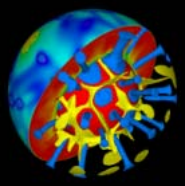
Tertiary-Quaternary magmatism in Europe: How has it influenced or been influenced by the evolution of the lithosphere?



ILP PLUME Project

Marjorie Wilson
School of Earth & Environment
Leeds University
LEEDS, UK

EMAW 2007
Ferrara, Italy: 29th August 2007

ILP PLUME PROJECT

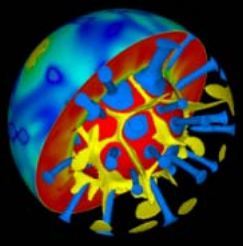


Image from JAMSTEC
Earth Simulation Centre
www.es.jamstec.go.jp

PLume-like instabilities in the
Upper Mantle beneath
Europe

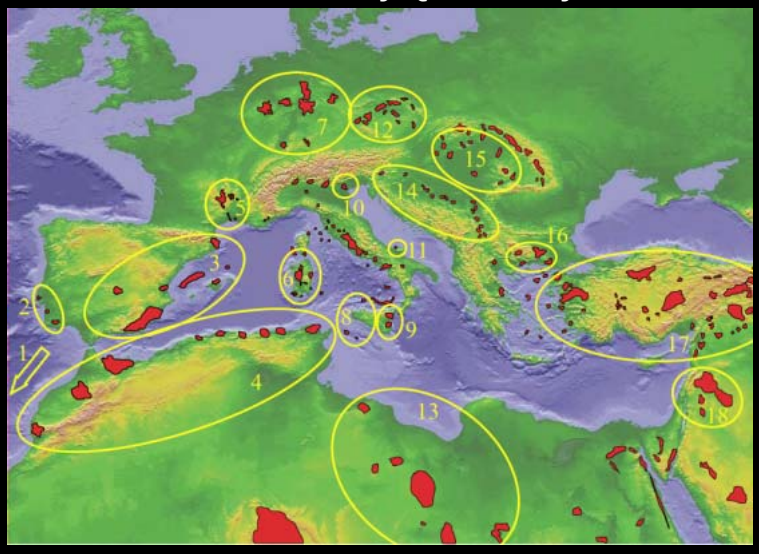
Marjorie Wilson
School of Earth & Environment
Leeds University, UK
Uli Achauer
EOST-IPG Strasbourg, France
Laboratoire de sismologie

INTERNATIONAL LITHOSPHERE PROGRAM

Acknowledgements

- Hilary Downes
- Michele Lustrino
- Jose-Maria Cebria
- Uli Achauer
- Jaromir Ulrych
- PLUME project partners
- Jeff Rosenbaum

Distribution of Tertiary-Quaternary volcanism



Wilson & Lustrino (2007) Earth Science Reviews

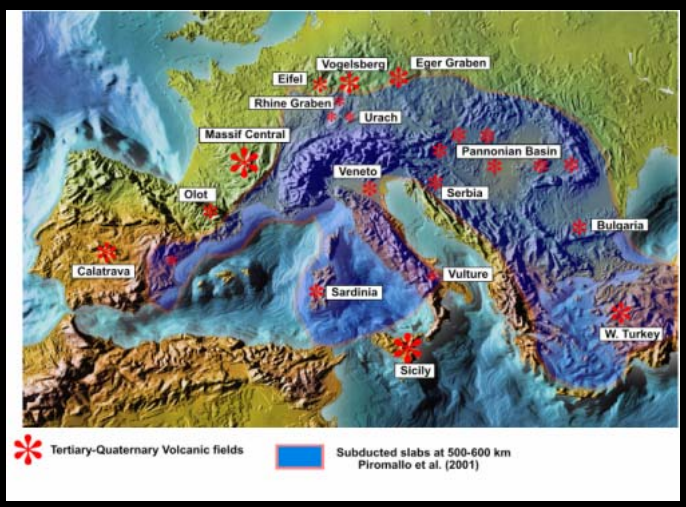
KEY QUESTIONS ABOUT THE MAGMATISM

- Why does it occur where and when it does?
- Role of the mantle lithosphere in magma generation processes - SOURCE or SINK?

