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A Glimpse into Mafic Magma Genesis in South Africa: Over the First 1.5 Billion Years of Earth History

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SPINIFEX and ZULU WARRIORS



“Here they come - thick as grass and black as night”
The battle of Rorke’s Drift – 22 January, 1879

A warrior of the uThulwana regiment

A Glimpse into Mafic Magma Genesis in South Africa Over the First 1.5 Billion Years of Earth History

By

Allan Wilson

School of Geosciences
University of the Witwatersrand

On the occasion of Allan Wilson's Inaugural Lecture
7 November 2011

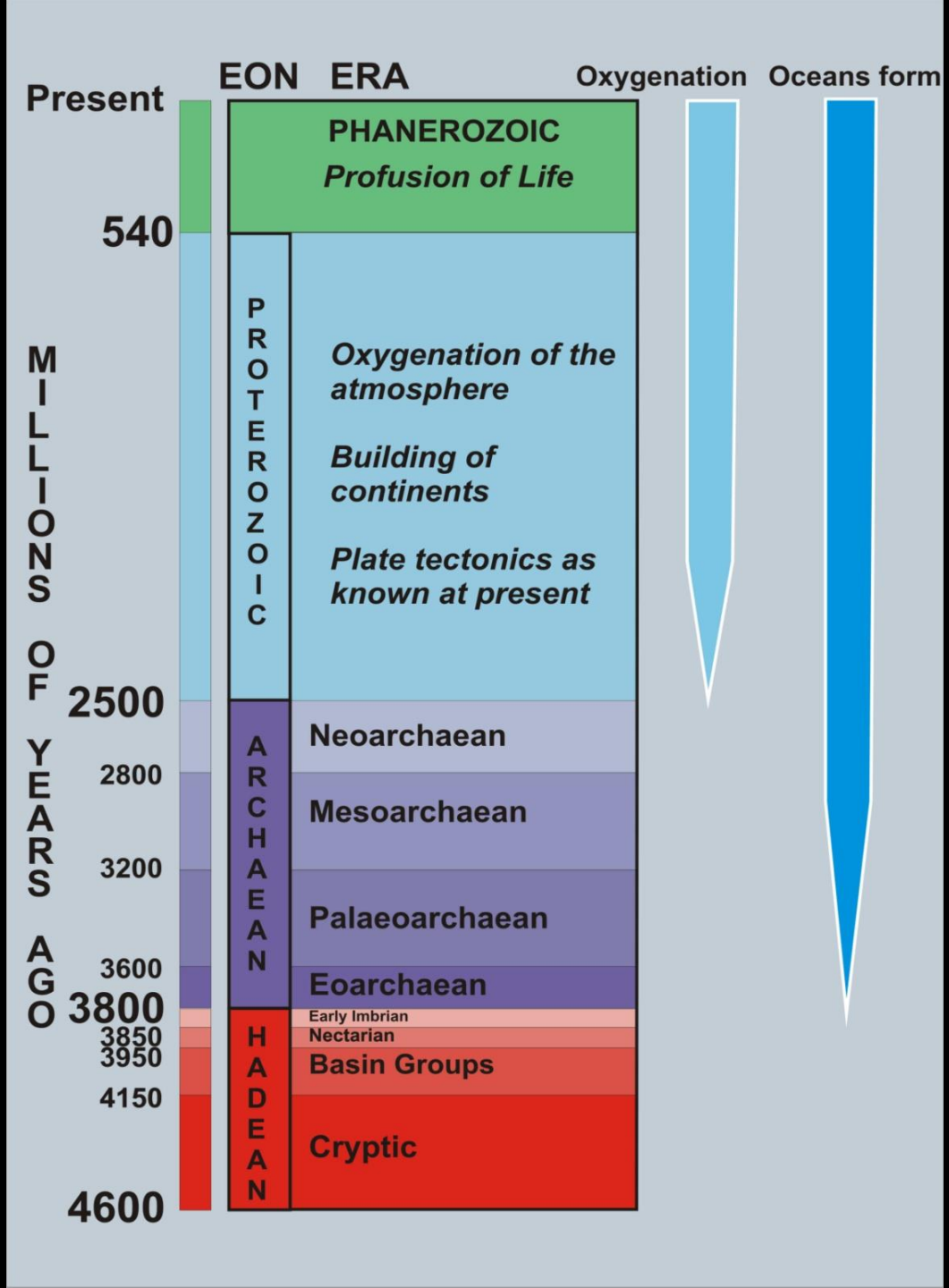
This talk will cover three areas of geology that I believe are important in the igneous history of South Africa spanning the first 1.5 billion years from 3.5 Ga to 2.0 Ga

The high-Mg lavas in Barberton and KwaZulu-Natal called komatiites 3.5 – 3.3 billion years ago

The volcanic rocks of the Pongola Supergroup 3.0 – 2.9 billion years ago

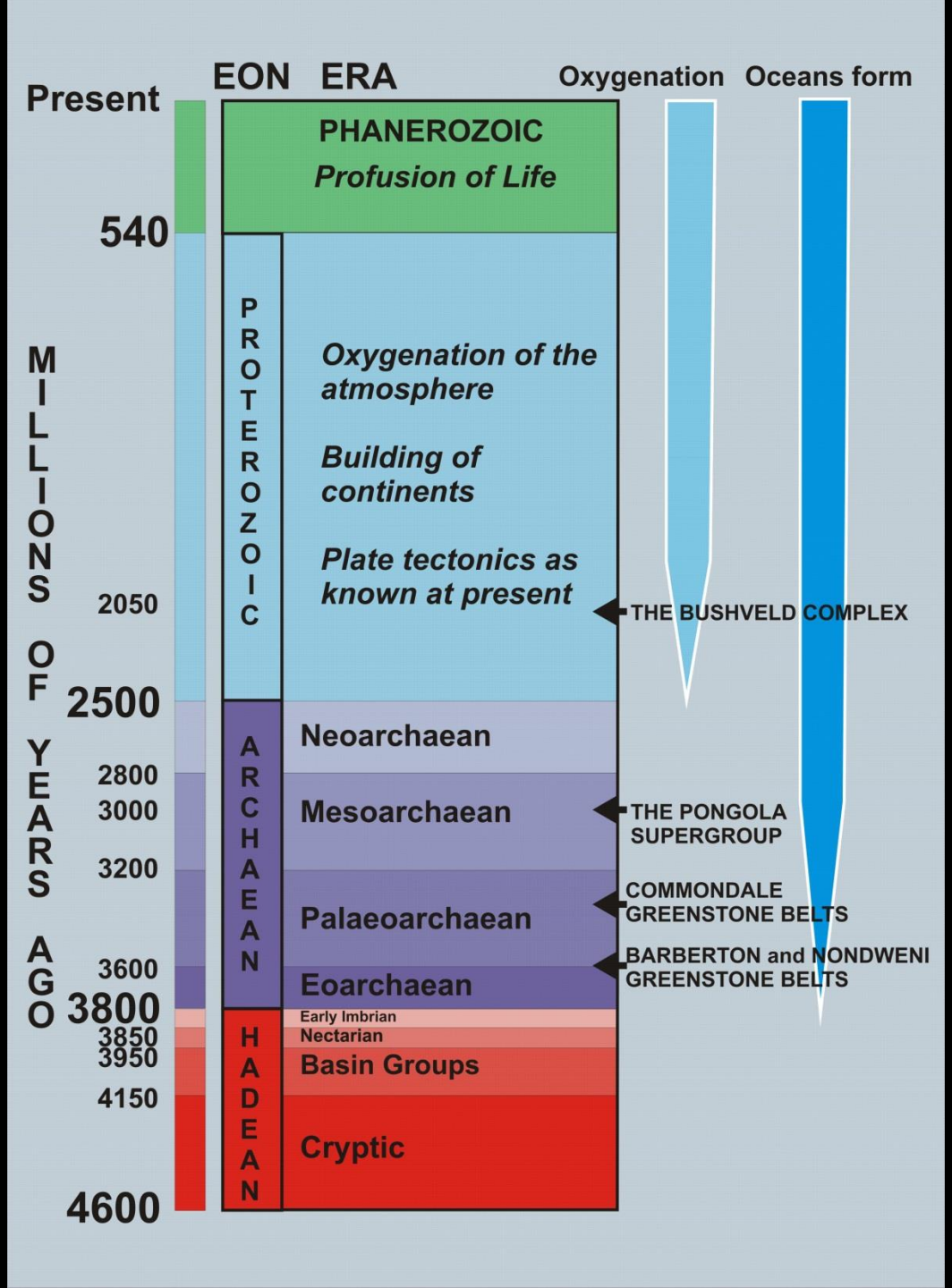
The Bushveld Complex 2.05 billion years ago

The Geological Time Scale



...zoic
From the Greek
'Zoe' – abundant life

The Geological Time Scale



...zoic
From the Greek
'Zoe' – abundant life

PLATE TECTONICS

It is the manifestation of, and the interaction of all dynamic processes on planet Earth involving the mantle, the crust, the hydrosphere and also the biosphere

It has controlled the way continental and ocean crust formed over millions of years

It has profoundly influenced the living environment

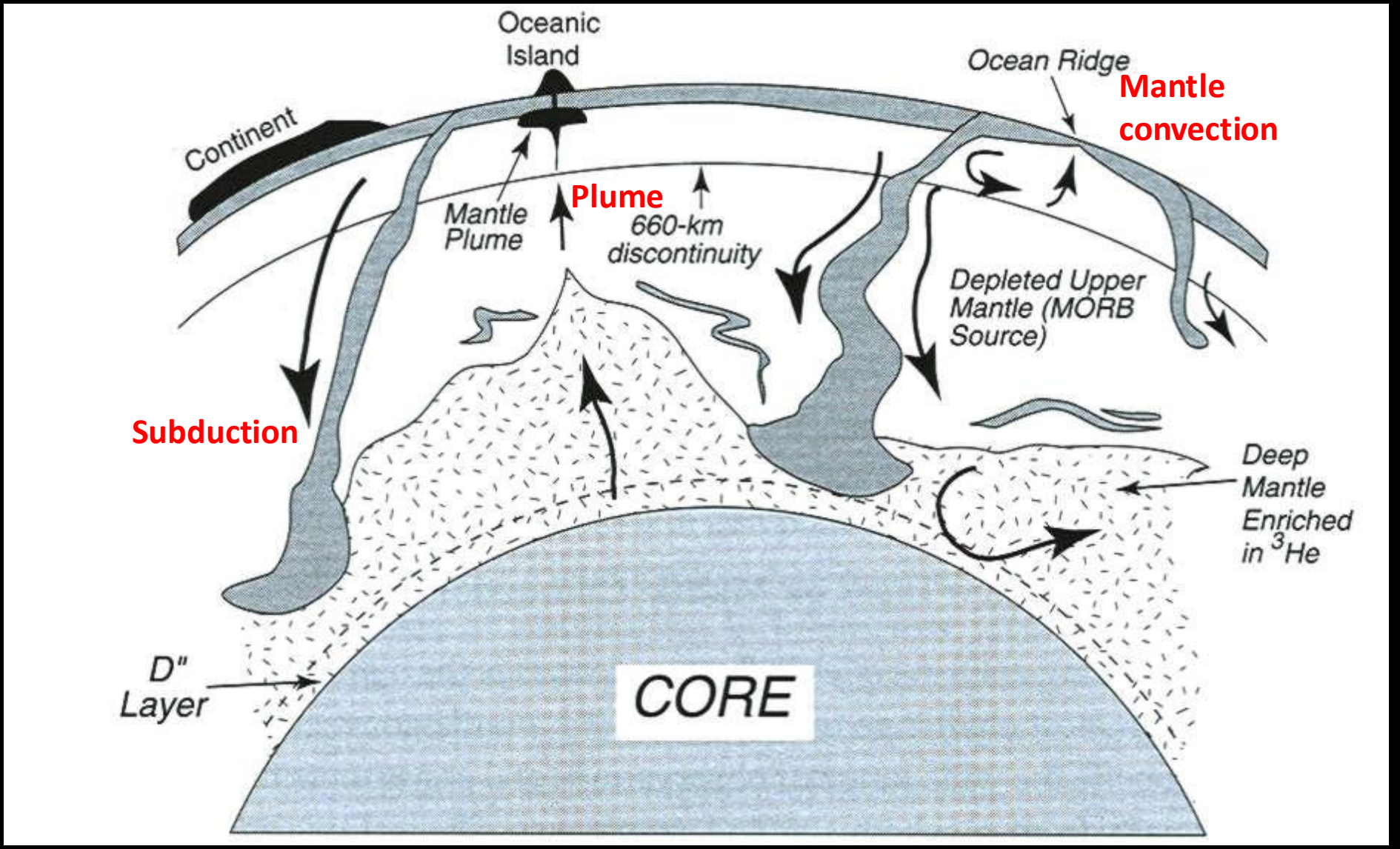
It has given rise to important economic mineral deposits

It drives the movement of the continents

Therefore by studying ancient volcanic rocks can we get an insight into the start of this process which is unique only to Earth in the Solar System

ONE BIG QUESTION - WHEN DID PLATE TECTONICS START AND WHAT FORM DID IT TAKE INITIALLY?

….. ***ONE OF THE GREAT MODERN CONTROVERSIES***



What are the major driving forces that produce molten rock (magma) - PLUME Plumes from the deep mantle ….. Melting by SUBDUCTION at plate boundaries may also have occurred … produce very different types of magma

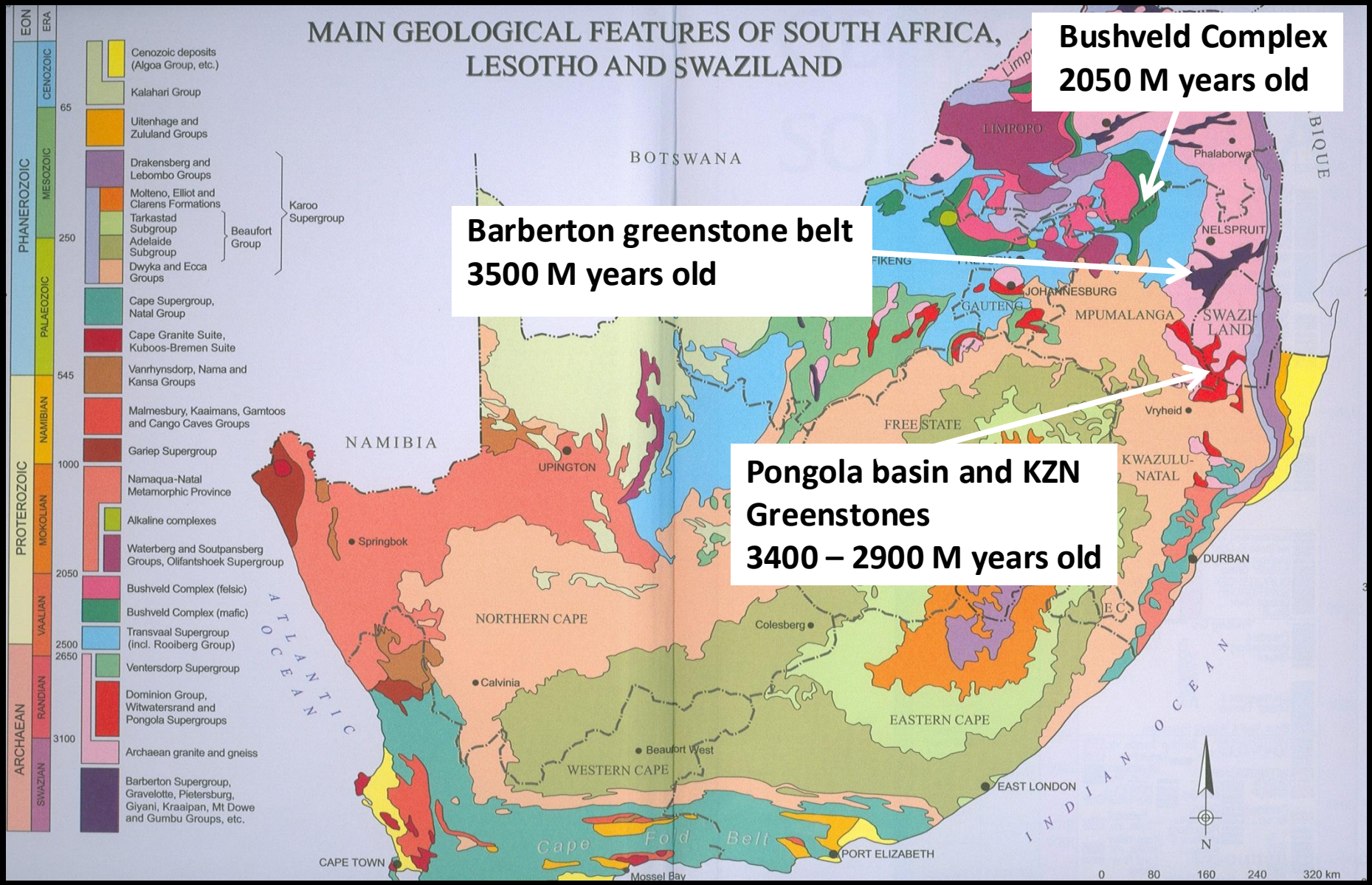


This is what the Earth probably looked like about 3 billion years ago
Volcanoes, ocean, stromatolites, spectacular sunsets, non-oxygen atmosphere
(Remember this)



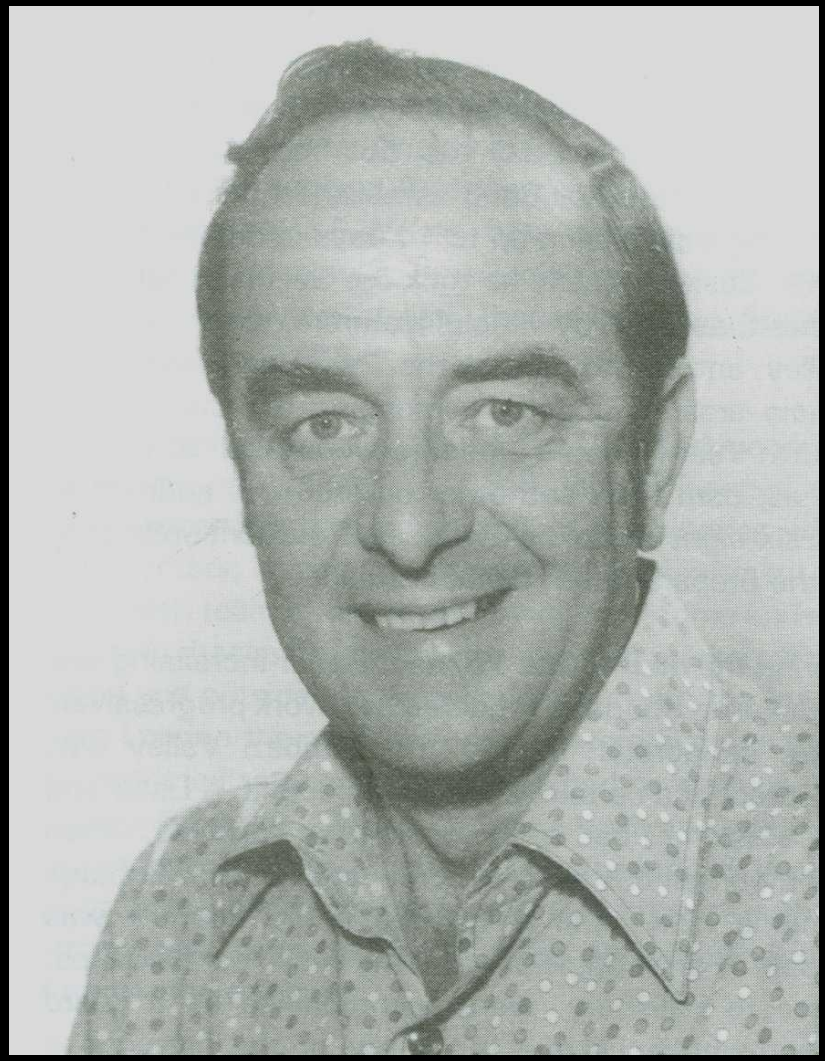
Stromatolites at Shark Bay (Australia) at present

Stroma – layer
Lithos - rock


MAIN GEOLOGICAL FEATURES OF SOUTH AFRICA, LESOTHO AND SWAZILAND
Bushveld Complex
2050 M years old
Barberton greenstone belt
3500 M years old
Pongola basin and KZN Greenstones
3400 – 2900 M years old
EON
ERA
PHANEROZOIC
CENOZOIC
MESOZOIC
PALAEOZOIC
PROTEROZOIC
NAMIBIAN
MOKOLIAN
VAALIAN
ARCHAEAN
RANDIAN
SWAZIAN
65
250
545
1000
2050
2500
2650
3100
Cenozoic deposits (Algoa Group, etc.)
Kalahari Group
Uitenhage and Zululand Groups
Drakensberg and Lebombo Groups
Molteno, Elliot and Clarens Formations
Tarkastad Subgroup
Adelaide Subgroup
Beaufort Group
Karoo Supergroup
Dwyka and Ecca Groups
Cape Supergroup, Natal Group
Cape Granite Suite, Kuboos-Bremen Suite
Vanrhynsdorp, Nama and Kansa Groups
Malmesbury, Kaaimans, Gamtoos and Cango Caves Groups
Gariep Supergroup
Namaqua-Natal Metamorphic Province
Alkaline complexes
Waterberg and Soutpansberg Groups, Olifantshoek Supergroup
Bushveld Complex (felsic)
Bushveld Complex (mafic)
Transvaal Supergroup (incl. Rooiberg Group)
Ventersdorp Supergroup
Dominion Group, Witwatersrand and Pongola Supergroups
Archaean granite and gneiss
Barberton Supergroup, Gravelotte, Pietersburg, Giyani, Kraaipan, Mt Dowe and Gumbu Groups, etc.
BOTSWANA
NAMIBIA
LIMPOPO
Phalaborwa
NELSPRUIT
JOHANNESBURG
GAUTENG
MPUMALANGA
SWAZI-LAND
FREE STATE
Vryheid
KWAZULU-NATAL
DURBAN
UPINGTON
Springbok
NORTHERN CAPE
Colesberg
Calvinia
EASTERN CAPE
Beaufort West
WESTERN CAPE
EAST LONDON
PORT ELIZABETH
CAPE TOWN
Mossel Bay
Cape Fold Belt
ATLANTIC OCEAN
INDIAN OCEAN
N
0
80
160
240
320 km



Professor Don Hunter
Head of Geology at University of Natal
in 1970's – 1990's



Professor Jimmy Wilson - Igneous petrologist at the University of Rhodesia (Zimbabwe) in 1970's



EXPENSIVE EQUIPMENT



Lava is usually perceived as flowing over the surface, as observed in these pictures



Lavas flow from beneath the colder outer skin – this is called INFLATION

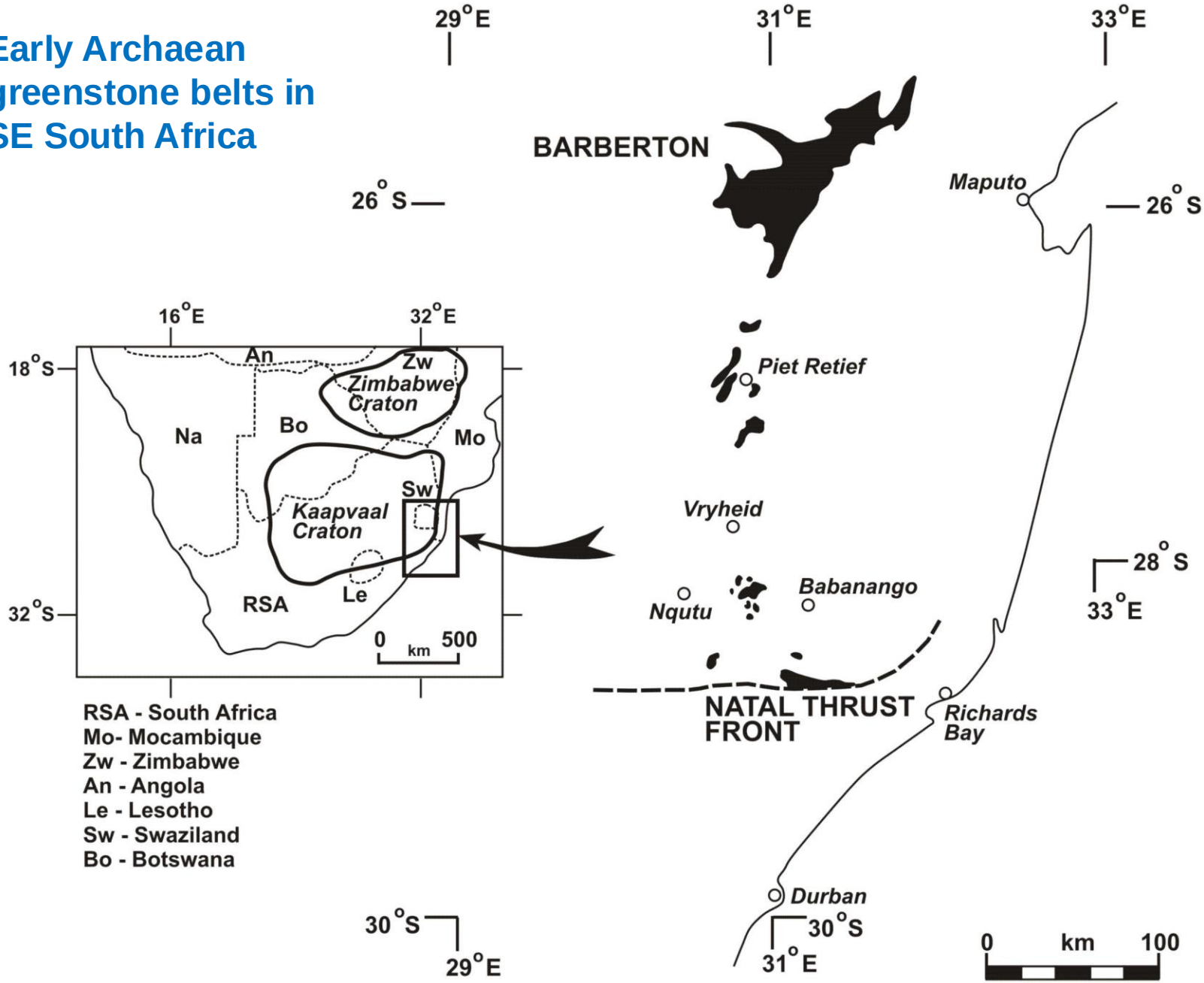


Amazing shapes – due to rapid rate of cooling freezing the skin



Classic ropy lava in basalt
(Remember this)

Early Archaean greenstone belts in SE South Africa

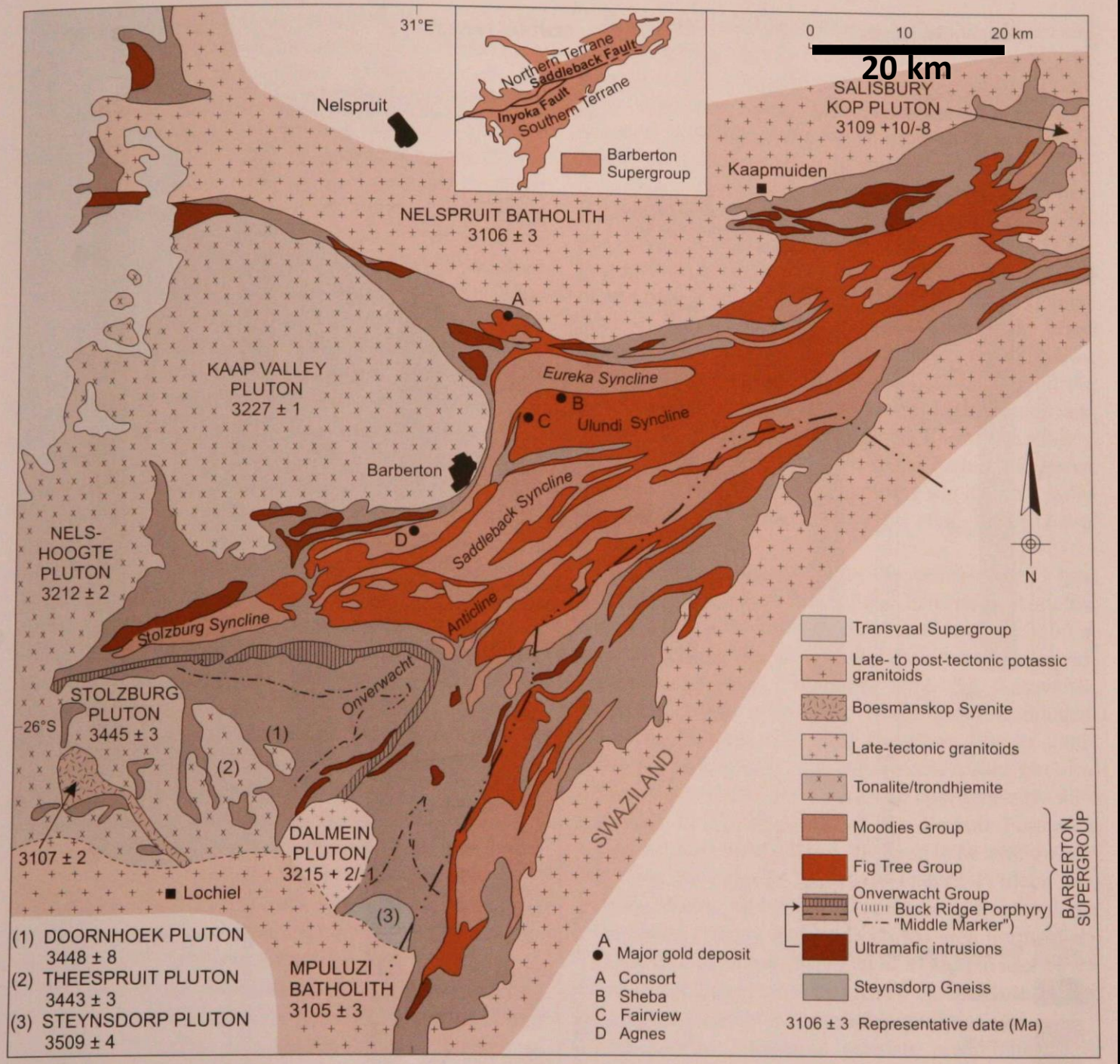


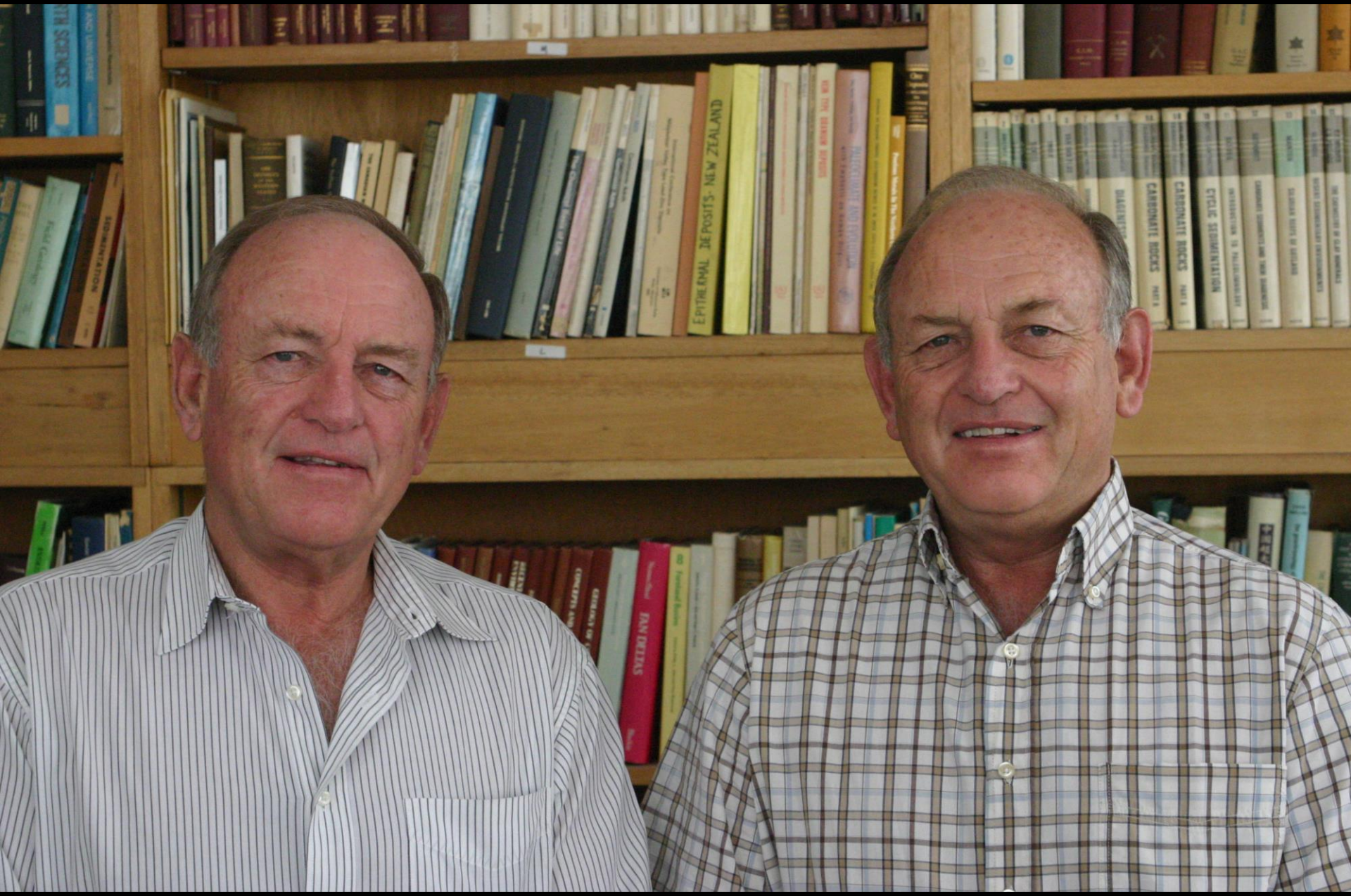
The Barberton greenstone Belt (3500 M yr old)

In the Onverwacht Group were found the hottest and the most Mg-rich lavas that were ever formed

KOMATIITES

White lava (white in colour) at 1600 °C and highly fluid





Richard and Morris Viljoen – discovered and named *komatiite* in 1969

THE BARBERTON INTERNATIONAL CONTINENTAL DRILLING PROGRAM (ICDP)

Information Circular of January 2011

14 Universities World-wide

Principal Investigators:
Nick Arndt (Grenoble)
Allan Wilson (Wits)
Axel Hofmann (UJ)

Drilling manager
Gordon Chunnett

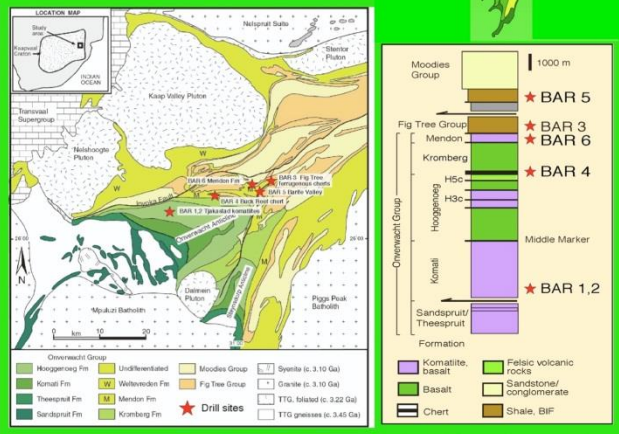
PEERING INTO THE CRADLE OF LIFE
SCIENTIFIC DRILLING IN THE BARBERTON BELT

The Barberton Greenstone Belt in South Africa sis one of the best-preserved successions of mid-Archean (3.5-3.2 Ga) supracrustal rocks in the world, and it is a remarkable natural laboratory where conditions and processes at the surface of the Archean Earth can be studied in detail. Despite generally good outcrop, nowhere in the Barberton belt are complete field sections preserved, and crucial features such as the contacts of lava flows and continuous successions of critical sedimentary rock sequences are not exposed. Only through drilling can we obtain the complete sections and relatively unaltered samples through the volcano-sedimentary successions. Two main targets have been identified:

1. Sedimentary sequences will provide information about erosion and sedimentation on the early Earth, the composition and temperature of Archean seawater, and one possible site where life emerged and evolved. Study of tidal sequences will provide information about the dynamics of the Earth-Moon system, and the investigation of spherule layers provide information about meteorite impacts on the early Earth.
2. Successions of ultramafic to felsic volcanic rocks will provide new insights into volcanic processes, dynamics of the crust and mantle, interaction between oceanic crust and the hydrosphere and biosphere. Sources of hydrothermal fluids on the ocean floor, driven by circulation of seawater through the volcanic pile, are a second habitat of early life.

