ESRF | The European Synchrotron

Synchrotron and the African fossil record: A decade of collaboration

-

V. Fernandez

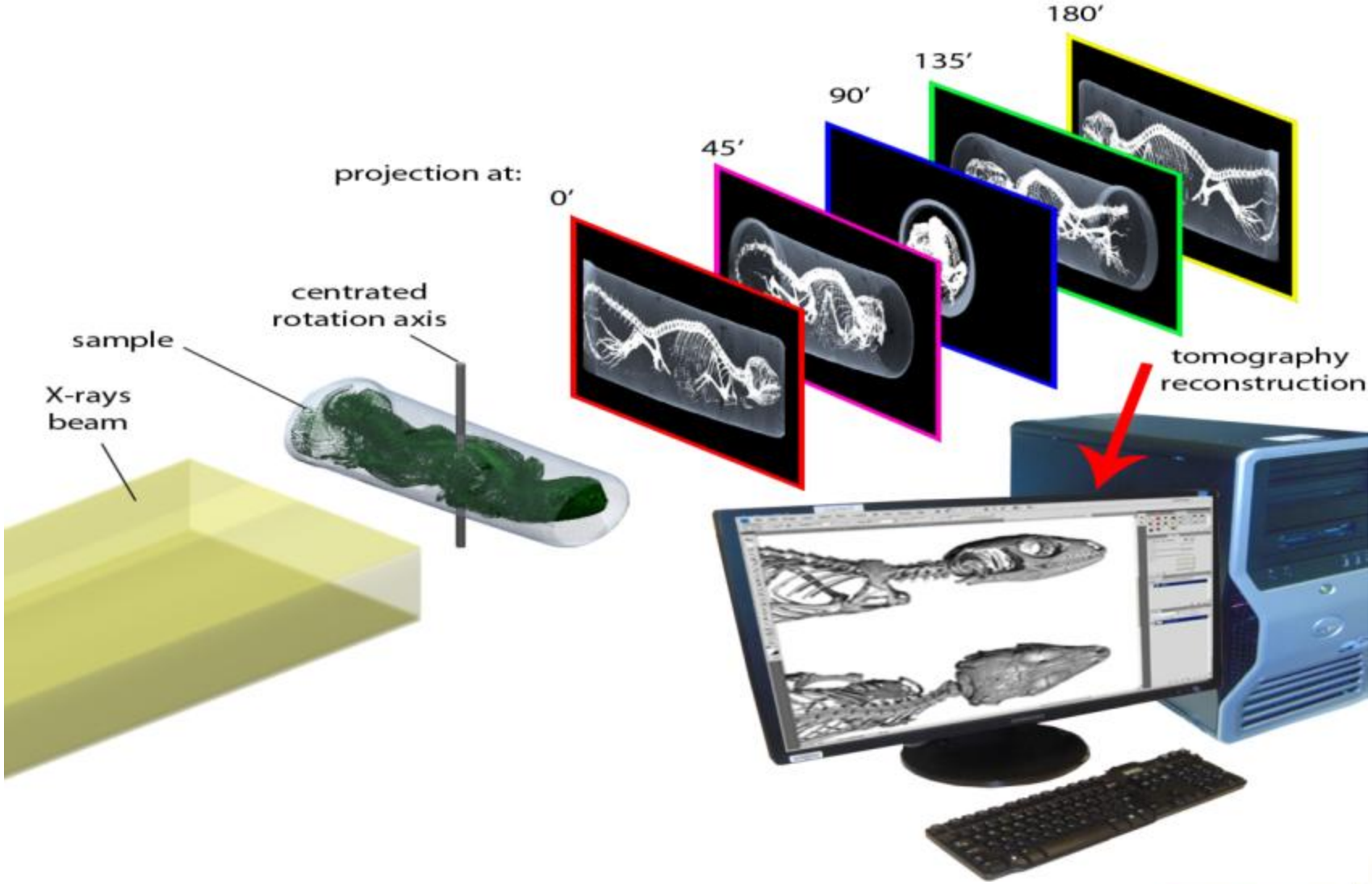
&

P. Tafforeau

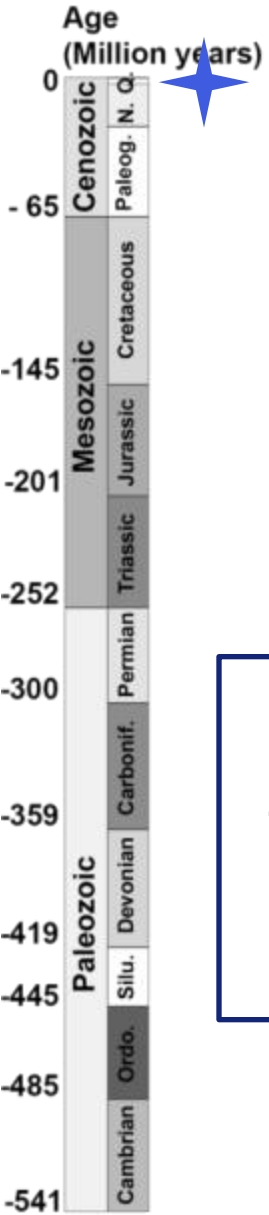
Why do palaeontologists are interested in X-rays?

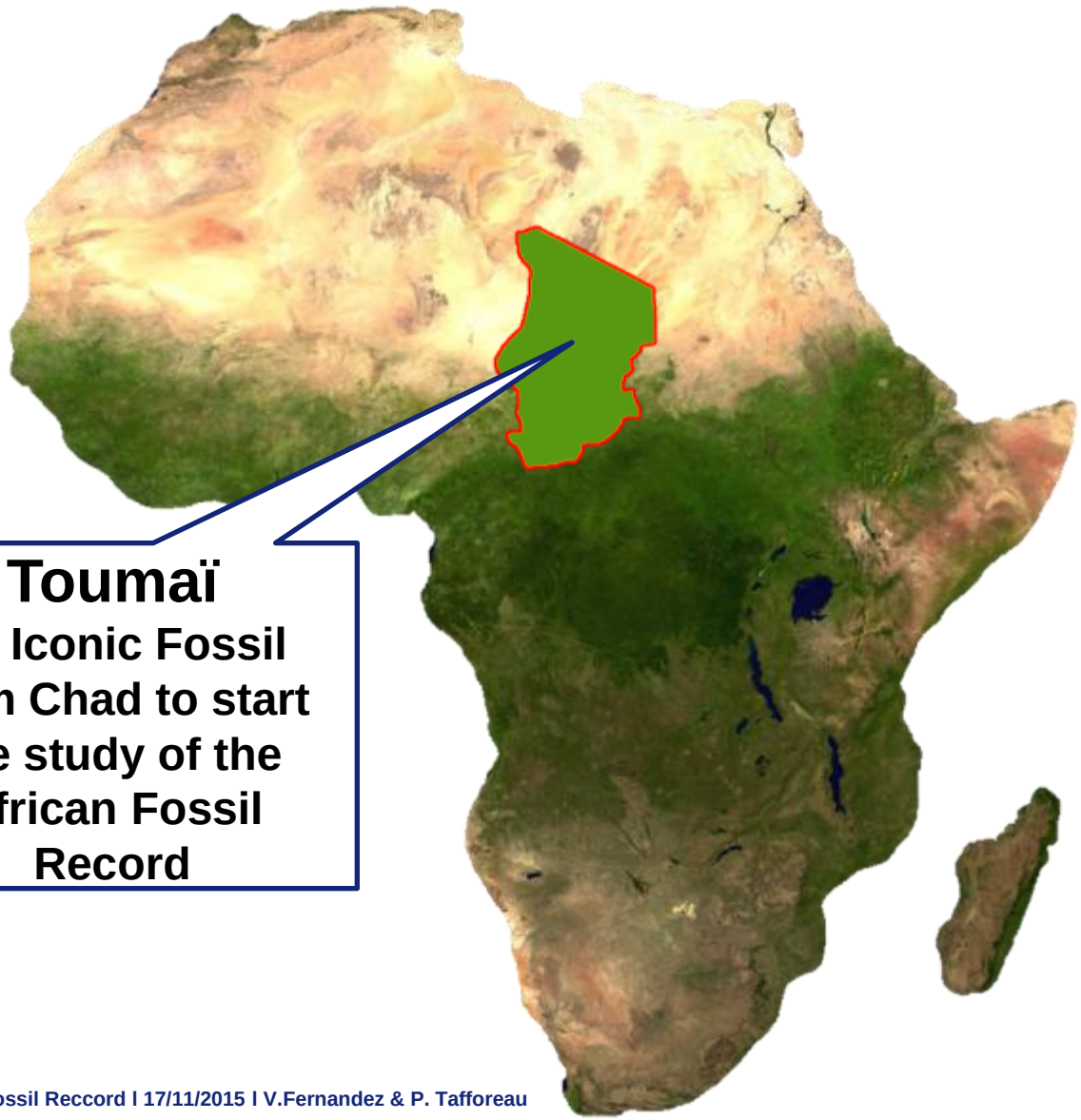
Fragile and unique fossils limit physical preparation

Principle of tomography



X-RAY IMAGING OF AFRICAN FOSSILS: A DECADE OF COLLABORATIONS





Toumaï

An Iconic Fossil from Chad to start the study of the African Fossil Record

VIRTUAL SECTIONING OF THE MANDIBLE

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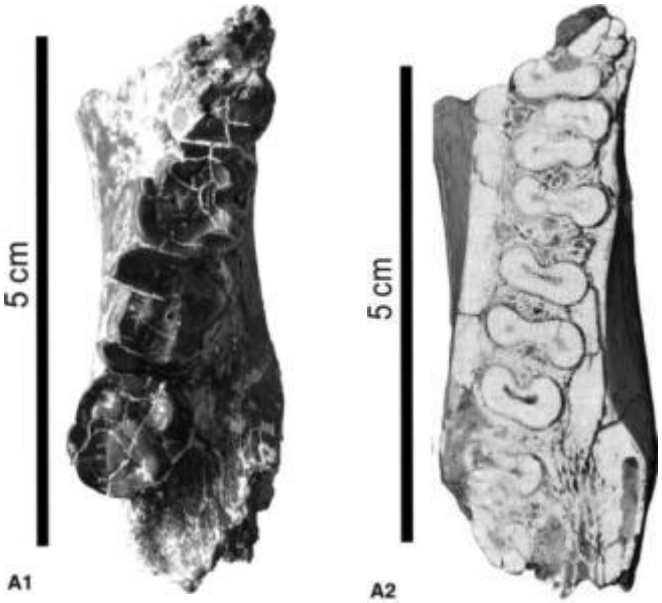
C. R. Palevol 3 (2004) 275–283

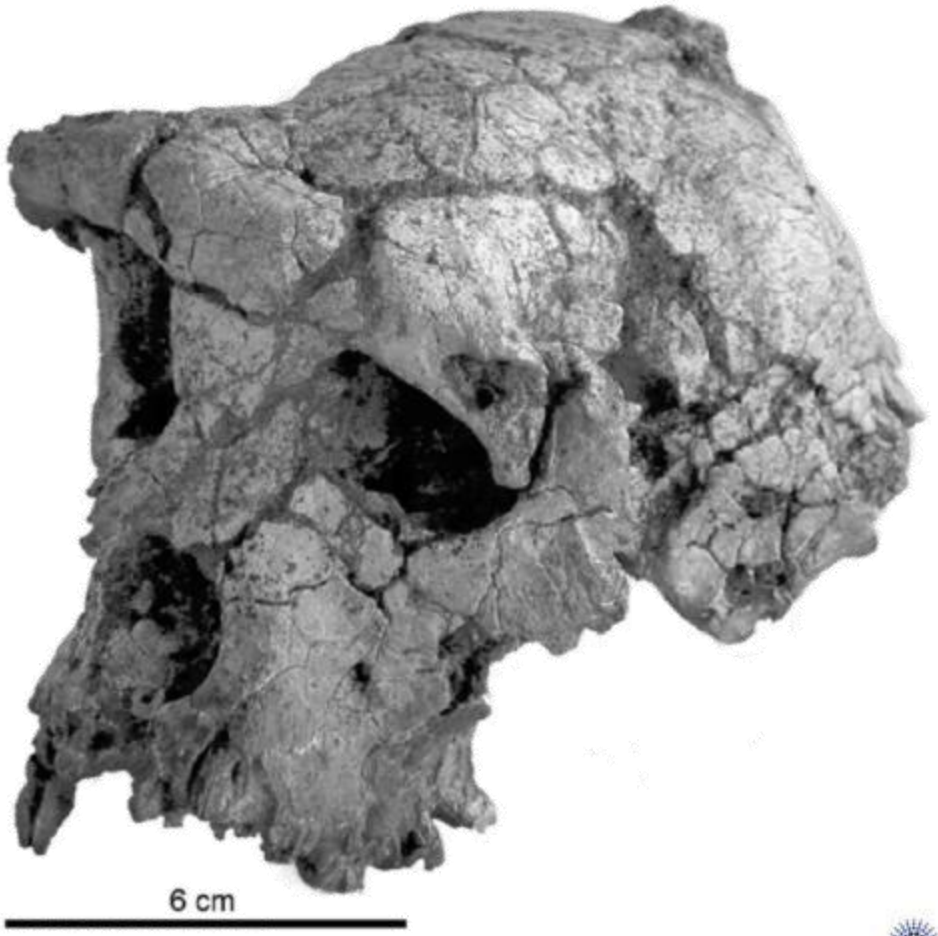
Comptes Rendus
PALEVOL

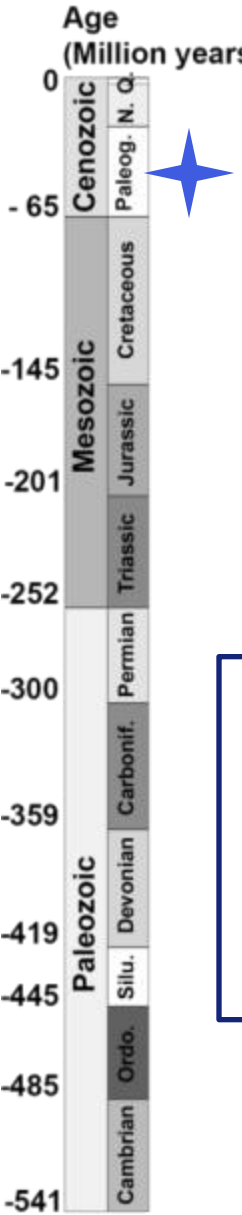
Paléontologie humaine et préhistoire

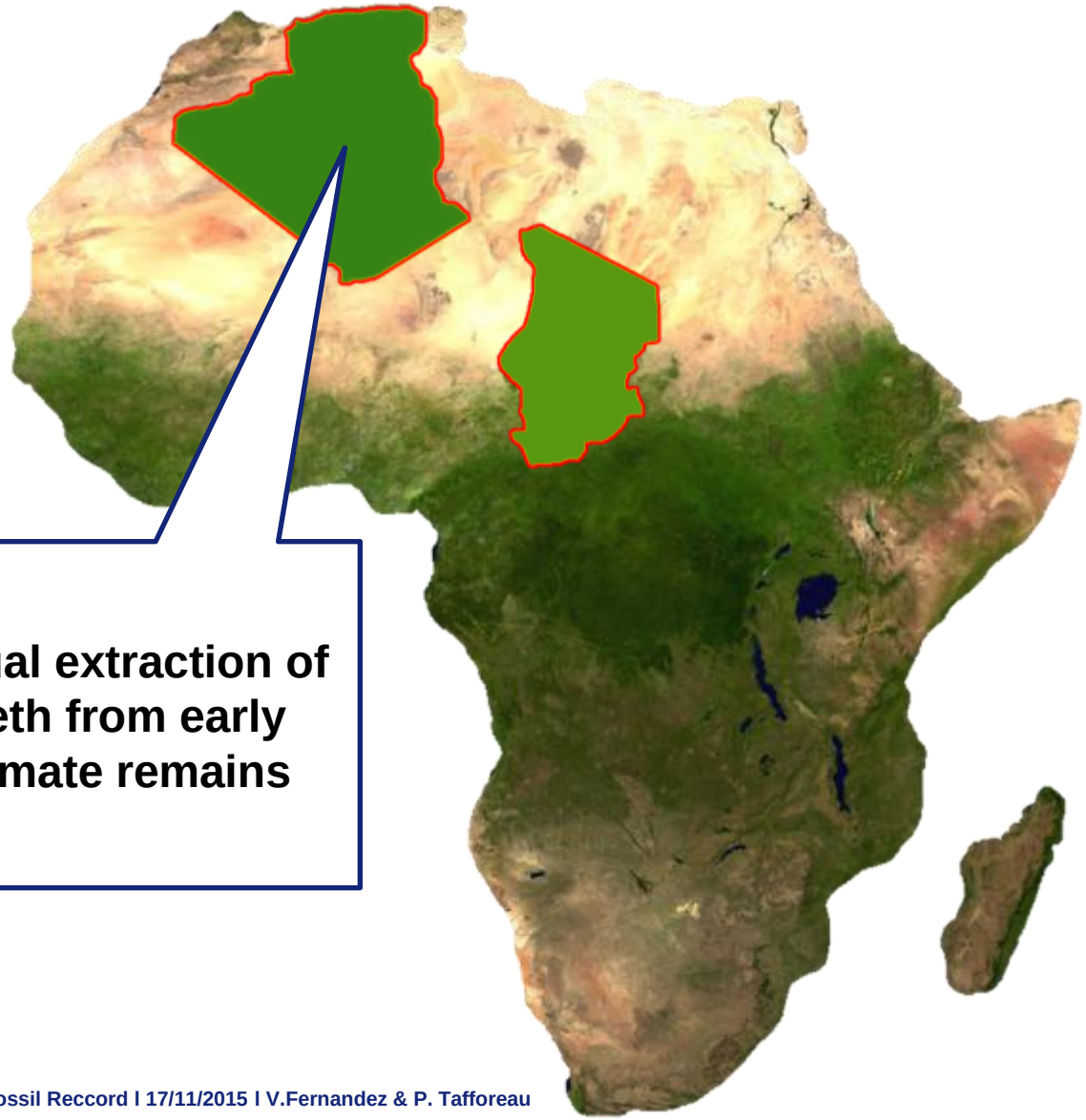
« Toumaï », Miocène supérieur du Tchad, le nouveau doyen du rameau humain

Michel Brunet [a,*], Franck Guy [a,b], Jean-Renaud Boisserie [a,c], Ahounta Djimdoumalbaye [a,d], Thomas Lehmann [a], Fabrice Lihoreau [a], Antoine Louchart [e], Mathieu Schuster [f], Paul Tafforeau [h], Andossa Likius [g], Hassane Taisso Mackaye [g], Cécile Blondel [a], Hervé Bocherens [h], Louis De Bonis [a], Yves Coppens [i], Christiane Denis [j], Philippe Duringer [f], Véra Eisenmann [j], Alexander Flisch [k], Denis Geraads [l], Nieves Lopez-Martinez [m], Olga Otero [a], Pablo Pelaez Campomanes [n], David Pilbeam [b], Marcia Ponce de León [o], Patrick Vignaud [a], Laurent Viriot [a], Christoph Zollikofer [o], Tous les co-auteurs sont membres de la Mission paléoanthropologique franco-tchadienne (MPFT) [1]









Virtual extraction of teeth from early primate remains

VIRTUAL EXTRACTION OF TEETH

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Journal of Human Evolution 47 (2004) 305–321

JHE

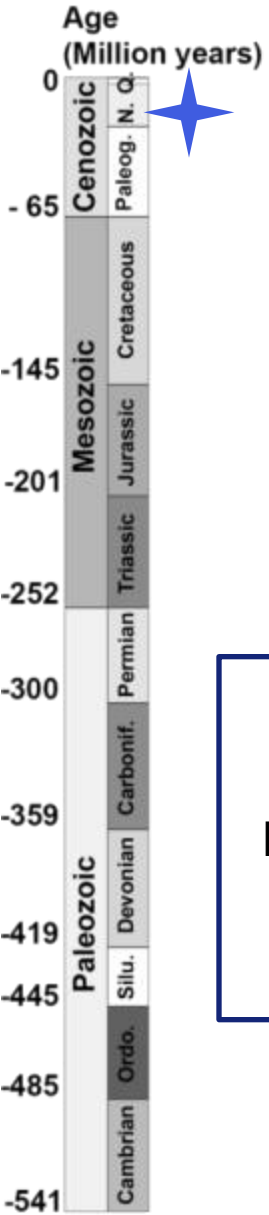
Discovery of a highly-specialized plesiadapiform primate in the early-middle Eocene of northwestern Africa

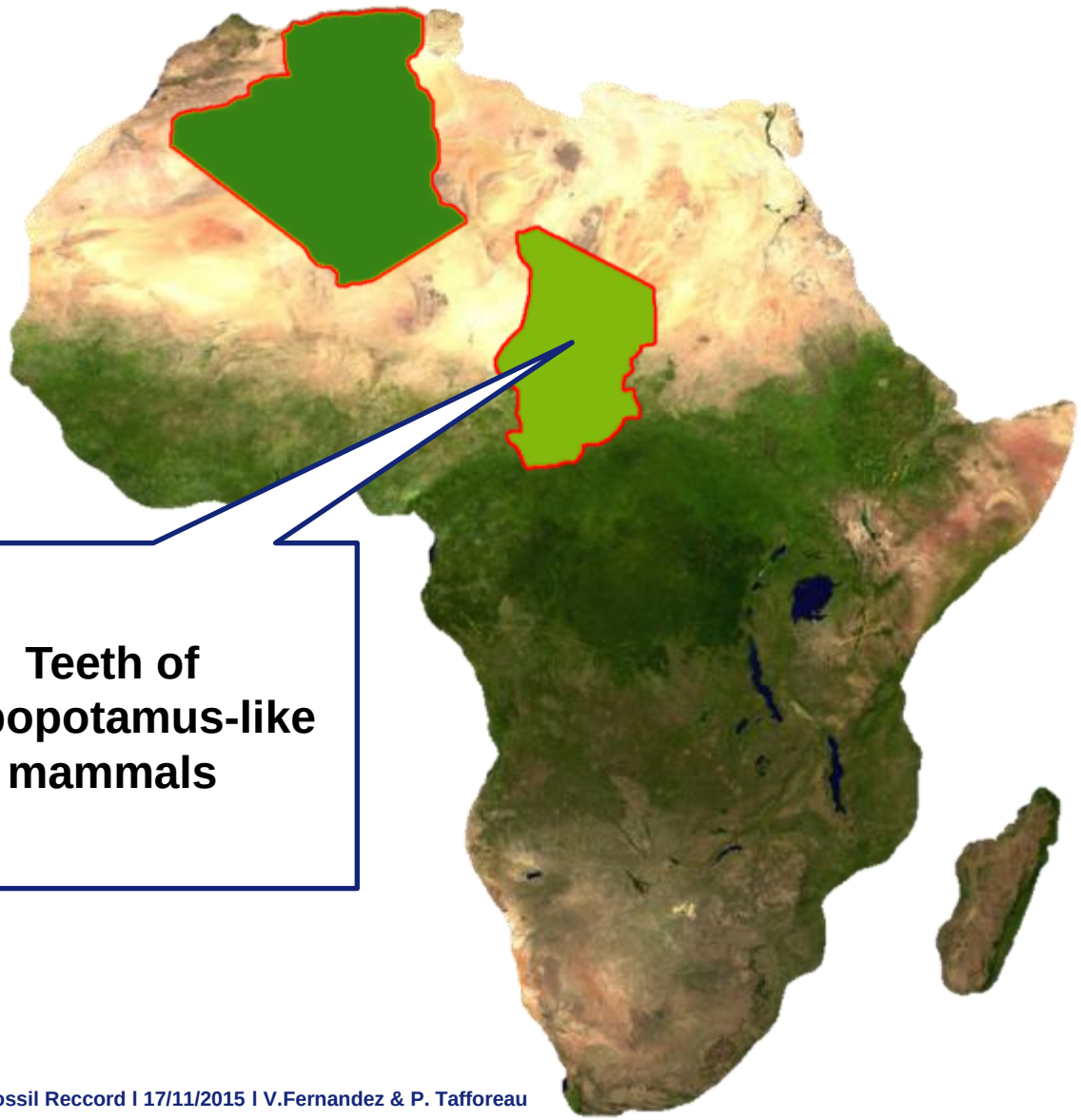
Rodolphe Tabuce[a,*], Mohamed Mahboubi[b], Paul Tafforeau[a], Jean Sudre[c]

[a]*Institut des Sciences de l'Evolution, Laboratoire de paléontologie, UMR 5554, Université Montpellier II, case courrier 064, 34095 Montpellier cedex 5, France*

[b]*Institut des Sciences de la Terre, Université d'Oran, B.P. El M'naouer, Oran, Algérie*

[c]*EPHE, Laboratoire de paléontologie, UMR 5554, Université Montpellier II, case courrier 064, 34095 Montpellier cedex 5, France*



