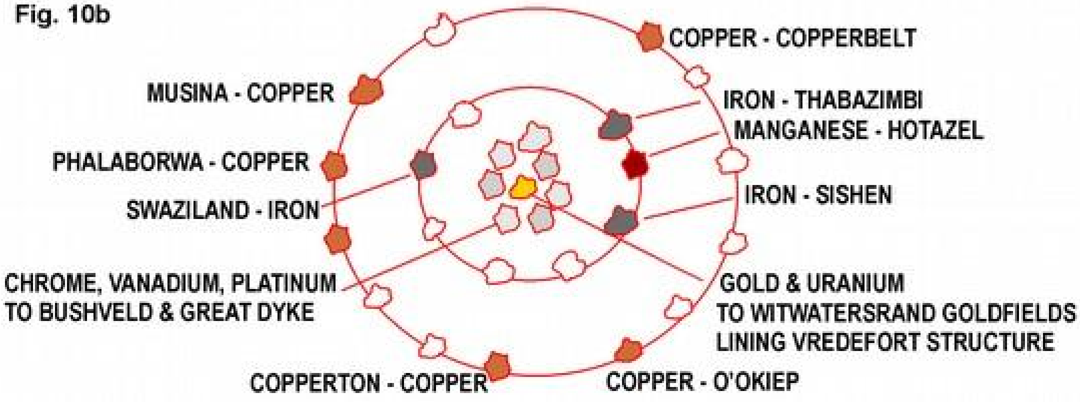
Past the Vredefort Structure the order of impact was reversed with iron and manganese impacting in a semi-circle from Thabazimbi to Swaziland and copper to the east at Phalaborwa and north from Musina on the Zimbabwe border to the Copperbelt in Zambia. The largest deposits of copper occur here, exporting about one million tonnes per year (Fig. 10 b & c). Close by over the border in the Democratic Republic of Congo (DRC) 58%, 64,000t/a, of the worlds cobalt is mined and exported.

It is also possible that the West Australian gold and iron were deposited by fragments from the same event as Australia would have been closely located for this impact at that period of time.

The approaching, shattered, planetary core was not a single compact object but would have been spread out whilst travelling through space. The fragments would collide with one another; bounce off for thousands of kilometres, then, the gravity from the heaviest, most densely packed core particles would draw them back again. This spreading out would be exacerbated by gravity when approaching a large object, like Planet Earth.

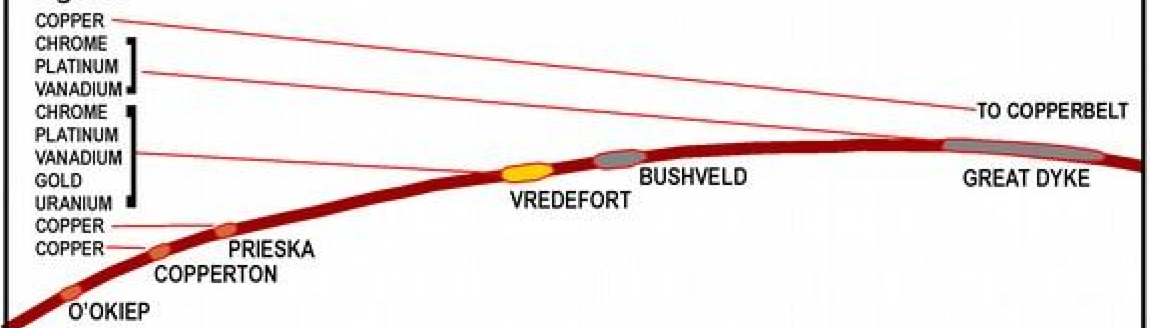
Some of the far outlying core impacted with the compact northern parts of Pangaea with what are now Canada, North America, France and Ukraine as the Manicouagan cluster of meteorites 214 Ma. The direction of approach and longitude matched the Vredefort-Bushveld-Great Dyke cluster as close as can be estimated for that period (Fig.3b).

Fig. 10b



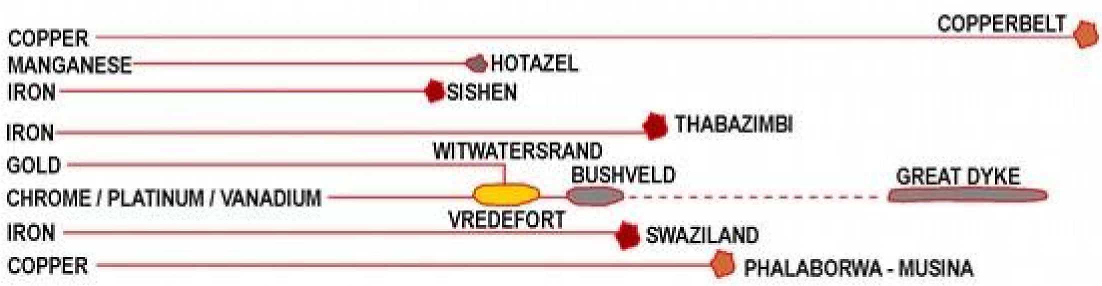
VIEW OF APPROACHING VREDEFORT METEOR CLUSTER

Fig. 10c



METALLIC IMPACTS - SECTIONAL VIEW FROM EAST

Fig. 10d



METALLIC IMPACTS - VIEW FROM ABOVE

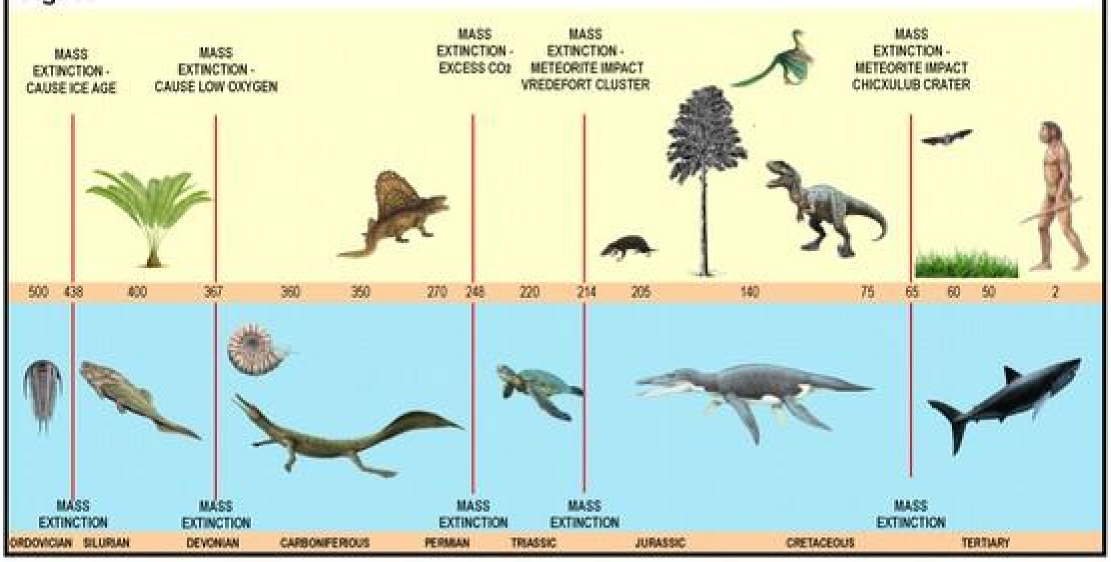
11.0 The Triassic-Jurassic mass extinction (Fig. 11)

The combined impacts of the Vredefort and Manicouagan clusters taking place within an hour, probably minutes, would have caused worldwide devastation with immediate effects from the blast wave, base surge, earthquakes, tsunamis and vaporization of water and rock. The dust and ejecta would be four metres thick one thousand kilometres away from the impact (Marcus, Melosh & Collins 2018) and as the dust encircled the world, visibility would be limited (Alvarez & Asaro 1990) making the air unbreathable for most animals. Only those that lived underground like our modern day moles or laid eggs that were buried and hatched later, like reptiles, survived. Longer term effects would have included global distribution of ejecta, wildfires and darkness, acid rain and greenhouse effects.

It is believed that large impact events occur roughly every one hundred million years and other extinction events are also likely to have been caused by large impacts (Grieve 1990). The end of the Triassic period, at 214 Ma, saw the extinction of 80% of species for which no clear reason has yet been found (Taylor 2018). It has been proposed that the Manicouagan cluster of impacts could have caused this extinction but there is no clear proof that they would have been large enough.

It is only that the date of the Vredefort Structure is believed to be 2020 Ma that this event was not ever considered as a candidate. I propose that the Triassic–Jurassic Mass Extinction was a direct result of the Vredefort/Great Dyke Impacts combined with the Manicouagan impacts in 214 Ma.