List of sites

Hole	*Target lithology*	*Length*
BAR 1A	Tjakastad komatiites	600m
BAR 1B	Tjakastad komatiites	150m
BAR 2	Fig Tree sediments	520m
BAR 3	Buck Reef chert	800m
BAR 4	Barite Syncline seds	800m
BAR 5	Mendon komatiites	300m



Geological map with drilling sites and stratigraphy of the Barberton Belt,.

The project is supported by the **International Continental Drilling Program (ICDP), the South African Council for Geoscience, and scientists and research councils** from 13 countries in five continents. The choice of targets, drilling strategies and scientific goals were discussed during planning meetings held in Johannesburg (October 2006), San Francisco (2006), Berlin (2007), Vienna (2008) and during a one-week field conference in the Barberton belt in 2007. The project was approved by the ICDP in August 2009 and authorization to drill was obtained in January 2011.

Six shallow (150 to 800m) holes will be drilled at five sites in July-September 2011.

Core will be logged and archived at the facilities of the Council for Geoscience in Pretoria and will be available for distribution early in 2012.

The drilling will be conducted using a standard rig and conventional technology under the supervision of Gordon Chunnett who will interact with the ICDP and with scientists of the Council for Geoscience and South African universities and mineral exploration companies. The distribution of samples and post-drilling research will be managed by a steering committee comprising representatives from all major participating countries.

icdp
European Science Foundation
Council for Geoscience
CSIC
Natural Environment Research Council
Université Joseph Fourier
NASA
Academy of Finland
DFG Deutsche Forschungsgemeinschaft
cnrs

THE BARBERTON GUARDIAN 15 July 2011

July 15 Feature 2011

International Scientists peer into craddle of life

The drilling and the follow-up study of drill core is a high-level, prestigious, international scientific project that is totally unrelated to mineral exploration and mining activities.

The Barberton greenstone belt, more commonly known as the Barberton Mountain Land, is famous all over the world. Geologists in many countries know that it contains the world's best examples of ancient volcanic and sedimentary rocks and that some of these contain traces of the oldest living objects.

These rocks date back to the first quarter of the Earth's history. For 70 years geologists, mainly South African, have come to Barberton to study the rocks, and in more recent years this work has gained momentum.

Each year there are visits from scientists from countries such as the USA, France, Germany, Netherlands, Japan and China; each year students not only from Johannesburg, Pretoria, Cape Town and other South African Universities, and also from foreign universities visit the region to learn about the unique set of rocks.

One special type of volcanic rock – komatiite – derives its name from the Komati River, and was so named by two Wits professors, the Viljoen brothers in 1969. Komatiites have since been recognized in other ancient parts of the world.

Despite the generally good outcrop of rocks at the surface, nowhere in the Barberton belt are complete sequences of rock preserved. Features that are crucial to their complete understanding, such as the contacts of lava flows and soft, easily eroded sedimentary rocks, are not present at the surface.

In order to obtain a continuous sequences of rocks, and also to obtain samples that are not affected by alteration, a group of South African and foreign scientists intend in the next two months to conduct a program of scientific drilling in various parts of the belt.

History Of Project

Five years of planning have gone into the project under the support of the International Continental Drilling Program (ICDP).

The idea of organizing a drilling project was conceived in May 2006 and this led to a series of meetings, sponsored by the European Science Foundation, to discuss the choice of targets, drilling strategies and scientific goals. The first was held at the University of the Witwatersrand in October 2006 and it was followed by other meetings in San Francisco (2006), Berlin (2007), Vienna (2008) and a one-week field conference in the Barberton belt in 2007.

The ICDP approved the project in August 2009 and the drilling permit was received from the Department of Mineral Resources in January of this year. A report on measures taken to minimize the environmental impact of drilling was also approved. Drilling will take place in July through September of this year.

Scientific Aims

The goals of the projects are entirely scientific. The aim of the group is to obtain a better understanding of the earliest history of our planet.

More specifically, the group will use the information obtained by the study of the drill core to determine what conditions were like at the surface of the planet, three and a half billion years ago, the time when the rocks of the Barberton greenstone belt were formed. This period in geological terms is called the Early Archaean and only few examples from this period have been preserved due to Earth's dynamic and turbulent history.

The Barberton greenstone belt is one of the best-preserved successions of Archaean rocks in the world, and it is a remarkable natural laboratory where conditions and geological processes of the distant past can be studied in detail. Some of these rocks are volcanic, having formed by eruptions of the oldest known volcanoes; others are sedimentary, having been deposited at the floor of ancient oceans. It was within this environment that primitive life first appeared and evolved, hence the title of the project. The aim of the group is to 'Peer into the Cradle of Life'. More specifically, the study of the sedimentary sequences will provide information about erosion and sedimentation on the early Earth, the composition and temperature of Archaean seawater, and one possible site where life emerged and evolved.

Study of tidal sequences will provide information about the dynamics of the Earth-Moon system, and the investigation of spherule layers (layers of tiny globular shaped particles) provide information about meteorite impacts on the early Earth.

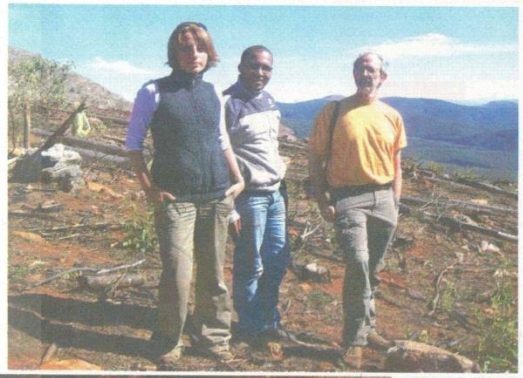
The study of the volcanic rocks will provide new insights into volcanic processes, dynamics of the Earth's crust and mantle, interaction between oceanic crust and the hydrosphere and biosphere and hence understanding the setting for the development of early life forms. Sources of hydrothermal fluids on the ocean floor, driven by circulation of seawater through the volcanic pile, are a further possible habitat of early life.

The drilling and the follow-up study of drill core is a high-level, prestigious, international scientific project that is totally unrelated to mineral exploration and mining activities.

Program

Drilling is expected to start in the week of 11-18 July. Five sites in different parts of the belt have been selected as shown in the figure. One site is situated just north of Tjakastad townsite in the southern part of the belt and the four others are located in the interior to the west of the Barberton-Havelock road.

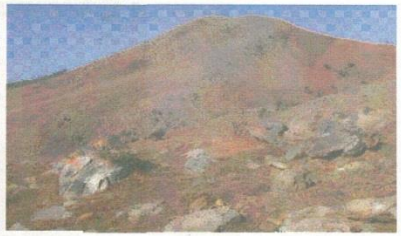
The drilling will be conducted using a standard rig and conventional technology under the supervision of operations manager Gordon Chunnett, assisted by Wits student Masi-











Peering into cradle of life: Scientists inspecting Barberton drilling site (main photo) Core in a core box which would look similar to that retrieved in the Barberton drilling program (top right photo) Drilling targets: stromatolite, early microbial life form (middle right photo); Buck Reef sediment (bottom right photo); banded iron formatio (bottom left photo)

with the ICDP and with scientists of the Council for Geoscience and South African universities and mineral exploration companies. The distribution of samples and post-drilling research will be managed by a steering committee comprising representatives from all major participating countries.

Science Committee

N. Arndt, University Joseph Fourier, 38400 Grenoble, France
P. Mason, University of Utrecht, Netherlands
A. Wilson, University of the Witwatersrand, South Africa
A. Hofmann, University of Johannesburg, South Africa
G. Byerly, Louisiana State University, Baton Rouge, LA 70803, USA
T. Cloete, Council for Geoscience, Pretoria, South Africa

Core will be logged and archived at the National Core Storage Facility of the Council for Geoscience in Pretoria and will be available for distribution to scientists in South Africa and overseas early in 2012 by way of motivation and application to the steering committee.

An important aspect of the project is the training of South African students in a unique area of geology as well as exposing local students to cutting-edge scientific procedures and analytical techniques.

More information

To inform the local community about the project, public meetings will be held in Badplaas and Barberton. Dates and venues will be given soon. Visits to the drilling sites can be arranged on appointment.

Two websites provide more information:

http://www.icdp-online.org/front_content.php?idart=2709
www.peeringintobarberton.org.za

Shifu uvumile kutsi bososesayensi bente lucwaningo lwabo

Chief gives green light geoscience reseachers

Shifu Makhosonkhe Cambridge Dlamini wasendzaweni yase Mbhuleni lefaka phakatsi indzawo yase Tjakastad uwusekele ngalokuphelele lomsebenti wabososayensi mhlabawonkhe lona wokwenta luphenyo ngetematje kumbe emdvwala kulendzawo yase Tjakastad. Lomsebenti wabososayensi utawuchutjelwa e Barberton greenstone belt, lebekuyindzawo leyatiwa ngekutsi ngase Barberton Mountain Land, lekuyindzawo leyatiwa mhlaba wonkhe. Ema Geologist emaveni lamanyenti ayati kutsi lendzawo ngiyo indzawo lehamba phambili lapha emhlabeni yekwenta kulinga ngr ancient volcanic kanye nema dvwala.

Lamadvwala aneminyaka leminingi leyengcile futsi anemlandvo lomuhle lapha emhlabeni. Eminyakeni lengemashumi lasikhombisa ema Geologist, ikakhulu alapha eningizimu ne Africa, afikile lapha kulendzawo yase Mjindini kutewucwaninga lamadvwala. Eminyakeni leyengcile lomsebenti ukhule ngendlela lesimanga futsi uyancomeka. Yonkhe minyaka kufika tivakashi tabososayensi labavela emaveni lafaka phakatsi l USA, France, Germany, Netherlands, Japan kanye ne Chana. Katsifutsi nebafundzi lababuya emaqveni lafaka phakatsi tifundza tase Johannesburg, Pretori Cape Town kanye nalamanye emenyunivesi alapha eningizimu Africa batewufundza ngalamadvwala langakavami.

Lokudriller kwalamadvwala kuyintfo lehamba phambili kuleliblangotsi labososayensi lapha emhlabeni jikelele. Lokudriller kwalamadvwala kufanele kutsi kucale kulelivi la 11-18 July. Tishlanu tindzawo kulelibhande leficokiwe njengaba kukhombakalisa kuleslifombe. Le core itakutsatfwa iyogcimwa kulendzawo lebatsi yi National Core Storage Facility of the Council for Geoscience e Pitoli. Itawulungelwa kutsi inikwe bososayensi balapha engizimu Africa kanye nebangenshcya kwetilwandle nakusuka umnyaka wa 2012. lomsebenti lomkhulu nakangaka utawuncedza bafundzi betekuncwaninga kwematje lapha ekhaya eningizimu Africa kakhulu ngendlela lesimanga



Chief Makhosonkhe Cambridge Dlamini ne baNkosi beVenda

Chief Makhosonkhe Cambridge Dlamini of Embhuleni, which includes the Tjakastad area, has given his full backing and go ahead to international scientists to undertake drilling operations in Tjakastad for scientific research.

The chiefs blessing came at a crucial time as the project was facing possible derailment over a misunderstanding as to the nature of the research, there some who thought it minerals exploration, however, all querries were straightrened out with the Council for Geosciences

The drilling will be conducted in the Barberton greenstone belt, more commonly known as the Barberton Mountain Land, which is famous all over the world.

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Drilling is expected to start in the week of 11-18 July. Five sites in different parts of the belt have been selected as shown in the figure. One site is situated just north of Tjakastad Township in the southern part of the belt and the four others are located in the interior to the west of the Barberton-Havelock road.

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The komatiite lava flows form resistant bands



The drilling starts





The first komatiite core drilled



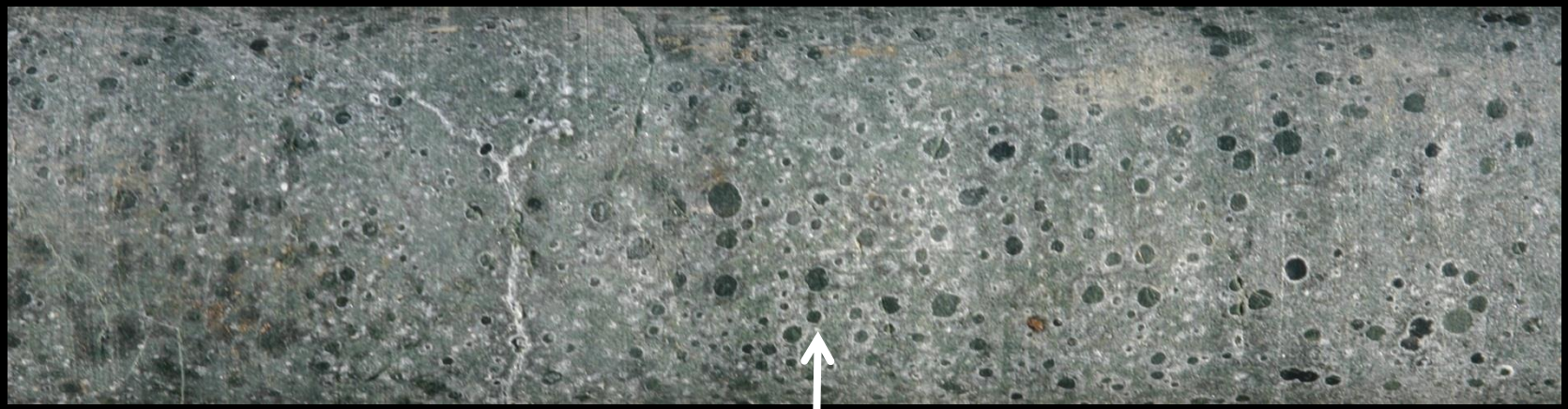
The Buck Reef drilling site


DIESEL
DR14
DR14



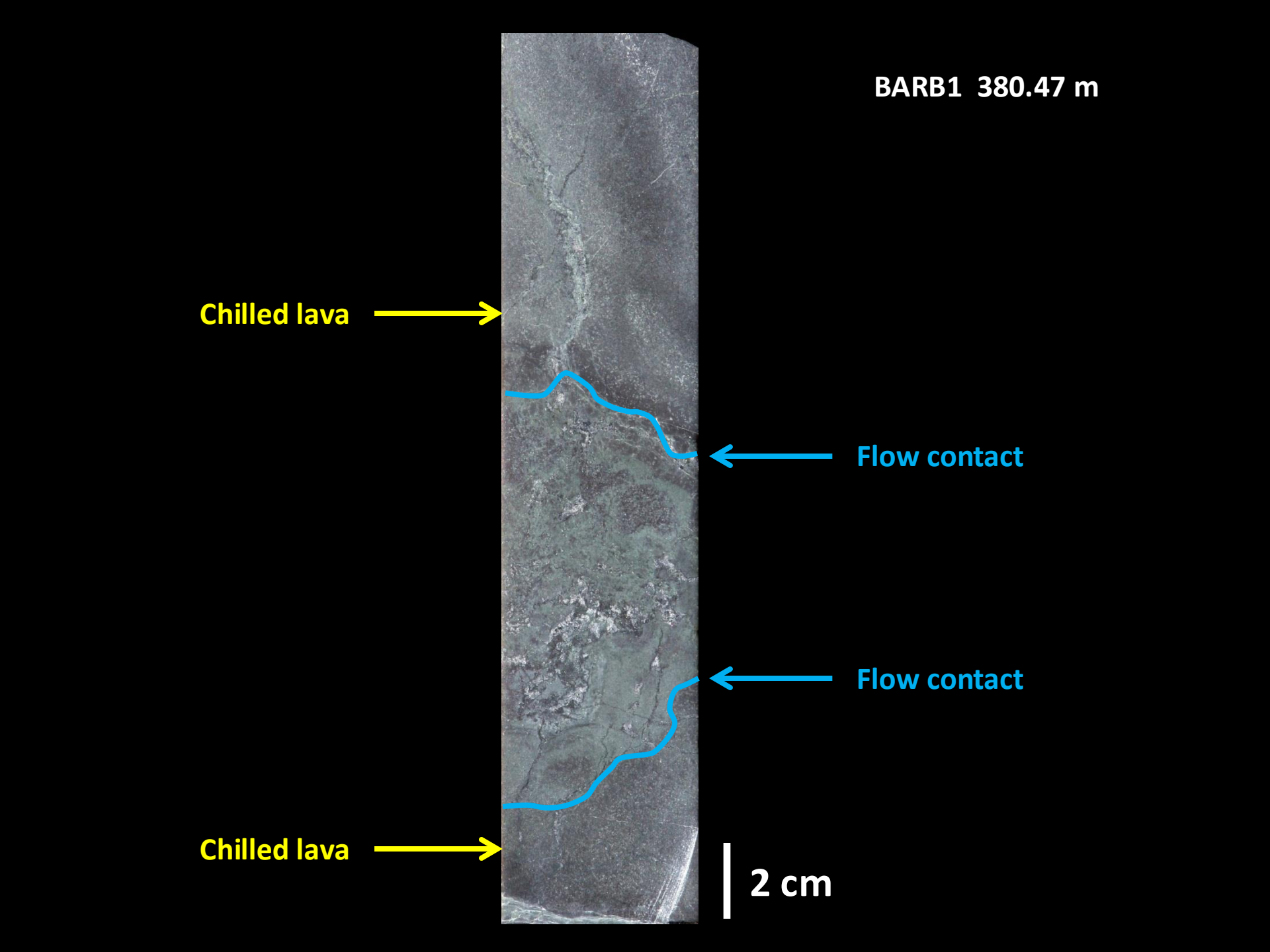
Buck Reef cherts



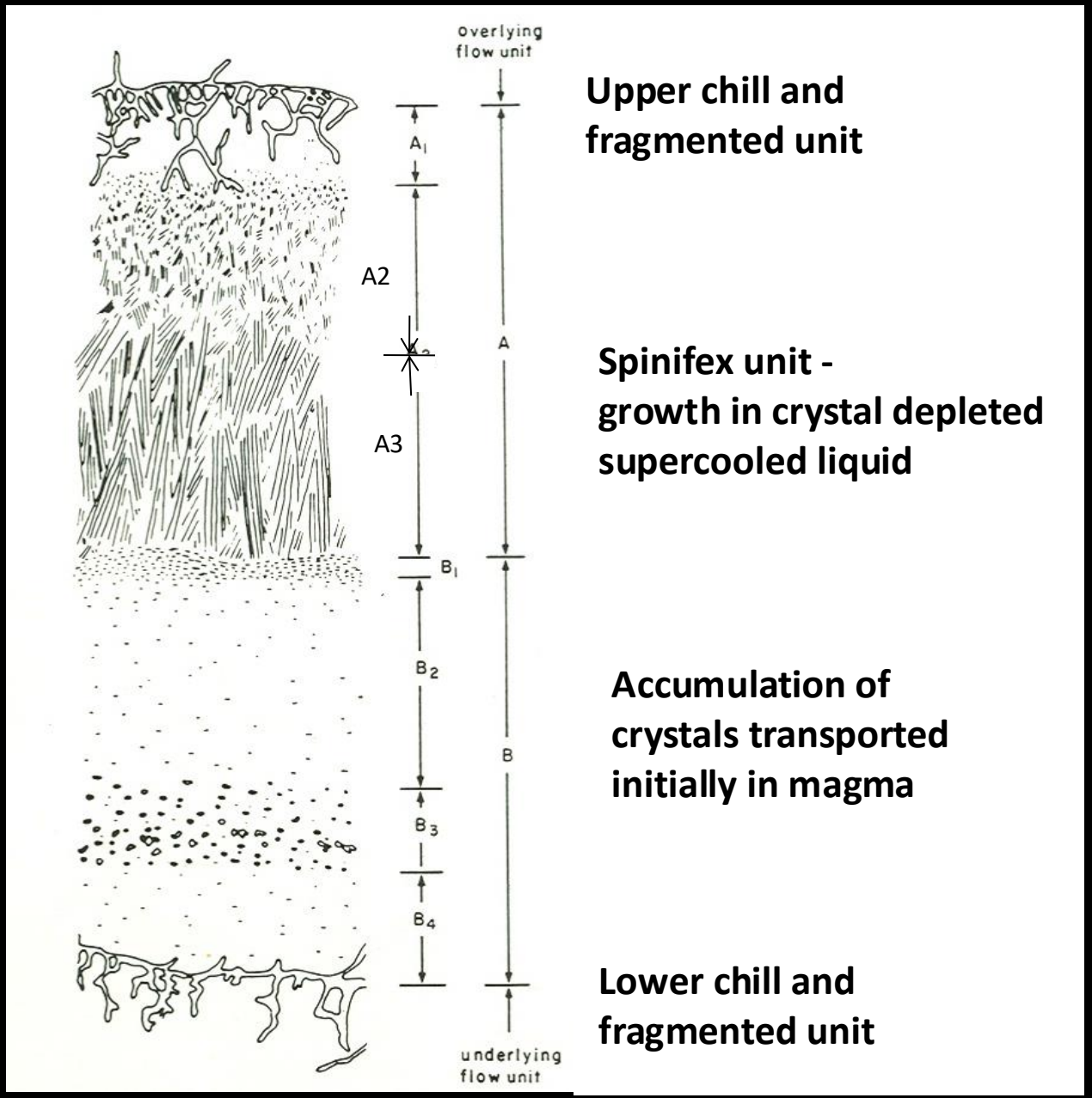


GAS BUBBLES CALLED VESICLES

The komatiite core has already revealed important structures


BARB1 380.47 m
Chilled lava
Flow contact
Flow contact
Chilled lava
2 cm

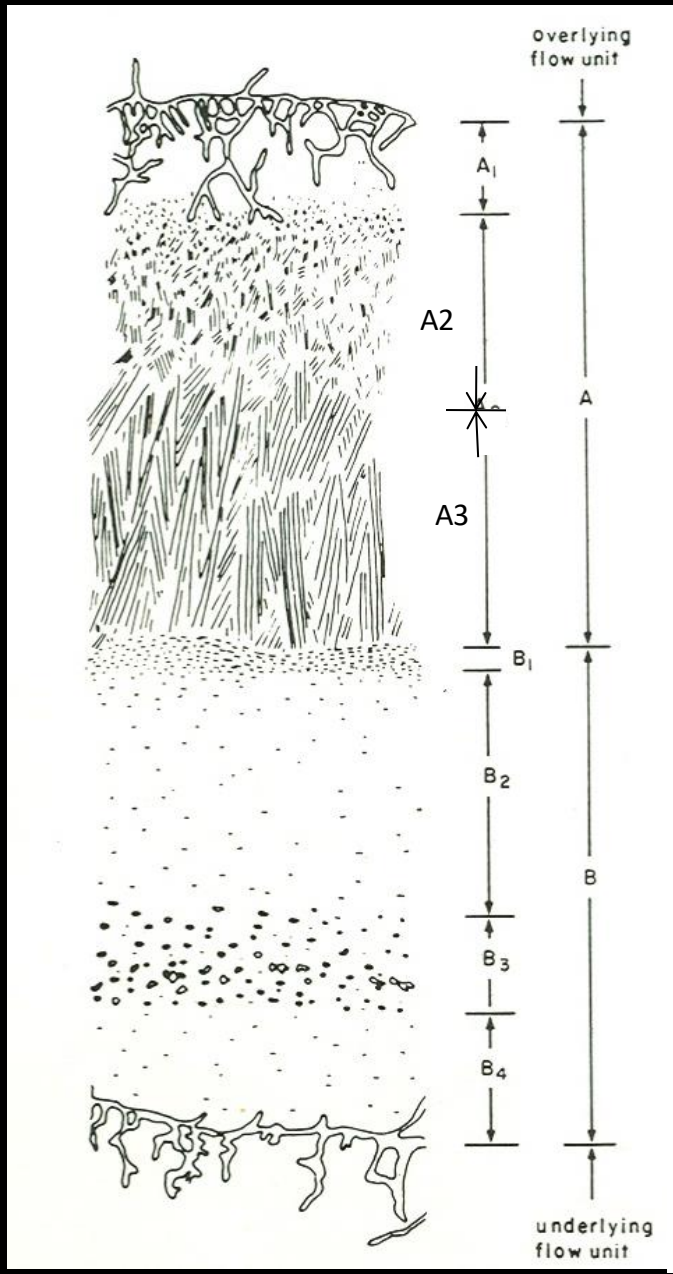
Pyke et al. 1977



Classic subdivision of the textured komatiite flow unit

CHILLS and SPINIFEX - Liquid compositions

CUMULATES - Not liquid compositions



Upper chill and fragmented unit

Spinifex unit - growth in crystal depleted liquid

Accumulation of crystals transported initially in magma

Lower chill and fragmented unit

So we have the paradox – what rocks represent liquids and what rocks represent extract from those liquids?