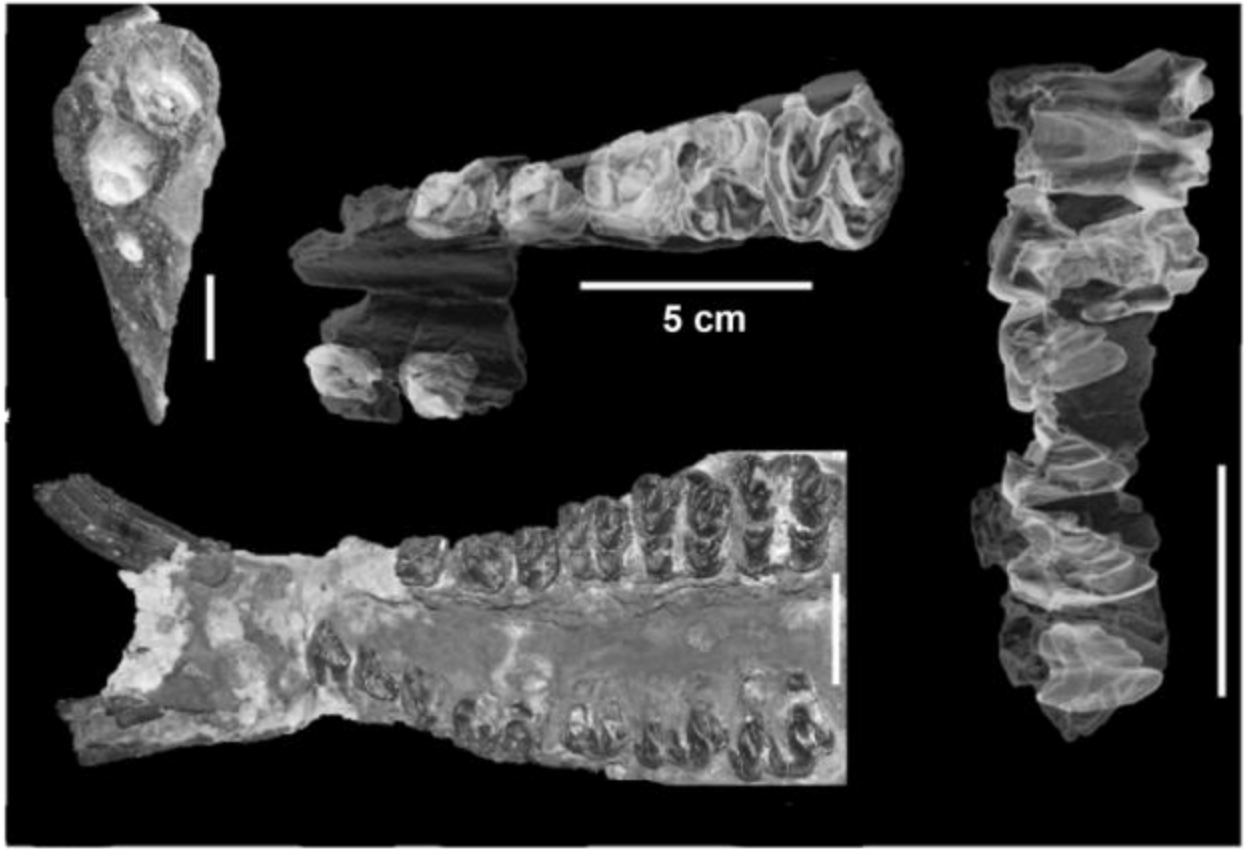


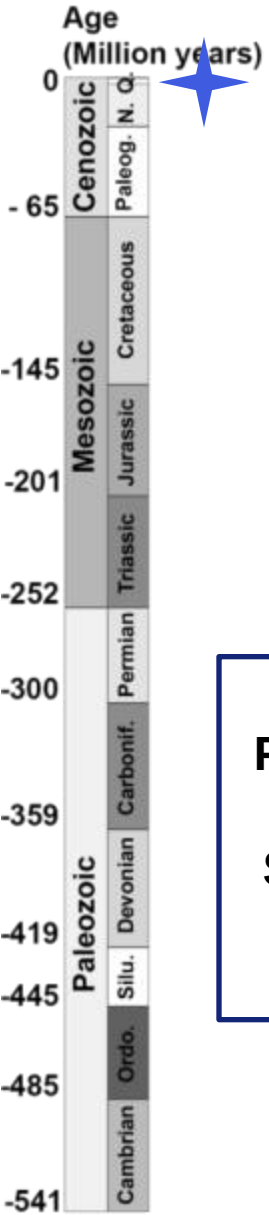
Teeth of hippopotamus-like mammals

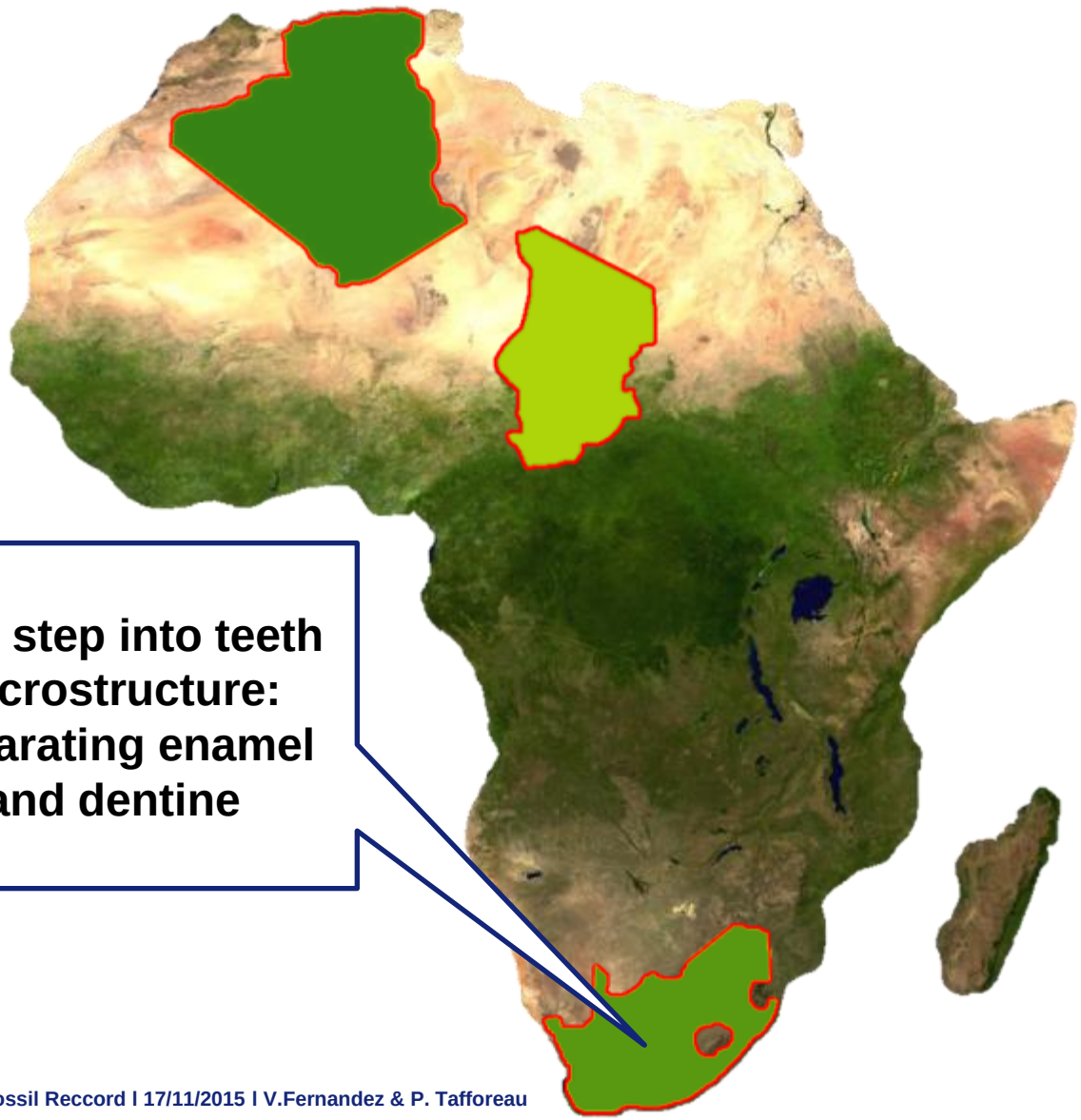
Anthracothere dental anatomy reveals a late Miocene Chado-Libyan bioprovince

Fabrice Lihoreau*[†‡], Jean-Renaud Boisserie*[§¶], Laurent Viriot*, Yves Coppens[‖], Andossa Likius[†], Hassane Taisso Mackaye[†], Paul Tafforeau*[,**], Patrick Vignaud*, and Michel Brunet*[‖]

PNAS
Proceedings of the National Academy of Sciences of the United States of America



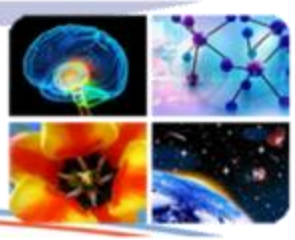




First step into teeth microstructure: Separating enamel and dentine

CHARACTERIZATION OF ENAMEL-DENTINE JUNCTION IN 3D

SOUTH AFRICAN
Journal of Science

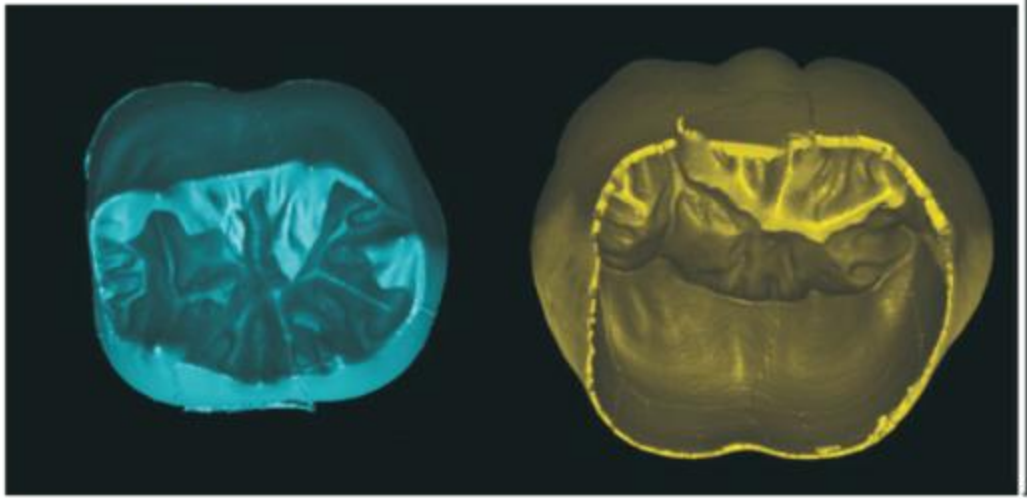


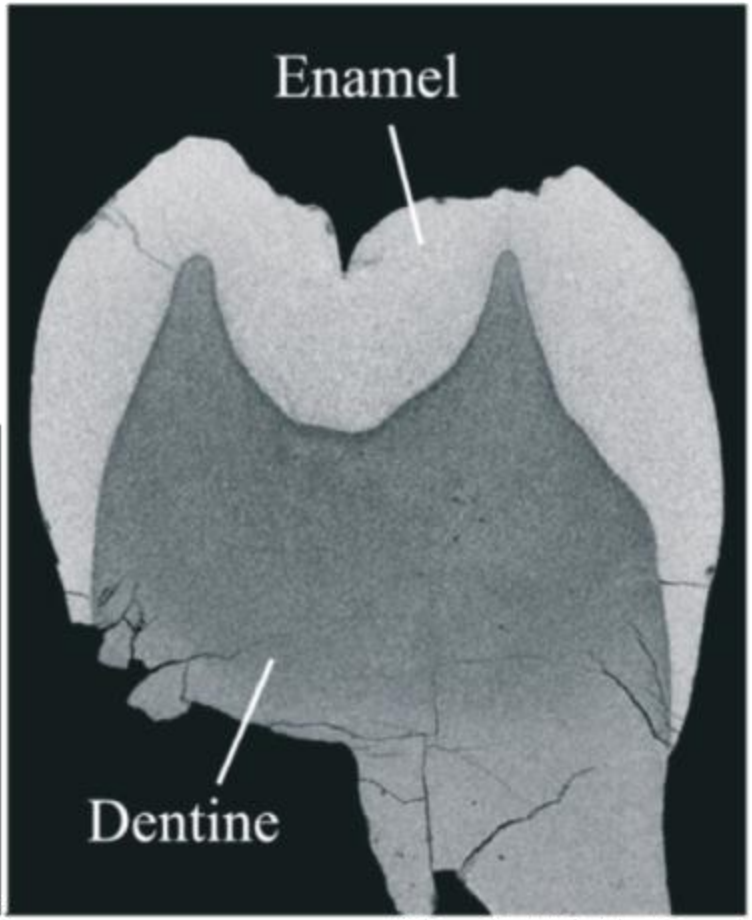
Research Letters

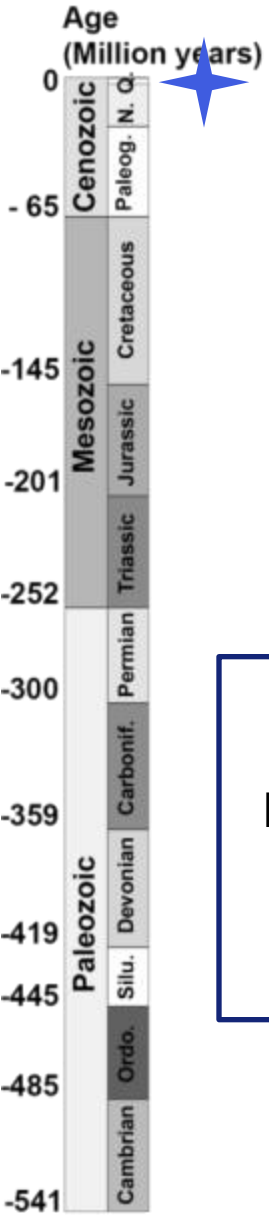
South African Journal of Science **102**, November/December 2006

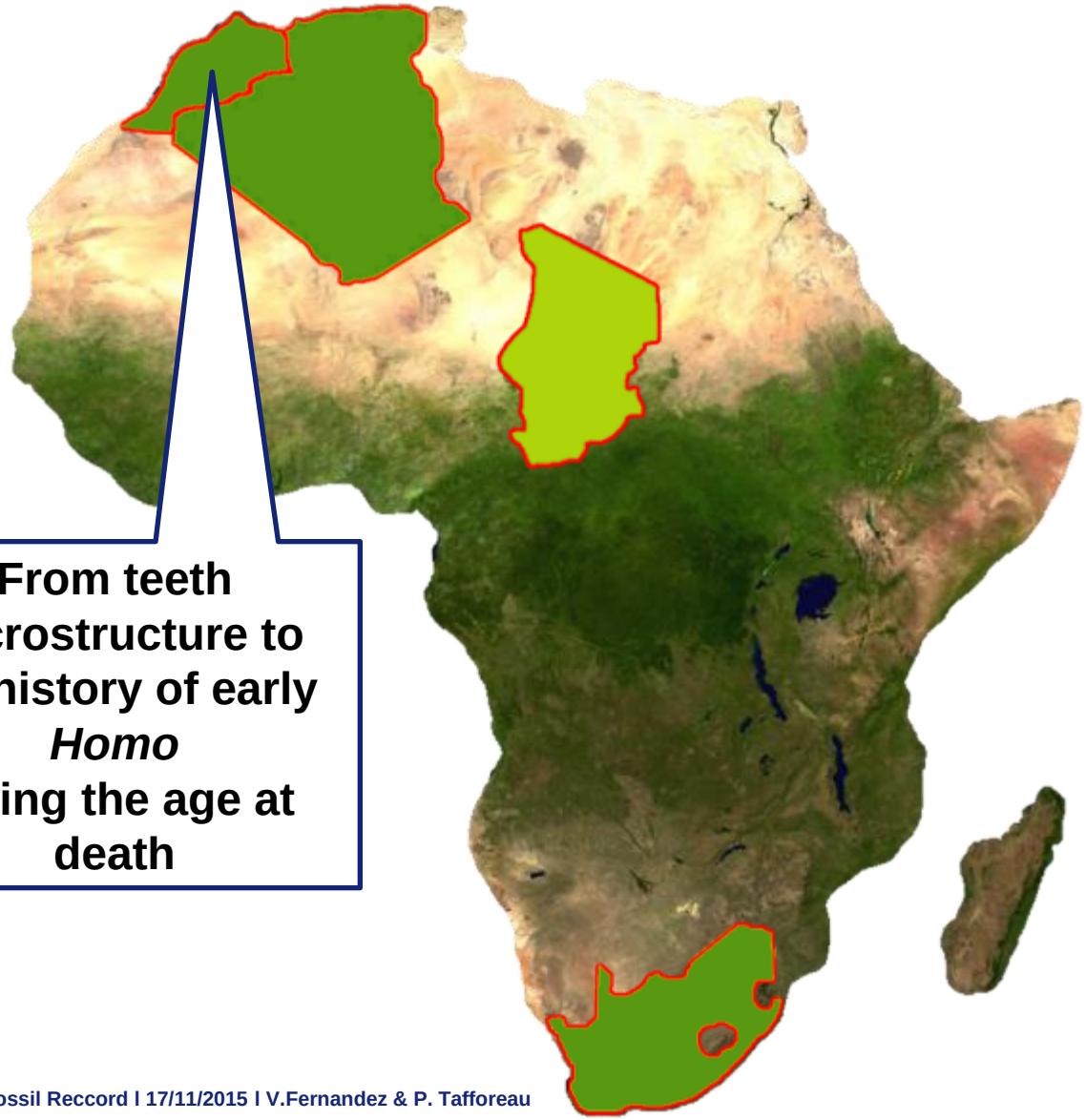
Molar crown thickness, volume, and development in South African Middle Stone Age humans

Tanya M. Smith[a*], Anthony J. Olejniczak[a], Paul Tafforeau[b,c], Donald J. Reid[d], Fredrick E. Grine[e] and Jean-Jacques Hublin[a]









From teeth microstructure to life history of early *Homo* giving the age at death

VISUALIZATION OF DAILY INCREMENTAL LINES

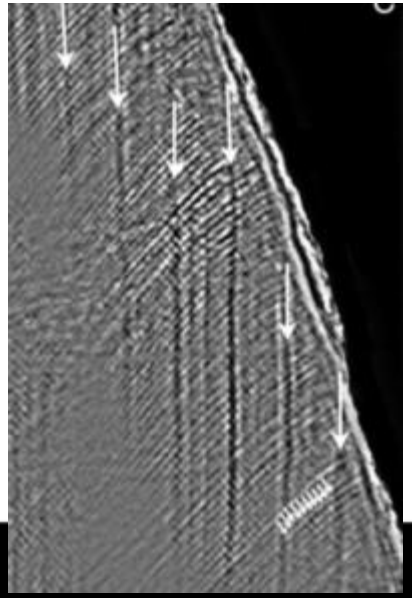
6128–6133 | PNAS | April 10, 2007 | vol. 104 | no. 15

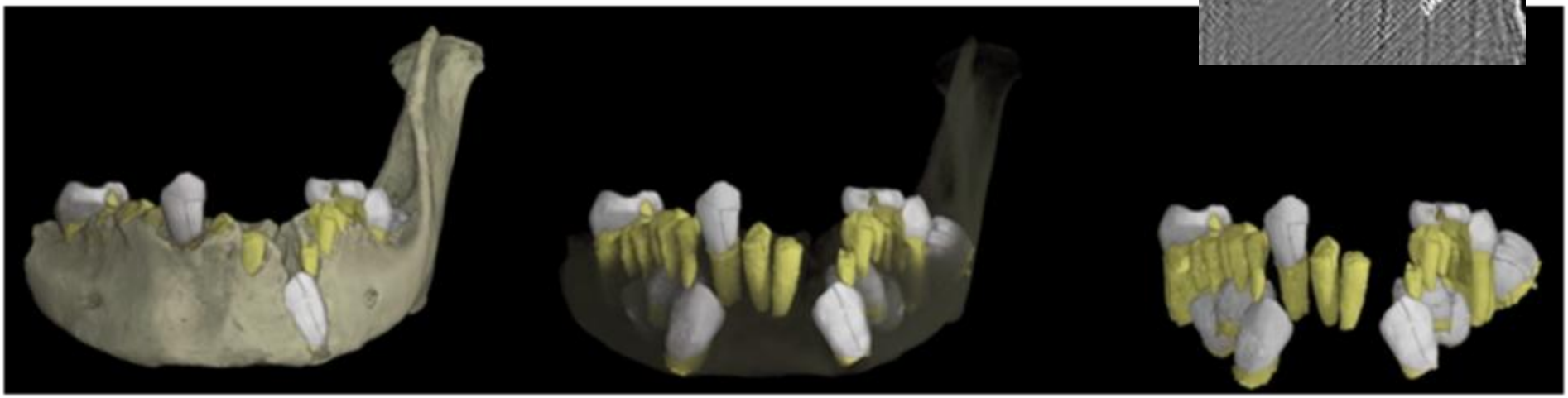
PNAS

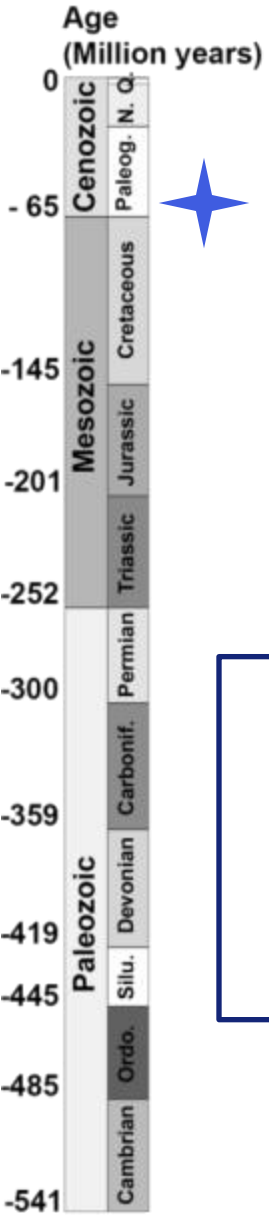
Proceedings of the National Academy of Sciences of the United States of America

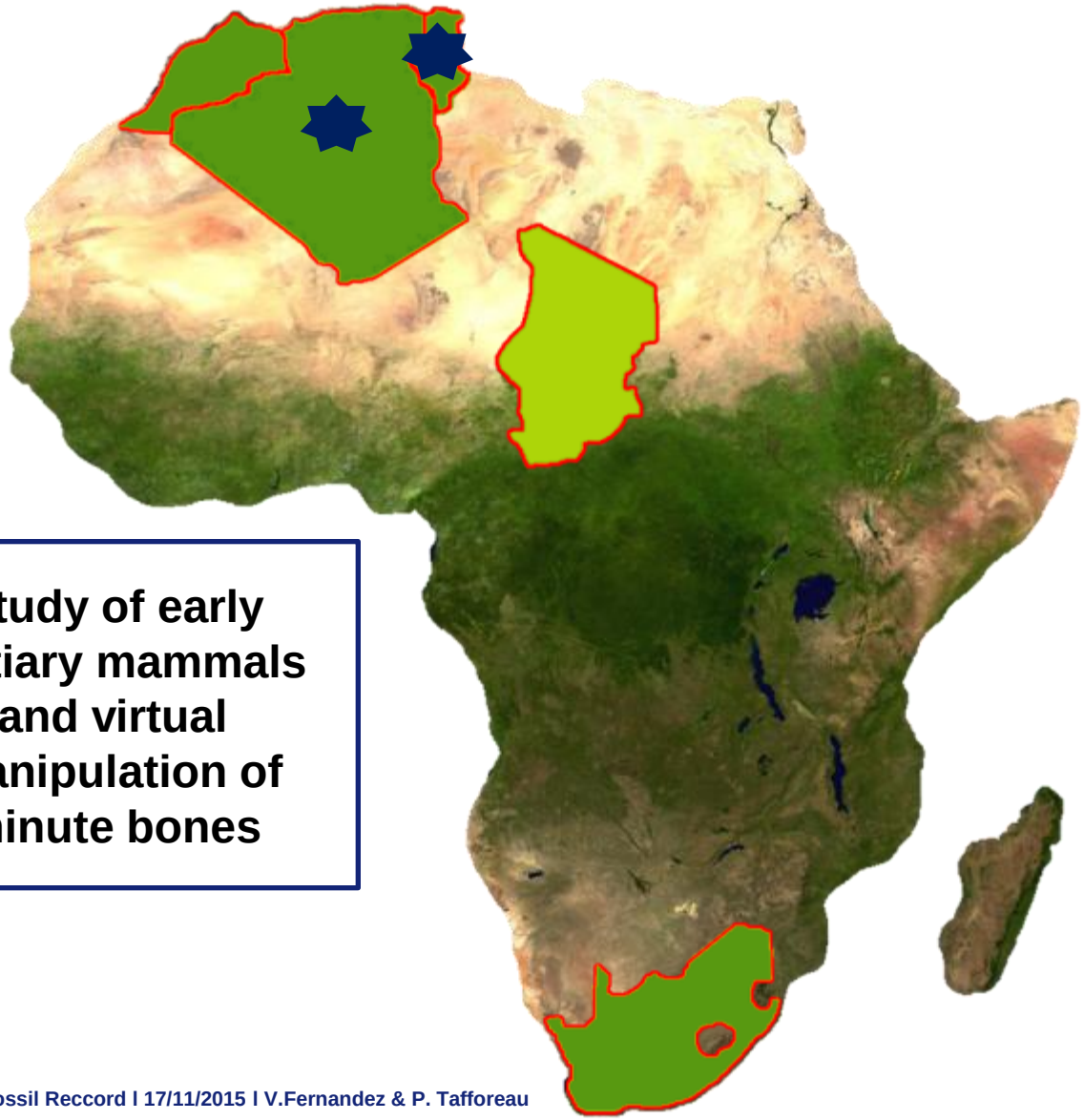
Earliest evidence of modern human life history in North African early *Homo sapiens*

Tanya M. Smith*†, Paul Tafforeau‡§, Donald J. Reid¶, Rainer Grün‖, Stephen Eggins‖, Mohamed Boutakiout**, and Jean-Jacques Hublin*









