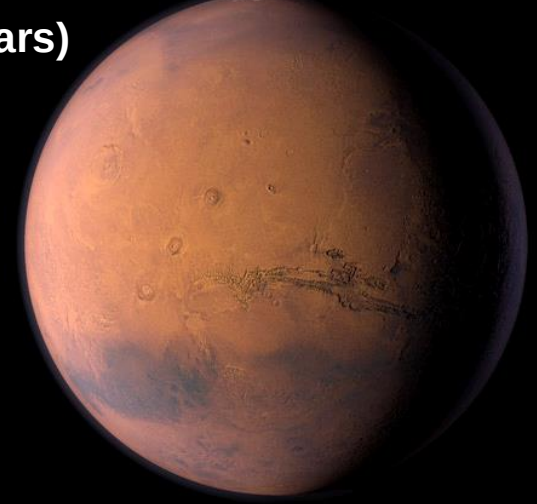


(with a brief stop on Mars)

From the Earth



and back again



To the Moon

Prof. Lewis D. Ashwal
Inaugural Lecture
Wits University
25 October, 2012



15 Minutes From Manhattan There's A Place
Where Even The Cops Fear To Tread.



PAUL NEWMAN in
FORT APACHE,
THE BRONX
The Cops Last Stand.

THE LIFE STORY OF A POLICE OFFICER

PAUL NEWMAN

FORT APACHE, THE BRONX

Starring **EDWARD ASNER** BEN WAHL RACHEL TROTTER

DANNY ABLE JIM JARVIS and KATHLEEN BULLER. Music by JONATHAN TURICK
Produced by MARTIN SCHWARTZ and GILL CHAMPION. Written by HERWOOD GOLLD

Directed by EDWIN PETTIE. Executive Producer: DWIGHT DUNLAP







1951



1953

Money for nothin...

May 21, 1961





DeWitt Clinton High School, Bronx, N.Y.

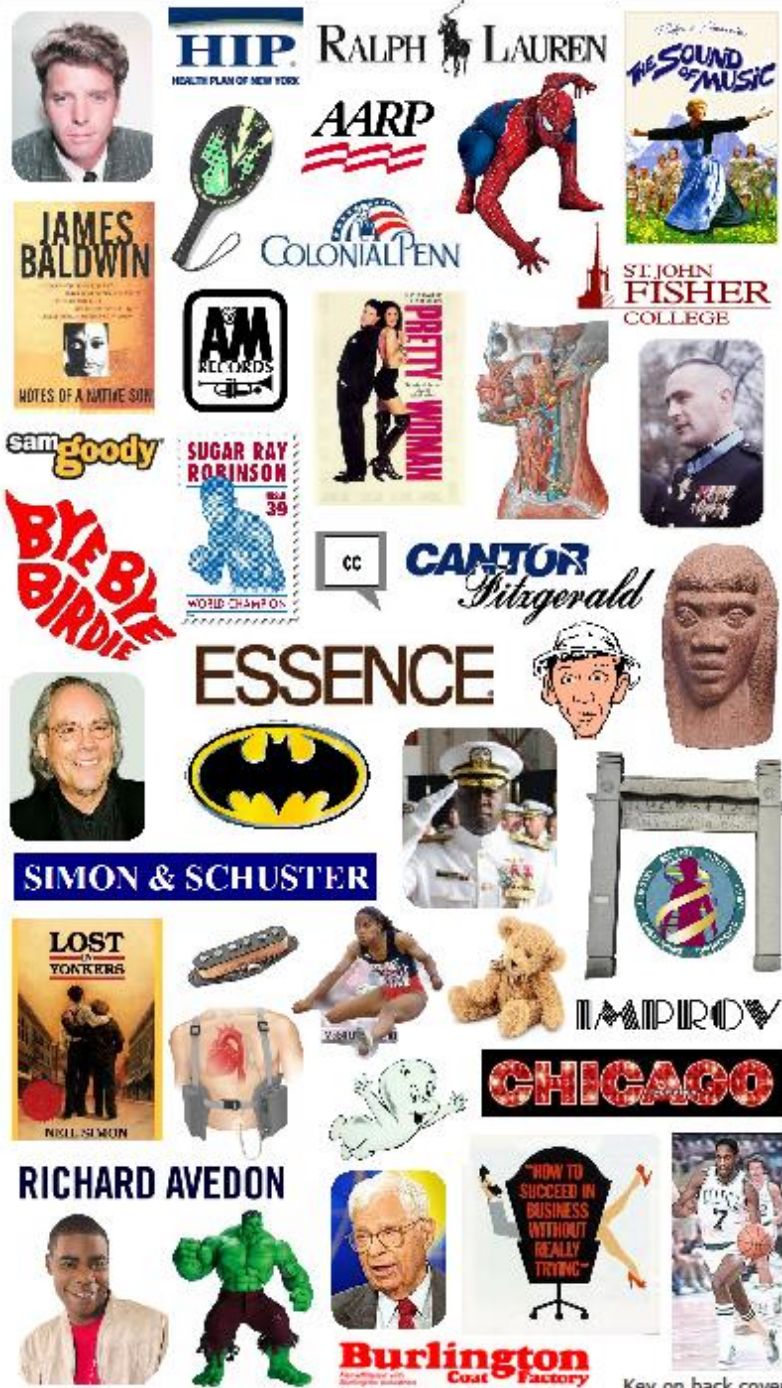
**DeWitt
Clinton
High
School**

**100 West Moshulu
Parkway South
Bronx, NY 10468**

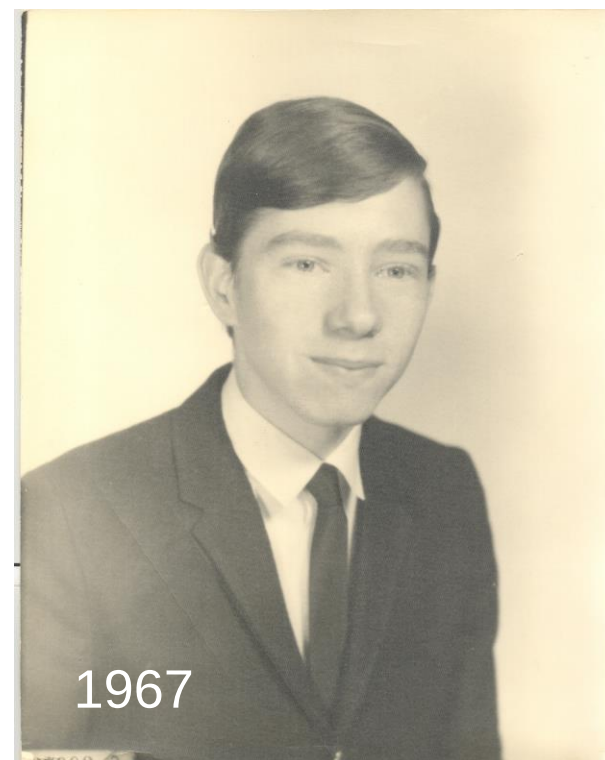


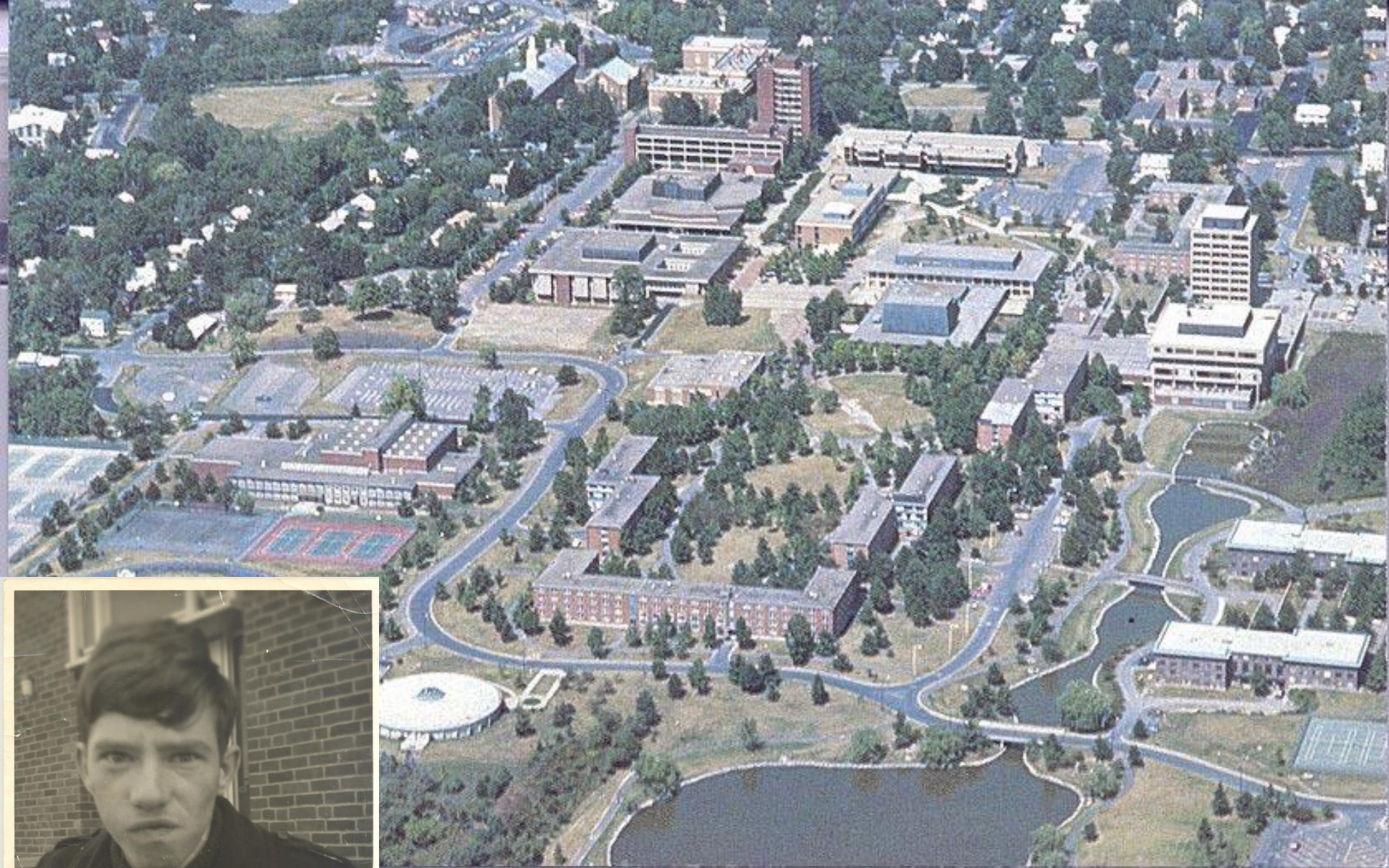
July 2012

Created by
Gerard J. Pelisson
for the DeWitt Clinton
Alumni Association

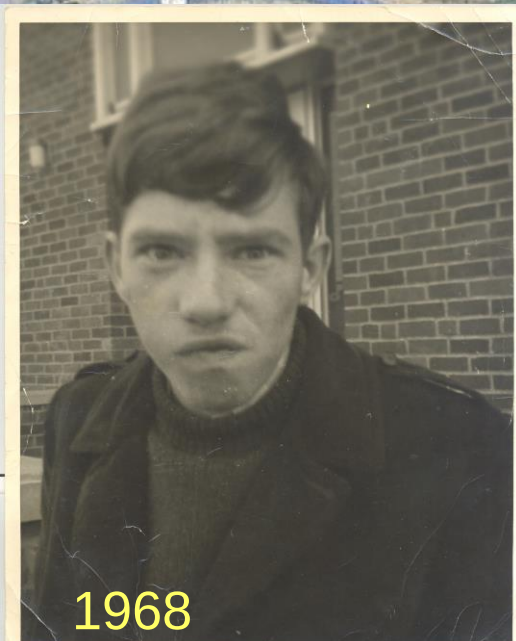


Key on back cover





SUNY New Paltz

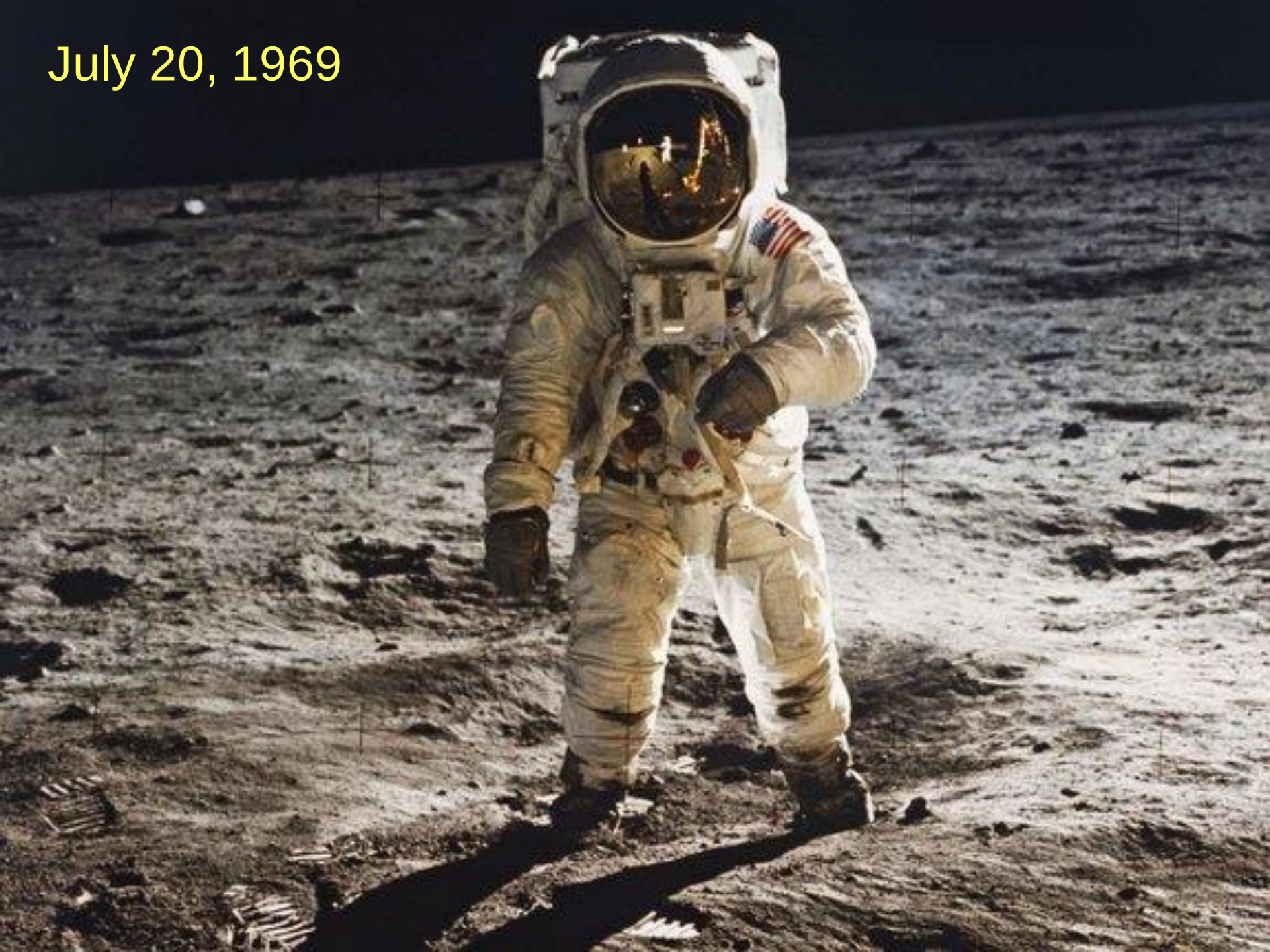


1968

July 16, 1969

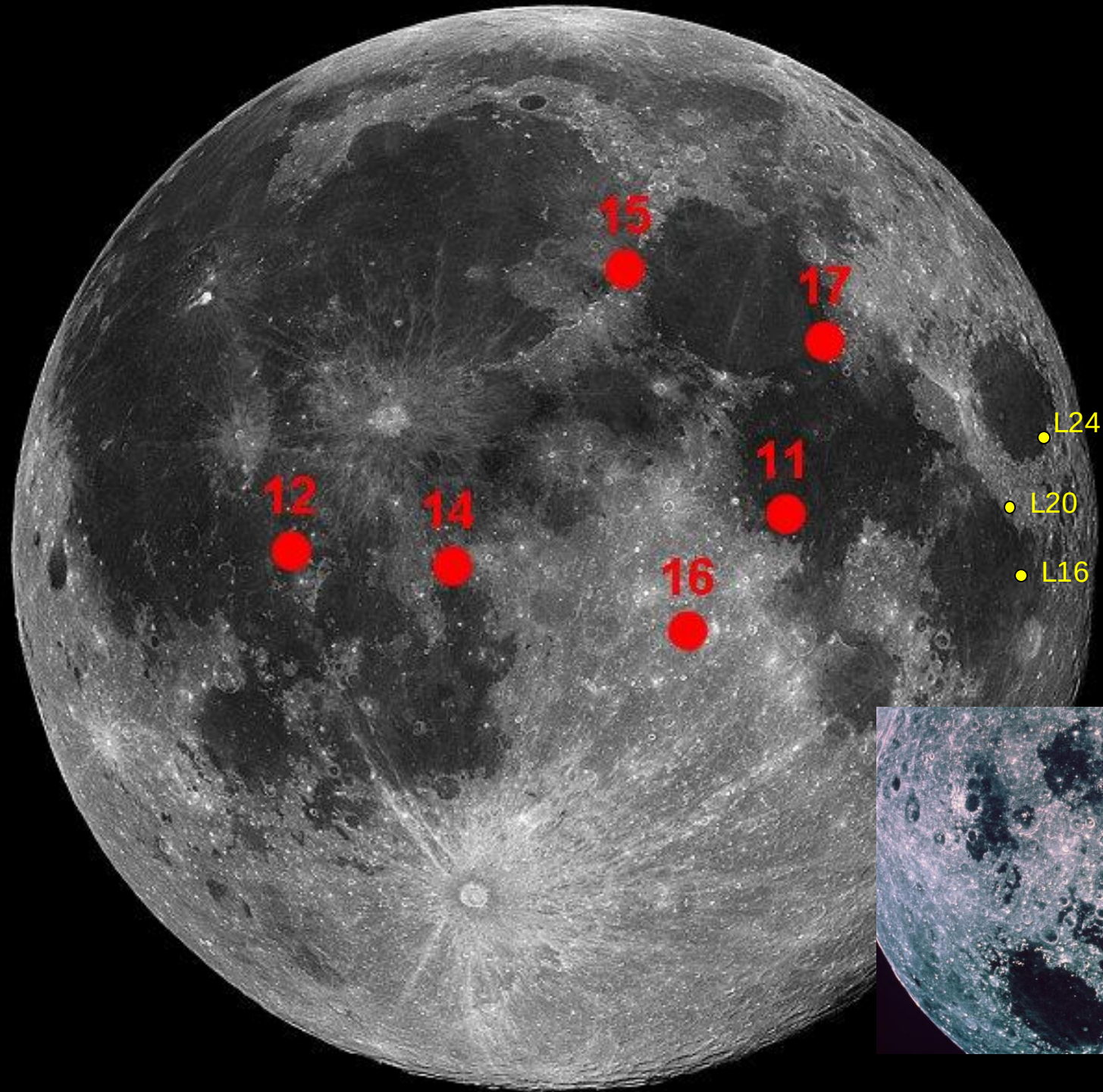


July 20, 1969





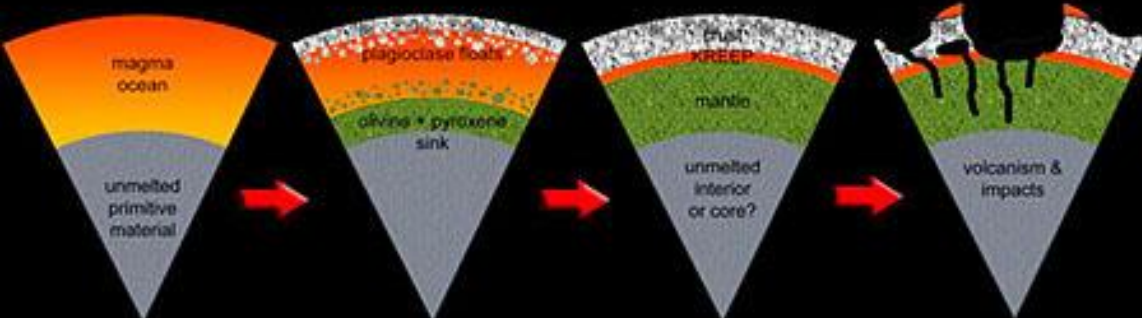
Woodstock, August 17, 1969





Apollo 11
sample 10085

Magma Ocean Evolution

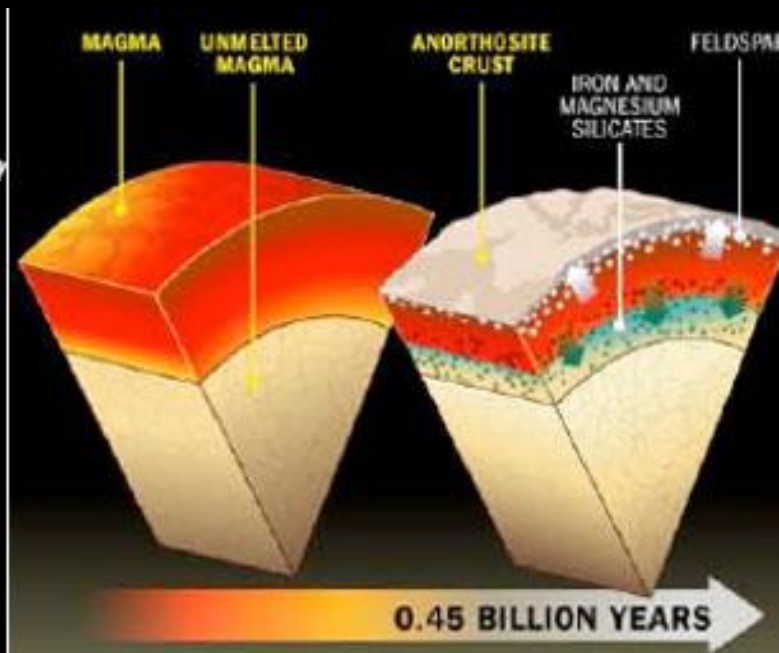


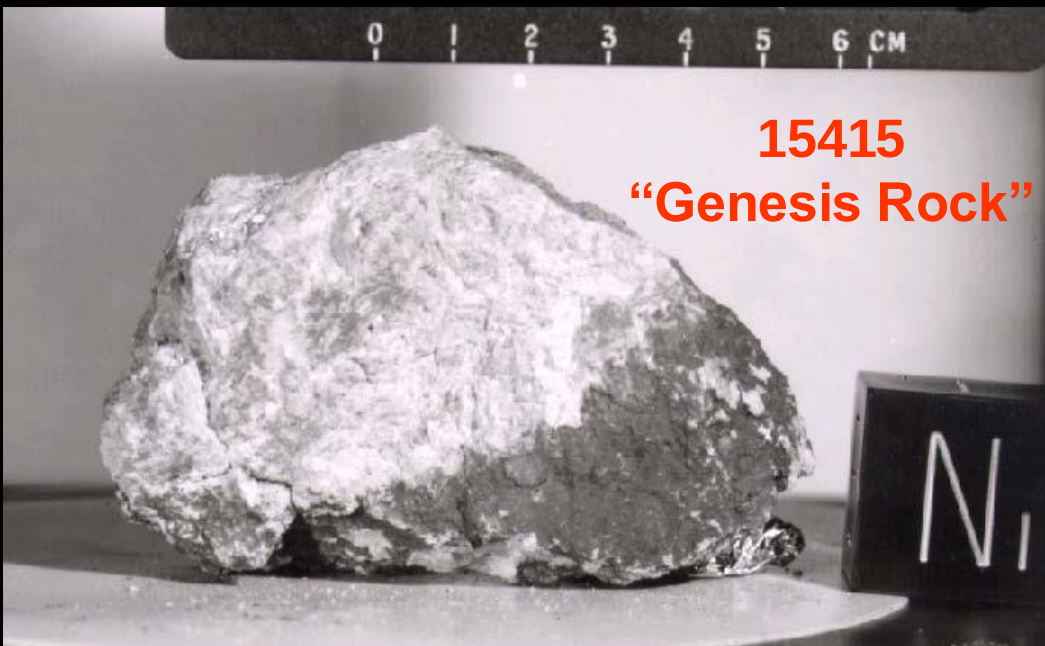
Result of hot accretion

Light minerals floated

Dense minerals sank

Whole mantle / partial mantle convection

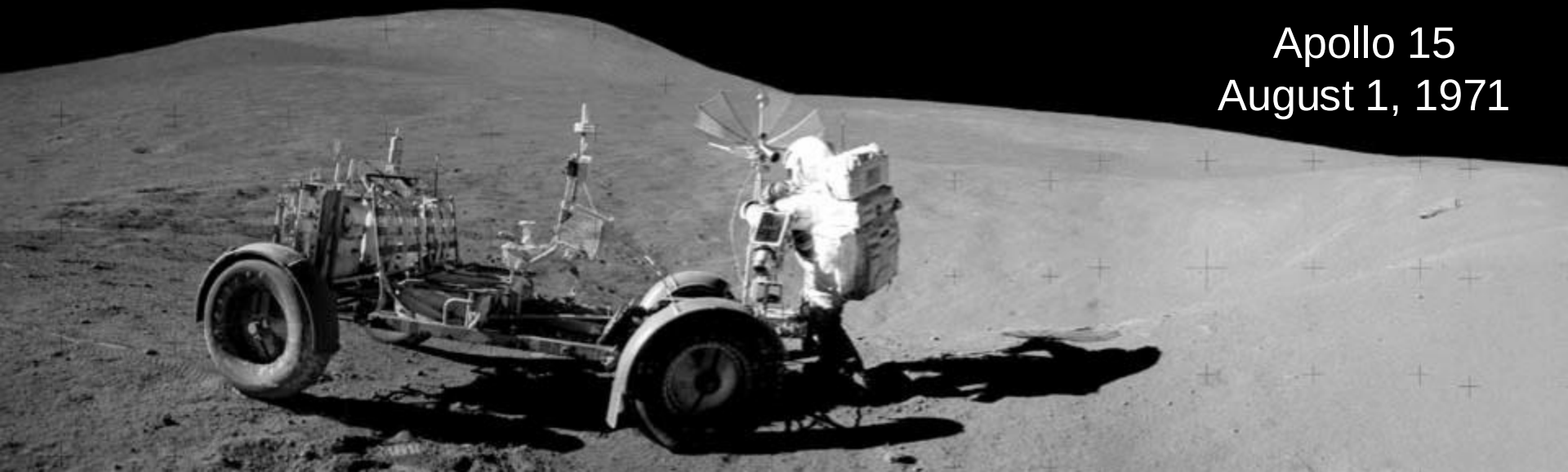




15415
"Genesis Rock"



Apollo 15
August 1, 1971





B.Sc. Graduation, 1971



Viet Nam, 1971

UMass



Peter Robinson



Tony Morse



Steve Haggerty

Princeton



Rob Hargraves



Linc Hollister



Tom Jordan



McCosh Hall, Princeton University

Petrologic evidence for a plutonic igneous origin of anorthositic norite clasts in 67955 and 77017

LEWIS D. ASHWAL

Department of Geological and Geophysical Sciences, Princeton University,
Princeton, N.J. 08540

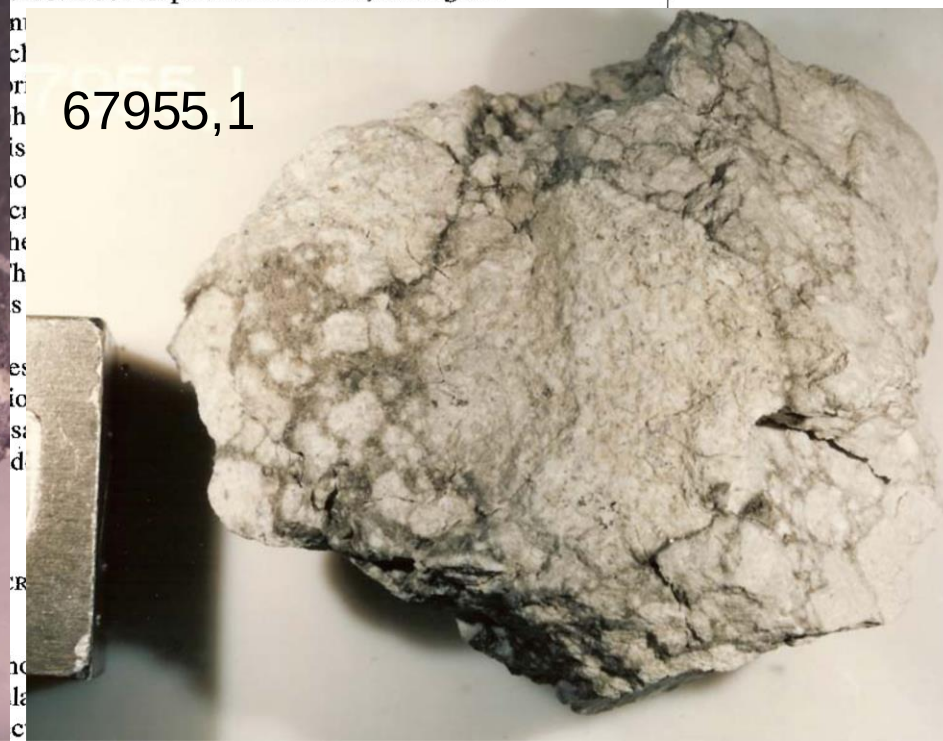
Abstract—Clasts of anorthositic norite in 67955 and 77017, and several other samples, are suggested to represent material which crystallized from a silicate magma in a plutonic environment. Although no statement can be made regarding the ultimate origin of the parent melt, its composition was relatively felsic, starting within the primary field of crystallization of either plagioclase or spinel. The sequence of crystallization was: plagioclase (and/or spinel)—olivine—low-Ca pyroxene—high-Ca pyroxene.