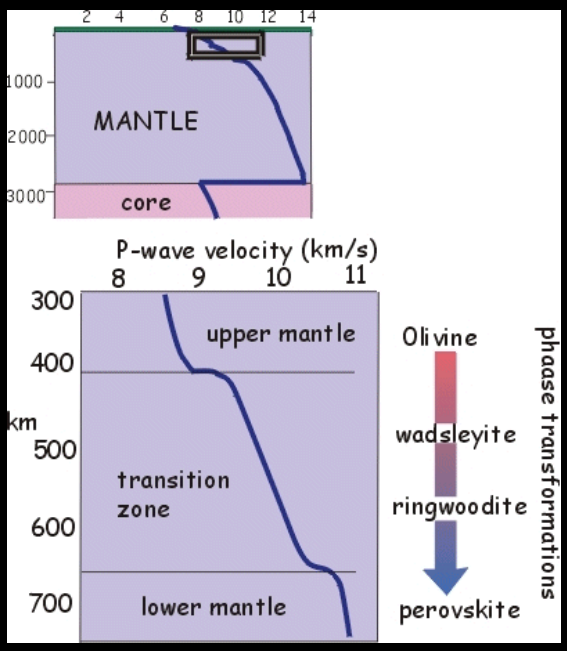
OBSERVATIONS

- Plume-like structures in the upper mantle - verified by local seismic tomography experiments
- Link with Alpine orogenesis & rifting
- Slab-graveyard in the Transition Zone
- Mantle xenoliths - fragments of the lithosphere
- Geochemistry of the most primitive mafic magmas

Association with fast seismic velocities in the Transition Zone at the base of the upper mantle



Base of the upper mantle (410-660 km) is seismically FAST - this could be a region of subducted slabs - SLAB GRAVEYARD



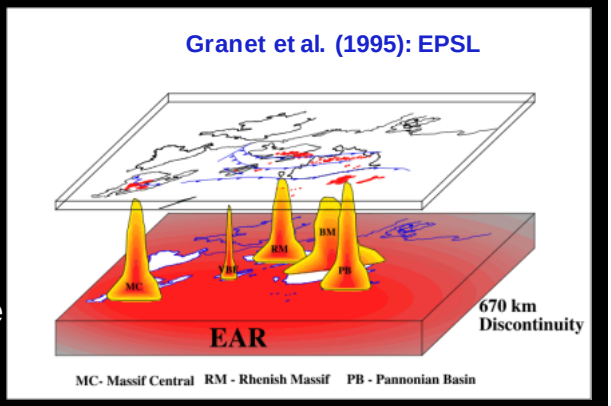
Transition Zone is seismically FAST - but not necessarily "COLD"

Is the Transition Zone a SLAB GRAVEYARD?

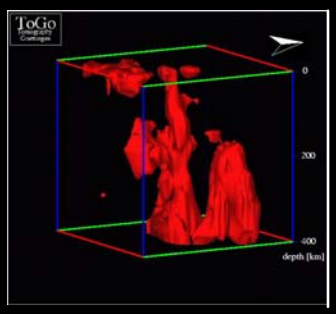
Based upon the results of a local seismic tomographic experiment in the Massif Central, in 1995 Granet, Wilson & Achauer proposed the existence of diapiric mantle upwellings (mantle "hot fingers") beneath each of the volcanic provinces

What do these convective instabilities in the European upper mantle look like?

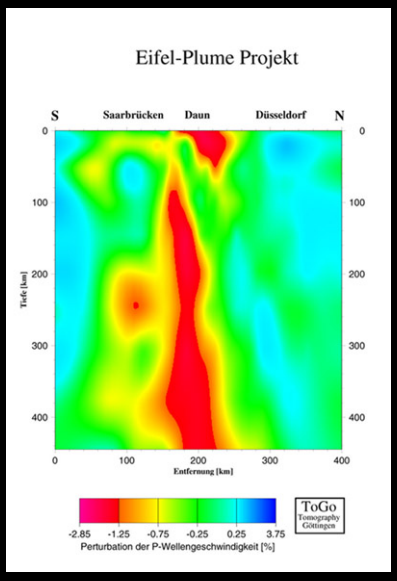
What is the evidence that they really exist?



EAR: European Asthenospheric Reservoir

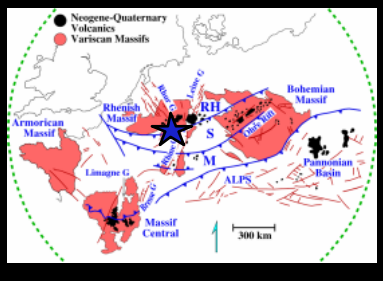


The Eifel plume



Ritter et al. (2001)

What do upper mantle plumes look like?



Does the European upper mantle look something like this……?