Study of early Tertiary mammals and virtual manipulation of minute bones

MINUTES BONES AND CHARACTERIZATION OF SYMMETRY

PROCEEDINGS OF THE ROYAL SOCIETY B
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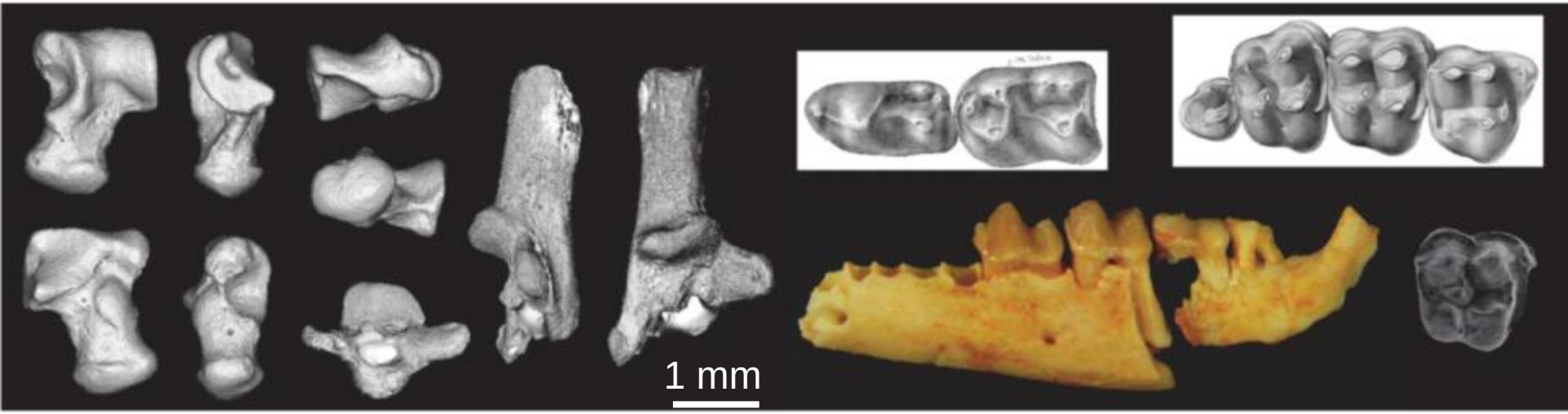
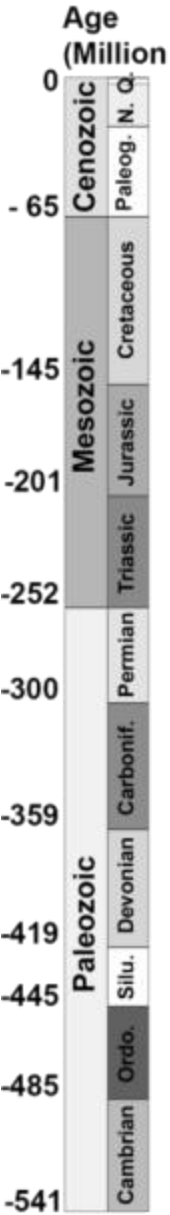
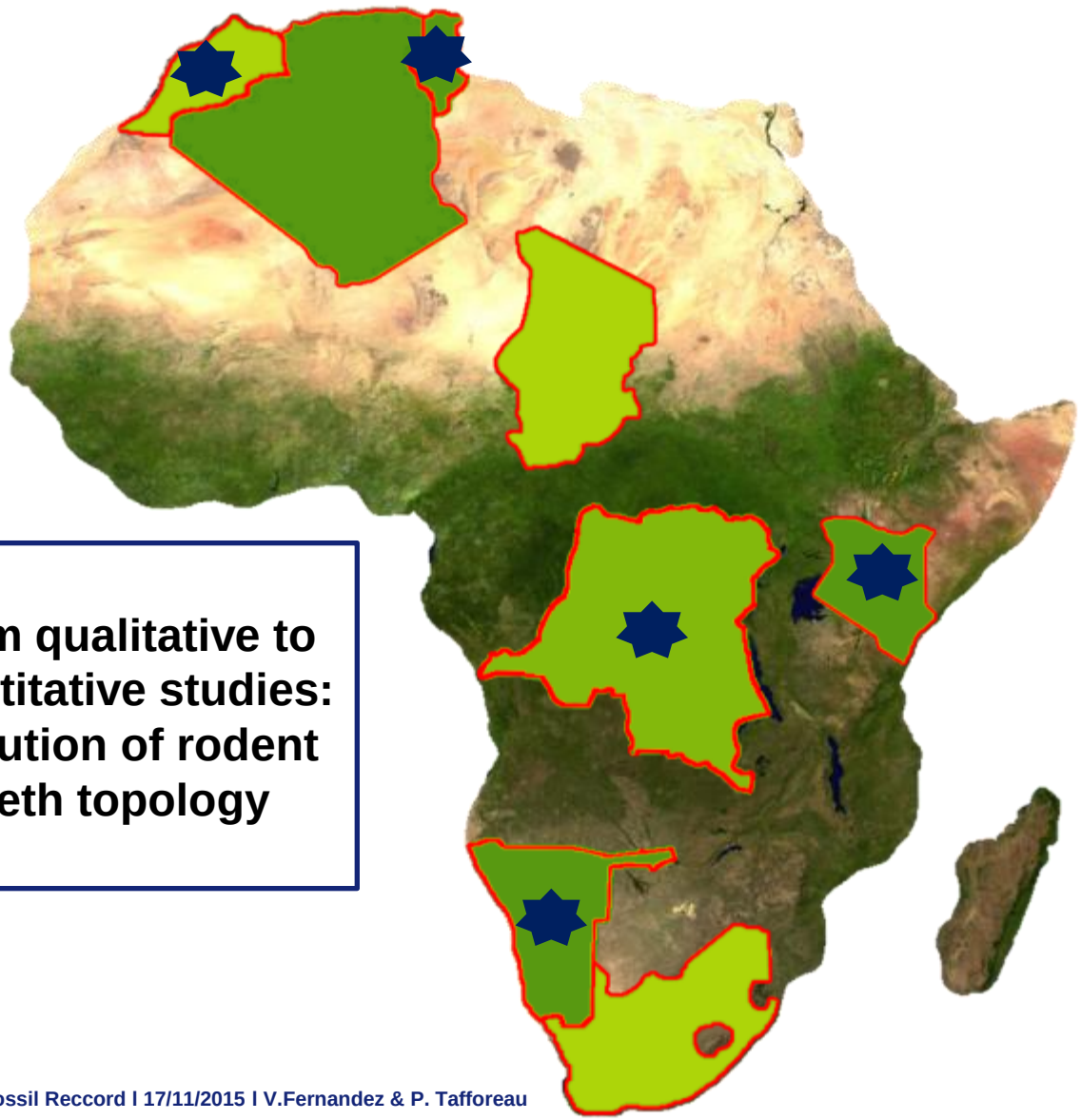
Proc. R. Soc. B
doi:10.1098/rspb.2006.0229
Published online

Early Tertiary mammals from North Africa reinforce the molecular Afrotheria clade

Rodolphe Tabuce[1,*], Laurent Marivaux[1], Mohammed Adaci[2], Mustapha Bensalah[2], Jean-Louis Hartenberger[1], Mohammed Mahboubi[3], Fateh Mebrouk[3,4], Paul Tafforeau[5,6] and Jean-Jacques Jaeger[5]







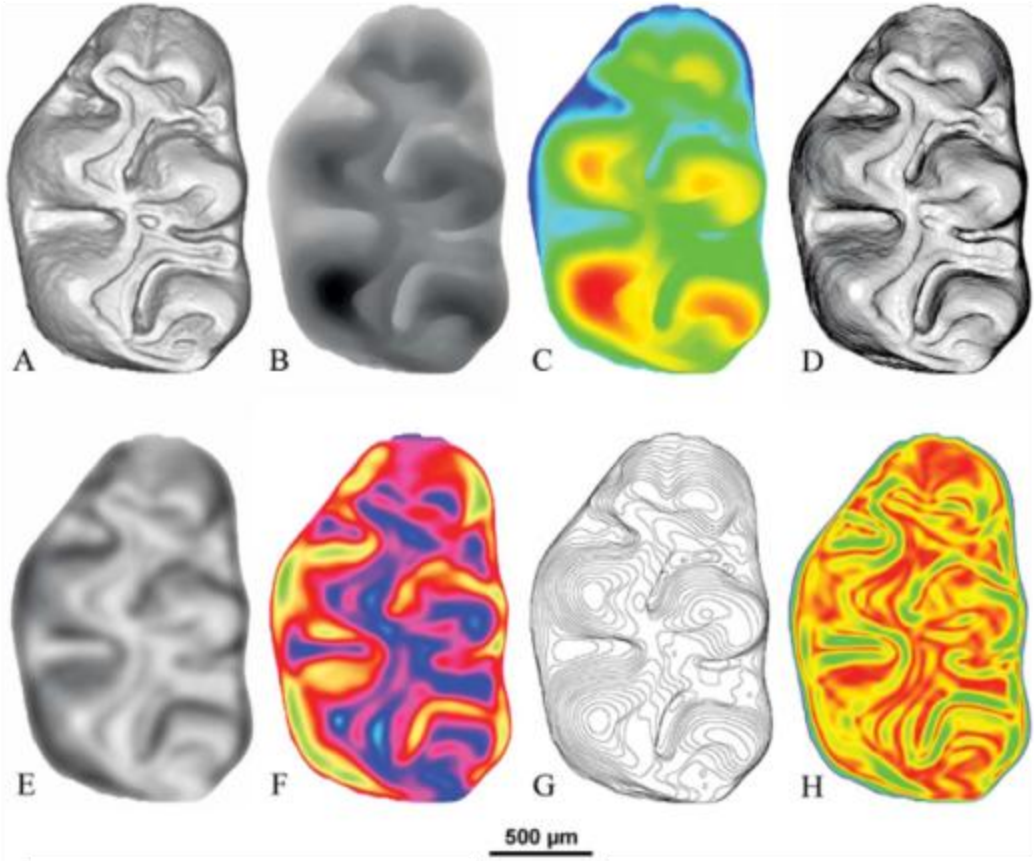
From qualitative to quantitative studies: evolution of rodent teeth topology

QUANTITATIVE ANALYSIS ON TEETH TOPOGRAPHY

Paleobiology, 34(1), 2008, pp. 46–64

Topographic maps applied to comparative molar morphology: the case of murine and cricetine dental plans (Rodentia, Muroidea)

Vincent Lazzari, Paul Tafforeau, Jean-Pierre Aguilar, and Jacques Michaux



QUANTITATIVE ANALYSIS ON TEETH TOPOGRAPHY

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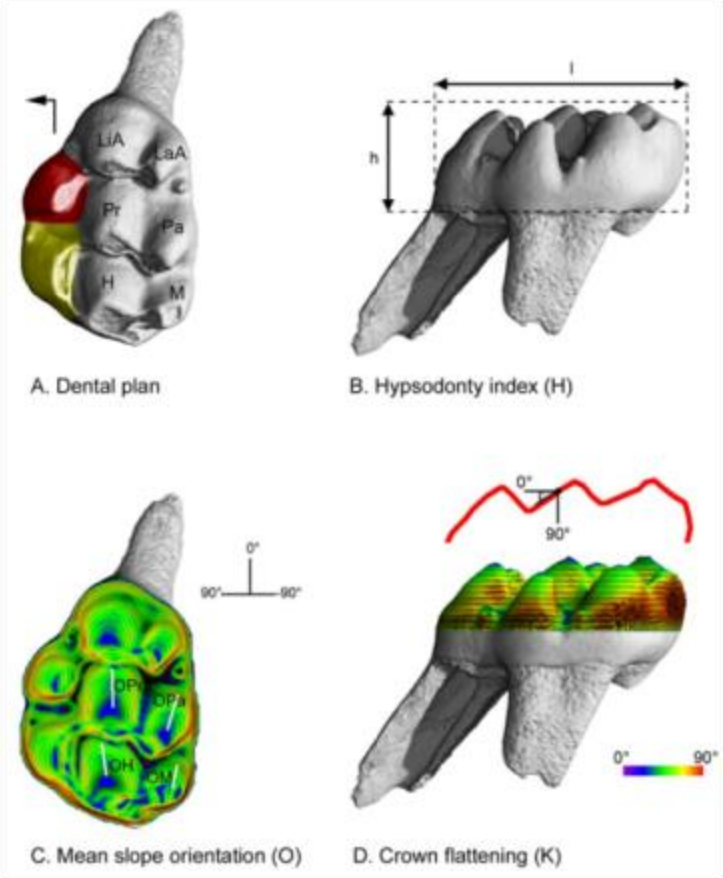
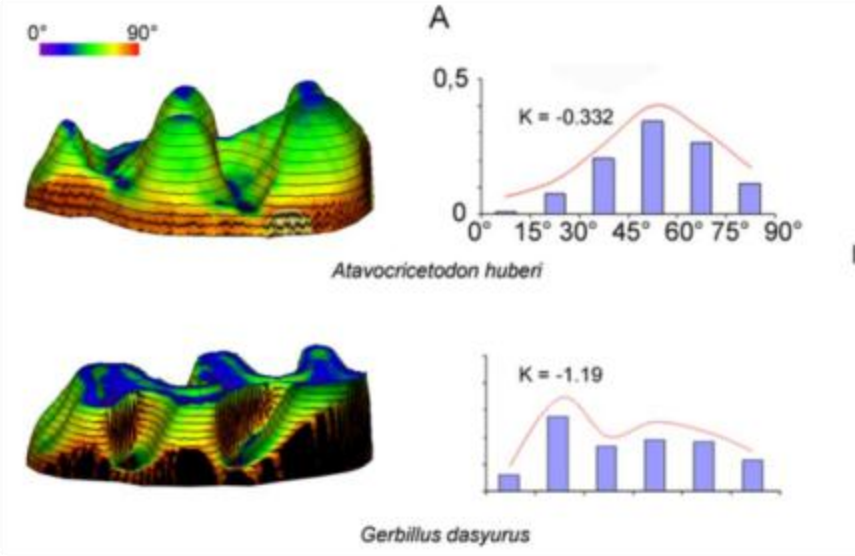
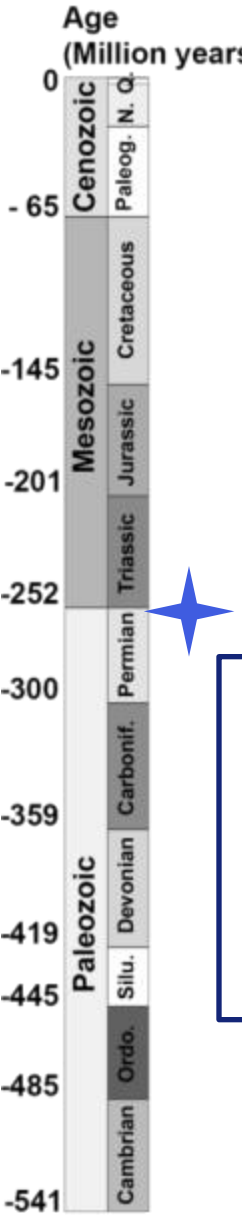
PLoS one

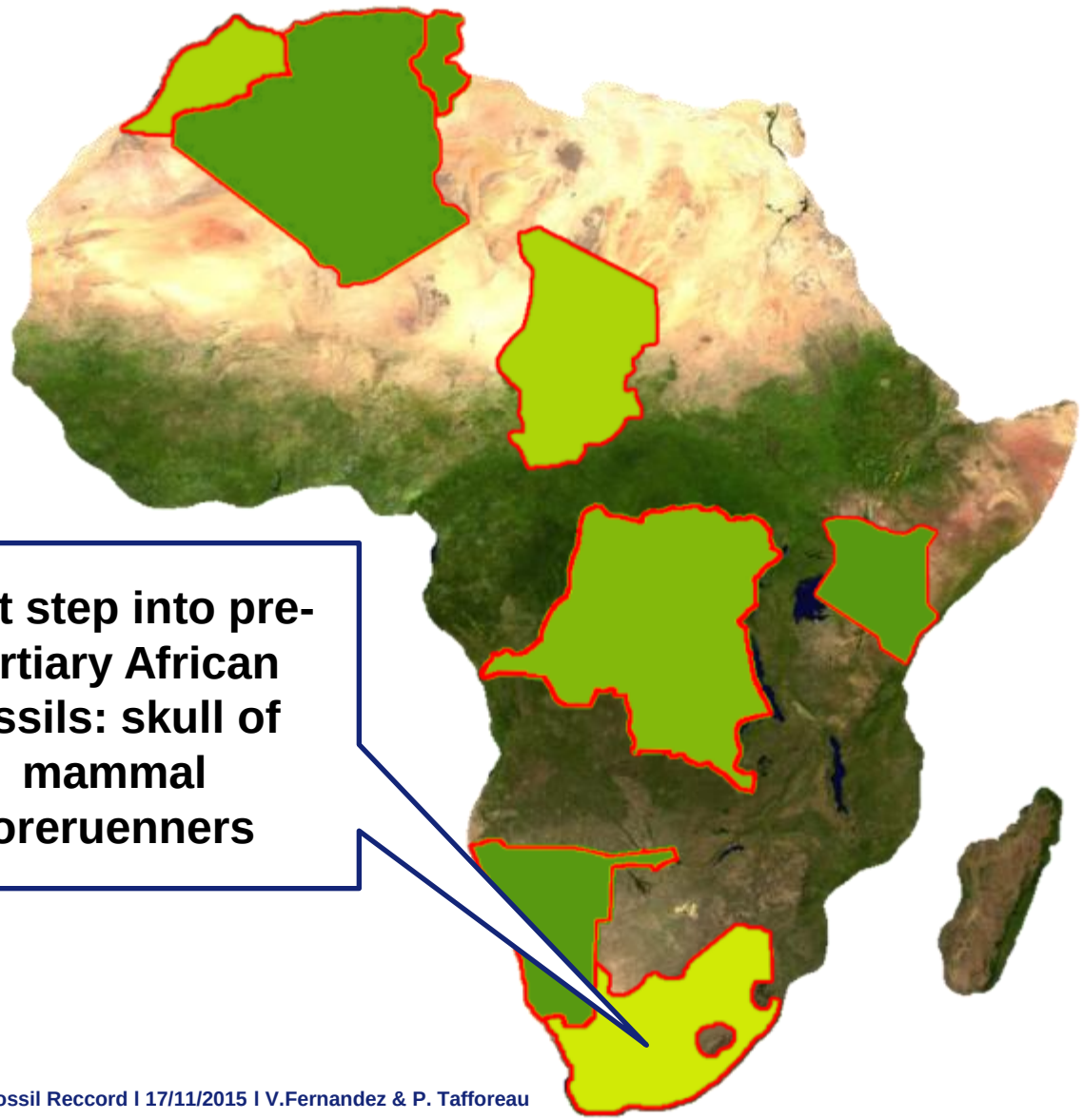
Mosaic Convergence of Rodent Dentitions

Vincent Lazzari[1,2¤*], Cyril Charles[3], Paul Tafforeau[2], Monique Vianey-Liaud[1], Jean-Pierre Aguilar[1], Jean-Jacques Jaeger[3], Jacques Michaux[4], Laurent Viriot[5*]

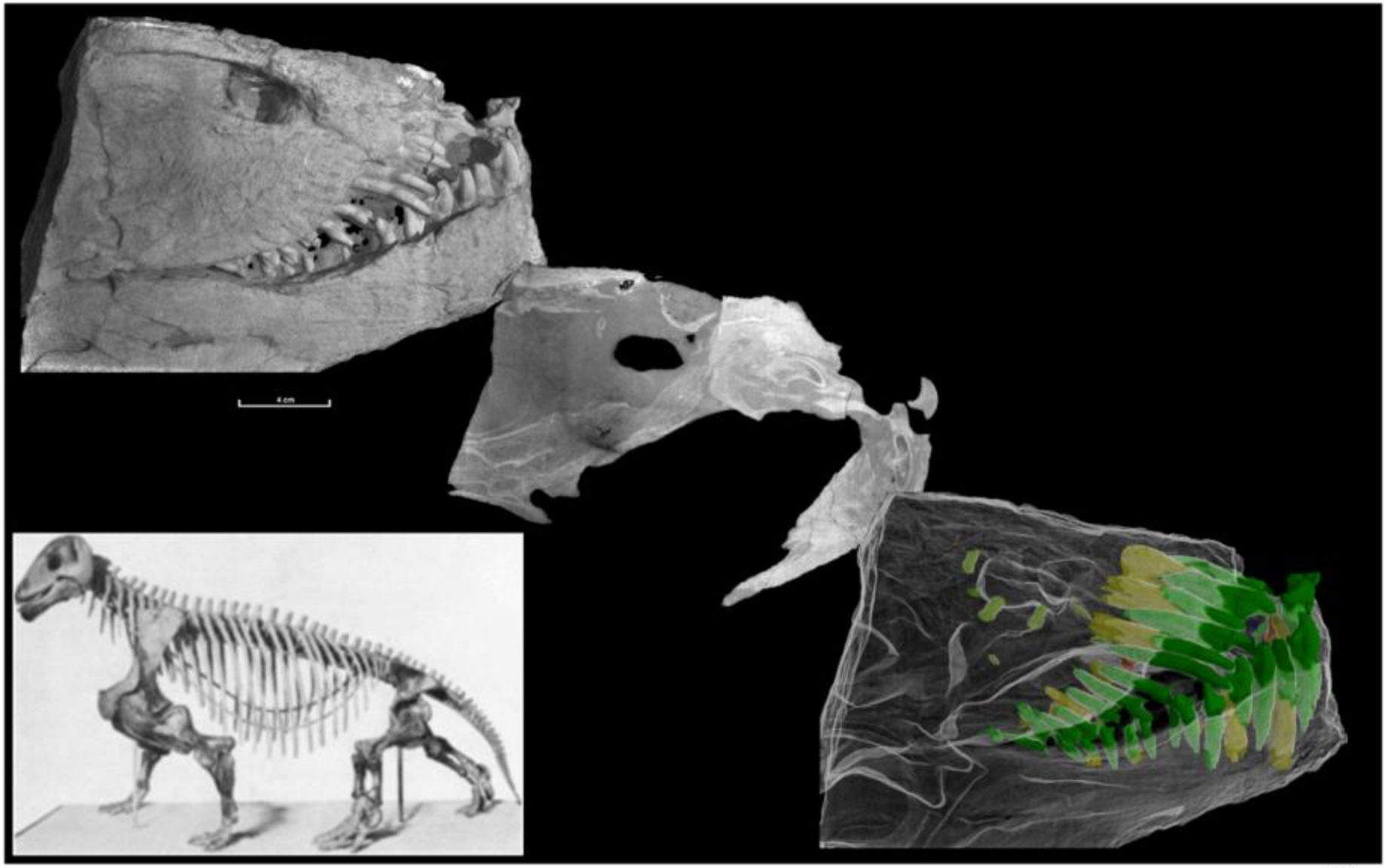








First step into pre-Tertiary African fossils: skull of mammal foreruenners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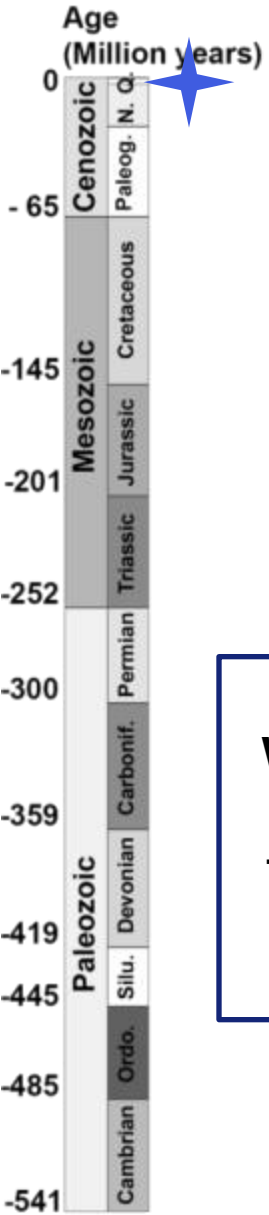
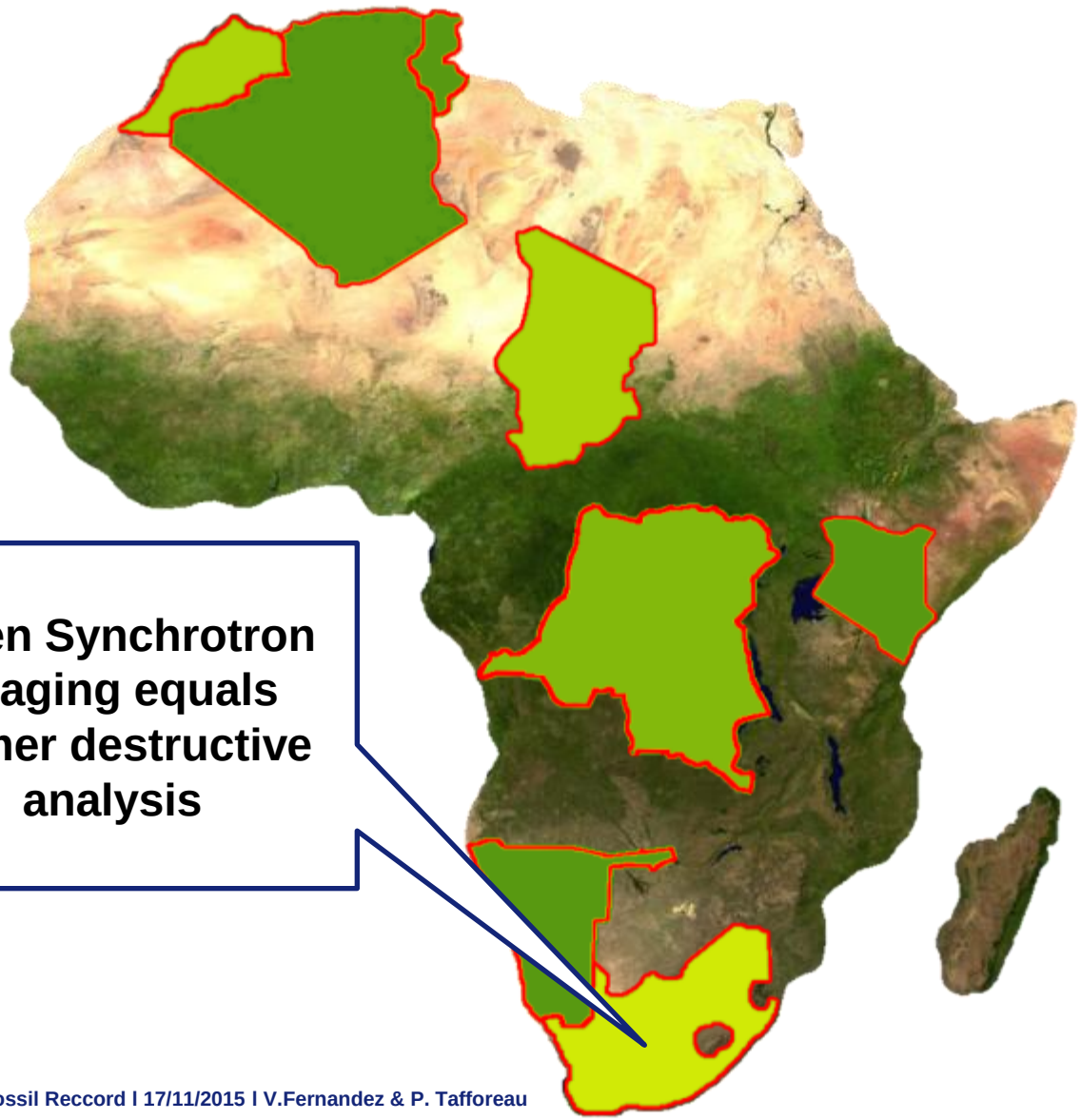