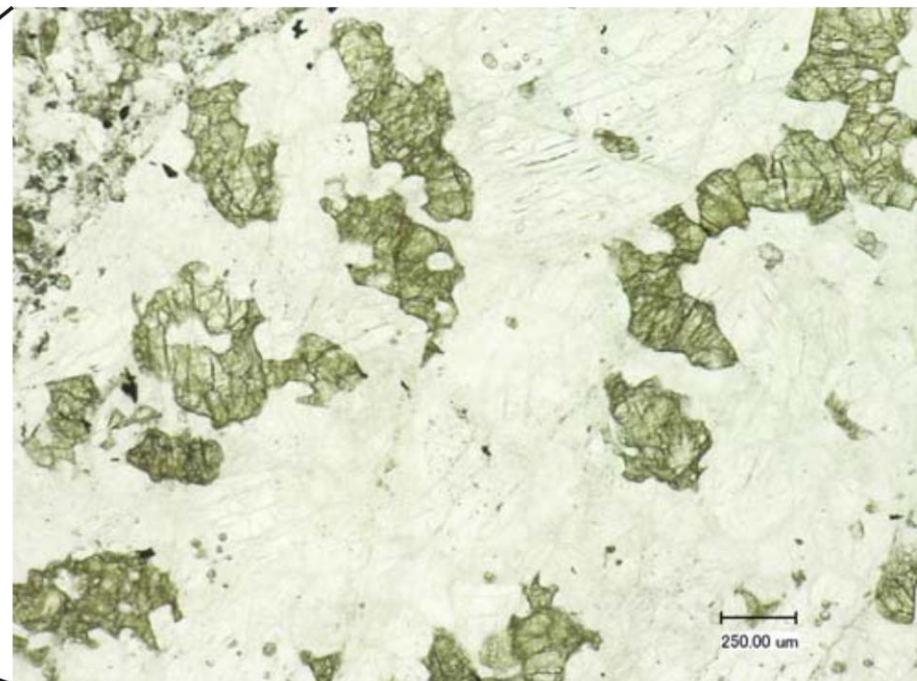
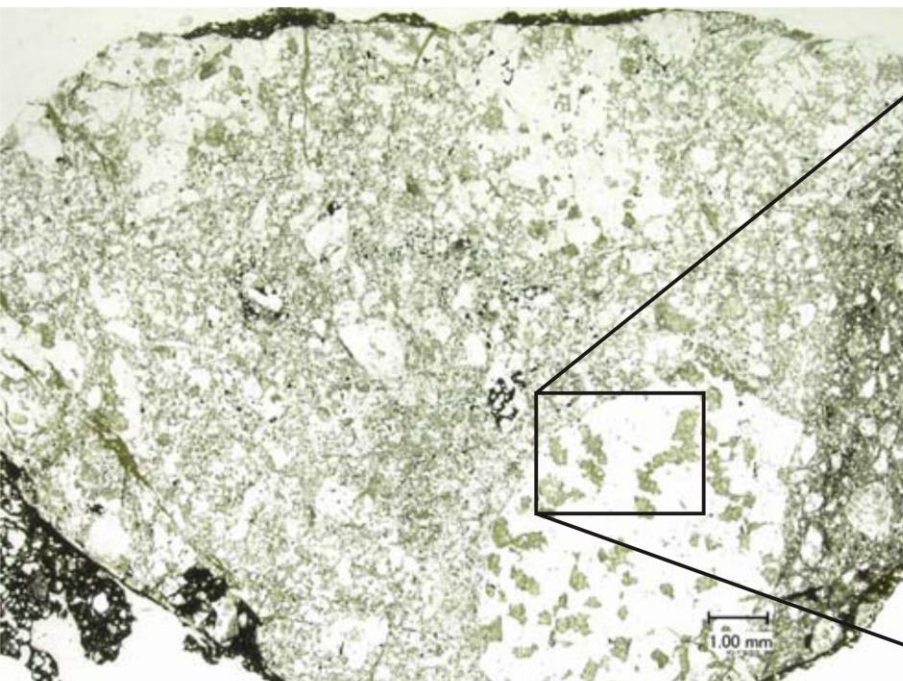
INTRODUCTION

...the conclusion that large-scale melting
...crustal development. However, among the

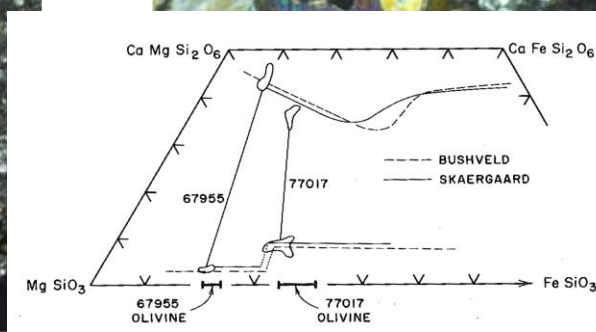
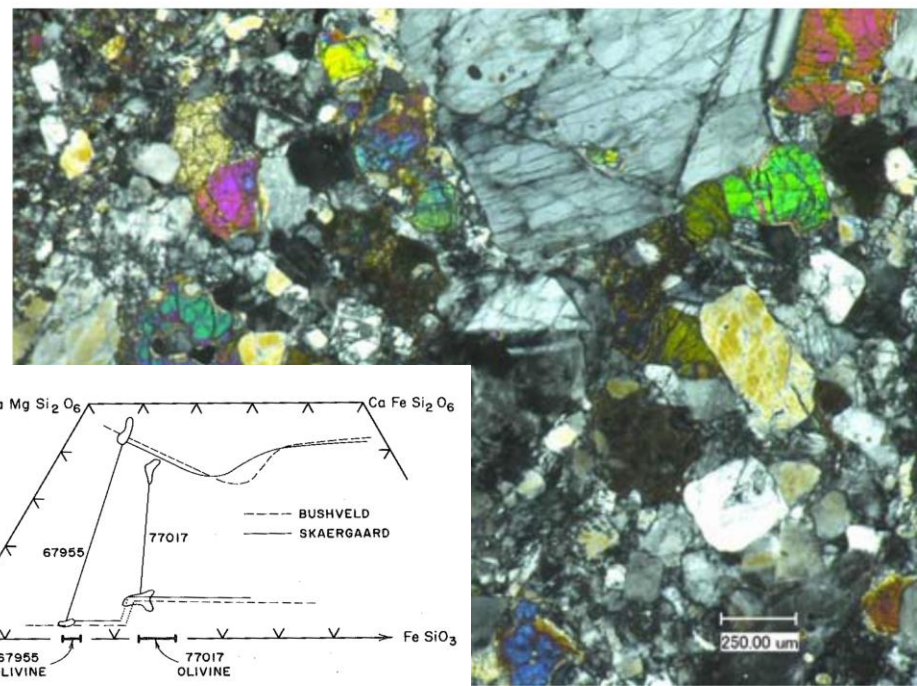
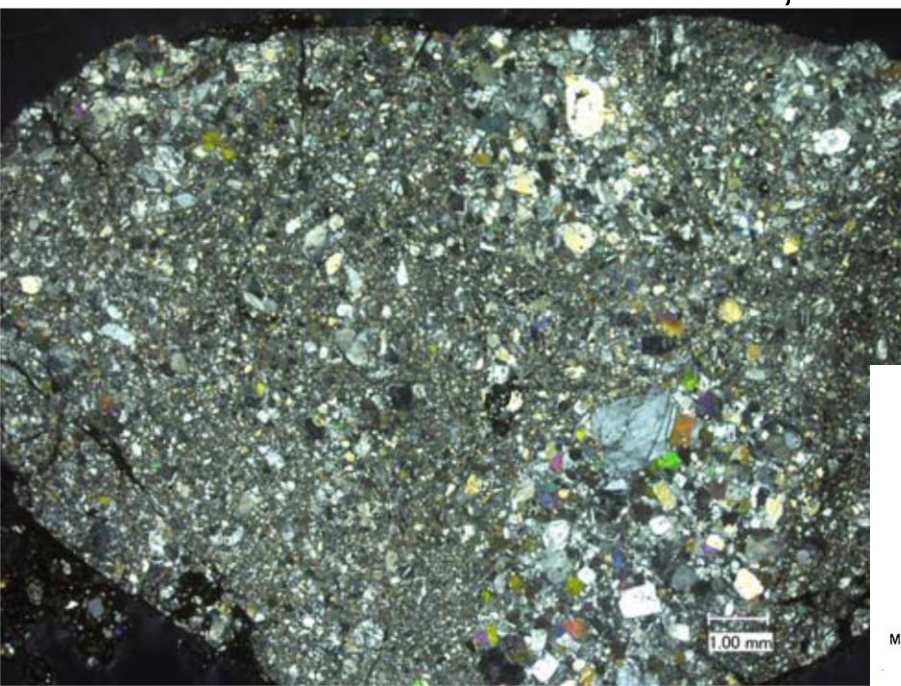


67955,1





77017, 69 thin section



Marcy anorthosite massif

Adirondacks, New York

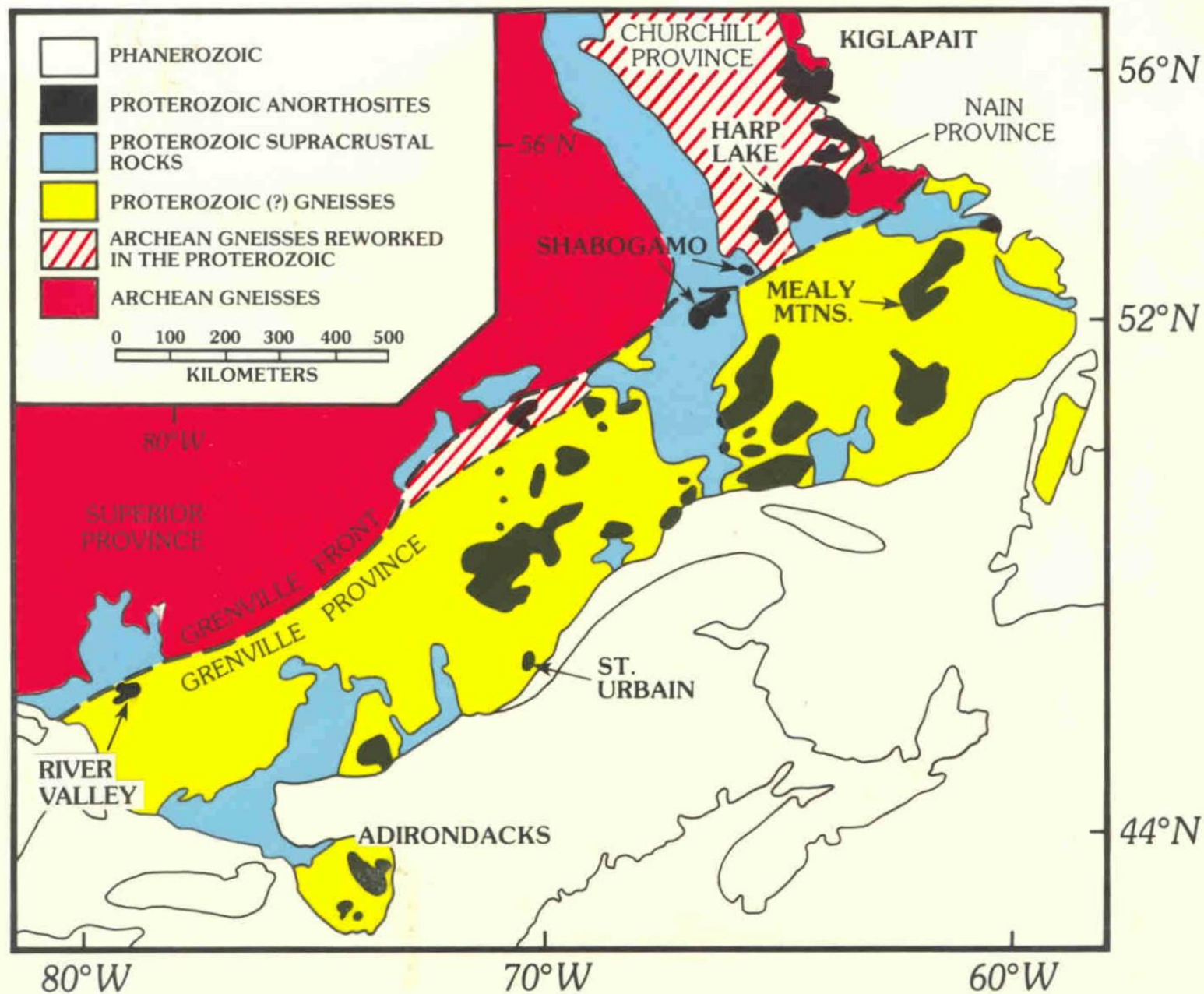




Lake Placid, N.Y.



Saranac Lake, N.Y.