Named after a spikey Australian grass called *Triodia spinifex*

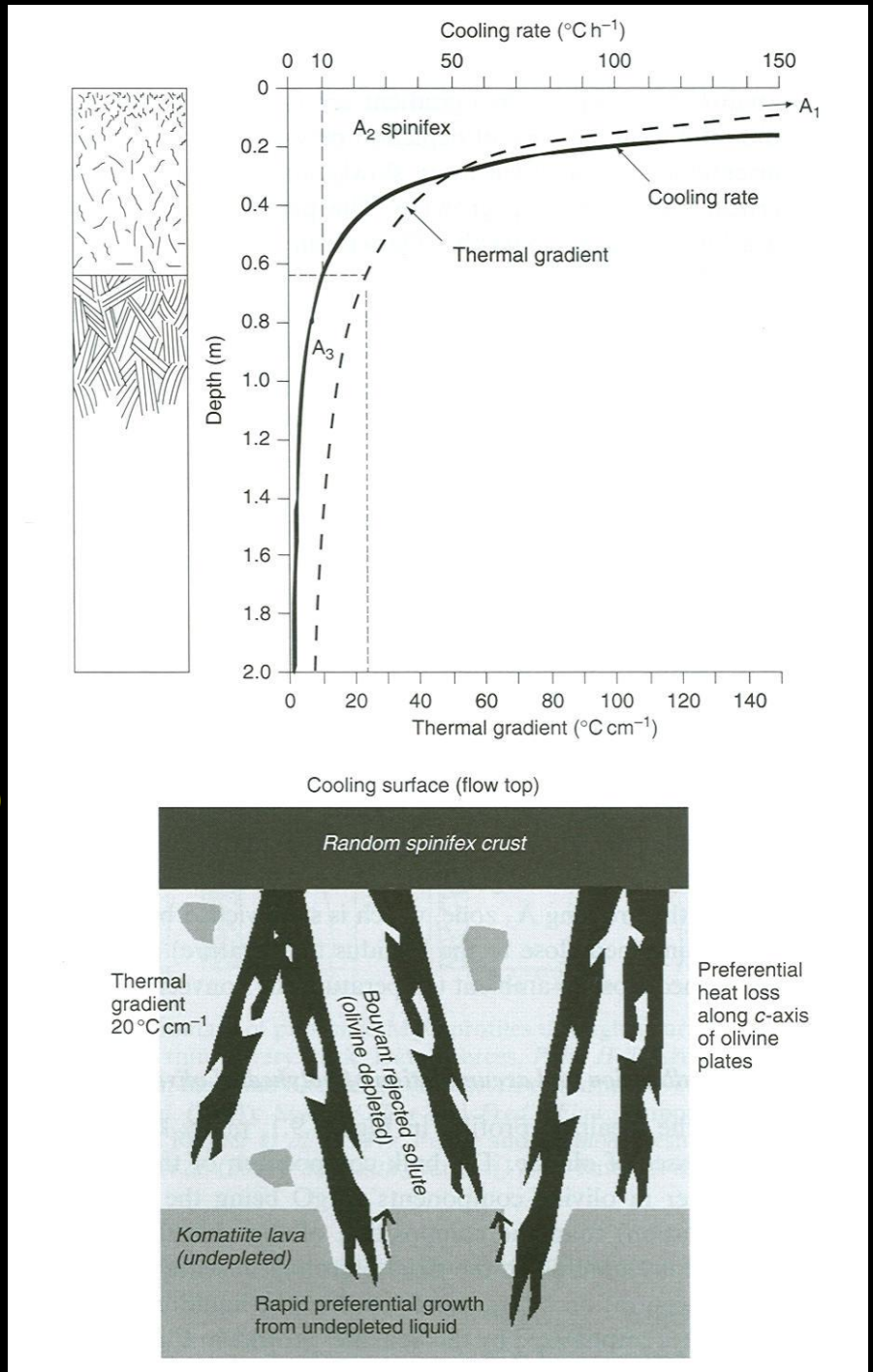
Remarkably, even though komatiites were discovered first in Barberton spinifex was first recognized as a unique texture in Australia



From Nick Arndt's book ***Komatiite*** (2008)

The hottest magmas that ever erupted ~ 1600° C

Also very high Mg contents ~ 25 – 30% MgO

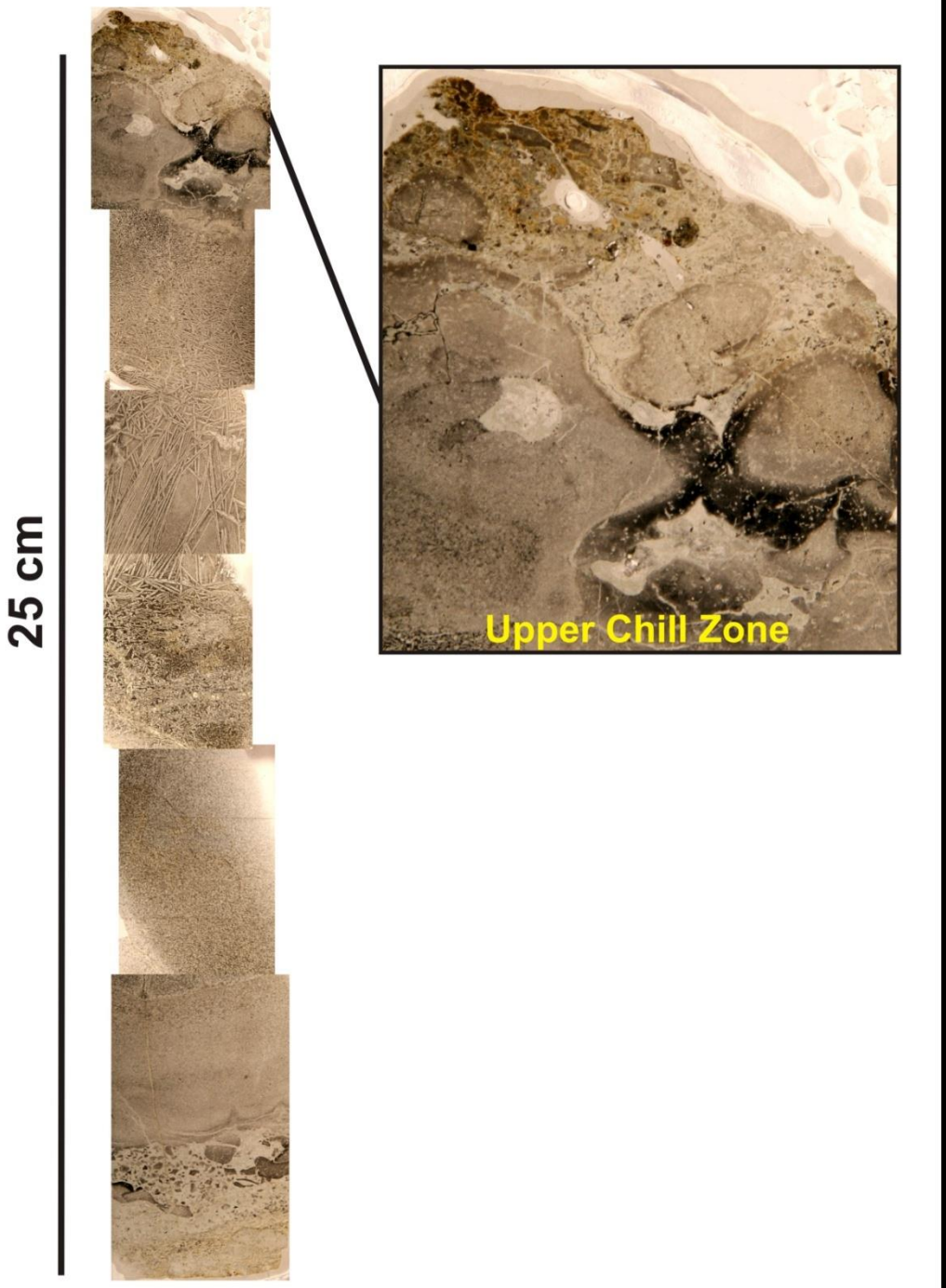


Spinifex forms by the unique combination of thermal gradient and the wide temperature interval between when crystals form and when complete solidification takes place

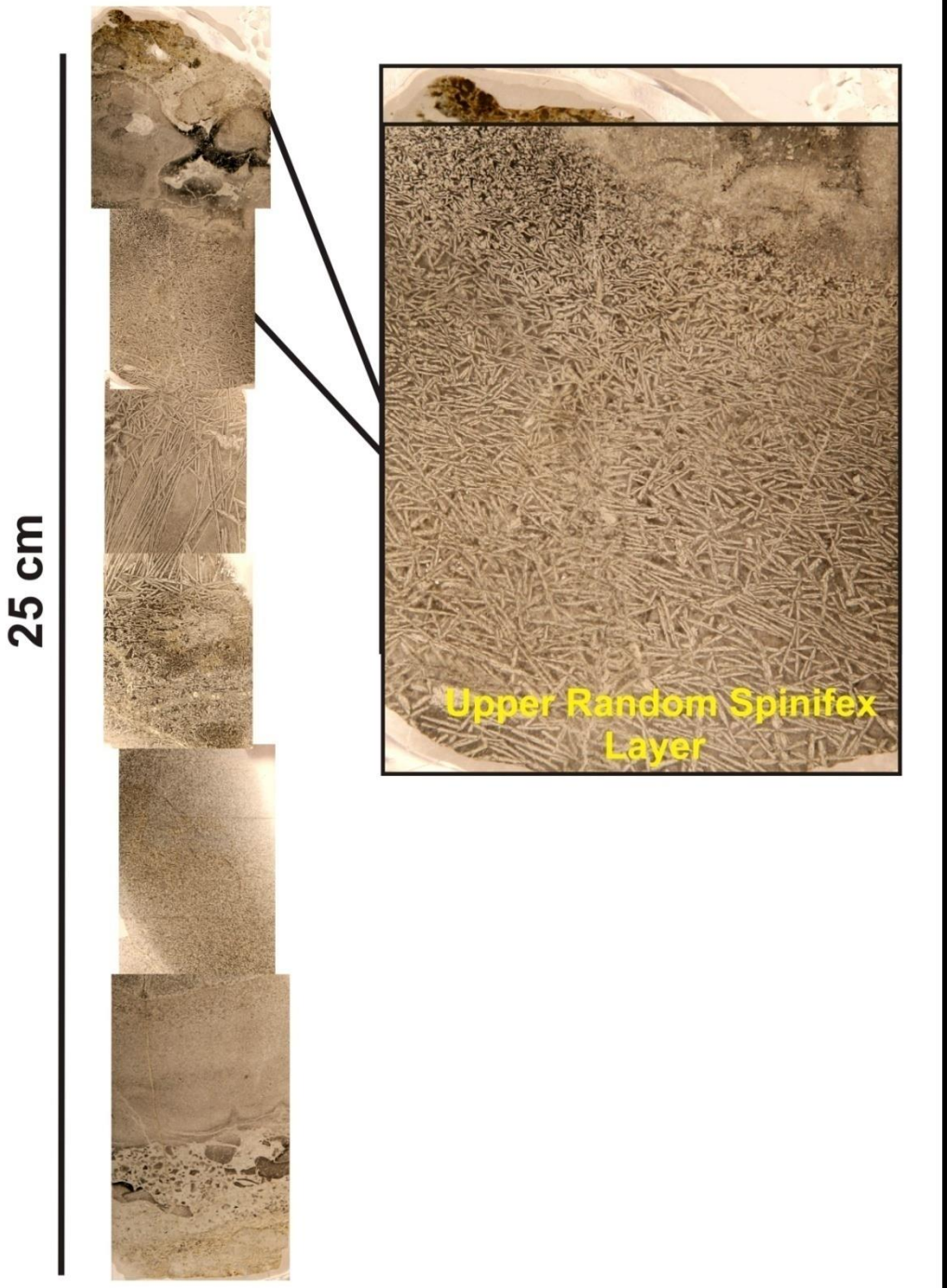
Section through a Barberton komatiite flow



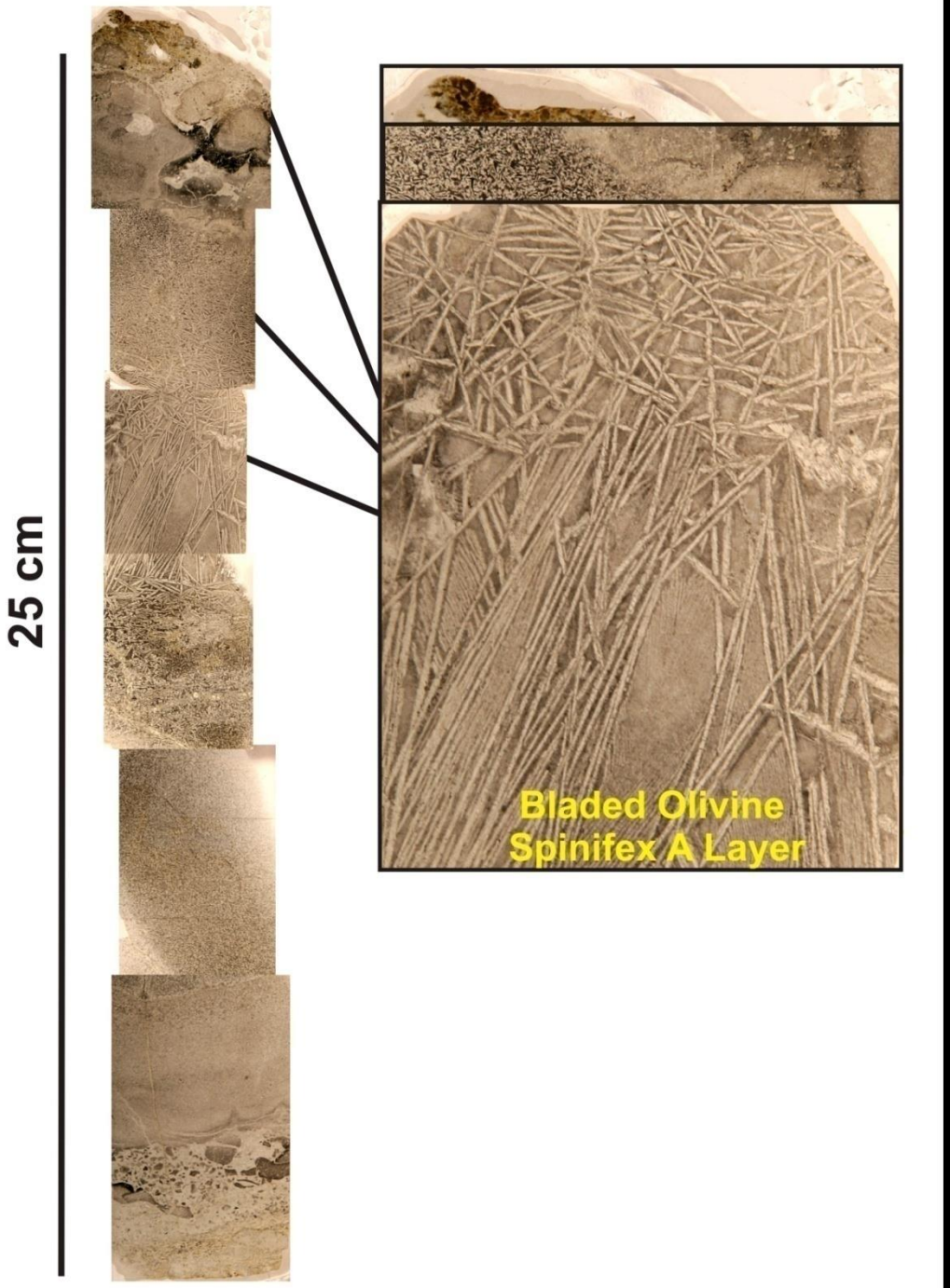
Section through a Barberton komatiite flow



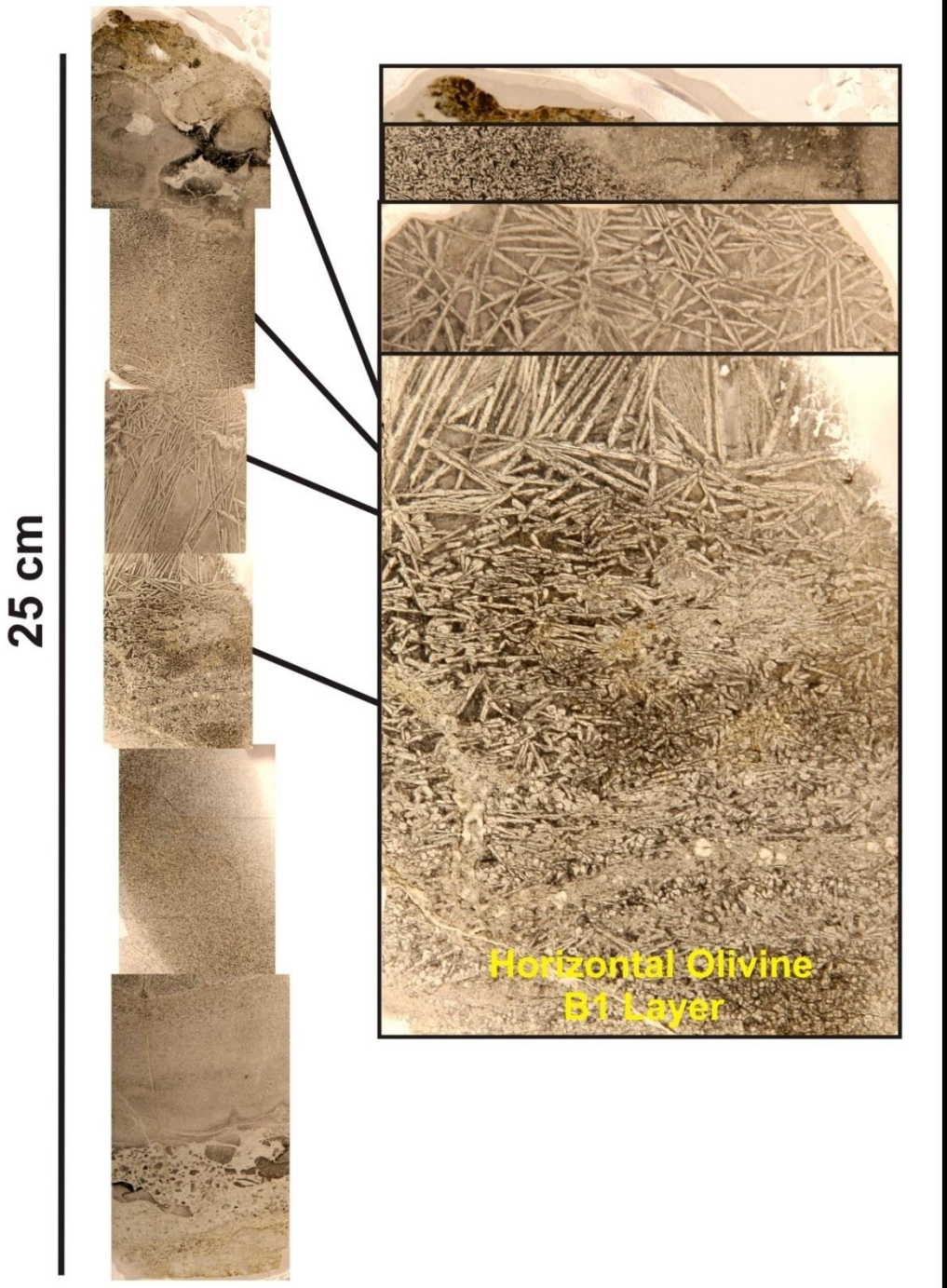
Section through a Barberton komatiite flow



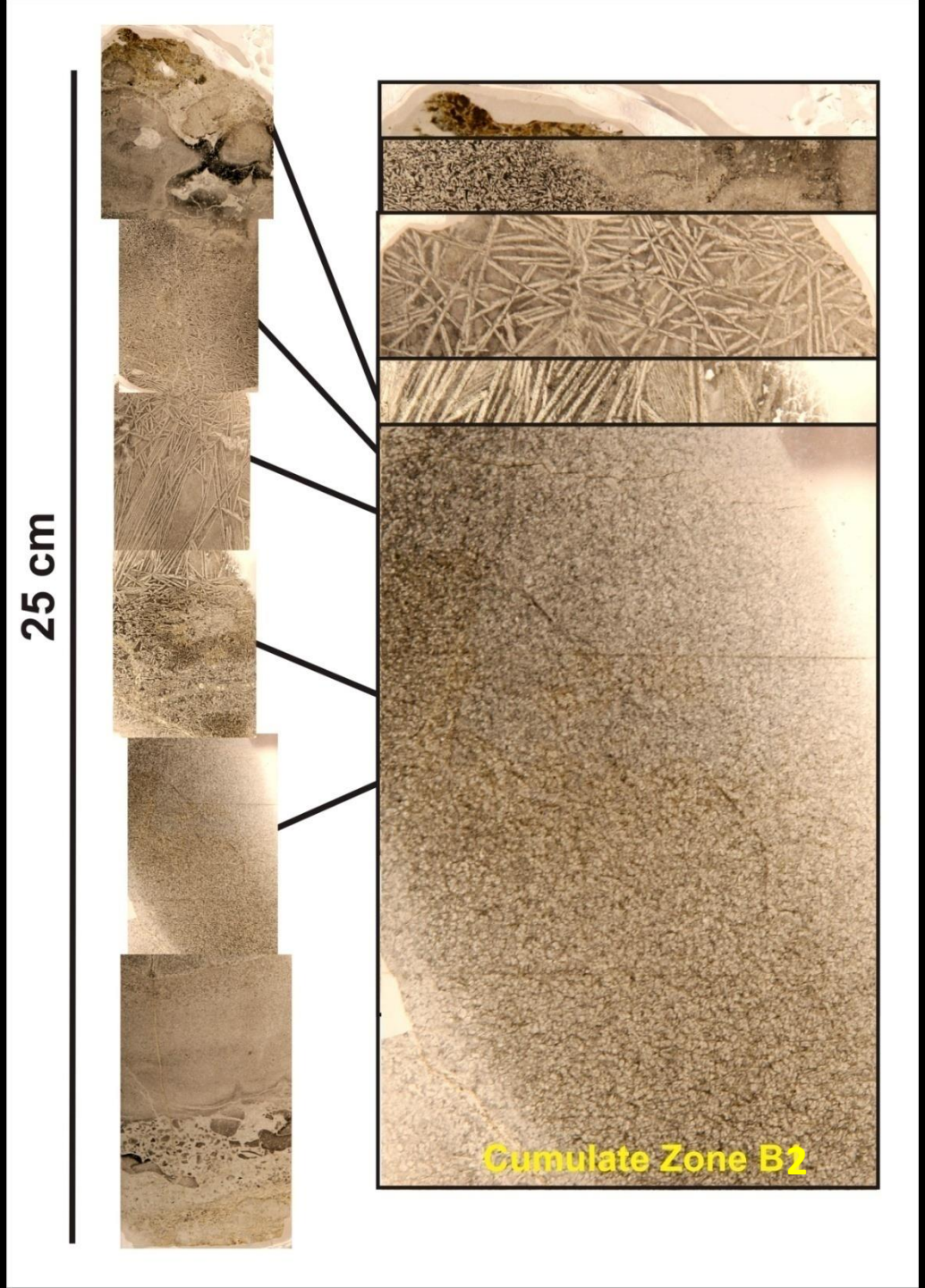
Section through a Barberton komatiite flow



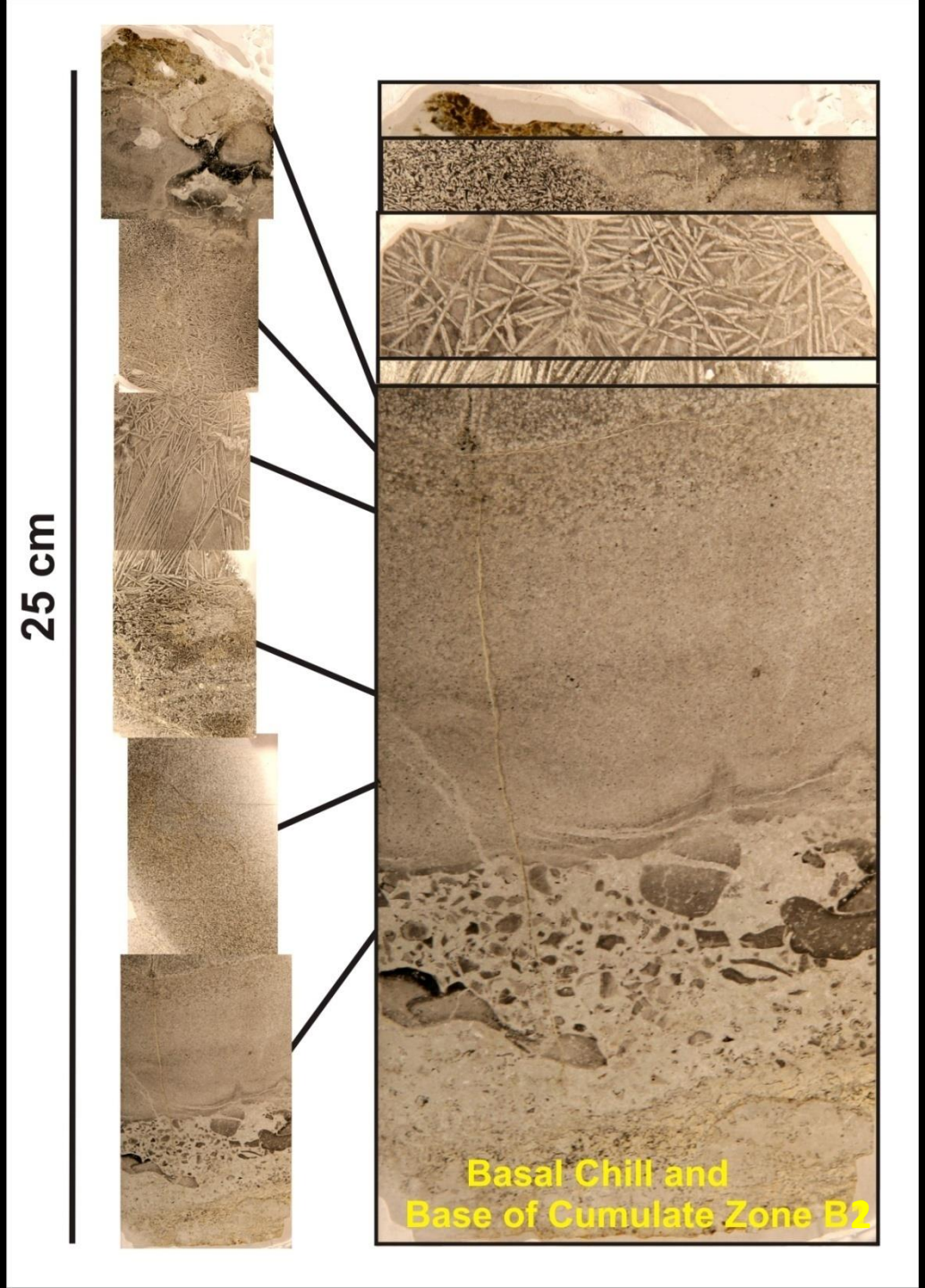
Section through a Barberton komatiite flow

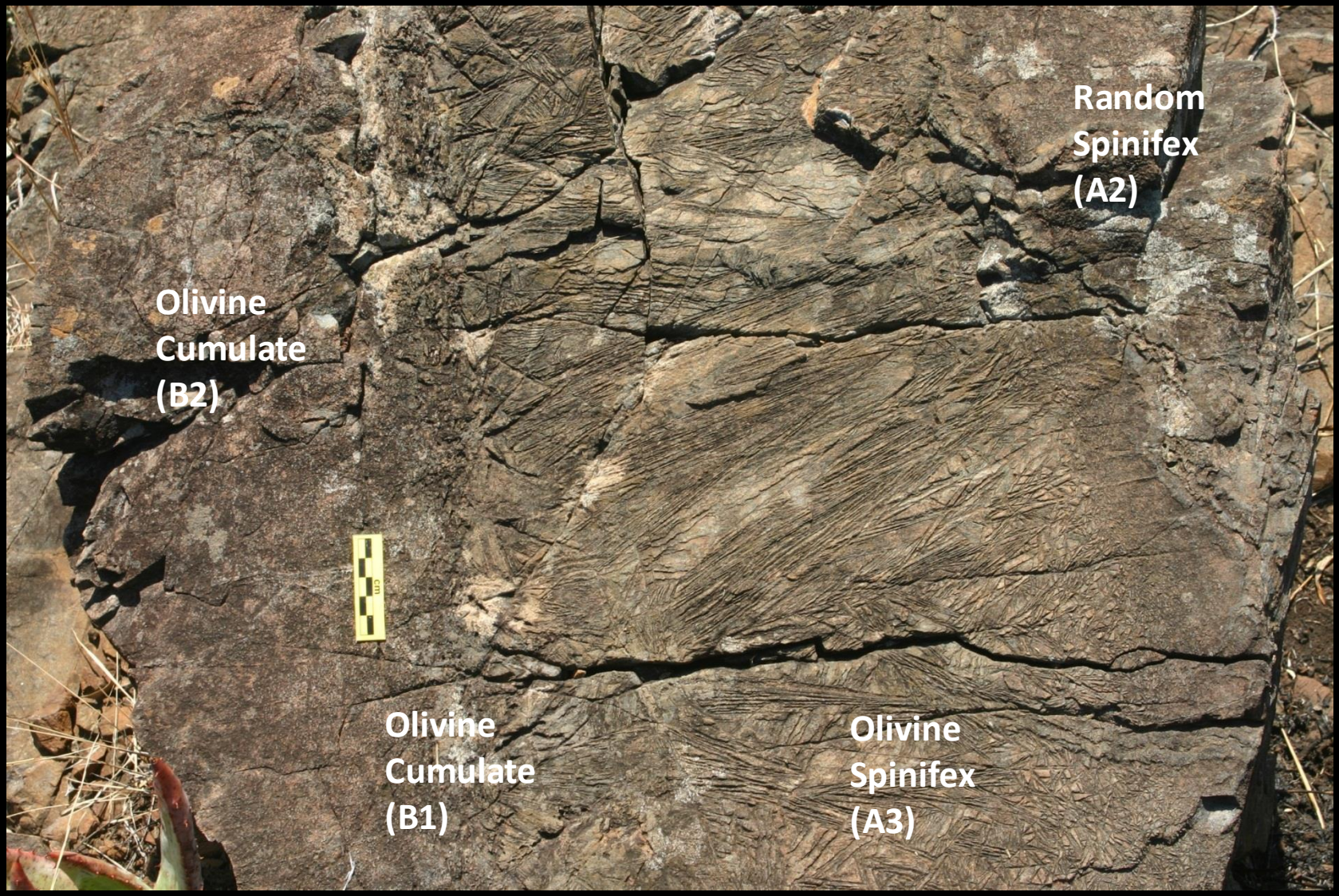


Section through a Barberton komatiite flow



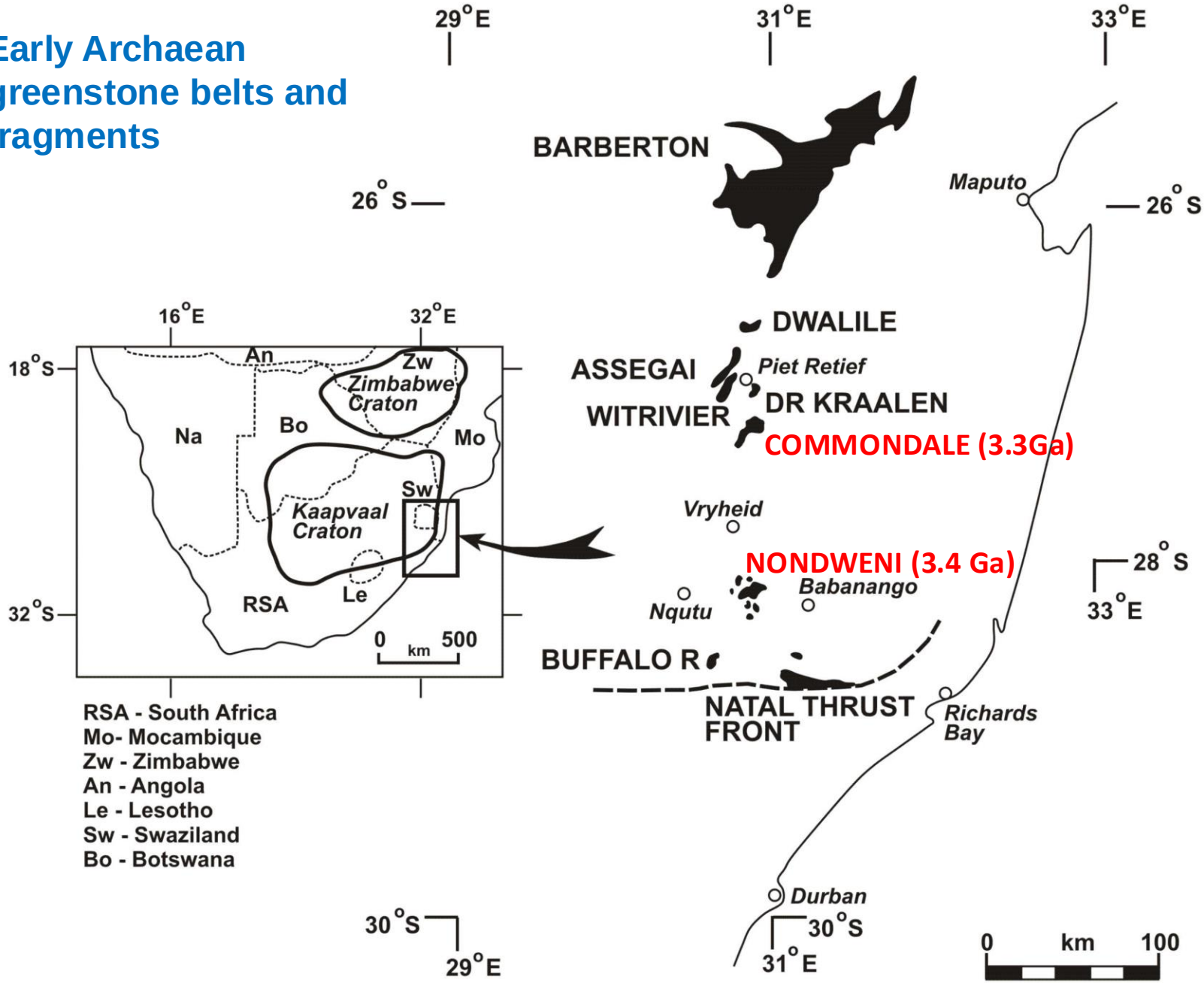
Section through a Barberton komatiite flow



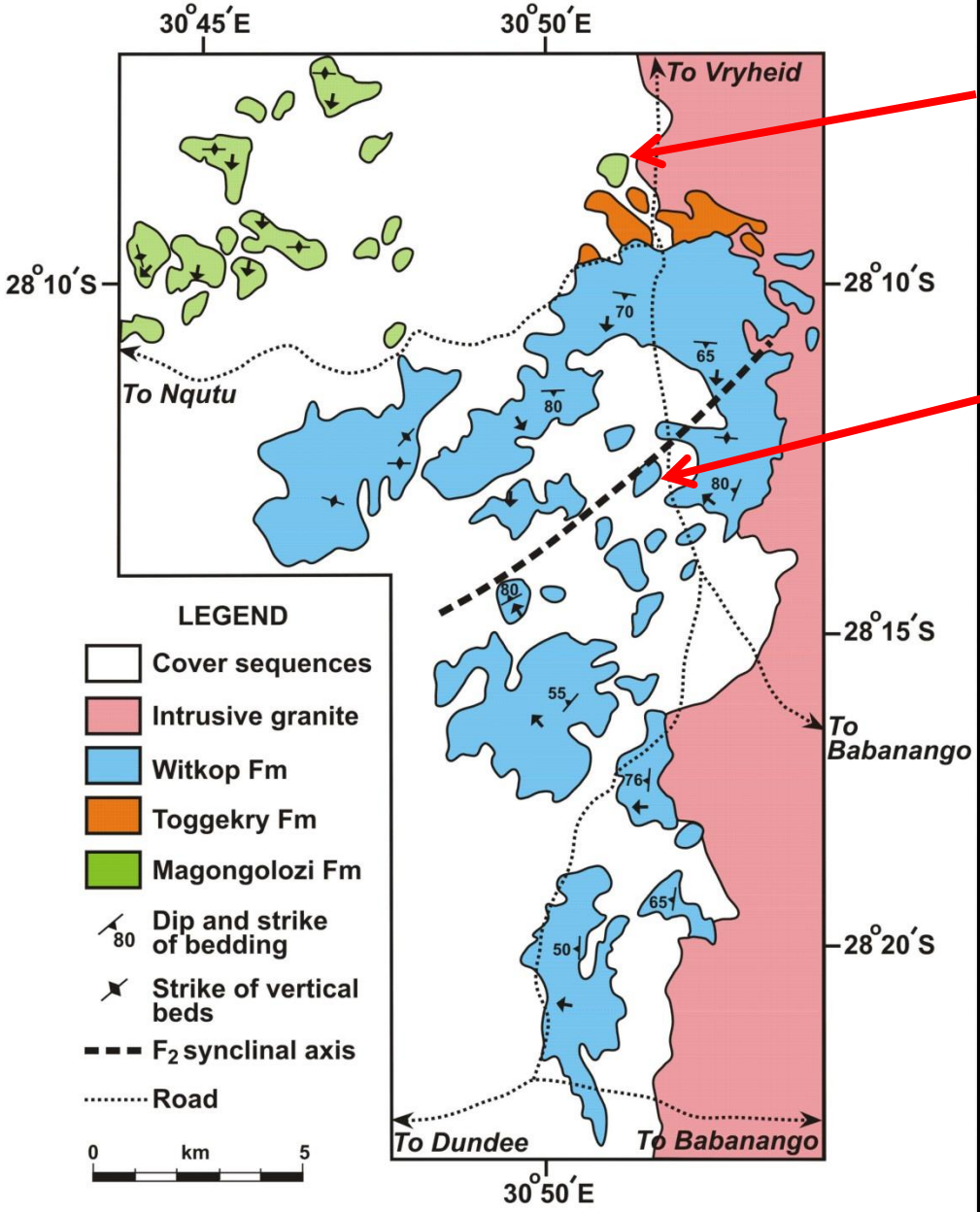


Most of these classic outcrops in Barberton have now been destroyed ….. so we now need drill core to study these rocks