When Synchrotron imaging equals former destructive analysis

VIRTUAL HISTOLOGY COMPARED TO INVASIVE TECHNIQUES

ELSEVIER

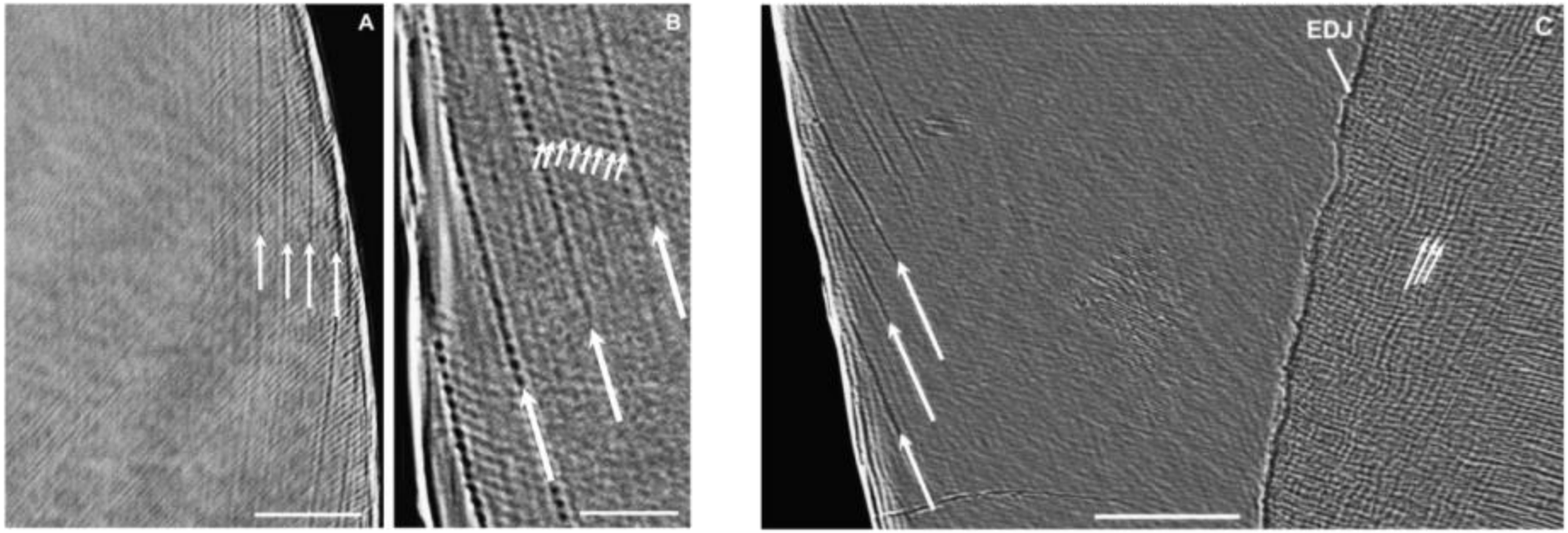
Journal of Human Evolution 54 (2008) 272–278

JHE

News and Views

Nondestructive imaging of hominoid dental microstructure using phase contrast X-ray synchrotron microtomography

Paul Tafforeau [a,b,*], Tanya M. Smith [c]



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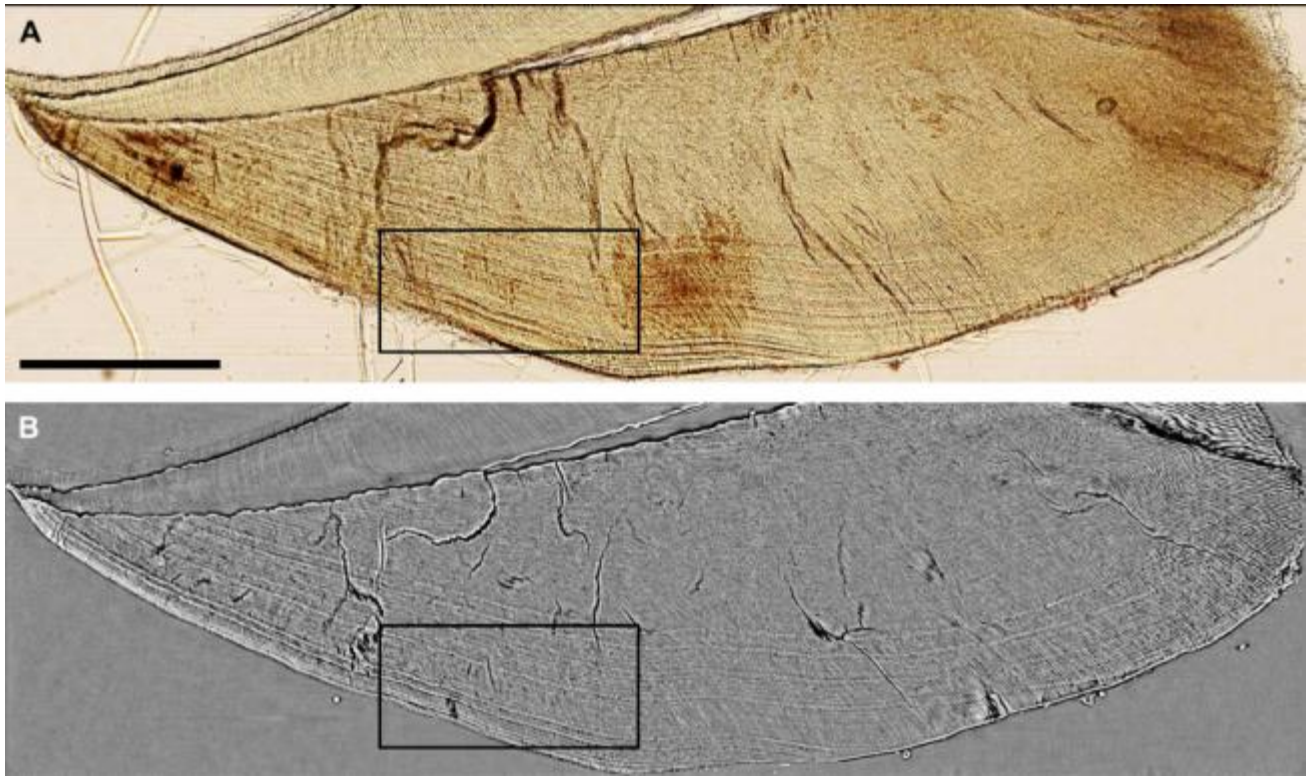

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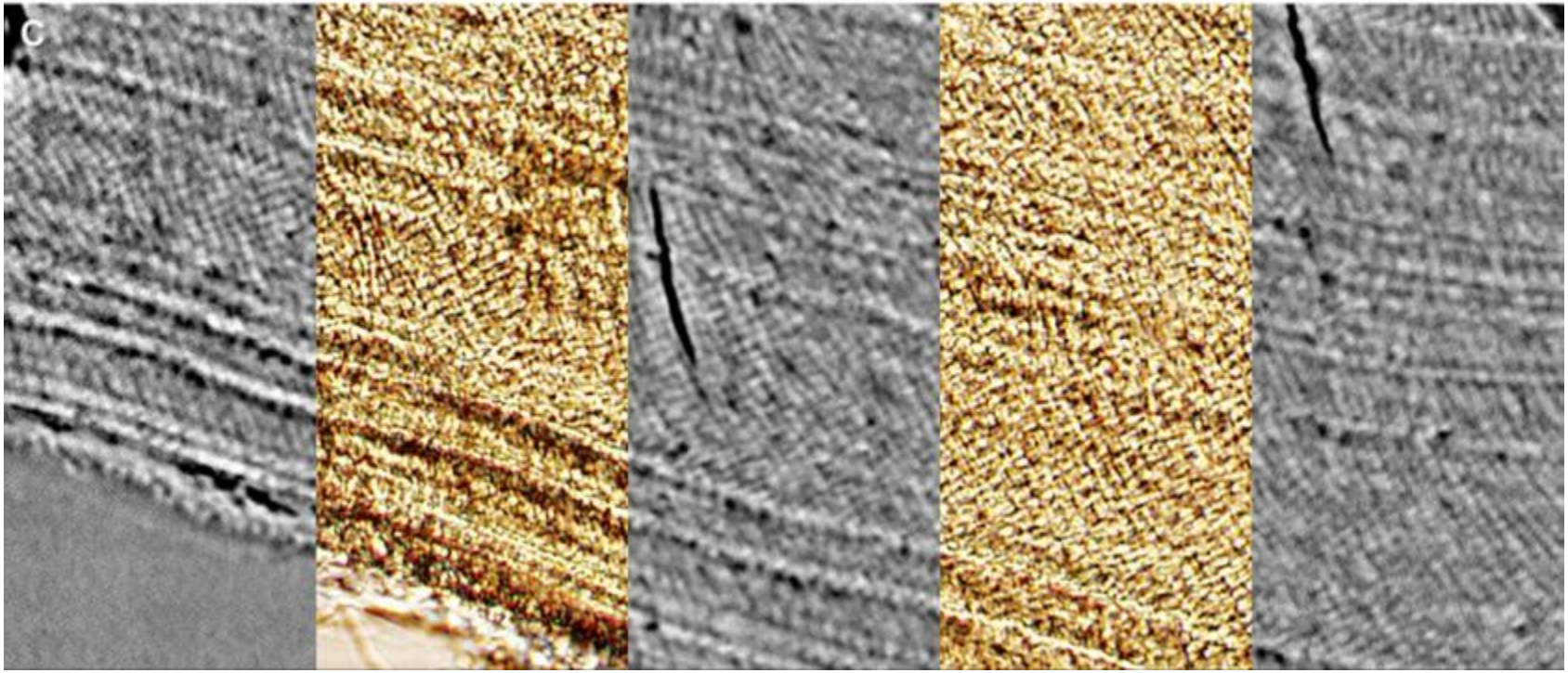
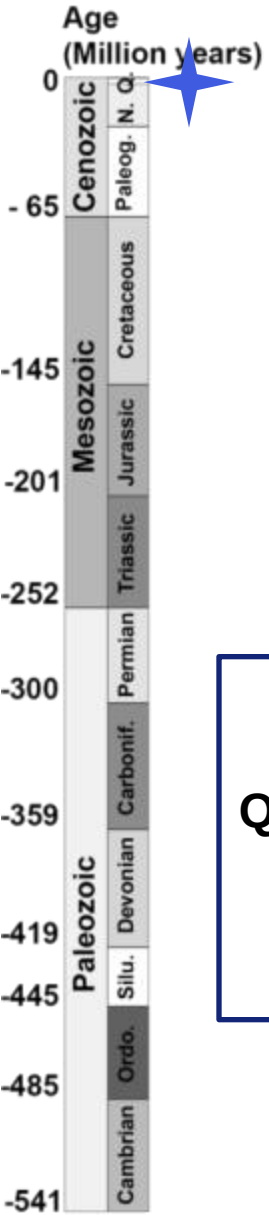
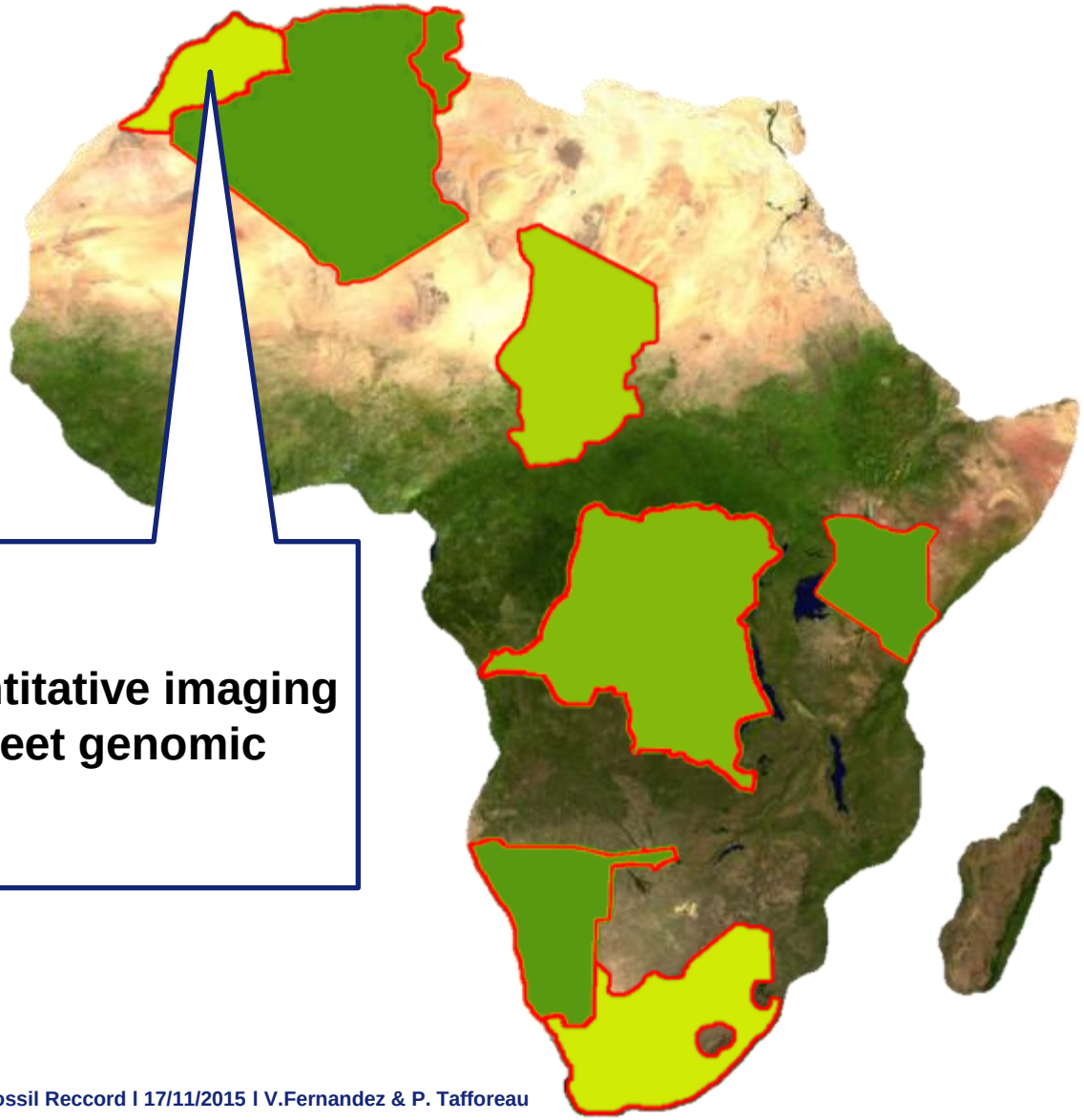






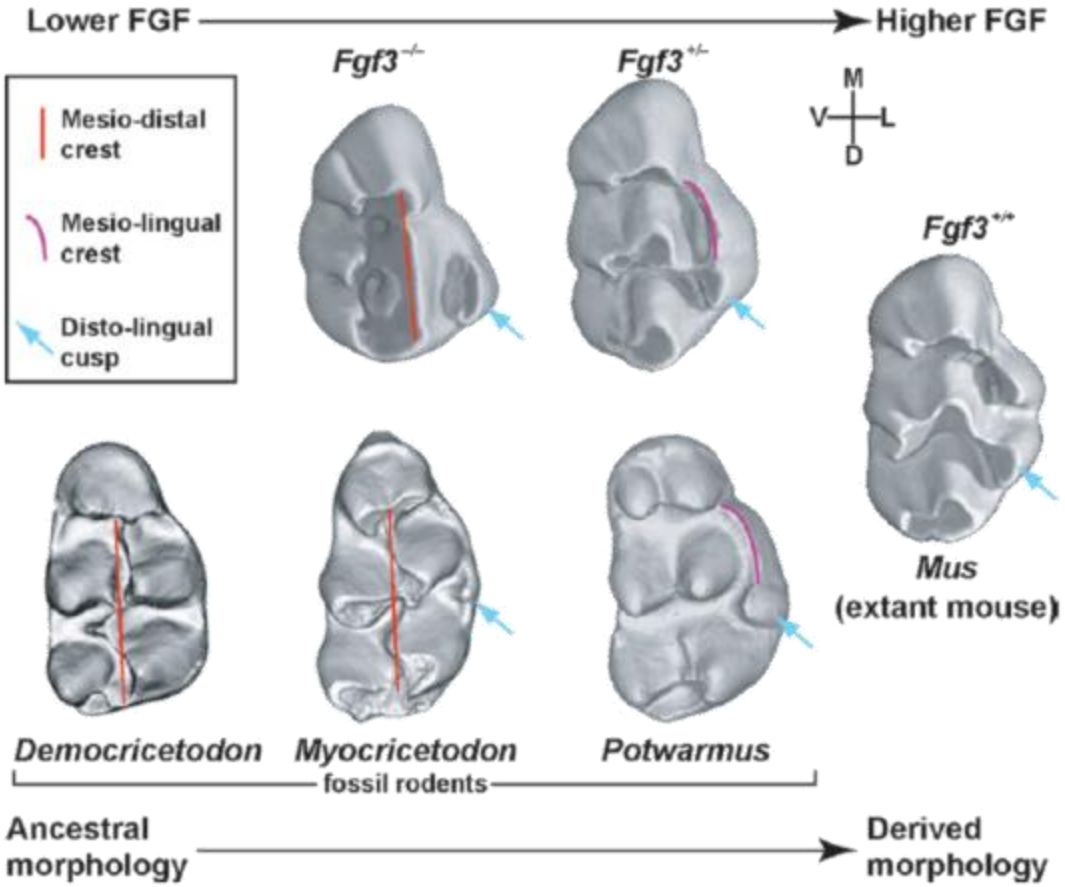
Quantitative imaging meet genomic

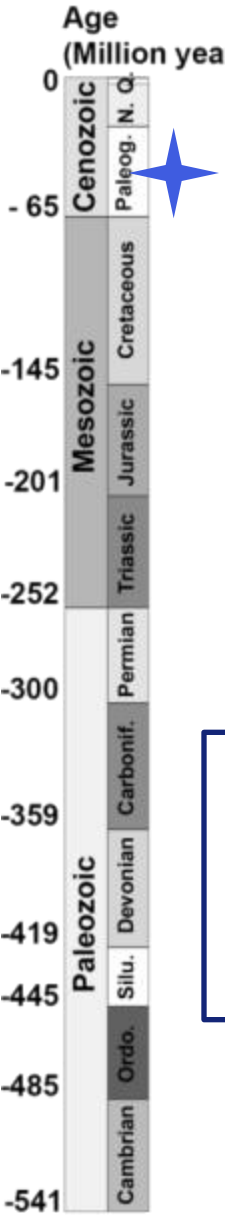
EVO-DEVO STUDIES

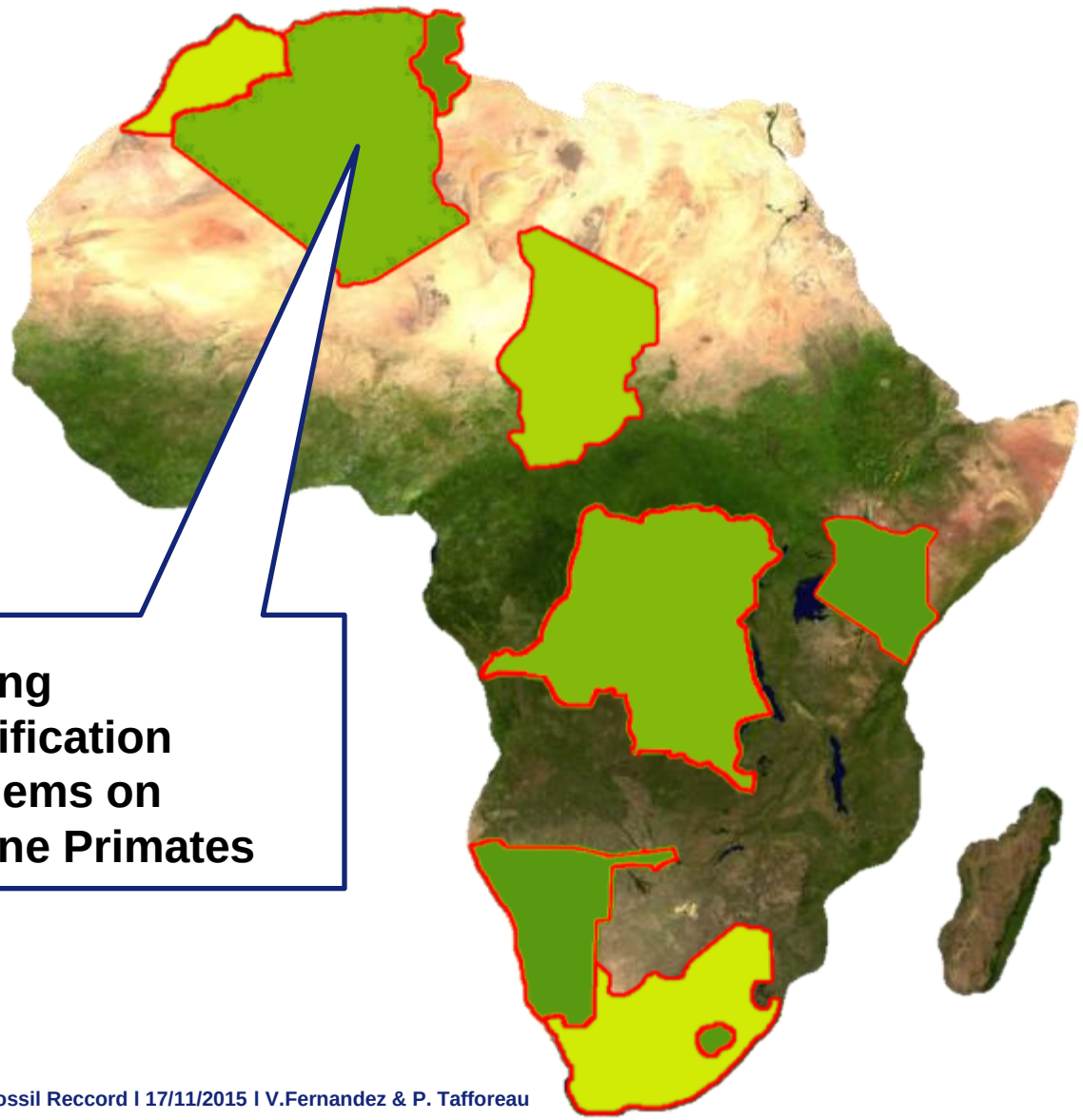
Modulation of *Fgf3* dosage in mouse and men mirrors evolution of mammalian dentition

Cyril Charles[a], Vincent Lazzari[b,1], Paul Tafforeau[c], Thomas Schimmang[d], Mustafa Tekin[e], Ophir Klein[a,2,3], and Laurent Viriot[f,2,3]

PNAS
Proceedings of the National Academy of Sciences of the United States of America







Solving identification problems on Eocene Primates

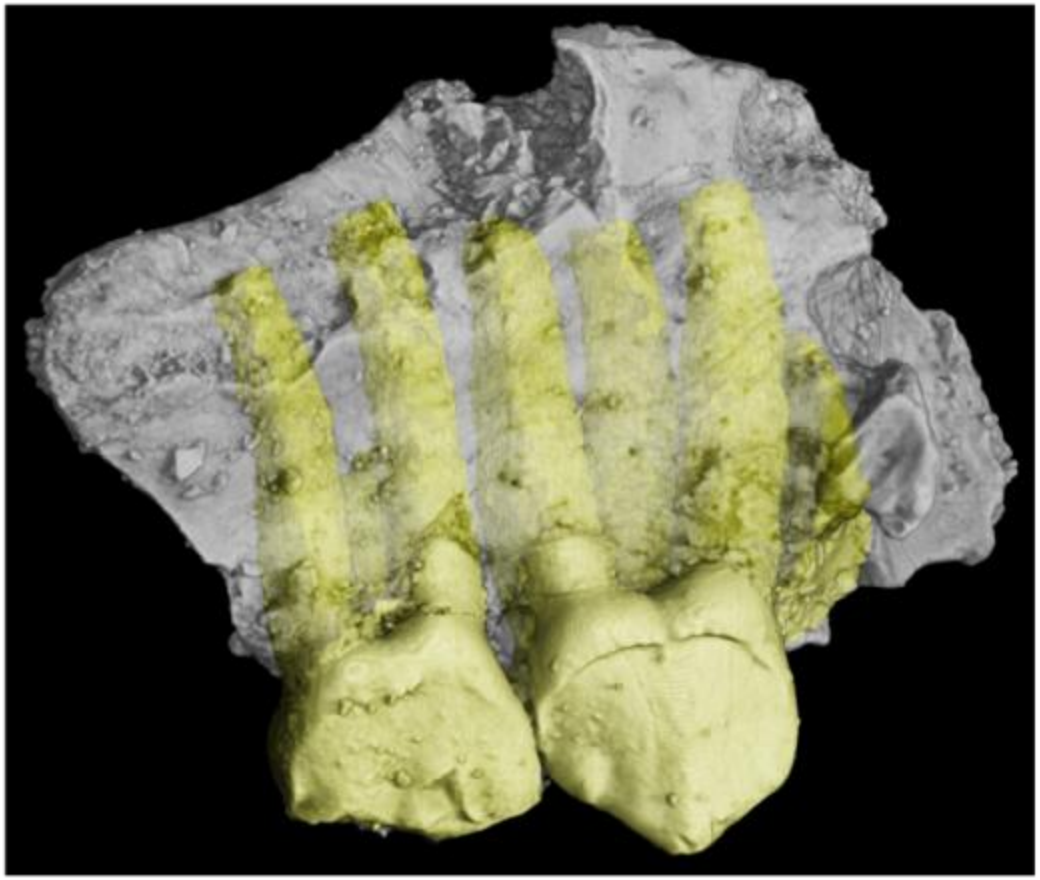
ACCESSING HIDDEN STRUCTURE TO UNDERSTAND EVOLUTION

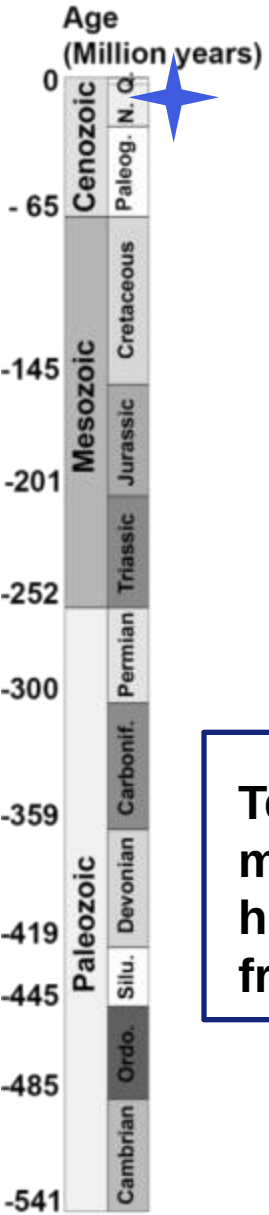
PROCEEDINGS OF THE ROYAL SOCIETY B

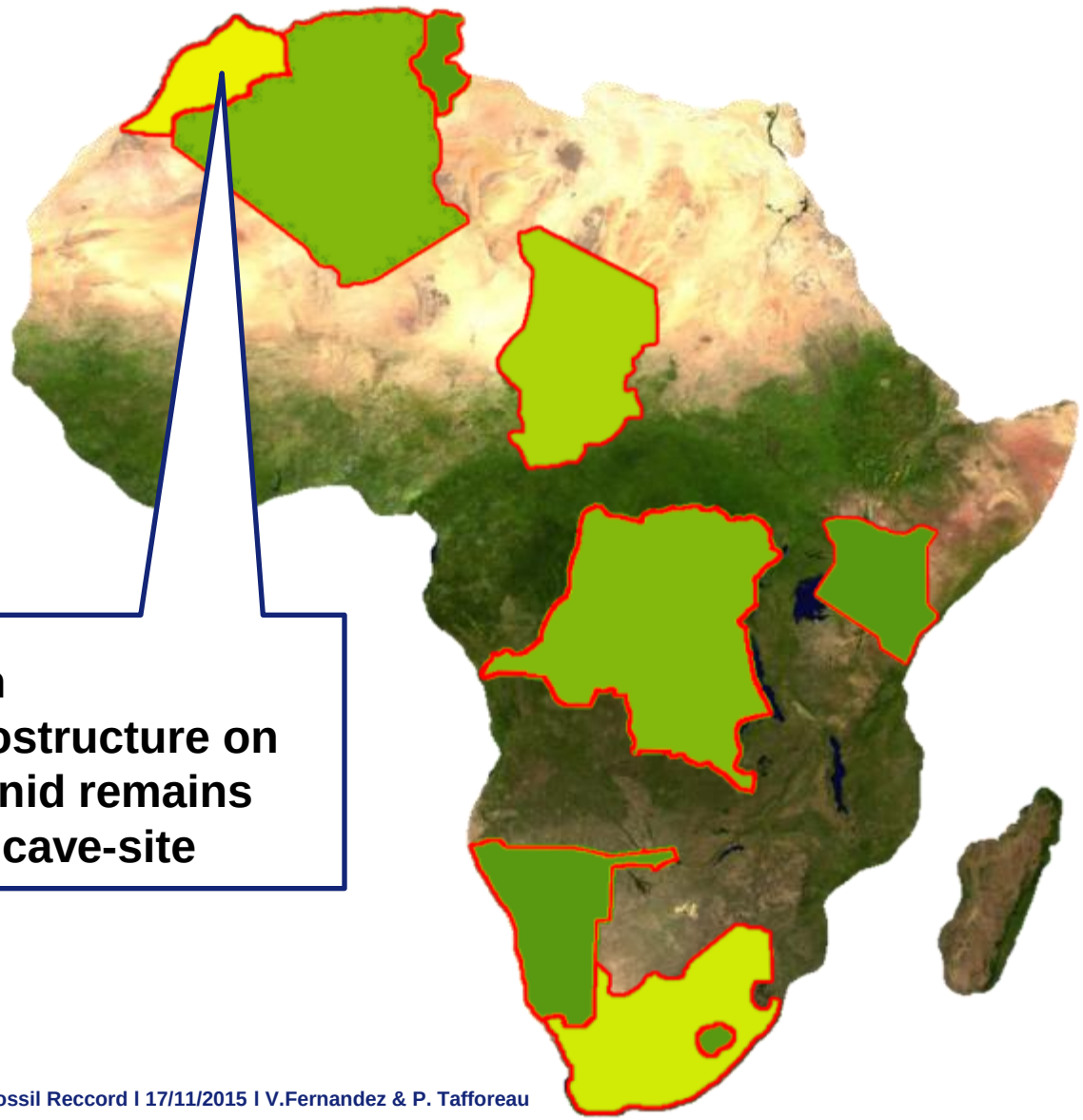
Proc. R. Soc. B (2009) **276**, 4087–4094
doi:10.1098/rspb.2009.1339
Published online 9 September 2009