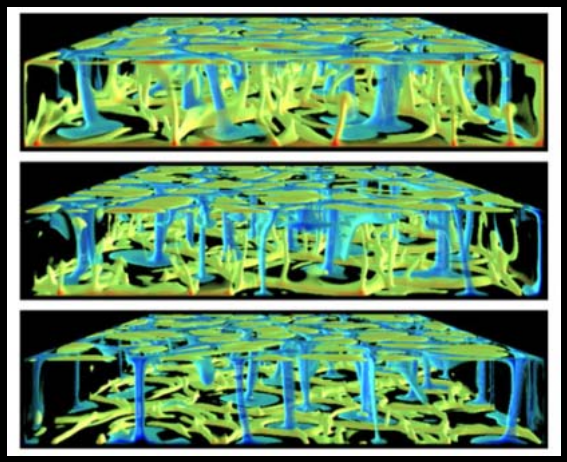


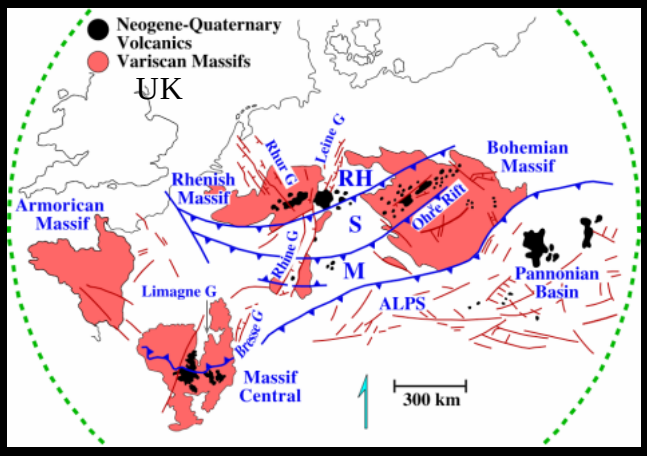
Image from JAMSTEC, Earth Simulation Centre, www.es.jamstec.go.jp

If so …. WHY?

Is this kind of mantle structure related to the collision of Africa with Eurasia during the Cenozoic?

WHAT CAN WE LEARN FROM THE VOLCANISM?

Tertiary-Quaternary volcanic fields are associated with basement uplift…….



Are the volcanic fields all associated with upper mantle velocity anomalies?

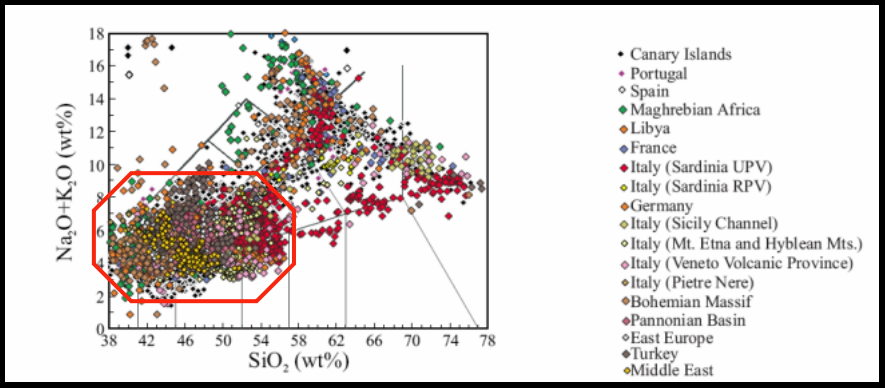
Can we identify a unique mantle source?

EAR?

How do we integrate the geochemical and geophysical data?

