(More than) fifty shades of plumes

Michele Lustrino
Dipartimento di Scienze della Terra
Sapienza Università di Roma
SAPIENZA UNIVERSITÀ DI ROMA
michele.lustrino@uniroma1.it

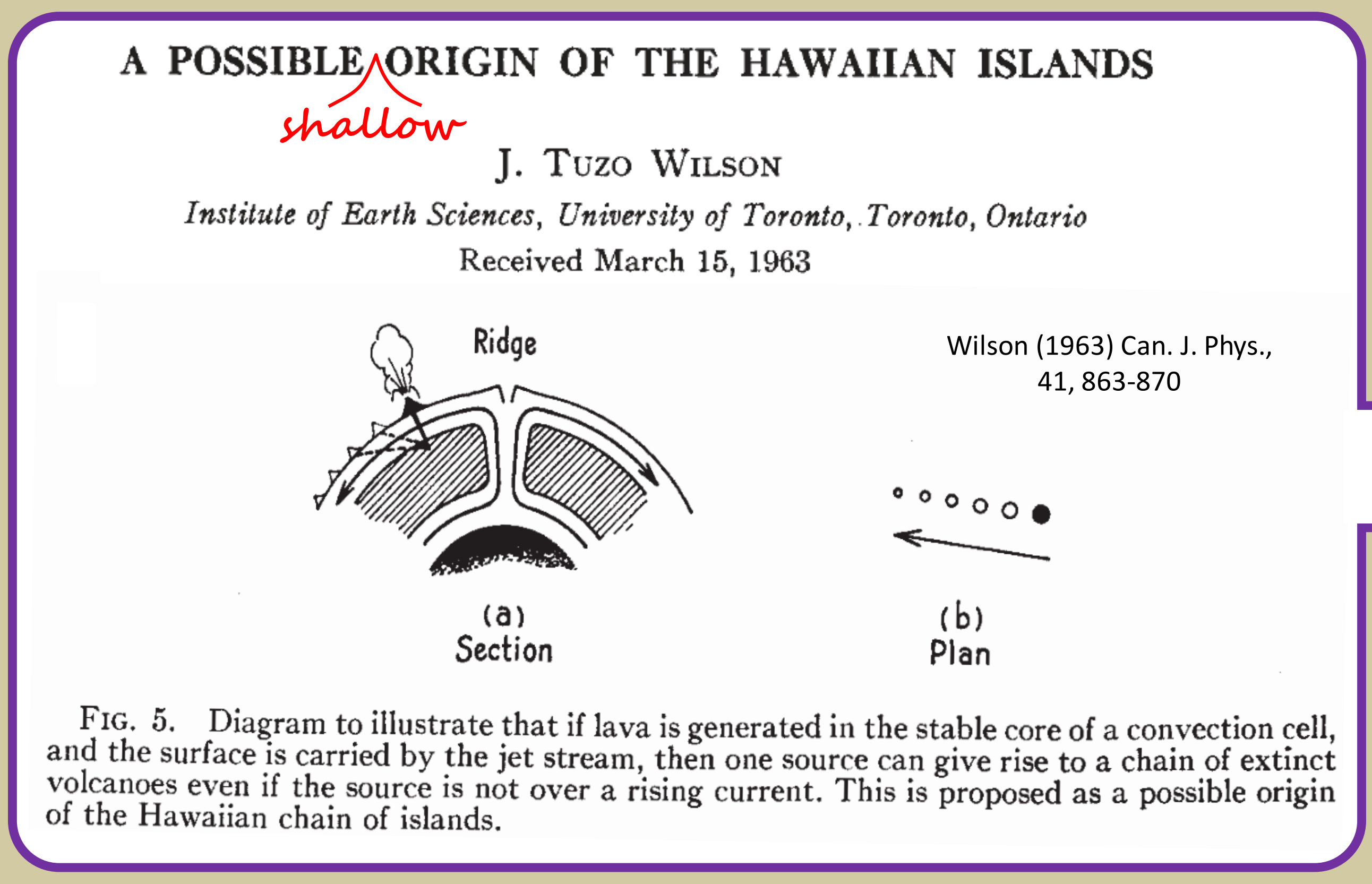
Some Mantle Plume definition…

Thermal *(1)*; **Fossil** *(2)*; **Channelled** *(3)*; **Toroidal** *(4)*; **Tabular** *(5)*; **Depleted Residual** *(6)*; **Finger-like** *(7)*; **Recycled** *(8)*; **Edge** *(9)*; **Cold** *(10)*; **Cacto-** *(11)*; **Super** *(12)*; **Asthenospheric** *(13)*; **Dying** *(14)*; **Not very energetic** *(15)*; **Spaghetti** *(16)*; **Baby** *(17)*; **Head-free** *(18)*; **Splash** *(19)*; **Pulsating** *(20)*; **Subduction fluid-fluxed Refractory** *(21)*; **Hydrogen** *(22)*; **Heterogeneous** *(23)*; **Flattened Onion** *(24)*; **Subduction-driving** *(25)*; **Subduction-triggered** *(26)*; **Washboard** *(27)*; **Bent-shaped** *(28)*; **Failing** *(29)*; **Delamination-triggering** *(30)*; **Concentrically-zoned** *(31)*; **Mushroom** *(32)*; **Laminar** *(33)*; **Advected** *(34)*; **Extinct** *(35)*; **Bilateral** *(36)*; **Bifurcated** *(37)*; **Geriatric** *(38)*; **Primary and Secondary** *(39)*; **Accreted** *(40)*; **Diverted** *(41)*; **Deformed** *(42)*; **Golden** *(43)*; **Veined** *(44)*; **Hidden** *(45)*; **Weak** *(46)*; **Pulsing** *(47)*; **Young** *(48)*; **Blob-like** *(49)*; Cavity *(50)*; **Starting** *(51)*; Passive *(52)*; **Stealth** *(53)*; **Tilted** *(54)*; **Asymmetric** *(55)*; **Mega** *(56)*; **Mini** *(57)*; **Not-hot** *(58)*; **Killer** *(59)*; **Deflected** *(60)*; **Stripy** *(61)* ; **Diamondiferous** *(62)* ; **Transient** *(63)* ; **Dehydrating** *(64)*; **Elusive** *(65)*; …