Anthropoid *versus* strepsirhine status of the African Eocene primates *Algeripithecus* and *Azibius*: craniodental evidence

R. Tabuce, L. Marivaux, R. Lebrun, M. Adaci, M. Bensalah, P.H. Fabre, E. Fara, H. Gomes Rodrigues, L. Hautier, J.-J. Jaeger, V. Lazzari, F. Mebrouk, S. Peigné, J. Sudre, P. Tafforeau, X. Valentin & M. Mahboubi







Teeth microstructure on hominid remains from cave-site

NON-INVASIVE APPROACH ON UNIQUE SPECIMEN

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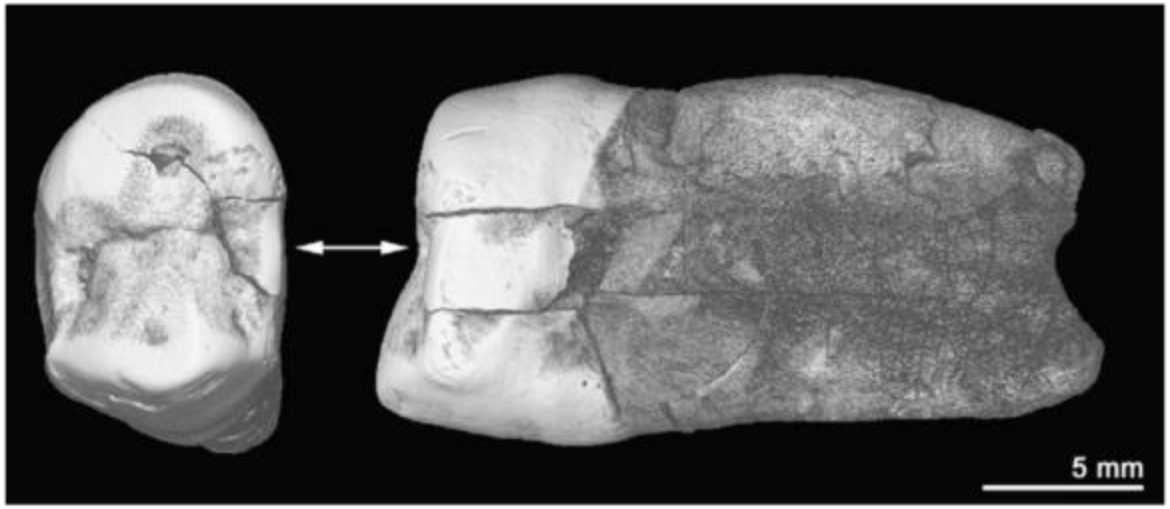
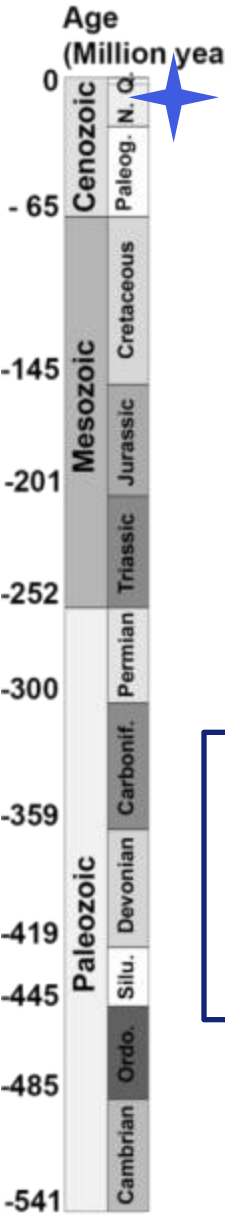
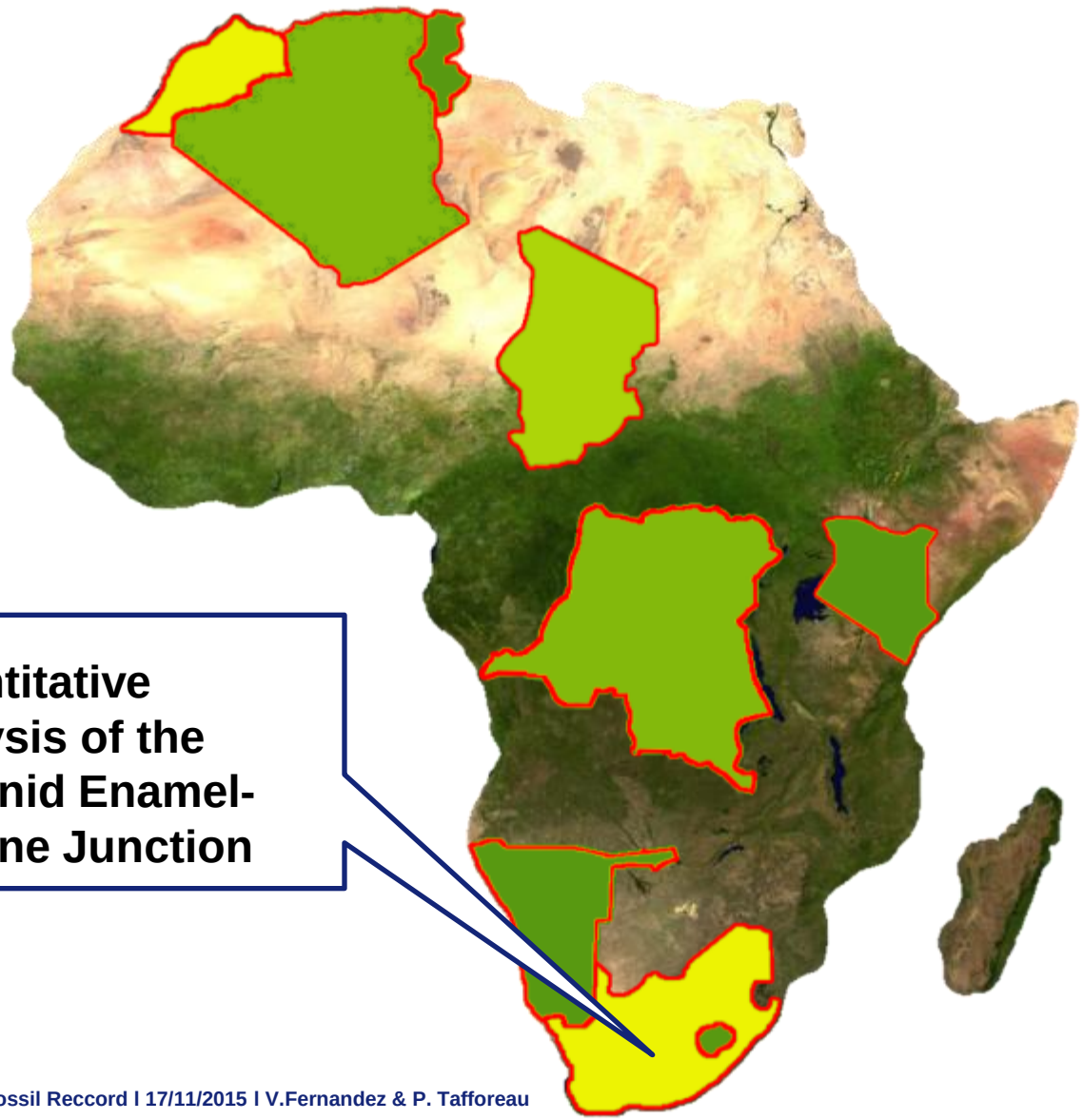
Hominid Cave at Thomas Quarry I (Casablanca, Morocco): Recent findings and their context

Jean-Paul Raynal [a,e,*], Fatima-Zohra Sbihi-Alaoui [b], Abderrahim Mohib [b], Mosshine El Graoui [b], David Lefèvre [c], Jean-Pierre Texier [a], Denis Geraads [d], Jean-Jacques Hublin [e], Tanya Smith [e,f], Paul Tafforeau [g,h], Mehdi Zouak [b], Rainer Grün [i], Edward J. Rhodes [j], Stephen Eggins [i], Camille Daujeard [a], Paul Fernandes [a], Rosalia Gallotti [k], Saïda Hossini [l], Alain Queffelec [a]





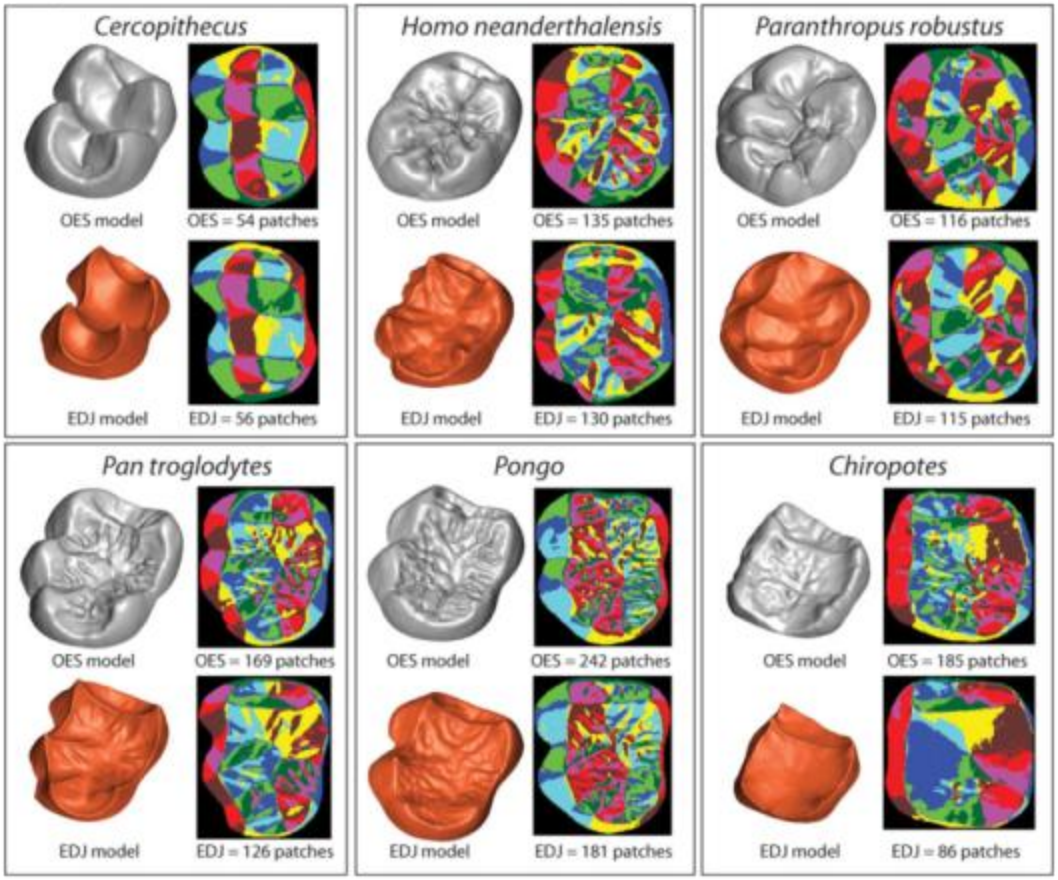


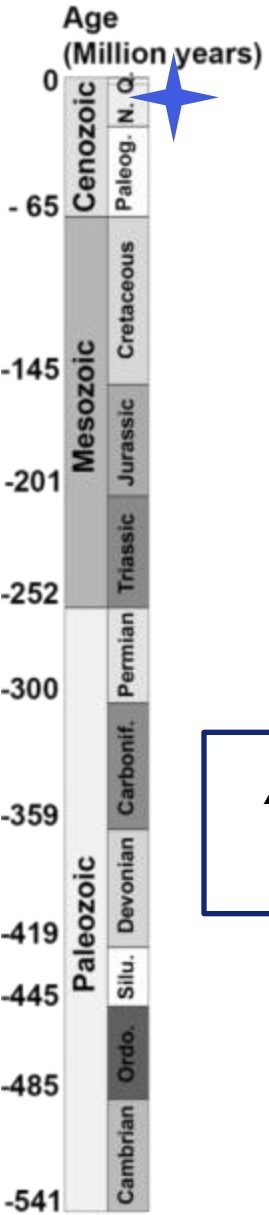
Quantitative analysis of the hominid Enamel-dentine Junction

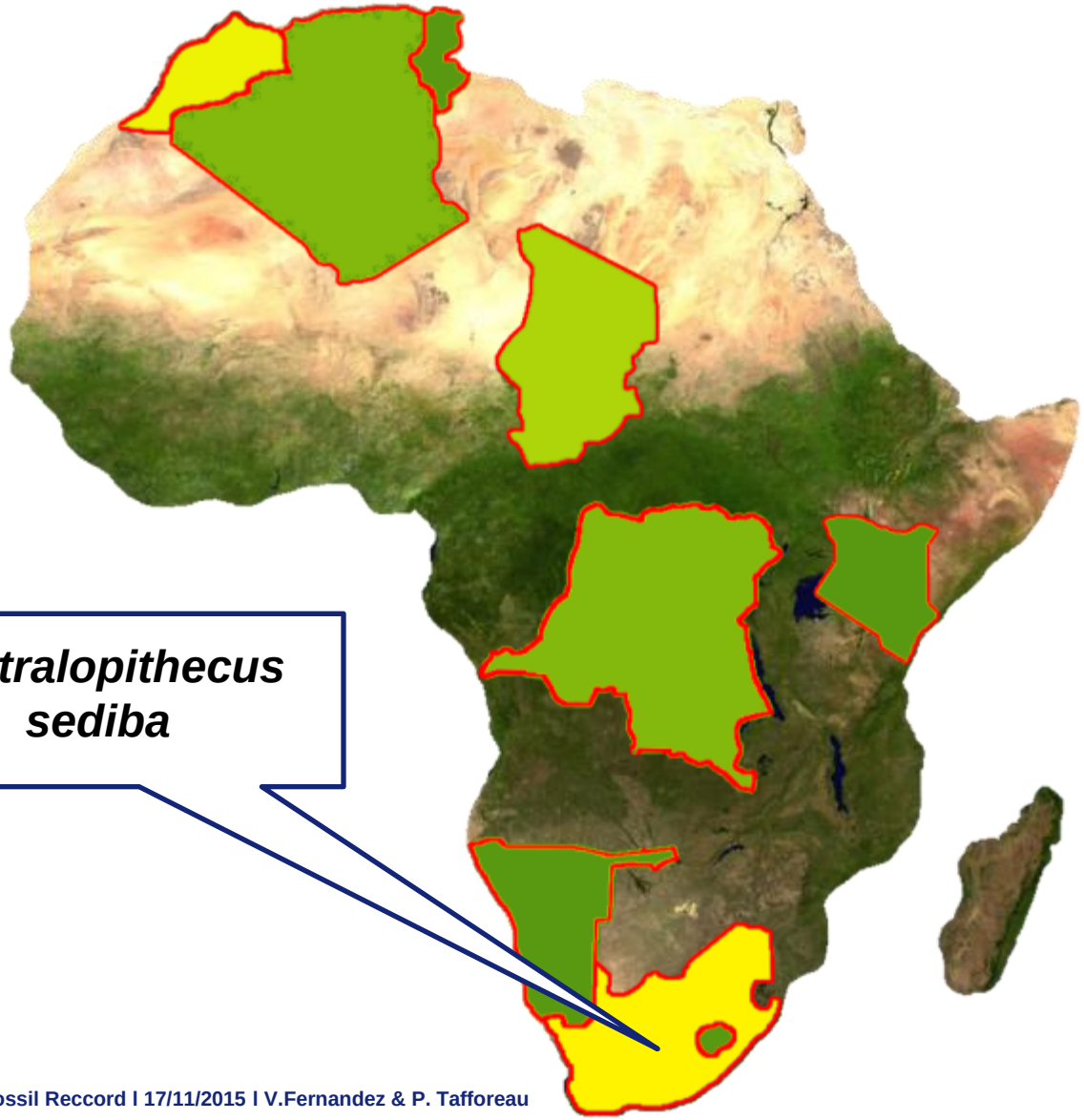
AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY 142:157–163 (2010)

Brief Communication: Contributions of Enamel-Dentine Junction Shape and Enamel Deposition to Primate Molar Crown Complexity

Matthew M. Skinner,[1*] Alistair Evans,[2] Tanya Smith,[1,3] Jukka Jernvall,[4,5] Paul Tafforeau,[6] Kornelius Kupczik,[1] Anthony J. Olejniczak,[1,7] Antonio Rosas,[8] Jakov Radovčić,[9] J. Francis Thackeray,[10] Michel Toussaint,[11] and Jean-Jacques Hublin[1]







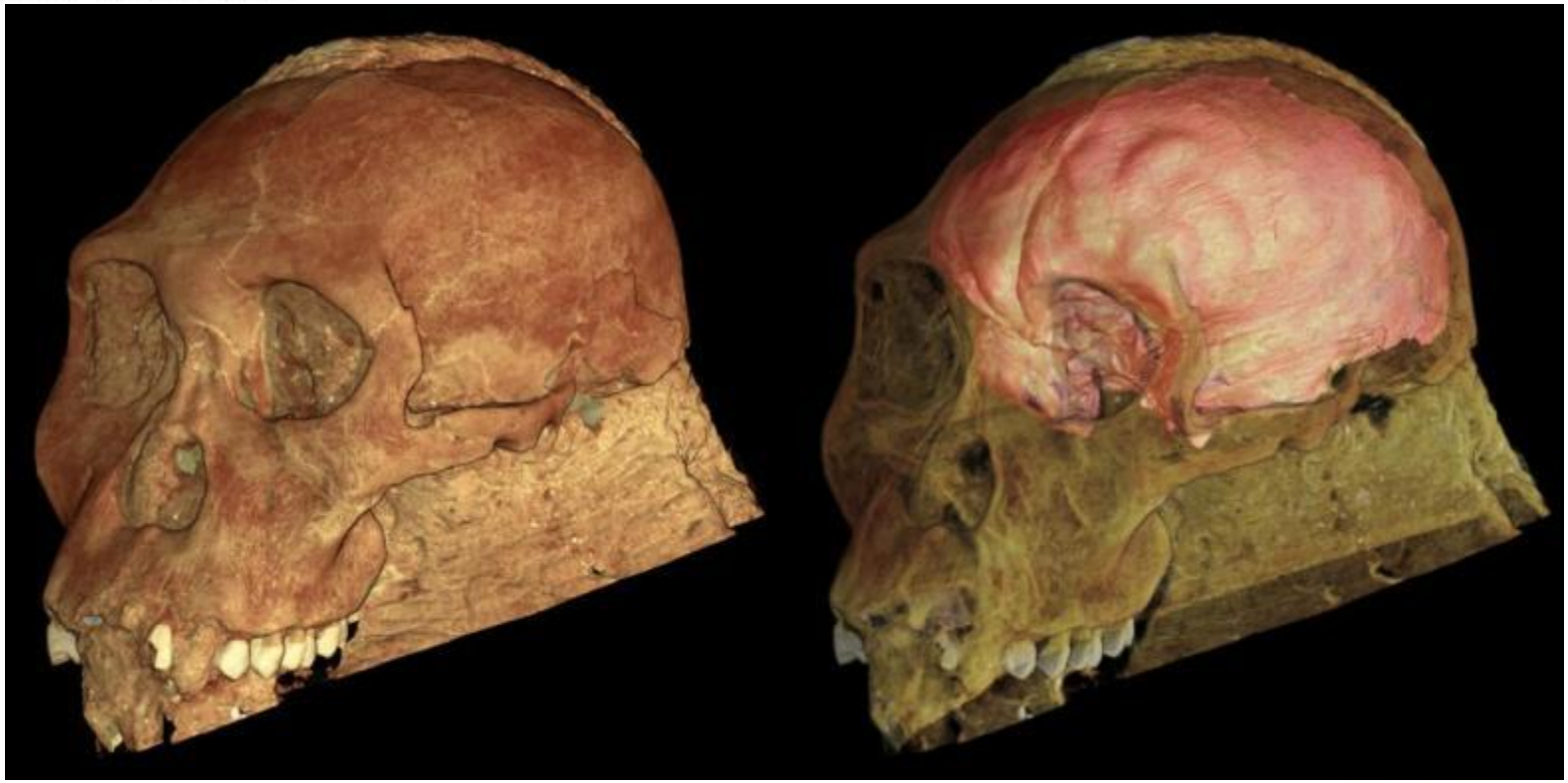
Australopithecus sediba

REPORTS

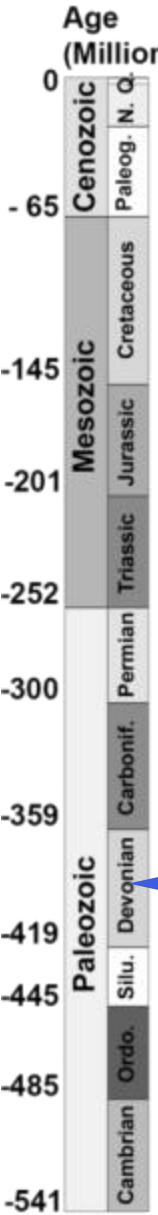
The Endocast of MH1, *Australopithecus sediba*

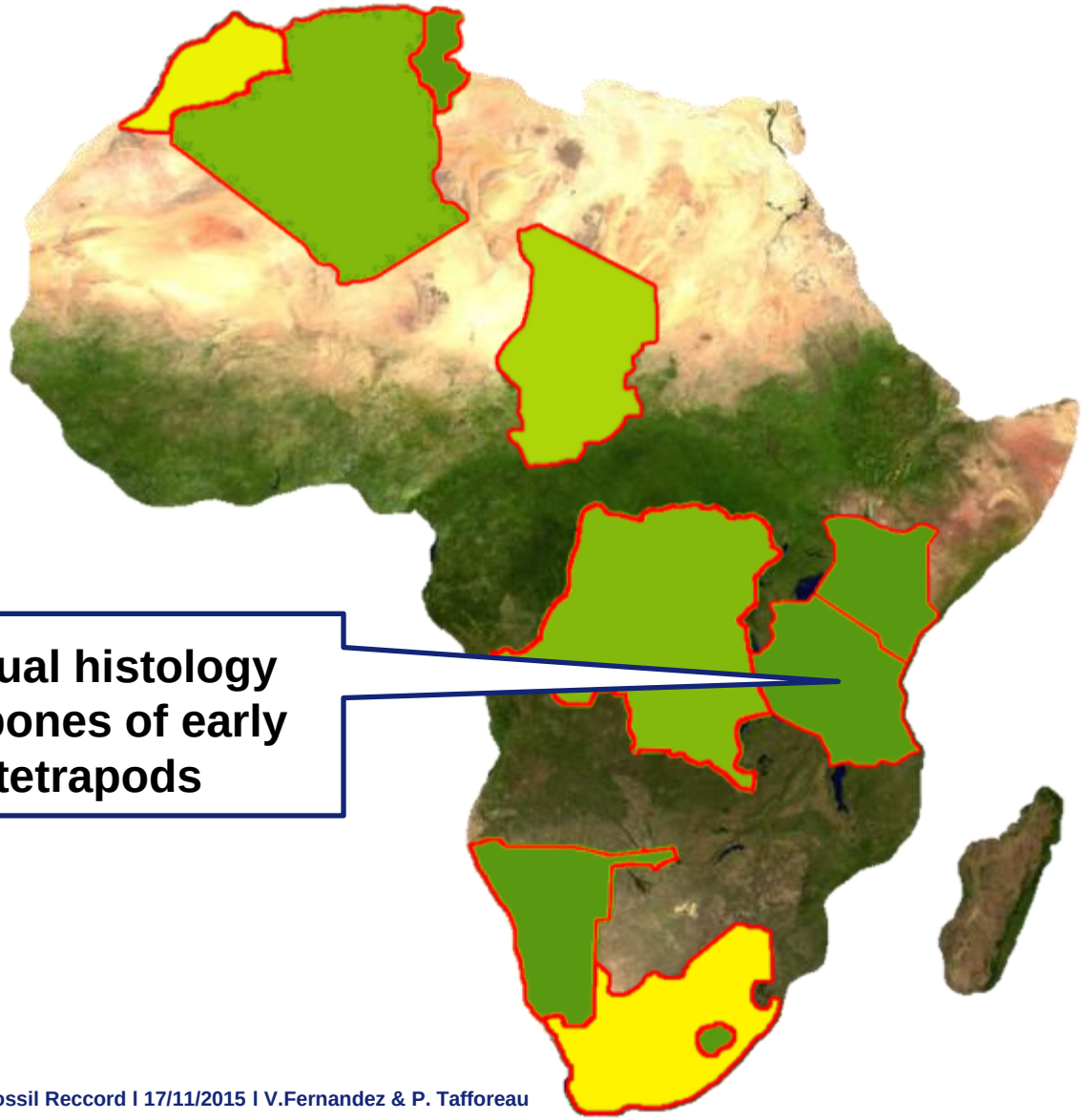
Science **333**, 1402 (2011);

