Measuring Earth's Magnetic Field at Sea

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INMARTECH 2018

THE AMERICAN WEEKLY

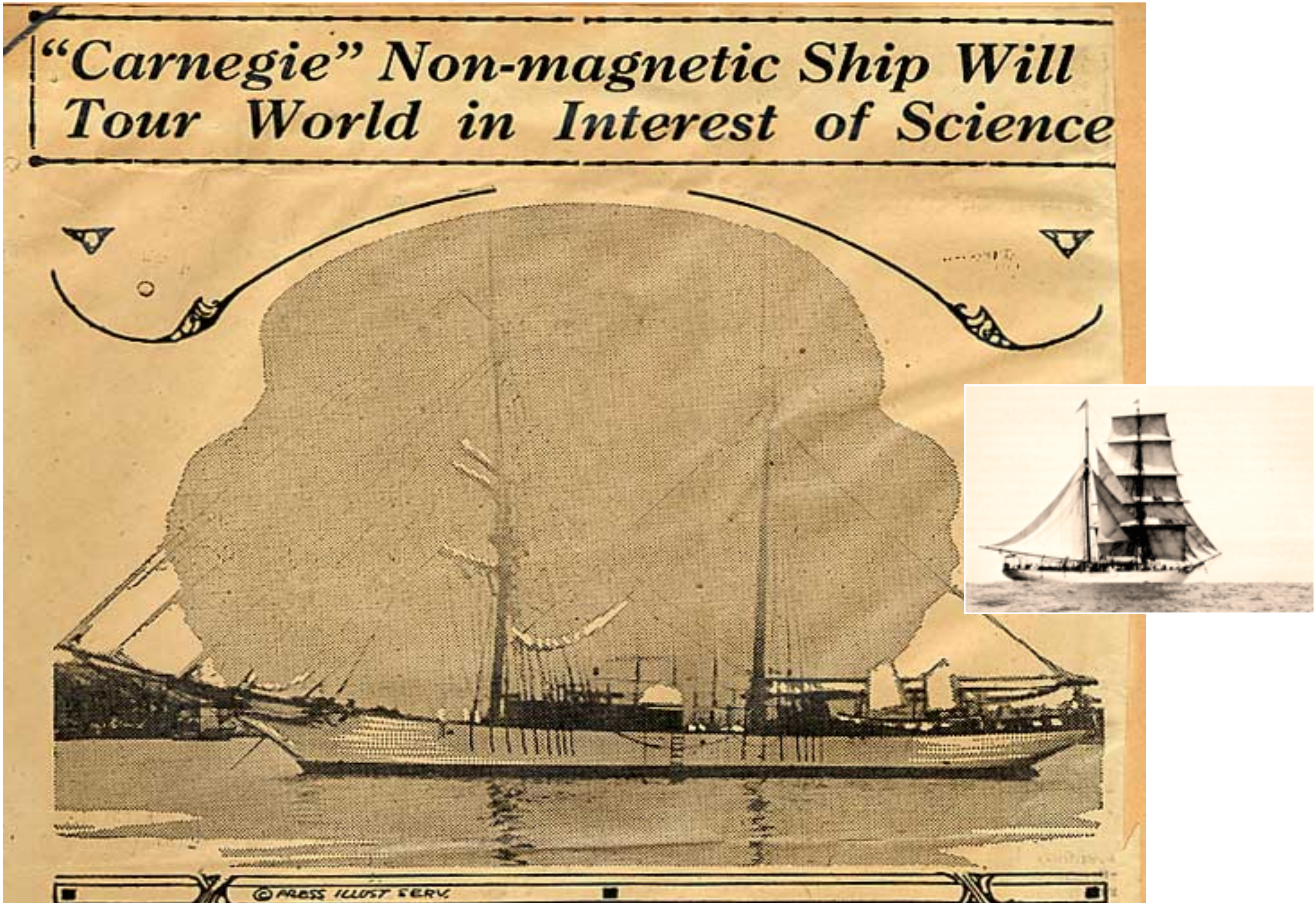
Greatest Circulation in the World

Magazine Section of the
Washington Herald
Sunday May 27, 1928

Magnetism, Supreme Mystery of Science

Colored Sketch of the Aurora Borealis, Reproduced from "The Forces of Nature," Published by Macmillan.