1 (*Griffiths & Campbell, 1990*); 2 (*Stein & Hofmann, 1992*); 3 (*Camp & Roobol, 1992*); 4 (*Mahoney et al., 1992*); 5 (*Hoernle et al., 1995*), 6 (*Danyushevsky et al., 1995*); 7 (*Granet et al., 1995*); 8 (*Gasperini et al., 2000*); 9 (*King & Ritsema, 2000*); 10 (*Hanguita & Hernan, 2000*); 11 (*Lundin, 2003*); 12 (*Condie, 2004*); 13 (*Seghedi et al., 2004*); 14 (*Davaille & Vatteville, 2005*); 15 (*Michon & Merle, 2005*); 16 (*Abouchami et al., 2005*); 17 (*Ritter, 2006*); 18 (*Ritter, 2006*); 19 (*Davies & Bunge, 2006*); 20 (*Krienitz et al., 2007*); 21 (*Falloon et al., 2007*); 22 (*Dobretsov, 2008*); 23 (*Ren et al., 2009*); 24 (*Beccaluva et al., 2010*); 25 (*Burov and Cloetingh 2010*); 26 (*Faccenna et al., 2010*); 27 (*Ballmer et al, 2011*); 28 (*Tosi & Yuen, 2011*); 29 (*Kumagai et al., 2008*); 30 (*Camp & Hanan, 2008*); 31 (*Hauri et al., 2004*); 32 (*Tan et al., 2011*); 33 (*Vatteville et al., 2009*); 34 (*Boschi et al., 2007*); 35 (*Merle et al., 2011*); 36 (*Farnetani et al., 2012*); 37 (*Rohde et al., 2013*) ; 38 (*Zhou and Dick, 2012*); 39 (*Tackley, 2008*); 40 (*Kipf et al., 2013*); 41 (*Rychert et al, 2013*); 42 (*Kincaid et al, 2013*) ; 43 (*Webber et al., 2013*); 44 (*Bianco et al., 2013*); 45 (*Yang and Leng, 2014*); 46 (*Yamamoto et al., 2007*); 47 (*Walters et al., 2013*); 48 (*Wang et al., 2013*); 49 (*Hanan and Schilling, 1997*); 50 (*Richards et al., 1989*); 51 (*Thompson and Gibson, 1991*); 52 (*Chung et al., 1998*); 53 (*Mittelstaedt and Turcotte, 2006*); 54 (*Shen et al., 2002*); 55 (*Bell et al., 2004*); 56 (*Thompson and Tackley, 1998*); 57 (*Ernst and Buchan, 2003*); 58 (*Kogiso, 2007*); 59 (*Courtillot and Fluteau, 2014*); 60 (*Thompson et al., 1998*); 61 (*Cordier et al., 2016*); 62 (*Kirdyashkin et al., 2016*); 63 (*Bell et al., 2013*); 64 (*Ito, 2001*); 65 (*Ritsema and Allen, 2003*)