Kristian J. Carlson,[1,2]* Dietrich Stout,[3] Tea Jashashvili,[1,4,5] Darryl J. de Ruiter,[1,6] Paul Tafforeau,[7] Keely Carlson,[6] Lee R. Berger[1,8]



From the collaboration between South Africa and the ESRF, I was able to join the Evolutionary Studies Institute at the Witwatersrand University (Johannesburg, South Africa) for 2 years post-doc





Virtual histology on bones of early tetrapods

VIRTUAL BONE HISTOLOGY VS. INVASIVE METHODS

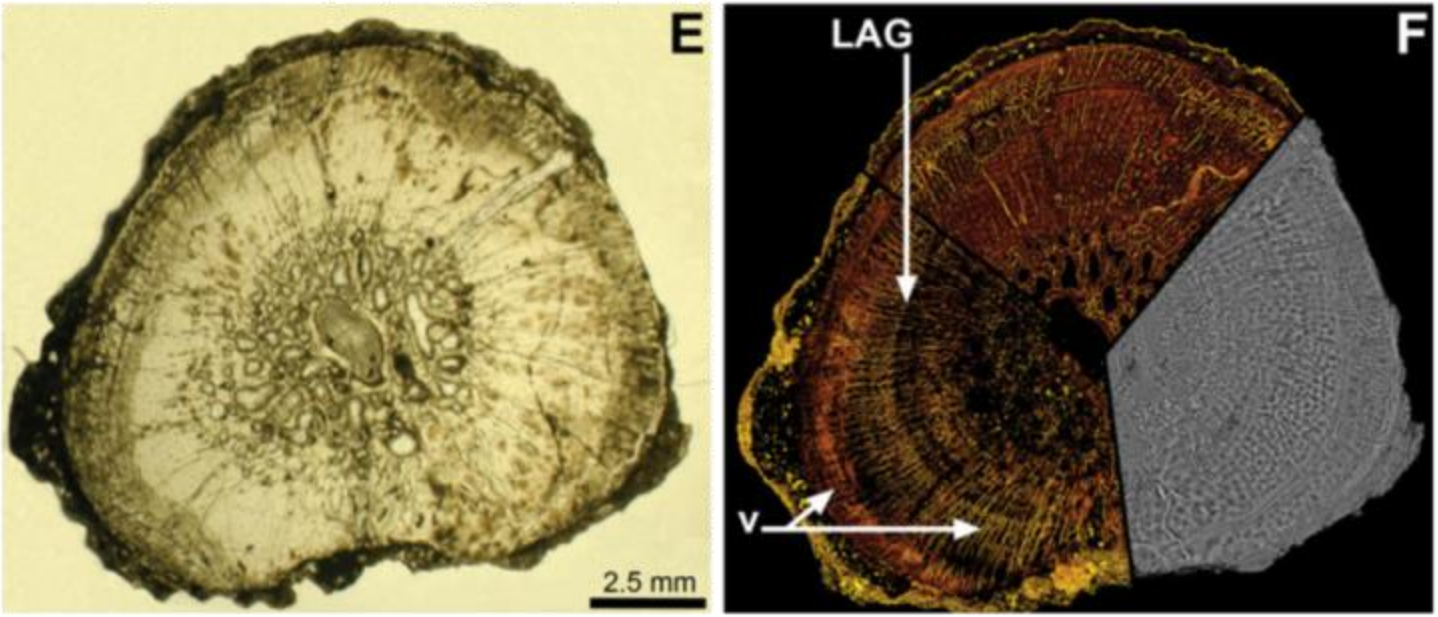
Microsc. Microanal. 18, 1095–1105, 2012
doi:10.1017/S1431927612001079

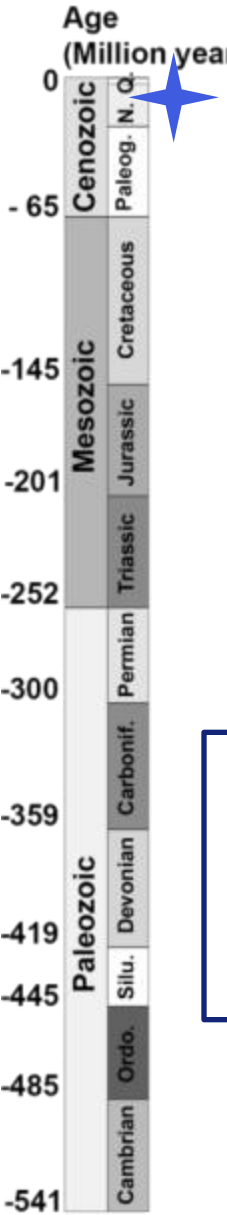
Microscopy AND Microanalysis

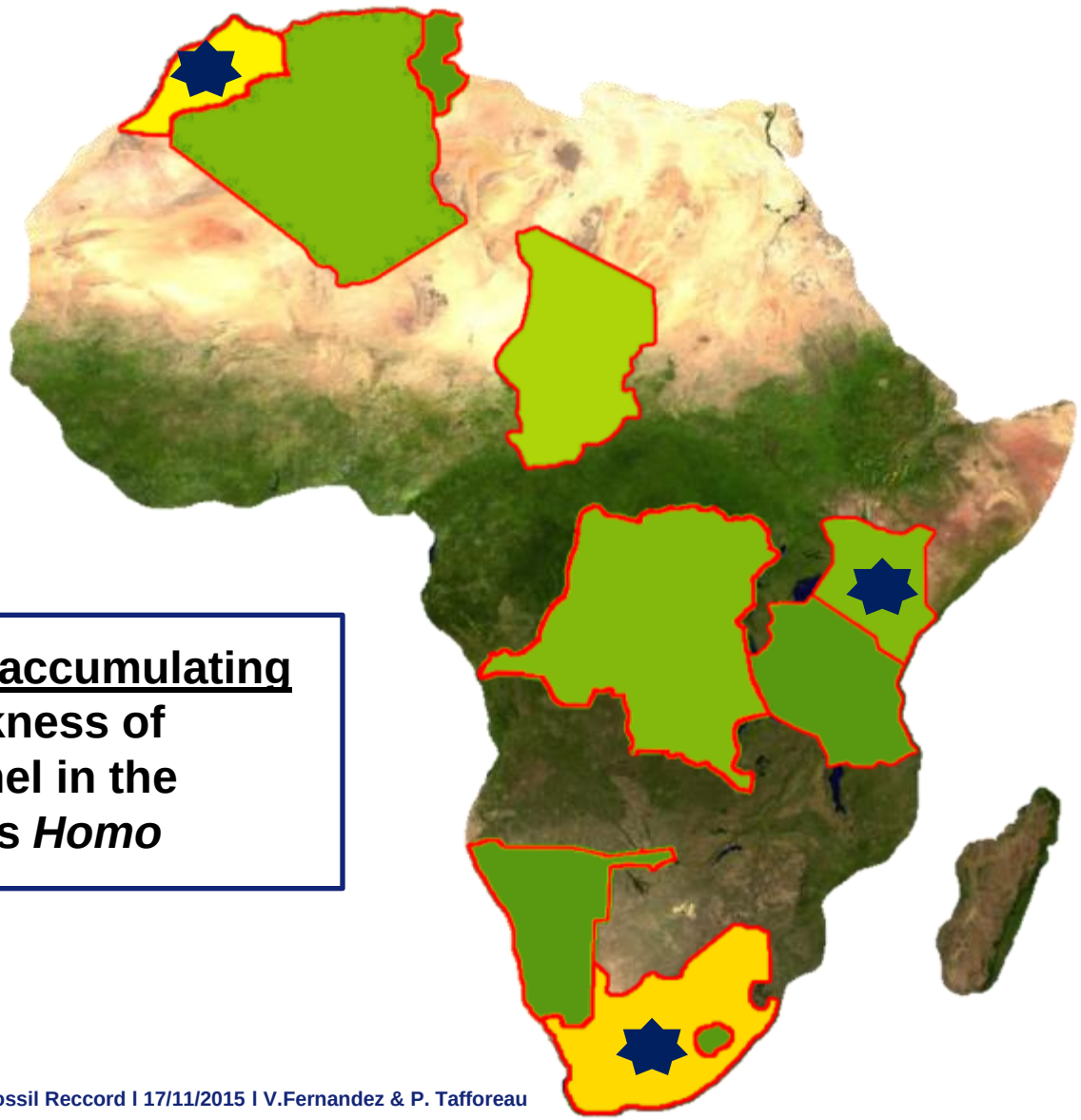
© MICROSCOPY SOCIETY OF AMERICA 2012

Three-Dimensional Synchrotron Virtual Paleohistology: A New Insight into the World of Fossil Bone Microstructures

Sophie Sanchez,[1,2,*] Per E. Ahlberg,[2] Katherine M. Trinajstic,[3,4] Alessandro Mirone,[1] and Paul Tafforeau[1]







<u>Data accumulating</u>
Thickness of enamel in the genus *Homo*

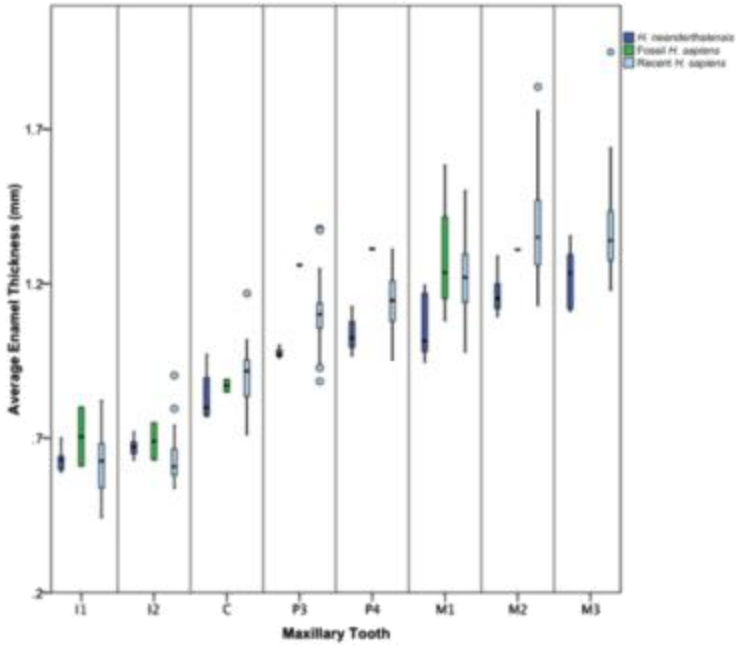
ELSEVIER

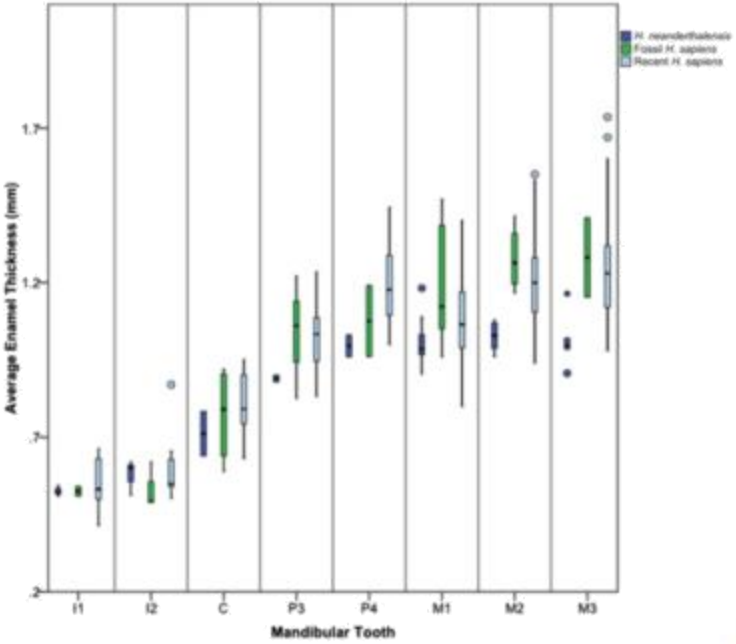
Journal of Human Evolution

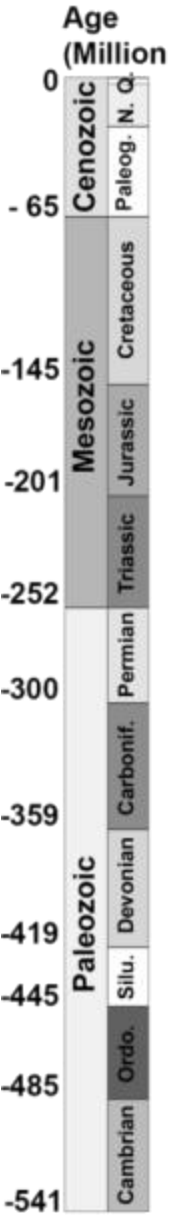
Journal of Human Evolution 62 (2012) 395–411

Variation in enamel thickness within the genus *Homo*

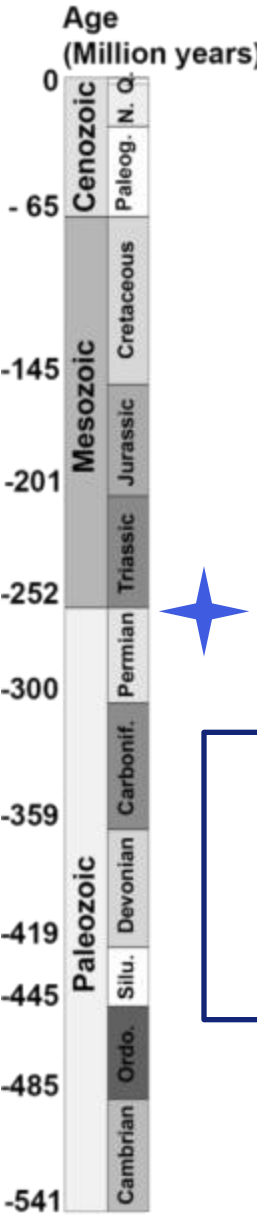
Tanya M. Smith [a,b,*], Anthony J. Olejniczak [b], John P. Zermeno [a], Paul Tafforeau [c], Matthew M. Skinner [b], Almut Hoffmann [d], Jakov Radovčić [e], Michel Toussaint [f], Robert Kruszynski [g], Colin Menter [h], Jacopo Moggi-Cecchi [i], Ulrich A. Glasmacher [j], Ottmar Kullmer [k], Friedemann Schrenk [l], Chris Stringer [g], Jean-Jacques Hublin [b]

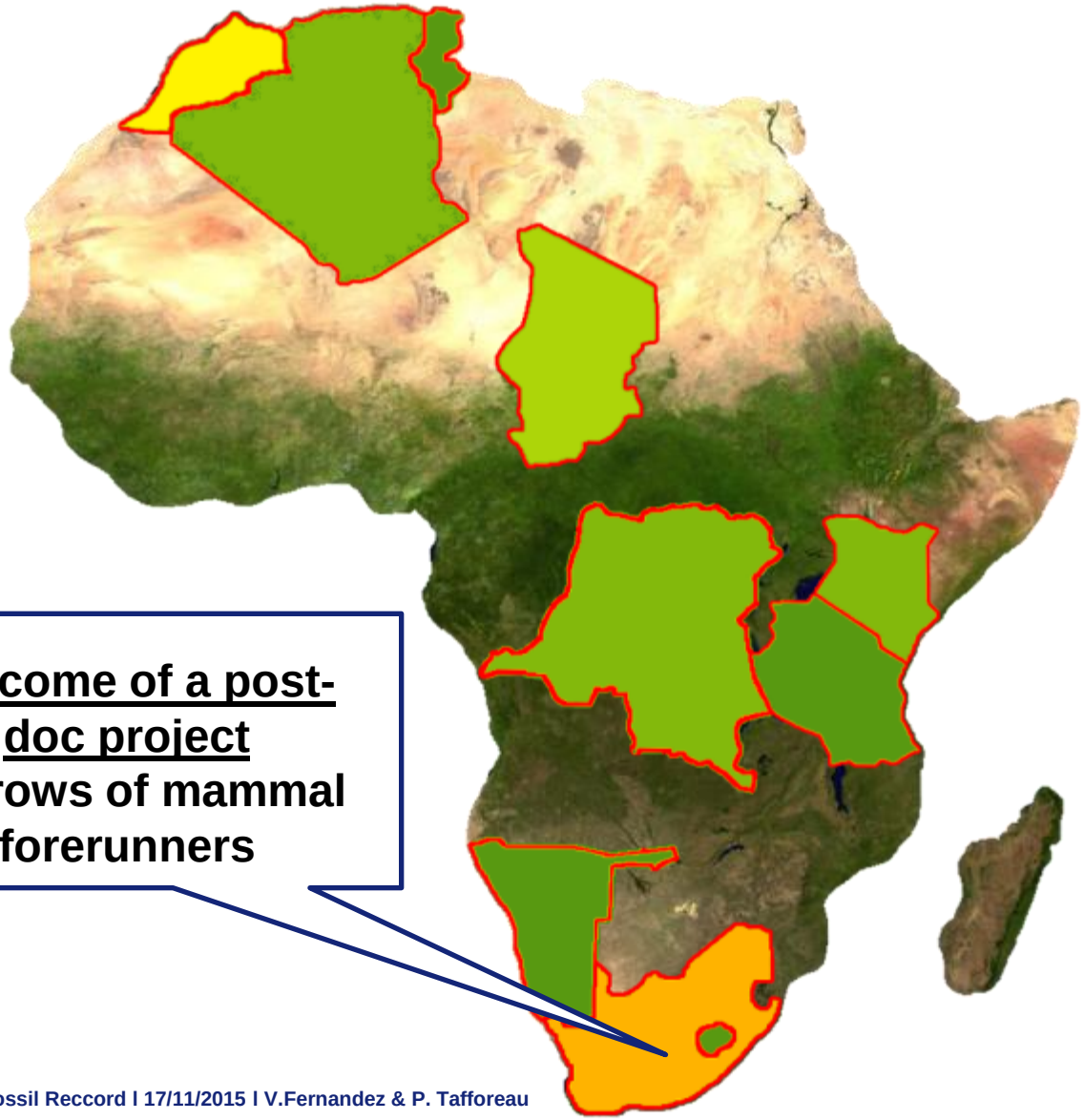






South Africa Joining the ESRF Facilitating collaborations





Outcome of a post-doc project

Burrows of mammal forerunners

FIRST FOSSIL BURROW CAST SCANNED

OPEN ACCESS Freely available online

PLOS | ONE

Synchrotron Reveals Early Triassic Odd Couple: Injured Amphibian and Aestivating Therapsid Share Burrow

Vincent Fernandez[1]*, Fernando Abdala[1], Kristian J. Carlson[1,2], Della Collins Cook[2], Bruce S. Rubidge[1], Adam Yates[1,3], Paul Tafforeau[4]

1 Evolutionary Studies Institute, University of the Witwatersrand, Johannesburg, Gauteng, South Africa, **2** Department of Anthropology, Indiana University, Bloomington, Indiana, United States of America, **3** Museum of Central Australia, Araluen Cultural Precinct, Alice Springs, Northern Territory, Australia, **4** European Synchrotron Radiation Facility, Grenoble,

DATA FROM THE BURROW SCANS USED FOR SIDES PROJECTS

Journal of Vertebrate Paleontology

Journal of Vertebrate Paleontology 33(6):1408–1431, November 2013
© 2013 by the Society of Vertebrate Paleontology

Ontogeny of the Early Triassic cynodont Thrinaxodon liorhinus (Therapsida): dental morphology and replacement

FERNANDO ABDALA,[*,1] SANDRA C. JASINOSKI,[2] and VINCENT FERNANDEZ[1,3]
[1]Evolutionary Studies Institute and School of Geosciences, University of the Witwatersrand, Private Bag 3, WITS 2050, Johannesburg, South Africa; National Research Foundation, Centre of Excellence: Palaeosciences, nestor.abdala@wits.ac.za;
[2]Department of Zoology, University of Cape Town, Private Bag X3, Rondebosch, South Africa 7701; Centre for Research in Computational and Applied Mechanics, University of Cape Town, Private Bag X3, Rondebosch, South Africa 7701, sandra_jas@hotmail.com;
[3]European Synchrotron Radiation Facility, 6 Rue Jules Horowitz, BP 220, 38043 Grenoble Cedex, France, vinfernand@gmail.com

The European Synchrotron | ESRF

DATA FROM THE BURROW SCANS USED FOR SIDES PROJECTS

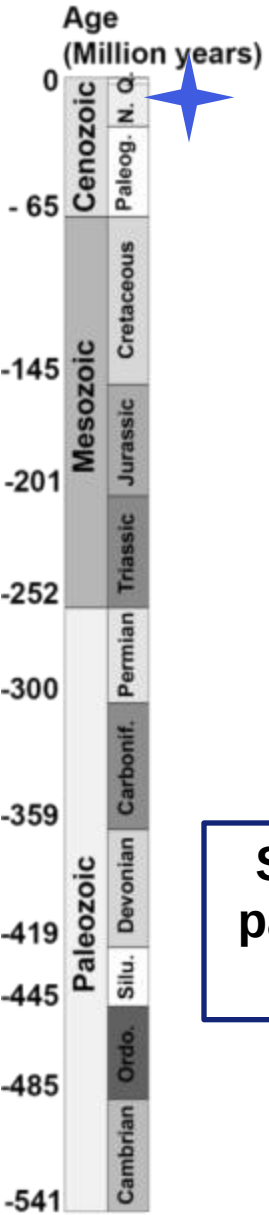
The Anatomical Record
Advances in Integrative Anatomy and Evolutionary Biology

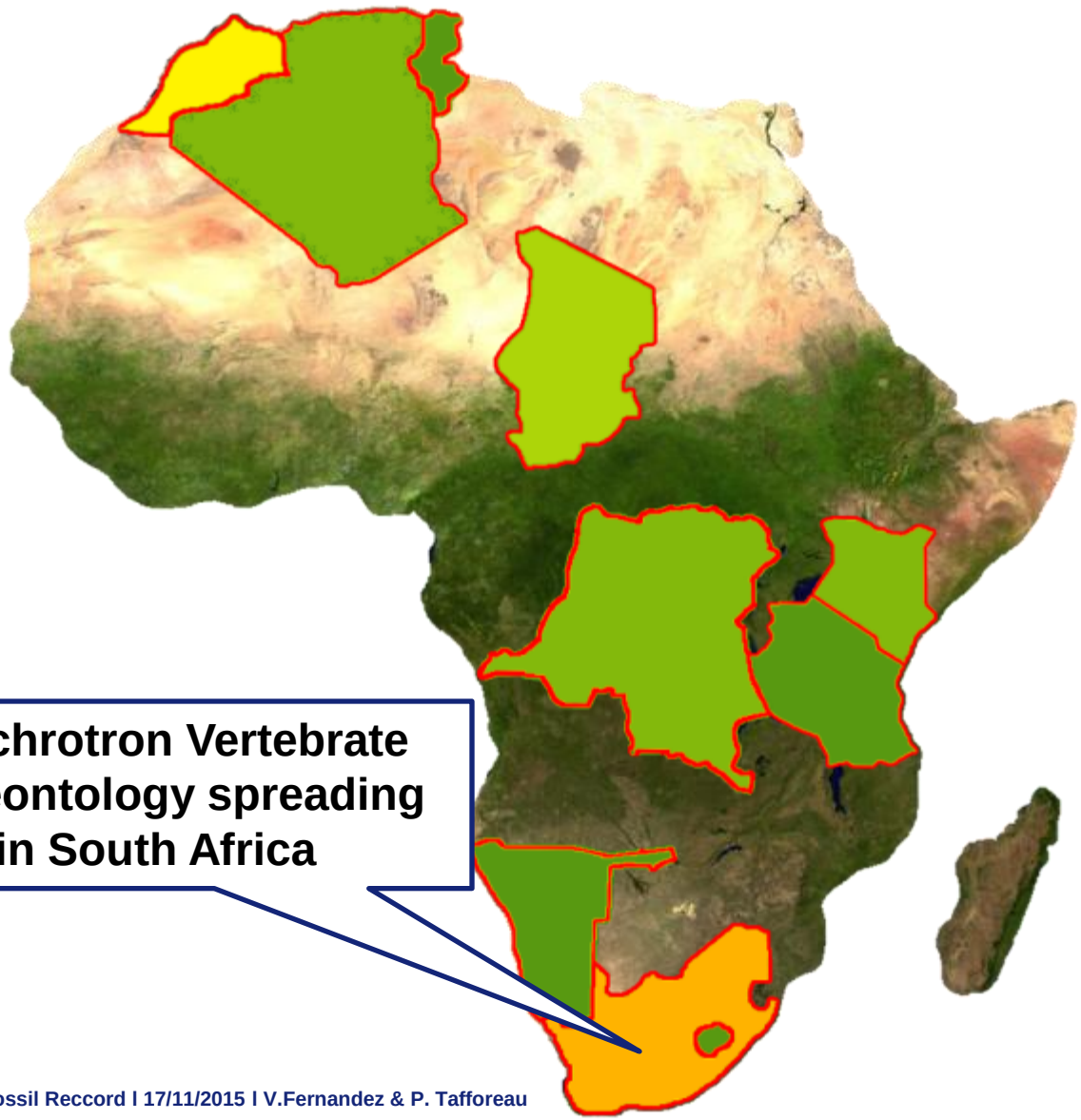
THE ANATOMICAL RECORD 298:1440–1464 (2015)