Carnegie Expedition 1909-1929



"Carnegie" Non-magnetic Ship Will Tour World in Interest of Science

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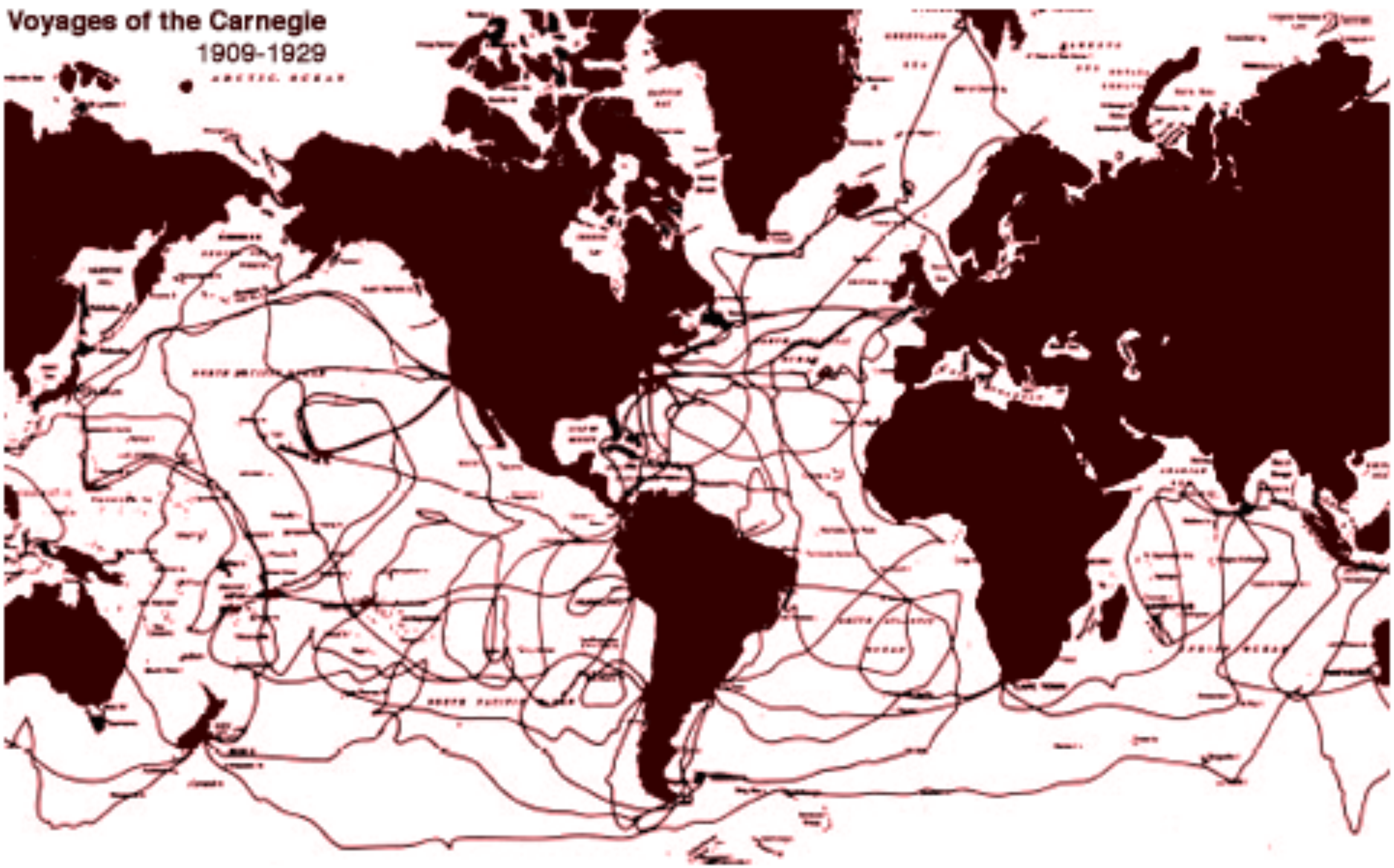
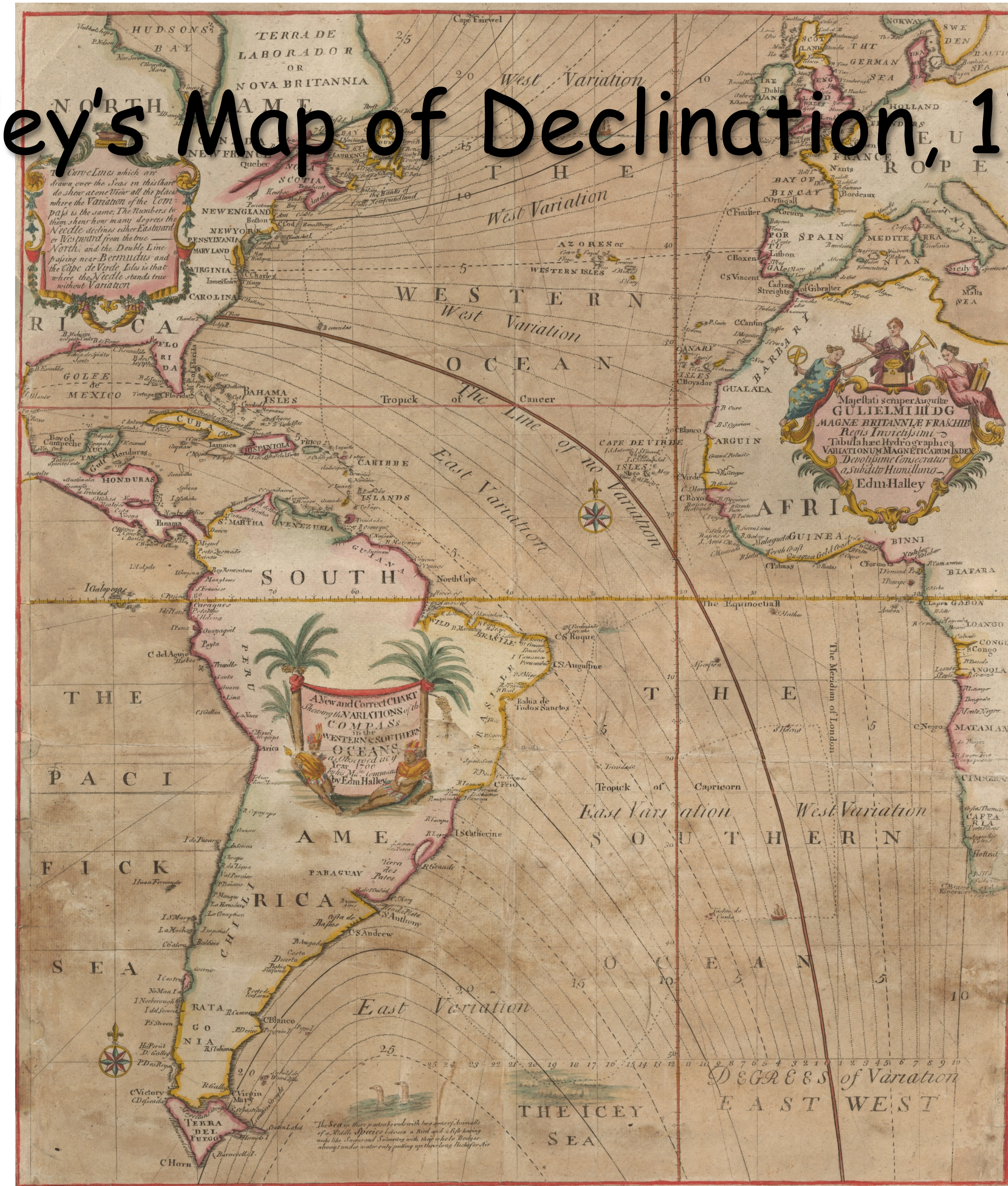
Carnegie Expedition 1909-1929