Morin, Quebec

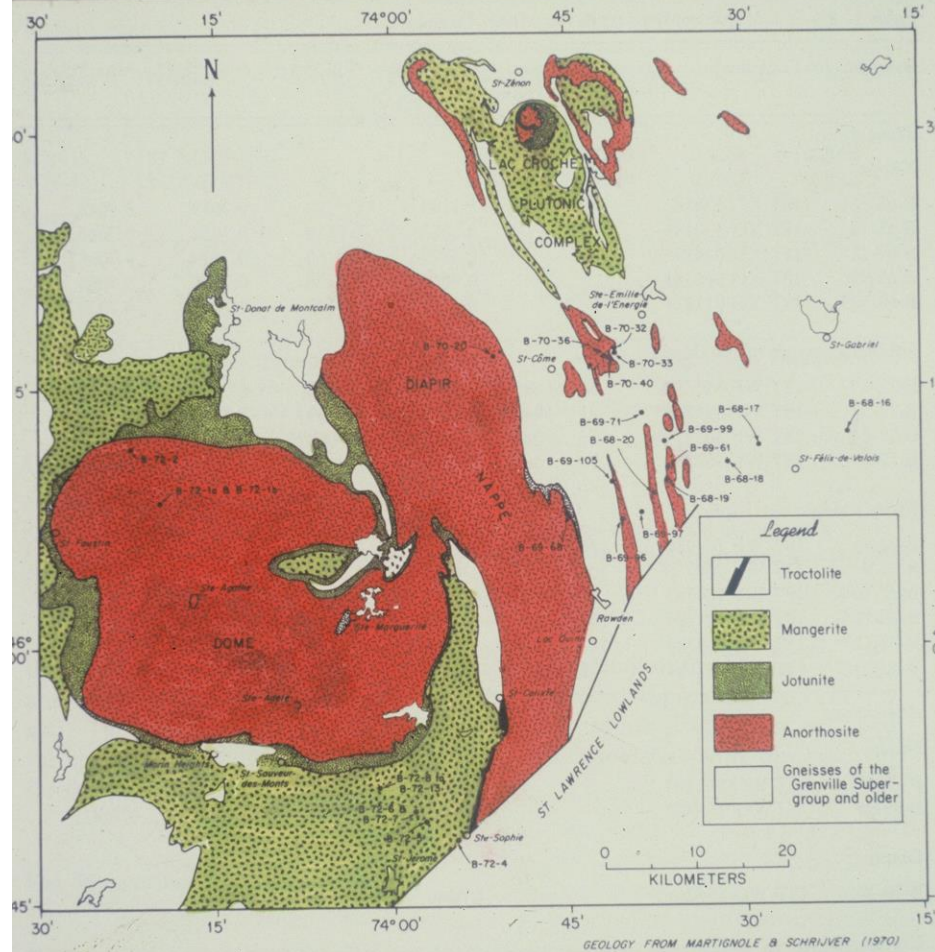


Fig. 1. Geologic map of the Morin Complex showing the sampling locations

Nain, Labrador

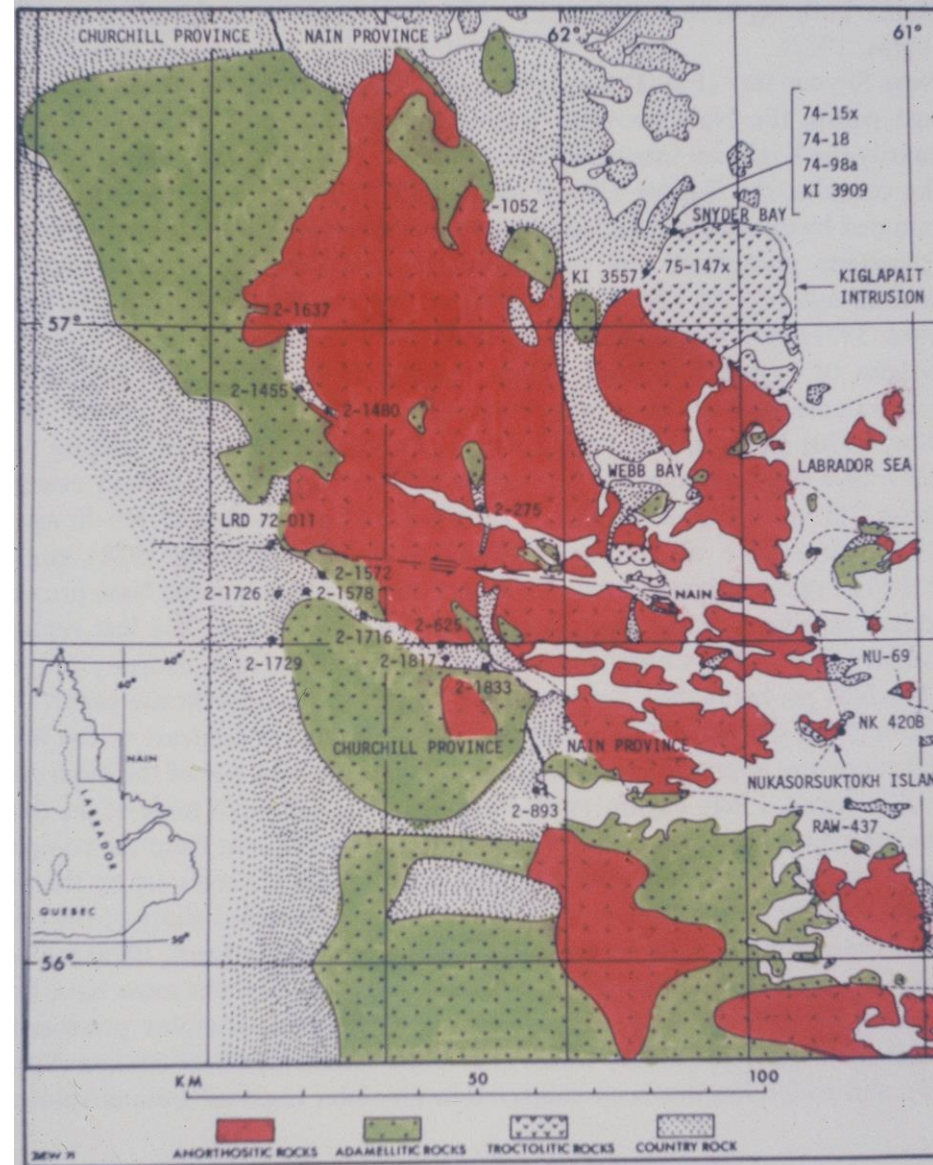
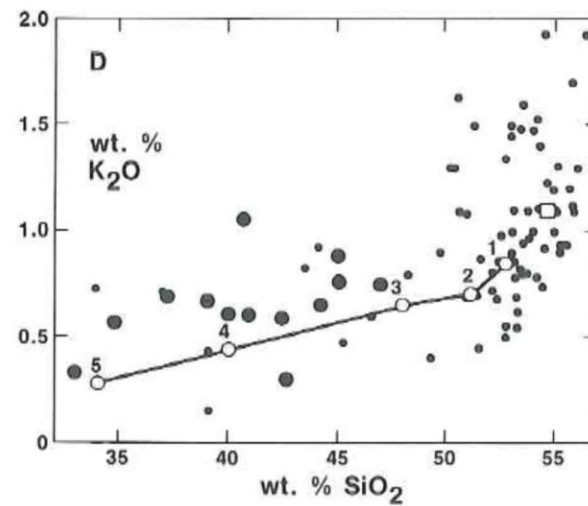
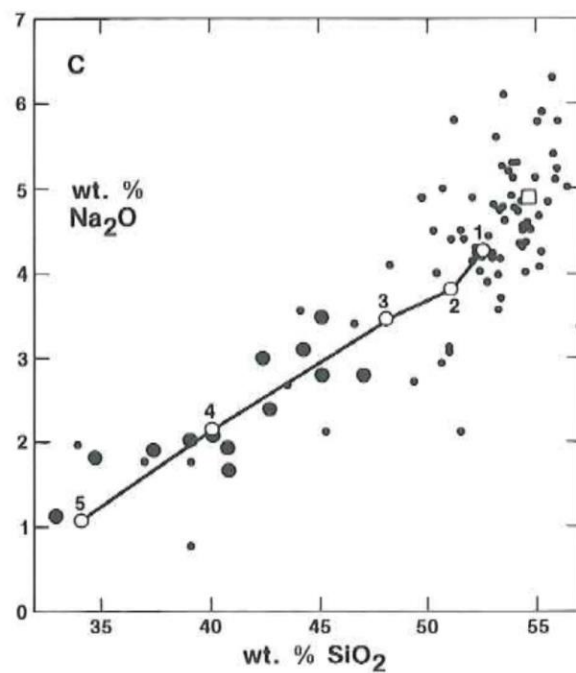
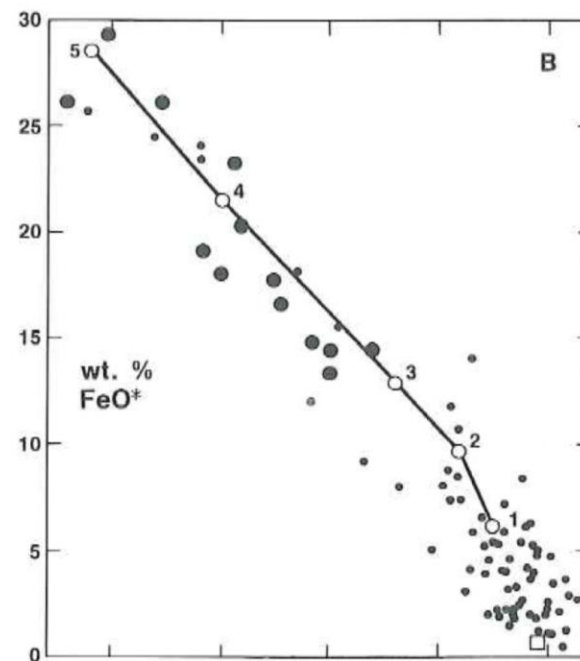
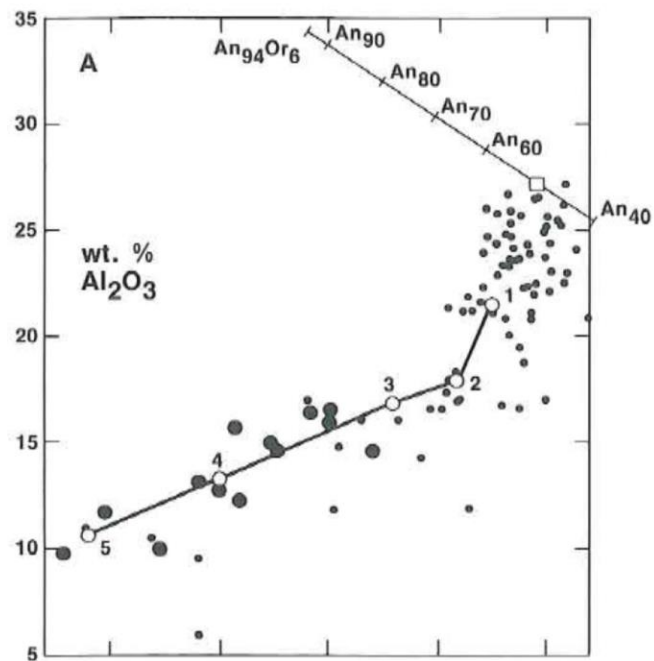
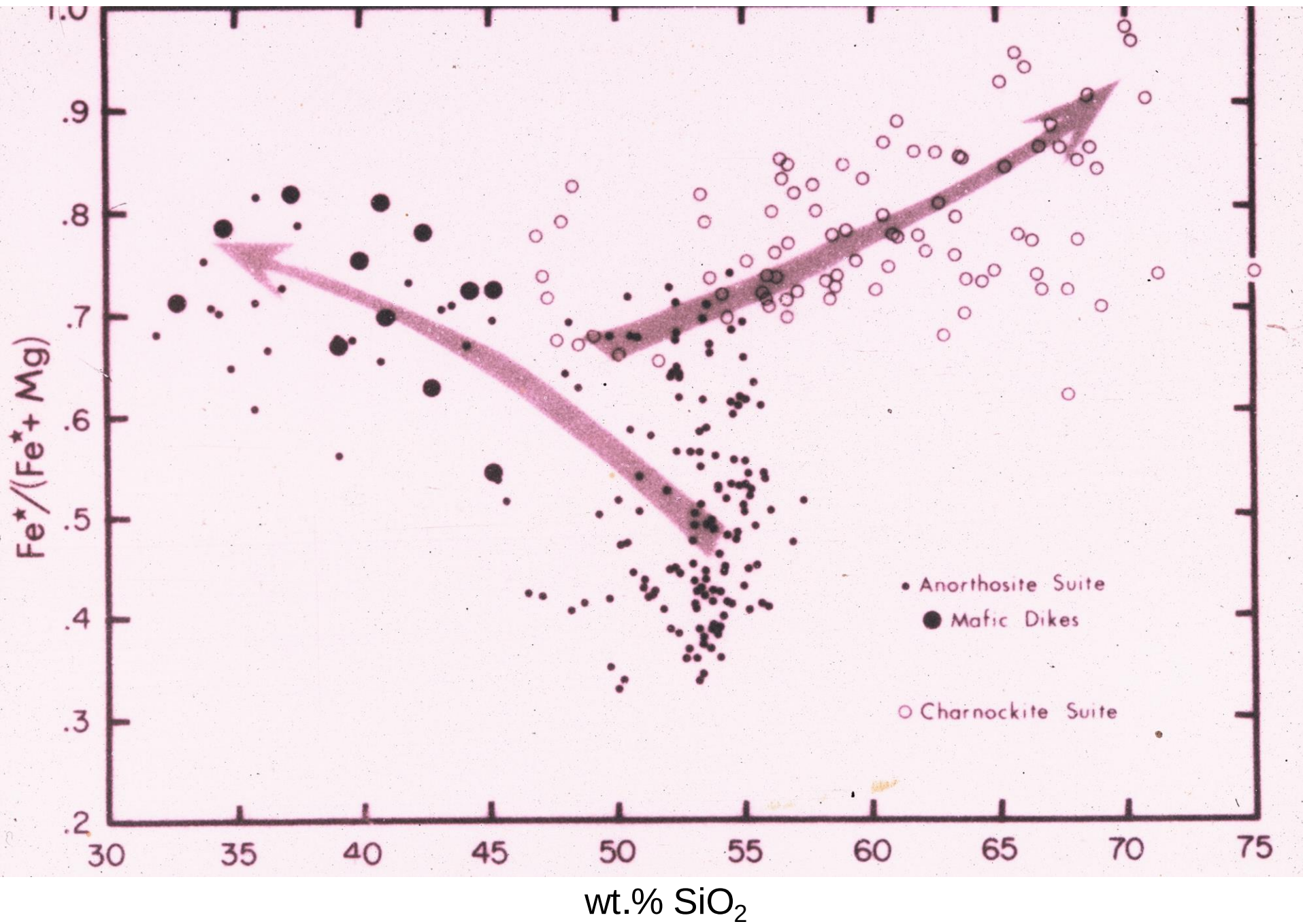
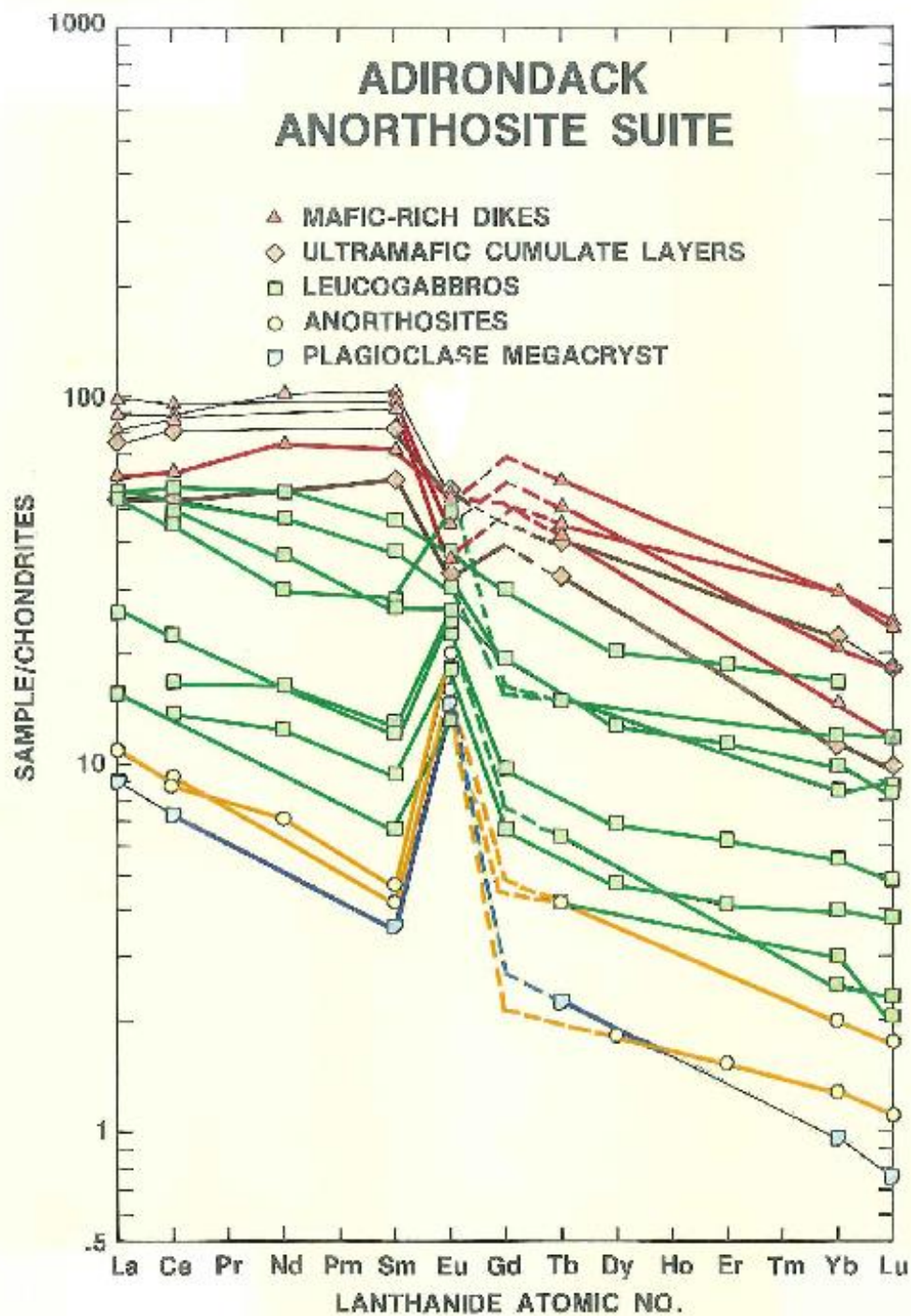


Fig. 1. Geologic map of Nain complex with sample locations. Geologic base map was compiled by D. deWaard based primarily on the field work of E. P. Wheeler, II.









Field Work, 1976



Bill Phinney, NASA JSC



Jeff Warner on his last day of work at JSC, 1982

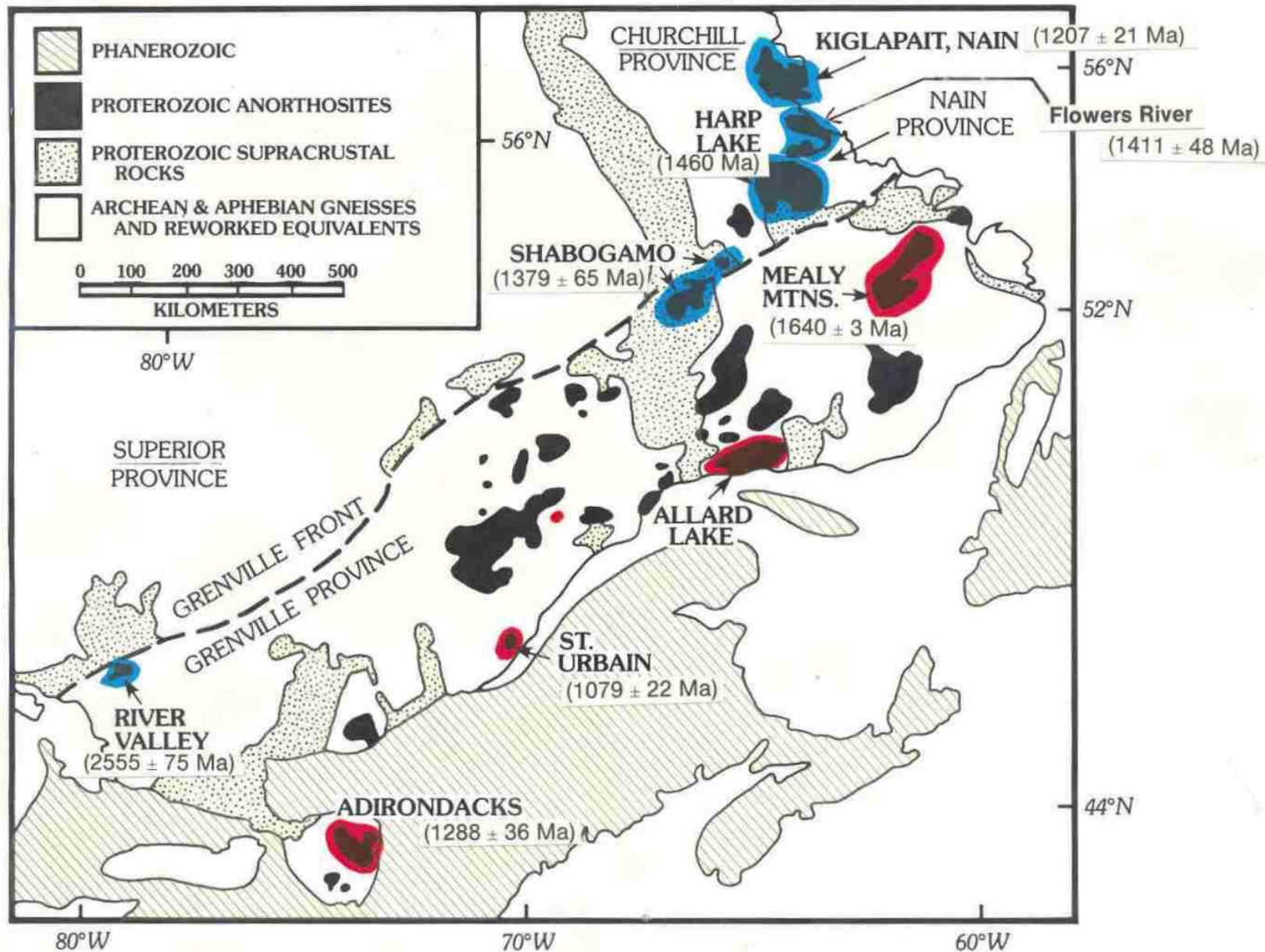
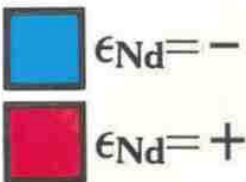


This view of the Pristine Sample Vault shows about one-third of the cabinets housed there.



Thermal ionization mass spectrometry lab
NASA Johnson Space Center, Houston





Isotopic evidence from the eastern Canadian shield for geochemical discontinuity in the Proterozoic mantle

L. D. Ashwal* & J. L. Wooden*

Lunar and Planetary Institute, 3303 NASA Road 1, Houston, Texas 77058, USA

Most workers agree that Proterozoic anorthositic massifs represent the crystallization products of mantle-derived magmas^{1,2}, although the composition of the parental melts is a major unsolved petrological problem³. As mantle-derived rocks, the massifs can be used as geochemical probes of their late Precambrian upper mantle sources. We report here Nd and Sr isotopic compositions of anorthosites and related rocks from the Grenville and Nain Provinces of the eastern Canadian shield. Here 75% of the Earth's known anorthosite is found in a 1,600-km belt from the Adirondack Mountains of northern New York State to the eastern coast of Labrador⁴ (Fig. 1). The results indicate that the massifs were derived from at least two distinct mantle source regions which were established before 1,650 Myr ago, and were episodically involved in magmatism over ~500 Myr. One reservoir, below the Grenville Province, and probably below much of the eastern Superior Province, was isotopically similar to the depleted, modern-day mid-ocean ridge basalt (MORB) source. The other reservoir was chondritic to moderately enriched, and is most easily identified in the Nain Province, but may have occurred scattered throughout the Superior Province.

The anorthosites were emplaced into presumed Archaean quartzofeldspathic gneisses, although in large areas of the Grenville Province, both massifs and basement rocks were reworked during late Proterozoic (about 1,000 Myr) Grenvillian metamorphism⁵. The Adirondack anorthosite may have crystallized as much as 300 Myr before high-pressure granulite facies metamorphism⁶. The other anorthosite massifs that we analysed are unmetamorphosed and include the large (7,000–8,000 km²) composite massifs at Harp Lake⁶ and Mealy Mountains, Labrador⁷, and a smaller complex (300 km²) at St Urbain, Quebec⁸ (Fig. 1). Isotopic data have been published for three mafic intrusions in Labrador: the Kiglapait layered intrusion^{9–11} and the Flowers River gabbro¹², both associated with the Nain anorthosite complex, and the Shabogamo gabbro, which intrudes supracrustal rocks of the Labrador Trough on both sides of, but within 25 km of the Grenville Front^{13,14} (Fig. 1).

Sr and Nd isotopic data for these anorthositic and mafic intrusions are given in Table 1. The massifs can be divided into two types based on location and Nd isotopic signature (Fig. 2). This division is possible despite uncertainties of up to 200 Myr in age and five epsilon units in initial Nd isotopic ratio (ϵ_{Nd} as defined in ref. 15), caused by the effects of metamorphism and crustal contamination⁵. South-east of a line roughly parallel to the Grenville Front (Fig. 1) anorthosites have positive ϵ_{Nd} values, implying sources with long-term depletion in light rare earth elements (LREE). To the north-west, anorthosites and mafic intrusions in Labrador have negative ϵ_{Nd} values that suggest derivation from LREE-enriched sources. With the exception of the Adirondack anorthosite, initial Sr isotopic ratios

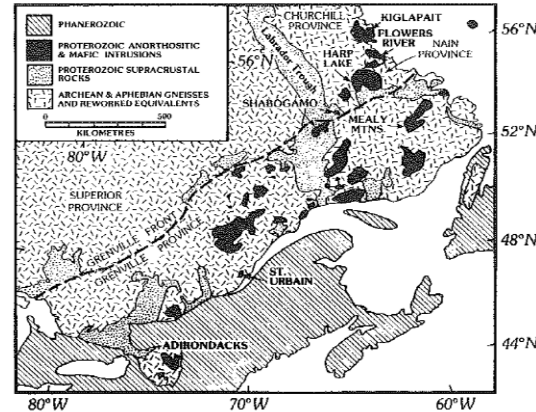


Fig. 1 Geological map of eastern North America showing locations of major Proterozoic anorthositic massifs and mafic intrusions.

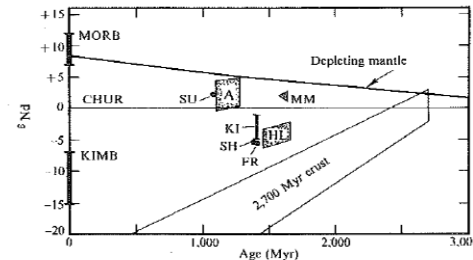


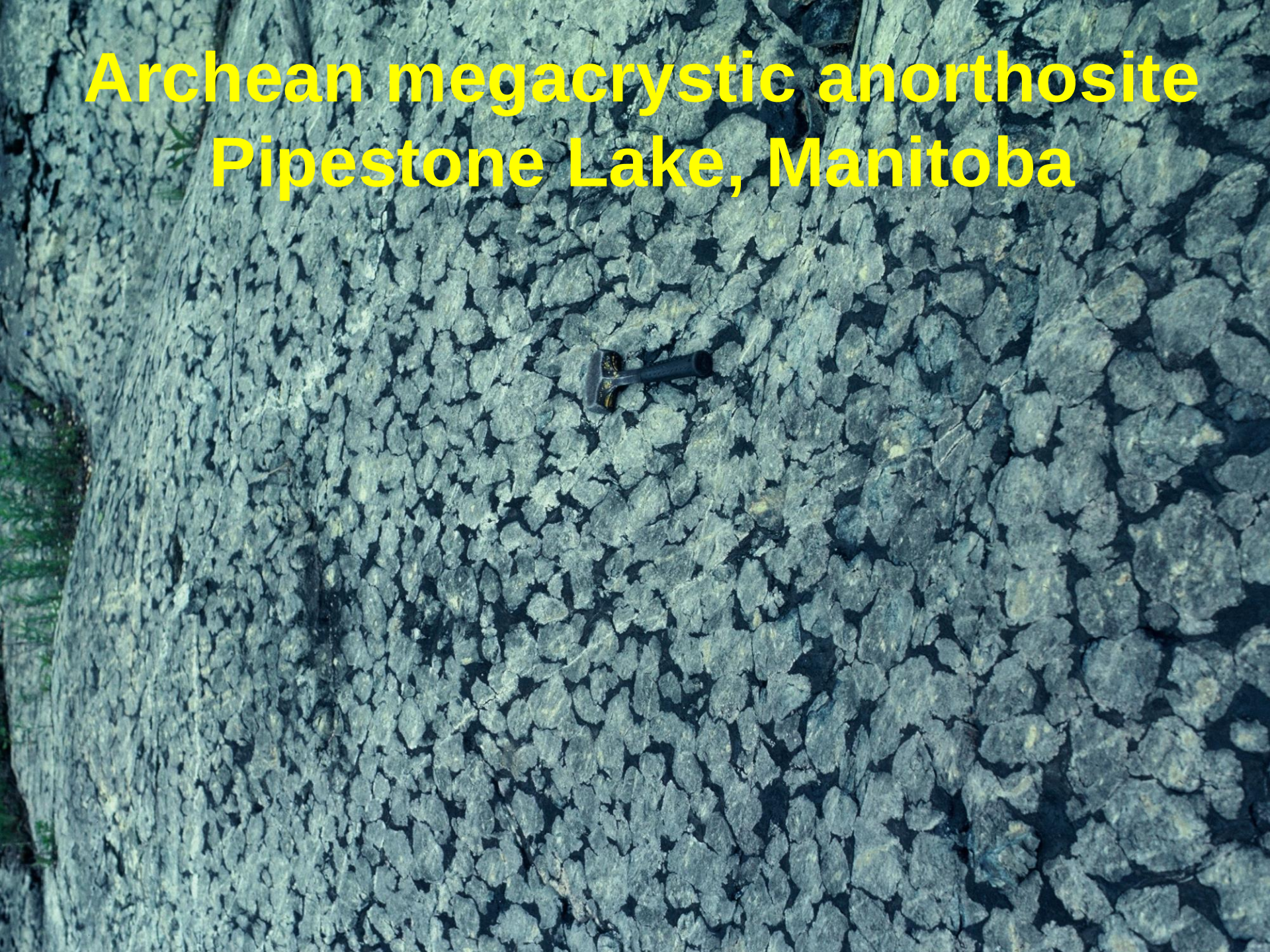
Fig. 2 Plot of age versus ϵ_{Nd} for Proterozoic anorthositic and mafic intrusions from the eastern Canadian shield. Massifs derived from sources with a depleted signature plot above the chondritic evolution line (CHUR), and include St Urbain (SU), Adirondacks (A) and Mealy Mountains (MM). Intrusions plotting below the CHUR line including Kiglapait (KI), Shabogamo (SH), Flowers River (FR) and Harp Lake (HL) may have been derived from enriched reservoirs. Data for some massifs are shown as polygons because of age uncertainties and contamination effects. Curve representing evolution of depleting mantle is from ref. 15; field showing evolution of 2,700-Myr silicic crust is from unpublished data of J.L.W. Ranges of ϵ_{Nd} for modern-day MORB²⁹ and Australian kimberlites (KIMB)¹⁸ are also shown.

It must be considered plausible that the Labrador massifs north-west of the Grenville Front do not reflect the isotopic compositions of their mantle sources, but instead were affected by a 'crustal' contaminant enriched in $^{87}\text{Sr}/^{86}\text{Sr}$ and depleted in $^{143}\text{Nd}/^{144}\text{Nd}$. It has been suggested, for example, that at least 20% assimilation of a granitic component by a mantle-derived mafic melt would be required to lower the ϵ_{Nd} of the Shabogamo gabbro from 0 to -5.3 (ref. 13). Much larger volumes of contaminant would be required if the primary melts were originally derived from a depleted source (Fig. 2). It is not clear the sufficient chemical metamorphism of the primary melts

GENERALIZED GEOLOGIC MAP OF SUPERIOR PROVINCE



Archean megacrystic anorthosite Pipestone Lake, Manitoba

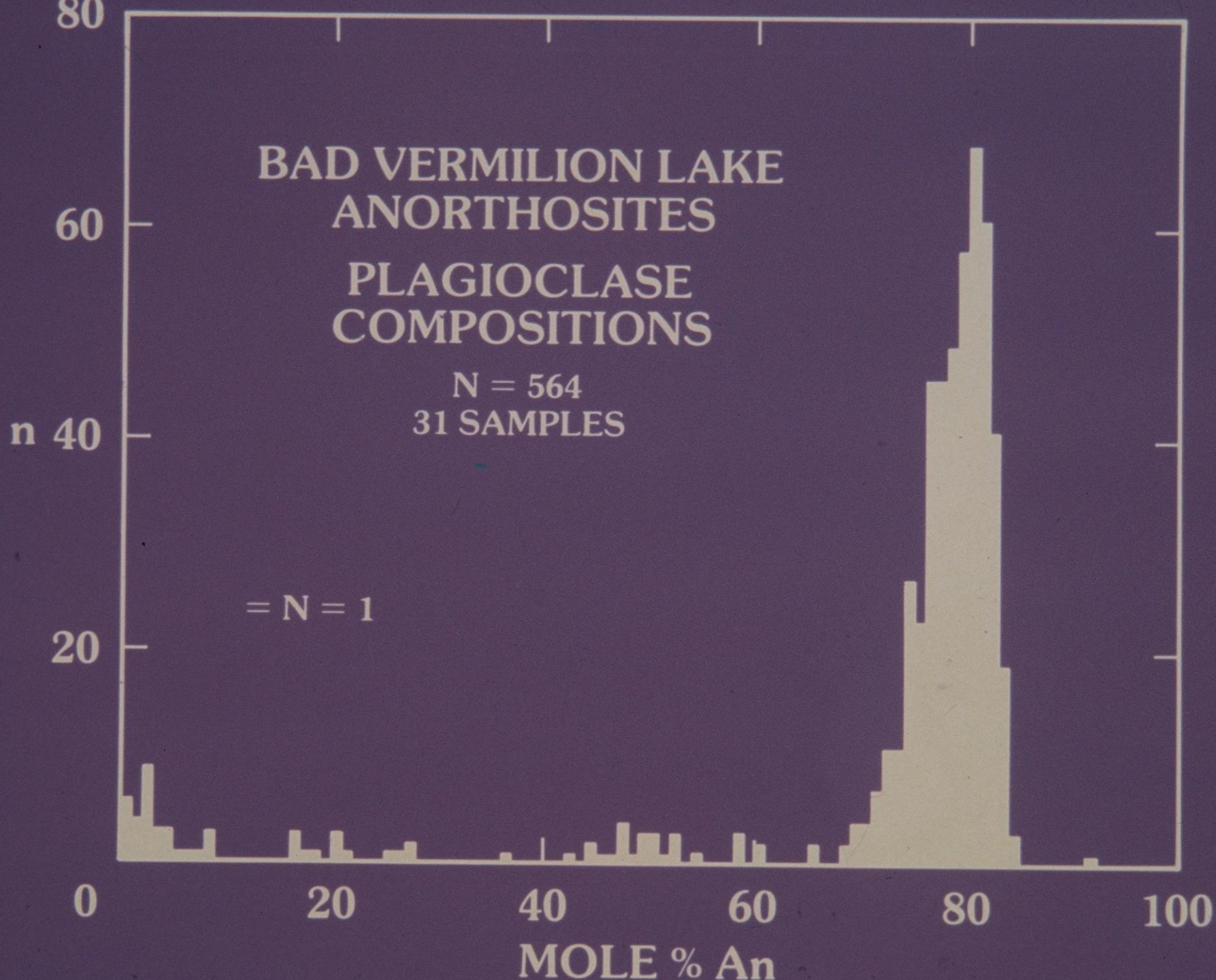




Bird River Sill, Manitoba



Bird River area, Manitoba



1981

Ashwal

Wood

Meteorites from Mars?