Fig. 11

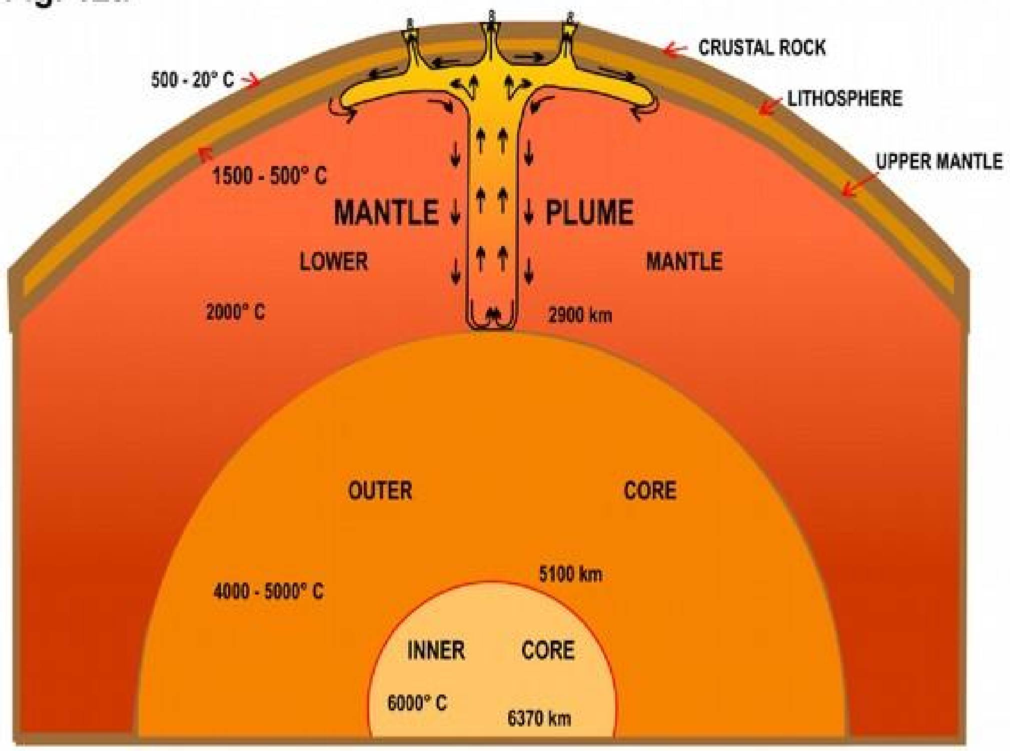


12.0 Karoo Mantle Plume (Fig. 12a &12b)

The Karoo Mantle Plume is an upwelling of very hot mantle material, with a stem, hundreds of kilometres across, and a radiating top under or through the Earth's crust. These are up to 3000 kilometres in diameter (Segev 2002), originating from the core-mantle boundary 2900 km below the surface. There are only about twenty of these plumes around the world, mostly welling up as wide mid-ocean ridges (Wyllie 1975). The giant Karoo Mantle Plume first erupted on the northern extremity of South Africa along the Limpopo River 204-205 Ma (Allsop & Roddick 1984; Kent, Storey & Saunders 1992).

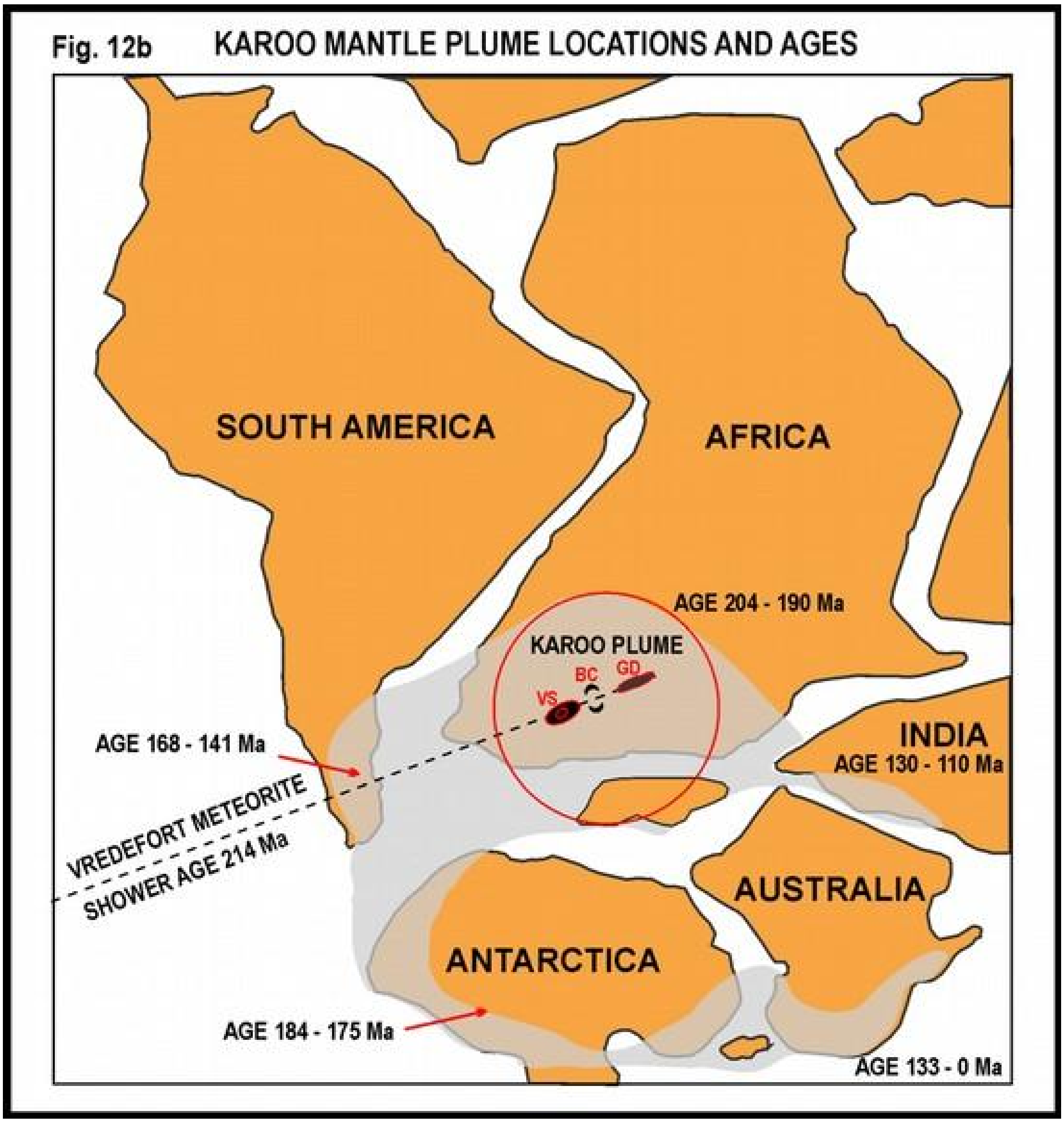
There was no known reason for this plume to rise under Gondwana, which had been part of a stable Pangaea for the previous 100 million years. I propose that the Vredefort Meteorite Impact of 214 Ma supplied the shock and heat energy to upset the equilibrium in the mantle below, giving the impetus for the plume to begin moving. Once started it became self-sustaining as the hotter mantle material that had been trapped below began to rise with convection currents.

Fig. 12a CROSS SECTION OF THE KAROO MANTLE PLUME



The Vredefort Impact shock wave travelled downwards until it reached the core-mantle boundary, about half way to the centre of the Earth, 2900 km in 10 minutes (Marcus, Melosh & Collins 2018). It then rebounded back up off the denser metallic core, like a billiard ball off the cushion, the turbulence leaving a disrupted path through the normally stable mantle

The second effect of the meteorite impact would be to dissipate energy into the mantle in the form of radiated heat directly below the shattered floor of the 50 km deep transient crater. This additional heat would cause the thick, molten magma in the mantle to become lighter than its surroundings resulting in the beginning of a slow upward movement. Once moving, the plume would continue to rise due to its hotter base. Mantle plumes, because of their sheer size and weight are very slow moving, a mere five centimetres per year (Wyllie 1975).



This would account for the time delay of about 10 million years between the Vredefort impact of 214 Ma and the start of a two kilometre uplifting of southern Africa. The mantle plume would have created the flood basalt of the Karoo system roughly 200 Ma (Storey, Leat & Ferris 2001). This was followed by the Drakensberg (185-180 Ma) capped by some 1.4 km of basaltic lavas (Veevers 1994; Johnson, van Vuuren, Hegenberger, Key & Shoko 1996).