Halley's Map of Declination, 1701



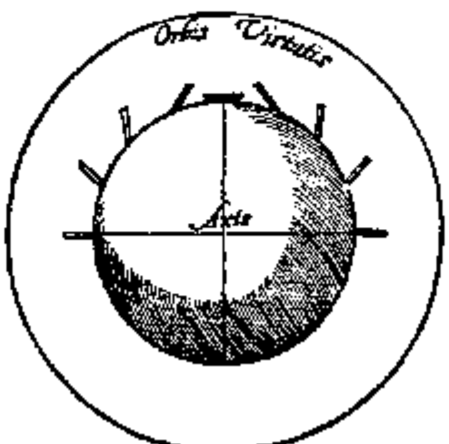
So, what is a Magnetic Field?

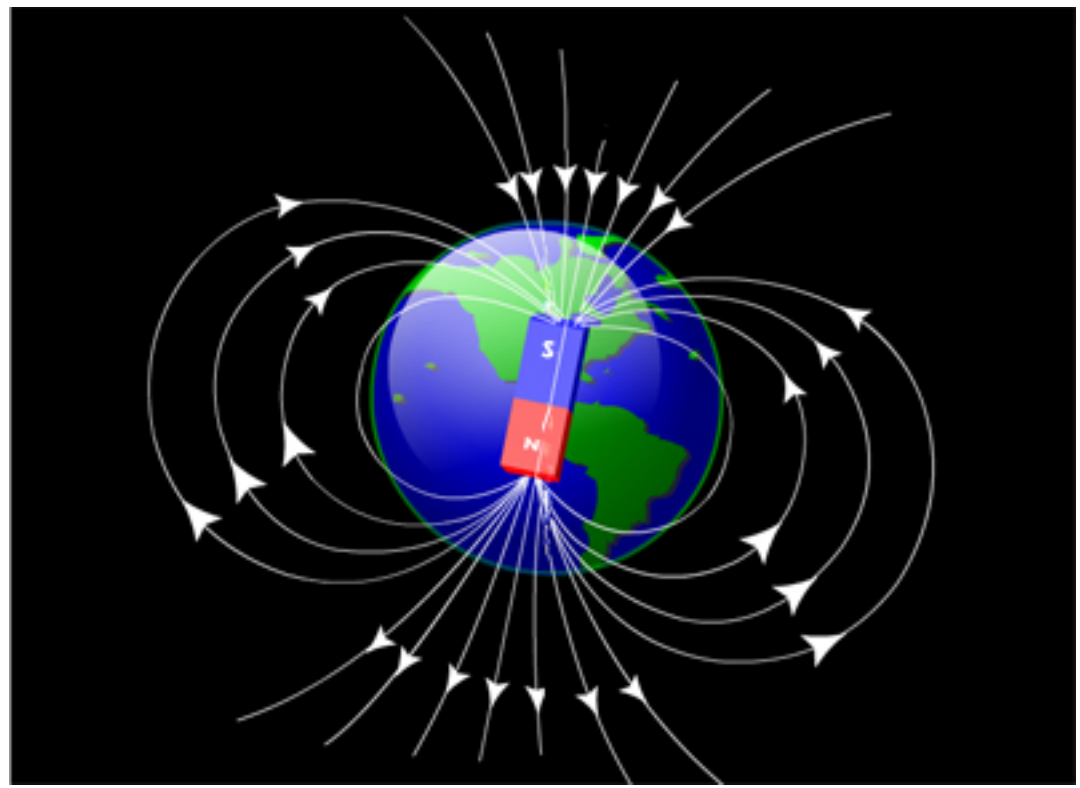
- Magnetic fields are generated by the motion of charge - electric currents or by quantum-mechanical spin of electrons in materials.

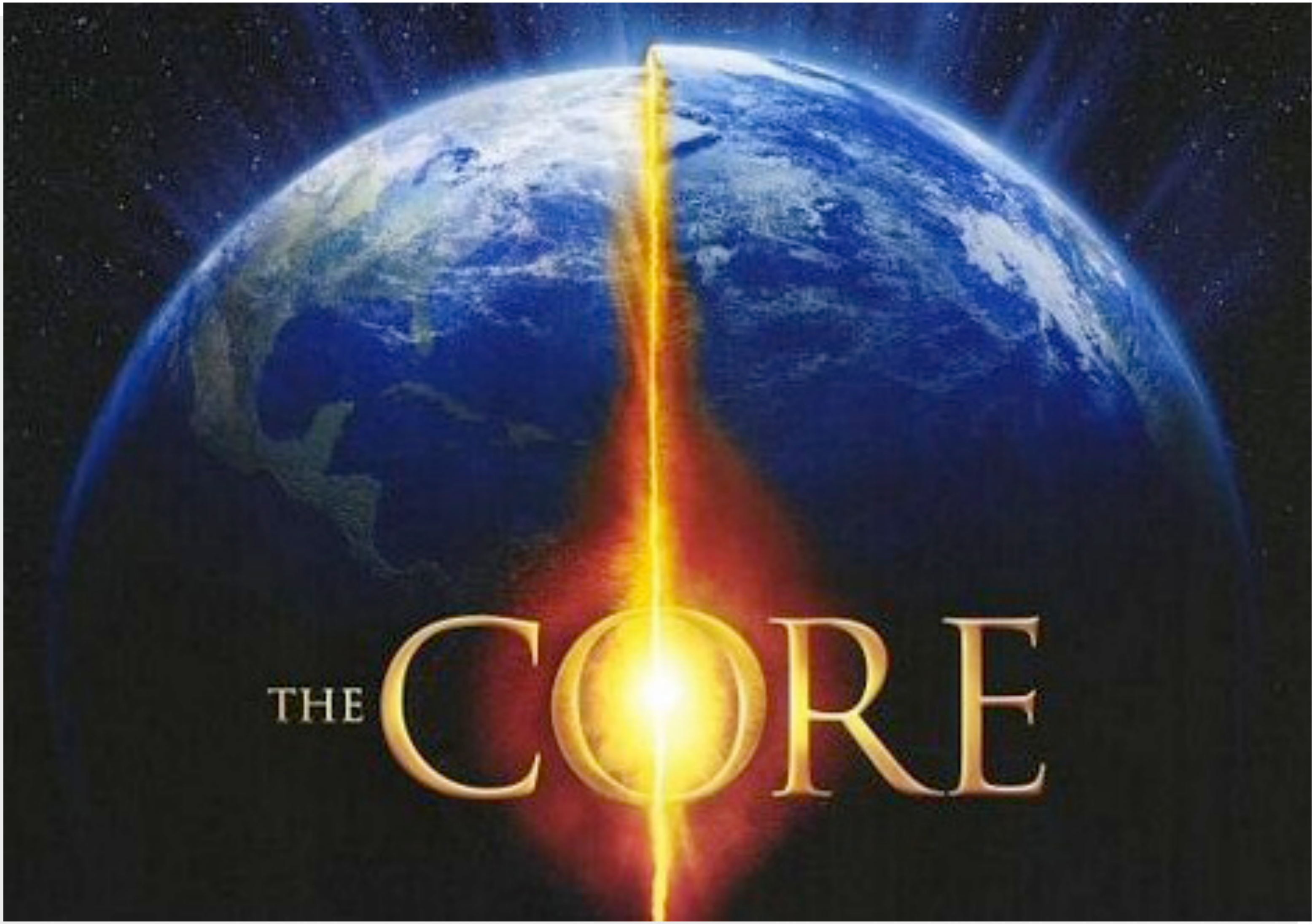
- It is a vector field in that it has both intensity and direction