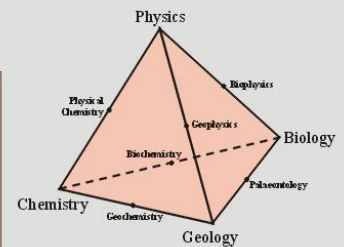
Advice to young scientists:

-Move off the corners of the tetrahedron

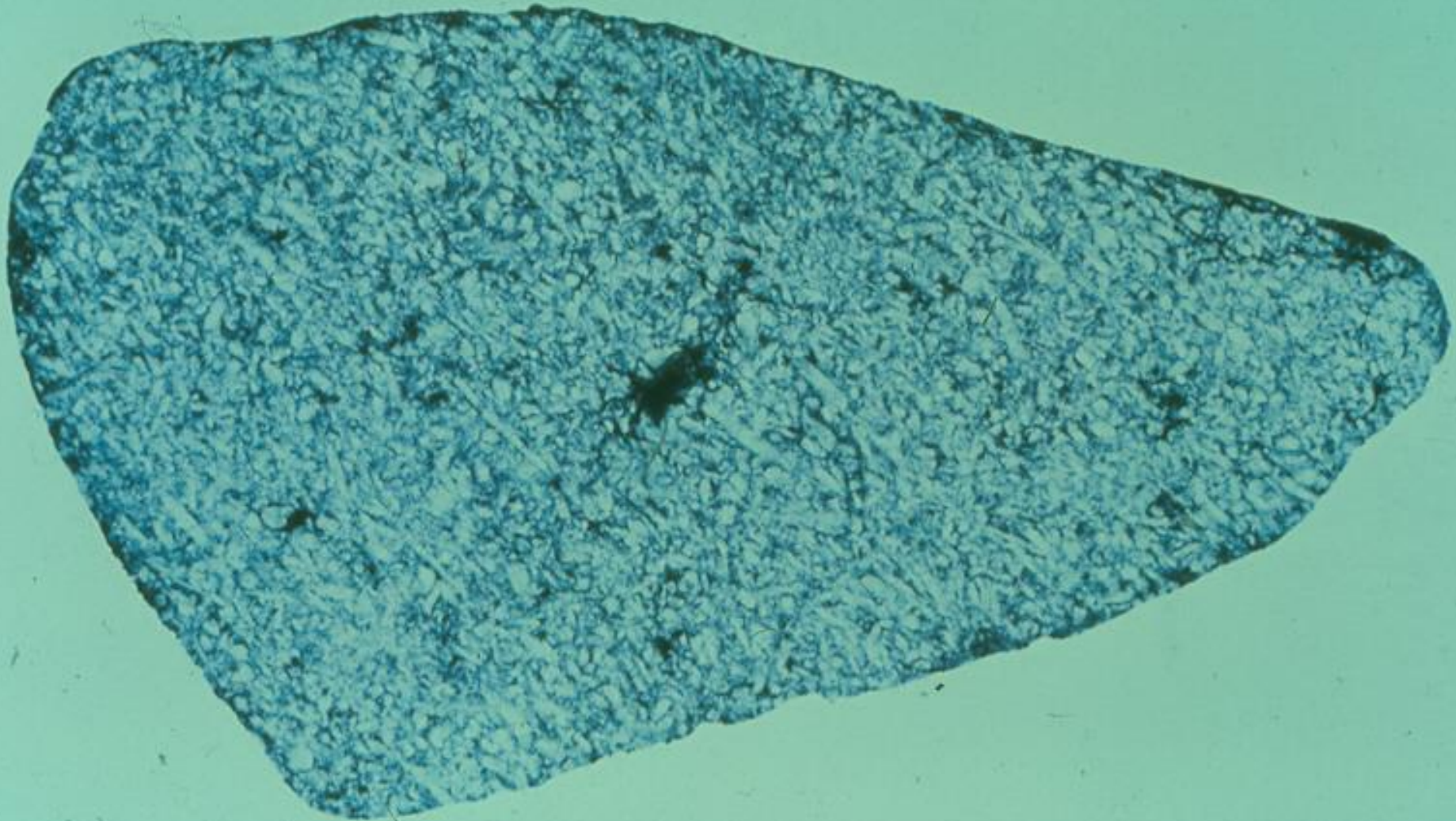
-Make measurements where no one
has made them before

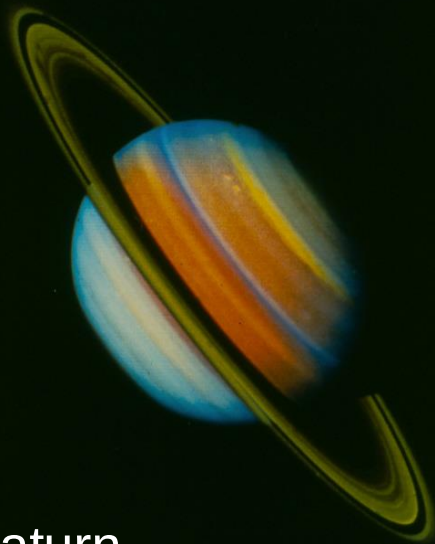
-Don't forget the scientific method

- Observation
- Hypothesis
- Test hypothesis
- Refine hypothesis



Shergotty meteorite, India (Mars)

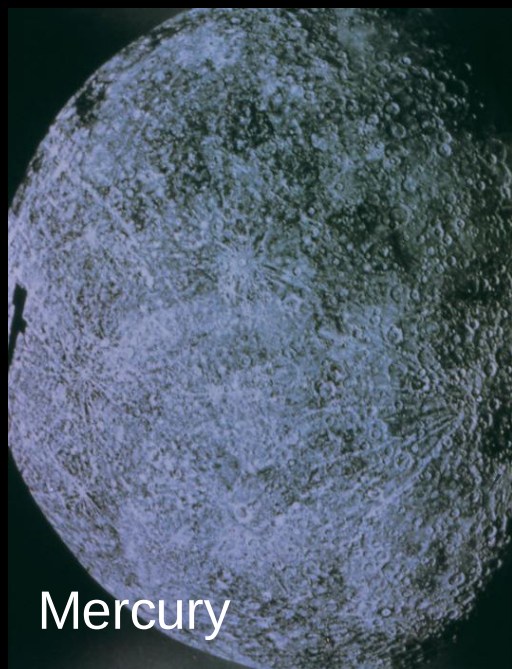




Saturn



Ganymede

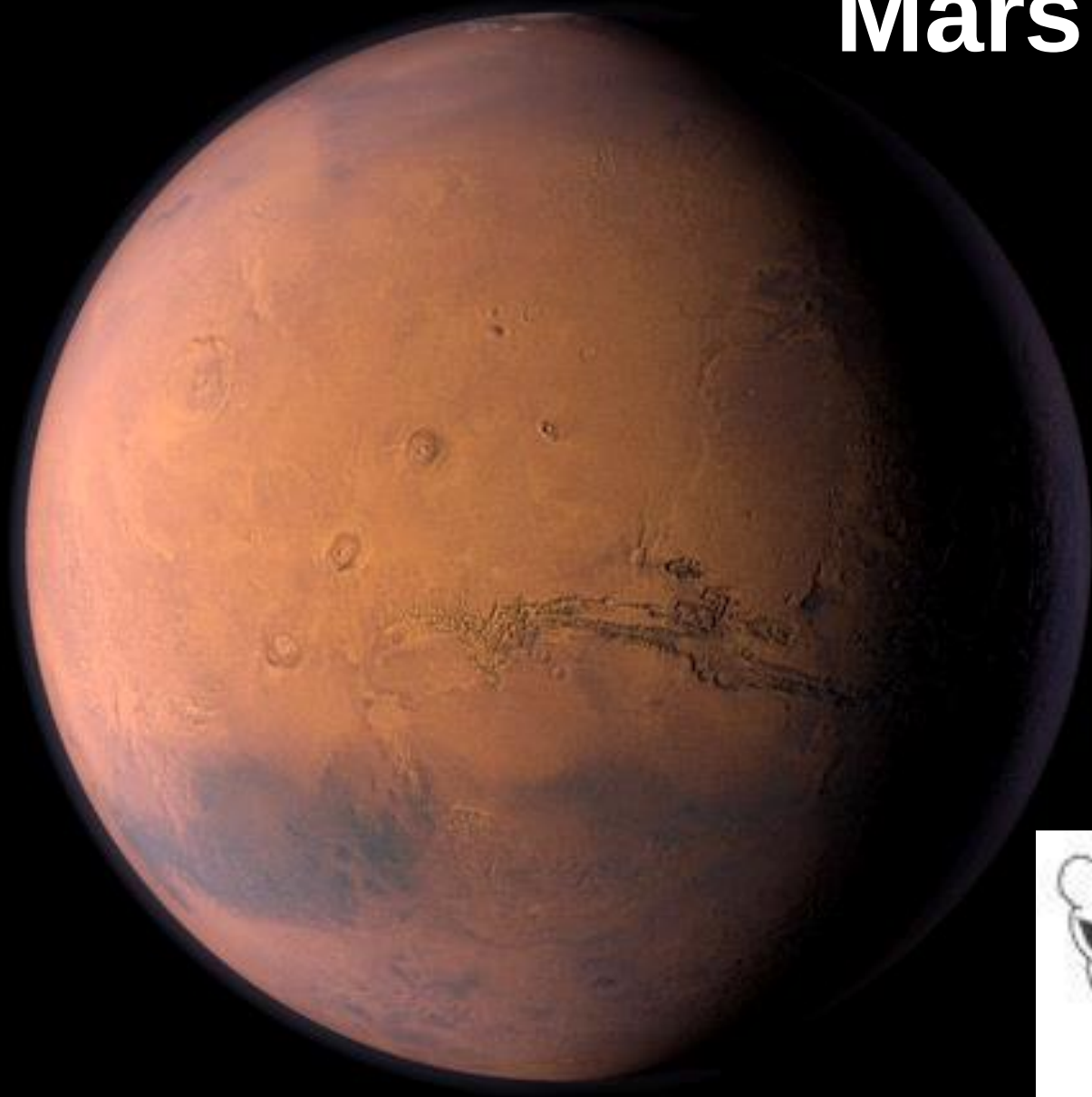


Mercury



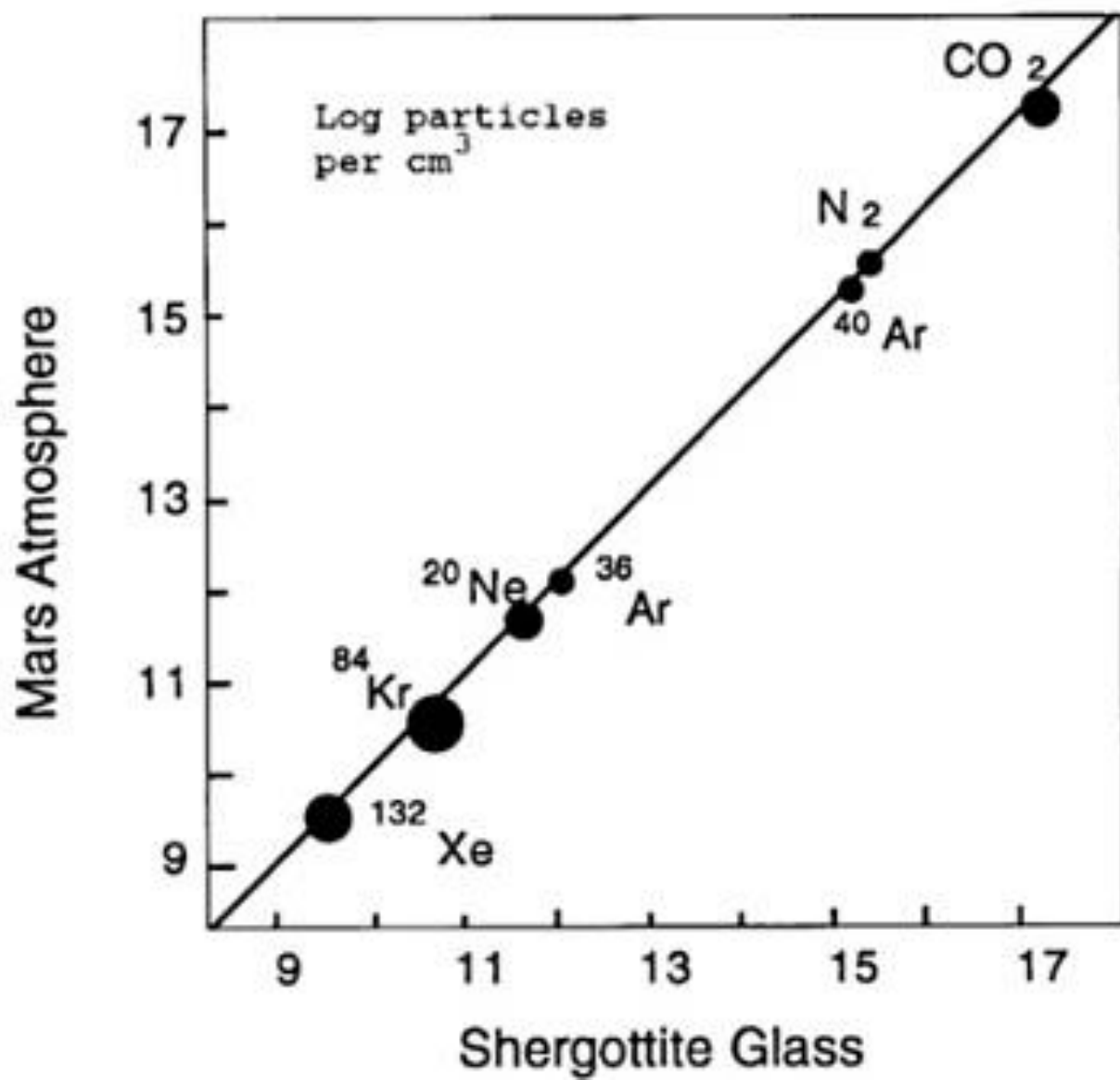
Venus

Mars





Shergottite EETA 79001



ALHA 84001 (Antarctica)- Lunar meteorite





ASTROGEOLOGY

A blast on the Red Planet may have launched some rocks on a 180 million-year trip to Earth

METEORITES FROM MARS?

by MARCIA BARTUSIAK

Some 180 million years ago, an immense meteor, or a comet streaked through the thin air of Mars and plunged with the force of many hydrogen bombs into the surface of the Red Planet. Driven by the stupendous energy released by that blast, billion-year-old chunks of volcanic rock several yards in diameter were hurled into space. There, they wandered for millions of years, at times colliding with other solar system debris. Eventually, by chance, some crashed into Earth,

where they are now baffling scientists and prompting disputes.

This scenario broadly outlines a theory that some scientists are coming to regard as a likely explanation for some of the strangest of all meteorites—the shergottites, nakhlites, and chassignites. What makes these meteorites so unusual is their apparent age; they seem to be much younger than any meteorite should be. Most meteorites are thought to be chunks of rock and scraps of iron and nickel left over from the

birth of the solar system more than 4.6 billion years ago.

While thousands of these other meteorites have been collected throughout the world, the young meteorites have been discovered in only nine places. One fell in 1960 near Allergotty in northeastern India, and was named for the town. Nearly a century later, a similar meteorite was found near Zagami, Nigeria; others have turned up in France, Australia, Brazil, Antarctica, and the state of Indiana. What they seem to share is a

ILLUSTRATION BY GEORGE A. HALL III



Roger Phillips
LPI Director 1979-1982



Kevin Burke
LPI Director 1982-1988



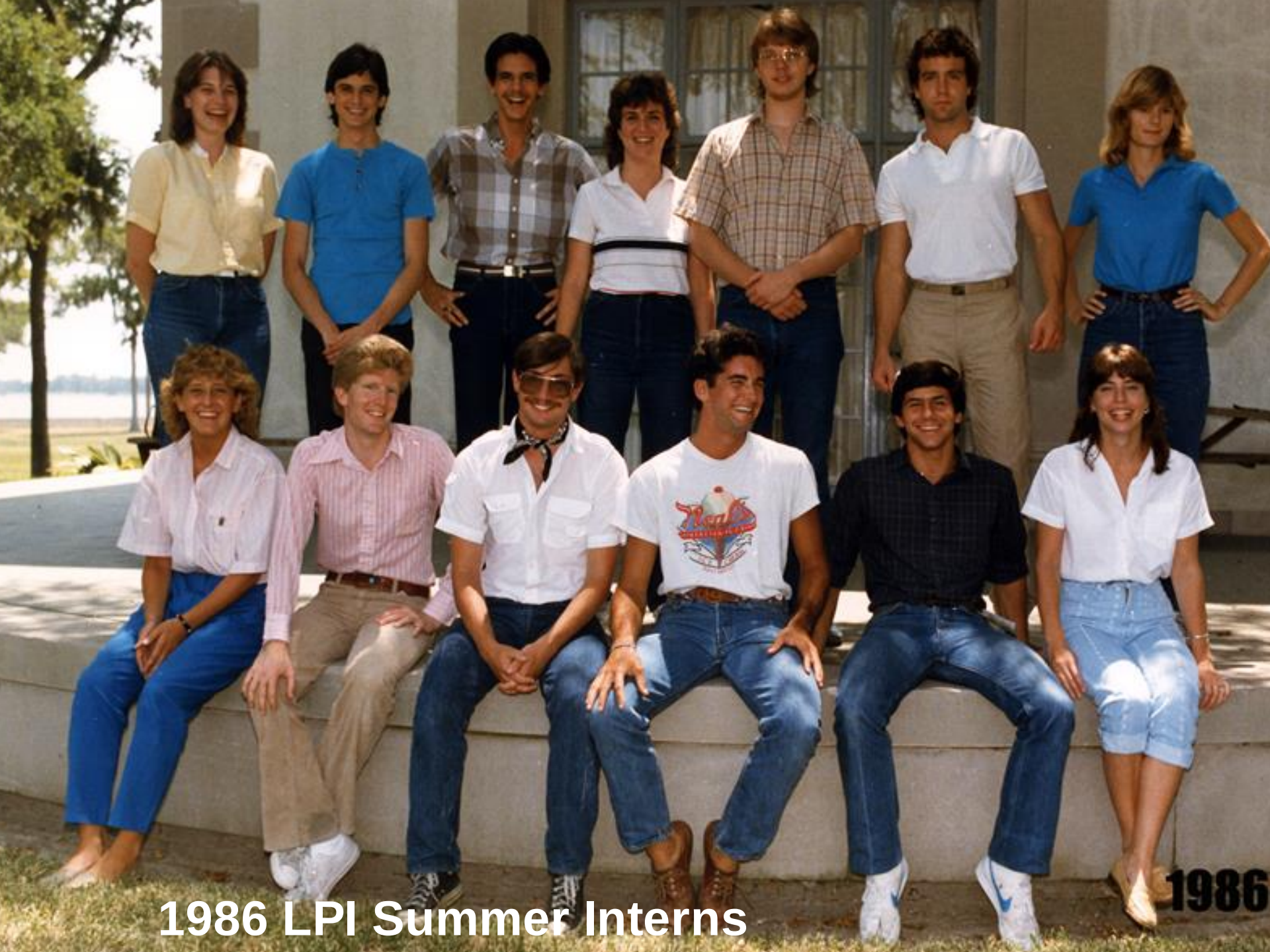
Lunar and Planetary Institute, Houston

Workshops: Early Crustal Genesis

- 1981- Early Crustal Genesis: Implications from Earth (Houston)
- 1985- The Earth as a Planet (Houston)
- 1985- Early Earth: Accretion to Older Archean (Houston)
- 1986- Tectonic Evolution of Greenstone Belts (Houston)
- 1988- Growth of Continental Crust (Oxford University)
- 1989- Archean Mantle (Houston)

Field Workshops

- 1982- Magmatic Processes of Early Planetary Crusts
(Beartooth Mountains, Montana)
- 1983- A Cross Section of Archean Crust
(Kapuskasing, Ontario)
- 1986- World's Oldest Rocks
(West Greenland)
- 1988- Deep Continental Crust of South India
(Hyderabad & Southern India)



1986 LPI Summer Interns

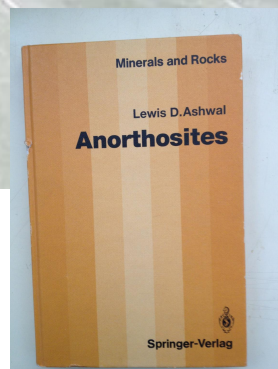
1986



Mike Colucci

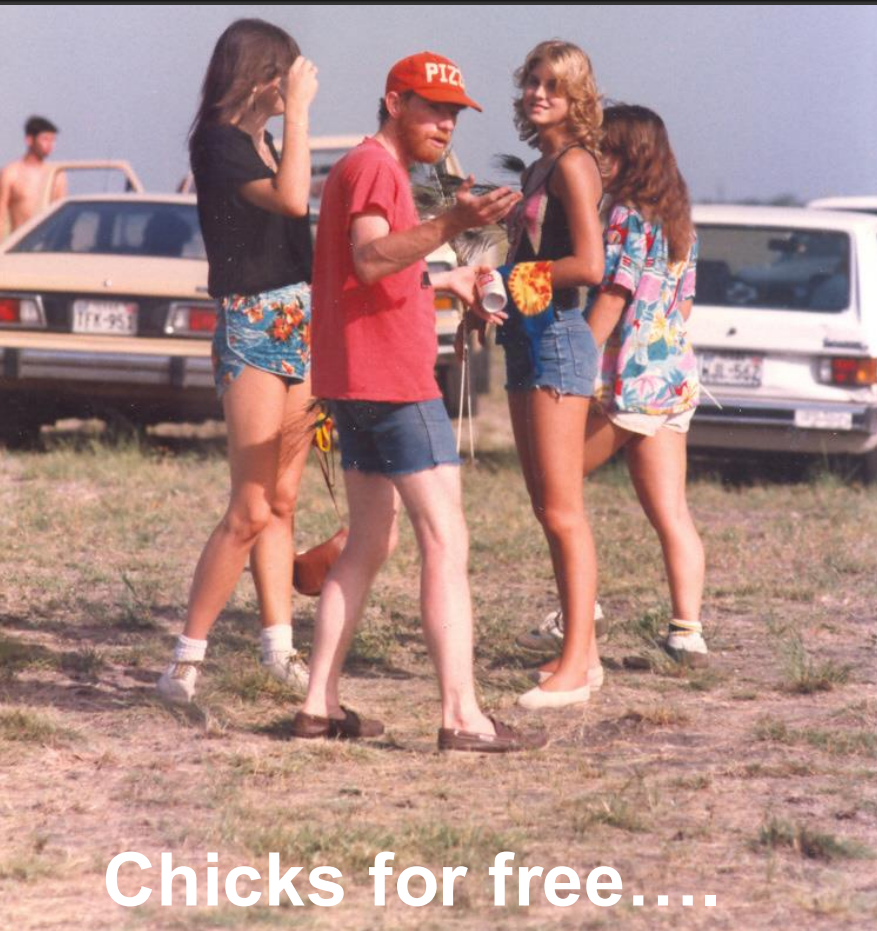


I-45 Dallas → Houston





Grateful Dead, Manor Downs, Texas, 1982



Chicks for free....



The Bags, 1988



African lithospheric structure, volcanism, and topography

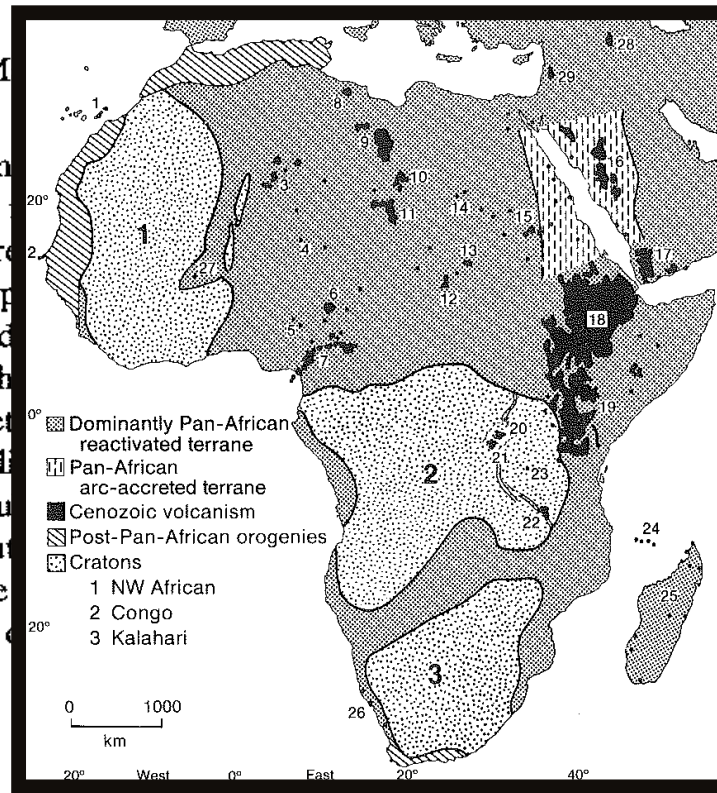
Lewis D. Ashwal and Kevin Burke

Lunar and Planetary Institute, 3303 NASA Road One, Houston, TX 77058 (U.S.A.)