Mantle plume hypothesis

First proposed in 1963 by J. Tuzo Wilson



A POSSIBLE shallow ORIGIN OF THE HAWAIIAN ISLANDS

J. TUZO WILSON

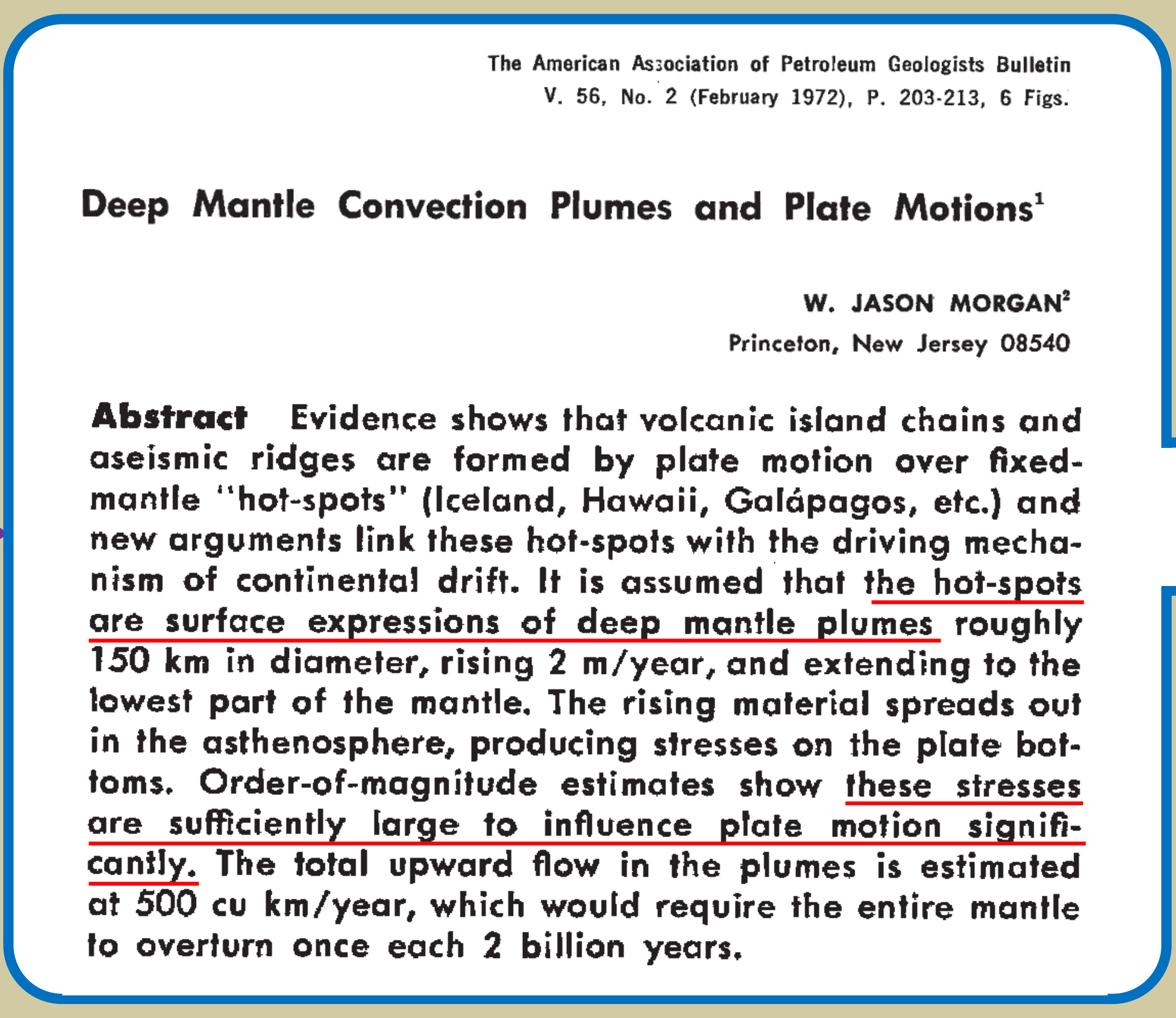
Institute of Earth Sciences, University of Toronto, Toronto, Ontario

Received March 15, 1963

Wilson (1963) Can. J. Phys., 41, 863-870

FIG. 5. Diagram to illustrate that if lava is generated in the stable core of a convection cell, and the surface is carried by the jet stream, then one source can give rise to a chain of extinct volcanoes even if the source is not over a rising current. This is proposed as a possible origin of the Hawaiian chain of islands.

From the original SHALLOW derivation model, the mantle plume concept passes to DEEP mantle source