- Field lines are loops - don't start and stop anywhere (no monopoles)

Sir William Gilbert
1600
De Magnete






THE CORE

11.01.02
THE ONLY WAY OUT IS IN

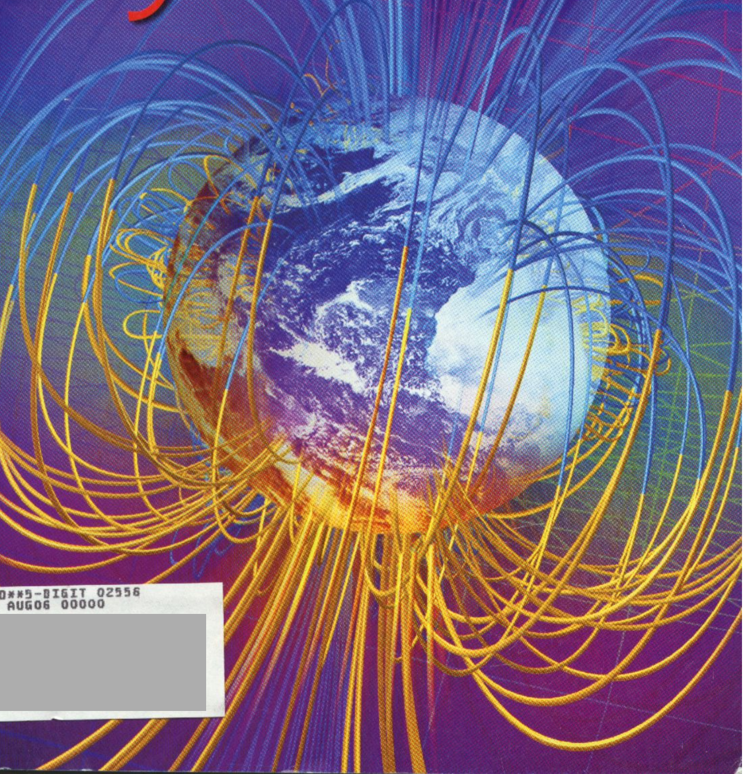
THE BEST HOPES FOR STOPPING SPAM • MANAGING THE FUTURE