One hundred and thirty five million years after the Karoo Plume first erupted it left a 'breadcrumb' trail of small volcano remnants from South Africa to Madagascar and then close to Reunion. This was the region where the south-west coast of India was situated about 65 Ma. It is therefore possible that the Deccan Traps were formed by the same mantle plume or an offshoot. As the crust then carried India northwards over the mantle the undersea mantle plume left its trail to the south, now at a small related hotspot under Marion Island (Courtillot 1990).

13.0 Continental drift 204 Ma till now (Fig.13a,b,c)

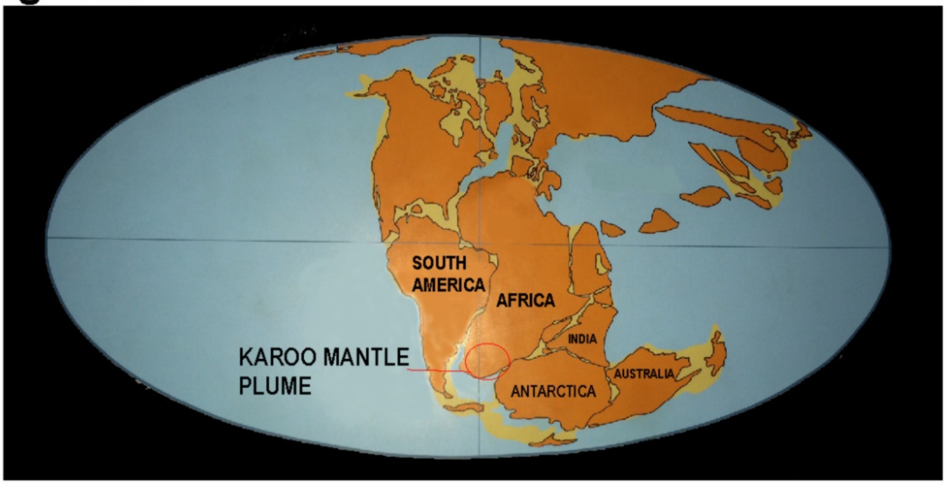
Before 1912, when Alfred Wegener, a German meteorologist, polar explorer and geophysicist, put forward his Continental Drift theory to the Geological Society in the Senckenberg Museum, few had ever thought that landmasses could move and most did not believe him (Wegner, 2012). One who did and helped with the proof was a South African geologist, Alex du Toit, who mapped the Gondwana Succession of glacial rubble, coal deposits and fossil plants to show that all the southern continents were joined about 200 Ma. Wegener died heroically on an expedition in Greenland in 1950. His theories only became accepted in the early 1960s when other proof, mainly based on ocean ridges and magnetic particles in rock, was presented (Hurley 1968).

As described previously, Gondwanaland amalgamated from 650-500 Ma and was then combined with Pangaea to be stable from 320 Ma until about 185 Ma at which time it started to break up and begin its slow drift apart (Veevers 2004). The centre of this expansion was southern Africa with South America heading west, Australia east, India north and Antarctica south to where they are today.

It would take an impact of such a magnitude as Vredefort to supply the energy to seed the growth of a mantle plume. This would begin the slow but sure upward doming and be the plate-driven mechanism resulting in volcanic eruptions, earthquakes and continental drift (Wyllie 1975) and the extrusion related to the breakup of Gondwana (Cox 1992).

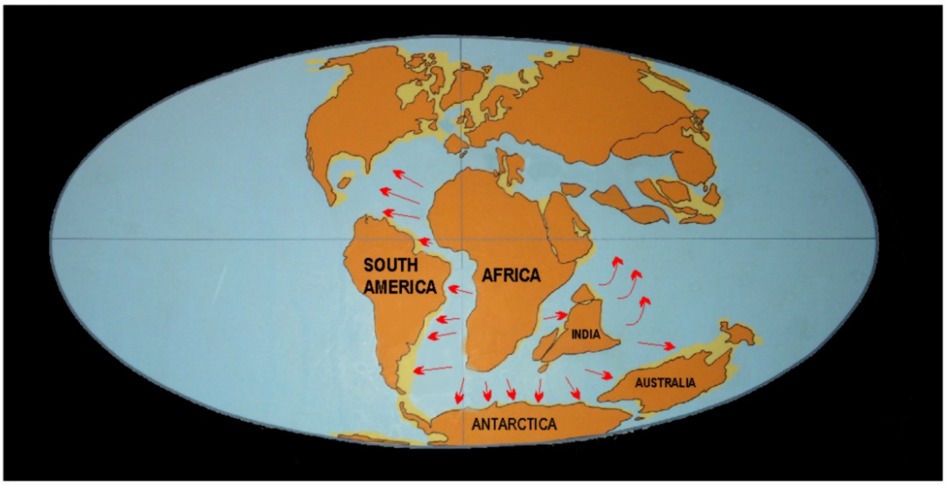
The Karoo Large Igneous Province of southern Africa is closely associated with a huge mantle plume which also spread out as the Ferrar Province, under Antarctica, Australia, Tasmania and New Zealand, as well as the Chon Aike Province under Patagonia (Storey 2004). These igneous provinces formed shortly before the continental breakup of Gondwana and the Karoo Province has been clearly linked to a mantle plume (Storey, Leat & Ferris 2001).

Fig. 13a



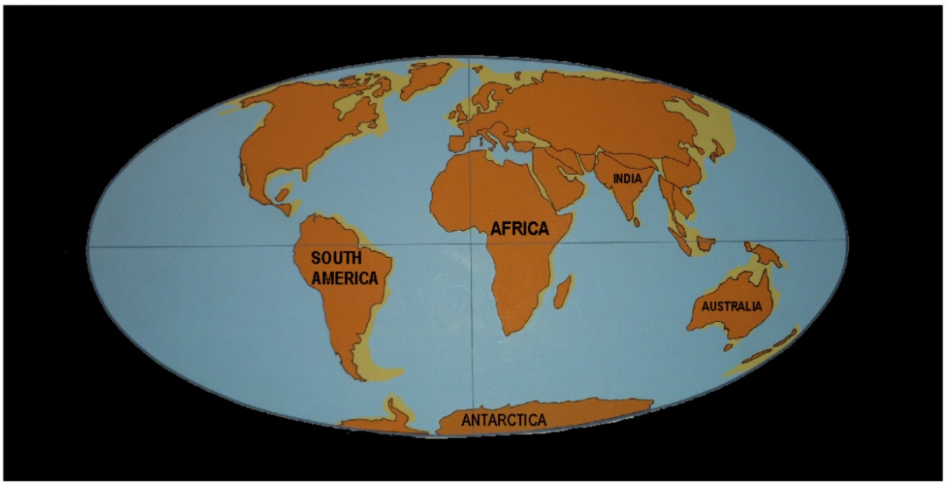
204 - 185 Ma continental drift restarted with southern Africa at epicentre over Karoo Mantle Plume.

Fig. 13b



95 Ma Continental drift with upwelling magma at mid-ocean rifts.

Fig. 13c



0 Ma locations of continentals today still moving slowly apart at 5-10 cm/year.

14.0 The diamond ring (Fig. 14)

It cannot be a coincidence that about 80 comparatively young, 100 Ma, kimberlite diamond pipes encircle the Vredefort crater. The largest of these are located from Letseng in Lesotho, Jagersfontein in the south-east, to Kimberley in the south, Finsch in the south-west, Jwaneng and Orapa in the west, Cullinan in the north and Venetia in the far north. Most of these are 200-300 km from the Vredefort Dome except Orapa and Venetia which are about 600 km (Vorster 2001).

In 2014 the South African diamond production was over eight million carats. That excludes Letseng, eleven diamonds over 100 carats in the first quarter of 2018, Botswana's Orapa and Jwaneng, and the diamonds washed into the Atlantic and mined in Namibia and Angola. The first diamond found in 1867 was the Eureka in Hopetown weighing 21 carats and the largest from Cullinan that weighed 3106 carats uncut (Chamber of Mines 2017).