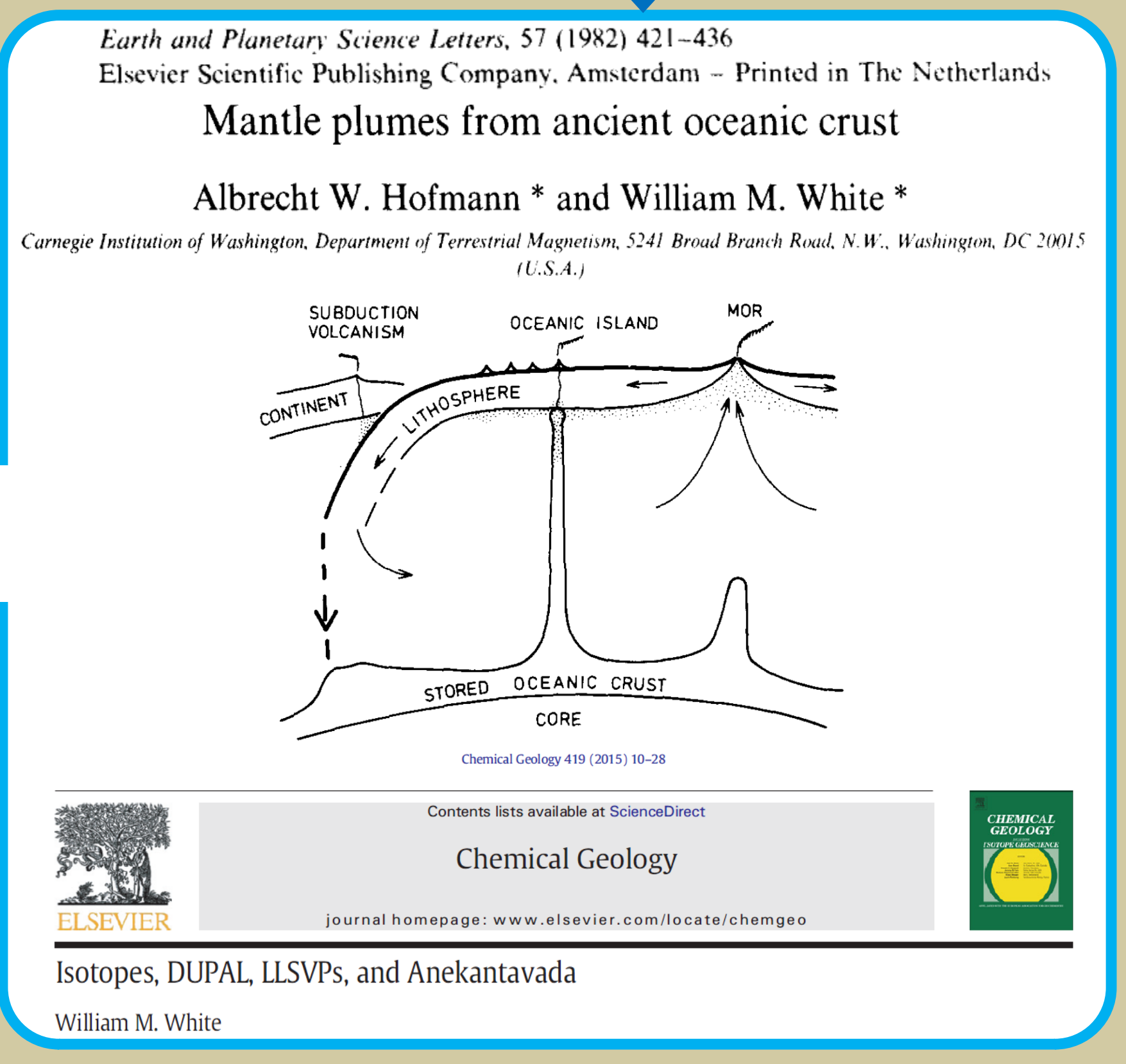
The American Association of Petroleum Geologists Bulletin
V. 56, No. 2 (February 1972), P. 203-213, 6 Figs.

Deep Mantle Convection Plumes and Plate Motions[1]

W. JASON MORGAN[2]
Princeton, New Jersey 08540

Abstract Evidence shows that volcanic island chains and aseismic ridges are formed by plate motion over fixed-mantle "hot-spots" (Iceland, Hawaii, Galápagos, etc.) and new arguments link these hot-spots with the driving mechanism of continental drift. It is assumed that the hot-spots are surface expressions of deep mantle plumes roughly 150 km in diameter, rising 2 m/year, and extending to the lowest part of the mantle. The rising material spreads out in the asthenosphere, producing stresses on the plate bottoms. Order-of-magnitude estimates show these stresses are sufficiently large to influence plate motion significantly. The total upward flow in the plumes is estimated at 500 cu km/year, which would require the entire mantle to overturn once each 2 billion years.

Geochemistry claims to have the power to distinguish mantle plume melts from "normal" (i.e., oceanic ridge) melts



Earth and Planetary Science Letters, 57 (1982) 421–436
Elsevier Scientific Publishing Company, Amsterdam – Printed in The Netherlands

Mantle plumes from ancient oceanic crust

Albrecht W. Hofmann * and William M. White *

Carnegie Institution of Washington, Department of Terrestrial Magnetism, 5241 Broad Branch Road, N.W., Washington, DC 20015 (U.S.A.)