Early Archaean greenstone belts and fragments



THIS AREA PRESERVES THE HISTORY OF THE COUNTRY AS WELL AS THE HISTORY OF THE PLANET



From Versfeld (1986)

Wilson and Versfeld (1994)

The site of the death of the Prince Imperial Louis Napoleon of France 1 June, 1879

Fort Newdigate -heliographic station. Overrun by a Zulu impi on 3 March, 1879



The Death of the Prince Imperial Napoleon of France

By Paul-Joseph Jamin

1st June, 1879



THE LATE PRINCE IMPERIAL.—THE ATTACK. 1st June, 1879 10.00 am

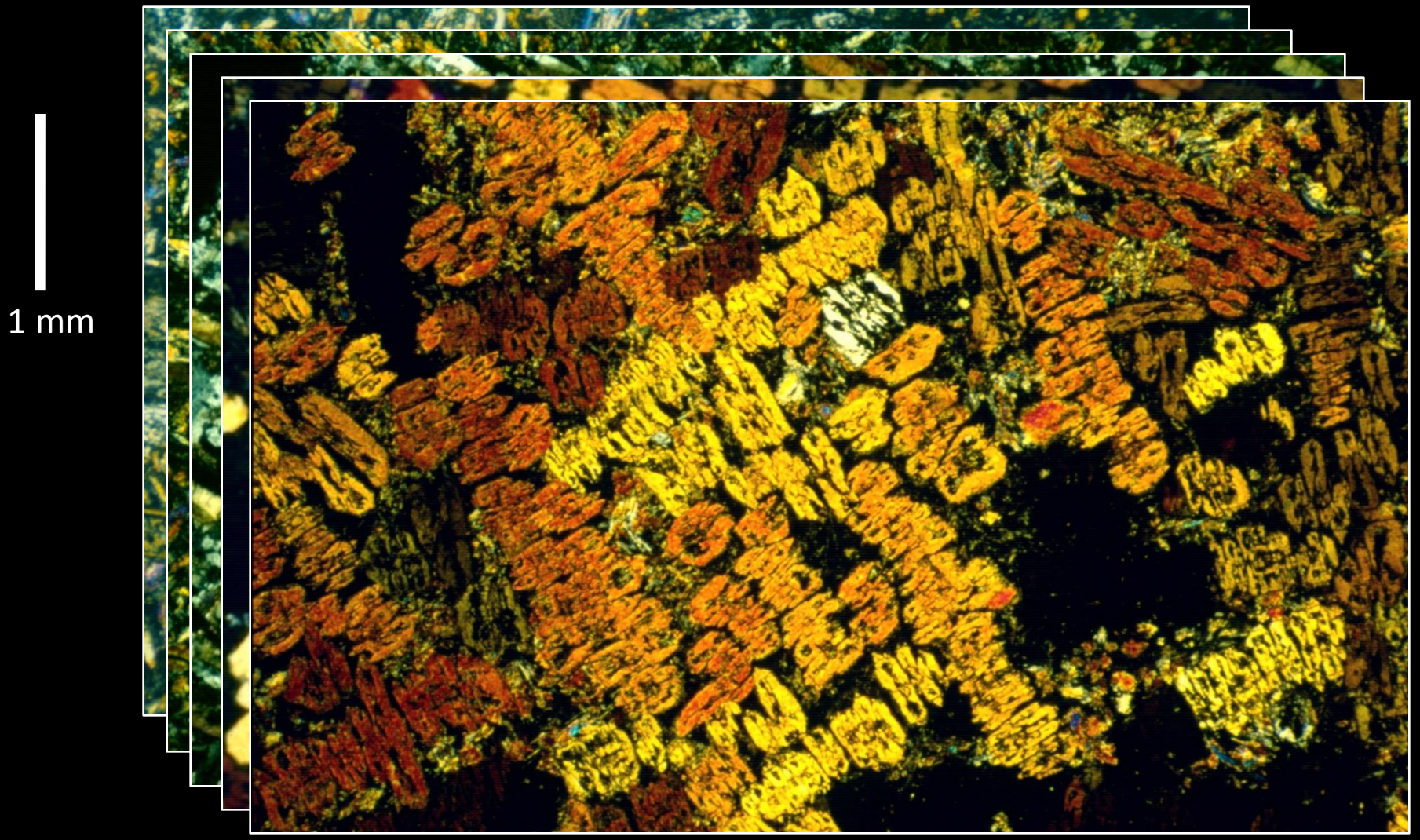


Giant PYROXENE spinifex from the Nondweni greenstone belt

Pyro – 'fire'
Xenos – 'stranger'



Giant OLIVINE spinifex from the Nondweni greenstone belt



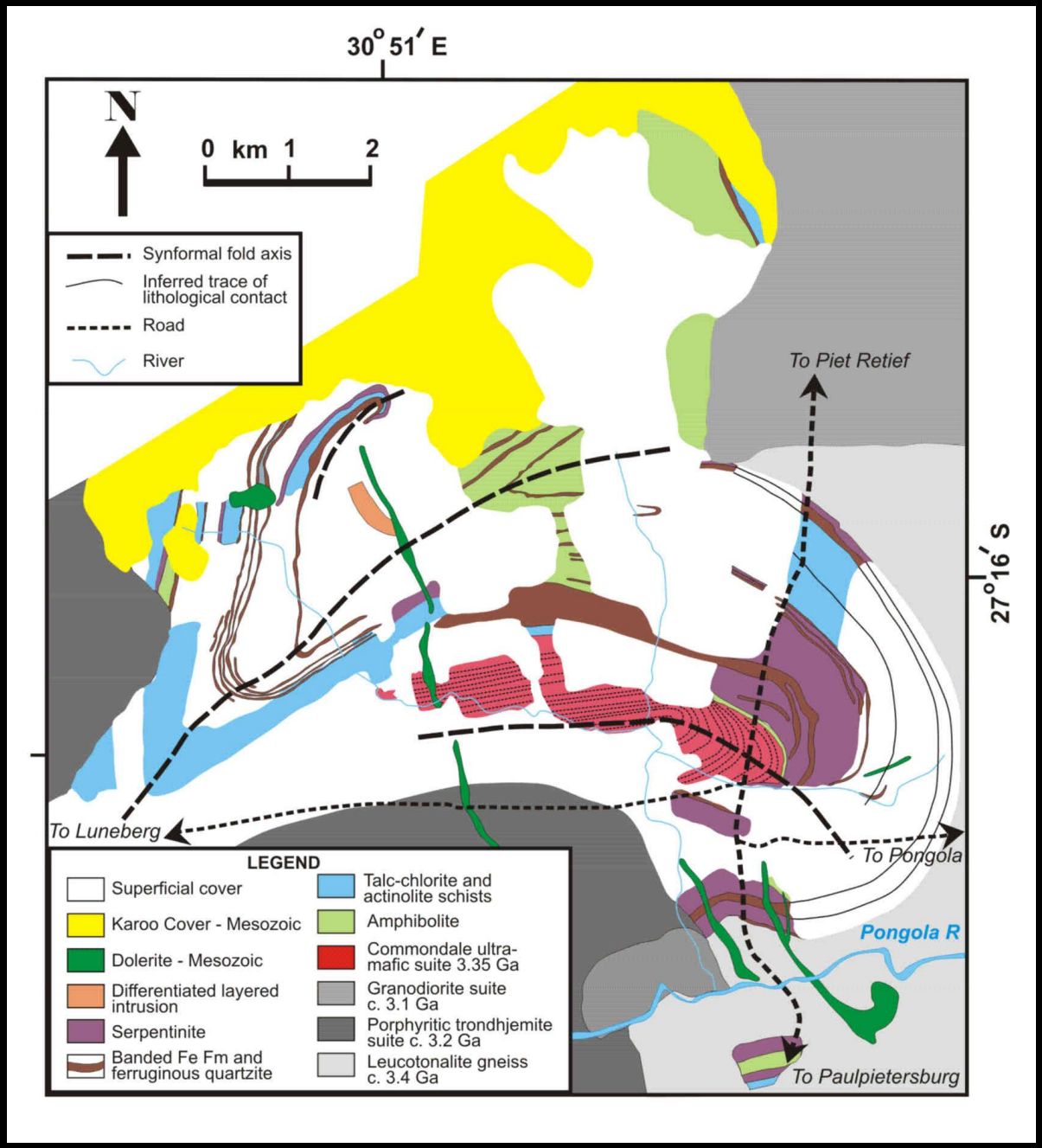
Photomicrographs from the Nondweni greenstone belt



The world's oldest stromatolites
3.4 billion years ago

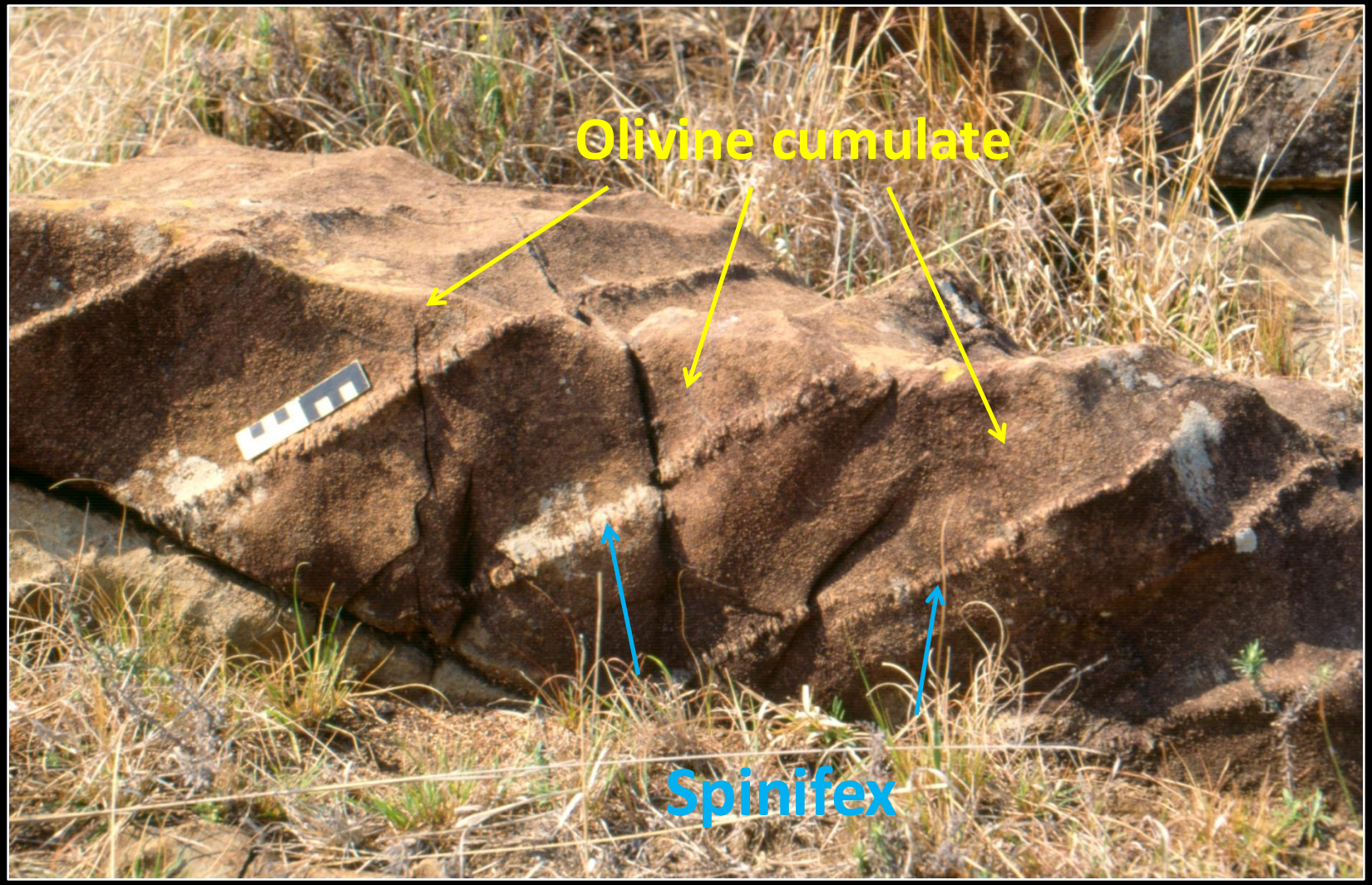
Xie, Hofmann, Hegner, Wilson, Wan, Liu
Gondwana Research (2011)

The Commondale greenstone belt holds some of the most important volcanic rocks - and maybe also a key to igneous processes in the Archaean

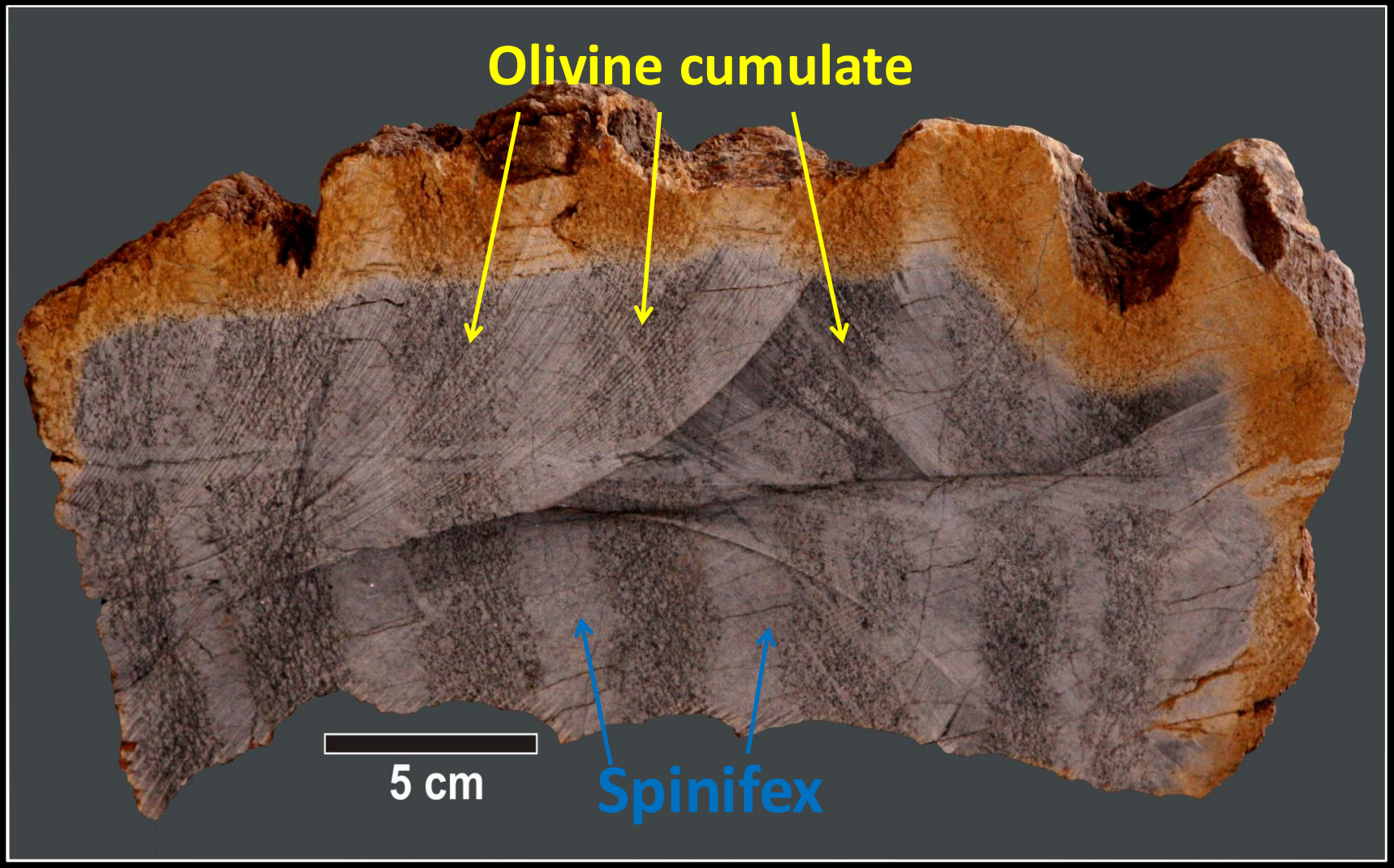




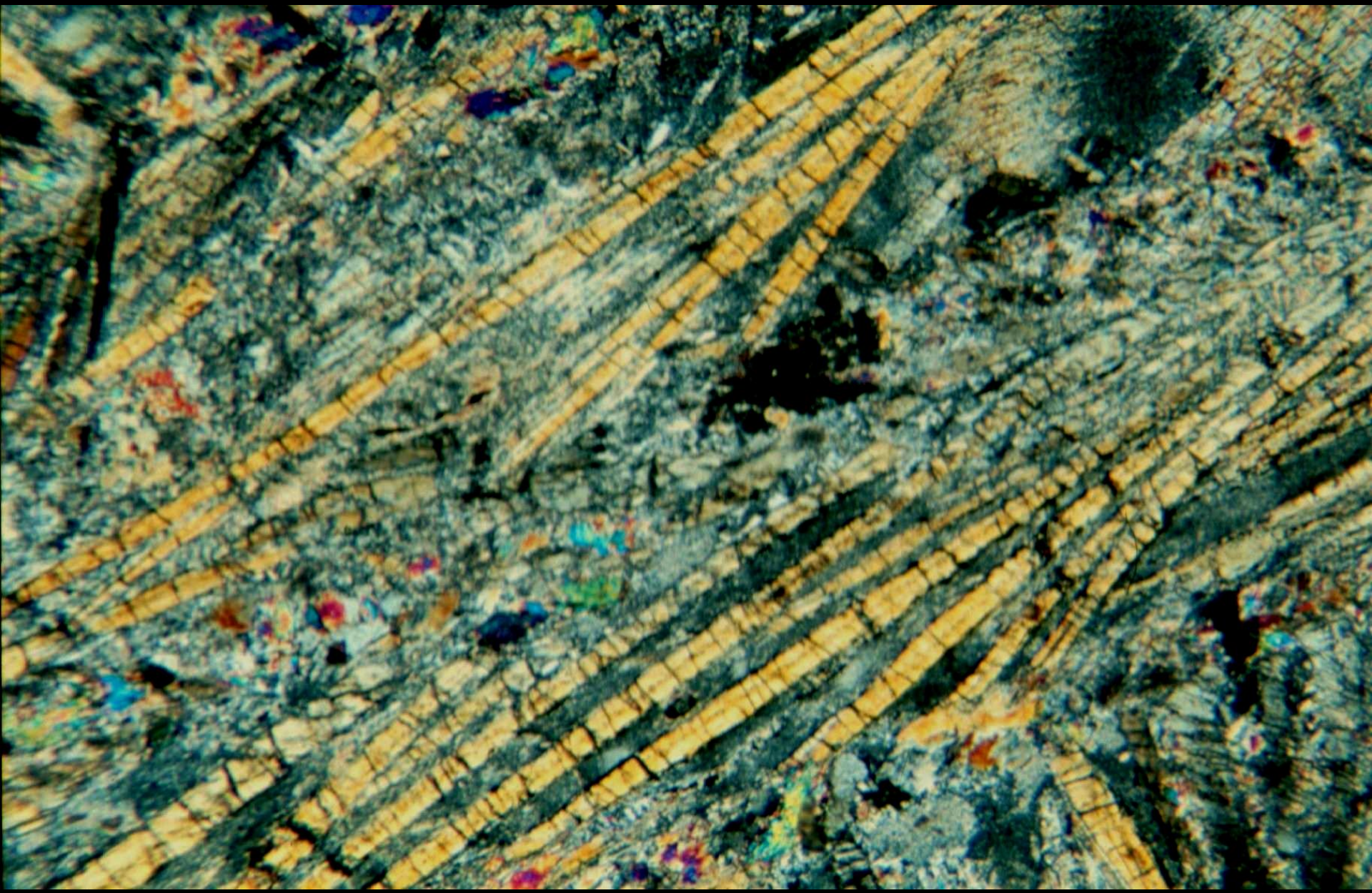
Olivine plate spinifex and unique pyroxene spinifex



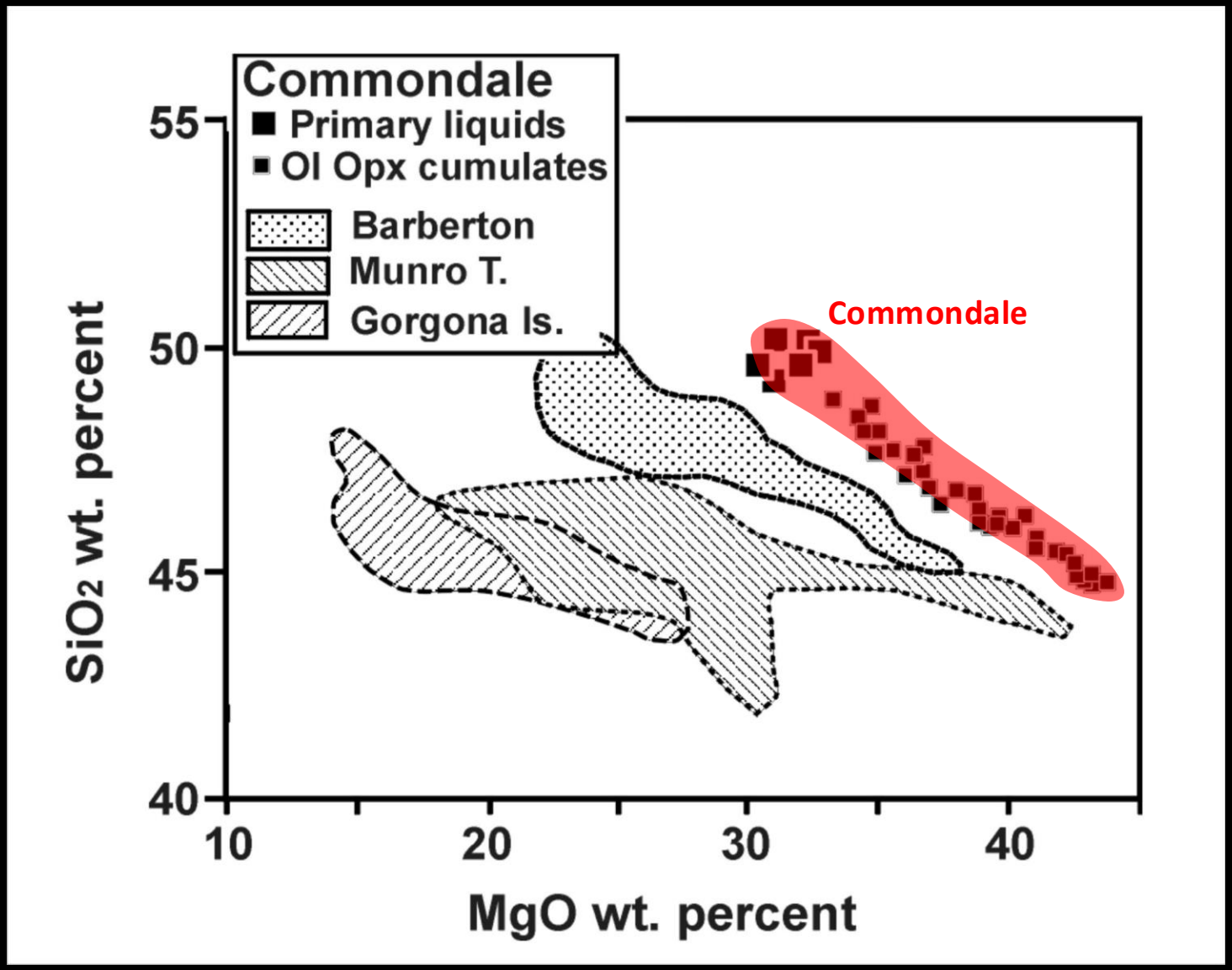
Regular layered spinifex in the Commondale Ultramafic Suite



Regular layered spinifex in the Commondale Ultramafic Suite

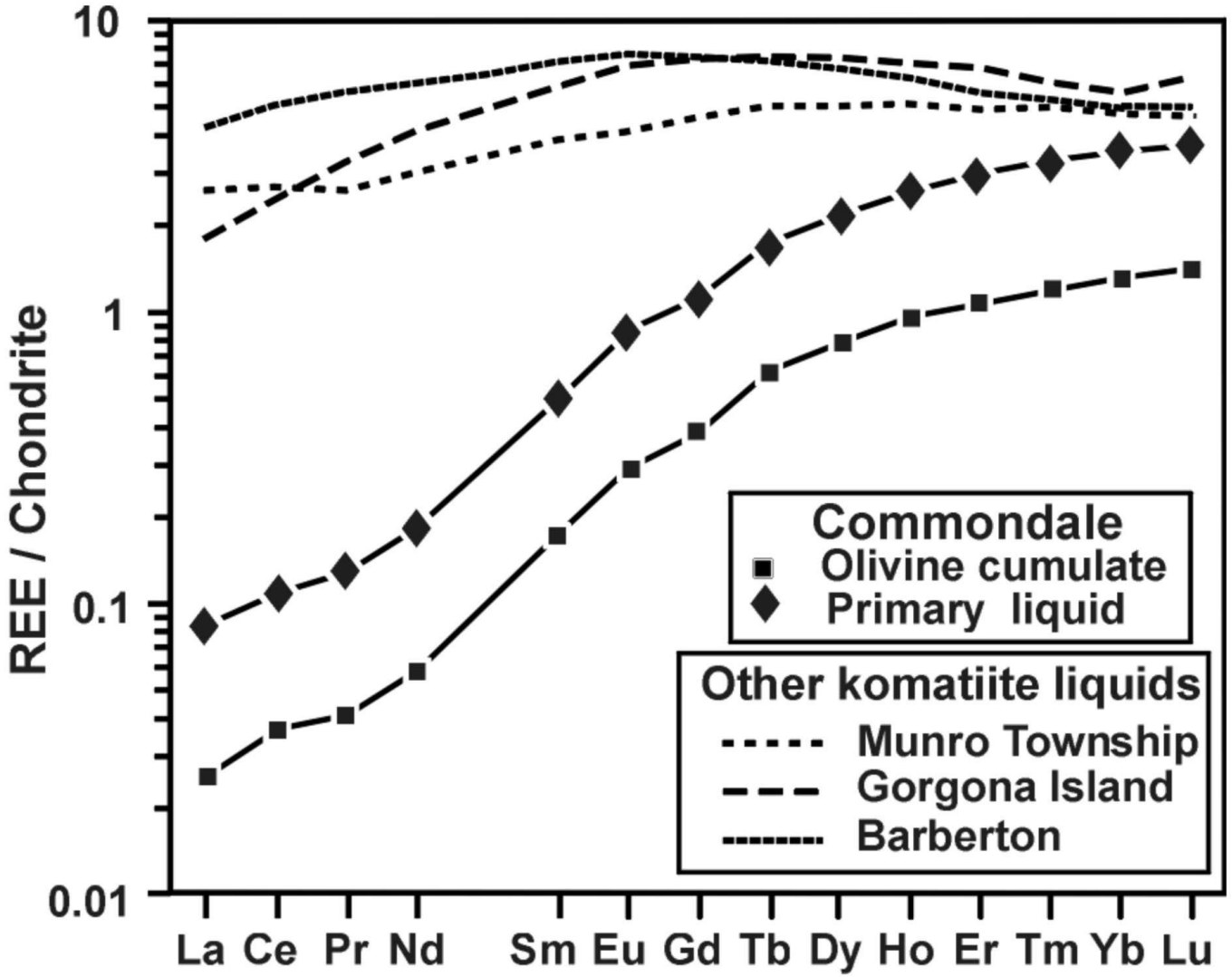


Rare orthopyroxene spinifex – this reflects both the high silica and high Mg content of the magma that gave rise to these structures



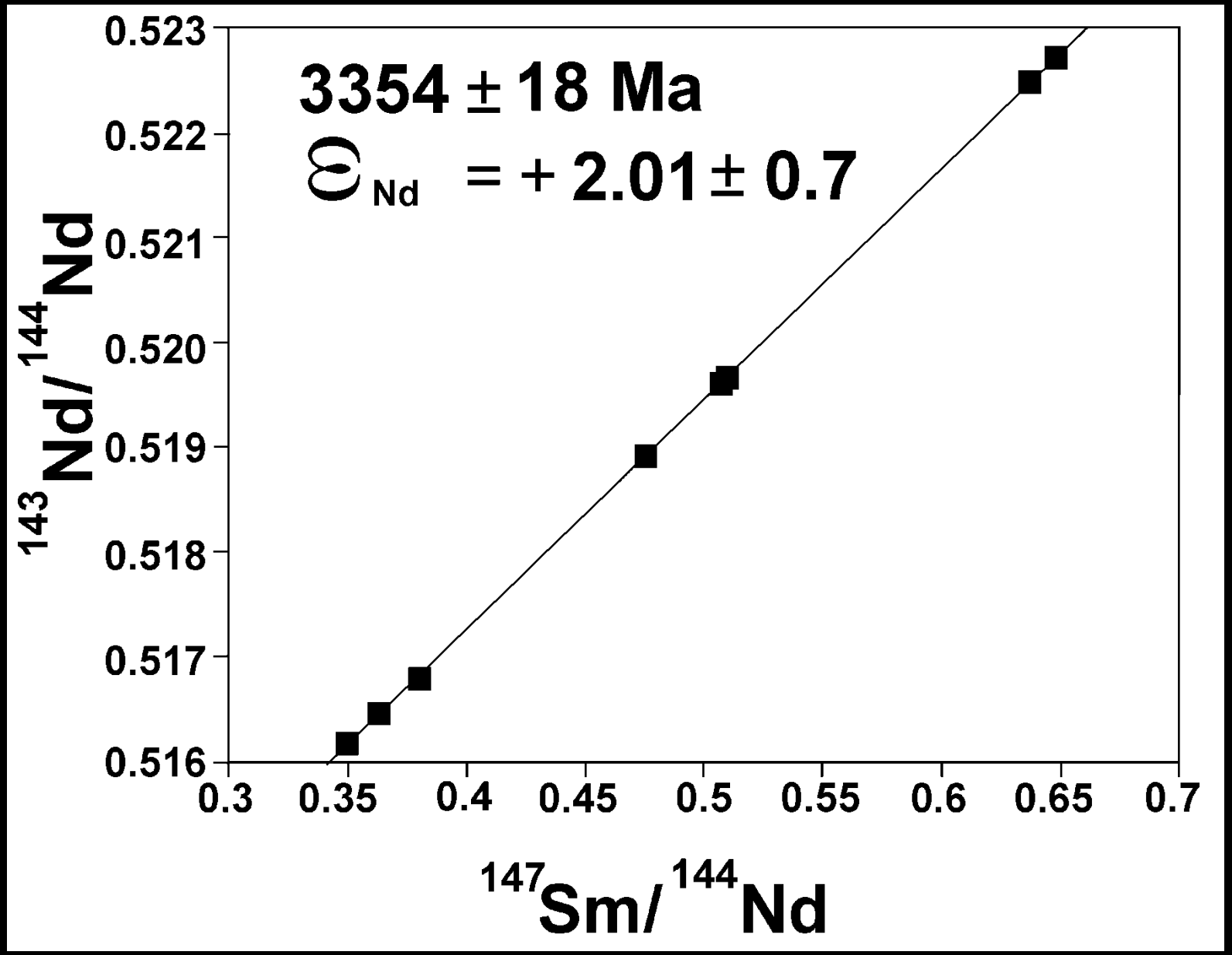
Commondale rock compositions in relation to other komatiite occurrences