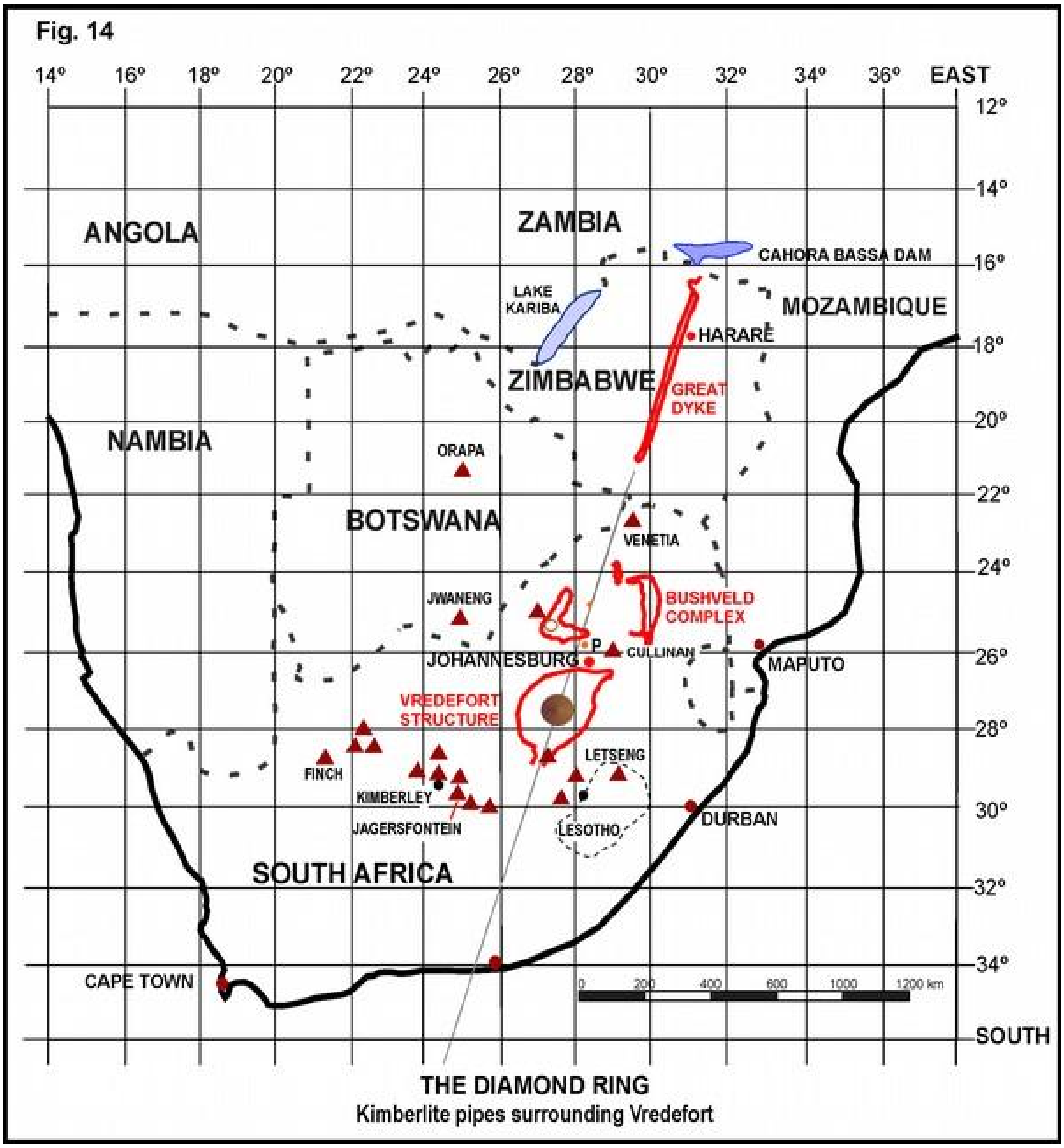
The requirements for the rich quantity, quality and size of diamonds to be formed in this specific area are as follows: A source of carbon is required to be converted into diamonds, this being from carbohydrates in gas, oil or coal. A sufficient amount of carbon needs to be deep underground, contained, and subjected to pressures of 100-150 Giga Pa, which is 1 to 1.5 million bar (atmospheres). It also needs to be raised in temperature to over a thousand degrees Celsius (Hart 1992) and it needs to be brought up to the surface from about 150 km deep in a relatively short period of time.

I propose that the Vredefort meteorite impacts drove large amounts of carbon down under the Earth's crust from the Glossopteris based Vryheid Coalfields. These coal seams were laid down below the Ecca formation from 298 to 252 Ma. This source of carbon then mixed with the mantle material.

Over the next 114 million years, as the mantle plume rose at 5 cm per year, the carbon-rich magma sank down the sides of the plume until they reached the core only to be circulated up again, a distance of 5,800 km. When they reached 150 km below the surface, where the pressures and temperatures are ideal the carbon-enriched magma formed diamonds. Increased heat in this area created the conditions 100 Ma for the diamond-rich Kimberlite to expand and explode upwards through a ring of weakened crust surrounding the Vredefort Structure.

This theory is supported by the time/distance between the Vredefort impacts and explosions of kimberlite out of the mantle plume and the composition of minerals in mantle peridotite which confirm the depth and temperature for the source of the kimberlite diamonds.

Although small diamonds have been found as a direct result of meteorite impacts (Anders 1965), these diamonds were not created directly by the impact as no coesite is found in the South African kimberlite (Wyllie 1975).



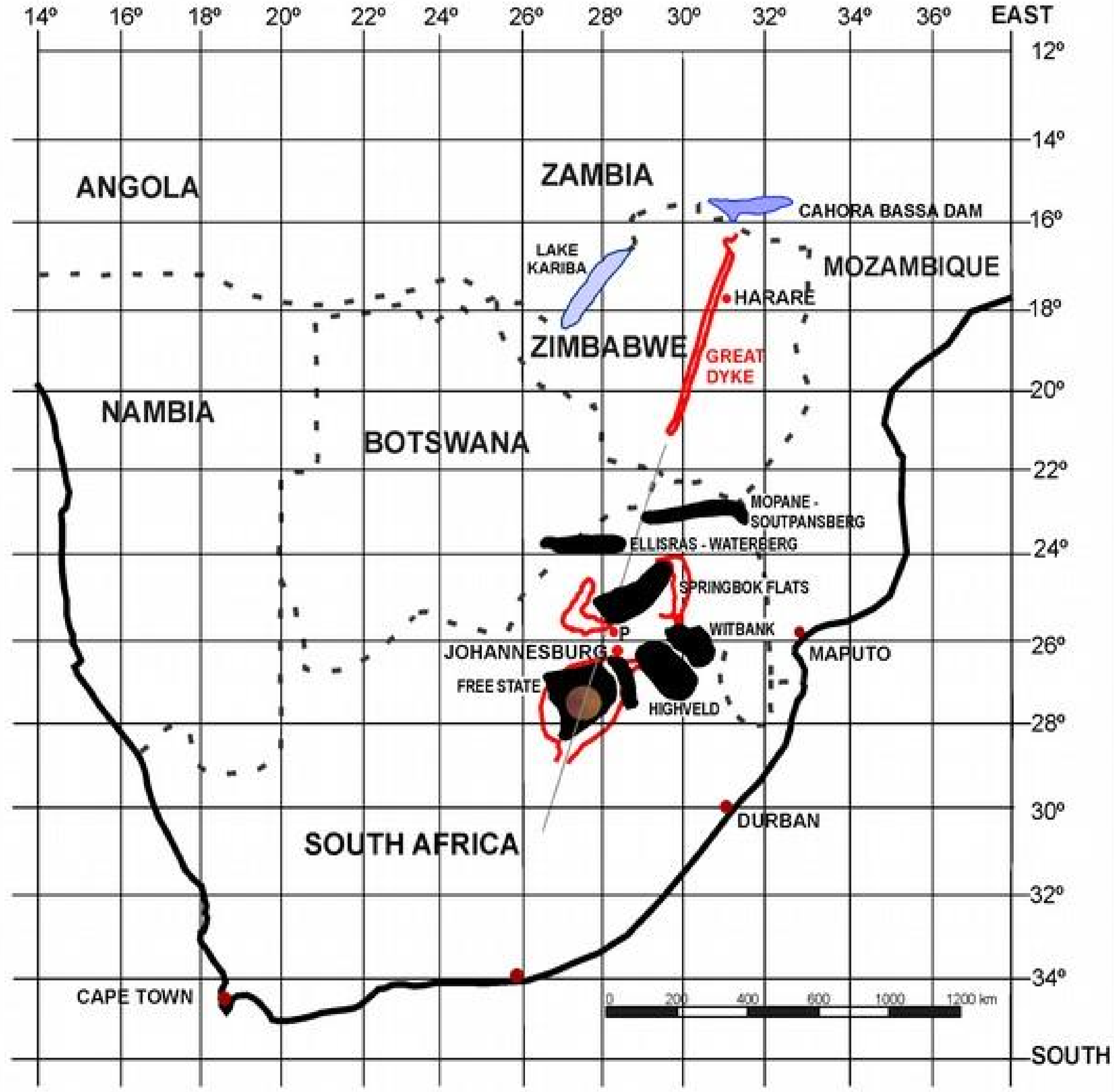
15.0 Coal in crater and ripple valleys (Fig. 15)

After the Vredefort Meteorites had left a huge, oval crater, three hundred and thirty by one hundred and sixty five kilometres in size and kilometres deep with the rebound cone in the middle, it became a deep lake with an island. This would look similar, but larger, than the Manicouagan Crater of today. In the now isolated valleys, between the crater impact ripples, lakes also formed.