Received M

1989

In Africa volumetrically minor, m
Pan-African (500 ± 150 Ma) crustal
indicating that Pan-African areas are
mantle, and propose a model to exp
lithosphere: (1) Cratons were formed
depleted, sub-oceanic-type mantle lith
beneath areas thickened during Tibet
fertile material which now forms the l
plate came to rest with respect to su
extracted magmas from the fertile bu
underlying convective pattern for the
volcanism but cratonic areas display c



concentrated in areas affected by
mic areas. We interpret this as
cratons by depleted lithospheric
e two kinds of African mantle
or this reason are underlain by
here has been delaminated from
African times) and replaced by
ted crust. (3) When the African
ut 30 Ma, heating from below
s a result of interaction with an
y both Neogene elevations and



Maarten de Wit (2003)



Chris Roering (1995)

Minerals and Rocks

Lewis D. Ashwal

Anorthosites

1993

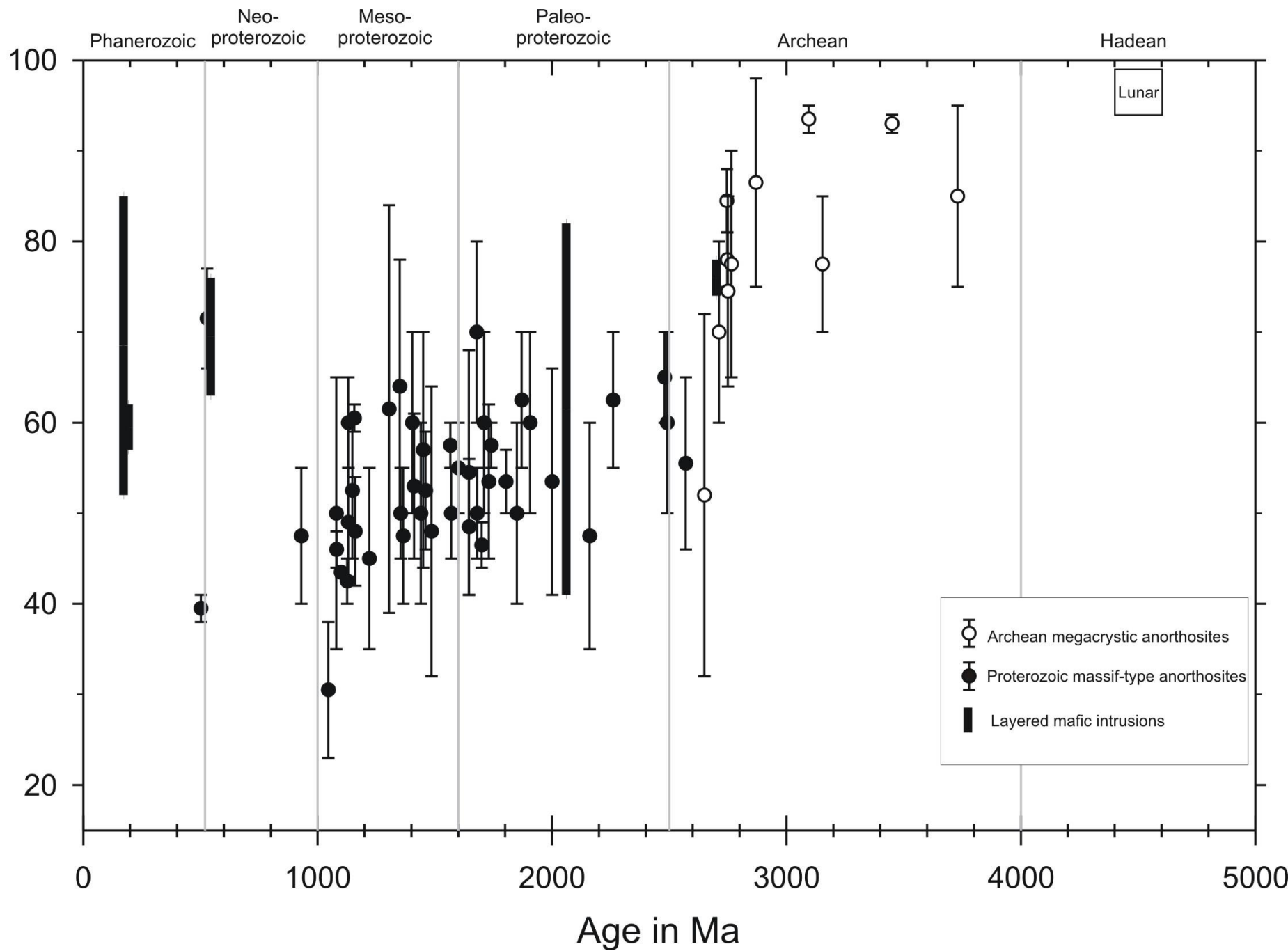


Springer-Verlag

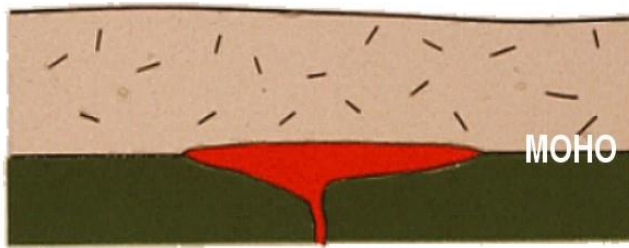
6 Types of Anorthosite

1. Archean megacrystic
2. Proterozoic massif
3. Stratiform (layered intrusion)
4. Oceanic
mid-ocean ridge
ophiolite
5. Inclusions
cognate
xenolithic
6. Extraterrestrial

An content of plagioclase



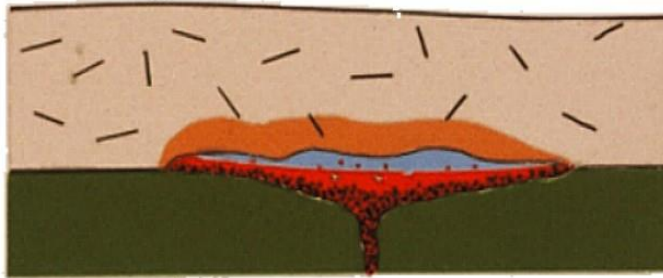
- 1.** Basaltic or
picritic
underplating



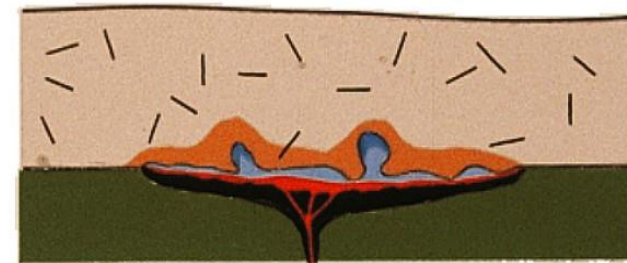
- 2.** Mafics crystallize
and sink; crustal
anatexis



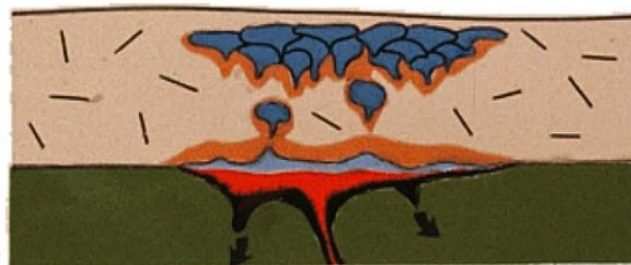
- 3.** Plagioclase
floats;
instabilities
develop



- 4.** Anorthosite
mushes ascend
as plutons



- 5.** Plutons coalesce
in upper crust to
form massifs;
ultramafics sink



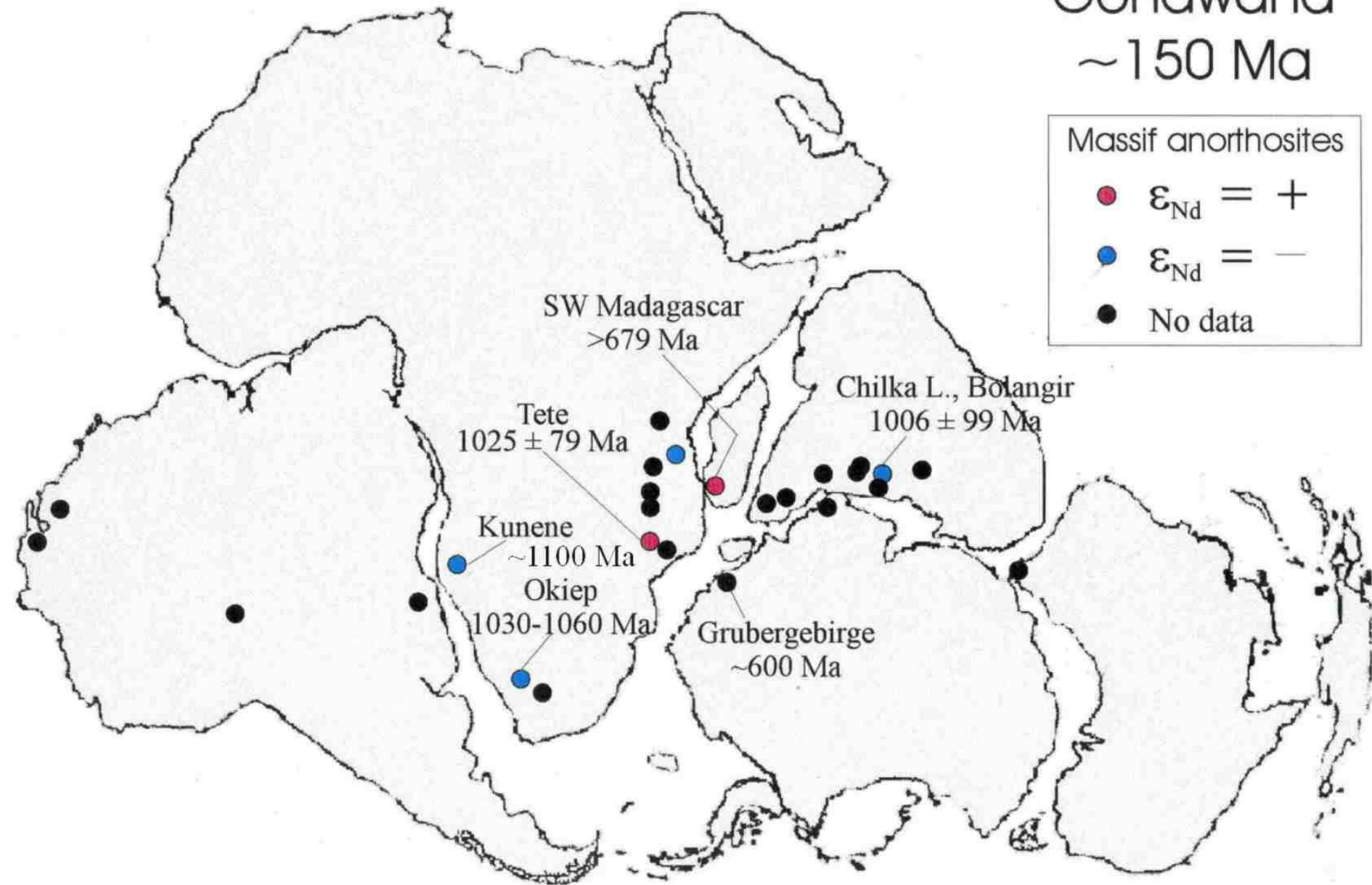
Gondwana ~150 Ma

Massif anorthosites

● $\epsilon_{\text{Nd}} = +$

● $\epsilon_{\text{Nd}} = -$

● No data



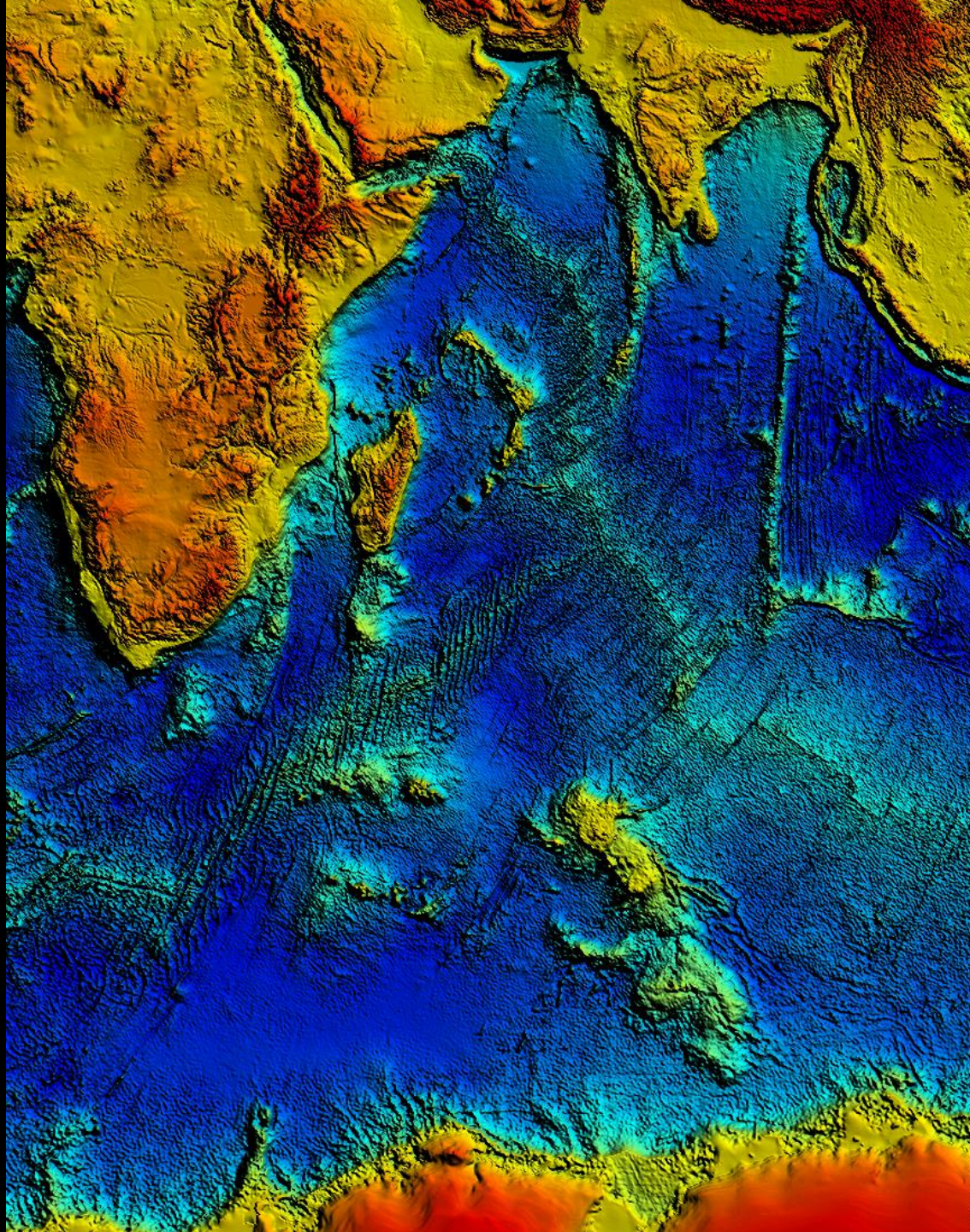
OXFORD MONOGRAPHS ON GEOLOGY AND GEOPHYSICS • 35