Wilson (2006) *Precambrian Research*



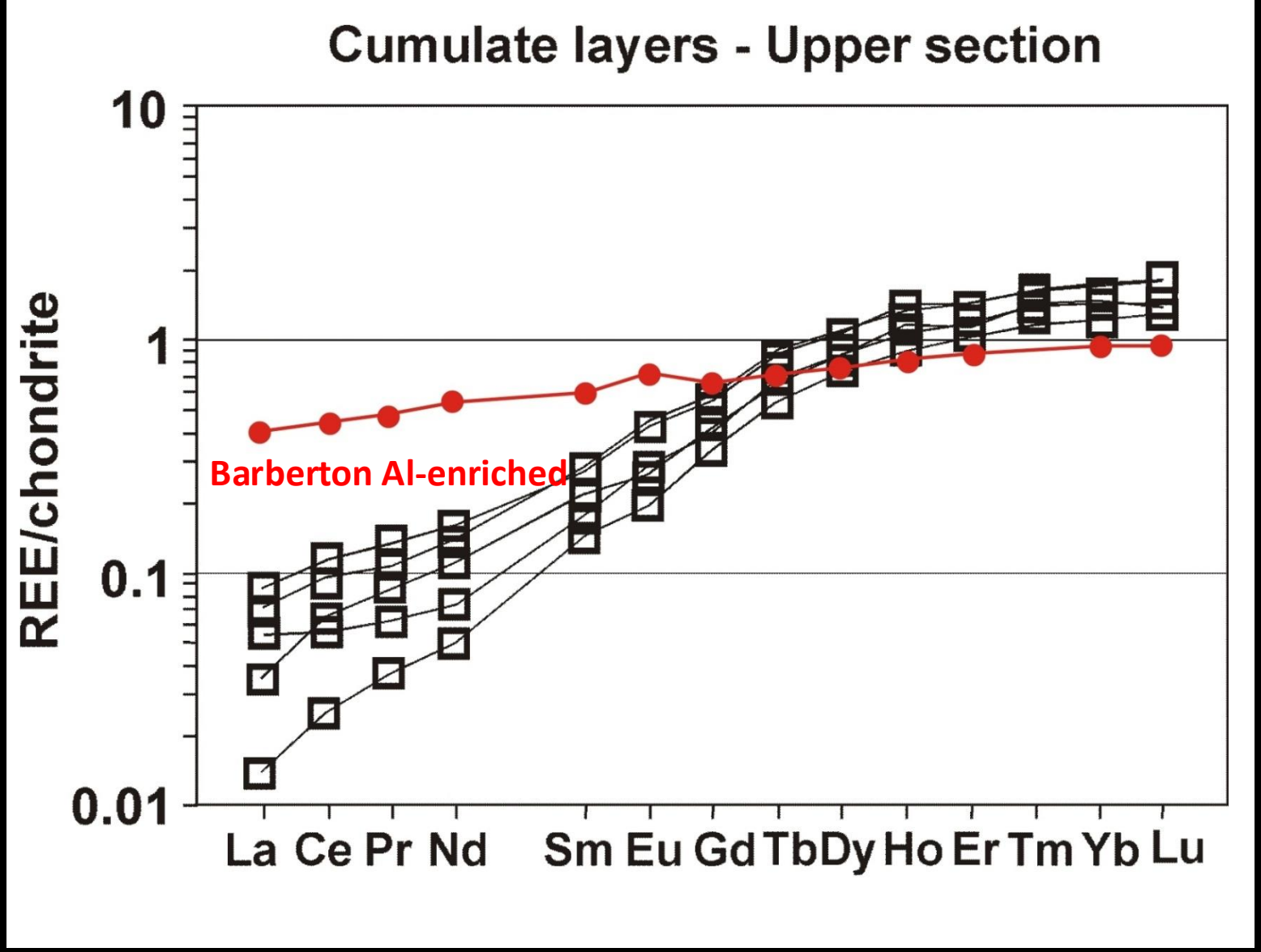
Extreme Light REE depletion of Commondale rocks and liquids

(Wilson, Shirey, Carlson – Nature, 2003)



One of the most precise Sm-Nd isochrons measured for ancient rocks

Wilson and Carlson (2000) *Earth and Planetary Science Letters*

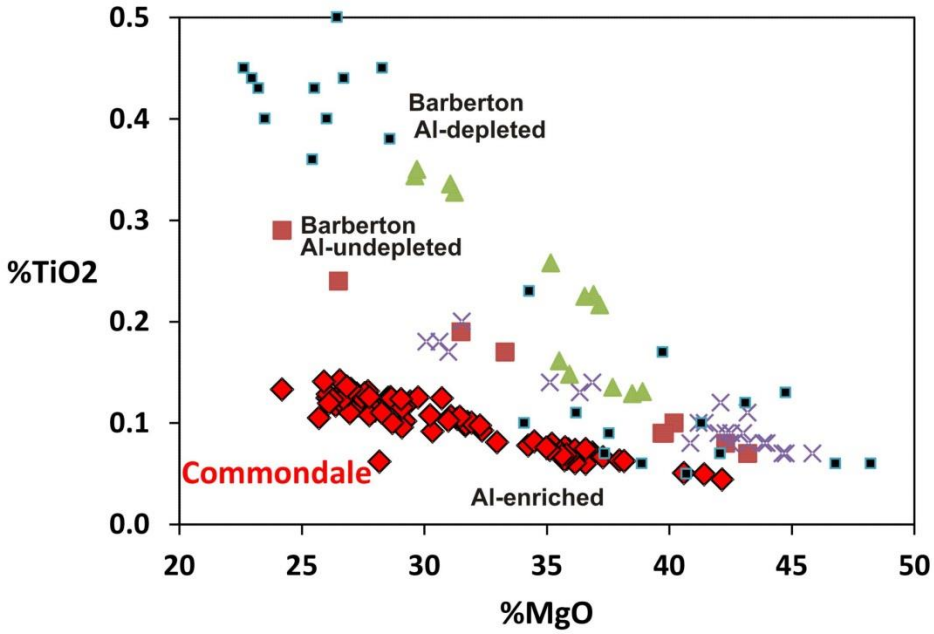


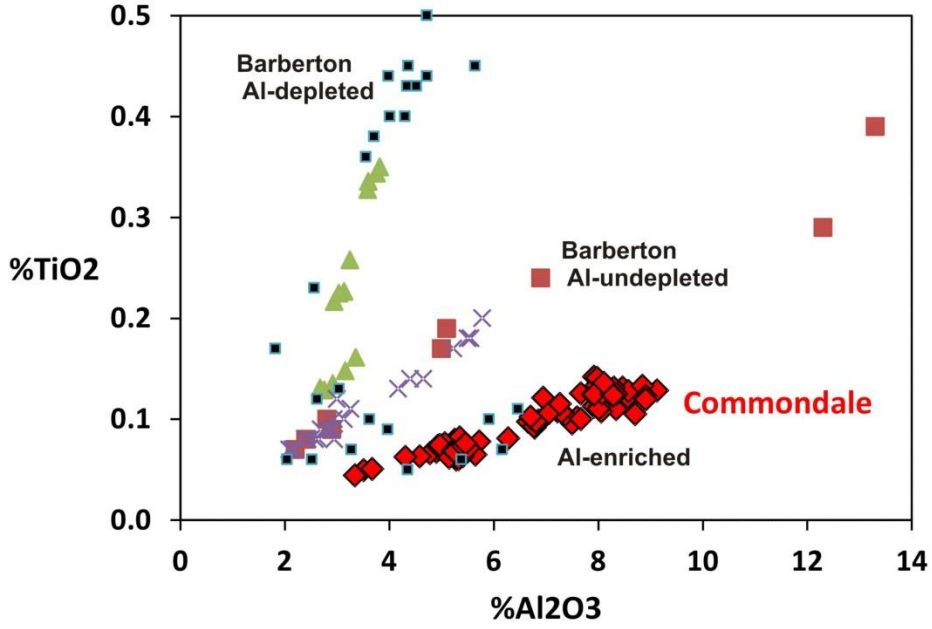
Commondale and Barberton REE data

Barberton data from Robin, Arndt, Chauvel, Byerly, Sobolev, Wilson *(Journal of Petrology, in press)*

The Commondale komatiites are the most depleted in trace elements ever recorded

Al and Ti are key elements in understanding the source of the magmas





Data sources:
Robin, Arndt, Chevaul, Byerly, Wilson (in press);
Kareem (unpub);
Wilson (unpub);
Byerly (1999)

Barberton komatiites that are Al-enriched belong to the uppermost volcanic unit – The *Mendon Formation* dated at 3334 ± 3 Million years (based on ages of enclosing sediments)

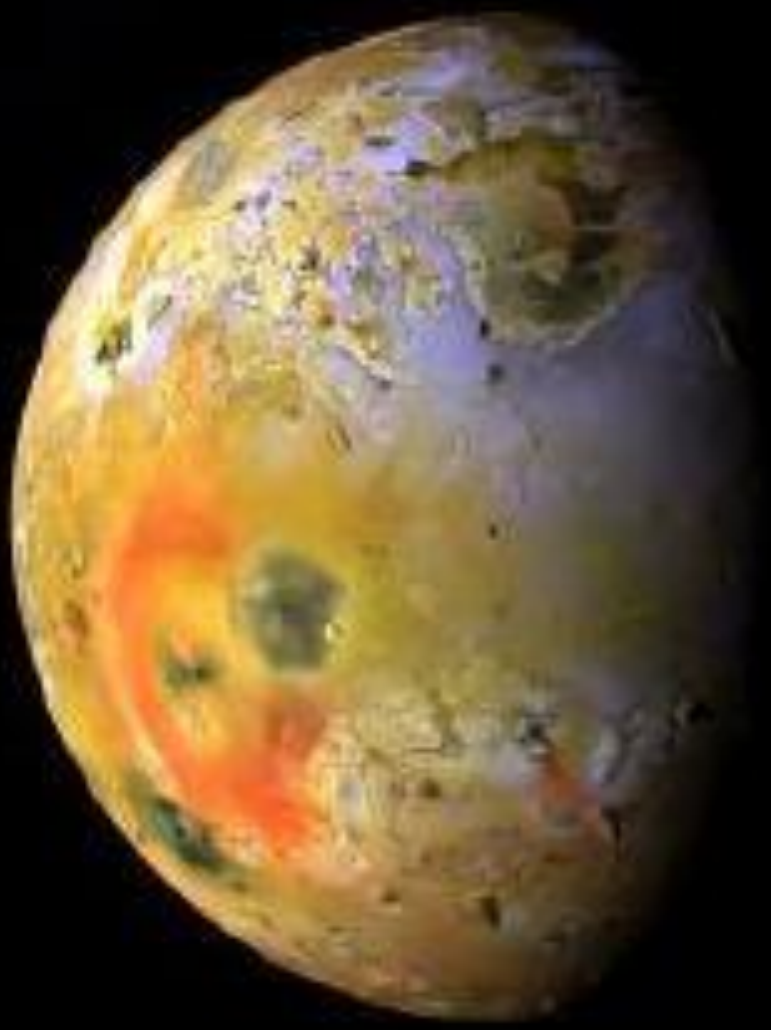
The *Commondale* komatiites are dated at 3354 ± 18 Million years

Both are highly depleted in trace elements

Both contain the most Mg-rich olivine encountered in komatiites BUT
Commondale is the most depleted komatiite ever recorded and has the most Mg-rich olivine (Mg# 0.962) ever recorded for a terrestrial igneous suite. It also has the highest silica content for these MgO contents.

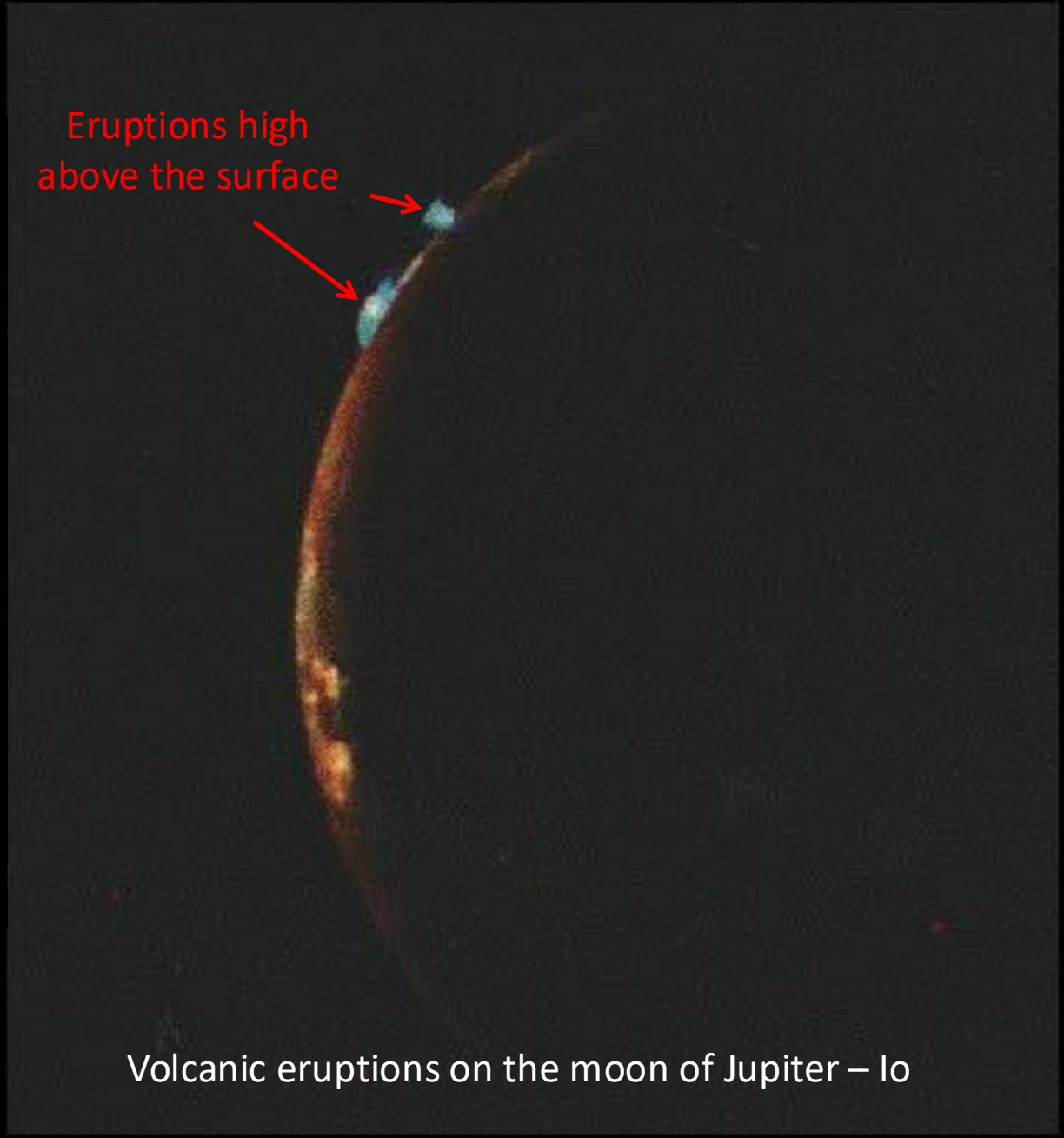
***** Mg# = MgO/(MgO+FeO) is a measure of the primitiveness and temperature***


NASA ‘s GALILEO JUPITER
DEEP PROBE SPACECRAFT
LAUNCHED 1989
Encounters with the
Moons Io and Europa



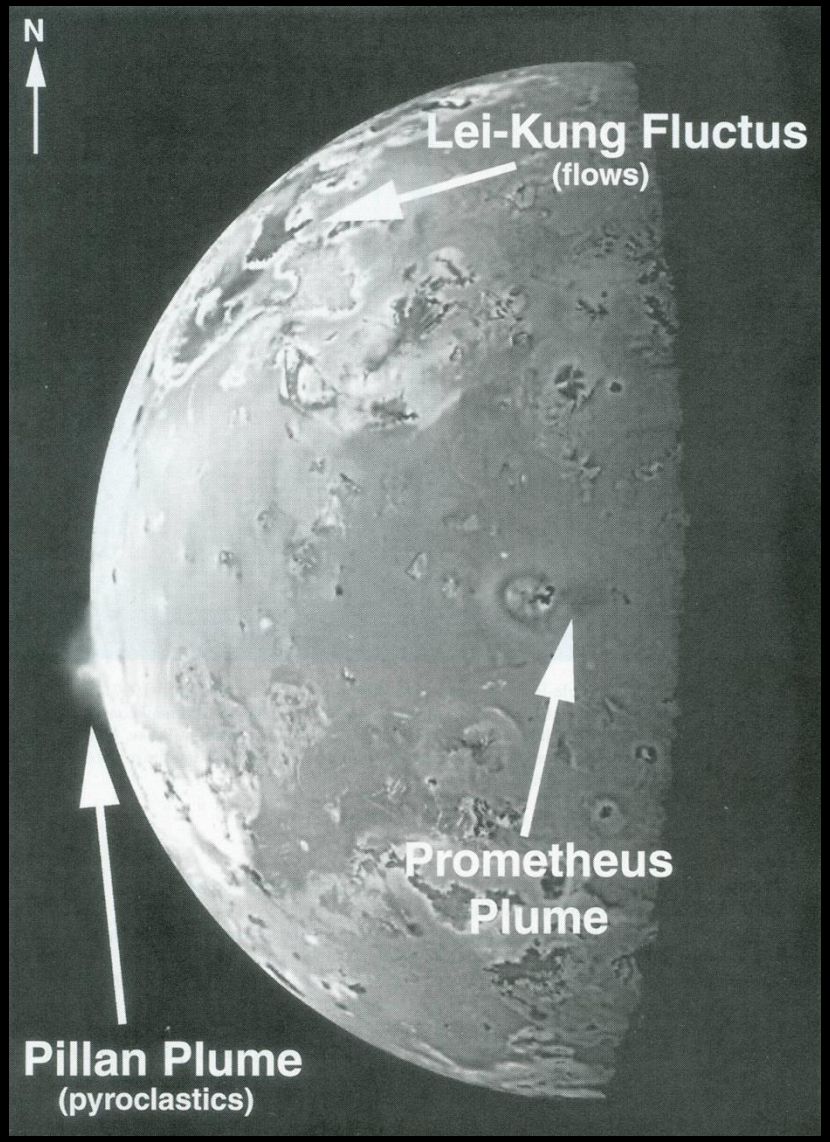
Volcanic eruptions on the moon of Jupiter – Io

Compositions of the Commondale komatiite type (High silica and high Mg)
It is not known how these lavas formed on Io



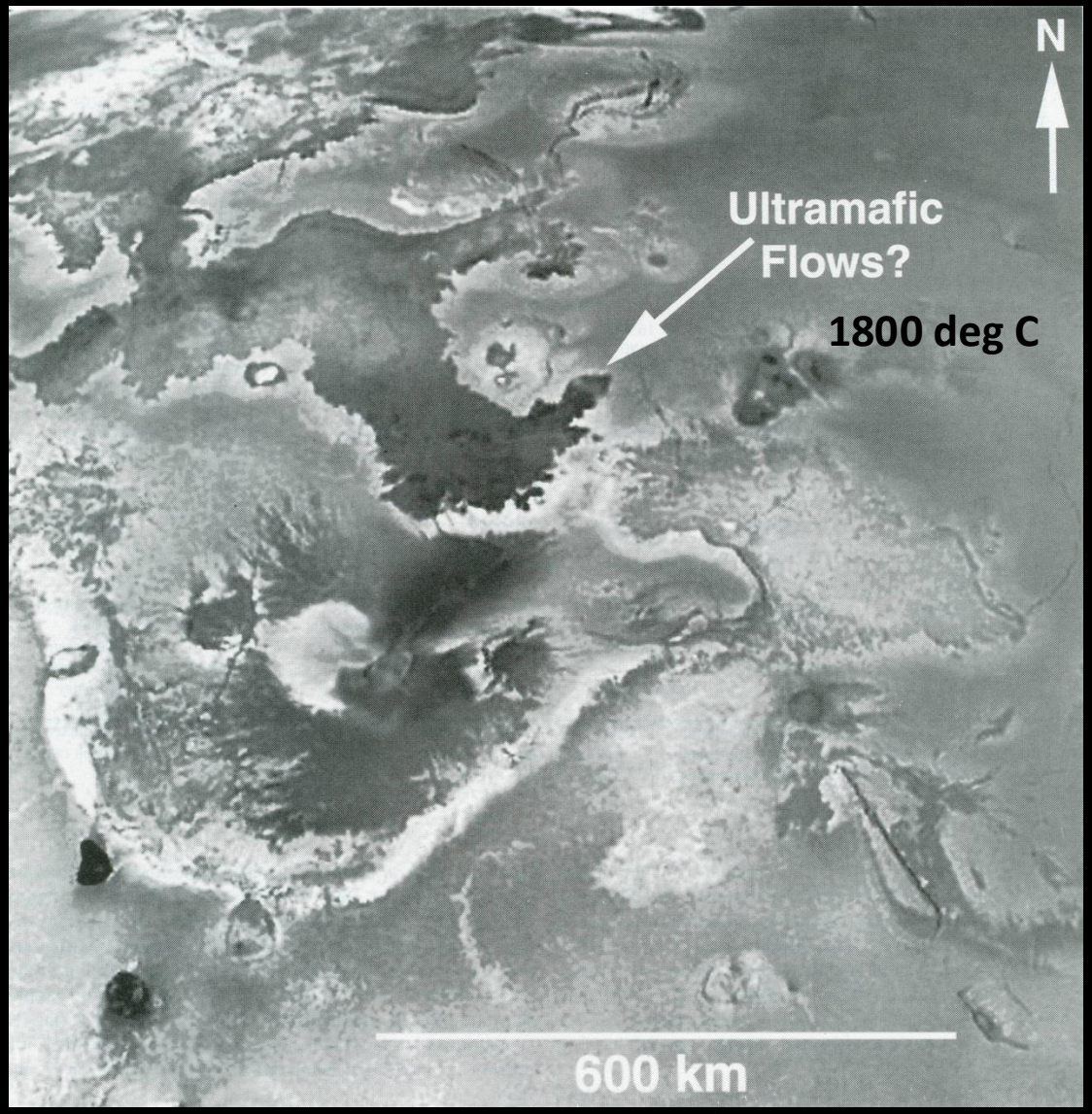
Volcanic eruptions on the moon of Jupiter – Io

Compositions of the Commondale komatiite type (High silica and high Mg)



Volcanic eruptions on the moon of Jupiter – Io

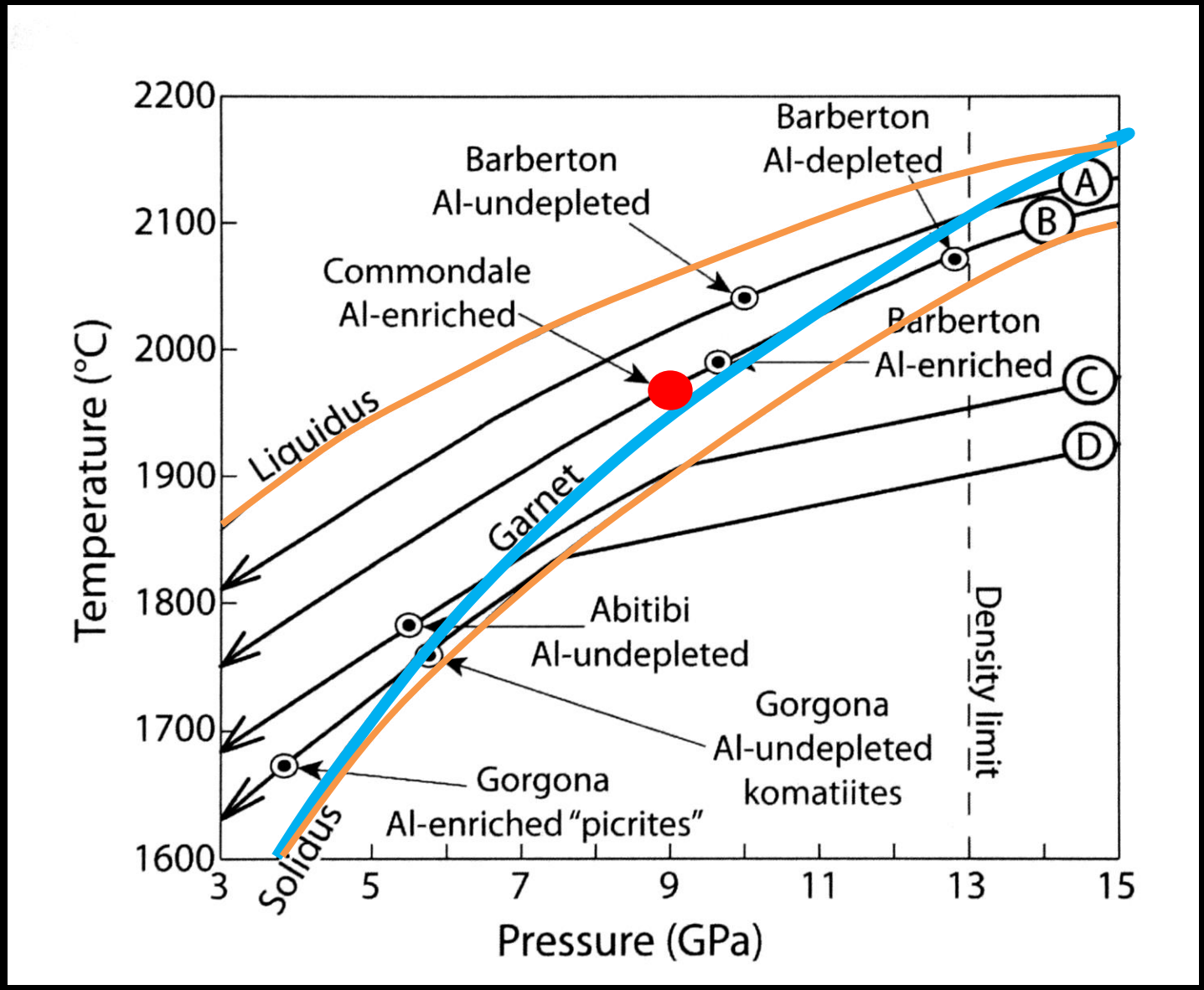
Compositions of the Commondale komatiite type (High silica and high Mg)



Volcanic eruptions on the moon of Jupiter – Io

Compositions of the Commondale komatiite type (High silica and high Mg)

Williams, Wilson, Greely (2000) - *Journal of Geophysical Research*



40% Melting from a depleted **PLUME** source in relation to the garnet stability field

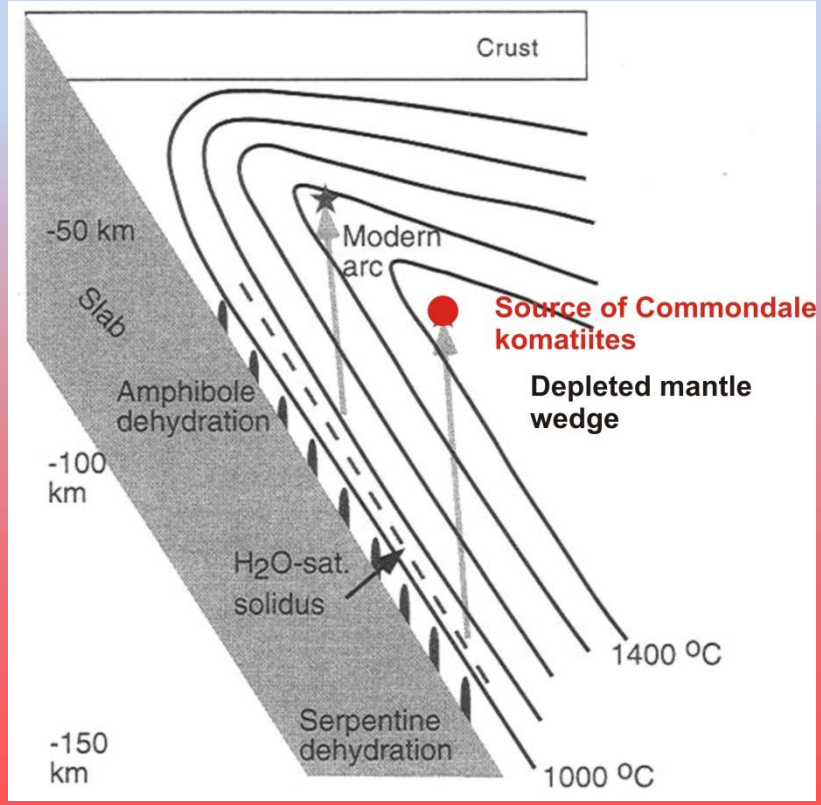
(Robin, Arndt, Chevaul, Byerly, Sobolev, Wilson – Journal of Petrology (in press))

The ages of Commondale and Mendon are essentially identical - deduce that there may be a more unique processes starting to take place at that time – that is a Plate Tectonic (arc) setting

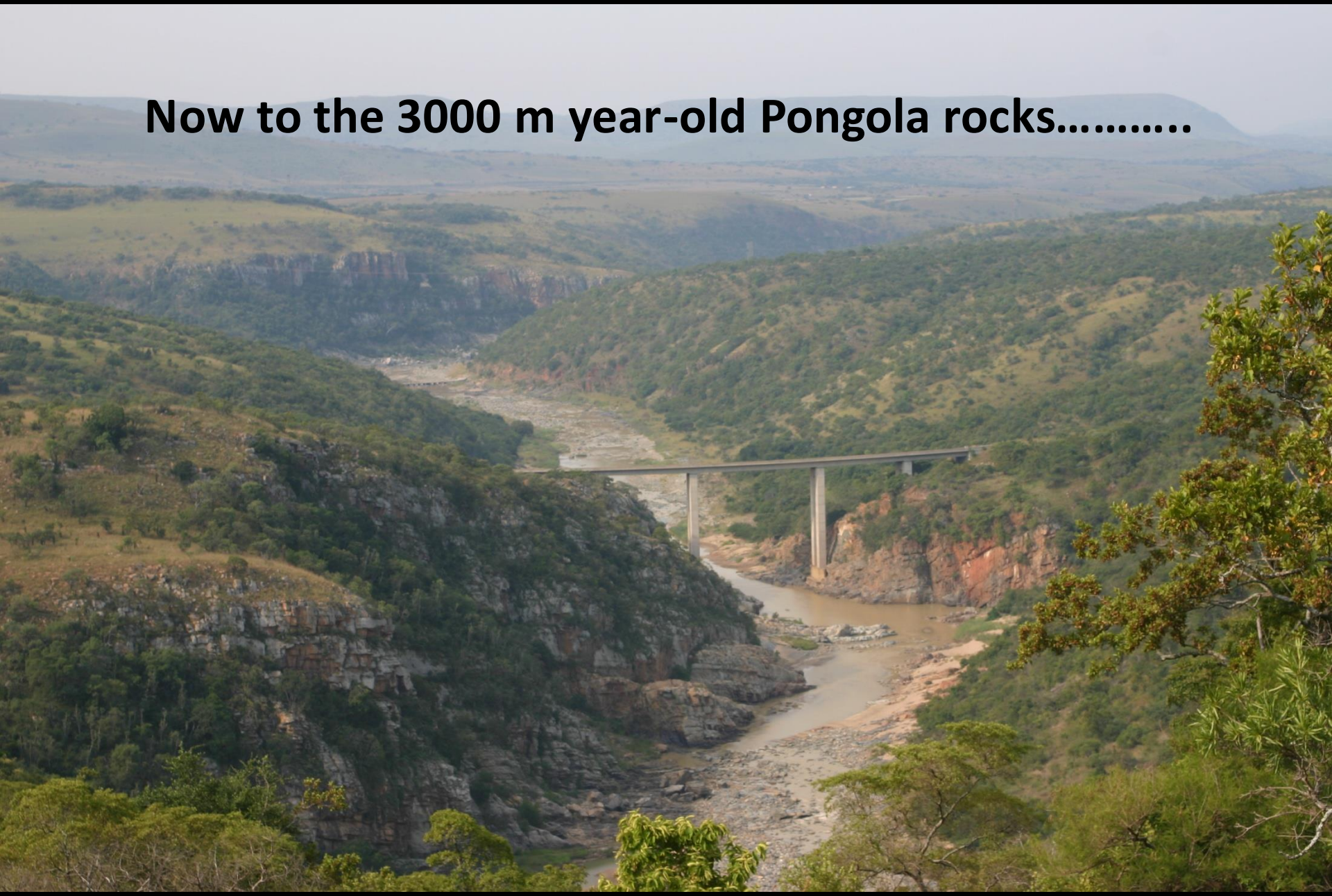
Melting of a highly refractory and depleted mantle source in a mantle wedge

(Wilson, Shirey, Carlson – Nature, 2003)

Unfortunately other researchers have obscured the picture by proposing that all komatiites were the result of wet mantle melting



Now to the 3000 m year-old Pongola rocks……..