As all these lakes silted up with inflowing rivers and streams, as well as air borne dust, their surface area became larger until they too reached a point where they became swamps with thick water loving plants. Not Glossopteris and Gangamopteris, as they had died out after creating the Natal Vryheid coalfields.

These large coalfields of the Free State cover most the area where the crater had been as well as the Highveld and Witbank Coalfields where the Ecca sediments had eroded into the crater leaving the Dwyka glacial debris exposed. In the Limpopo Province there were more large coalfields, the Springbok Flats in the Bushveld Complex as well as Ellisras (Waterberg) and Mopane (Soutpansberg) that occurred in the west-east valleys between the mountain ranges, the ripples north of the Vredefort Structure. These coalfields were laid down after the glaciation and Dwyka 288 Ma which would mean that the ripples are younger than this date.

Fig. 15



COAL IN CRATER AND RIPPLE VALLEYS (SYNCLINES)

16.0 Dating; 2020 Ma, 2055 Ma & 2575 Ma or 214 Ma – to summarise.

‘The sciences progress not so much by the discovery of new truth as they do by the correction of old error’ (Robert Dietz August 1961b).

16.1 Vredefort - Dating on the rebound

The Vredefort Dome has a remnant rebound central core made up of target rock thrown up from the transient cavity floor. This took place seconds after the explosion that created the chamber following the impacts. This floor was part of the 20 km thick, deeply buried Transvaal Supergroup which has strata aged from about 3000 Ma at the bottom to 1800 Ma at the top of the Rooiberg Group. Most of the rebound and collar rock fell back into the crater with the balance being eroded to the present ground level.

Depending on which layer of the floor strata is at this present dome ground level, an age determination dating of 2020 Ma for the Vredefort Impact Structure would be of the local rock and not the meteorite.

Graham Ryder of the Lunar and Planetary Institute in Houston said, after examining lunar rock from the Apollo mission, that ages of rocks are not easily reset. Most are broken up but not substantially heated (Taylor 1994). This theory is borne out in the Vredefort Dome where experienced geophysicists concluded that there was no evidence for shock melting, nor do the geological settings favour this. They only found melting of local country rocks and no impact melt with local material (Reimold, Hoffmann, Hauser, Schmitt, Zaag & Mohr-Westerheide 2016).

If the rocks within the Vredefort Dome were not heated sufficiently to reset their age at the time of impact then the radiometric dating would show the age of the local rocks and not the age of impact. These target rocks are aged between 3000 Ma and 1800 Ma which would fit in with an age of 2020 Ma for that particular layer being dated of the uplifted rocks. This would have nothing to do with the age of the impact, which could be 214 Ma.

16.2 Bushveld Complex - dating between strata layers

Scientists cannot date fossils themselves but they can accurately date the strata layers above and below to get precise dates of when the fossils were laid down. In 1980, Luis and Walter Alvarez, Frank Asaro and Helen Michels could date the mass extinction by measuring the age of strata above and below iridium from a meteorite that rained down worldwide. This was shortly after the great meteorite impact which caused the Cretaceous-Paleogene (K-Pg) mass extinction which wiped out the dinosaurs 65.5 Ma. Fern spores below but not above the iridium layer confirmed this mass extinction marker.

These examples of dating are possible because the fossils or iridium were laid down on top of a layer of strata of measurable age and then covered by another layer of measurable age. One can then assume that the fossils or iridium is of an age between the two.

However, if you have many kilometres of sediment laid down between 3000 and 1800 Ma and can measure how old every layer is from bottom to top, you cannot know the age of minerals that were intruded later from the side. Imagine shooting a bullet today into the side of a cliff where the strata is 2055 Ma. This does not make the bullet 2055 million years old.

In our case, the meteorite's minerals and magma in the Bushveld Complex were intruded horizontally, forcing the floor down and the roof up, between layers of strata in the Transvaal Supergroup that are same age as claimed for the formation of the Bushveld Complex.

If 2055 Ma is the age of the target rock layer there is nothing to prevent the horizontal intrusion of the Bushveld Large Igneous Complex from taking place in 214 Ma.

16.3 The Great Dyke in Zimbabwe-dating the strata.

This straight, 550 km long, chrome and platinum mineral-rich, penetrative crater across the Zimbabwe Craton is obviously part of the meteor shower that caused the Vredefort Structure.

The Vredefort Structure and Bushveld Complex are probably related, being unique, contemporary, and close (Elston & Twist 1986), within 500 km of each other. The Merensky Reef in the Bushveld Complex and the Great Dyke contain similar minerals and the Great Dyke is also close, within 500 km. It is exactly in line and has the same approach angle, allowing for about 5-8 degrees of longitude, as Vredefort and Bushveld.

Accepting that the three sites are from the same meteor cluster then there is a problem with the current event formation age determination of 2020 Ma (Vredefort), 2055 Ma (Bushveld) and 2575 Ma (Great Dyke), a spread of 555 million years. If, however you look at the age of target rock you will see that, in each case, this would fit in with 2020 Ma, 2055 Ma and 2575 Ma respectively. If, incorrectly, the target rock has been dated instead of the meteorite fragments this means that the common impact age could be 214 Ma for all three events.

16.4 Glaciation

We know from Chapter 5 that four kilometre thick ice followed by glaciation from 302 Ma to 288 Ma would have levelled any protrusions. This would mean that any signs of the impact and the resulting ripples would have been eroded if they were older than this glaciation era.

The string of shock-sheared caves parallel to the Witwatersrand Ridge is certain to be connected to the Vredefort Impact but not at 2020 Ma. These caves had to have been formed after the Dwyka Glaciation period which ended 288 Ma as they definitely could not support 4 km thick ice followed by a serious glaciation event. As the oldest other cave system known is dated at 340 Ma this makes 214 Ma far more likely.

16.5 Multiple meteorite impacts 214 Ma

From Chapter 3.0 we know that it is unlikely that Vredefort, Bushveld and Great Dyke were three separate events, and that the combined event would have been a once in a solar lifetime occurrence. The window of opportunity for this combined multi-particle event to take place in the same direction, west to east, the same longitude and angle of approach would have to be at the same time and date as that of the Manicouagan cluster of 214 Ma.

16.6 Events after 214 Ma

The following major events took place after 214 Ma that would require an enormous amount of energy to occur:

- Mass extinction: We know that the Triassic-Jurassic Mass Extinction occurred at approximately 214 Ma where 80% of all species became extinct
- Mantle plume: The Karoo Mantle Plume formed under the Vredefort Structure, first surface signs appearing in 204 Ma
- Continental drift: The Gondwana Continents began to separate 185 Ma with South Africa being the central point.
- Diamonds: The world's largest explosion of Kimberlite diamond pipes occurred, mostly in a circle around the Vredefort Structure 100 Ma
- Coal: Huge deposits within the Vredefort Structure, on its edge and to the north surrounded by the Bushveld Complex and in valleys between ripples of upturned strata.

16.7 Comments about the age of the Vredefort Structure and Bushveld Complex

In the early 1960s, before the radiometric 2020/2060 Ma dates were arrived at, geophysicists and astrophysicists of the time believed that the Vredefort Structure's age was in the order of at least 250 Ma (Dietz 1961) or that it was comparatively young looking for the ages given to them.

'Unless a crater is unusually large all traces of its presence will be eroded away in less than 600 million years' (Wetherill 1979).

'Old craters are less abundant simply because they have been destroyed by erosion, sedimentation and other geologic processes' (Grieve 1990).

'The Bushveld magmatic province is an unusual LIP. In spite of its Palaeoproterozoic age [2055 Ma] it is undeformed' (Kinnaird 2005).

17.0 Reference list

ADAMSKY, V. & SMIRNOV, Y. 1994. 'Moscow's biggest bomb: the 50-Megaton test of October 1961. *Cold War International History Project Bulletin',* Issue 4, fall 1994; p. 3, 19-21.

ALLSOPP, H.L., FITCH, F.J., MILLER, J.A. & REIMOLD, W.U. 1991. '^{40}Ar-^{39}Ar stepheating age determinations relevant to the formation of the Vredefort Dome'. *South African Journal of Science* 87, pp. 431-442

ALLSOPP, H.L. & RODDICK, J.C. 1984. 'Rb-Sr and 40Ar–39Ar age determination on phlogopite micas from the pre Lebombo Group, Dokolwayo kimberlite pipe'. *Special Publication of Geological Society of South Africa,* 13, pp. 267-271

ALVAREZ, W. & ASARO, F. 1990. 'An extraterrestrial Impact'. *Scientific American*, October.