Greenstone Belts

Edited by
MAARTEN DE WIT
and
LEWIS D. ASHWAL

1997

OXFORD SCIENCE PUBLICATIONS





Ampanihy Shear Zone,
SW Madagascar

60 km





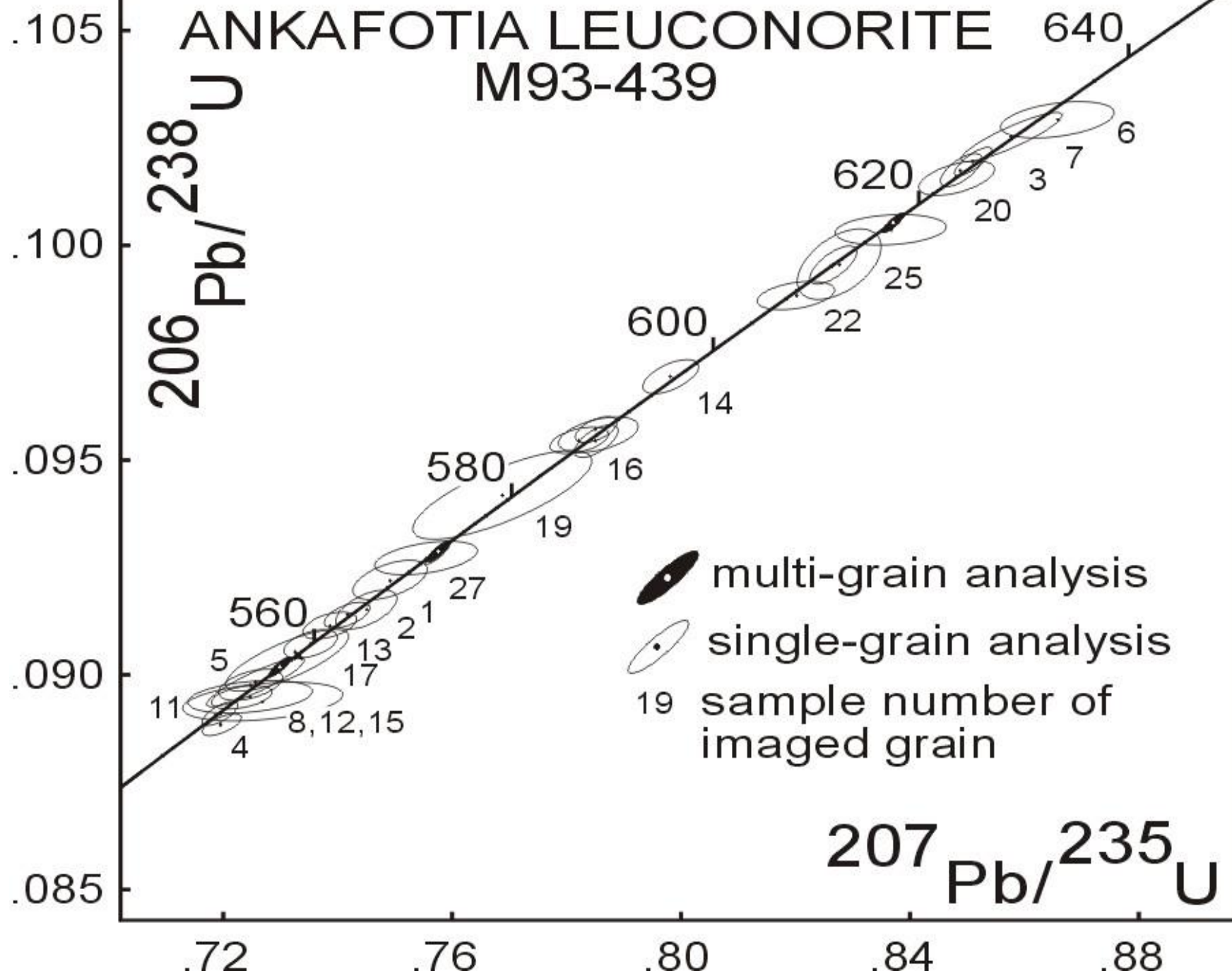
Richard Viljoen



Ankafotia anorthosite, SW Madagascar, 1992

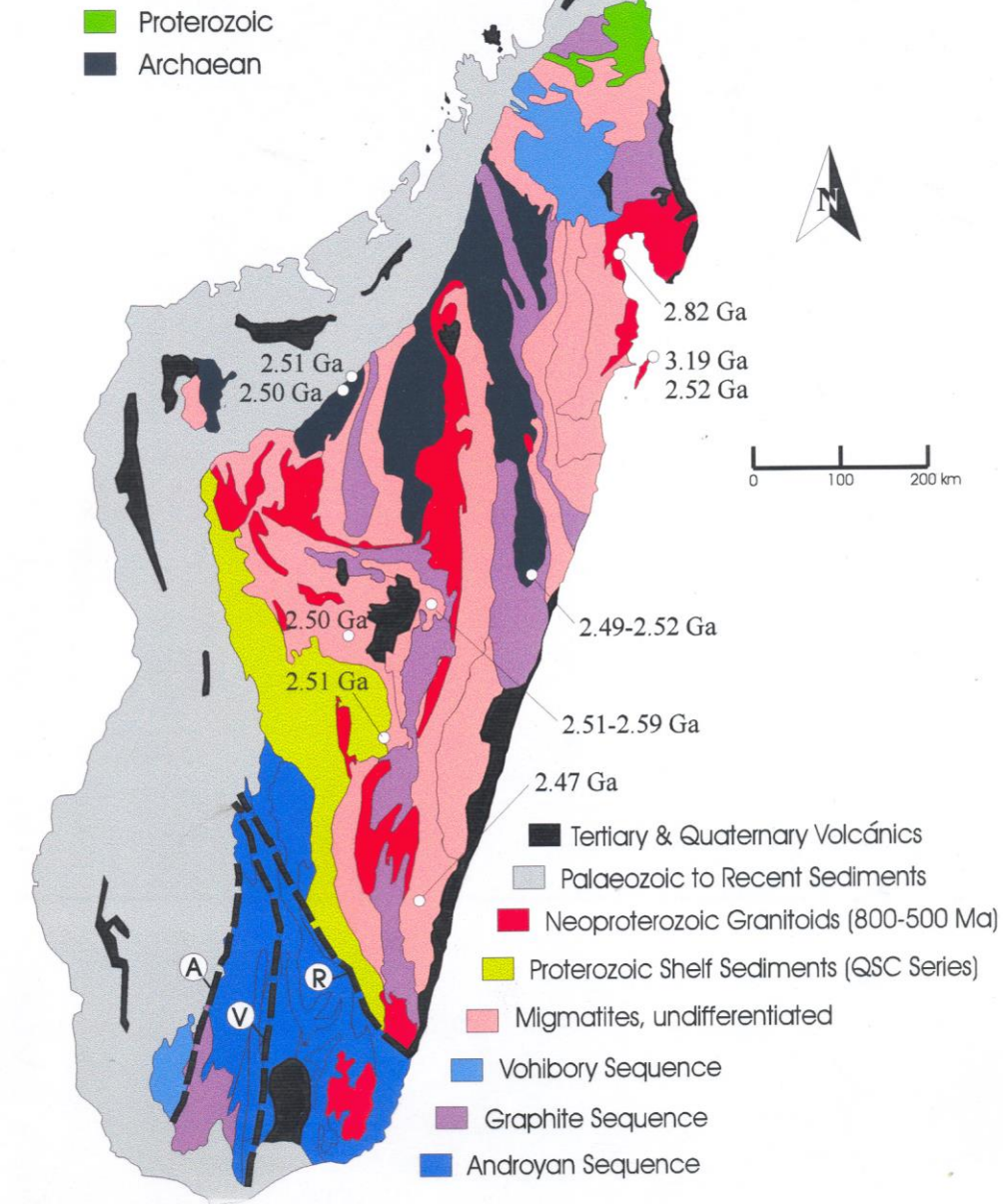
ANKAFOTIA LEUCONORITE
M93-439

$^{206}\text{Pb}/^{238}\text{U}$



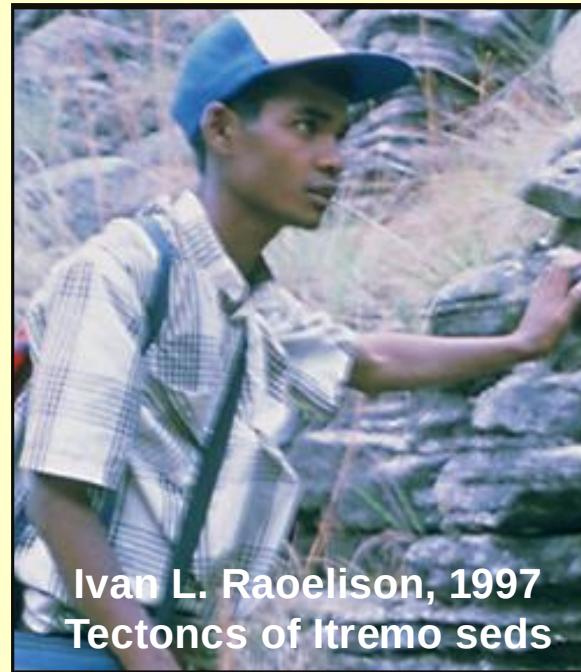
Madagascar, Generalized Geology

Mafic Gneiss and Schist Belts

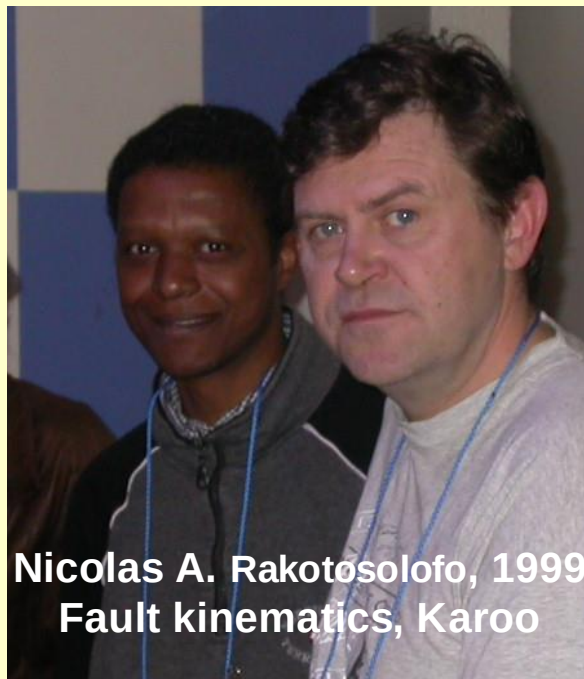




Leon G. Randrianasolo,
1995: Ampanihy shear zone



Ivan L. Raelison, 1997
Tectonics of Itremo sediments

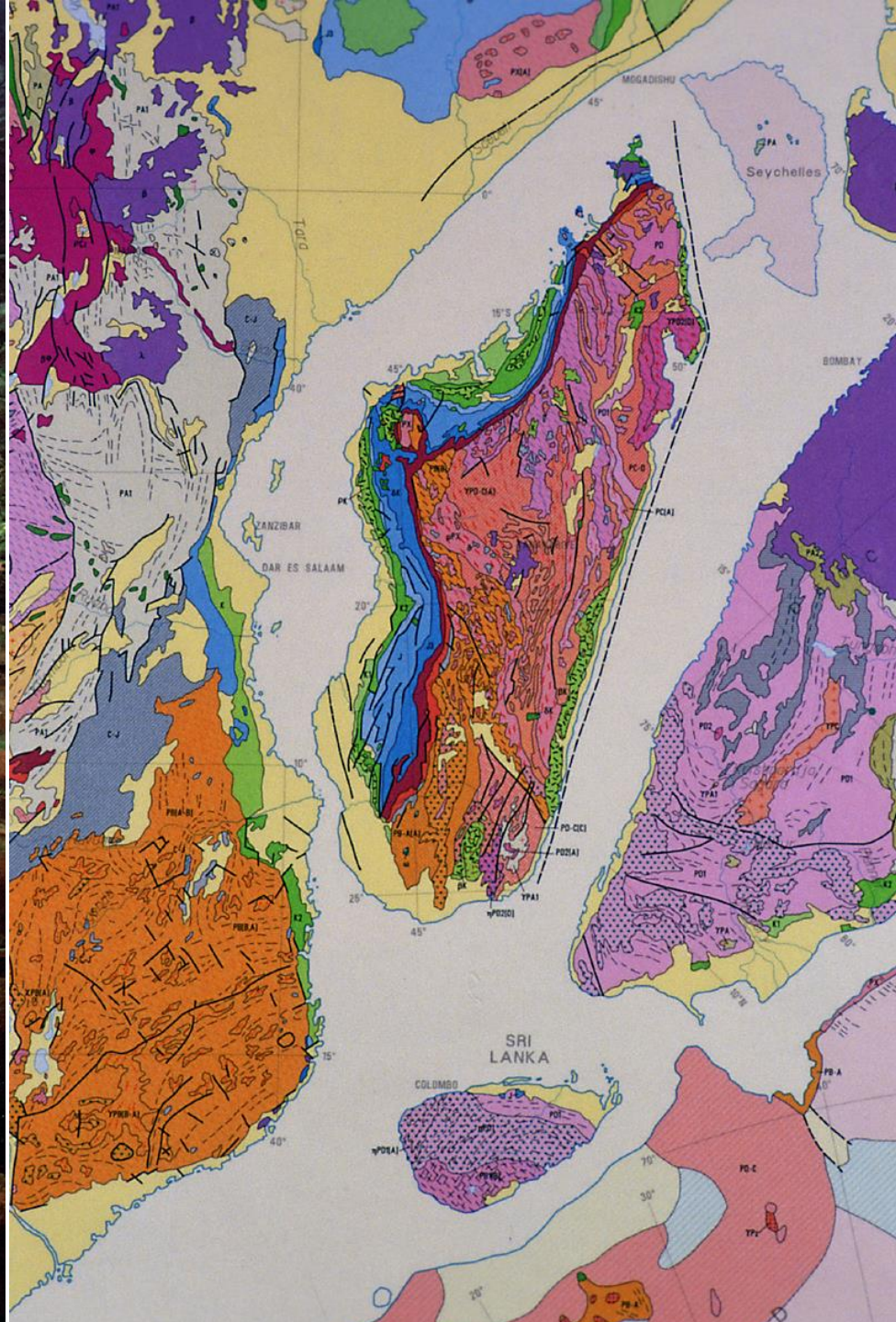


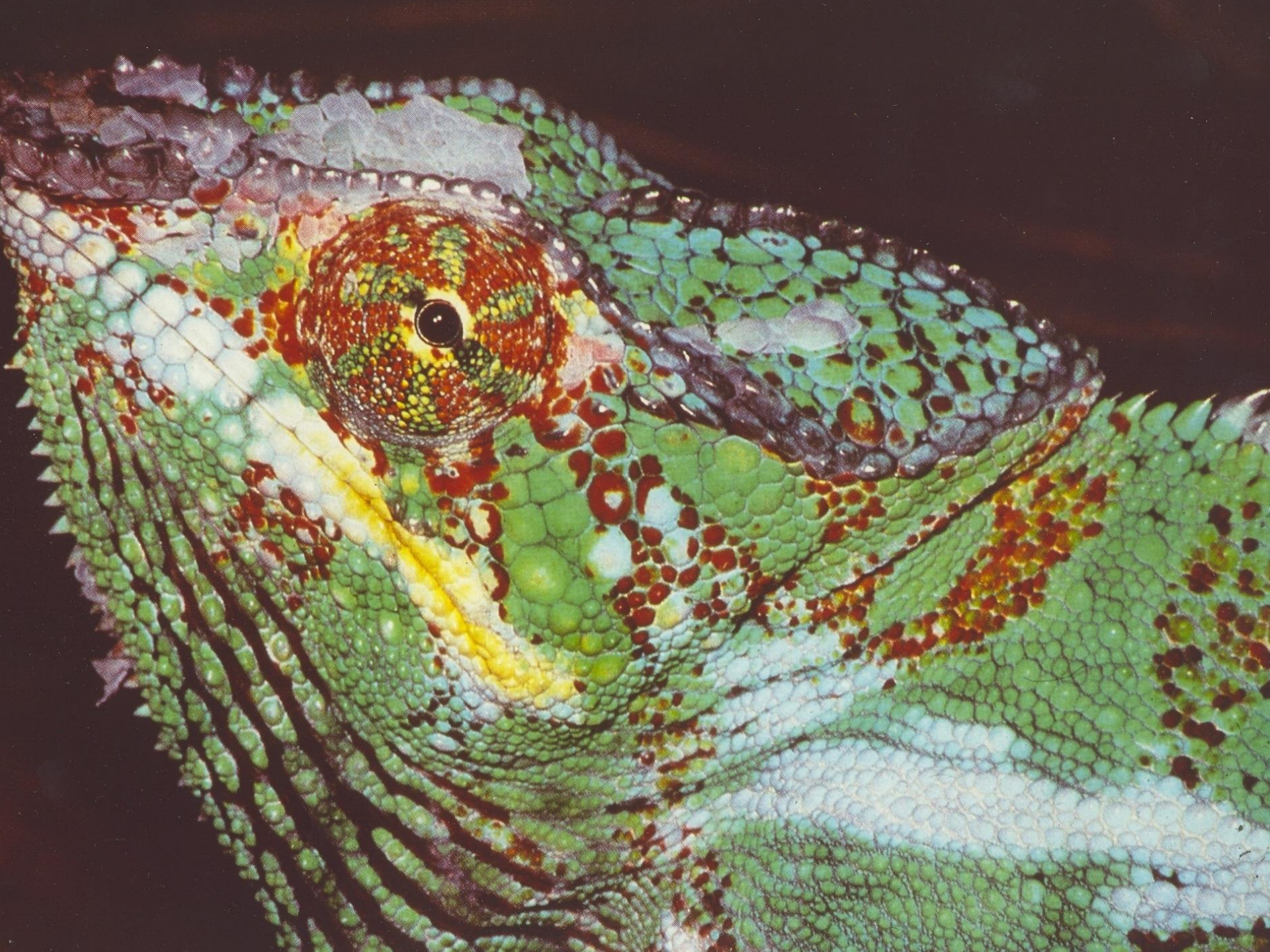
Nicolas A. Rakotosolofo, 1999
Fault kinematics, Karoo



Rindrahasy H. Rakotoarimanana,
2001: Granite-hosted Gold













Mike Knoper

The Bushveld Complex
(see enlarged, below)



Republic of
South Africa

WATERBERG
TWEESPALK

WAR SPRINGS

Eastern Limb

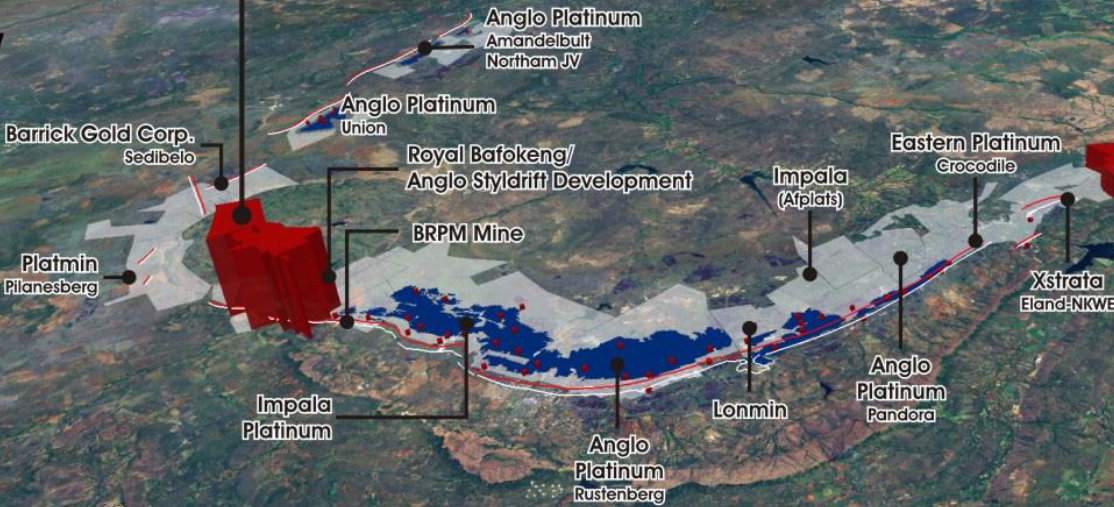
WBJV - PTM/PLG
Feasibility Study Complete

PTM/PLG-SABLE
JOINT VENTURE

Pretoria

Johannesburg

Western Limb

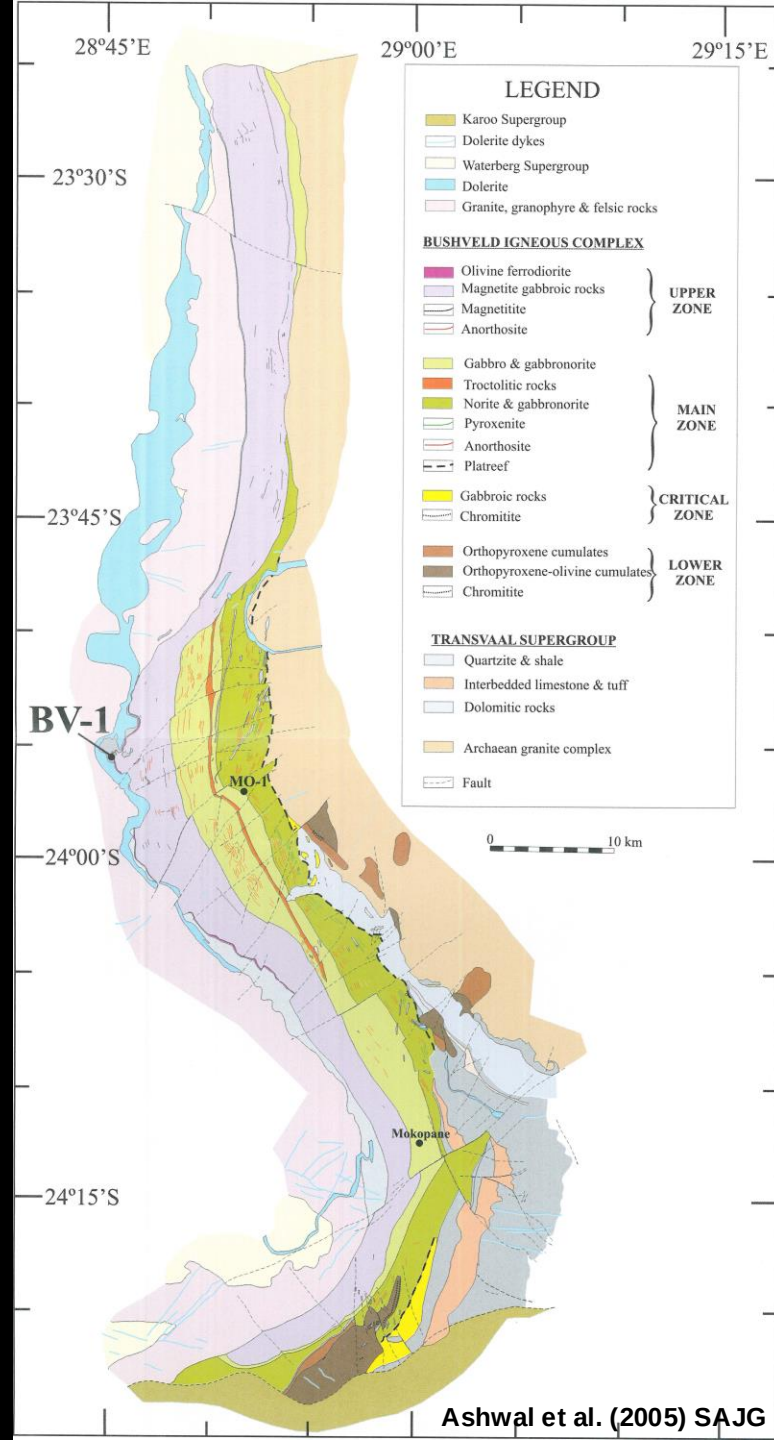
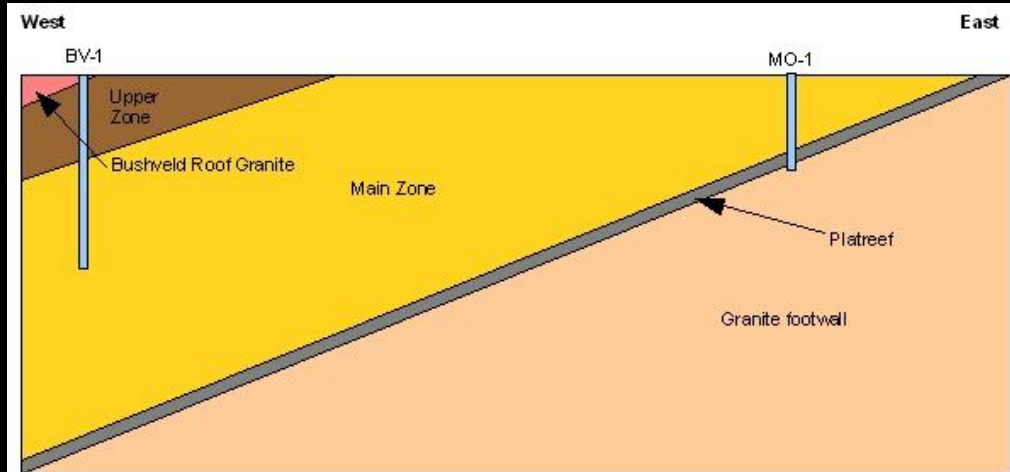
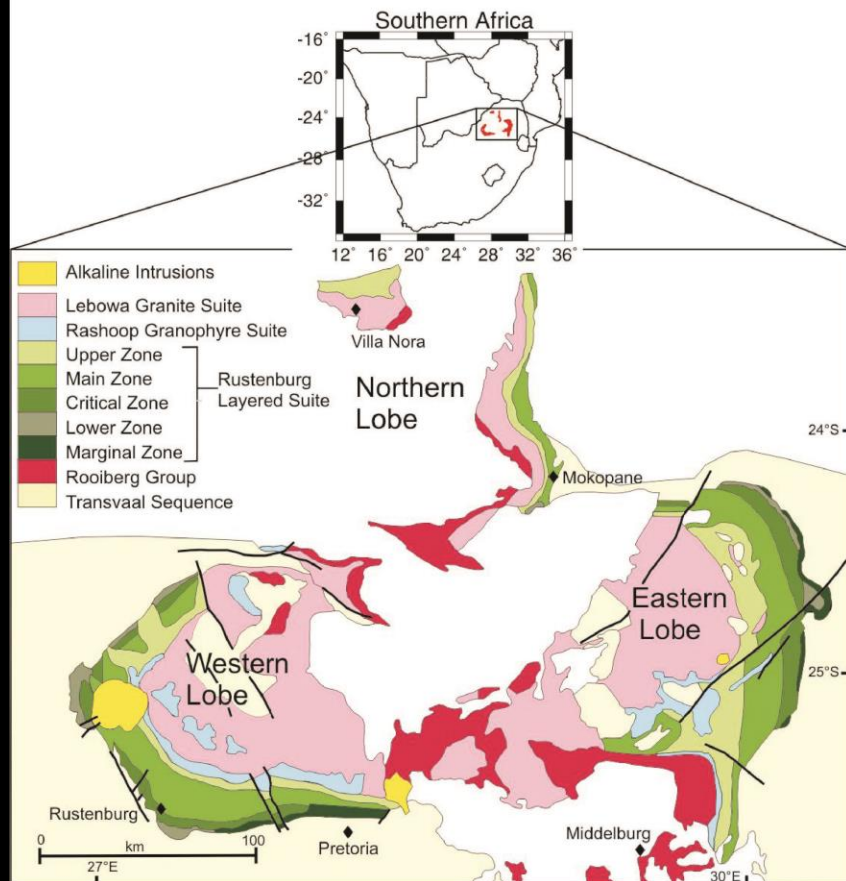


- Mine Shafts
- Mined Out Areas
- Merensky Reef
- UG2 Reef



**PLATINUM
GROUP
METALS**

PLG: NYSE AMEX
PLG: TSX





**Bellevue borehole
(top half)**



**Bellevue borehole
(bottom half)**



**Moordkopjie
borehole (partial)**

681 samples

Magnetic susceptibility:
n = 109,506

Density: n = 2,409

Microprobe:

- plag: 5,748
- opx: 4,469
- cpx: 4,585
- oliv: 949
- biot: 854
- amph: 524
- mag: 1,166
- ilm: 278

TOTAL: 18,573



4.5 km

Sampling intervals

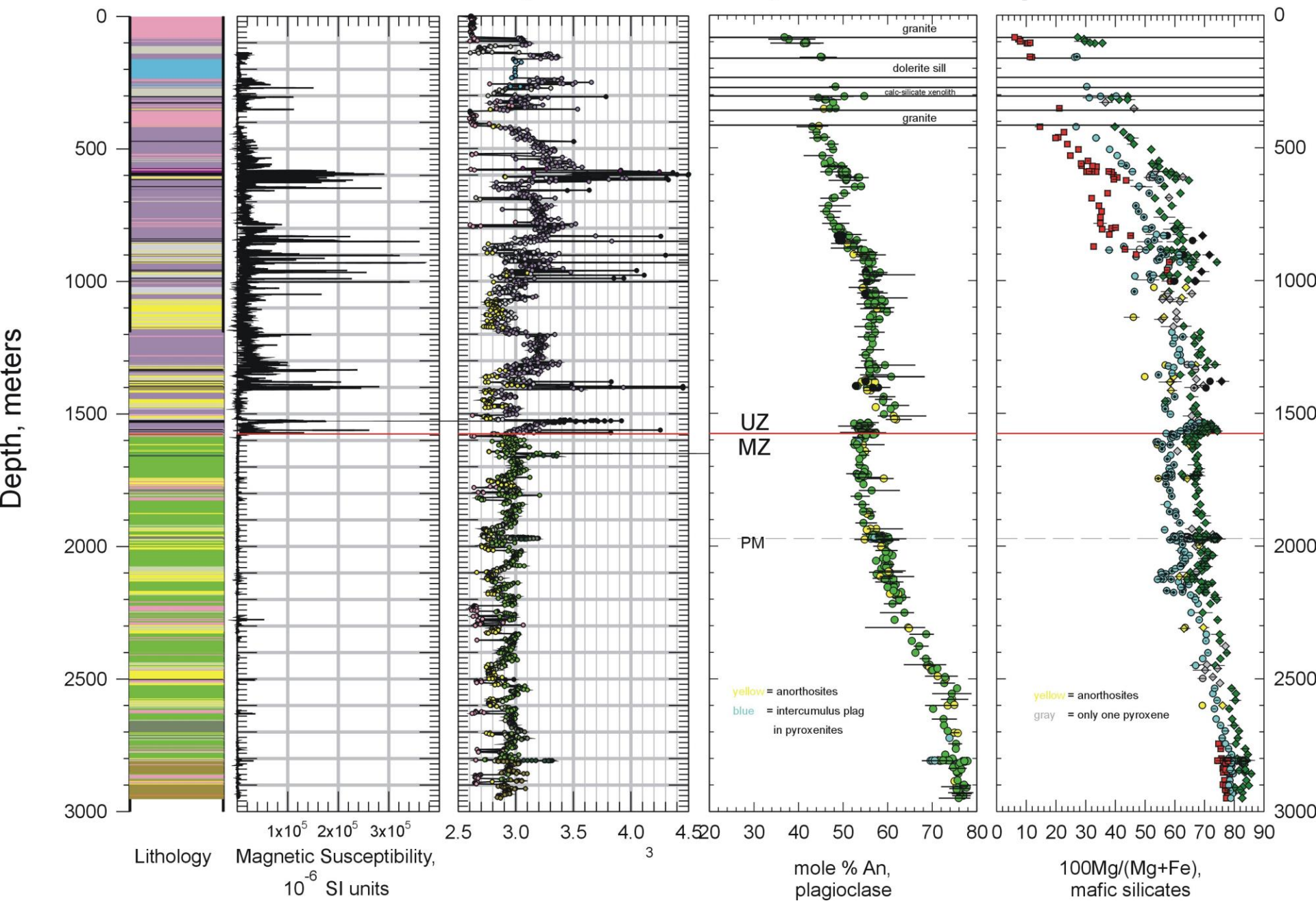
Mag: 1-2 cm

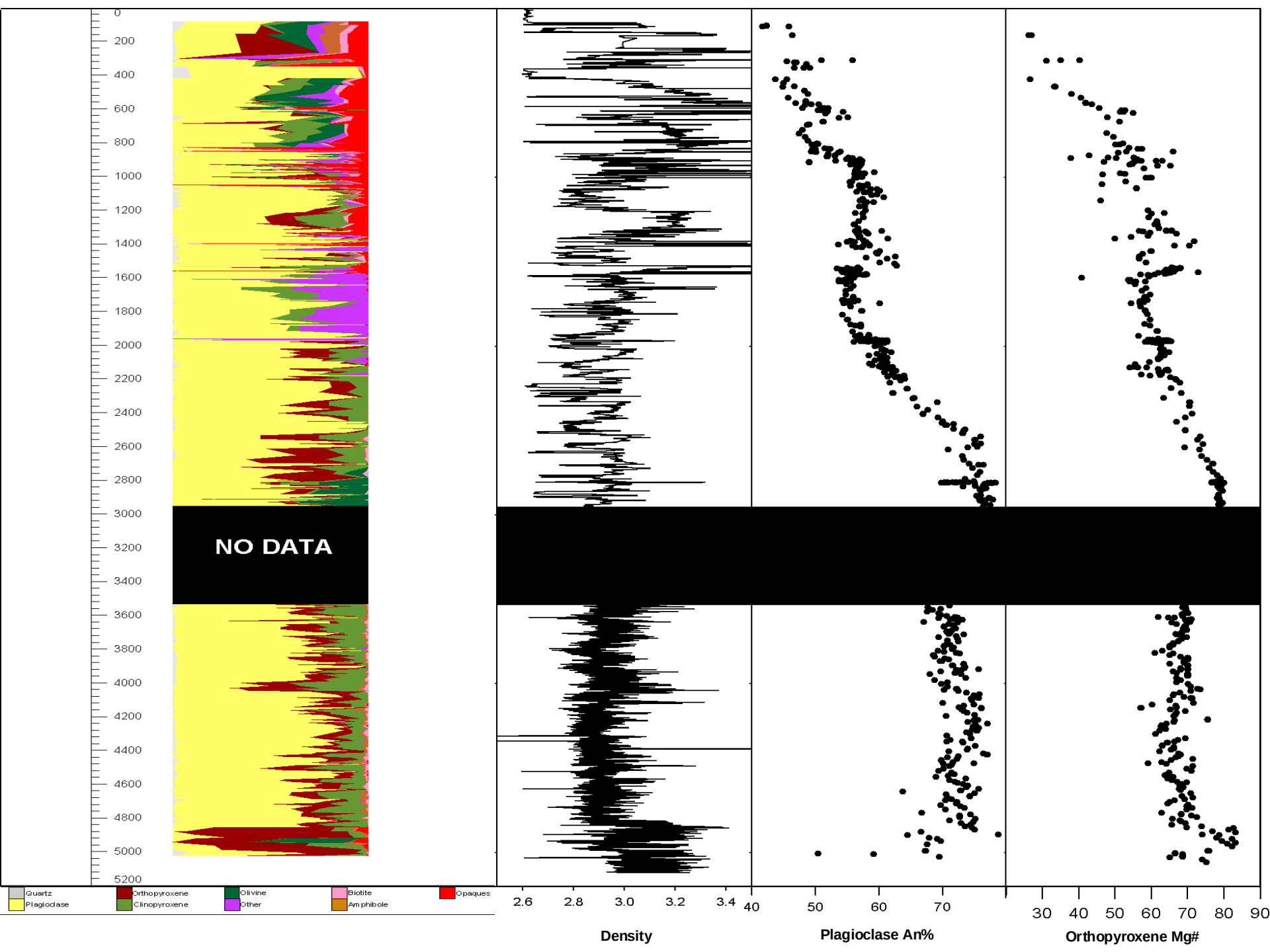
Density: ~1.5 - 2 m

Rock & min chem:
~6 - 7 m

**Near-continuous dataset
for entire Bushveld
stratigraphy, Northern Lobe**

Bellevue borehole, Northern Limb, Bushveld Complex

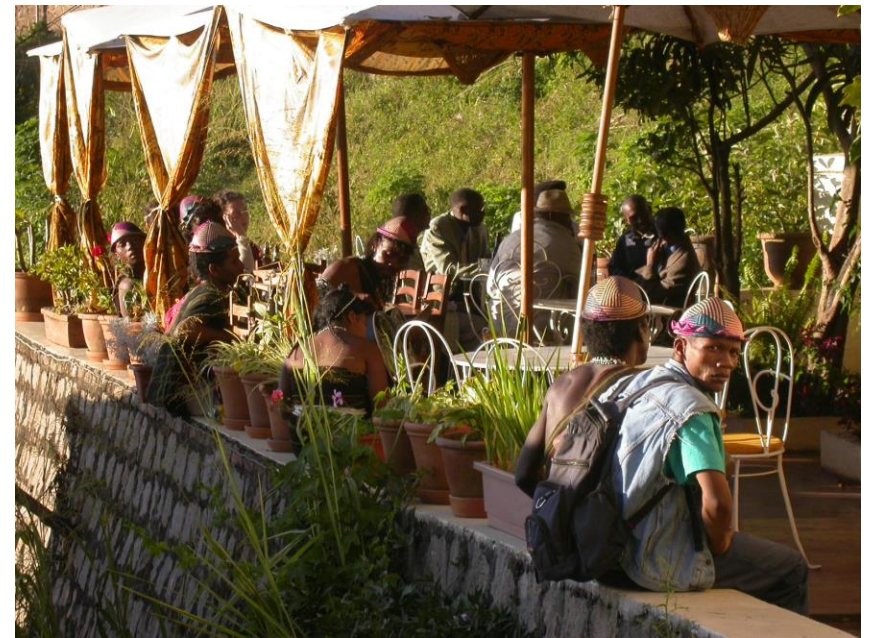
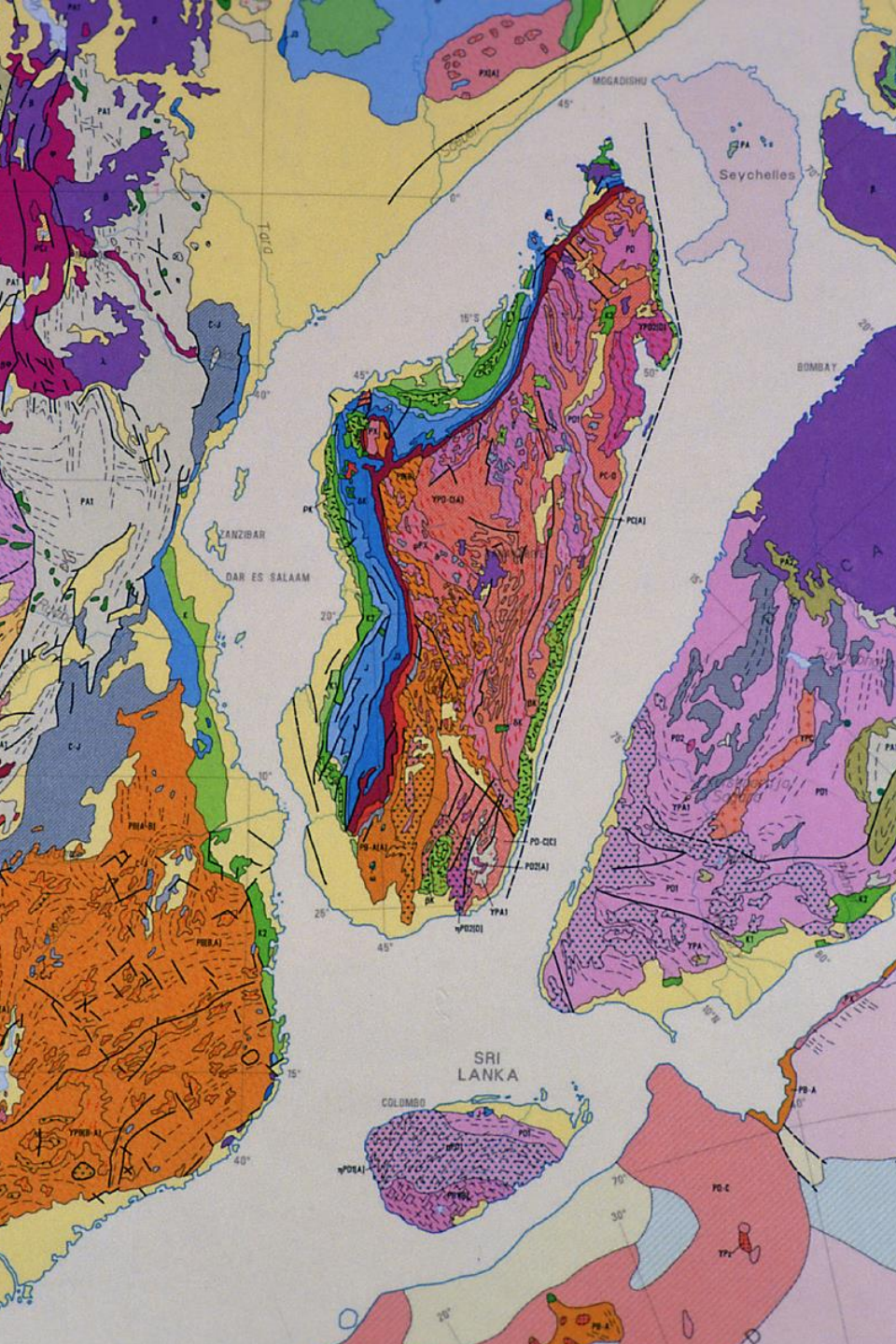