SCIENTIFIC AMERICAN

Monkey Business: The Evolutionary Roots of Economic Behavior

APRIL 2005 $4.99
WWW.SCIAM.COM

WHAT FLIPS THE MAGNETIC POLES? THE ANSWER LURKS IN THE EARTH'S Geodynamo



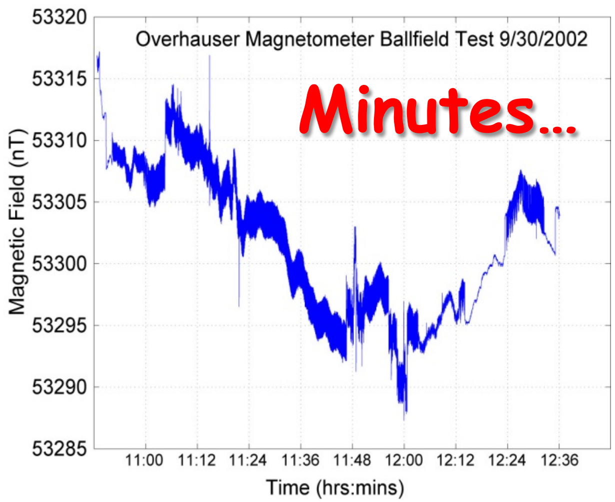