Ontogeny of the Early Triassic Cynodont *Thrinaxodon liorhinus* (Therapsida): Cranial Morphology

SANDRA C. JASINOSKI,[1]* FERNANDO ABDALA,[1] AND VINCENT FERNANDEZ[2]

[1]Evolutionary Studies Institute, University of the Witwatersrand, WITS 2050, Johannesburg, South Africa
[2]European Synchrotron Radiation Facility, 71 rue des Martyrs, Grenoble, France





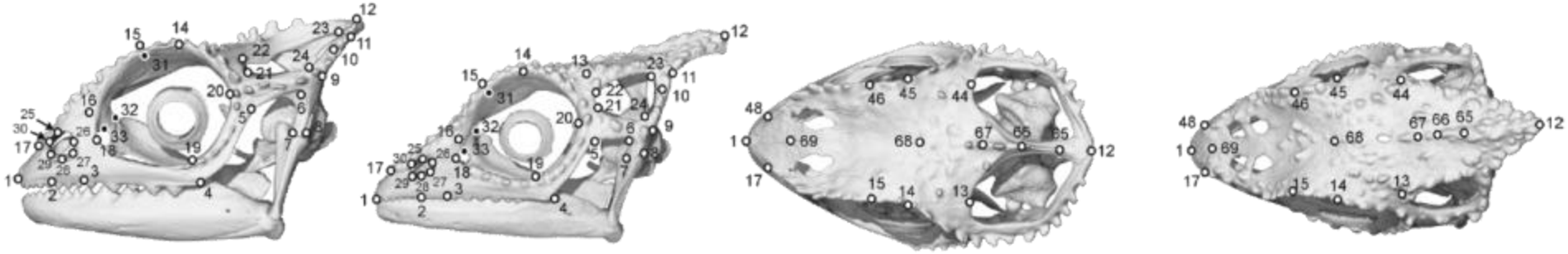
Synchrotron Vertebrate palaeontology spreading in South Africa

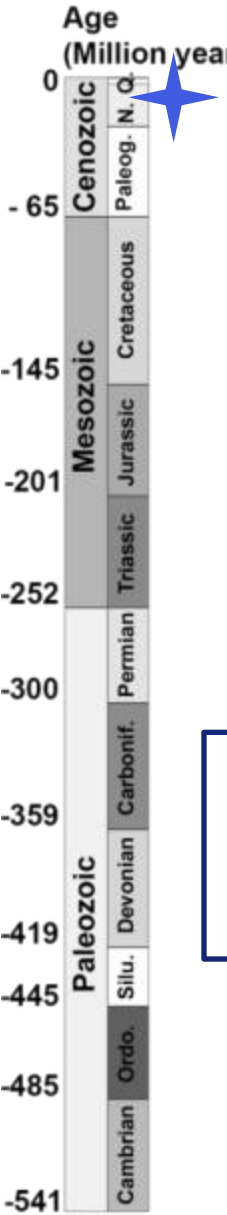
Sci Nat (2015) 102:2
DOI 10.1007/s00114-014-1254-3

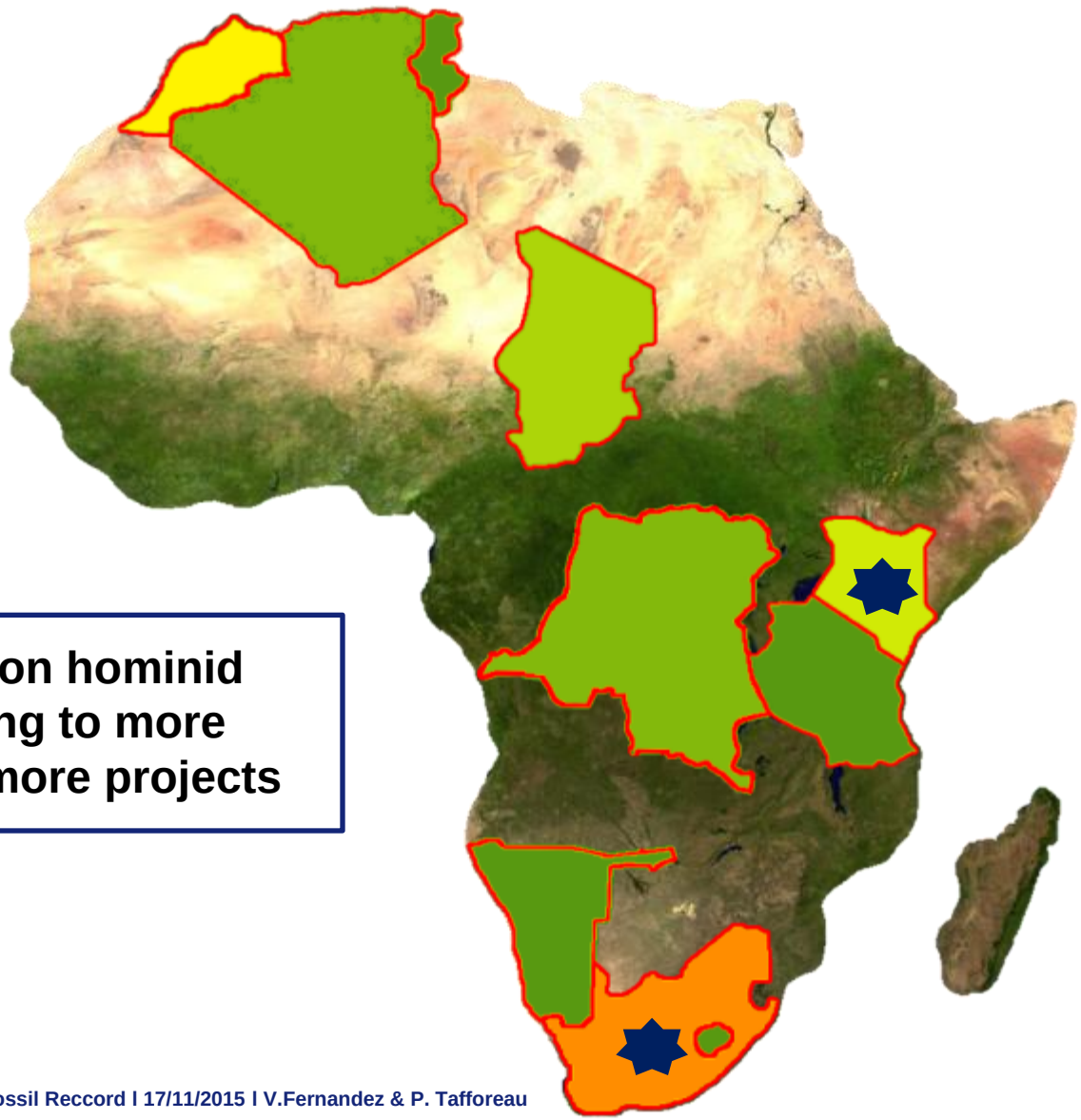
ORIGINAL PAPER

Morphometric analysis of chameleon fossil fragments from the Early Pliocene of South Africa: a new piece of the chamaeleonid history

Alexis Y. Dollion · Raphaël Cornette · Krystal A. Tolley · Renaud Boistel · Adelaïde Euriat · Elodie Boller · Vincent Fernandez · Deano Stynder · Anthony Herrel







Data on hominid leading to more and more projects

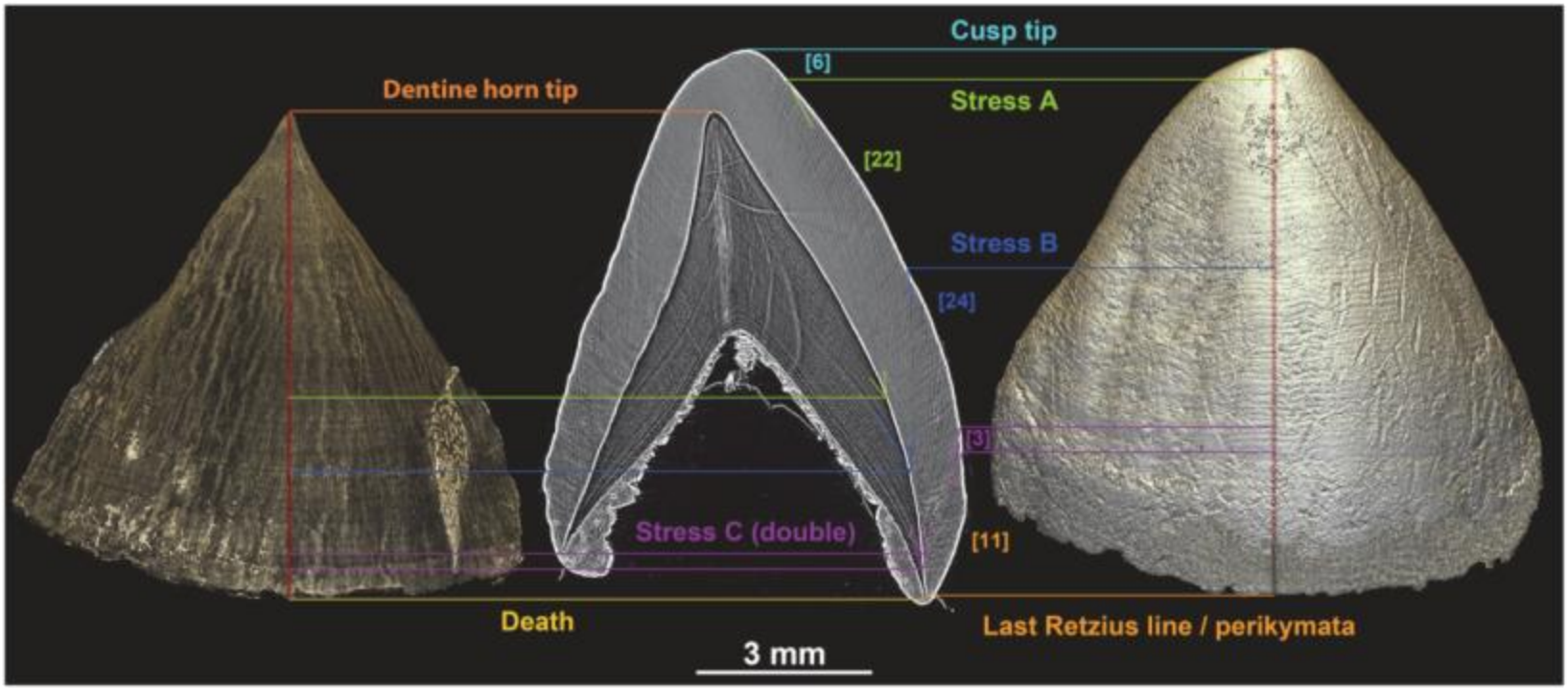
DEVELOPMENTAL PATTERN OF FOSSIL HOMININS

PLOS | ONE

RESEARCH ARTICLE

Accessing Developmental Information of Fossil Hominin Teeth Using New Synchrotron Microtomography-Based Visualization Techniques of Dental Surfaces and Interfaces

Adeline Le Cabec[1,2,3]*, Nancy Tang[2,4], Paul Tafforeau[1]*



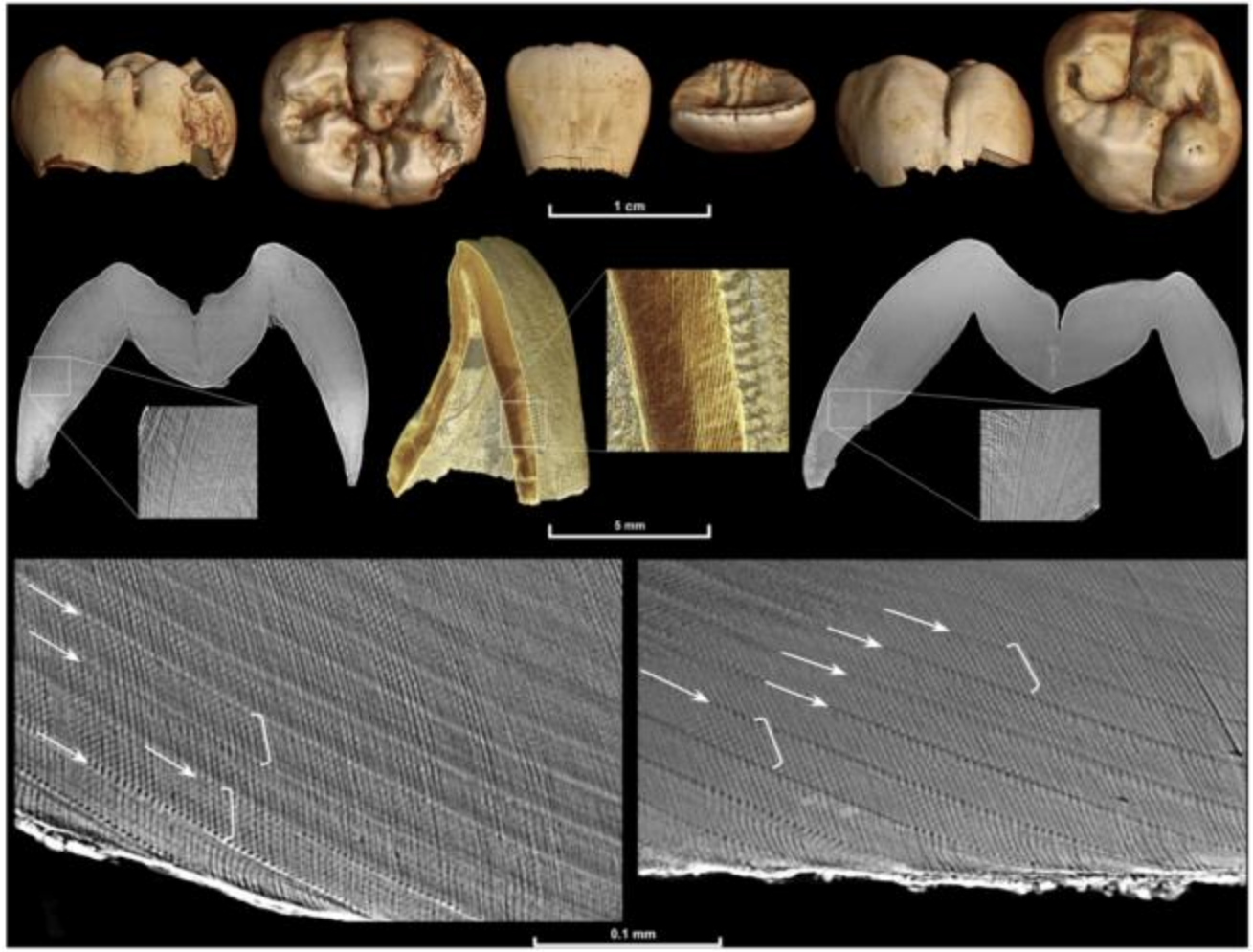
DEVELOPMENTAL PATTERN OF FOSSIL HOMININS

RESEARCH ARTICLE

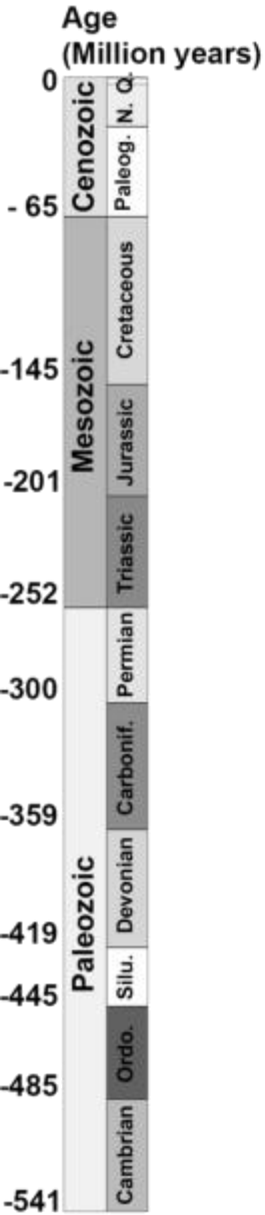
PLOS | ONE

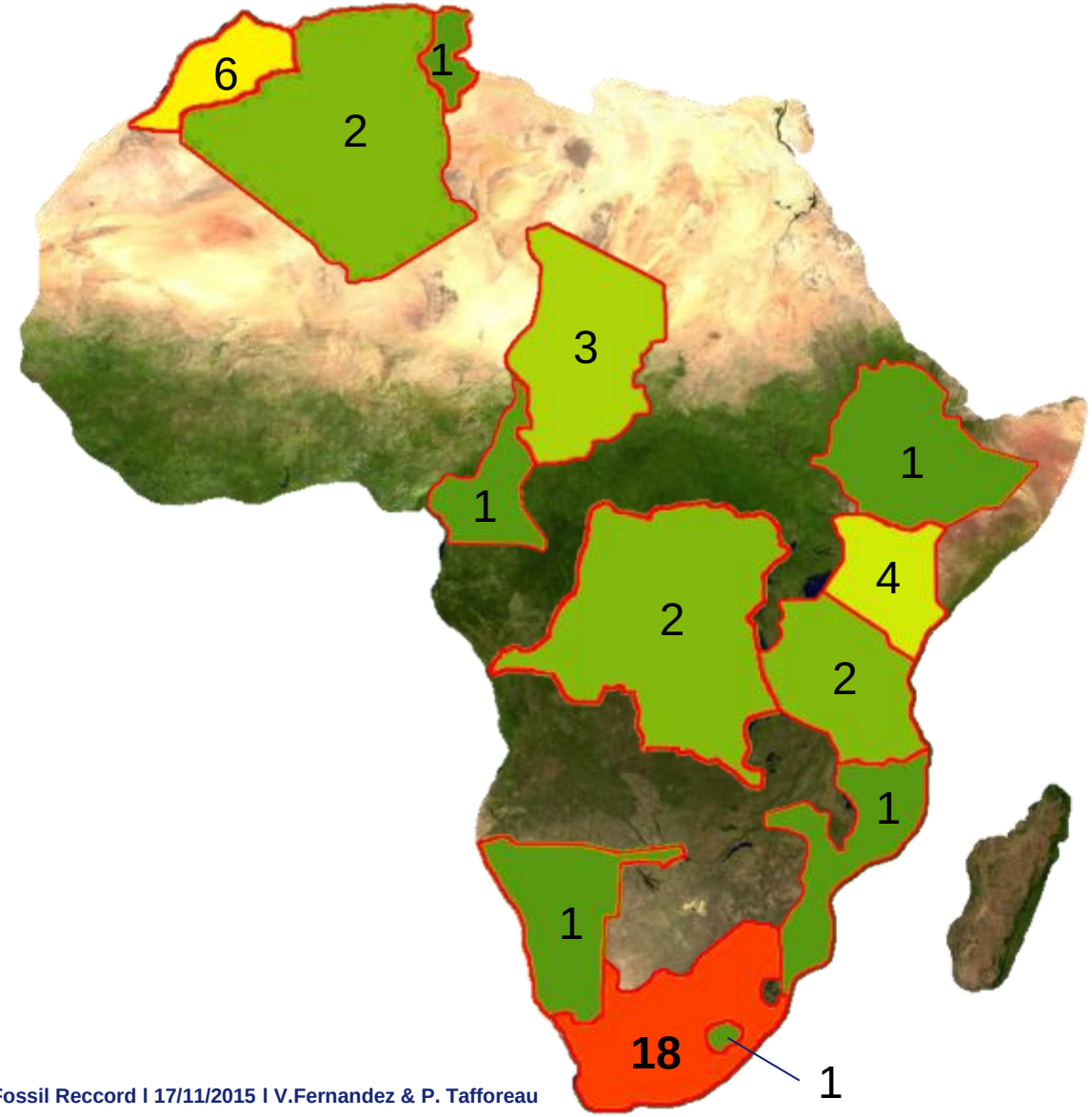
Dental Ontogeny in Pliocene and Early Pleistocene Hominins

T.M. Smith, P. Tafforeau, A. Le Cabec, A. Bonnin, A. Houssaye, J. Pouech, J. Moggi-Cecchi, F. Manthi, C. Ward, M. Makaremi & C.G. Menter

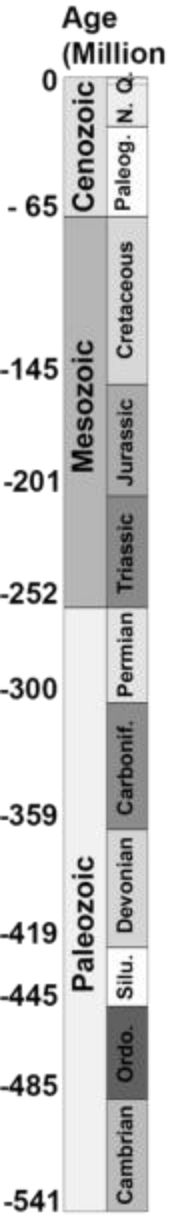


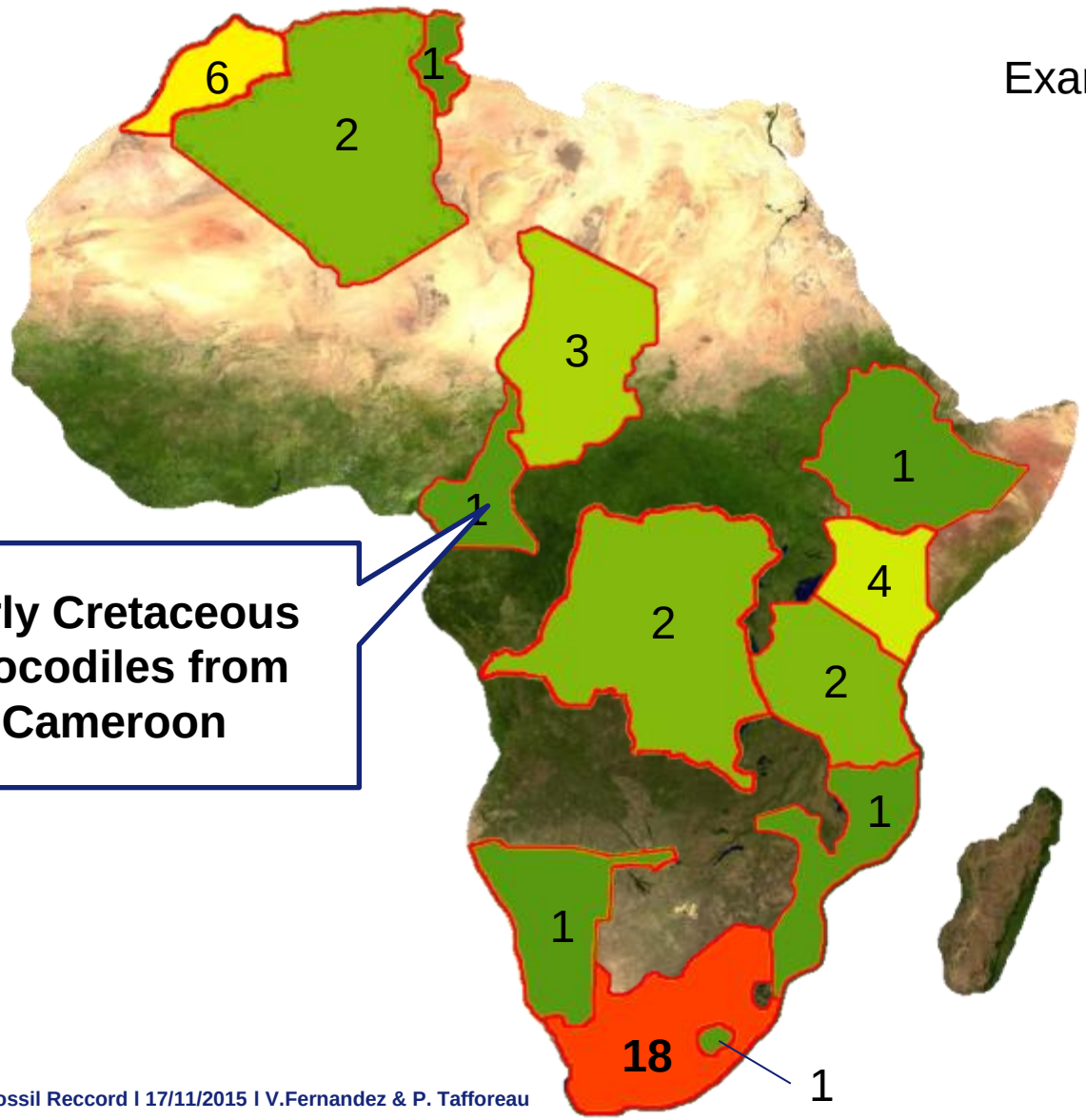
Number of articles (or upgoing projects) per country