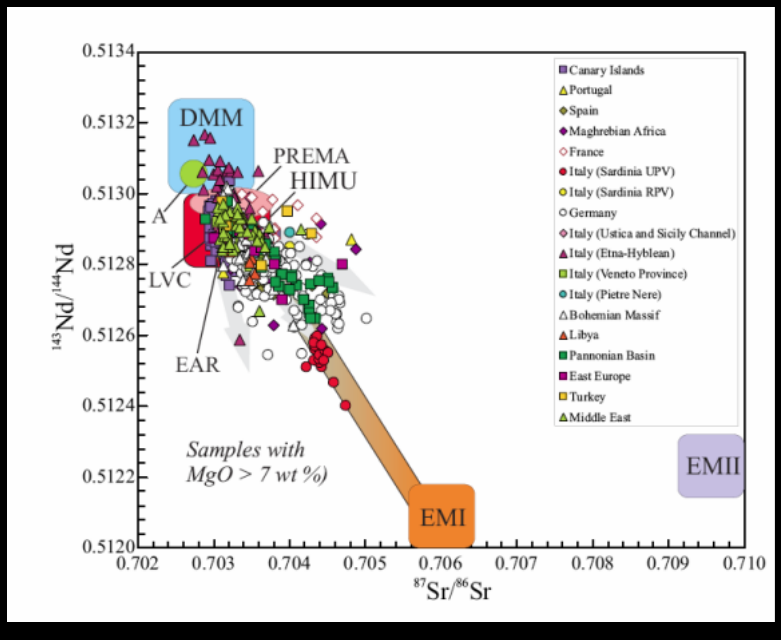
Chemistry of the volcanic rocks

Melilitites, nephelinites, basanites, alkali basalts, sub-alkaline basalts

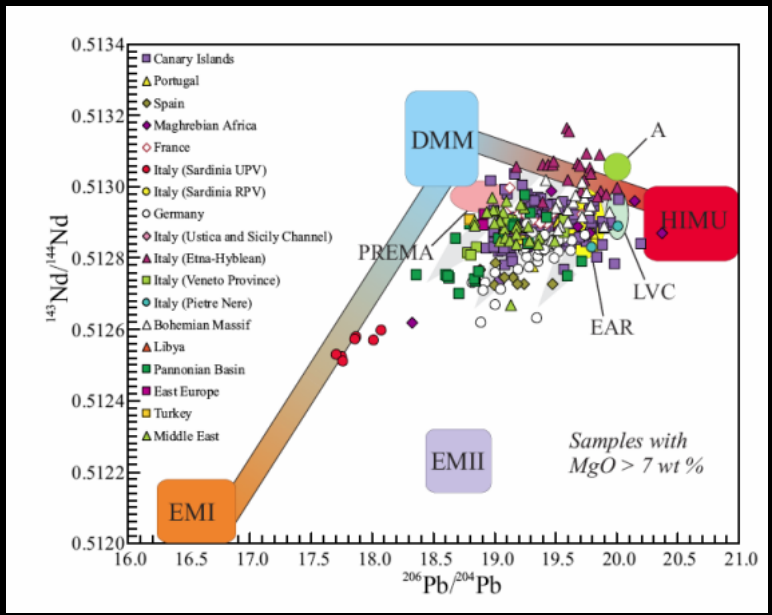


Lustrino & Wilson (2007): Earth Science Reviews
Compilation of >12,000 samples

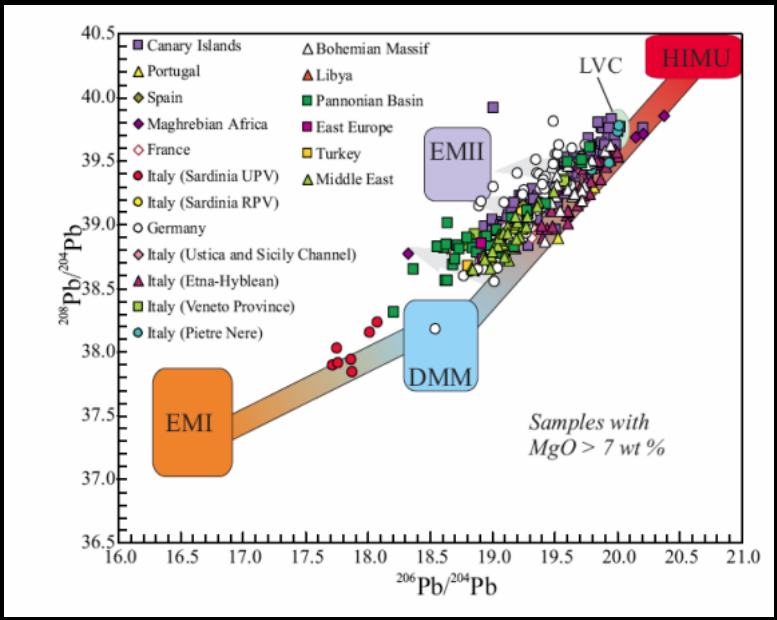
Nd-Sr isotope data



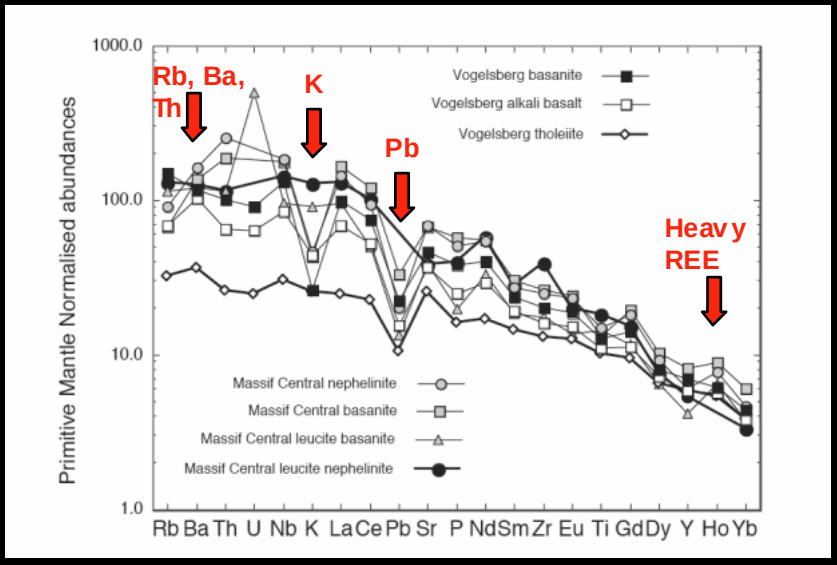
Nd-Pb isotope data

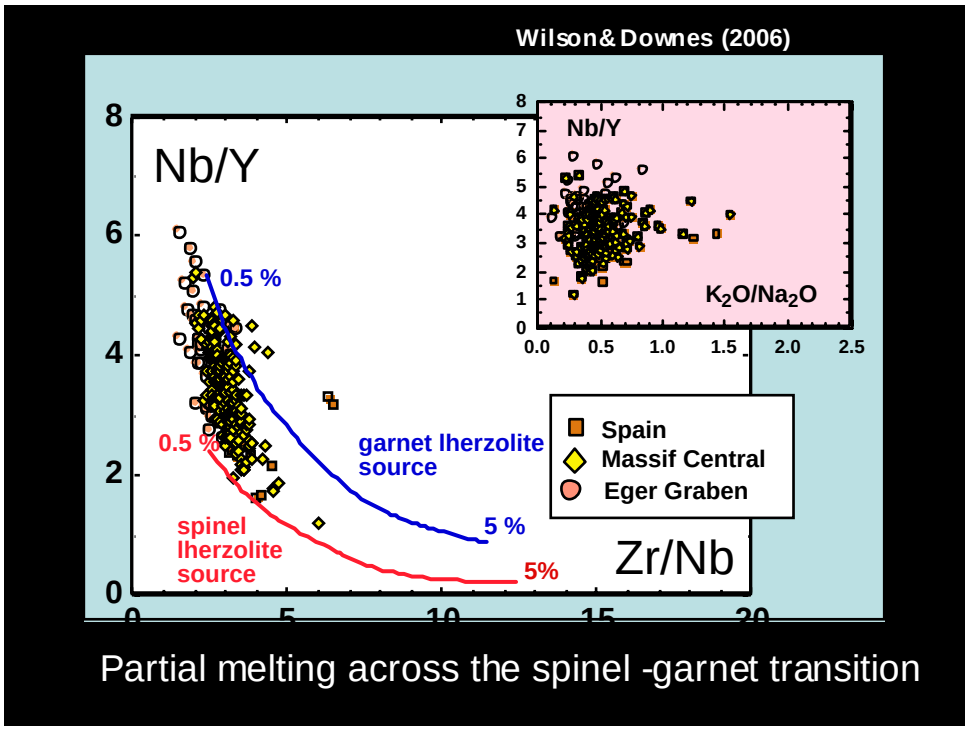


Pb isotope data

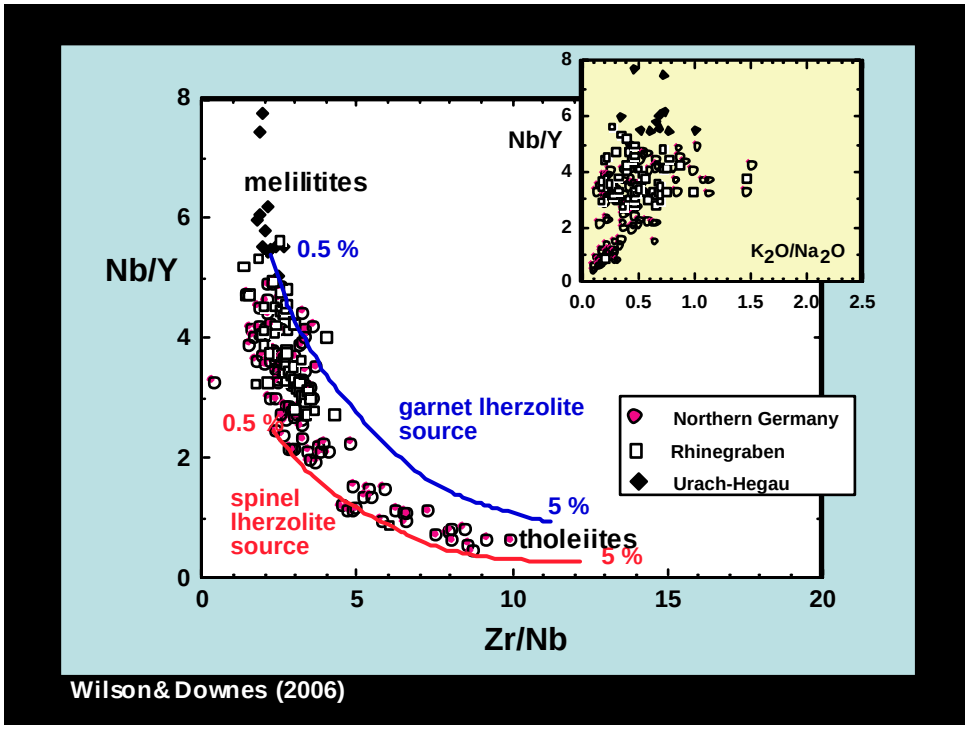