Superconductor Breaks the Rules

The Splice of Life: Why Humans Don't Need More Genes

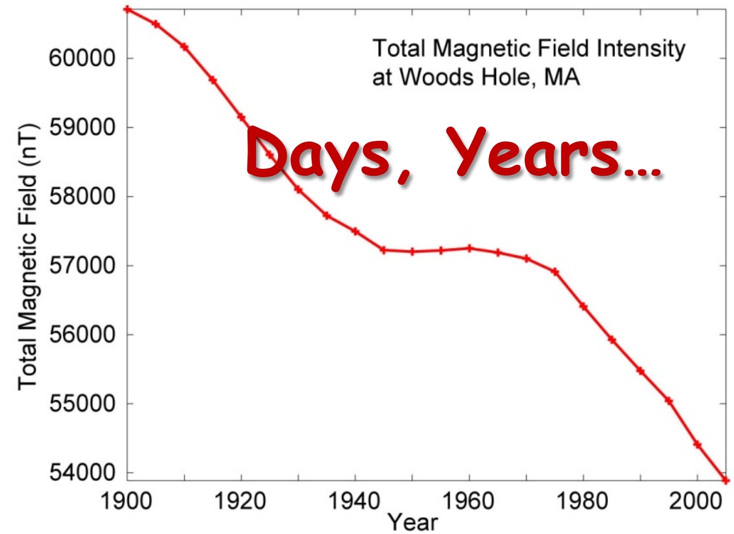
New Painkillers from a Toxic Snail

Magnetism -
A dynamic property of the Earth

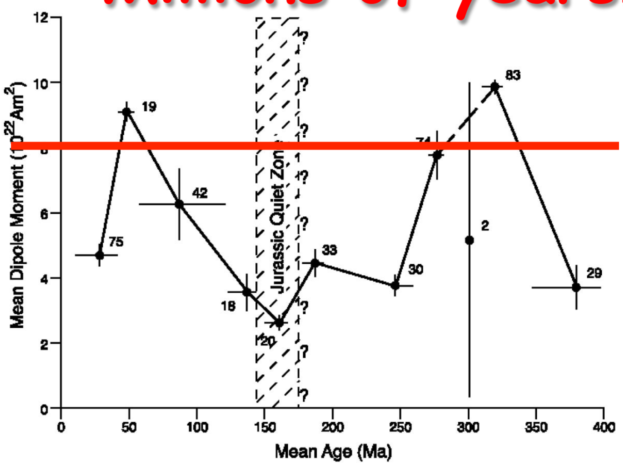
Minutes…