ANDERS, E. 1965. 'Diamonds in meteorites'. *Scientific American*, October

ARMSTRONG, R. & OSBORNE, L. 2007. 'The world's oldest caves: How did they survive and what can they tell us?' *Time in Karst Postojna* 2007, pp. 133-142

BANGERT, B., STOLLHOFEN, H., LORENZ, V. & ARMSTRONG, R. 1999. 'The geochronology and significance of ash-fall tuffs in the glaciogenic Carboniferous-Permian Dwyka Group of Namibia and South Africa'. *Journal of African Earth Sciences* vol. 29(1), pp. 33-49

BARNES, V.E. 1961. 'Tektites' *Scientific American,* November

BARRINGER, B. 1964. 'Daniel Moreau Barringer (1860-1929) and his crater' *Meteoritics*, vol. 2, pp.183-199

BEALS, C.S. 1958. 'Fossil Meteorite Craters'. *Scientific American* July, 1958.

BOARDMAN, L. 1977. '*Kalahari Wealth, the story of manganes*e' Samancor sponsored. Purnell & Sons, Cape Town. SBN 360 002730

BOON, J.D. & ALBRITTON, C.C. 1936. 'Meteorite craters and their possible relationship to Cryptovolcanic Structures.' *Field and Laboratory*, vol. 5, No. 1, pp. 1-9

BOON, J.D. & ALBRITTON, C.C. 1938. 'Established and supposed examples of meteoritic craters and structures'. *Field and Laboratory*, vol. 6, pp 44-56

BUCHER, W.H., 1963. 'Are Cryptovolcanic Structures Due to Meteoritic Impact?' *Nature,* March 30. pp. 1241-1245

CARTER, N.L. 1965. 'Basal quartz deformation lamellae - a criterion for recognition of impactites'. *American Journal of Science* vol. 263 pp 786-806

CAWTHORN, R.G. & WALRAVEN, F. 1998. 'Emplacement and crystallisation time for Bushveld Complex'. *Journal of Petrology,* vol. 39, issue 9, September 1998, pp 1669-1687 https://doi.org/10.1093/petroj/39.9.1669

CHAMBER OF MINES. 2017. '*Gold-key facts and figures'*. www.chamberofmines.org.za/sa. mining/gold Retrieved 20180614

CHARTERS, A. C. 1960. ‘High-Speed Impacts’. *Scientific American,* October

COFFIN, M.F. & ELDHOLM, O. 1994. ‘Large Igneous Provinces: crustal structure, dimensions and external consequences’. *Reviews of Geophysics*, vol. 32, pp.1-36

COURTILLOT, V.E. 1990. ‘Volcanic Plumes’. *Scientific American,* October

COX, K.G. 1992. ‘Karoo igneous activity, and the early stages of the break-up of Gondwanaland’, in: Story, B.C., Alabaster, T. and Pankhurst, R.J. (Eds*), ‘*Magmatism and the causes of continental breakup’. *Geological Society Special Publication,* vol.68, pp.137-148

DALY, R.A. 1947. ‘The Vredefort Ring Structure of South Africa’. *Journal of Geology, vol.* 55, pp. 125-145

DENCE, M.R. 1968. ‘Shock zoning at Canadian craters: Petrography and structural implications’. In: *Shock metamorphism of natural materials.* Edited by French B.M. & Short N.M. Baltimore: Mono Book Corporation. pp. 169-184

DIETZ, R.S. 1961a. ‘Vredefort Ring Structure: Meteorite Scar?’. *Journal of Geology,* vol.69, p499

DIETZ, R.S. 1961b. ‘Astroblemes’. *Scientific American*, August

DINEEN, A.A., FRAISER, M.L. & ISBELL, J.L. 2013. ‘Palaeoecology and sedimentology of Carboniferous glacial and post-glacial successions in the Paganzo and Río Blanco basins of northwestern Argentina, Sedimentological Impact’. *Geological Society, London, Special Publications. vol.* 376, pp.109-140, 147

DIRKS, P.H.G.M. & JESMA, H.A. 2002. ‘Crust-mantle decoupling and the growth of the Archaean Zimbabwe craton’. *Journal of African Earth Sciences*, vol. 34, pp. 157-166 [3] https://dx.doi.org/10.1016/S0899-5362 (02) Retrieved 20180320

ELKINS-TANTON, L.T. 2016. ‘Solar System Smashup’. *Scientific American*, December

ELSTON, W.E. & TWIST, D. 1986. ‘Bushveld Complex, South Africa: is Rooiberg felsite an impactite?’. *Lunar and Planetary Institute.* NASA 1986 LPI…17.204E

FRENCH, B.M. 1990. Absence of shock-metamorphic effects in the Bushveld Complex, South Africa, results of an intensive search. *Tectonophysics* vol.171, pp.1-4 (287) http://sciencedirect.com/journal/techtonphysics/vol/171 Retrieved 20180411

FRIESE, A.E.W., CHARLESWORTH, E.G. & MCCARTHY, T.S. 1995. Tectonic processes within the Kaapvaal Craton, *Economic Geological Research Unit,* University of Witwatersrand, Johannesburg

GAYRE OF GAYRE R, 1972. ‘The origin of Zimbabwean Civilisation’. *Galaxie Press*

GIBSON, R.L. & STEVENS, G. 1998. Regional metamorphism due to anorogenic intracratonic magmatism. What drives metamorphism and metamorphic reactions? P.J.O.B. Treloar, P.J. London, *Geological Society of London:* pp.121-135.

GRIEVE, R.A.F., ROBERTSON, P.B. & DENCE, M.R. 1981. ‘Constraints on the formation of ring impact structures, based on terrestrial data’. *In Multi-ring basins,* edited by Schultz P.H. and Merrill R. B. New York: Pergamon Press. pp. 37-50

GRIEVE, R. 1990 ‘Impact Cratering on Earth’. *Scientific American,* April.

HANCOX, P.J. & GOETZ, A.E. 2014. ‘South Africa’s coalfields-a 2014 perspective’. *School of Geosciences.* University of Witwatersrand, *& Department of Geology,* University of Pretoria. https://repository.up.ac.za/handle/2263/58453 Retrieved 20170501

HARGRAVES, R.B. 1961. ‘Shatter cones in the rocks of the Vredefort Ring, Transvaal’ *Geological Society of South Africa*, vol. 64, pp147-154

HARMER, R.E. & ARMSTRONG, R.A. 2000. ‘New precise dates on the acid phase of the Bushveld and their implications’. Abstract. *Workshop on the Bushveld Complex*, 18th-21st November 2000, Burgersfort. University of the Witwatersrand, Johannesburg

HART, R.J. 1992. *Earth and Planetary Science Letters* vol. 147, pp. 25-30

HENKEL, H & REIMOLD, W.U. 1996. ‘Integrated Gravity and Magnetic Modelling of the Vredefort Impact Structure: Reinterpretation of the Witwatersrand Basin as the Erosional Remnant of an Impact Basin’. *Economic Geology Research Unit,* University of the Witwatersrand, 1996-Cratering-89 pages

HORTON, D.E., POULSEN, C.J. & POLLARD, D. 2010. ‘Influence of high-latitude vegetation feedbacks on late Paleozoic glacial cycles’. *Natural Geoscience* vol.3 pp. 572-77

HURLEY, P.M. 1968. ‘The Confirmation of Continental Drift’. *Scientific American,* April

JOHNSON, M.R., VAN VUUREN, C.J., HEGENBERGER, W.F., KEY, R. & SHOKO, U. 1996. ‘Stratigraphy of the Karoo Supergroup in southern Africa: an overview’. *Journal of African Earth Sciences,* vol. 23, pp. 3-15

KAMO, S.L., REIMOLD, W.U., KROGH, T.E. & COLLISTON, W.P. 1996. ‘A 2023 Ma age for the Vredefort impact event and a first report of shock metamorphosed zircons in pseudotachylictic breccias and granophyre’. *Earth and Planetary Science Letters,* Vol. 144, pp369-388

KENT, R.W., STOREY, M. & SAUNDERS, A.D. 1992. ‘Large igneous provinces: Sites of plume impact or plume incubation?’ *Geology*. vol. 20, pp. 891-894

KINNAIRD, J.A. 2005. ‘The Bushveld Large Igneous Province’. *School of Geosciences,* University of Witwatersrand www.largeigneousprovinces.org/sites/default/files/BushveldLIP.pdf Viewed 20170501

LEHMANN, O. 1959. ‘Look beyond the wind’. *Published by Howard Timmins* (Hans Merensky biography)

M829A3. 2016. ‘M829A3 Penetration Power’. Google: *M829A3 Penetration.* Select *Below the Turret,* 10 Feb 2016 Viewed 20180512

MALIK, J. 1985. ‘Hiroshima and Nagasaki yields’. *Los Alamos National Laboratories*. LA-8819 UC-34 September 1985. www.osti.gov/opennet/manhattan-project-history/publications/LANLHiroshimaNagasaki Yields.pdf Viewed 20180513