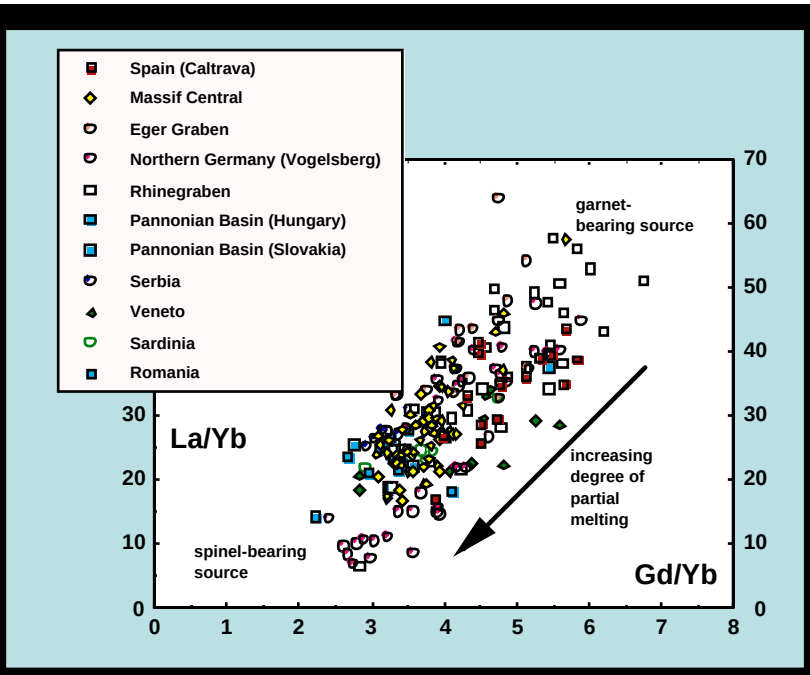
Trace elements → Amphibole in source





Partial melting across the spinel -garnet transition

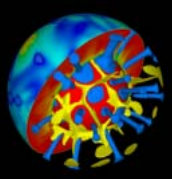


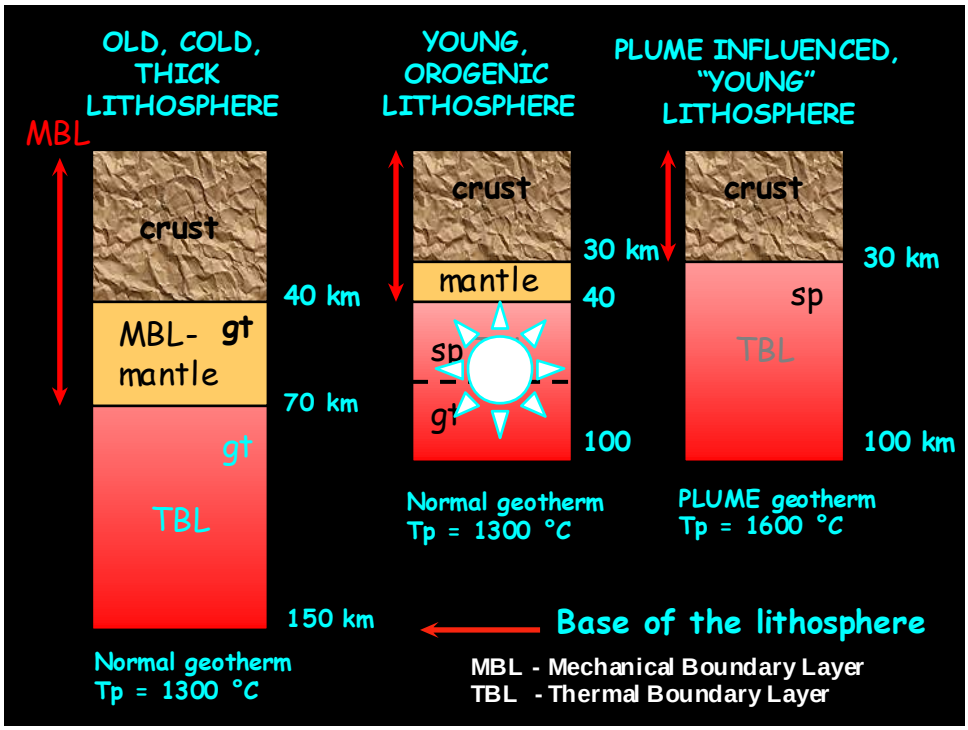


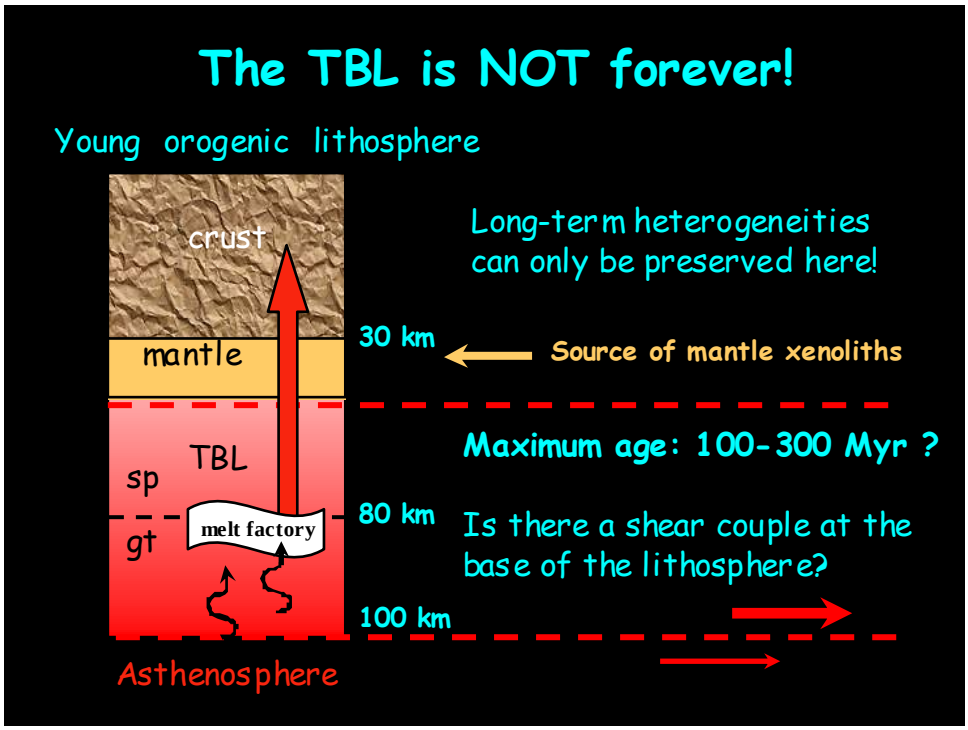
Wilson& Downes (2006)

What can we conclude thus far?

- magmas are generated by partial melting across the spinel to garnet transition
- mantle source contains amphibole