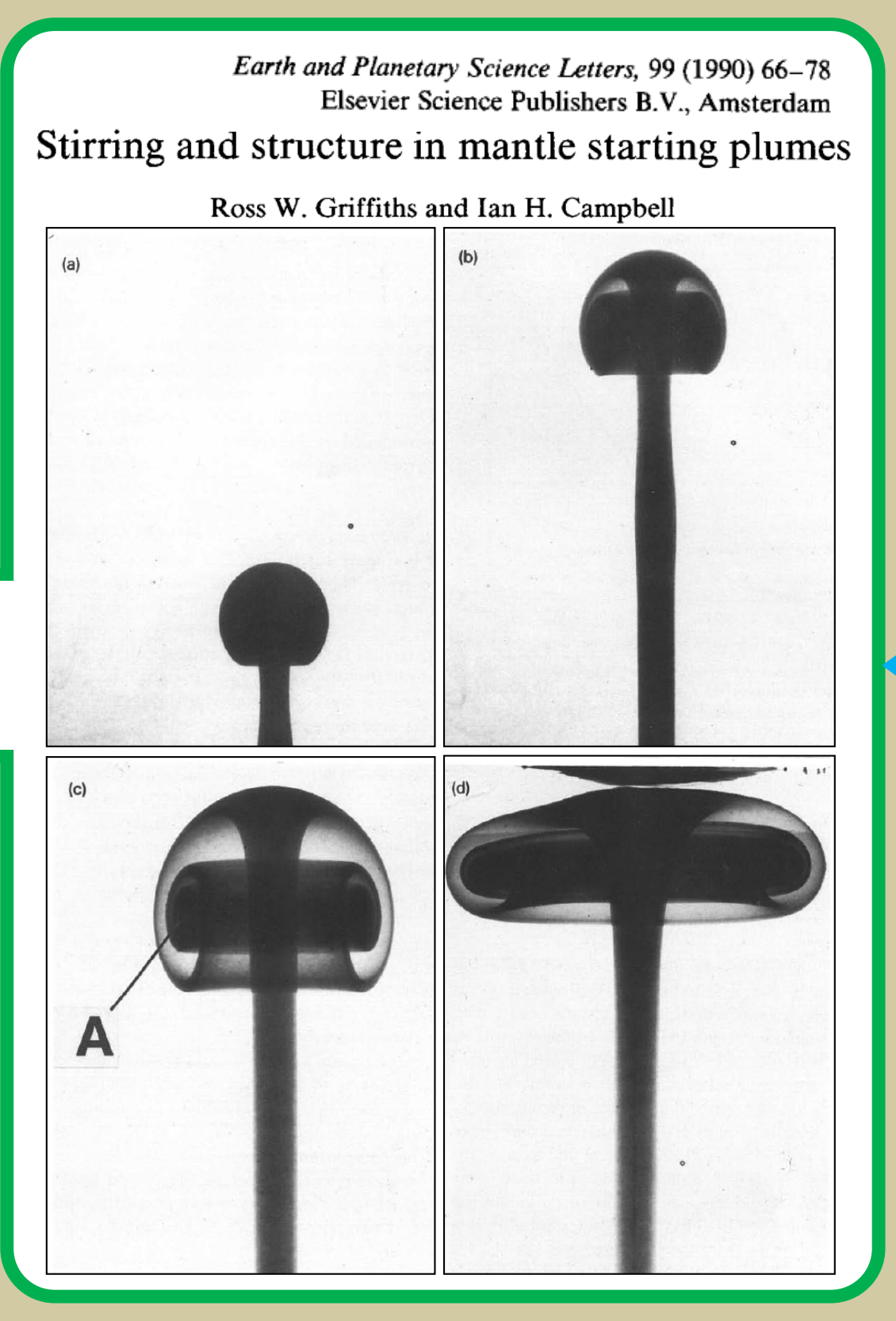
Chemical Geology 419 (2015) 10–28

Contents lists available at ScienceDirect
Chemical Geology
journal homepage: www.elsevier.com/locate/chemgeo