‘MAP STUDIO. 2015. Southern Africa, RoadMap’. *7th Edition*, 1:3 500 000 & *Zimbabwe Adventure RoadMap*, 1st Edition, 1:200 000. www.mapstudio.co.za pdf version available

MARCUS, R., MELOSH, J. & COLLINS, G. 2018. '*Earth impact effects'*. www.purdue.edu/ impactearth Viewed 20180412

MARTINI, J.E.J. 1978. 'Coesite and stishovite in the Vredefort Dome, South Africa'. *Nature* vol. 272, pp.715-717

MELOSH, H. J. 1989. 'Impact Cratering: A geological process'. *Oxford University Press*, New York, New York

MILANKOVITCH, M. 2018. 'Feature Articles'. - *NASA Earth Observatory* https://earthobservatory.nasa.gov/ Features/Milankovitch/milankovitch_2.php Viewed 20180205

MONTANEZ, I.P. & POULSEN, C.J. 2013. 'The Late Paleozoic Ice Age: An Evolving Paradigm'. *Annual review Earth and Planetary Science* 2013 vol. 41 pp.629-656, www.annualreview.org

MOORBATH, S. 1977. 'The Oldest Rocks and the Growth of Continents'. *Scientific American,* March

NININGER, H.H. 1949. 'Oxidation studies at Barringer Crater'. *American Philosophical Society Yearbook* pp. 126-133

OBERTHUER, T., DAVIS, D.W., BLENKINSOP, T.G. & HOEHNDORF, A. 2002. 'Precise U–Pb mineral ages, Rb–Sr and Sm–Nd systematics for the Great Dyke, Zimbabwe—constraints on crustal evolution and metallogenesis of the Zimbabwe Craton'. *Precambrian Research*, vol.113, pp.293-306 http://ingentaconnect.com/content/els/ 03019268/2002/00000113/00000003/ art00215. Viewed 20171020

PARKES, CSIRO. 'Every day hundreds of thousands of meteors crash into the Earth' www.parkes.atnf.csiro.au/people/sar049/eternal_life/asteroid/asteroid.html Viewed 20180210

PRETORIUS, D.A. 1991. 'The sources of the Witwatersrand gold and uranium: a CONTINUED difference of opinion'. *Society of Economic Geology, Monograph* vol.8 pp.139-163

PREVEC, R. 2011. 'A structural re-interpretation and revision of the type material of the glossopterid ovuliferous fructification Scutum from South Africa'. *Palaeontologia Africana vol.* 46, pp. 1-19

REIMOLD, W.U., HOFFMAN, M., HAUSER, N., SCHMITT, R.T., ZAAG, P.T. & MOHR-WESTERHEIDE, T. 2016. 'A geological contribution to the discussion about the genesis of impact-related Pseudotachylitic breccias: Studies of PTB in the Otavi and Kudu Quarries of the Vredefort Dome support the "In Situ Formation" hypothesis'. *South African Journal of Geology* vol.119.3 pp.453-472 doi:10.2113/gssajg.119.3.453

REIMOLD, W.U. & GIBSON, R.L. 1996. Geology and evolution of the Vredefort impact structure, South Africa. *Journal African Earth Sciences* vol. 23, pp. 125-162

REIMOLD, W.U. & KOEBERL, C. 2014. 'Impact structures in Africa: a review' *Journal of African Earth Sciences* 93 (2014) 57-175

RHODES, R.C. 1975. New evidence for impact origin of the Bushveld Complex, South Africa *Geology* (October) pp.459-554

SCHROEDER, C. 2018. University of Stirling. *Reported in Cosmos magazine*. www.theconversation.com/metal-asteroid-psyche-is-all-set-for-an-early-visit-from-nasa-88044 Viewed 20171212

SCOATES, S.J. & FRIEDMAN, R.M. 2008. 'Precise age of the platiniferous Merensky Reef, Bushveld Complex, South Africa, by the U-Pb Zircon Chemical Abrasion ID-TIMS Technique'. *Economic Geology* May 2008; 103 (3) DOI:10.2113/gsecongeo.103.3.465

SEGEV, A. 2002. 'Flood basalts, continental breakup and the dispersal of Gondwana: evidence for periodic migration of upwelling mantle flows (plumes)' (PDF) *European Geosciences Union. Stephan Mueller Special Publication Series,* vol. 2, pp. 171-191. Bibcode: 2002SMSPS...2.171S

Senckenberg Museum Frankfurt, Graphics. '*Continental Drift maps 540 Ma to 1.6 Ma'*

SHAND, S.J. 1916. 'The pseudotachylite of Parijs (OFS) and its relation to 'Trap-Schotten Gneiss' and 'flinty crush-rock'. *Quarterly Journal Geological Society of London*, vol.72 pp.198-221

SPRAY, J.G., KELLEY, S.P. & REIMOLD, W.U. 1995. 'Laser probe 40Ar-39Ar dating of coesite and Stishovite-bearing pseudotachylites and the age of the Vredefort impact event'. *Meteoritics* vol. v30, pp. 335-343

SPRAY, J.G., KELLEY, S.P. & ROWLEY, D.B. 1998. 'Evidence for a late Triassic multiple impact event' *Nature* vol. 392 pp.171-173 (12 March 1998) doi:10.1038/32397

STEELE, D. 1998. 'Crater chain points to impact of fragmented comet'. *The University of Chicago Chronicle*, March 19, 1998 vol. 17, no. 12.

STOREY, B.C., LEAT P.T. & FERRIS, J.K. 2001. 'The location of mantle plume centres during the initial stages of Gondwana breakup'. *Geo. Soc. Of America* Special Paper 352, pp.71-80

STOREY, B.C. 2004. 'Links between large igneous provinces and breakup of Gondwana'. *Large Igneous province Commission. International Association of Volcanology and Chemistry of the Earth's Interior*. www.largeigneousprovinces.org/node/27 Viewed 20180202

STRUVE, O. 1950. 'The Great Meteor of 1947'. *Scientific American*, June

TACKLEY, P. 2017. 'Mafic to Felsic'. *Geophysicist at the Swiss Federal Institute of Technology, Zurich.* As reported by Shannon Hall in Scientific American, December 2017

TAYLOR, G. J. 1994. 'The Scientific Legacy of Apollo'. *Scientific American*, July

TAYLOR, P. 2018. 'The big five mass extinctions'. *Credit Natural History Museum,* http://cosmosmagazine.com/palaeontology/big-five-extinctions Viewed 20161011

THERRIAULT, A.M., GRIEVE, R.A.F. & REIMOLD, W.U. 1996. 'Original Size of the Vredefort Structure: Implications for geological evolution of the Witwatersrand Basin'. *Meteorites & Planetary Science* vol. 32, pp. 71-77

TUCKER, S.J. 2015. ‘Armageddon Cave’. *South African Spelaeological Association* vol. 41, pp. 28-47, http://wwwscintilena.com/wp-content/uploads/2015/11/SASABulletinVol-41-2015-final.pdf Viewed 20180320

TURTLE, E.P. 2005. In ‘Large Meteorite Impacts III’. Issue 384 Edited by Thomas Kenkmann, Friedrich Horz & Alexander Deutsch

TURTON, A. 2012. ‘Going Underground for Water’. *Media* Club http://www.anthonyturton.com. Retrieved 20120604

VEEVERS, J.J. 2004. ‘Gondwanaland from 650–500 Ma assembly through 320 Ma merger in Pangaea to 185 Ma breakup: supercontinental tectonics via stratigraphy and radiometric dating’. *Earth Science Reviews* vol. 68, 1-2, pp.1-132. Elsevier

VEEVERS, J.J., COLE, D.I. & COWAN, E.J. 1994. ‘Southern Africa: Karoo Basin and Cape Fold Belt’ *Memoirs of the Geographic Society of America* vol. 184(1), pp. 223-279

VORSTER, C.J. 2001a. www.geoscience.org.za/images/Maps/rsadeposits.gif Viewed 20180610

VORSTER, C.J. 2001b www.geoscience.org.za/index.php/publication/downloadable-material Viewed 20180610

WALRAVEN, F. 1987. ‘Textural, geochemical and genetic aspects of the granophyric rocks of the Bushveld Complex’. *Memoir 72, Geological Survey South Africa*, pp 145

WALRAVEN, F. & MARTINI, J. 1994, ‘Zircon Pb-evaporation age determinations of the Oak Tree Formation, Chuniespoort Group, Transvaal Sequence: implications for Transvaal-Griqualand West basin correlations’. *S. African Journal of Geology, 1995, vol. 98(1), pp.58-67*

WEGNER, A. 2018 Senckenberg Museum Frankfurt. *GFZ German Research Centre for Geoscience.* Re: Continental drift. https://phys.org/news/2012-01-flipped-toe-years-continental-drift.html Viewed 20171102

WETHERILL, G.W. 1979. ‘Apollo Objects’. *Scientific American*, March

WHITESIDE, H.M., HIEMSTRA, S.A., GLASSPOOL, K.R., PRETORIUS, D.A. & ANTROBUS, E.A. 1976. ‘Gold in the Witwatersrand Triad’. *Mineral Resources of the Republic of South Africa*’. *Government Printer*. pp. 39-68

WILSON, J., FERRÉ, E.C. & LESPINASSE, P. 2000. ‘Repeated tabular injection of high-level alkaline granites in the eastern Bushveld, South Africa’. *Journal of the Geological*

WORLD BANK 2018 http://www.worldbank.org/en/region/afr/brief/the-kariba-dam-rehabilitation-project-fact-sheet Viewed 20180610

WYLLIE, P.J. 1975. ‘The Earth’s Mantle’. *Scientific American* March.