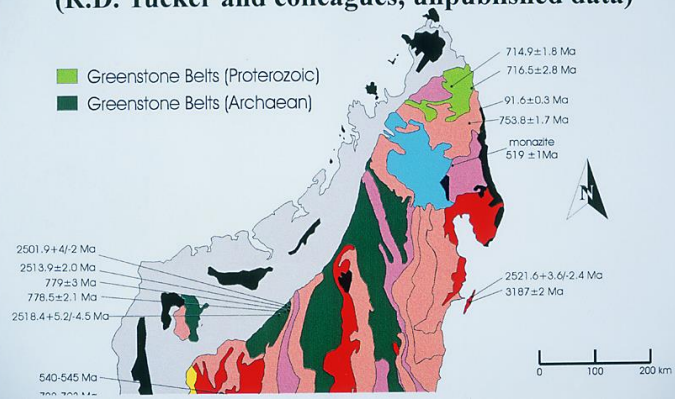
Trond H. Torsvik

~1995





Madagascar, U-Pb Zircon Ages
(R.D. Tucker and colleagues, unpublished data)



Rajasthan, 1999



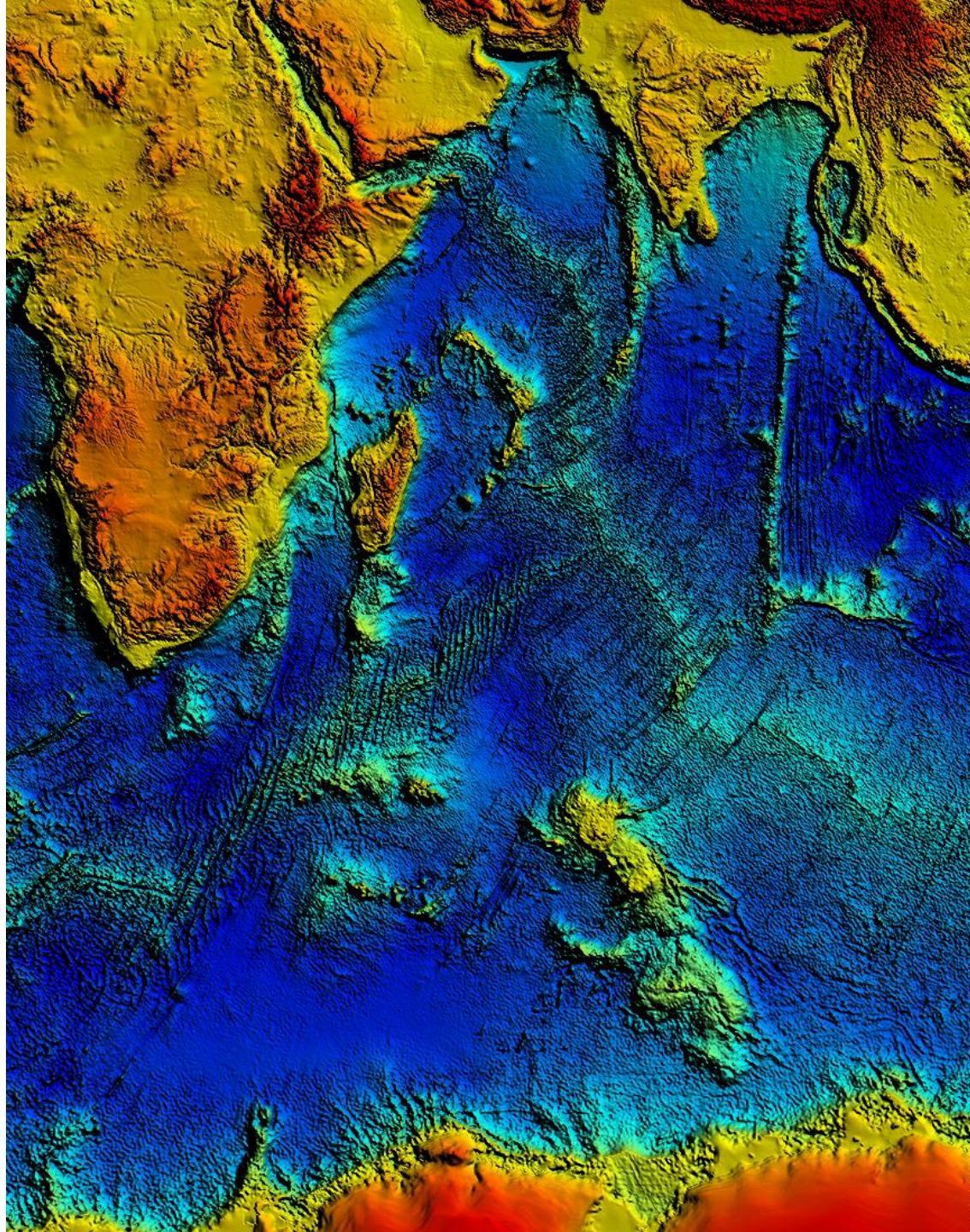
Belinda van Lente, M.Sc. 2002



**Lisa M. Carter,
M.Sc. 2005**



3. 3. 2002





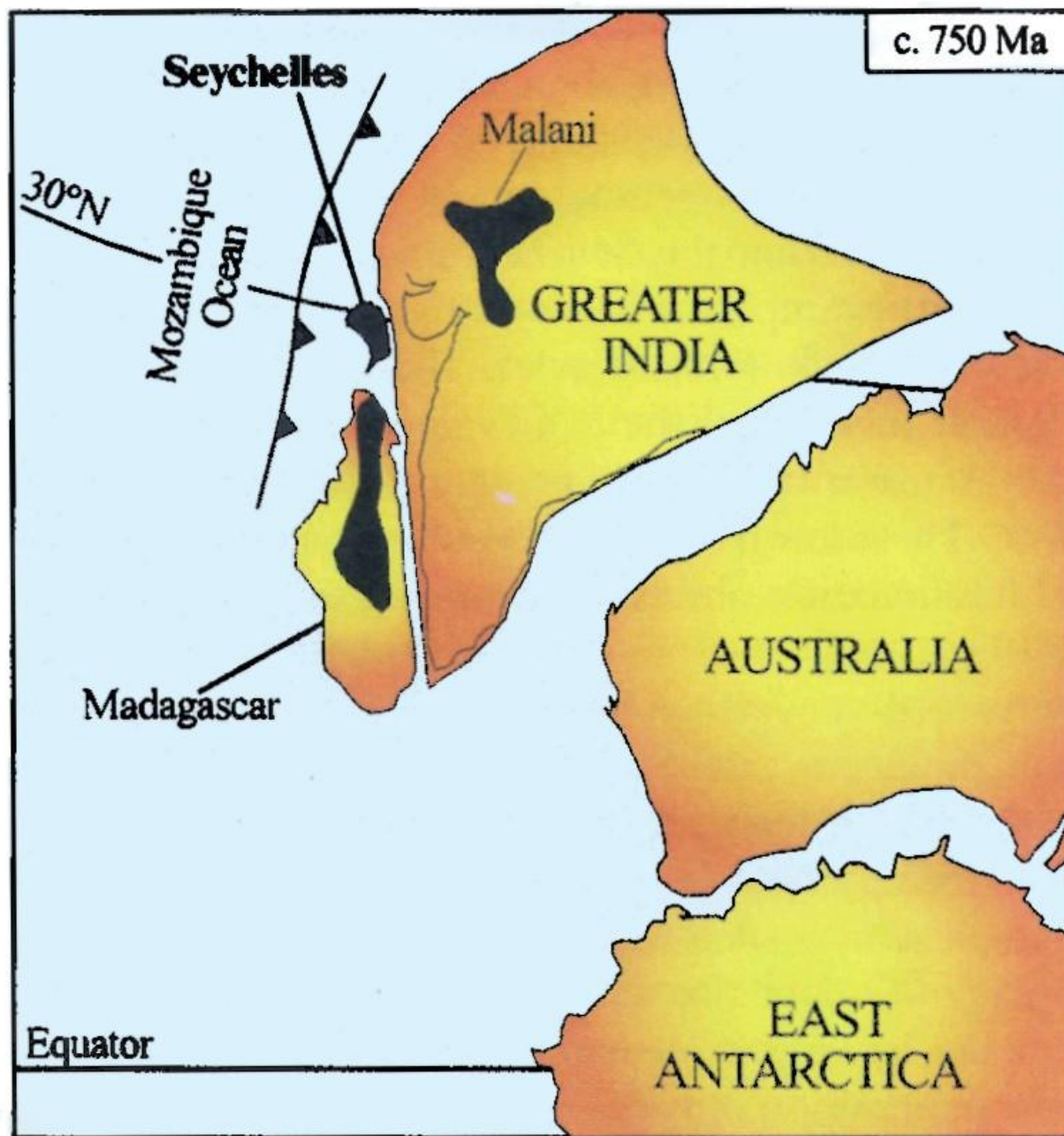
North Island, Seychelles, 1997



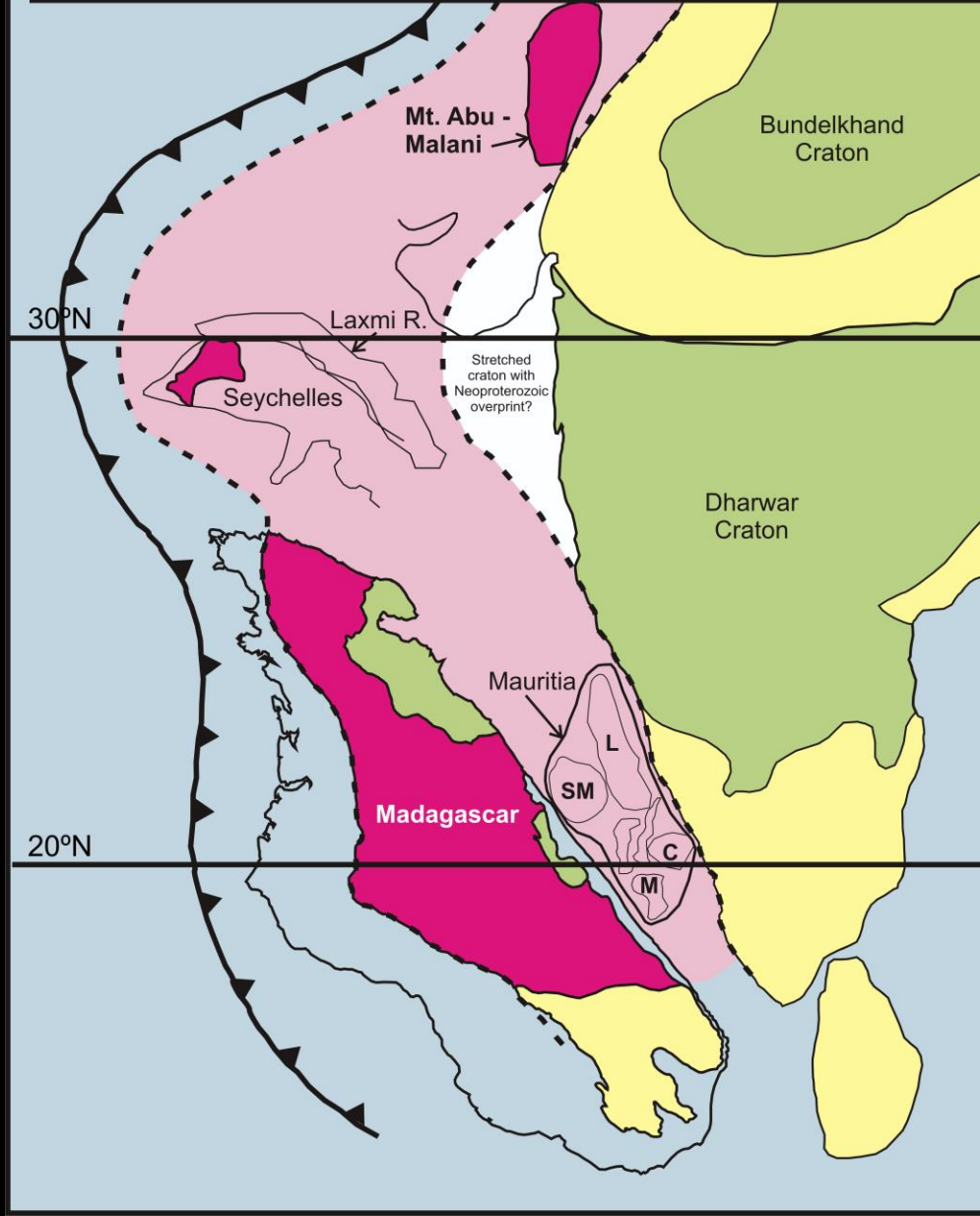


**Seychelles:
granite & dolerite, 750 Ma**

Rodinia
~750 Ma



After Ashwal et al. (2002)



Western Rodinia

Ashwal et al., in prep

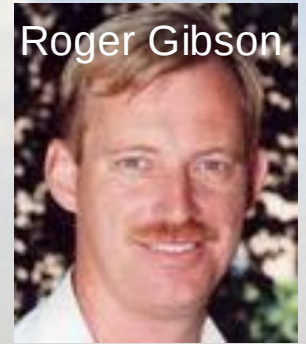
Spike McCarthy



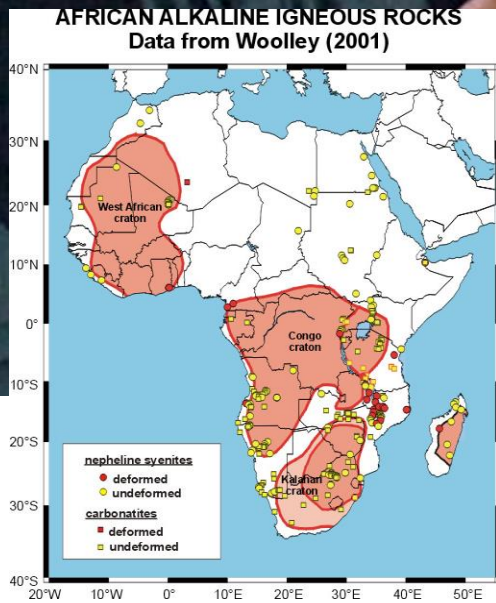
Paul Dirks



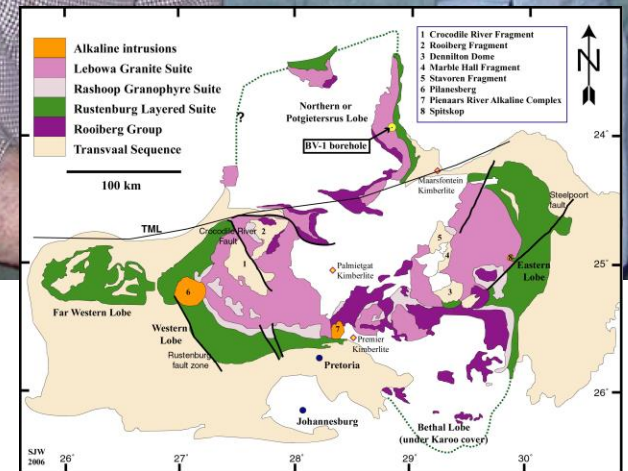
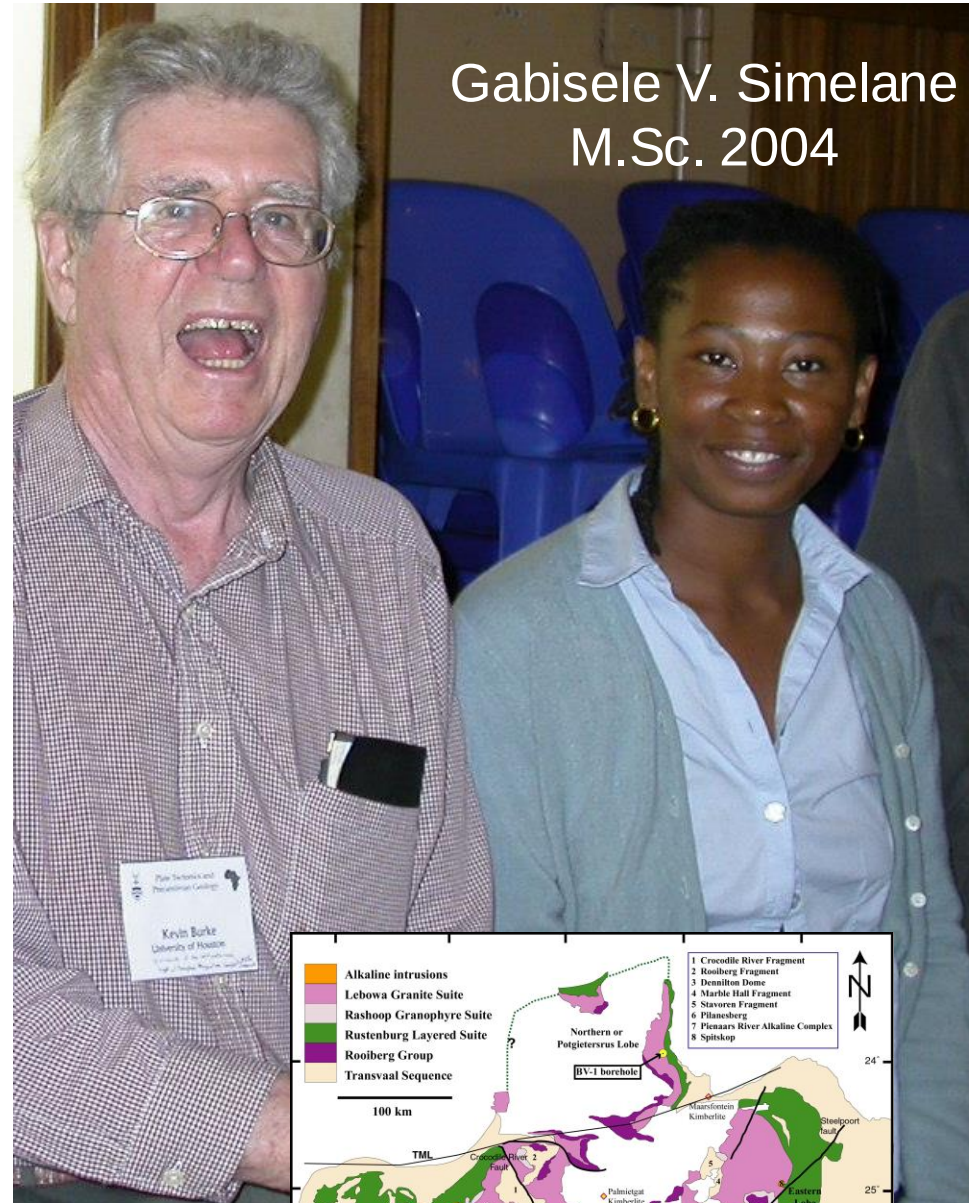
Roger Gibson