Isotopes, DUPAL, LLSVPs, and Anekantavada

William M. White

Mantle plumes are "created" also in laboratory with unrealistic constraints

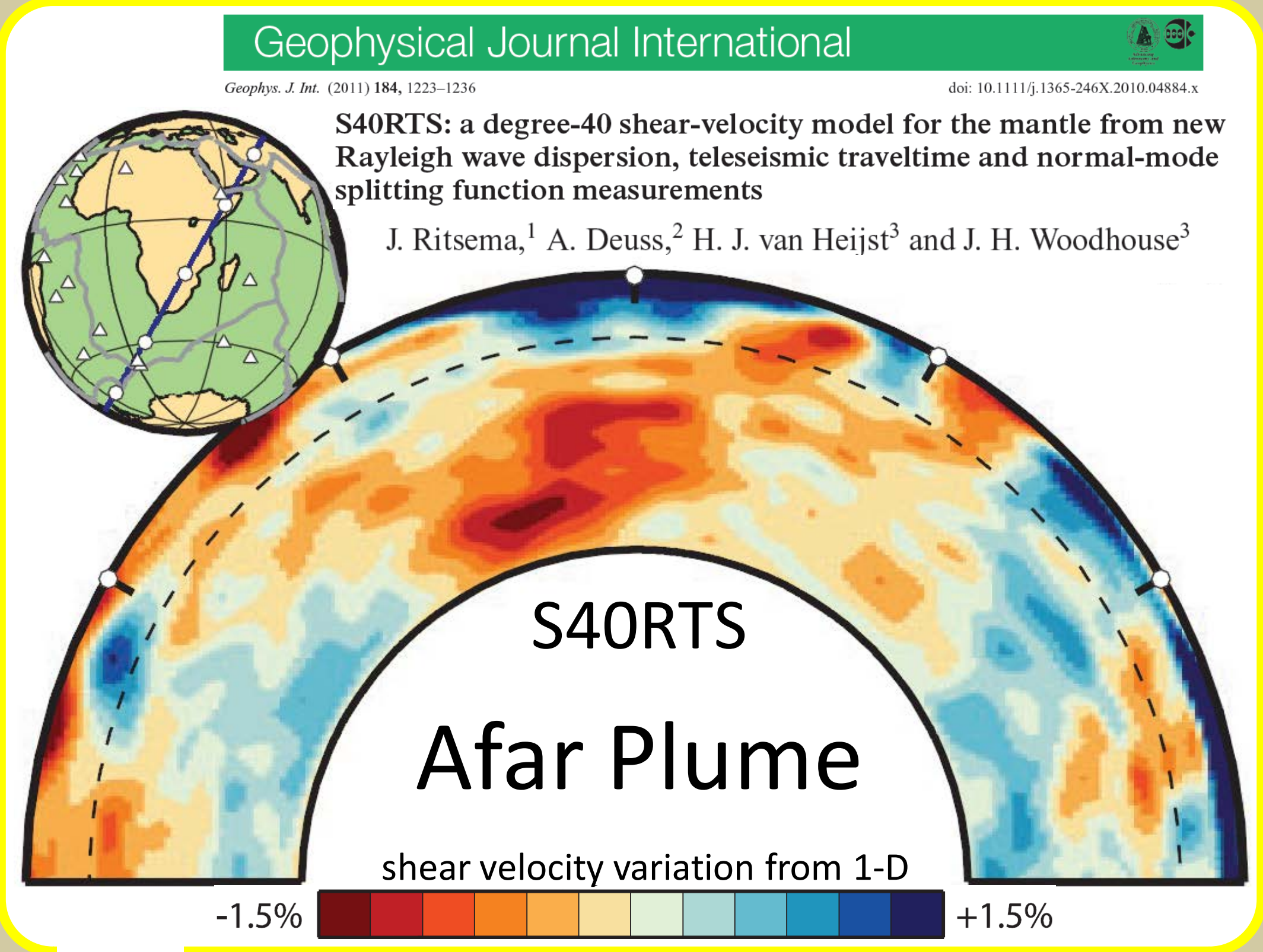


Earth and Planetary Science Letters, 99 (1990) 66–78
Elsevier Science Publishers B.V., Amsterdam

Stirring and structure in mantle starting plumes

Ross W. Griffiths and Ian H. Campbell

And are also seen as whole-Earth features identified with seismic tomography



Geophysical Journal International

Geophys. J. Int. (2011) **184**, 1223–1236 doi: 10.1111/j.1365-246X.2010.04884.x

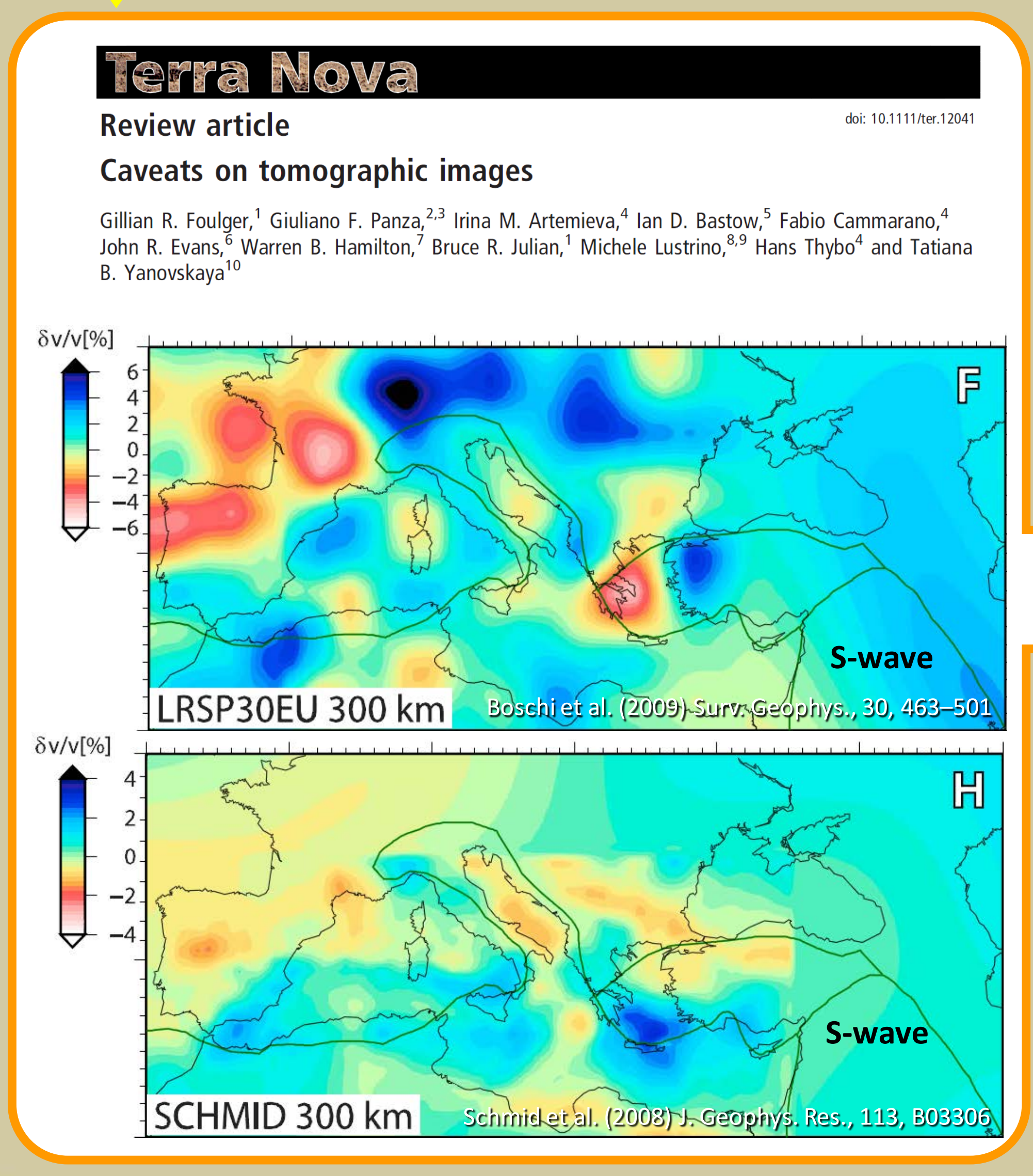
S40RTS: a degree-40 shear-velocity model for the mantle from new Rayleigh wave dispersion, teleseismic traveltime and normal-mode splitting function measurements