Recommended reading

Meteorite Craters by Kathleen Mark. University of Arizona Press, Tucson

Meteorite Impact!:The Danger from Space and South Africa's Mega Impact by Wolf Uwe Reimold and Roger L. Gibson. Available from Amazon Books.

For additional photographs and general information:-

http://en.wikipedia.org/16_psyche (Metallic asteroid)

http://en.wikipedia.org/Great Dyke (For good photo)

https://en.wikipedia.org/wiki/Pigeonite

https://en.wikipedia.org/wiki/_M829

18.0 Dr. Hans Merensky. The world's greatest geologist

(Look Beyond the Wind by Olga Lehmann)

When Dr Hans Merensky returned to South Africa after studying geology in Germany he went for a holiday in South West Africa. Whilst there, railway workers discovered a diamond in a new cutting near Swakopmund. Merensky went to look and found a seam of 185 Ma fossilized oyster shells which Witwatersrand University identified as warm water oysters. This led him to propose that there were undersea volcanoes that warmed the water and spewed up the diamonds. He was right about volcanoes as the mid-Atlantic Ridge was close by then! After he became rich and famous for his platinum reef and Chrome discoveries he returned to South West Africa to look for the Oyster Line near the Orange River. Here, about a kilometre in from the sea he found rich deposits of diamonds.

The Earth's crust had split along that coastline about 185 Ma leaving a warm sea as it was shielded by the new continent of South America. There was volcanic activity along this coast as the continents started to spread and the mid-Atlantic ridge began life in this narrow channel. However, Merensky was wrong about the source of the diamonds. These had come from the interior of southern Africa, washed down the Orange River and up the channel, to be deposited along the coastline where the oysters lived. As the channel widened the cold water entered from the south and the oysters died out. The diamond-laden beaches silted and widened for kilometres and additional diamonds were deposited out to sea where they are now mined by dredgers.

Later he discovered the Free State Goldfields even though they were buried more than a kilometre under the Karoo sediments. When very old he discovered large deposits of phosphates and copper at Phalaborwa. He was truly the greatest geologist of all time.

19.0 Dr. Leslie Boardman

'Kalahari Wealth, the story of manganese' Samancor sponsored. Purnell & Sons, Cape Town. SBN 360 002730

Dr Leslie G Boardman, a Geologist, who was one of our scoutmasters in the 1950s, discovered the iron ore at Sishen (sixth largest) and the adjacent Kalahari manganese deposits (largest in the world). He spent many years living in the 'bush' in tents and a caravan searching through the 160 kilometre belt of farms with a small Askania magnetometer, even composing contracts with local farmers on a battered old typewriter (Boardman 1977). For all his discoveries he never received any compensation other than his salary. I accompanied the Boardman family on two holidays around South Africa in 1959 and 1960 where he introduced us to geology and the Vredefort Crater as it was believed then, 60 kilometres in diameter and 10 kilometres deep.

20.0 About the author, David Parkinson Howcroft

David Howcroft is a Fellow and Past President of the Society for Automation, Instrumentation, Measurement and Control in South Africa. (SAIMC) and Past Chairman of the Industrial Instrumentation Group (IIG)

Born in Cape Town during 1942, he grew up in Johannesburg, serendipitously in the lee of Northcliff, the highest outcrop of the uplifted Witwatersrand, the White Waters Ridge.

After matriculating at Roosevelt High School he went to Cambridge and studied electronics at the Pye Radio and Television training college. 1960 was the age of the first commercial transistors and his final project was to build a 9-transistor portable radio. Each separate transistor was the size of a fingernail. Today, in a memory stick, billions of transistors fit in the same space!

After two years of practical experience in North and South Rhodesia (now Zambia and Zimbabwe), he returned to Johannesburg to study further at Witwatersrand Technical College and use his knowledge of electronics to work in industry on instrumentation and automation.

Personal Notes:

Over the next 47 years:

- Designed, installed and commissioned automation systems for just about every industry in South Africa
- Installed the measuring instruments for the first synthetic diamond press in South Africa at De Beers Diamond Research Labs as well as steelmaking at Iscor, continuous casting at Highveld Steel, arc furnaces at Middleburg, Impala Platinum at Springs, vanadium at Steelpoort and gold refining in Germiston

- Was in charge of the supply and installation of electrical data logging transducers for Escom and SA Railways

- In 1980, started his own business that designed and installed equipment for automation of factories at Unilever, SA Breweries, Nestle and many more

- Presentations on automation to final year students of Witwatersrand University at the invitation of Prof Roy Marcus

- Designed a 32 channel computer-based FFT sound analyser for large power station boilers to identify and locate high-pressure leaks before they could cause serious consequential damage. When he sold his businesses and retired in 2010, over 260 of these systems had been fitted to boilers on power stations in South Africa and around the world

- During 2008 he was invited to consult on measuring instrumentation for the Nuclear Pebble Bed Reactor which should have made South Africa the world leader in this technology. Unfortunately, as the prototype was being built, the funding was suddenly diverted to the more immediate needs of the FIFA 2010 soccer World Cup with its' required stadiums, roads, trains and airport infrastructures.

Dynamic systems

In order to control anything, whether compressing carbon into diamonds, continuous casting steel or ensuring the quality of beer, one needs to understand the process and then imagine the dynamics of how the system will operate and what you want it to do. You then select sensors to measure force, level, temperature, pressure, flow, speed, frequency, time, distance, position, composition and anything else that may be required. For this one needs a thorough understanding of science as modern instrumentation uses almost every technology known. Level alone can be measured using optical, mechanical, electrical (resistive, capacitive inductive), pressure, force, acoustic, radar, laser, and nuclear technology.

I have always maintained that 'instrumentation is the practical application of science'. Luckily, I was always seriously interested in science and an avid reader of Scientific American for more than 50 years. During a lifetime in Process Automation, I knew instinctively which processes would work and how to automate them.

I have approached my thirty five year interest in the Vredefort Meteorite Impact in the same way. Even though the forces, pressures and temperatures are almost beyond imagination, the philosophy remains the same. I am not looking at the geology in a conventional way, but rather from what feels right to me both physically and dynamically.

From 1964 onwards my work took me to many mines, going down cramped, wet, crowded, high-speed cages into the bowels of the Earth. It became obvious to me that the gold in the Witwatersrand Complex was related to the Vredefort Meteorite Structure. I was always told that this was not the accepted geological explanation because the dates were wrong although everyone always thought it was a good story.

In the early 1990s, I produced my first PowerPoint on this subject, which I called ‘Meteorites, Minerals and Merensky’. This, and updated versions have entertained and intrigued many groups of people ever since.

In order to understand what I feel you have to really open your mind to the immensity of the variables involved. Most of them are millions, if not billions of times greater than what we are used to in the world around us. I believe that I am offering a valid and considered solution to the mystery of the Vredefort Structure.

These hypotheses regarding the meteorites and the minerals deposited in 214 Ma could change the way that we look at the geology of southern Africa and the worldwide effects that resulted.

Copyright 2018 David Howcroft (dave(at)howcroft.co.za)

21.0 Acknowledgements

To my wife, Suzy, who not only listened and encouraged me to continue writing, but also made it possible by leaving me in isolation for eight hours a day for more than a year. This valuable time was necessary to research and record all the scientific papers needed to provide proof for the hypotheses I proposed. In the end, she spent the time to proof read and edit the text.

To my family and friends – especially Robert, Patricia, Lorika and Rey who read the proofs and encouraged me to complete the document.

To Dr Ronald William Day of the Gondor Writers' Centre for the technical editing and constructive comments. www.gondorwriterscentre.com

To Elaine Ouston of the Gondor Writers' Centre in Landsborough, Queensland, for the graphic art and patience.

To my favourite South African artist, Michael Albertyn, who painted the background Strydpoortberge from a photograph taken by myself on a field trip.