- association with "plume-like" structures in the upper mantle
- regional association with fast seismic velocity anomalies in the upper 400-600 km of the mantle - ? SLAB GRAVEYARD
- common mantle source Sr-Nd-Pb isotope characteristics - EAR (European Asthenospheric Reservoir)




OLD, COLD, THICK LITHOSPHERE
YOUNG, OROGENIC LITHOSPHERE
PLUME INFLUENCED, "YOUNG" LITHOSPHERE
MBL
crust
MBL- gt mantle
gt
TBL
40 km
70 km
150 km
crust
mantle
sp
gt
30 km
40
100
crust
sp
TBL
30 km
100 km
Normal geotherm
Tp = 1300 °C
PLUME geotherm
Tp = 1600 °C
Normal geotherm
Tp = 1300 °C
Base of the lithosphere
MBL - Mechanical Boundary Layer
TBL - Thermal Boundary Layer

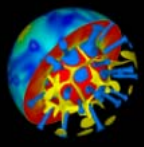

The TBL is NOT forever!
Young orogenic lithosphere
crust
mantle
sp
TBL
gt
melt factory
30 km
80 km
100 km
Asthenosphere
Long-term heterogeneities can only be preserved here!
Source of mantle xenoliths
Maximum age: 100-300 Myr ?
Is there a shear couple at the base of the lithosphere?