Madelein Gerber
B.Sc. Hons 2002
M.Sc. 2005



Gabisele V. Simelane
M.Sc. 2004





Madelein Gerber
M.Sc. 2005

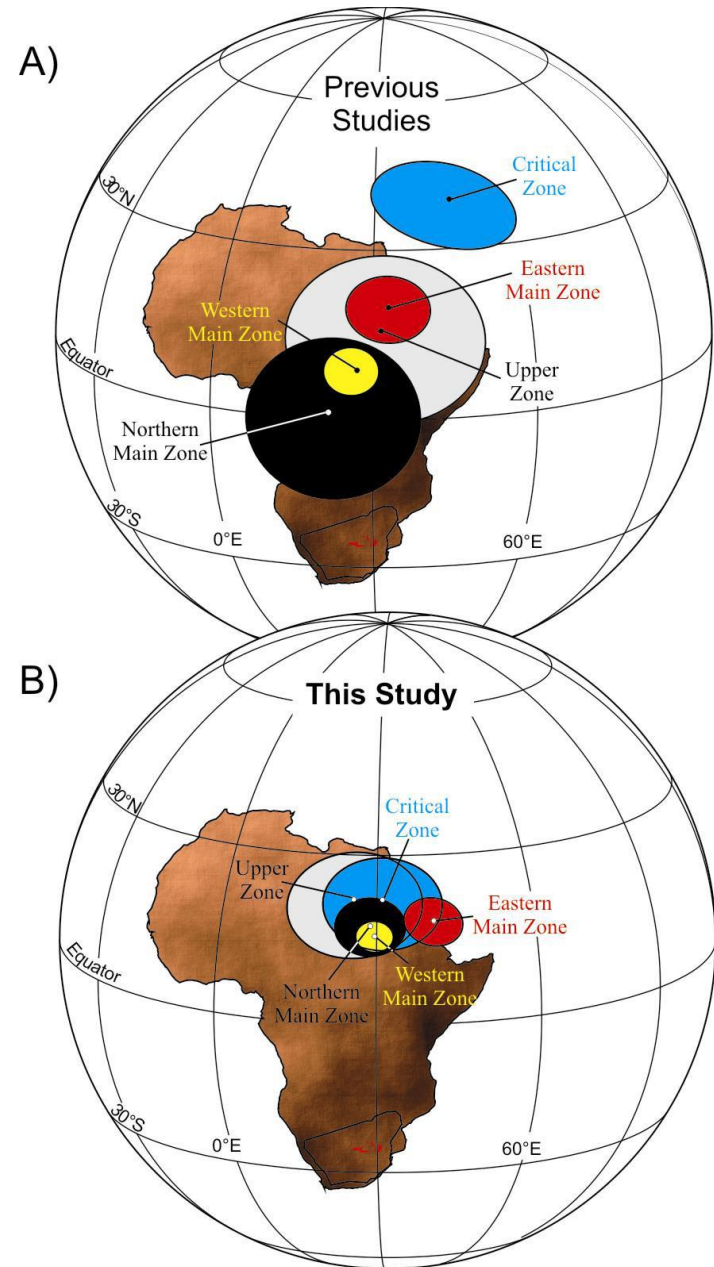
R. James Roberts
Ph.D. 2009



Finnmark, Northern Norway

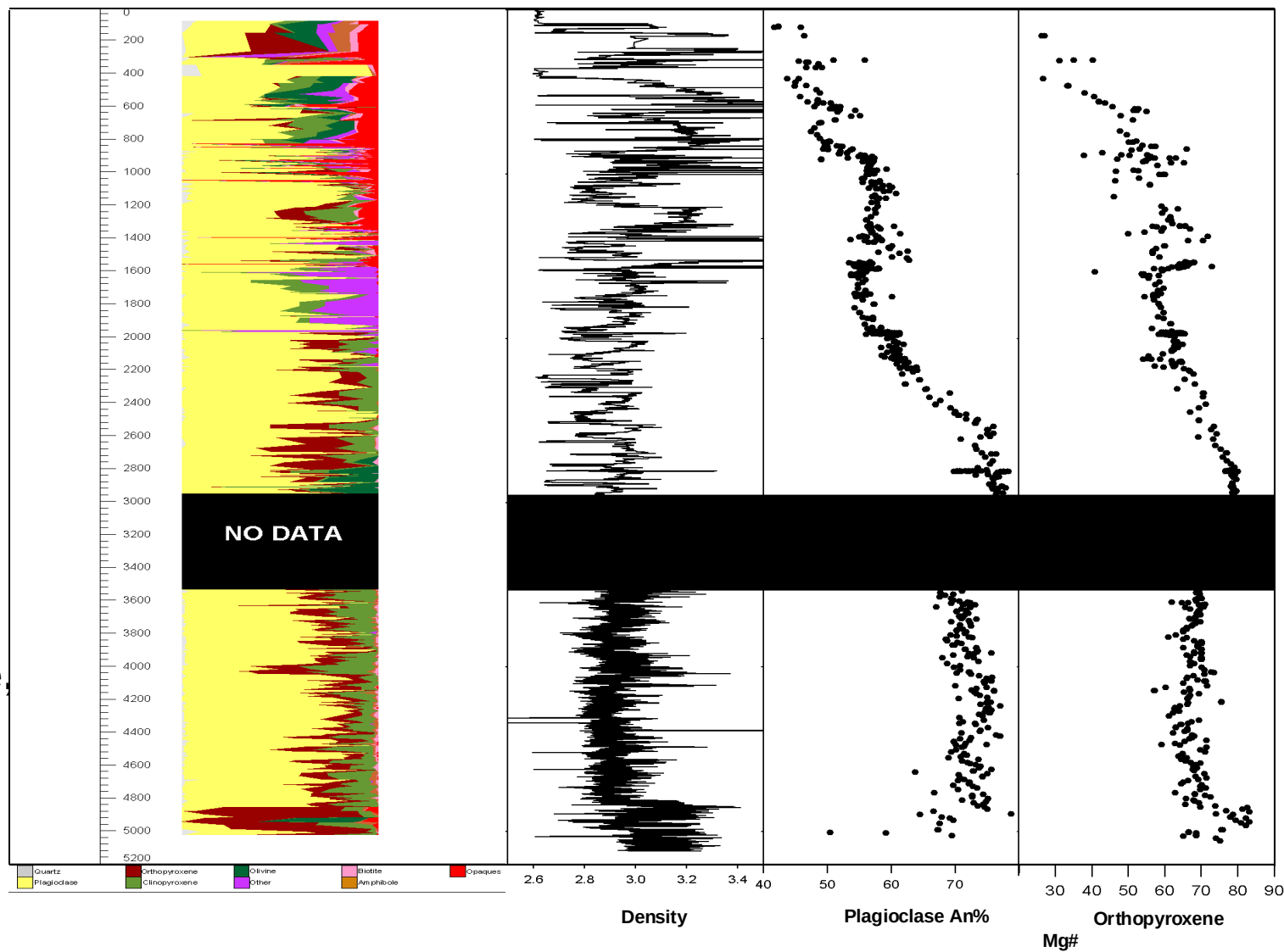


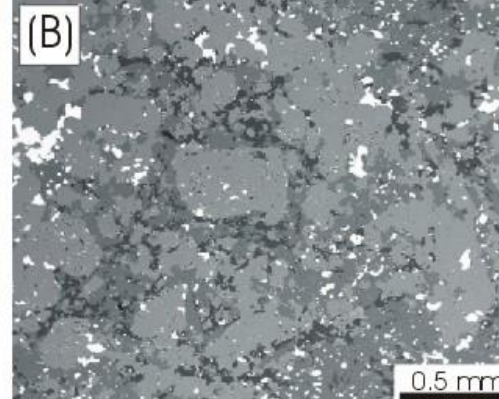
Shawn Letts, Ph.D. 2009



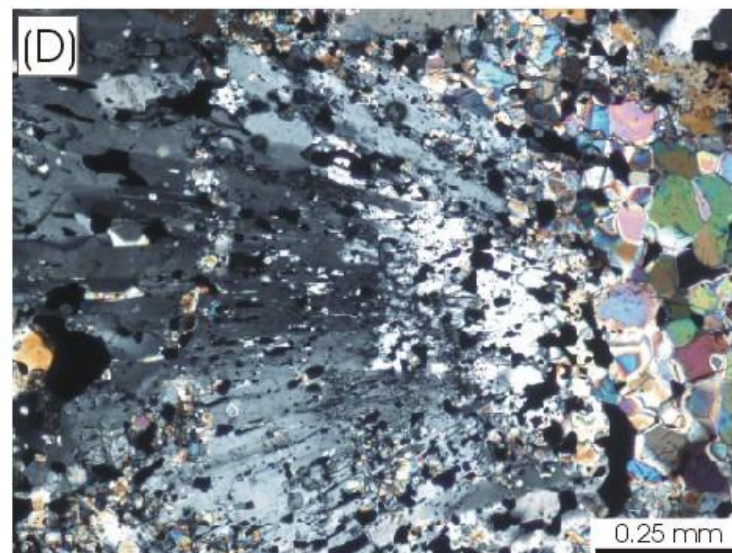
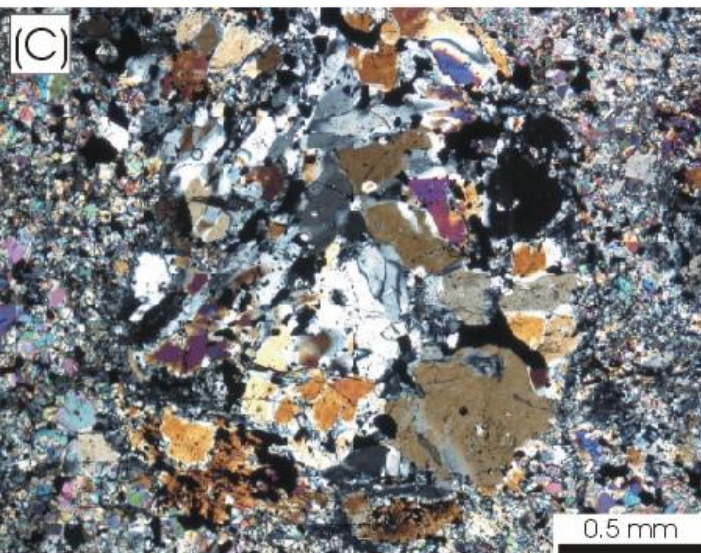


Freddie Roelofse,
Ph.D. 2010



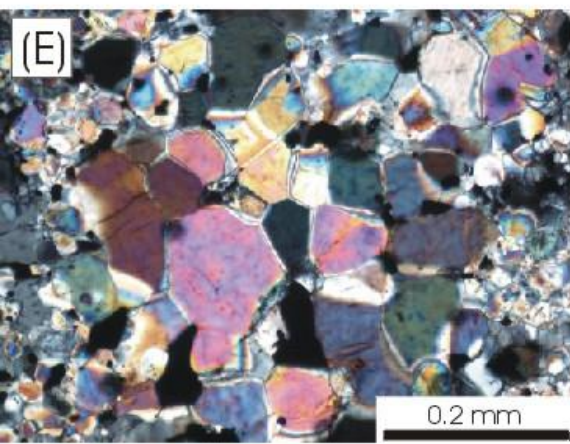


Morokweng meteorite



First report of
bolide in impact
melt

Maier et al.
Nature, 2006

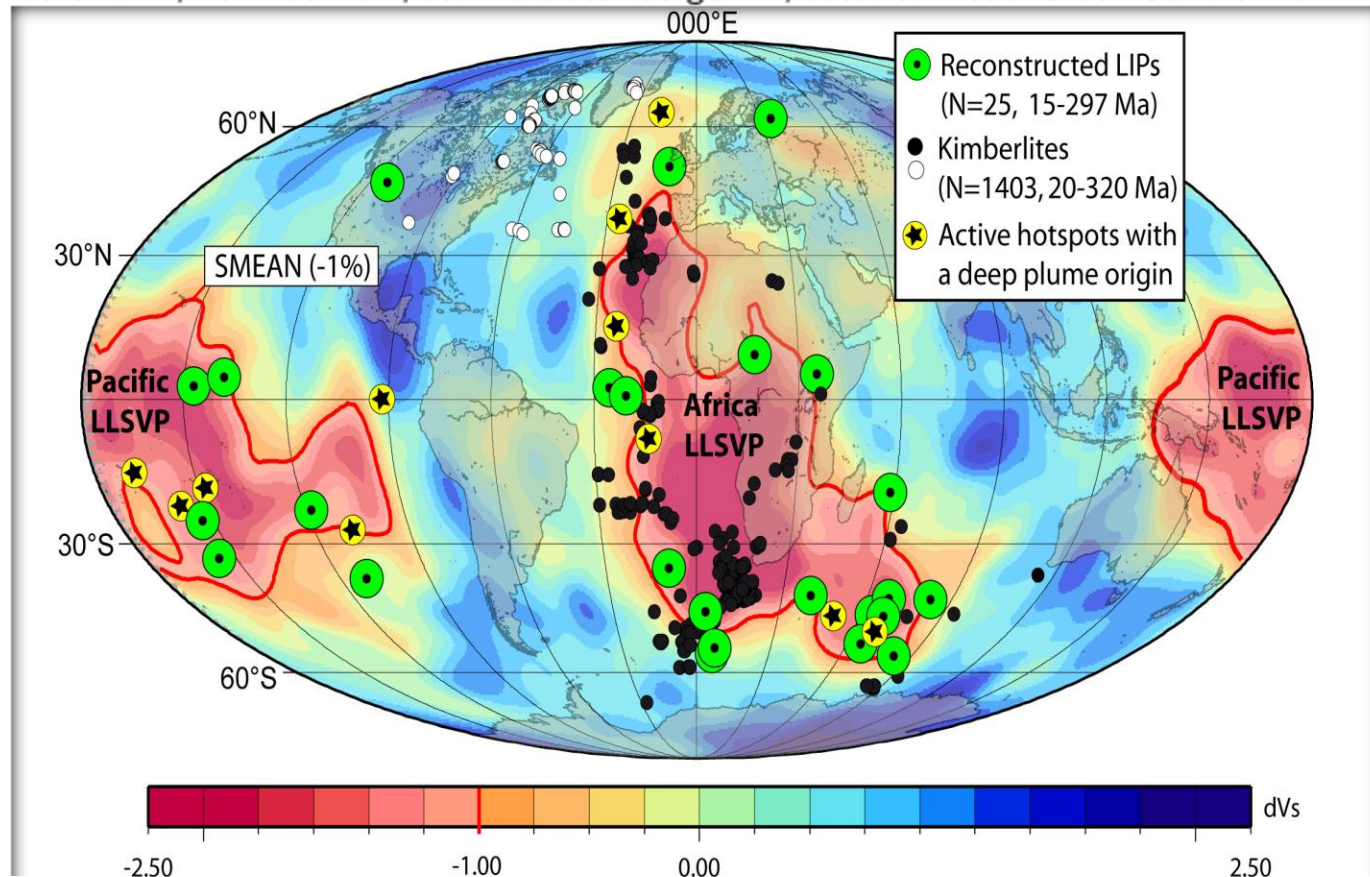


Marco Andreoli

LETTERS

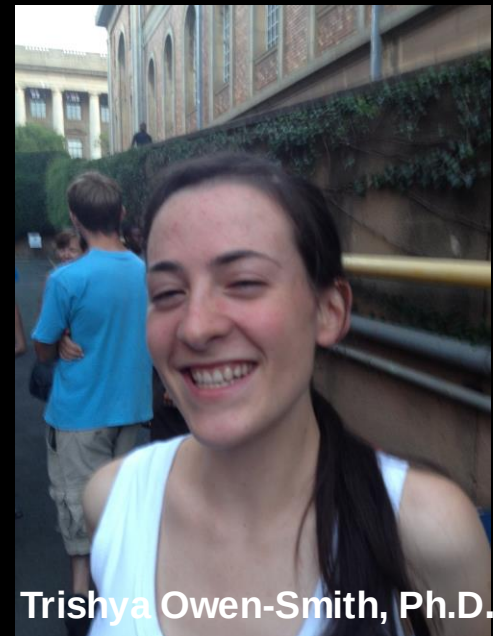
Diamonds sampled by plumes from the core–mantle boundary

Trond H. Torsvik^{1,2,3}, Kevin Burke^{3,4}, Bernhard Steinberger^{1,2,5}, Susan J. Webb³ & Lewis D. Ashwal³





Natalie Deseta, Ph.D.



Trishya Owen-Smith, Ph.D.



Grant Bybee, Ph.D.



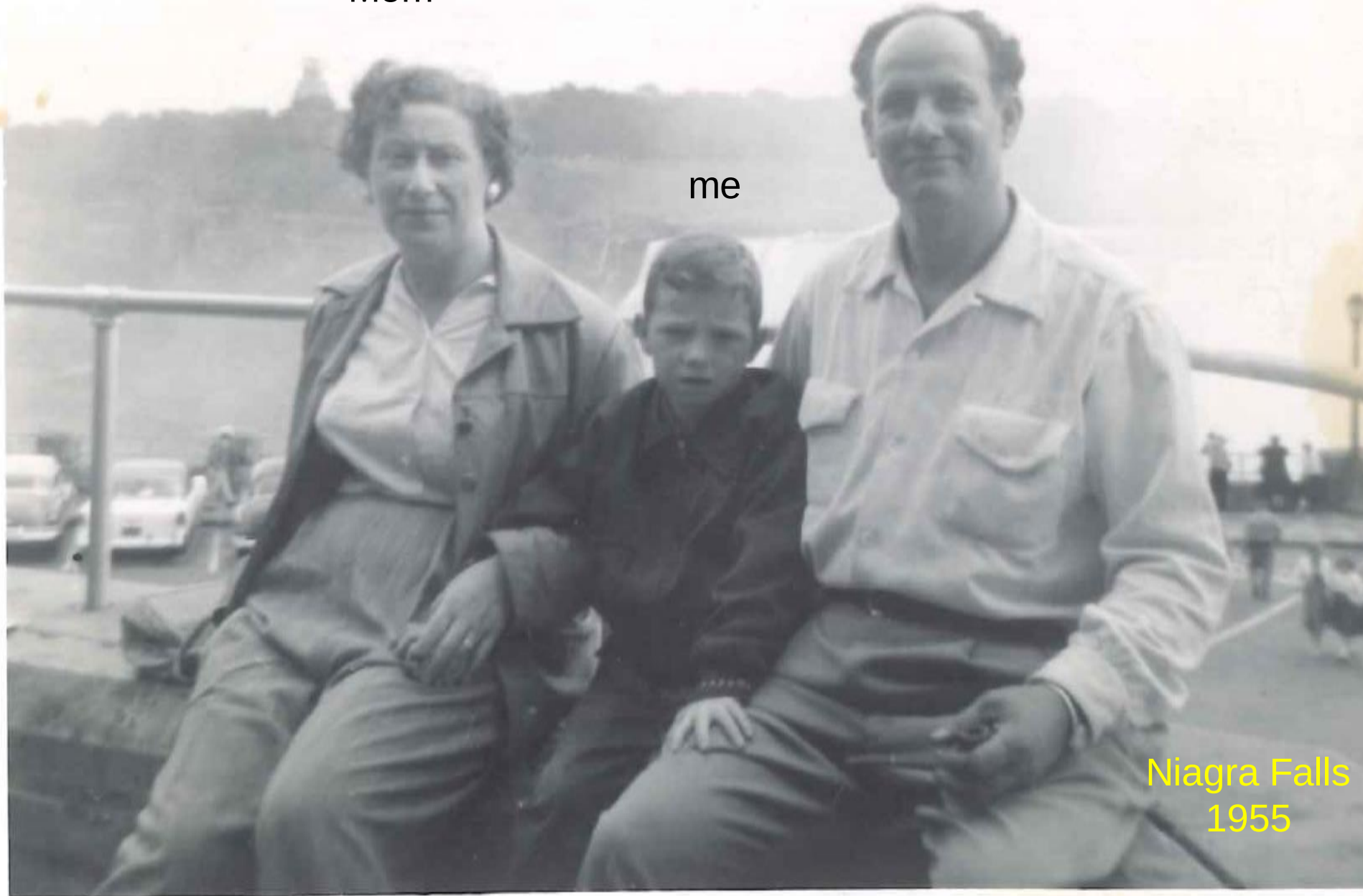
**Rogers Munyai,
B.Sc. Hons.**

Dad

Mom

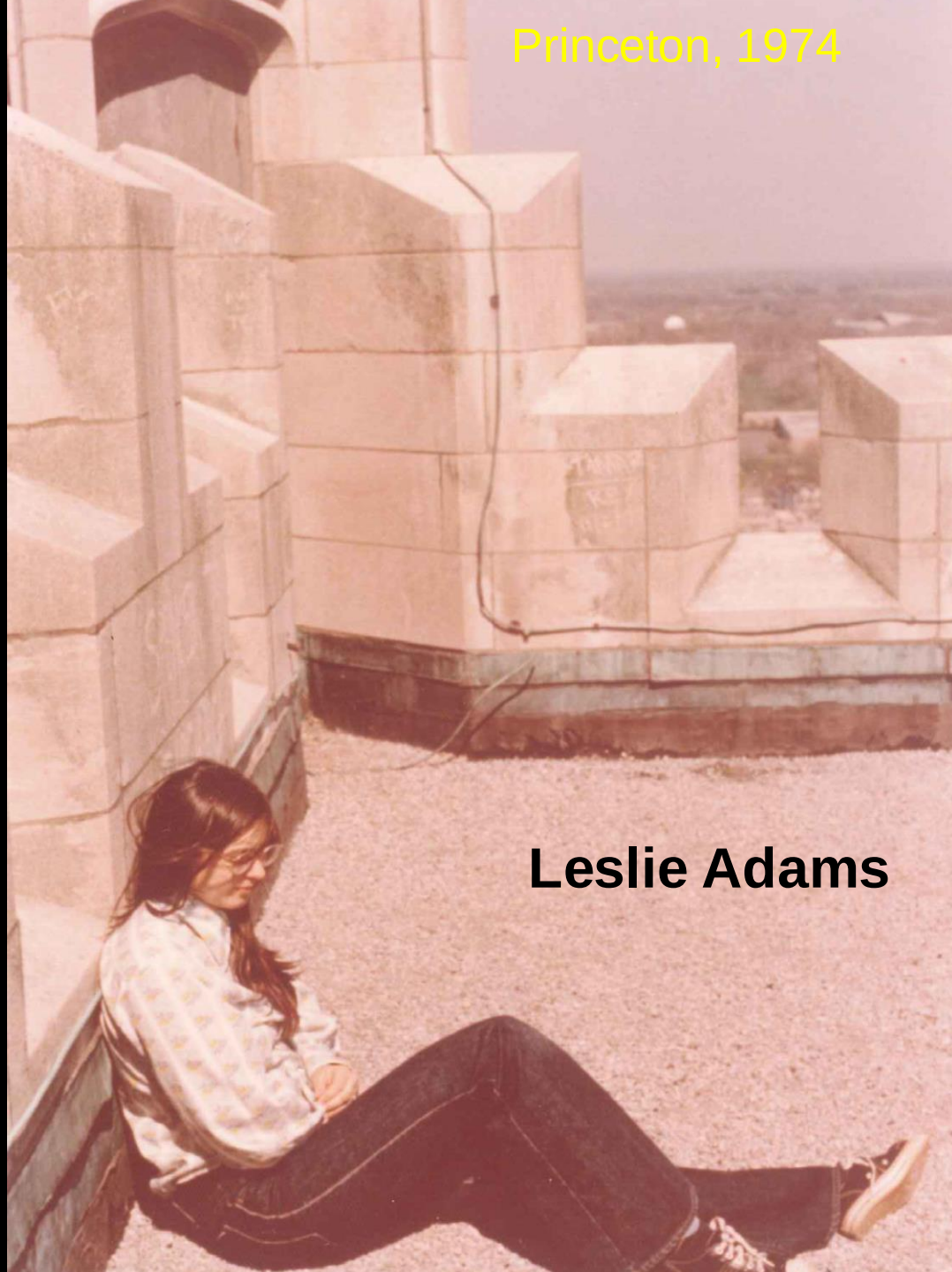
me

Niagra Falls
1955

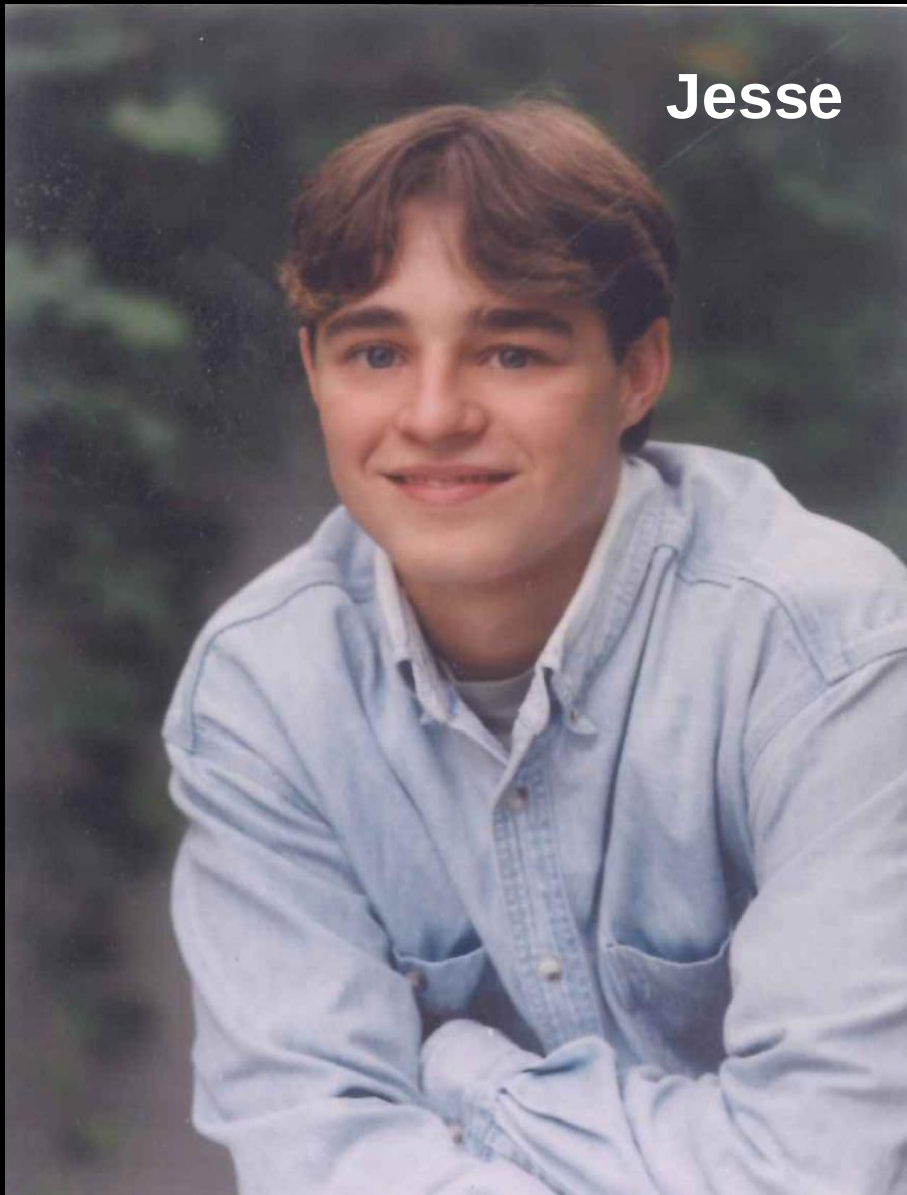


Princeton, 1974

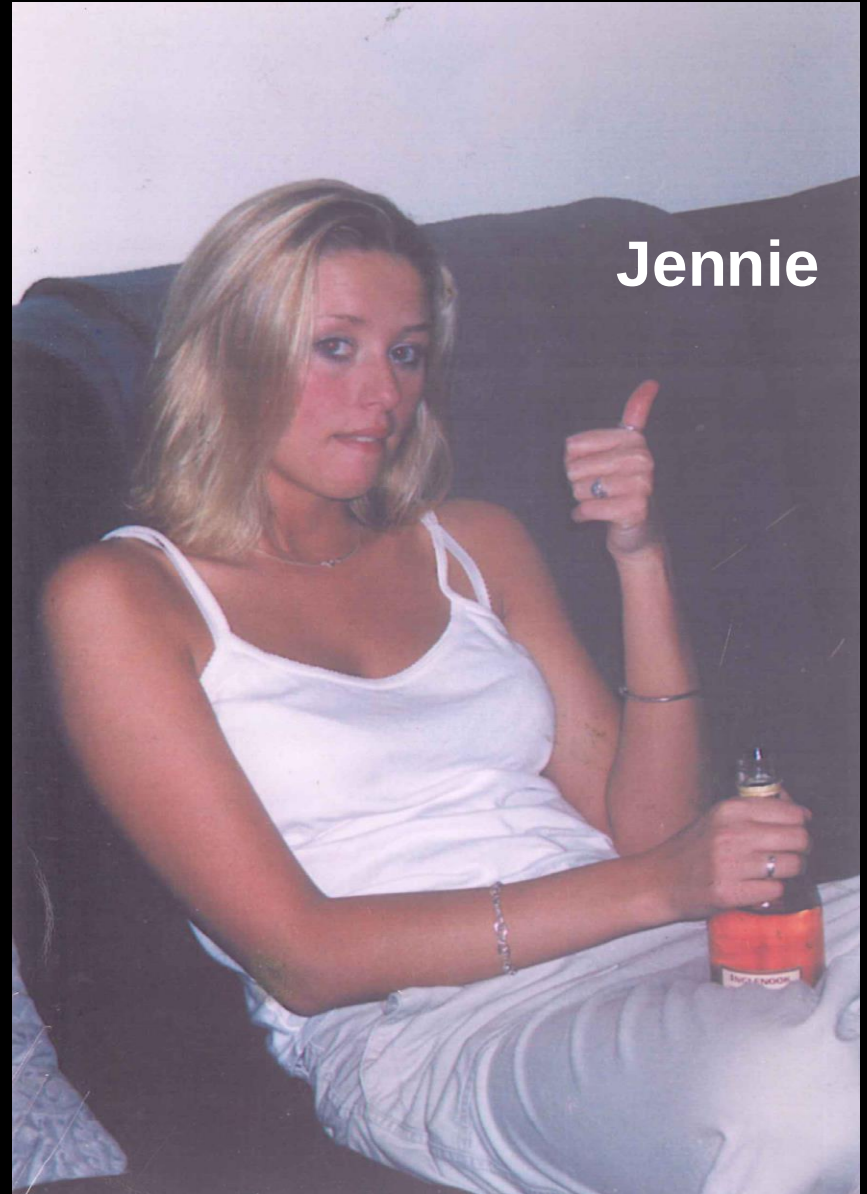
Leslie Adams



Jesse



Jennie





Sam



Ben

SUE !!!!!!!!!!!



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Norwegian Research Council
Norwegian Geological Survey

Gold Fields of South Africa
Anglo Platinum
Anglo American
De Beers
BHPBilliton
Atomic Energy Corporation
Rareco

Thank you!