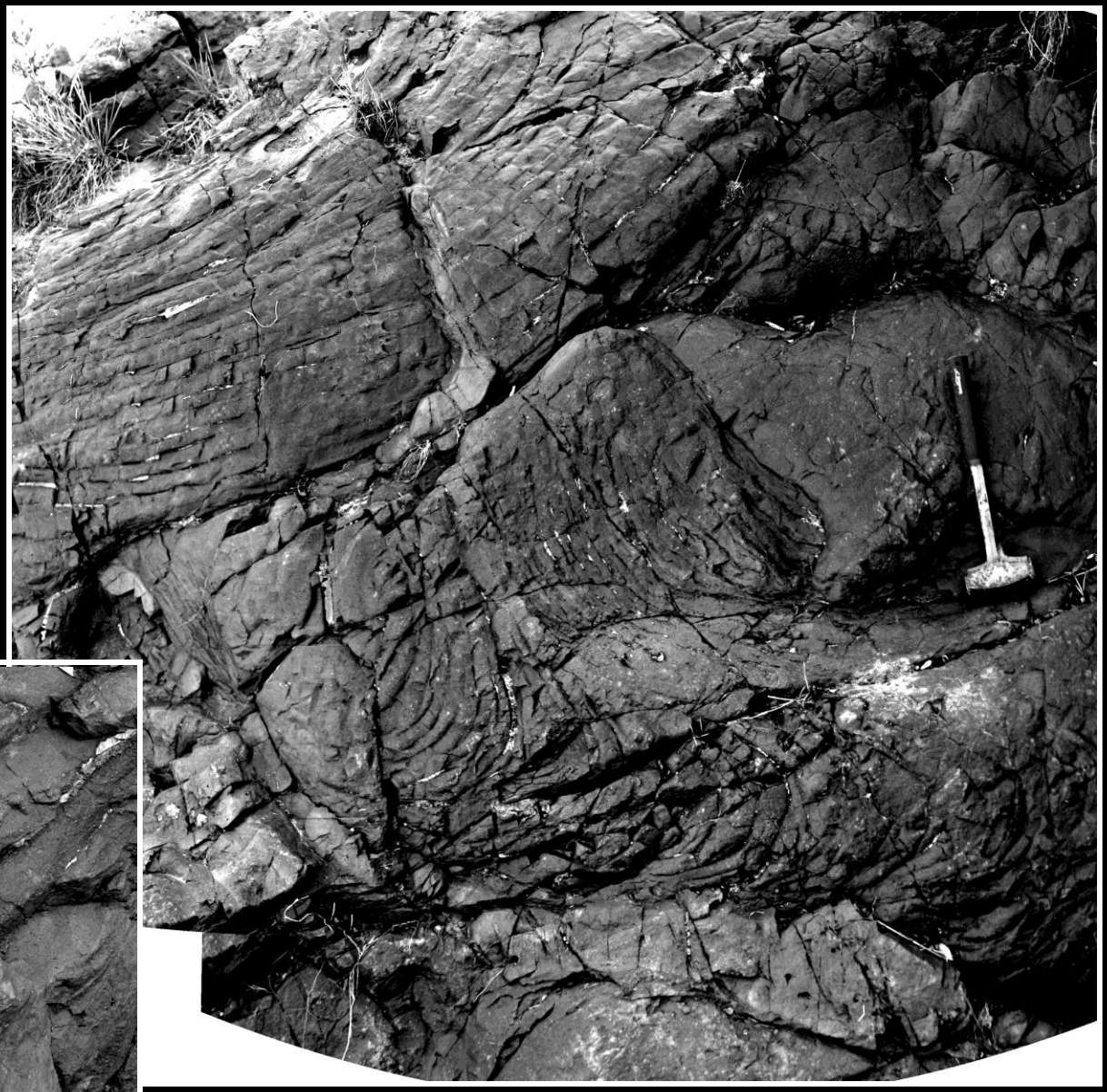


The Pongola Group has the best preserved volcanic rocks of the 3000 Ma Mid-Archaean

White Mfolozi River section

Ropy surfaces,
lava clefts, lava
fracturing and break-outs
-classic examples of
the inflation process

These are basalts not komatiites





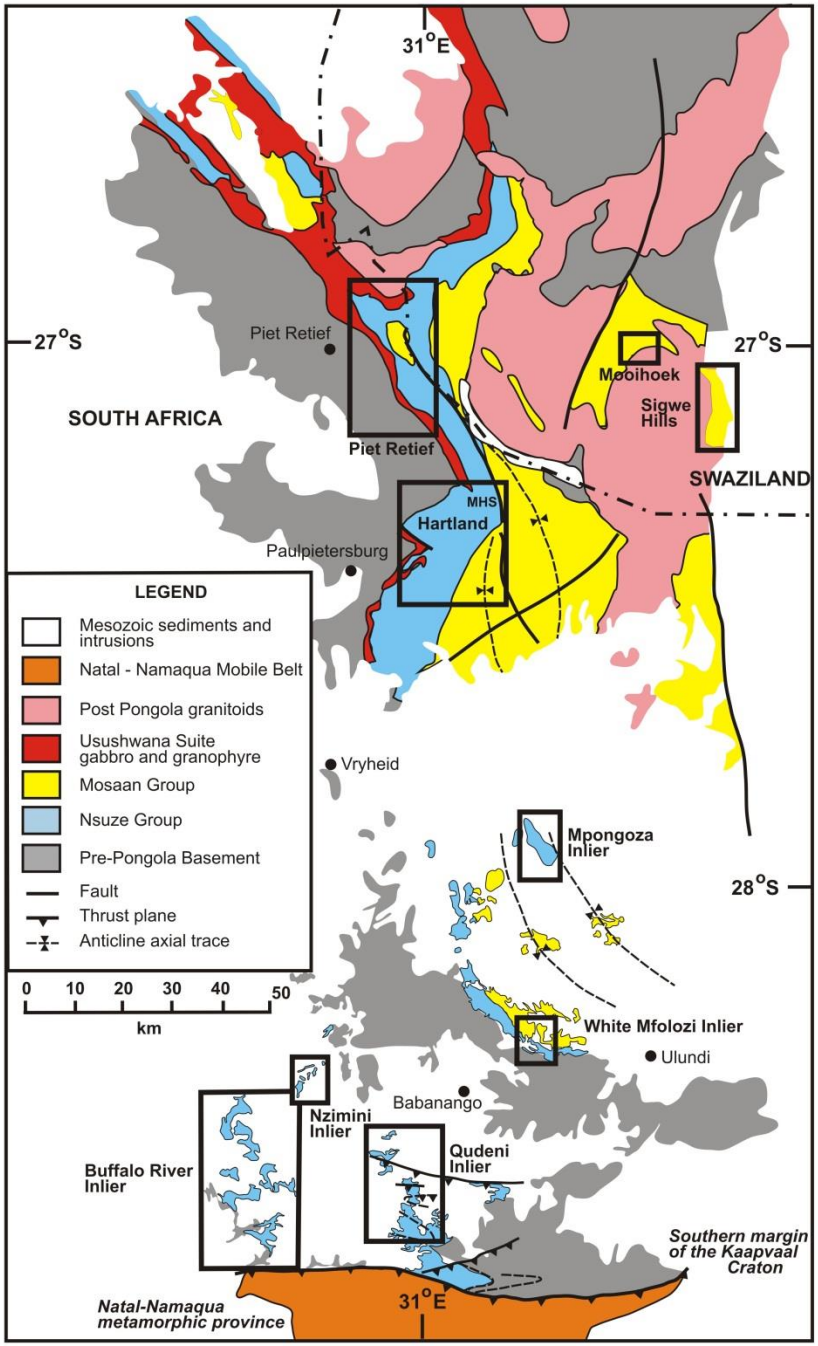


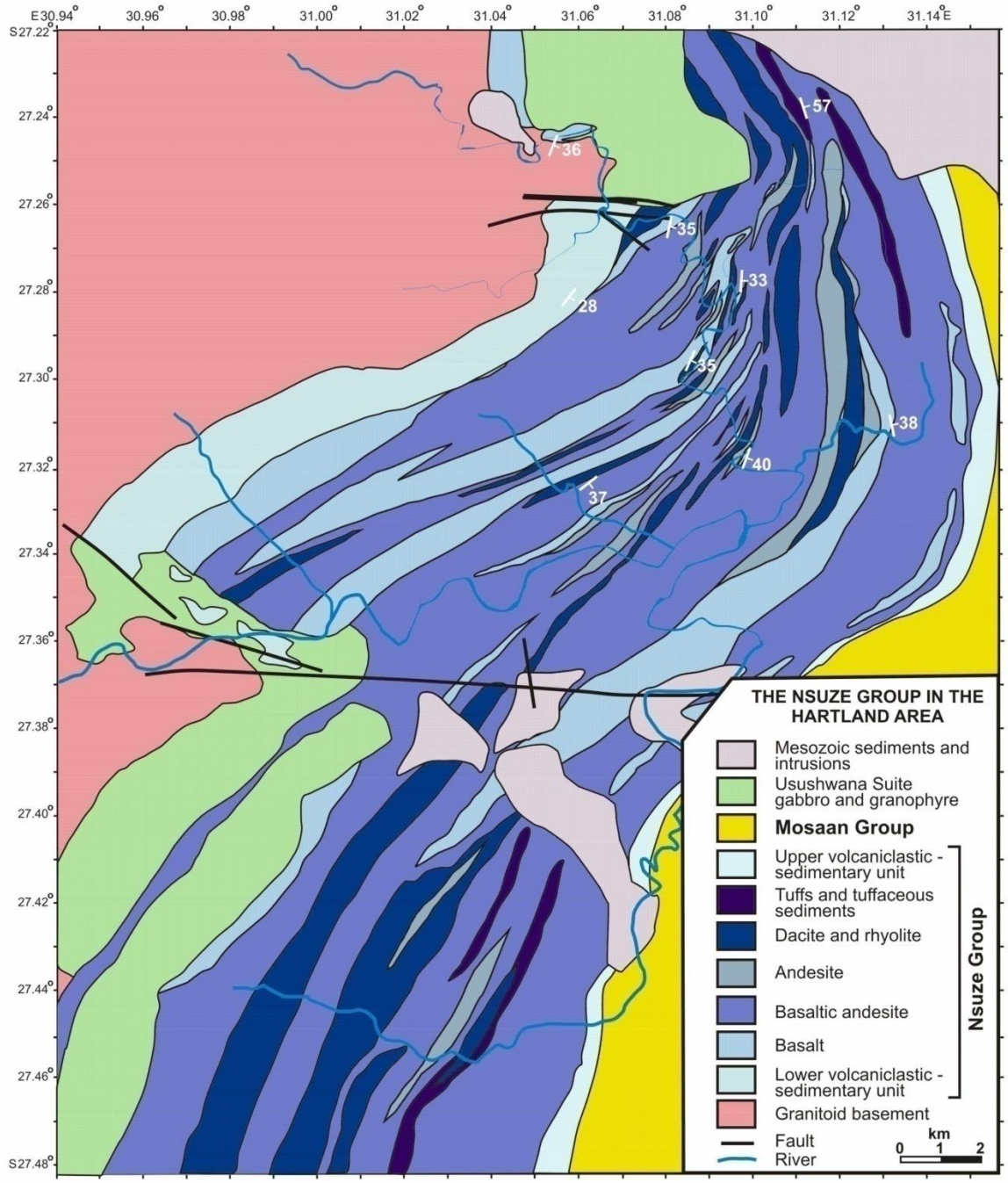


Clear contacts between lava flows


Porphyritic andesite with aphyric (crystal free) basalt
(no chill contacts)

Areas of the Pongola have been mapped in great detail by my students and co-workers over the last 30 years





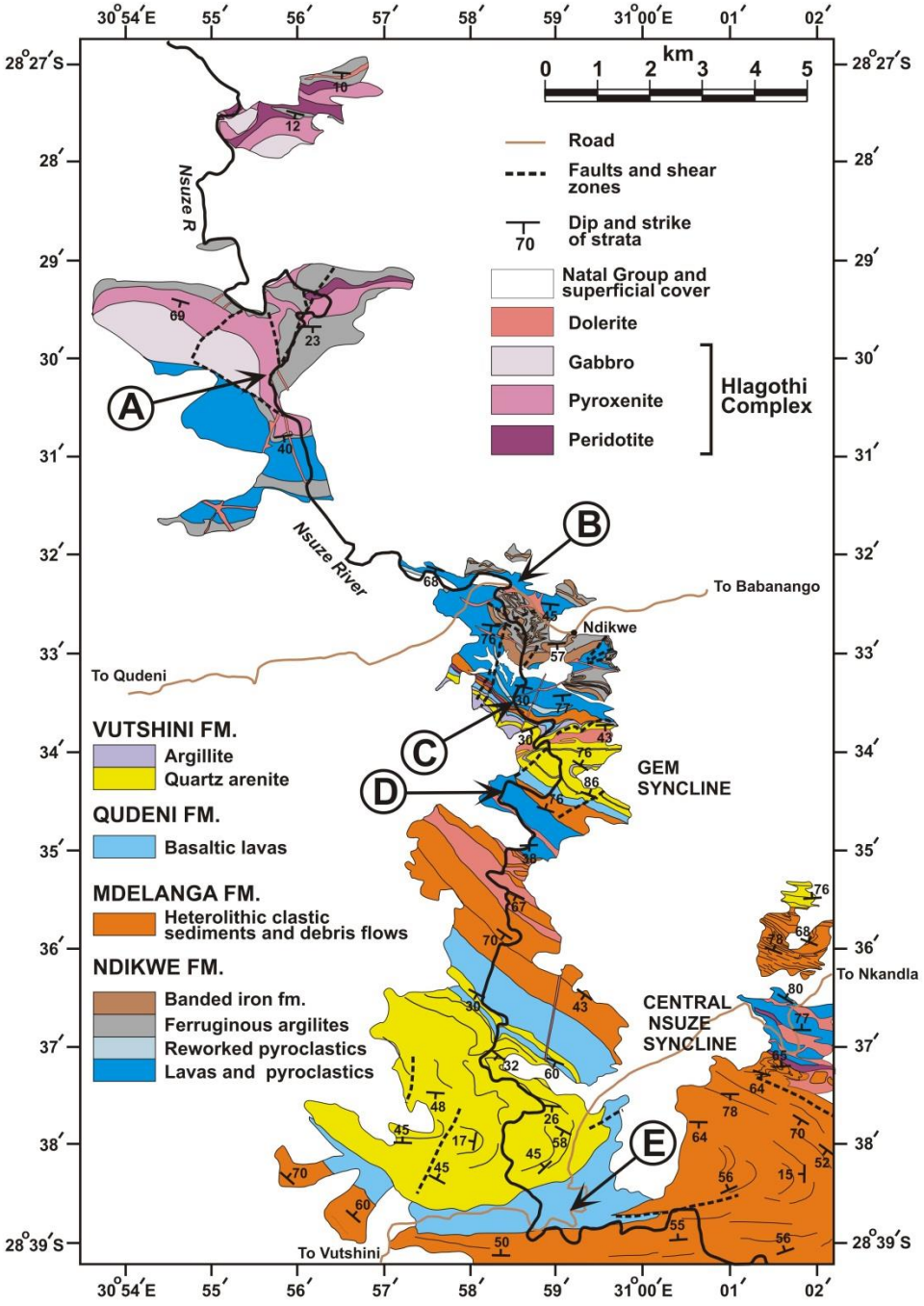
Hartland
Eastern Mpumalanga

Lava outflows from individual volcanoes 3 billion years ago

Map 30 km x 22 km

Groenewald (1984)
MSc (Natal)

Wilson (current mapping) in the heart of Zululand





Southern Zululand



On the road to Nkandla



Cr – rich ash-mud drapes and layers in the Qudeni Fm



Rapidly deposited clastic sediments in the Qudeni Fm

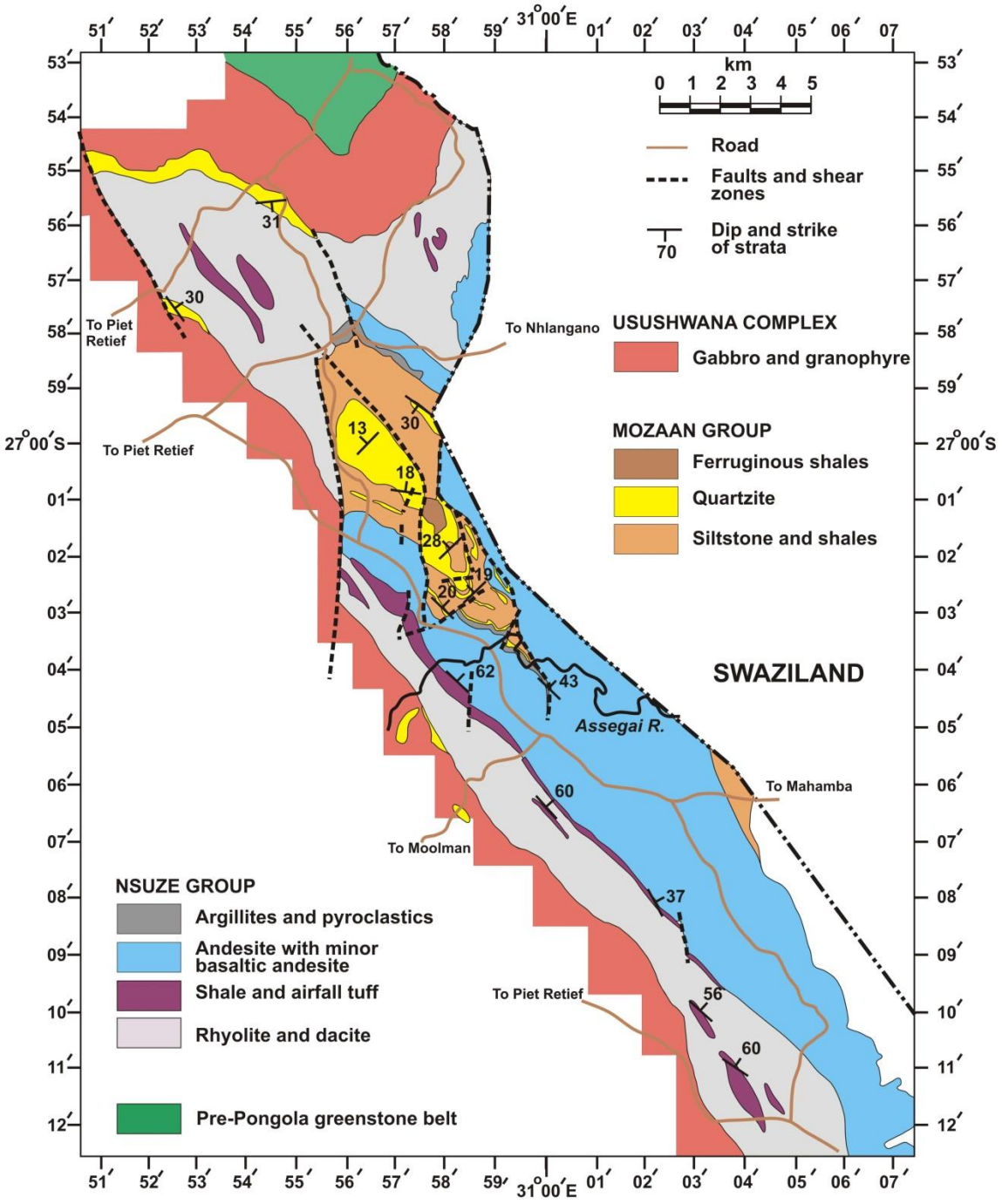


Bomb tuff in the Ndikwe Formation



Amygdaloidal basalt in the Ndikwe Fm
– site of one of the first U-Pb dates *(Burger and Coertze, 1973)*

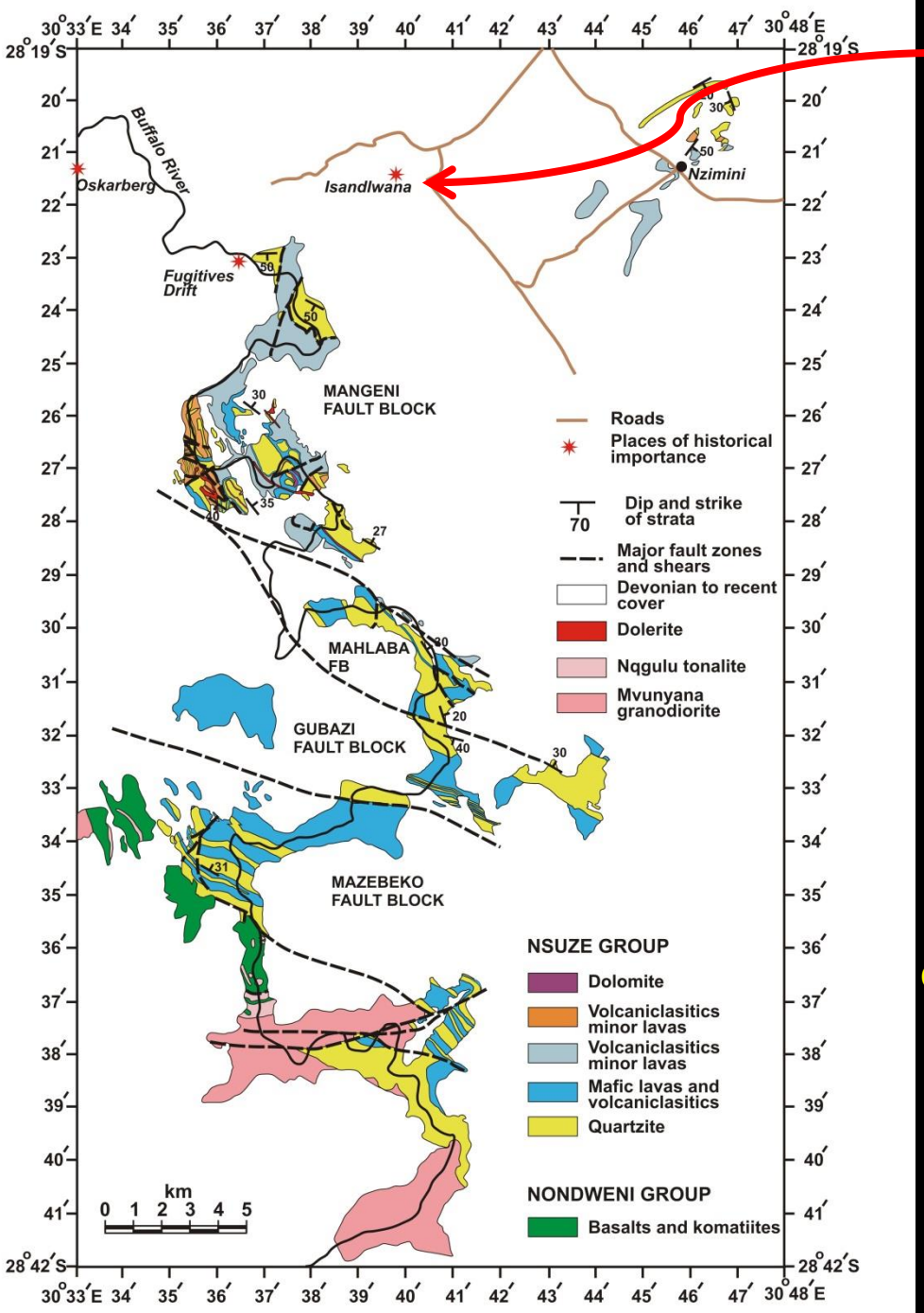
Hatfield (1990)
MSc (Natal)



3 BILLION YEAR OLD ARCHAEAN GEOLOGY IN THE BUFFALO RIVER GORGE

Dixon (2003)
PhD (Natal)

Wilson (current mapping)



The Zulu advance
11.45 am
22nd January, 1879

Three important historical sites

*

Isandlwana

*

Fugitive's Drift on the Buffalo River

*

Oskarberg and Rorke's Drift

"Men of Harlech stop your dreaming,
Can't you see their spear points
gleaming ……. "



24th Regiment of the South Wales Borderers

Site of the battle of Isandlwana 22nd January, 1879



The Battle of Isandlwana 22nd January, 1879
Survivors of the 24th rallying around the colours

Painting by C.E. Fripp
1880



The 24th's last moments at Isandlawana

A typically heroic engraving from the *London Illustrated News* that the Victorian public liked to see of their army



Saving the Colours by Alphonse de Neuville

Depicts Lts. Melville and Coghill escape from Isandlawana but they were caught and killed at the Buffalo River at Fugitive's Drift



Fugitive's Drift

Retreat of the colours across the Buffalo River on 22 January, 1879 after the defeat at Isandlwana

The Illustrated London News
29th March, 1879



The Battle of Rorke's Drift - late on 22nd January, 1879
Painting by Alfonse de Neuville (1880)

Ending in the Battle of Ulundi
4th July, 1879

IN MEMORY OF

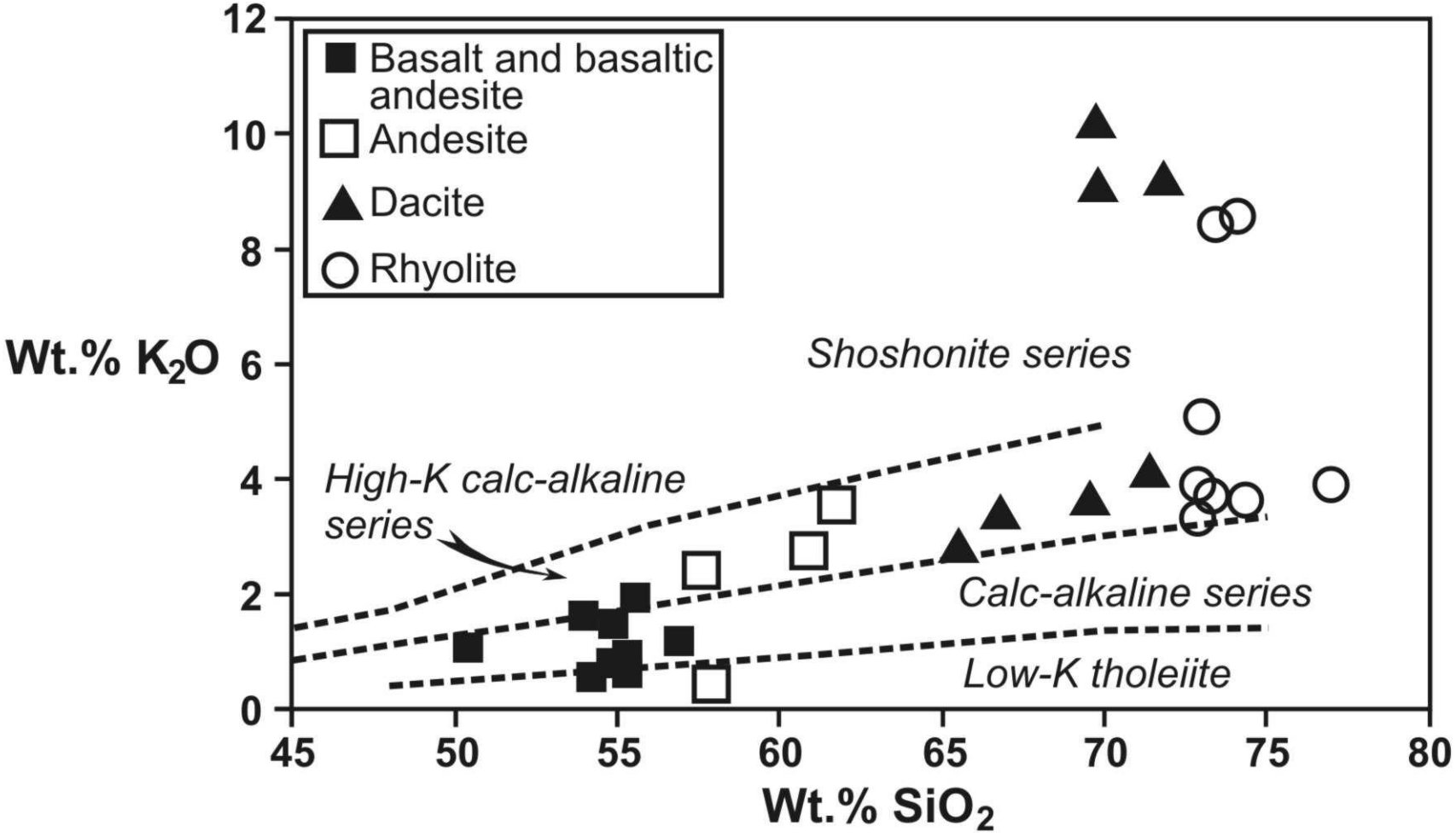
THE BRAVE WARRIORS WHO FELL

HERE IN 1879 IN DEFENCE OF THE

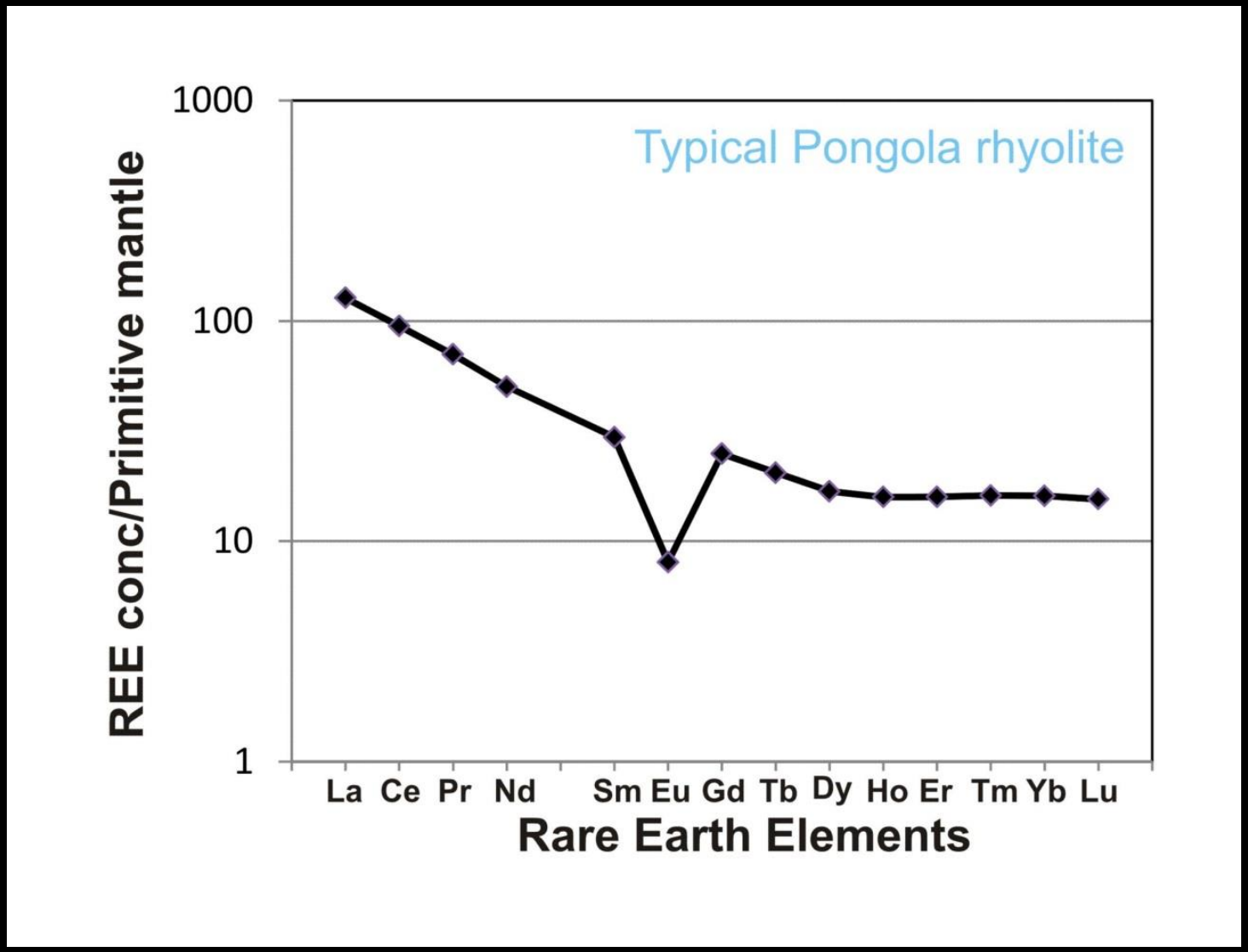
OLD ZULU ORDER



The Nsuze Group at the entrance to the Buffalo River gorge



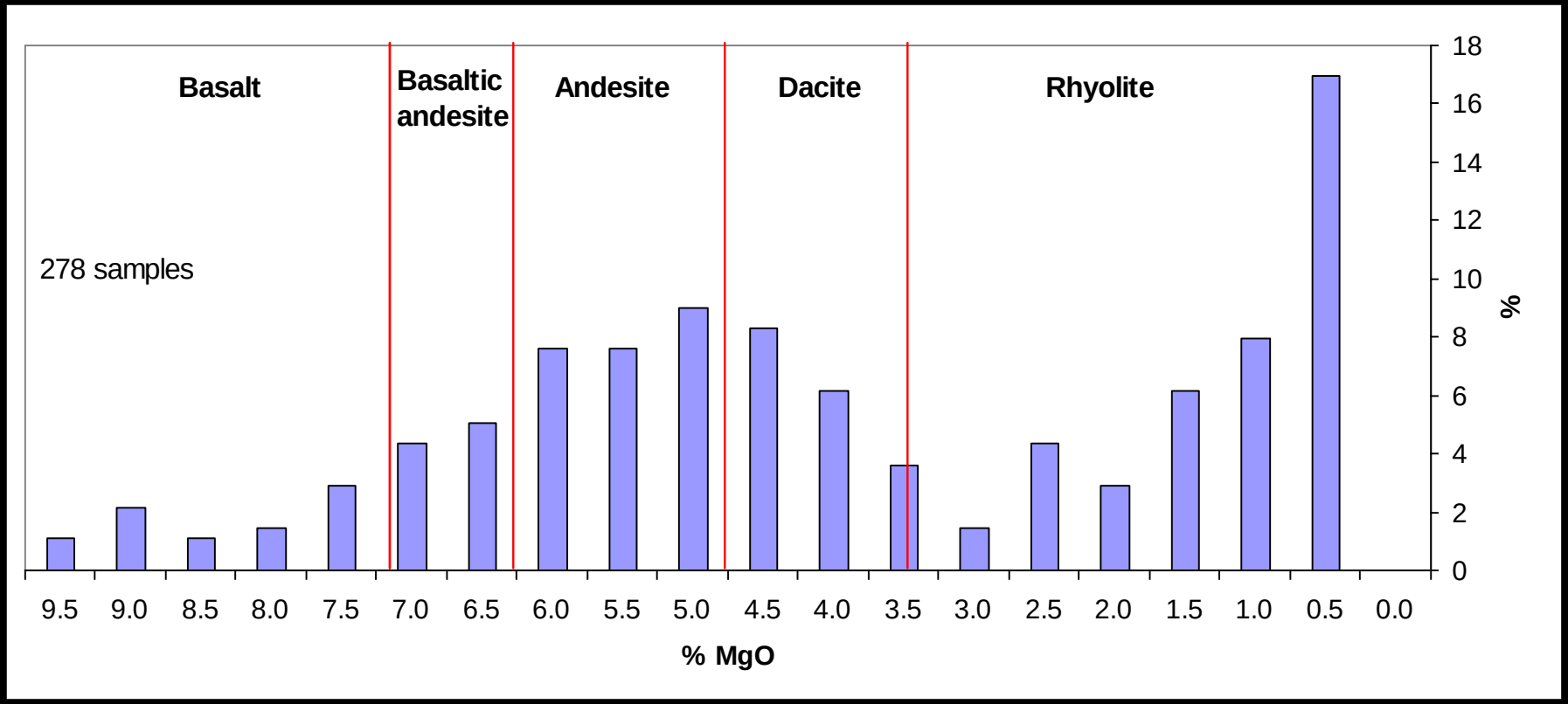
In the Pongola the high K trends (in combination with trace elements) may be indicative of an arc-type setting which implies **PLATE TECTONICS** similar to what is known at present - Similar to the Andes at present