J. Ritsema,[1] A. Deuss,[2] H. J. van Heijst[3] and J. H. Woodhouse[3]

Tomography cannot identify mantle plumes. Its resolution is too low at high depth. Seismic waves are not influenced by temperature only (as instead commonly assumed)

Mantle plumes cannot be identified with geochemistry. No way to do that. Sr-Nd-Pb-Hf-O-Os-W isotopic ratios can be explained in terms of crustal lithology recycling

A correct approach must take into account seismology, geochemistry, petrology, mineral physics, volcanology, structural geology, field geology and, above all, obvious evidences



Terra Nova

Review article

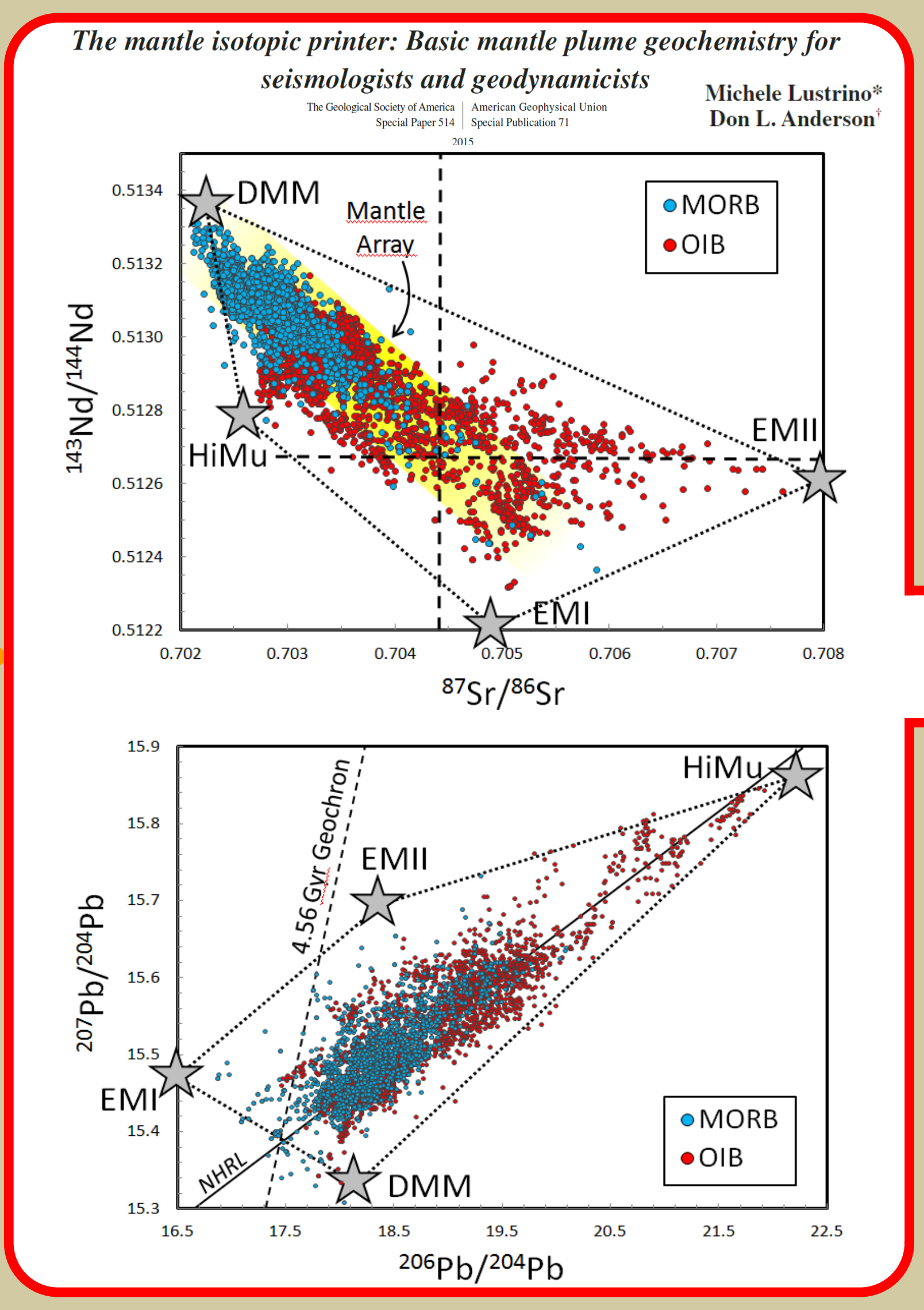
doi: 10.1111/ter.12041

Caveats on tomographic images

Gillian R. Foulger,[1] Giuliano F. Panza,[2,3] Irina M. Artemieva,[4] Ian D. Bastow,[5] Fabio Cammarano,[4] John R. Evans,[6] Warren B. Hamilton,[7] Bruce R. Julian,[1] Michele Lustrino,[8,9] Hans Thybo[4] and Tatiana B. Yanovskaya[10]