What causes the short-wavelength instabilities in the upper mantle beneath Europe?

- Are they PLUMES related to mantle convection?
- If so, are they thermal or compositional instabilities?
- If NOT, how else might they originate?

OPTIONS

- HOT ? unlikely
- WET ?
- Geodynamically induced "splashes" ?

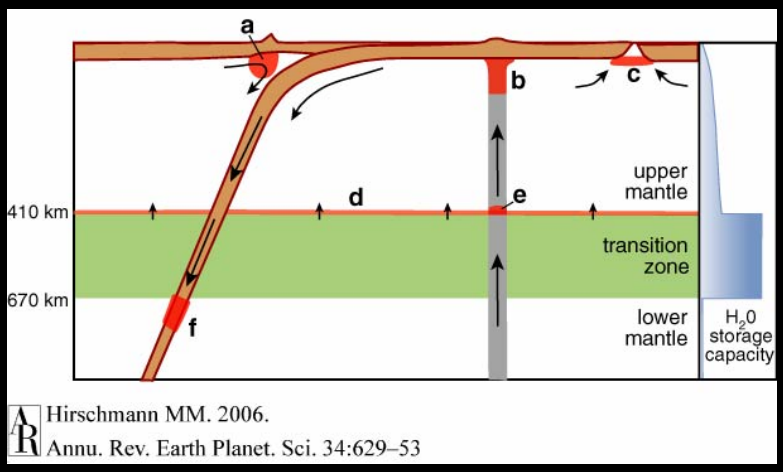


Splash plumes

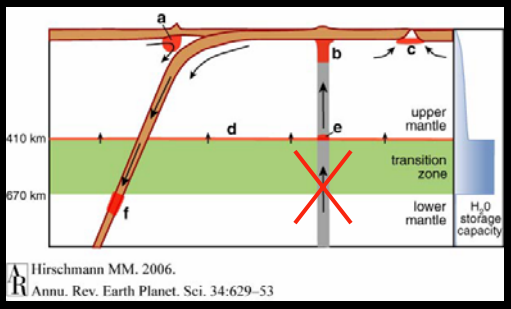
Davies & Bunge (2006)
Geology 34 : 349-352

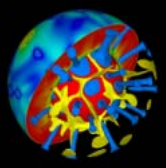
PLUME-like instabilities are dynamic upwellings representing upper mantle displaced by delaminating slabs of subducted oceanic lithosphere

POSSIBLE - post-collisional tectonic setting



So how about "WET" ?
The Transition Zone could be the "wettest" part of the Earth's mantle!

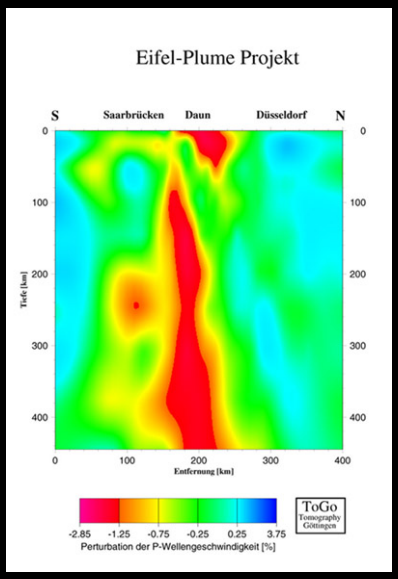




Locations of wet melting

European "PLUMES" are loci of fluid release from the top of the TRANSITION ZONE

Partial melting is triggered deep (point e) at 410 km depth
Small-degree melts migrate upwards
At "b" melt fractions from the melting column "pool" close to the base of the lithosphere and segregate



CONCLUSIONS

- European "plumes" are the products of fluid release from the top of the Transition Zone
- So - they are "wetspots" NOT "hotspots"
- The lithosphere is a "sink" not a source for magmatism - although it can locally "contaminate" the magmas
- The "melt factory" is at the base of the lithosphere

PREDICTIONS

- ALL "plume-like" structures which terminate at 660 km depth (determined by seismic tomography) are fluid-release structures (INCLUDING ICELAND)
- The distinctive chemistry (EAR/FOZO) of the associated intra-plate basalts is linked to fluid release from subducted oceanic lithosphere stored in the Transition Zone
- The paradigm should be applicable globally