Arc-type REE pattern…… also pattern of most crustal granites



Ultramafic volcanic bombs and lapilli in the southern facies



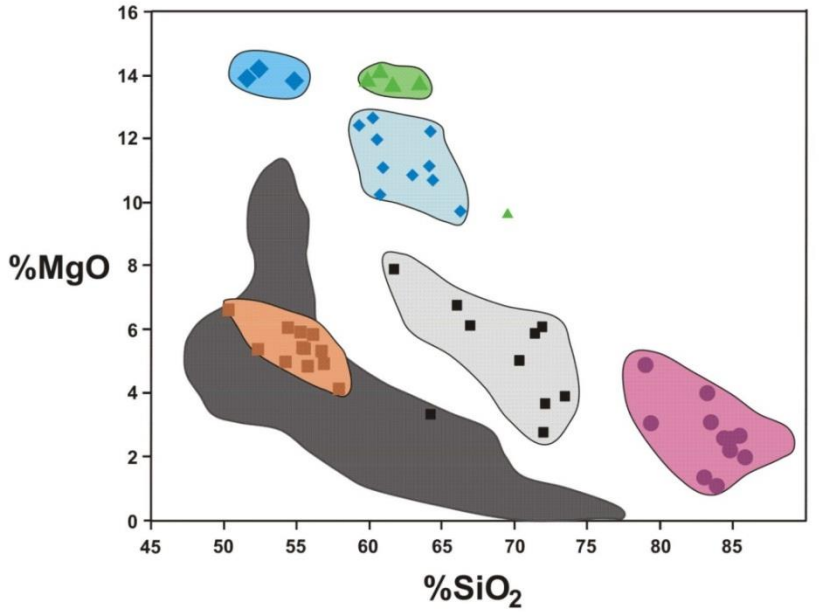
Bimodal distribution with high proportion of andesite – another indicator of a subduction setting – possibly similar to the Andes of today

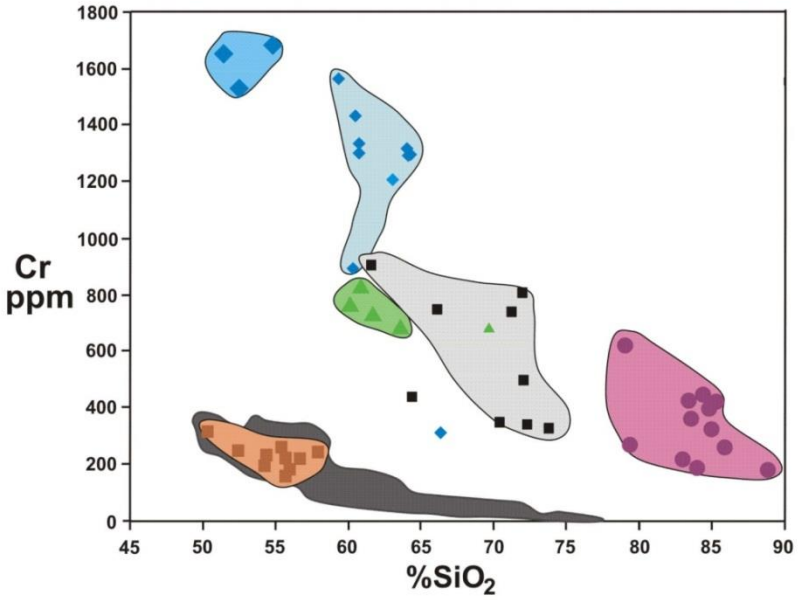


Chert fragments: SiO_2 85% MgO 3% Cr 400 ppm

Volcaniclastic matrix: SiO_2 65% MgO 12% Cr 1200 ppm

Cr-Mg gel?





All data north of the Babanango line (incl.type area)

Basaltic andesites of Qudeni Fm

Ndikwe Formation South of Babanango line

Ultramafic pyroclasts - Mzimini area

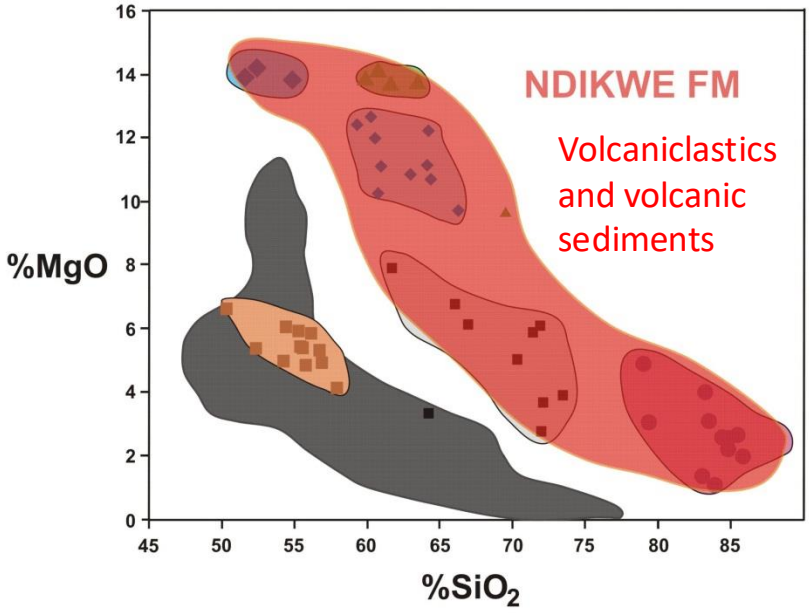
Ultramafic volcaniclastics - Mzimini area

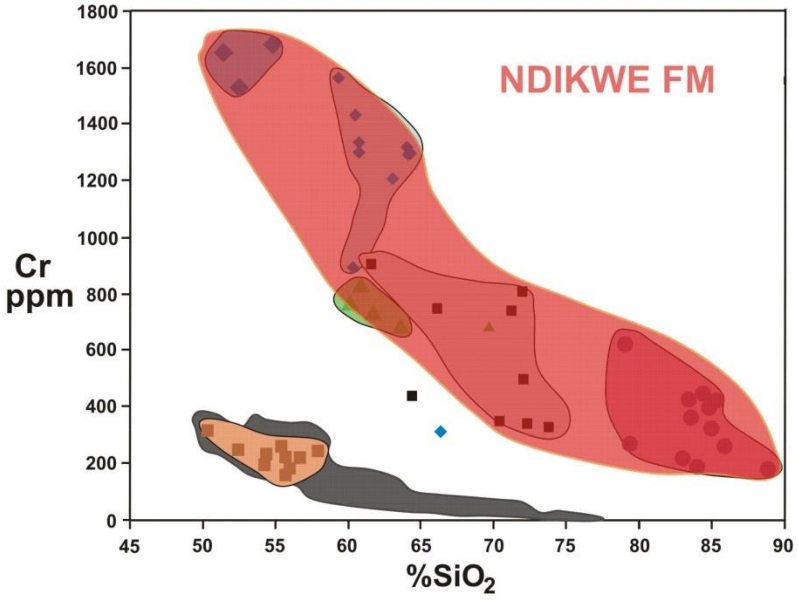
Ultramafic volcaniclastics - Ndikwe area

Ultramafic ash, terrigenous sediments, crystal tuff - Mzimini area

Chert fragments of ultramafic ash and chemical sediments - Mzimini area

PYROCLASTIC LAVA AND VOLCANICLASTIC COMPOSITIONS IN THE SOUTHERN PONGOLA REGION





All data north of the Babanango line (incl.type area)

Basaltic andesites of Qudeni Fm

Ndikwe Formation South of Babanango line

Ultramafic pyroclasts - Mzimini area

Ultramafic volcaniclastics - Mzimini area

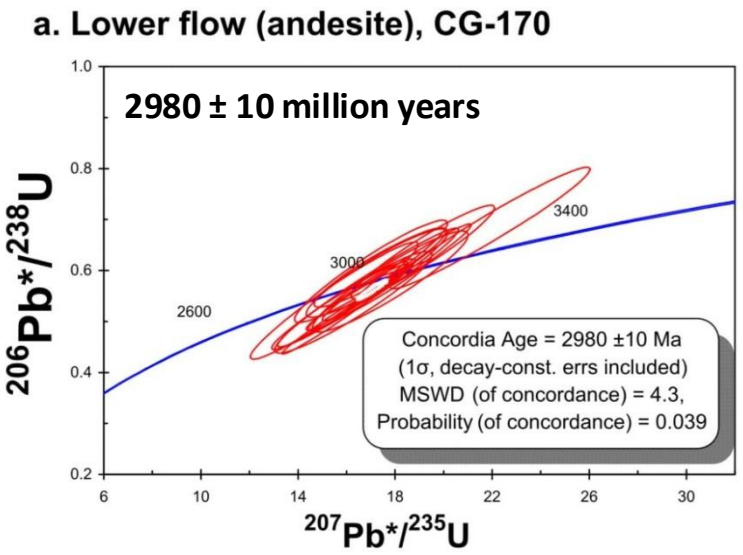
Ultramafic volcaniclastics - Ndikwe area

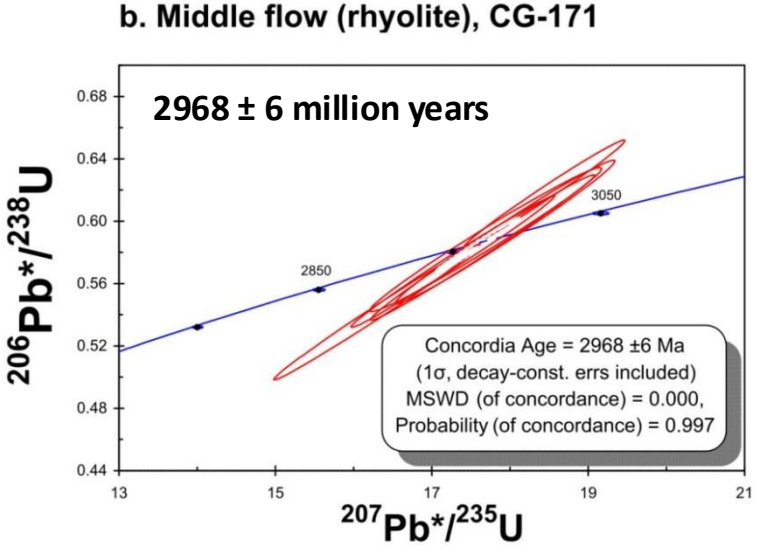
Ultramafic ash, terrigenous sediments, crystal tuff - Mzimini area

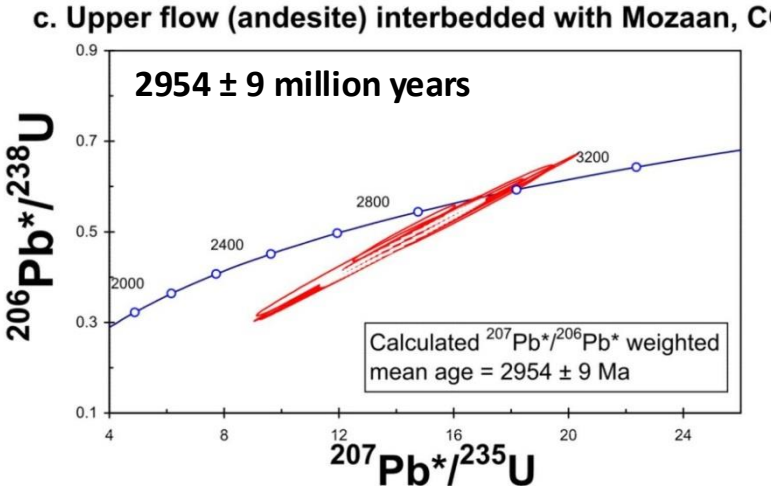
Chert fragments of ultramafic ash and chemical sediments - Mzimini area

PYROCLASTIC LAVA AND VOLCANICLASTIC COMPOSITIONS IN THE SOUTHERN PONGOLA REGION

U – Pb isotopic dating

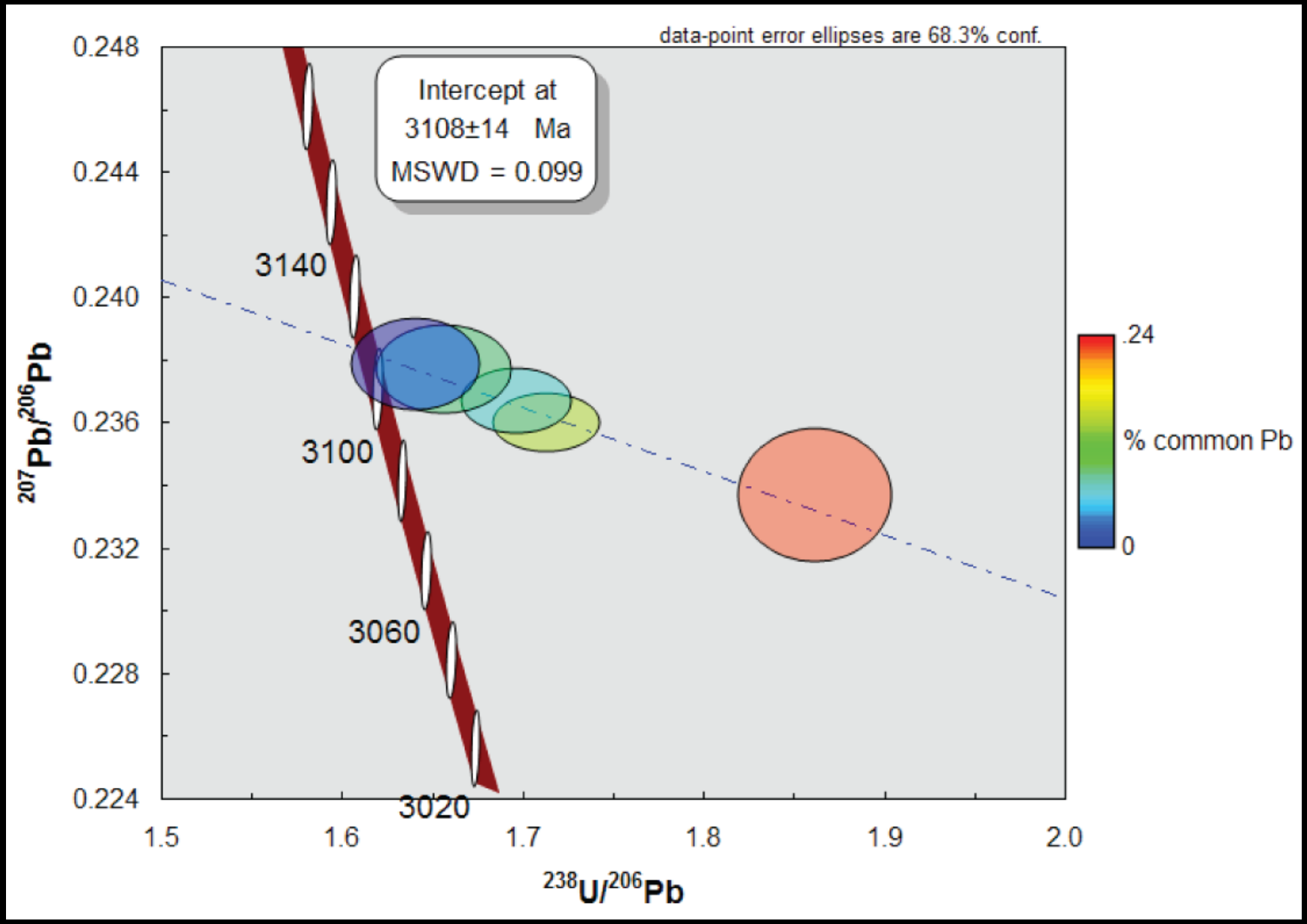




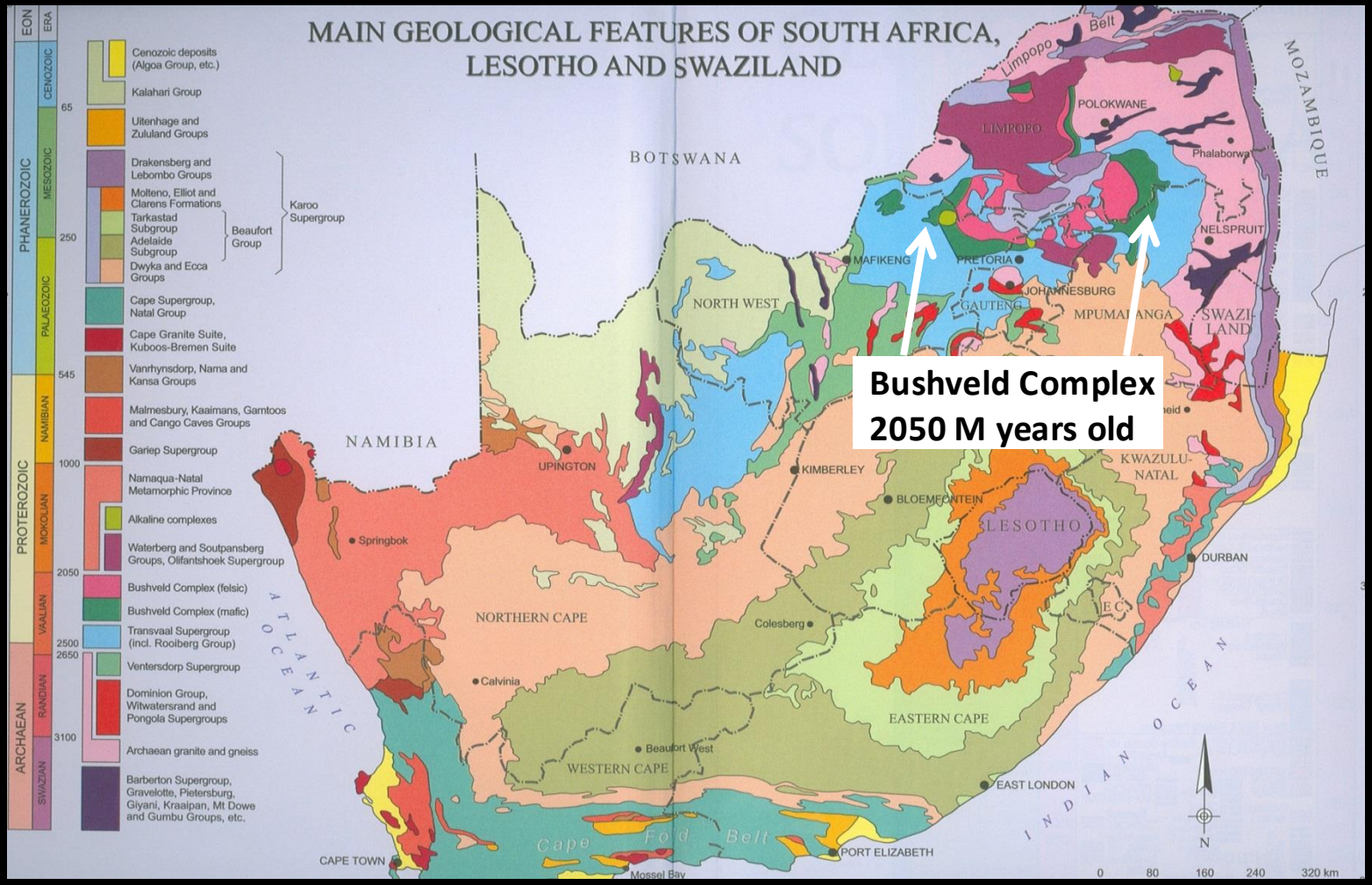


Mukasa, Young
And Wilson (in review, 2011)
Precambrian Research

Time of formation of the Pongola SG (middle) between 7 and 45 million years or a subsidence/accumulation rate of 200 – 1400 m per million years – far higher than in the Phanerozoic

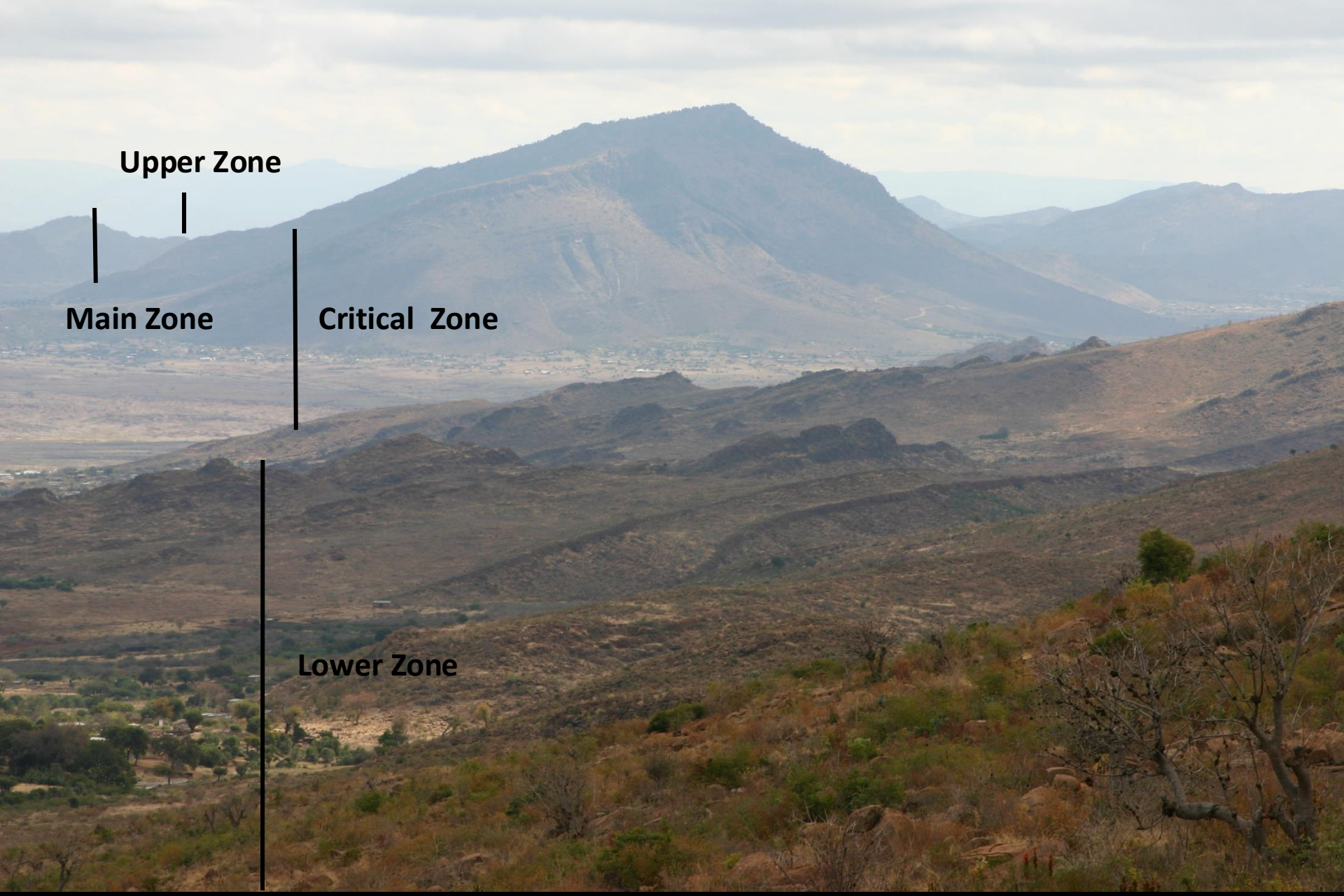


The age in the south is 100 m yr older than in the north …… the Pongola basin started forming initially in the south



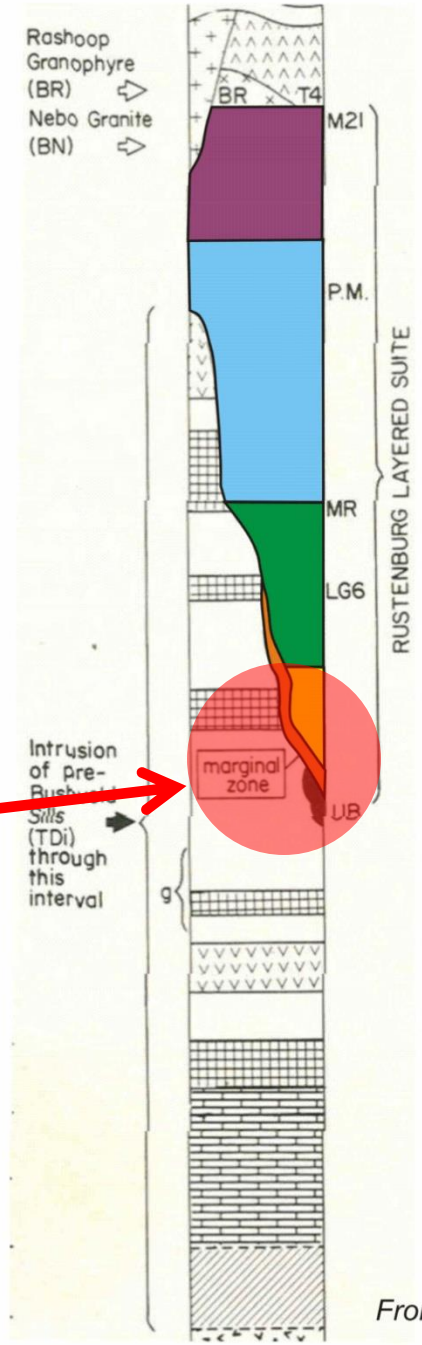
THE BUSHVELD COMPLEX

Unlike the greenstone belts and the Pongola SG the rocks of the Bushveld Complex are not lavas, these rocks are made up of crystals called cumulates ….. the challenge facing geologists is to identify what the original magmas were and where they came from



Spectacular layers but determining the magma composition is much more difficult ….
This section is 10 km thick (This in the Burgersfort area in Mpumalanga)