Boschi et al. (2009) Surv. Geophys., 30, 463–501

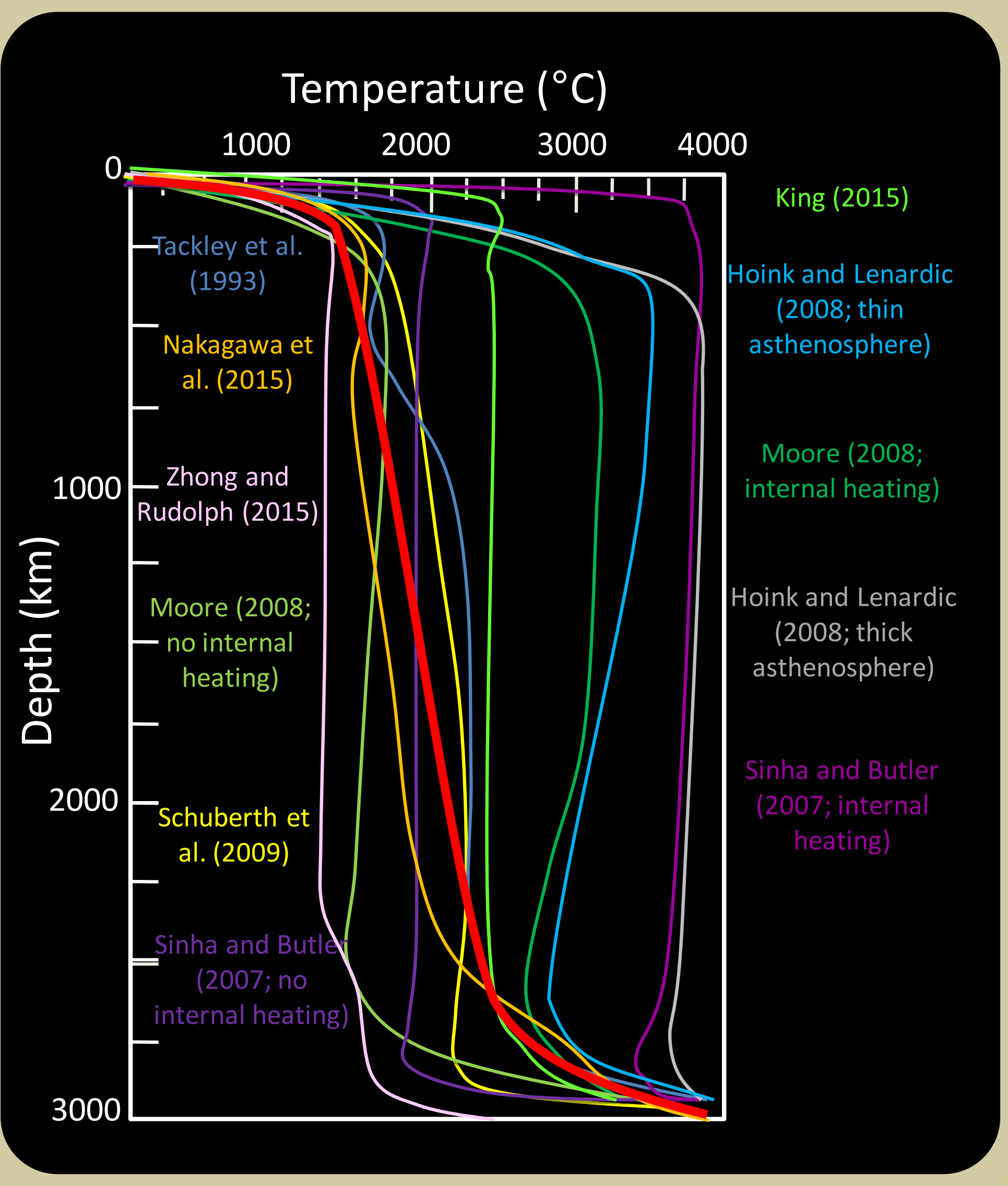
Schmid et al. (2008) J. Geophys. Res., 113, B03306



The mantle isotopic printer: Basic mantle plume geochemistry for seismologists and geodynamicists

Michele Lustrino*
Don L. Anderson†

The Geological Society of America Special Paper 514 | American Geophysical Union Special Publication 71
2015



1) The Earth's interior comprised between the two thermal boundary layers is likely to be subadiabatic. Shear heating and U-Th-K concentration can render the shallow mantle hotter than the deep mantle. High Tp of "plume" magmas not necessarily indicates an origin from D". The mantle cools the outer core, it is not the core to heat the mantle. The calculation itself of Tp is at least dubious and risky without correct petrographic investigation.
2) Geochemical end members (e.g., HIMU, EMI and EMII) can be entirely located in the shallow non-convecting volume of the mantle, while the fourth (DMM), which is by far the more abundant volumetrically, can reside in the transition zone.