Number of articles or (ongoing) projects per country

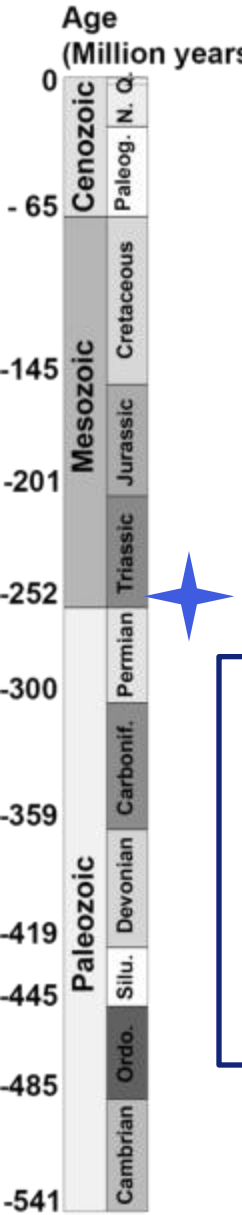


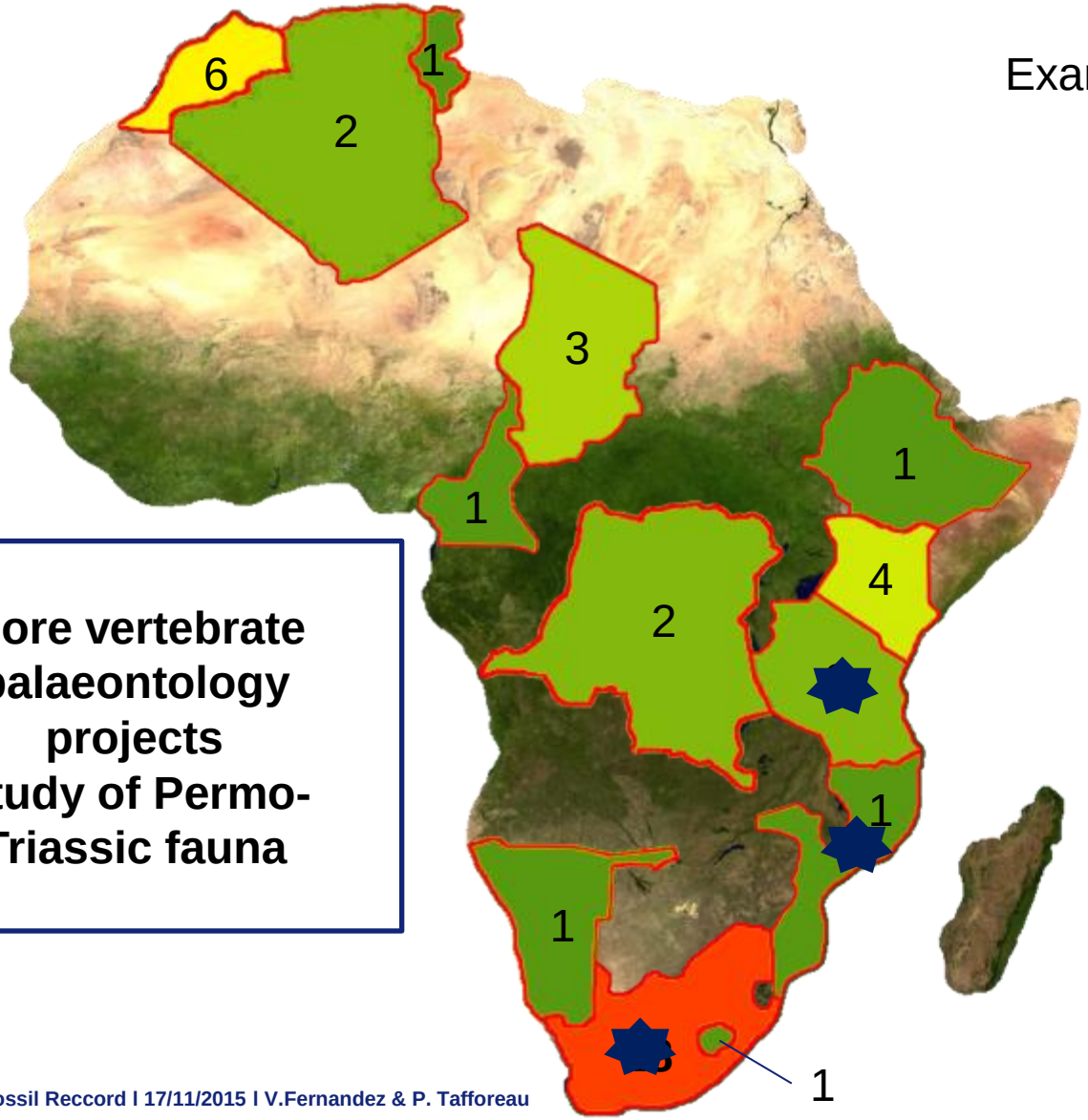


Example of ongoing projects

Early Cretaceous Crocodiles from Cameroon

Number of articles (or upgoing projects) per country

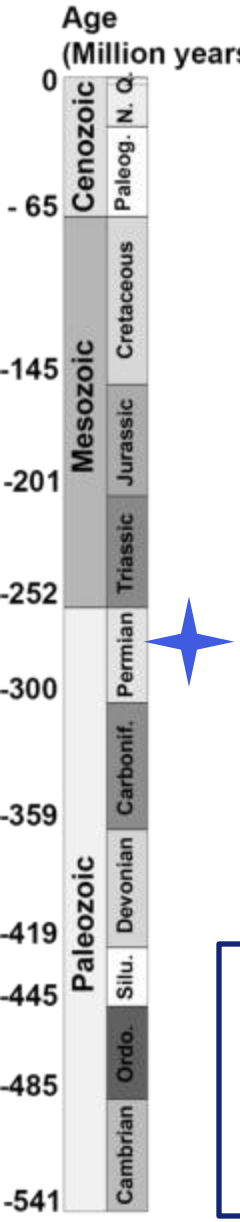


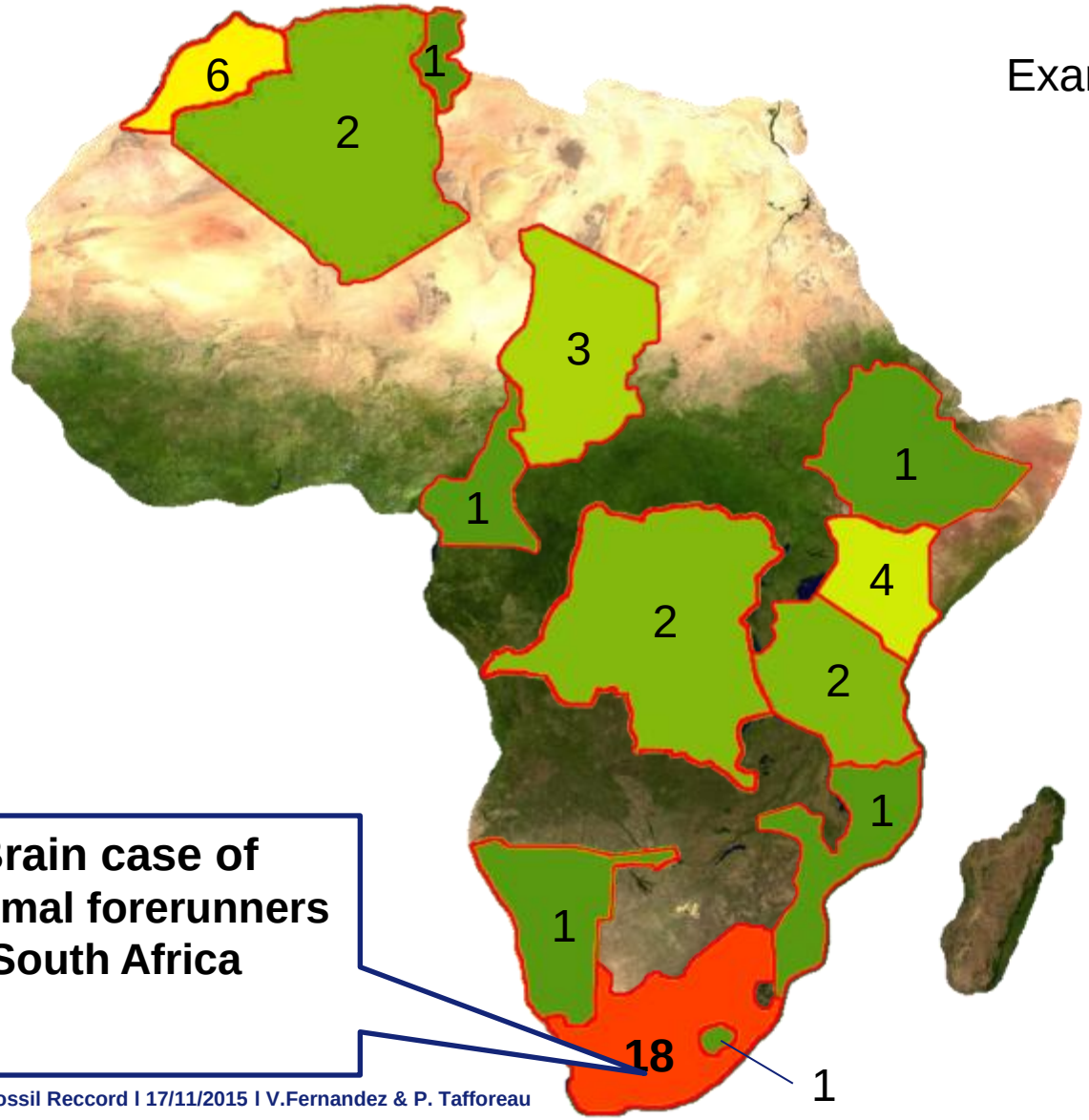


Example of ongoing projects

More vertebrate palaeontology projects
Study of Permo-Triassic fauna

Number of articles or (ongoing) projects per country

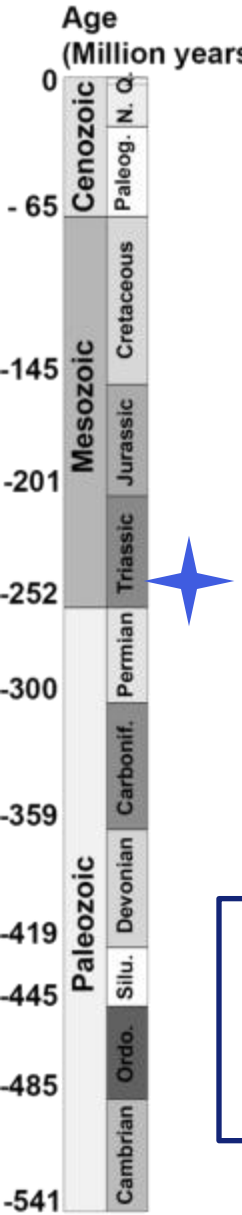


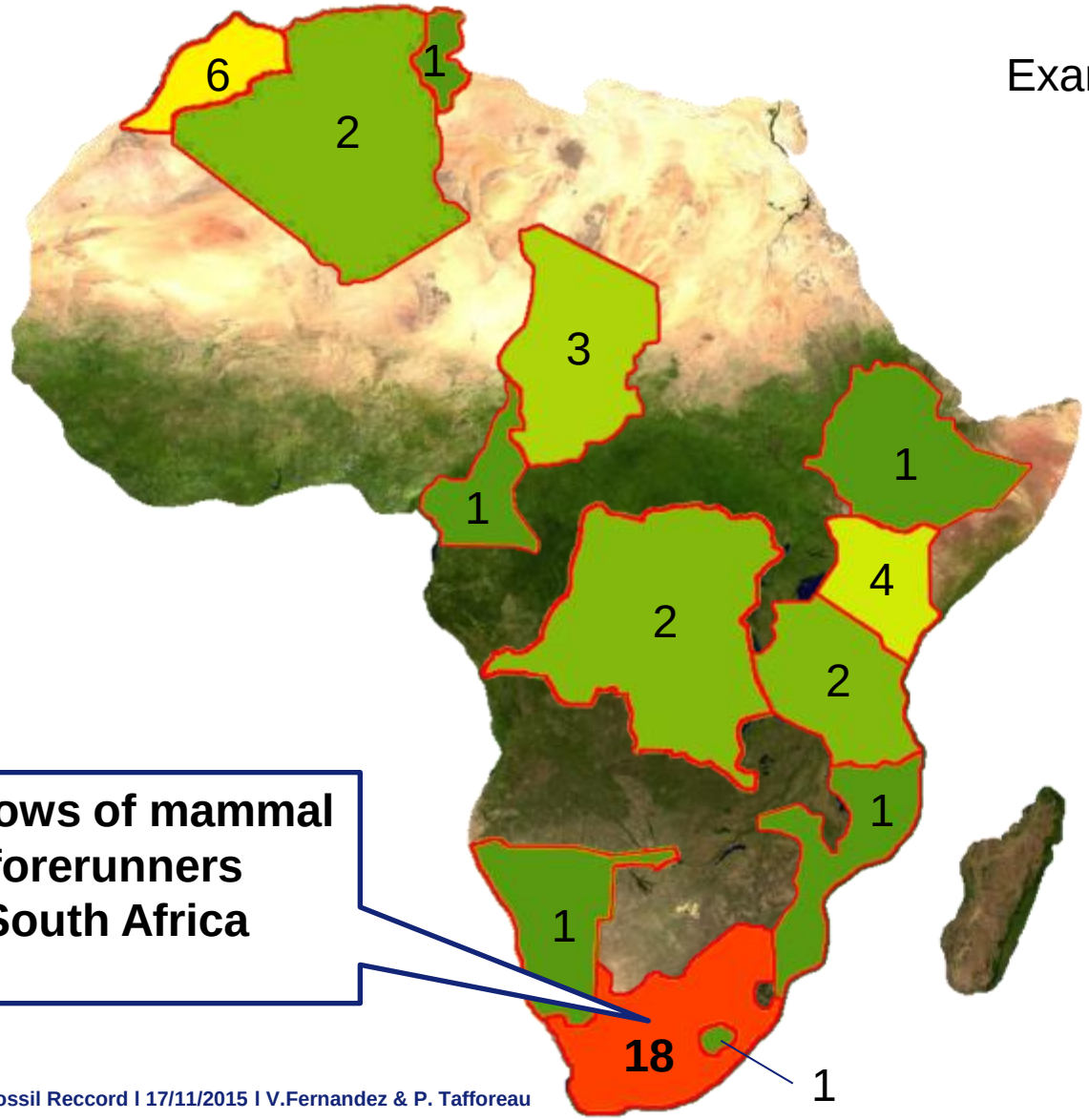


Example of ongoing projects

Brain case of mammal forerunners South Africa

Number of articles or (ongoing) projects per country

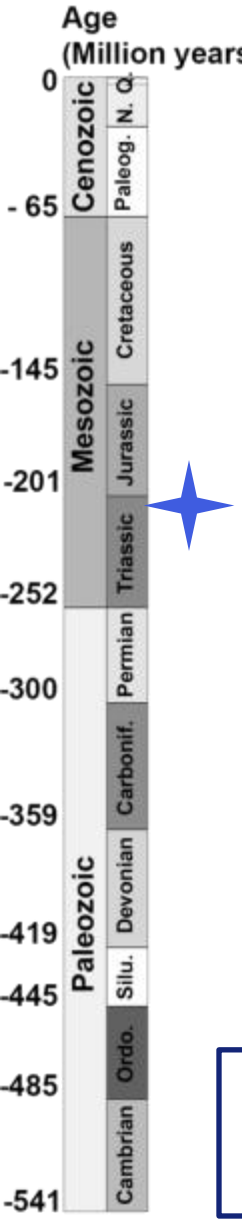


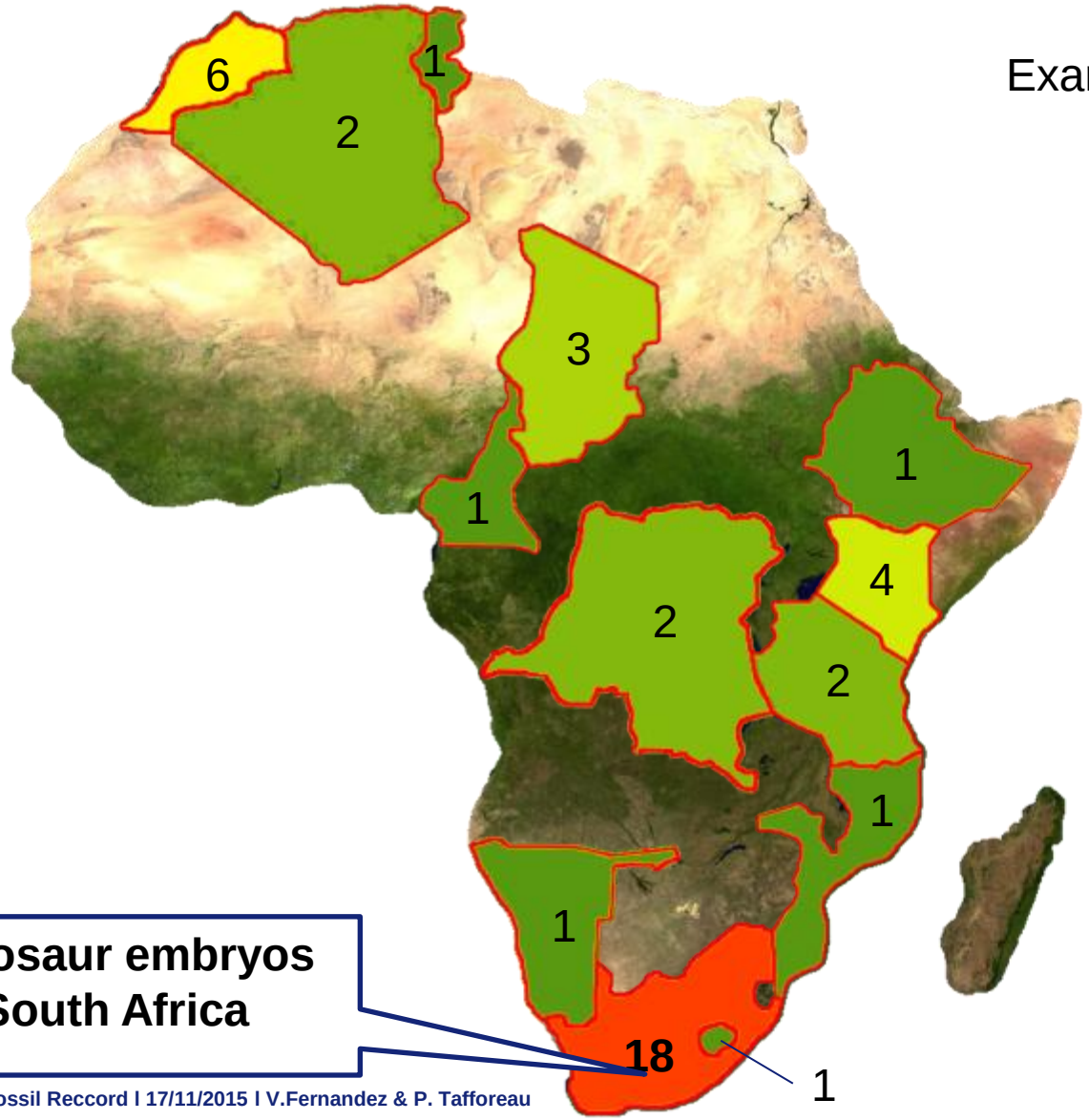


Example of ongoing projects

Burrows of mammal forerunners South Africa

Number of articles or (ongoing) projects per country





Example of ongoing projects

Dinosaur embryos South Africa

THE CONVERSATION AFRICA PILOT

Academic rigour, journalistic flair

Dinosaur eggs get ready to hatch their secrets – 200 million years later

June 22, 2015 6:46am SAST

One of Kitching's original find of eggs, after being prepared by Diane Scott. Supplied

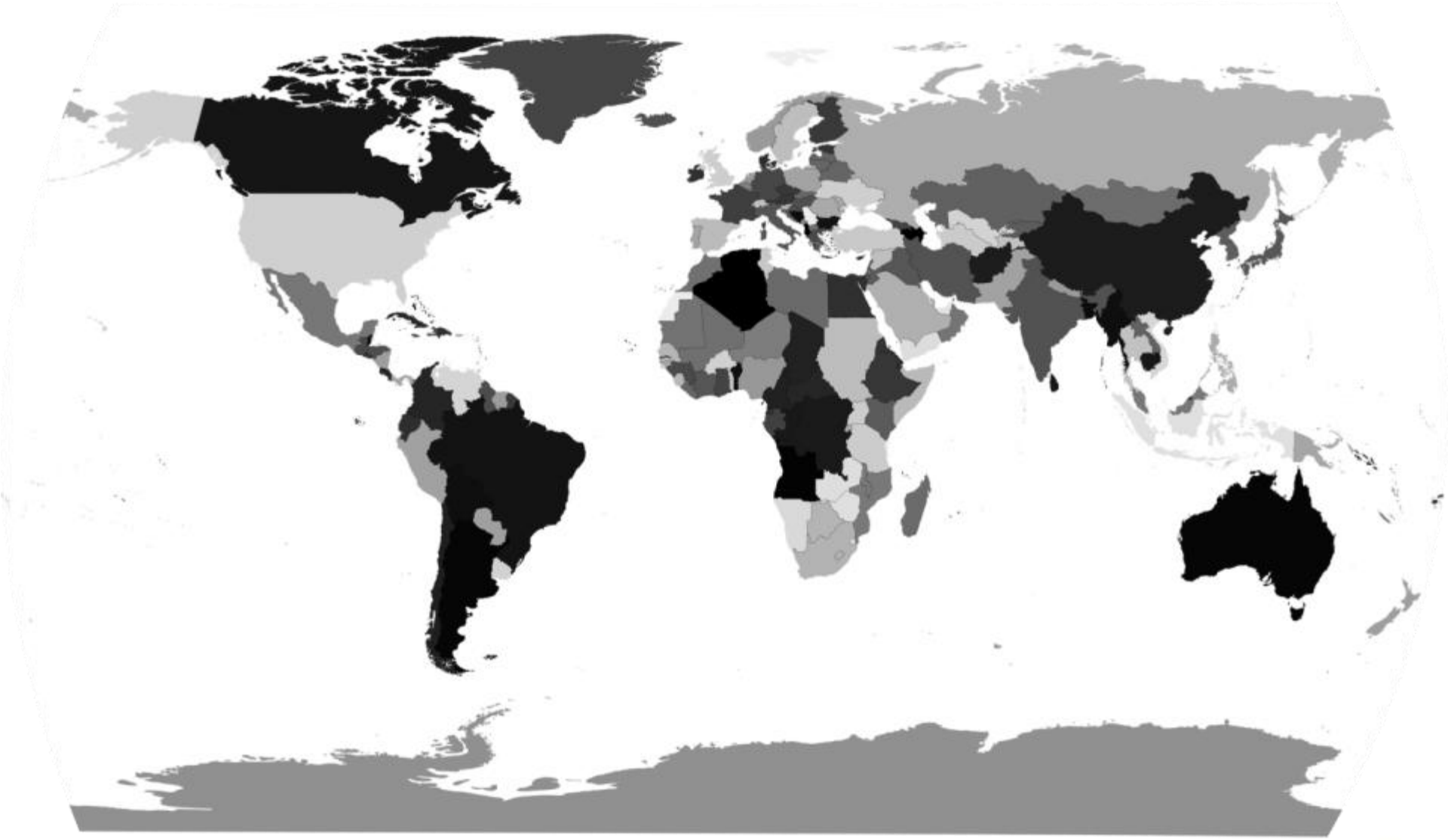
CT scans come to the rescue

The solution to all of these problems lies in CT scanning the specimen. The x-ray resolution needed to study the embryos is so high (six microns, or .006mm) that only a few facilities in the world are capable of performing the study.

In late 2014, a team of us put together a winning proposal to scan the eggs at the European Synchrotron Radiation Facility in Grenoble. At the facility, a huge ring of electrons (almost a kilometre in circumference) travelling at .99% of the speed of light continuously generates beams of high-energy X-rays. These beams can be harnessed with great precision to peer through rocks and image the fossils inside.

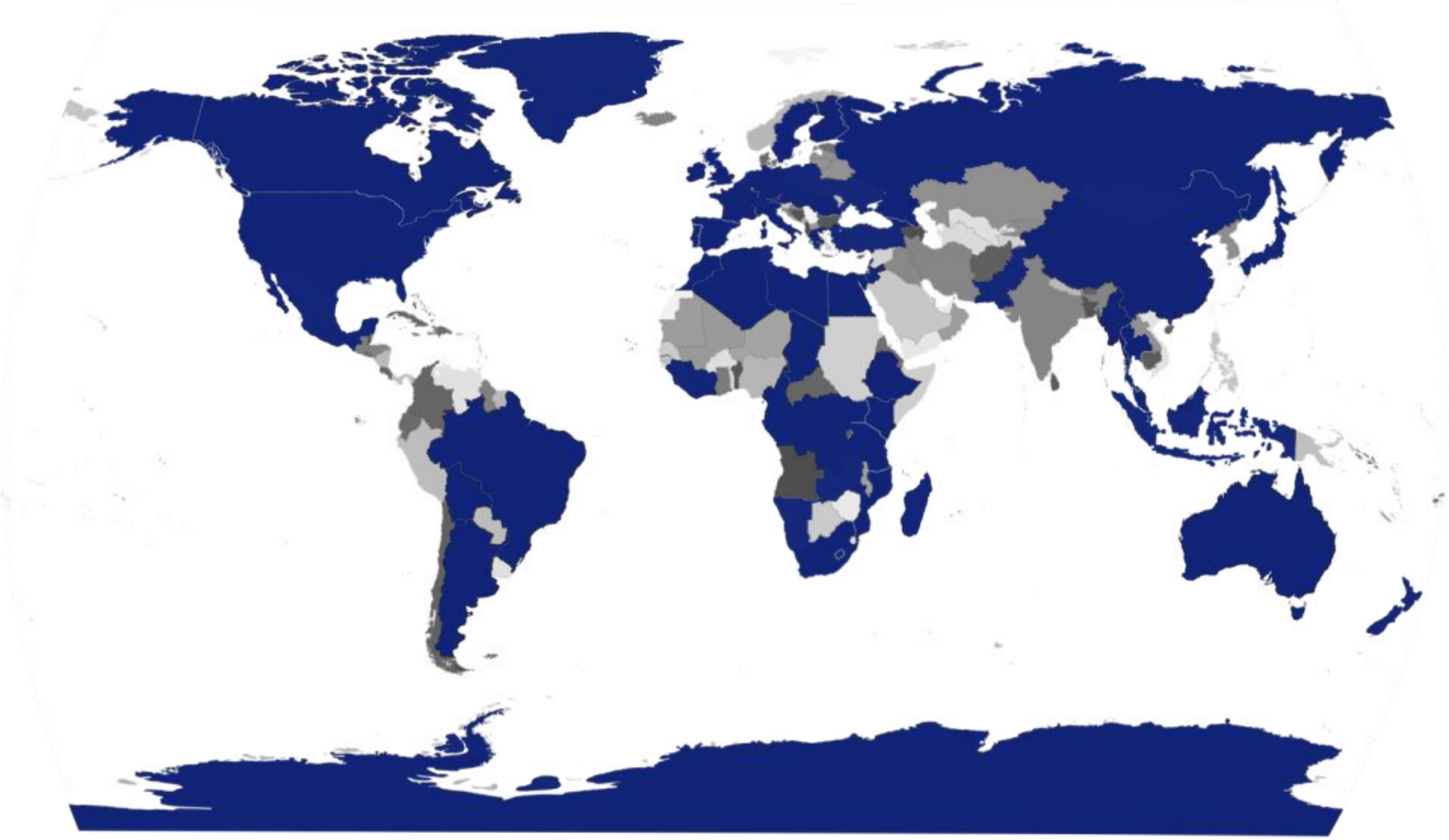
The European Synchrotron Radiation Facility in Grenoble. Jonah Chalmers

A WORLDWIDE COMMUNITY



A WORLDWIDE COMMUNITY

In Blue: country from which material was scanned for palaeontological studies



ACKNOWLEDGEMENTS

ESRF

ID 19

The African Light Source Conference and Workshop

CENTRE OF EXCELLENCE PALAEOSCIENCES

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

And also ID17 and BM05

science & technology
Department: Science and Technology
REPUBLIC OF SOUTH AFRICA

PASI ALL FROM ONE

NRF National Research Foundation

ACKNOWLEDGEMENTS

Thank you for your attention