Simplified stratigraphy of the Bushveld Complex



Upper Zone

Main Zone

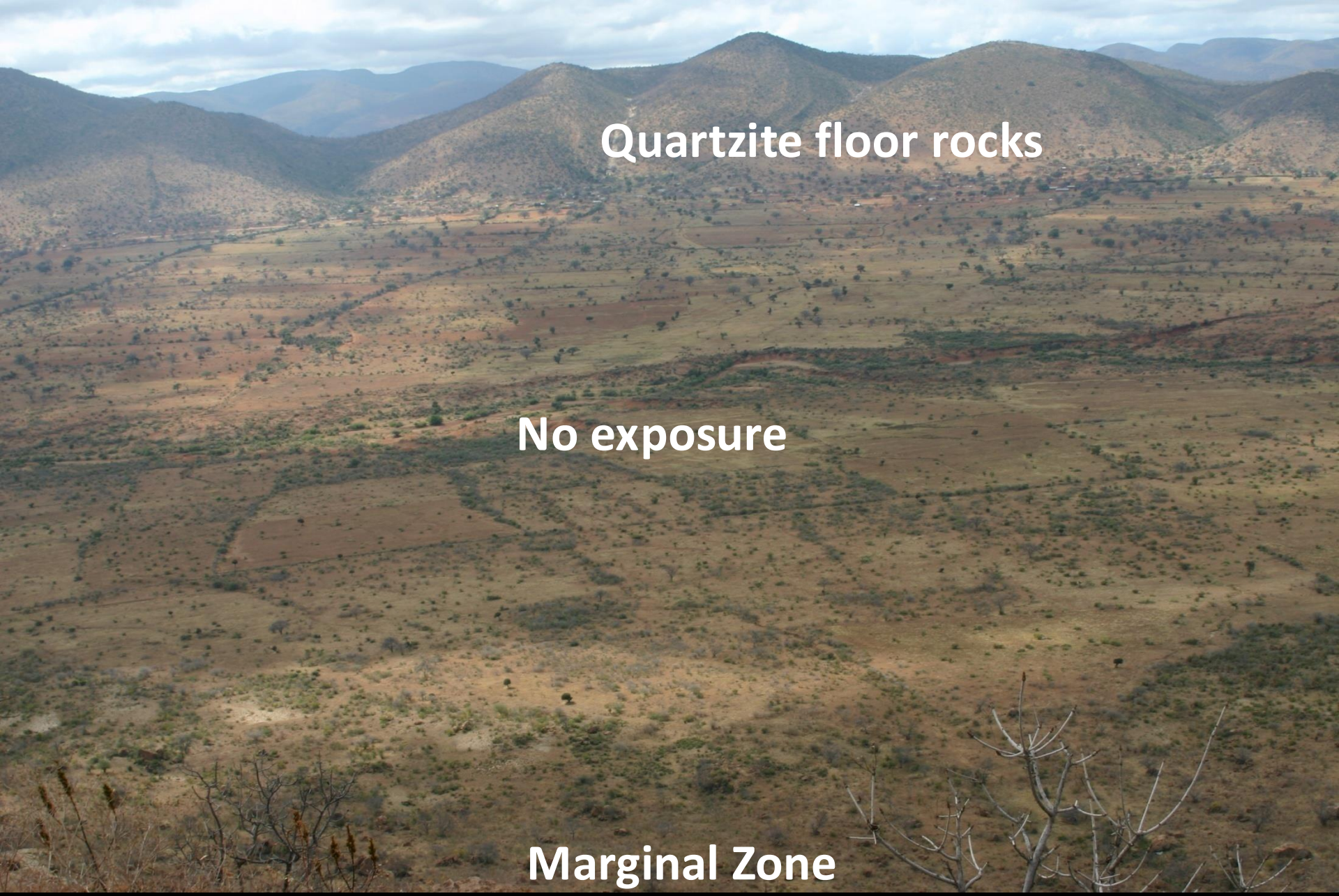
Critical Zone

Lower Zone

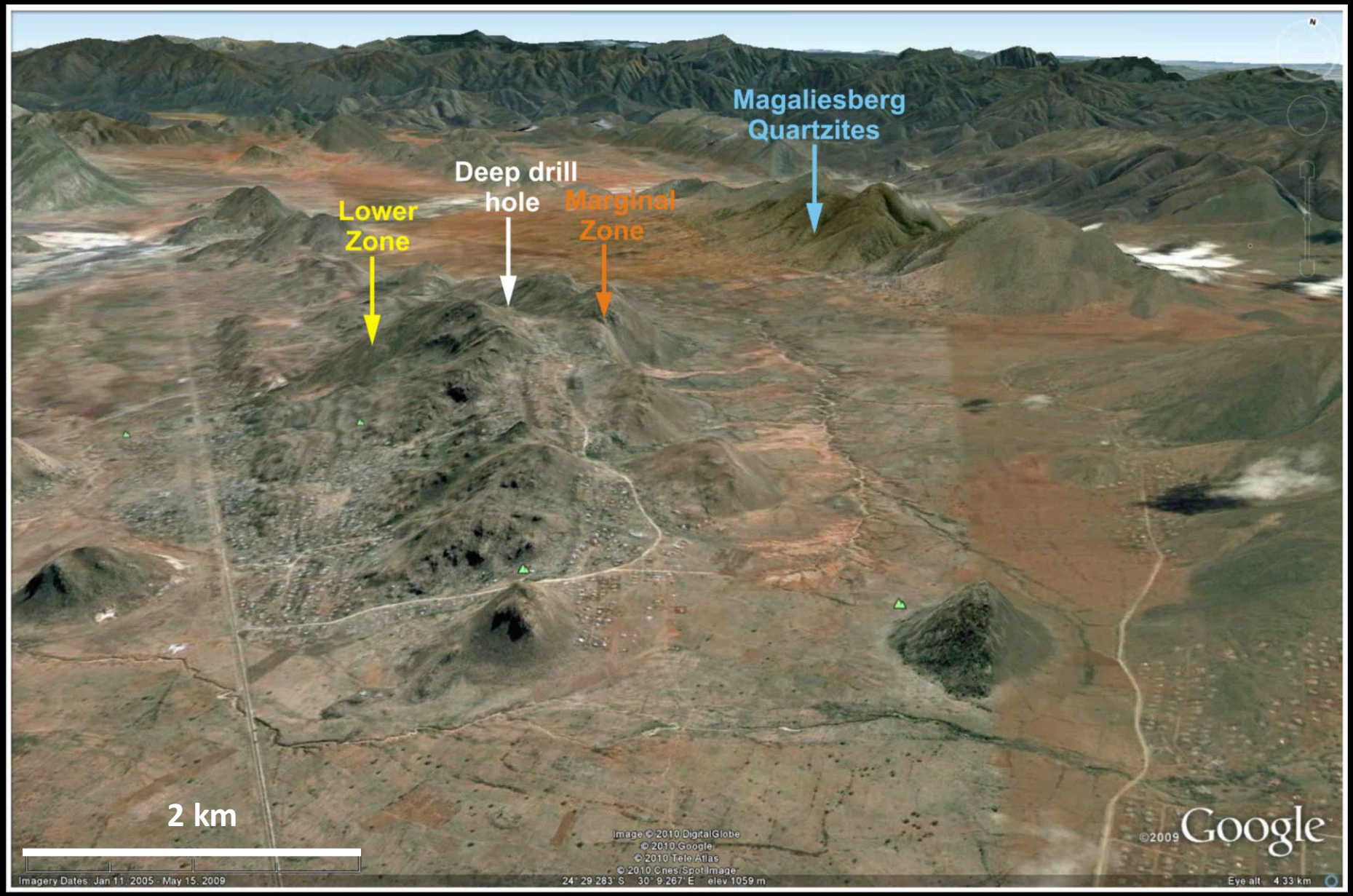
Transvaal SG and Bushveld sills

What happens here? ….the start of the intrusion

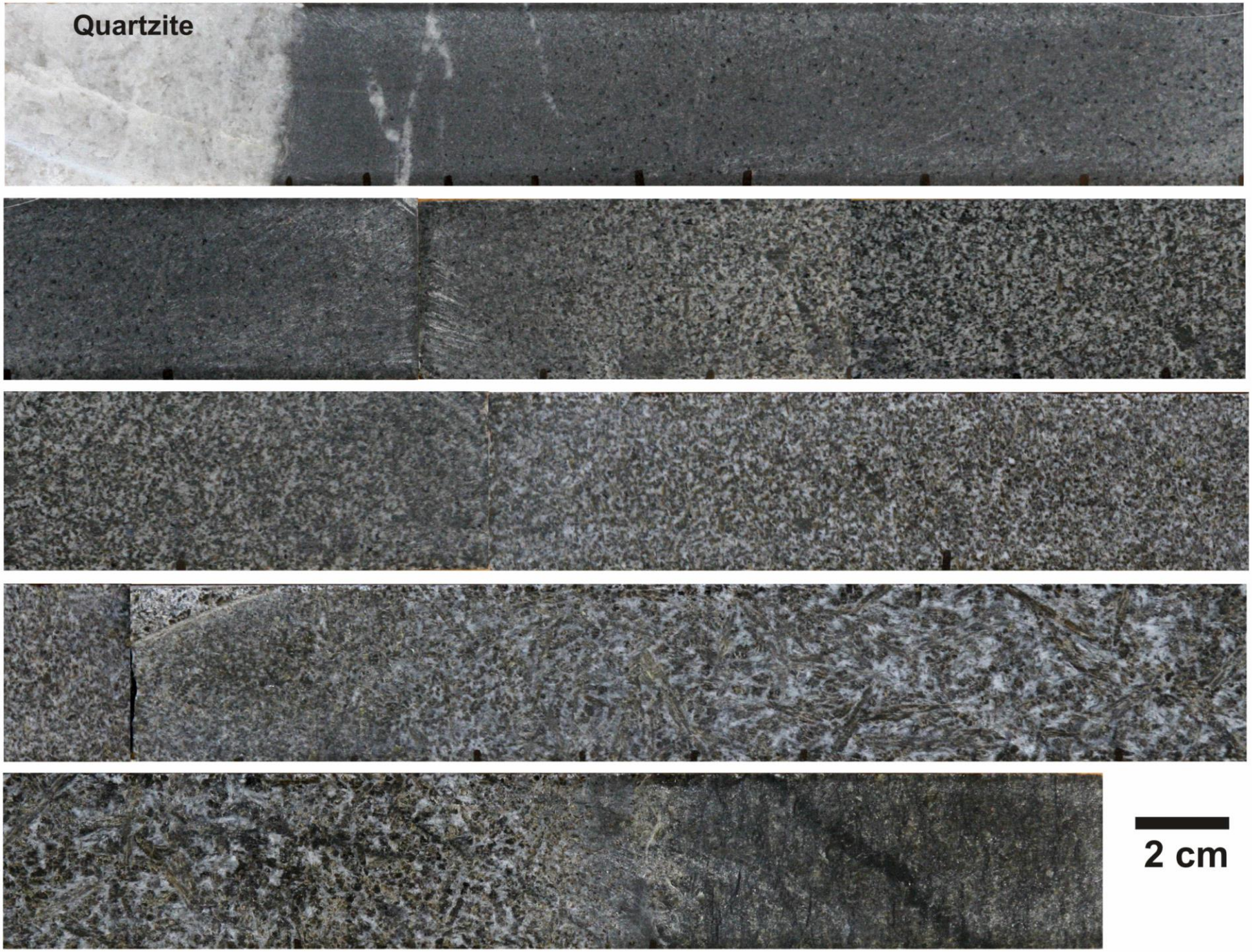
From Sharpe and Chadwick (1982)

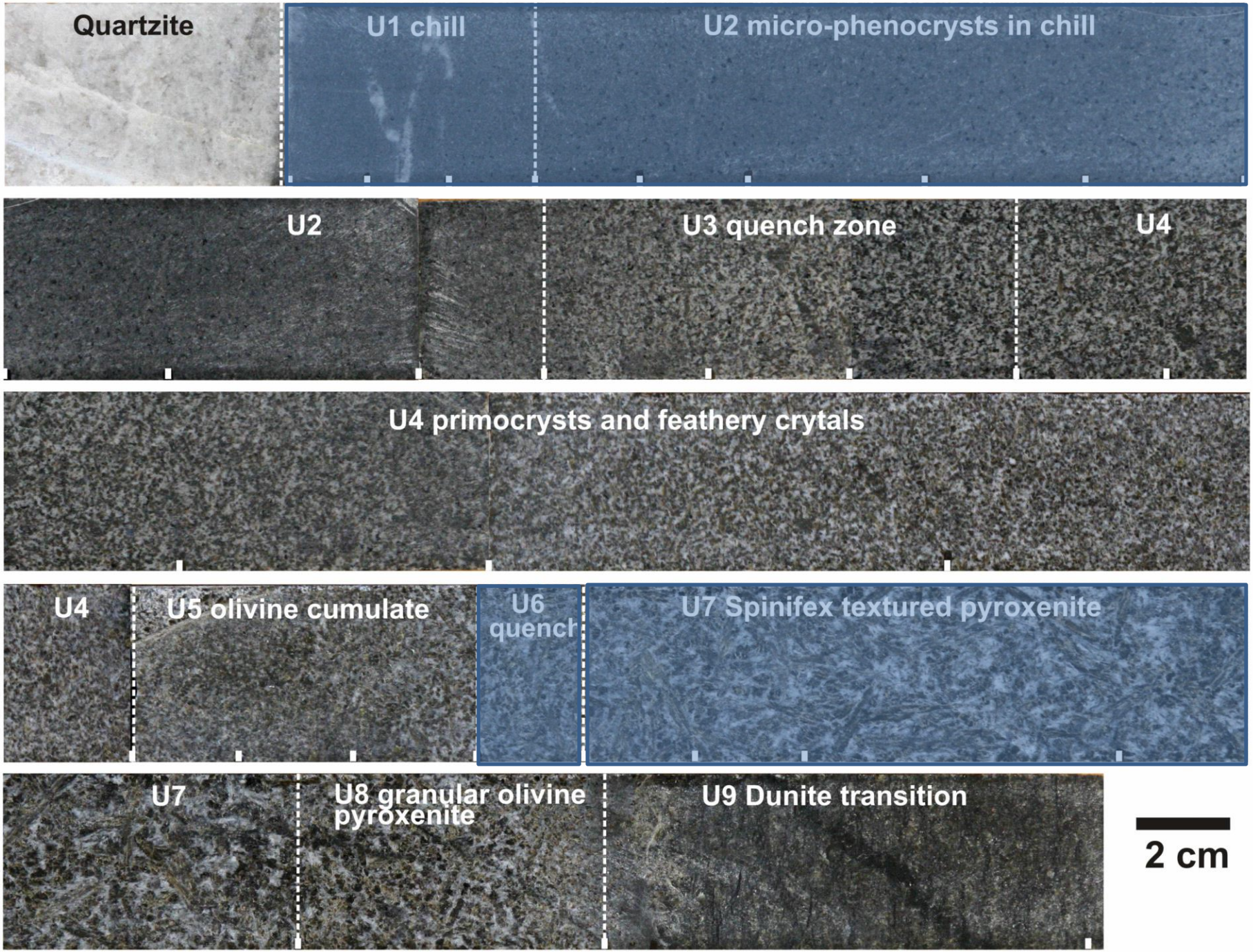


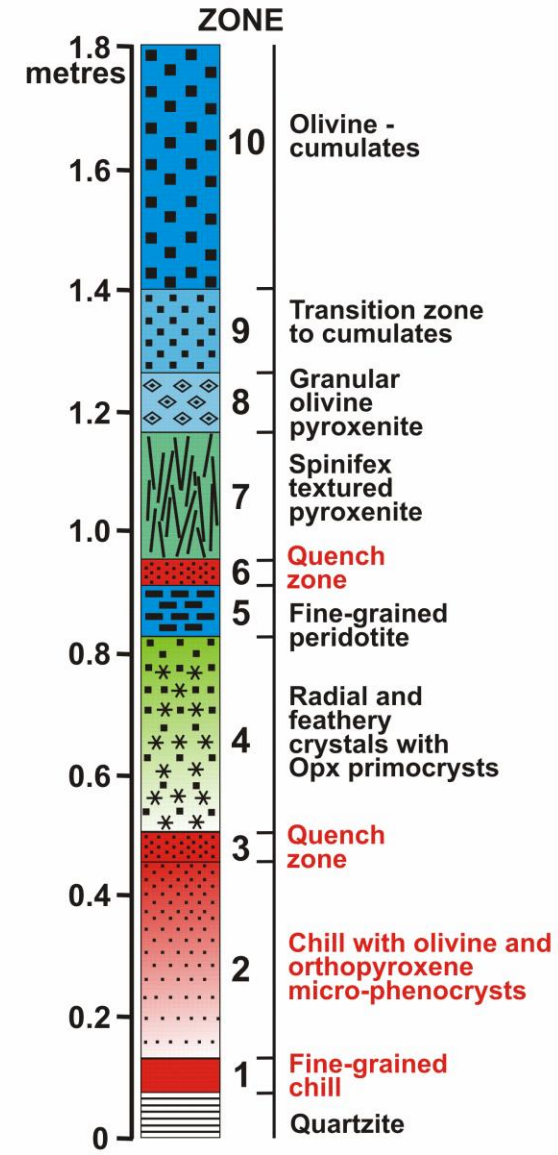
View looking NORTH in an area of the eastern Bushveld Complex
Burgersfort area



View towards the north west…….Gordon Chunnett one day drilled a deep borehole here


Quartzite
2 cm


Quartzite
U1 chill
U2 micro-phenocrysts in chill
U2
U3 quench zone
U4
U4 primocrysts and feathery crytals
U4
U5 olivine cumulate
U6 quench
U7 Spinifex textured pyroxenite
U7
U8 granular olivine pyroxenite
U9 Dunite transition
2 cm

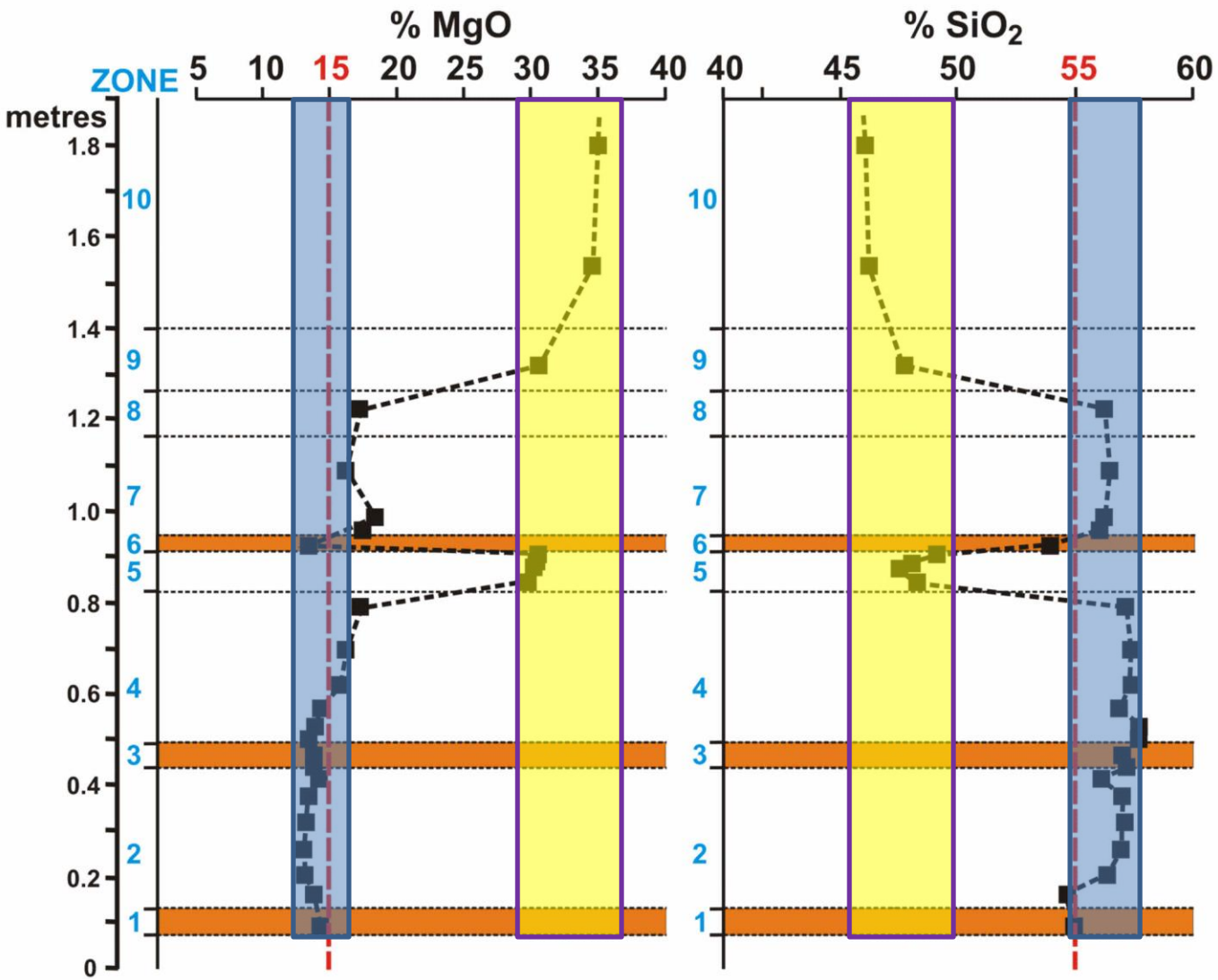


LOWER ZONE CHILL MARGIN SEQUENCE

The only section known in the Bushveld which shows the transition from quenched or frozen Liquid to cumulates

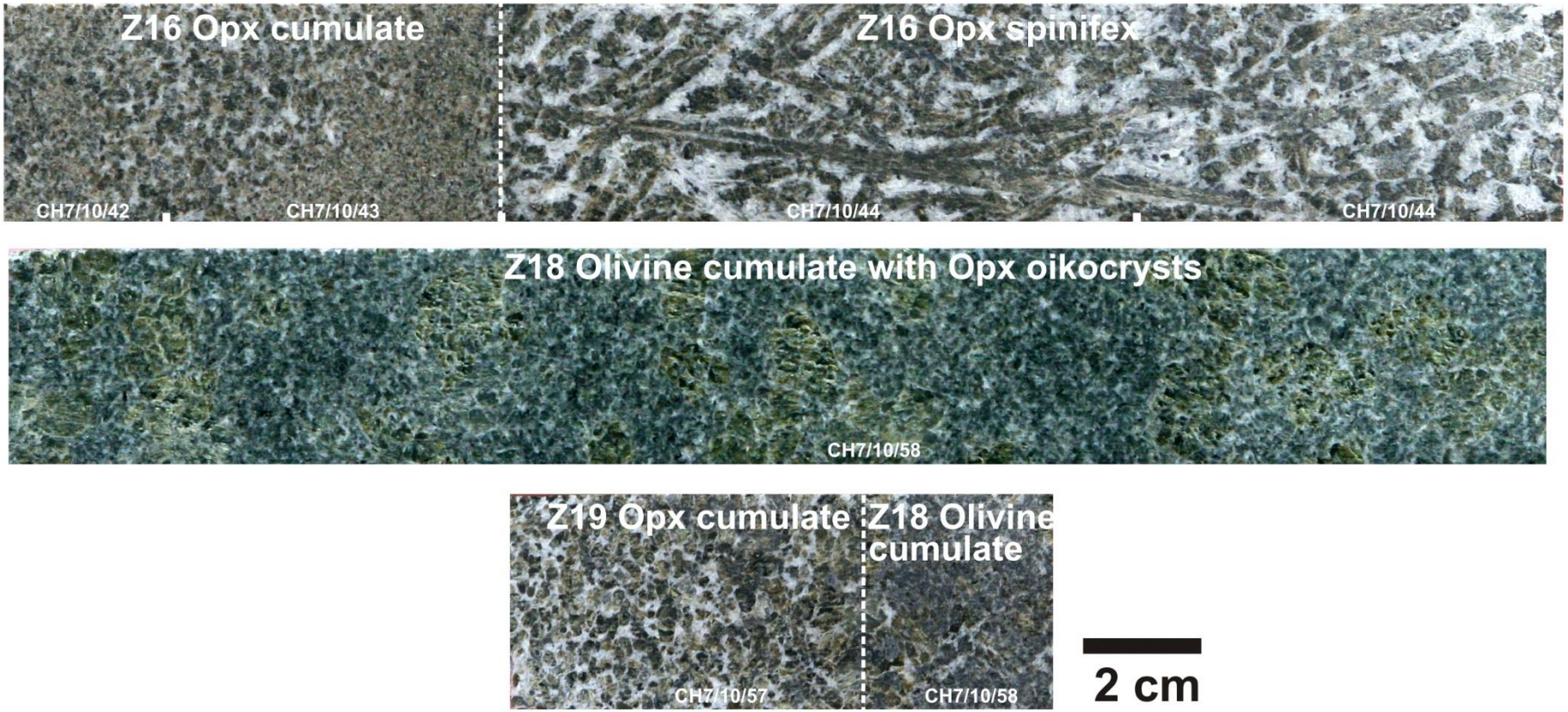
1m !!! ….. this is the key to 10 000 m of Bushveld sequence

(Apologies to my distinguished and learned Bushveld colleagues!!)



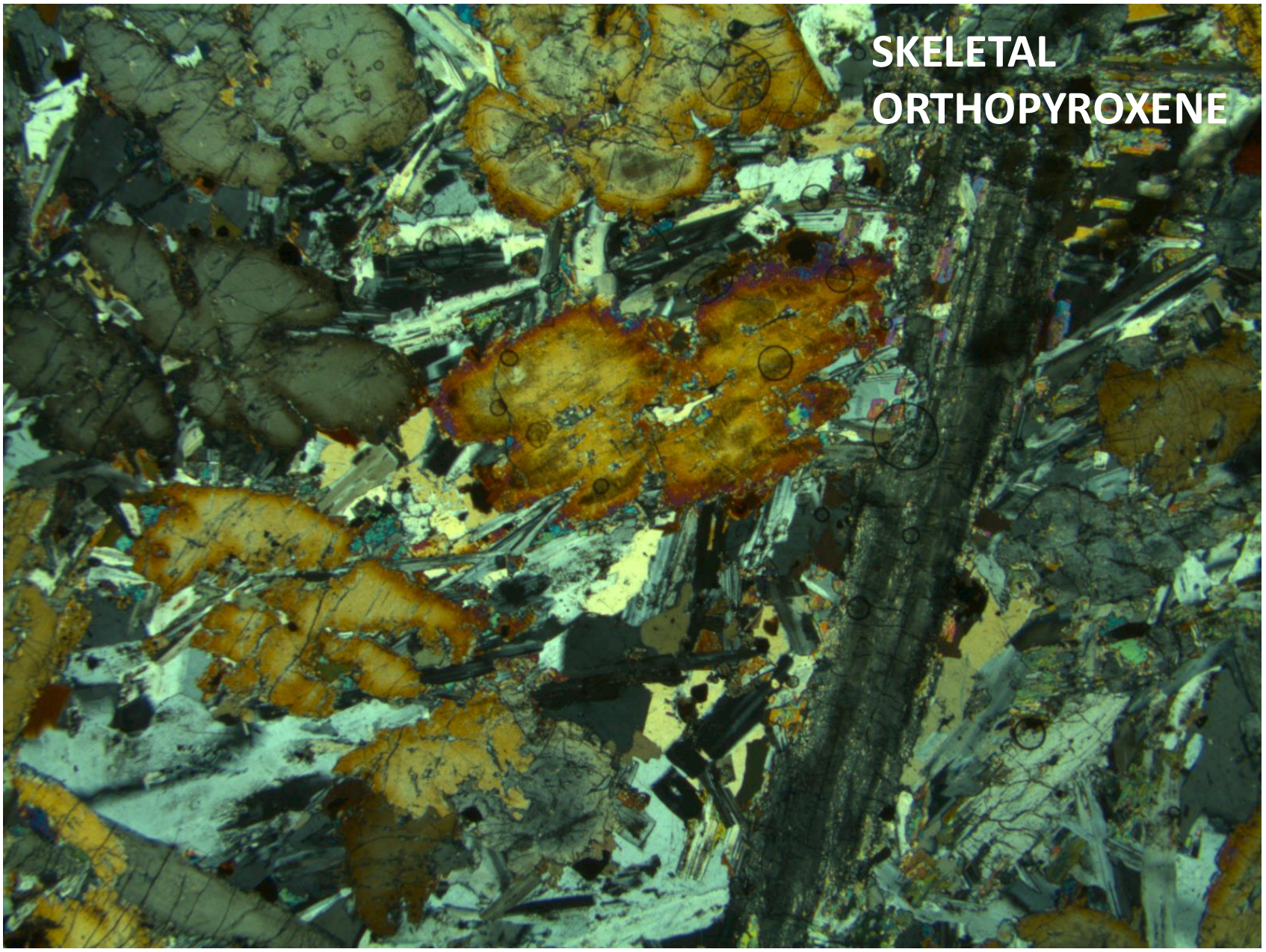
LIQUID COMPOSITIONS **CUMULATES**

Wilson (*Journal of Petrology – under review*)



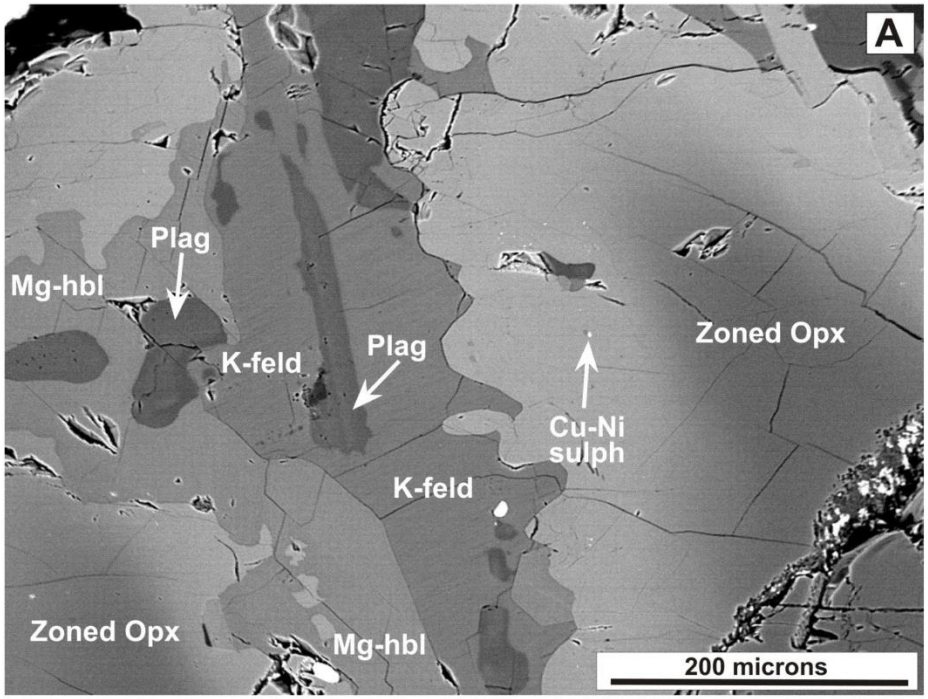
First described occurrence of preserved liquid compositions actually in the Bushveld sequence …… other occurrences occur outside of the Bushveld as Marginal Sills

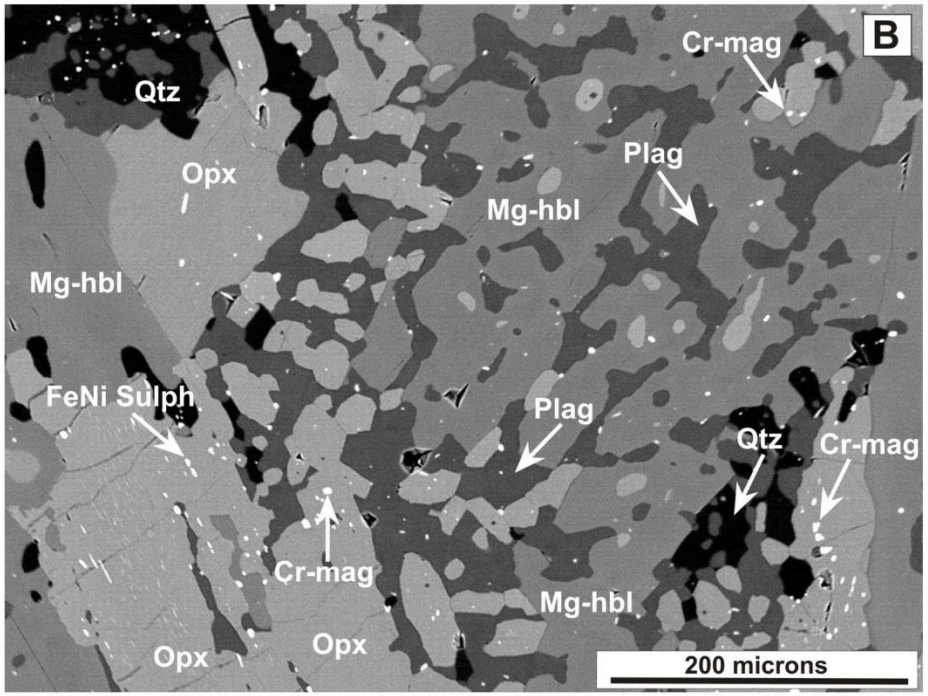
The cumulates also give insight into the first Bushveld magma



The transition between cumulates and quenched textures

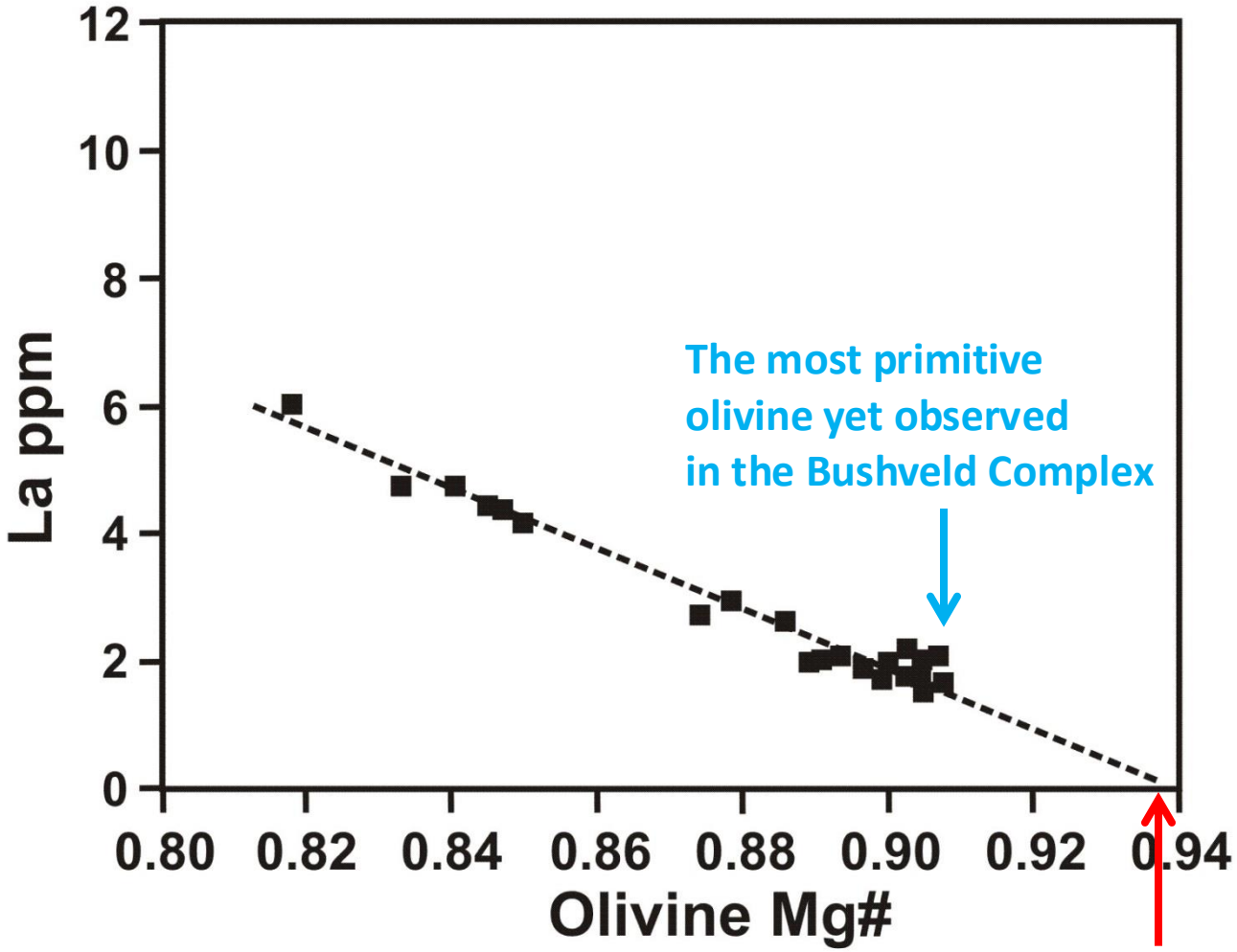
Photographs under the microscope using polarized light





Back-scattered electron images give detailed phase and mineral composition maps

(High resolution electron microscope at the University of Tasmania)



Combination of the Mg content of the olivine and trace elements tells us how they formed

A mantle origin may be inferred for the first stage of the Bushveld Complex …. previously has not been proven

Mg#=MgO/(MgO+FeO)
Is a measure of the primitiveness of the olivine

But trace element intercepts indicate they may have been even more Mg-rich

SOME POINTS THAT I HAVE TRIED TO MAKE

Rocks are studied on many different scales to understand their origin using many different chemical and microscope techniques as well as field work

While only three case studies have been presented each one provides different clues as to how igneous rocks formed that now make up the crustal geology of South Africa over the first 1.5b years

The greenstone belts, the Pongola Basin and the Bushveld Complex are unique in the Earth's geological record and are all world famous

My work has been to try and contribute to understand their formation by looking at critical formations, textures, compositions and structures - that is what I have tried to share with you today

Central to being able to achieve this has been excellent facilities and good technical support and the opportunity to travel and work in other labs and to engage with other scientists

So many of the areas of important geology are also closely linked with the history of South Africa – in some cases inseparable and always fascinating

And finally

Nature composes some of her loveliest poems for the microscope and the telescope

Theodore Roszak (American historian and scholar)
Where the Wasteland Ends, 1972

Thank you for attending!