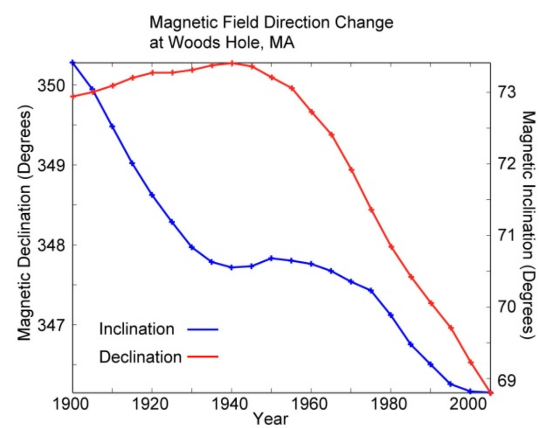
Days, Years…



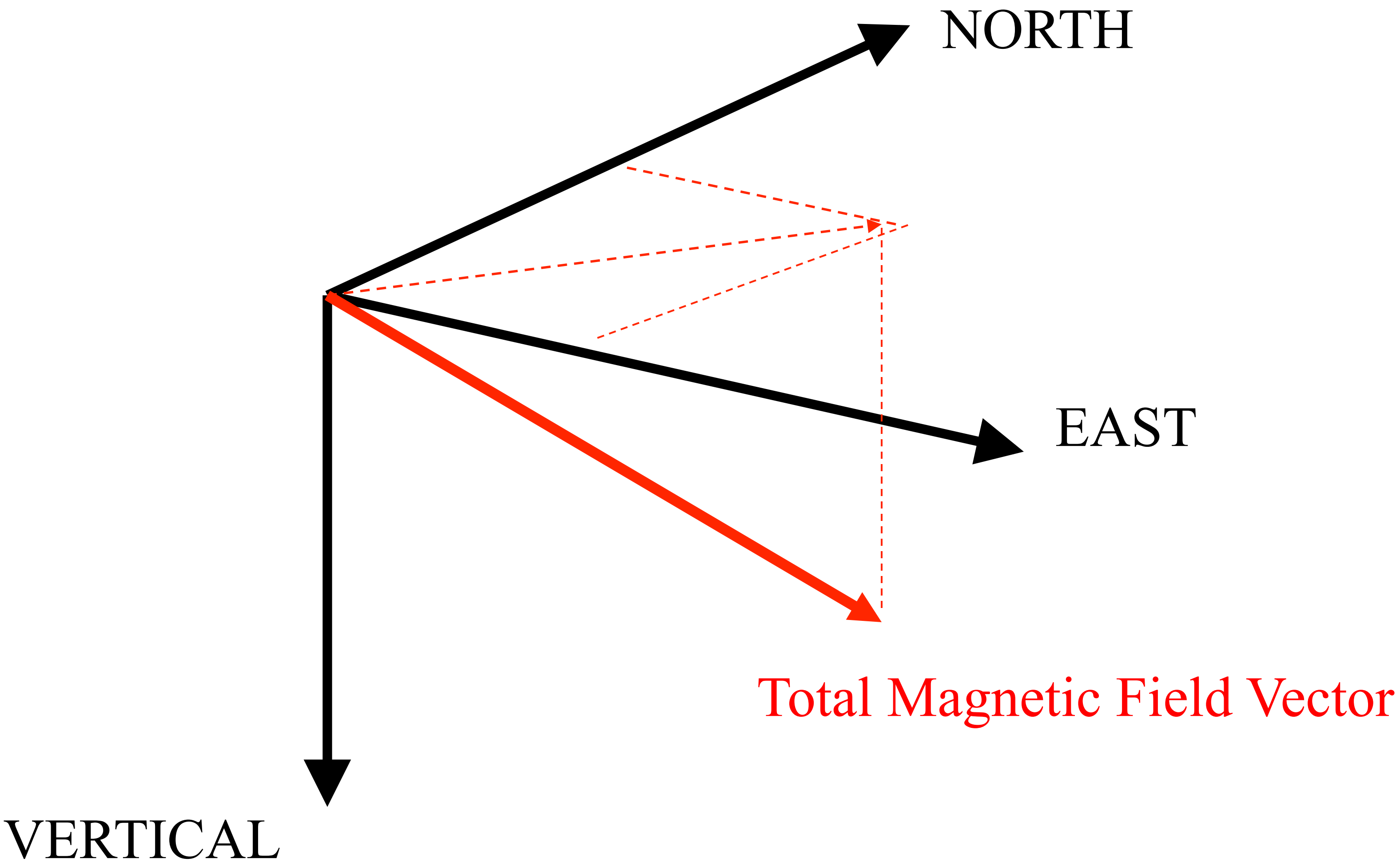
Millions of years…



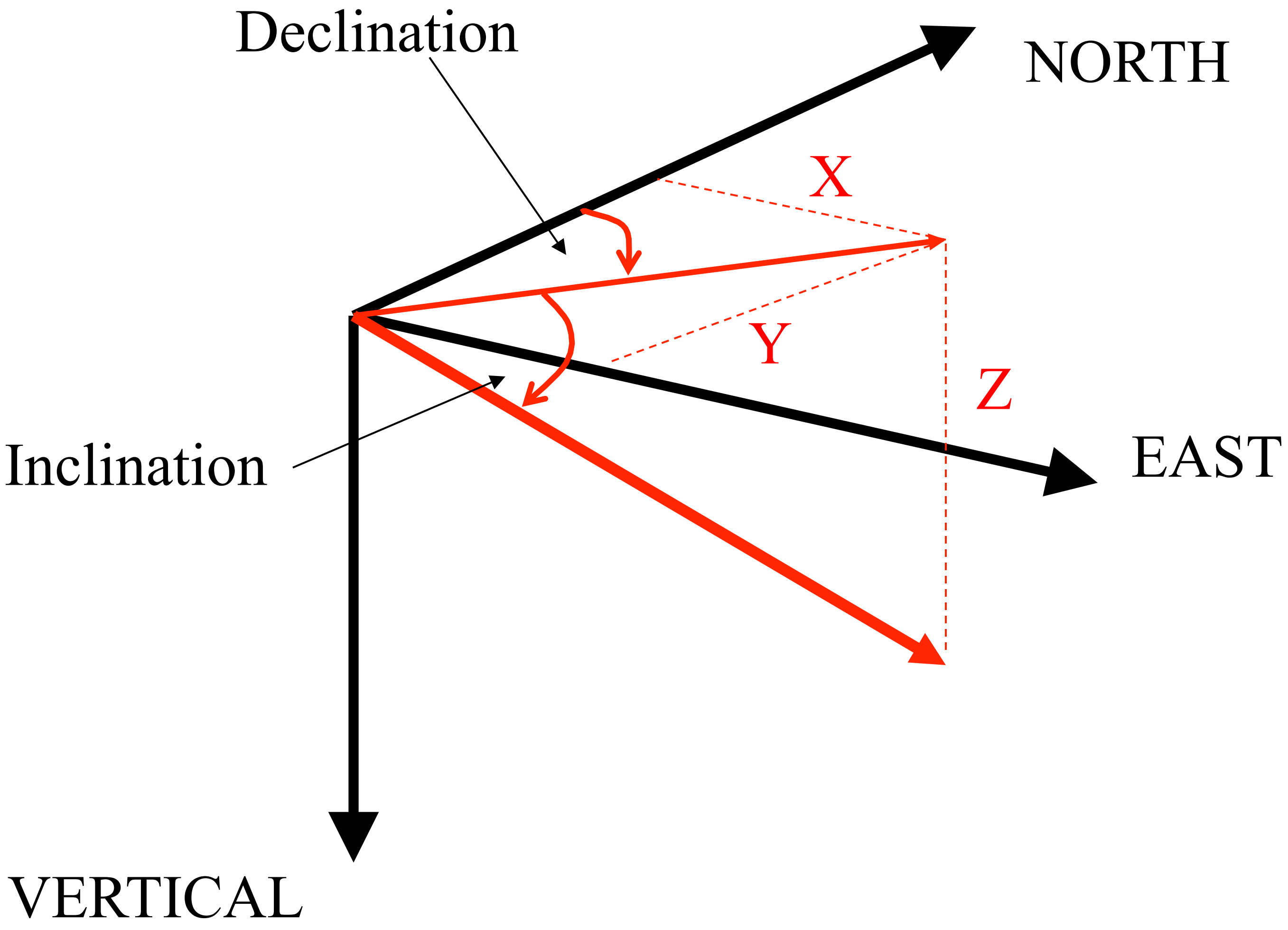
Decades…



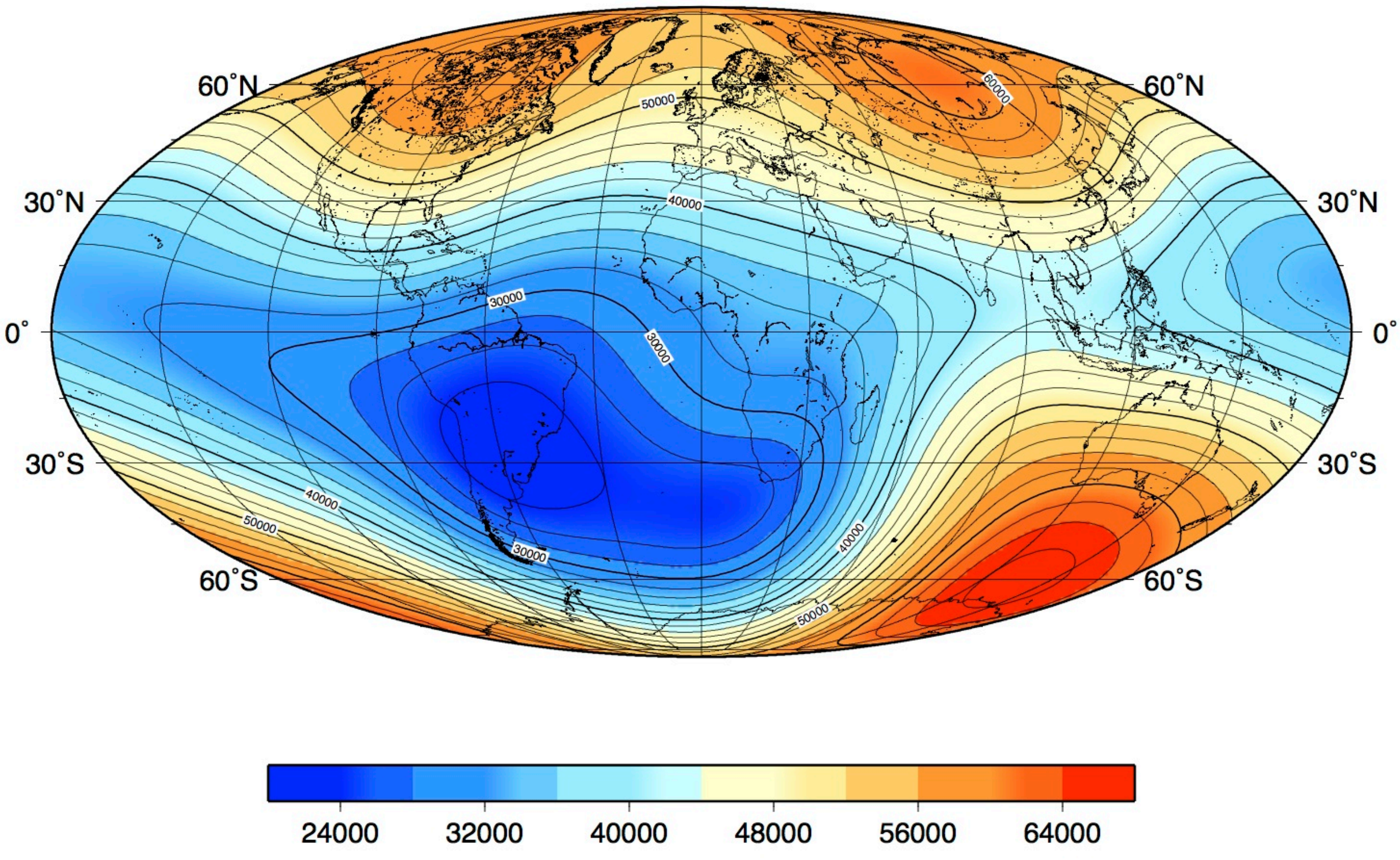
Magnetic Field Coordinates



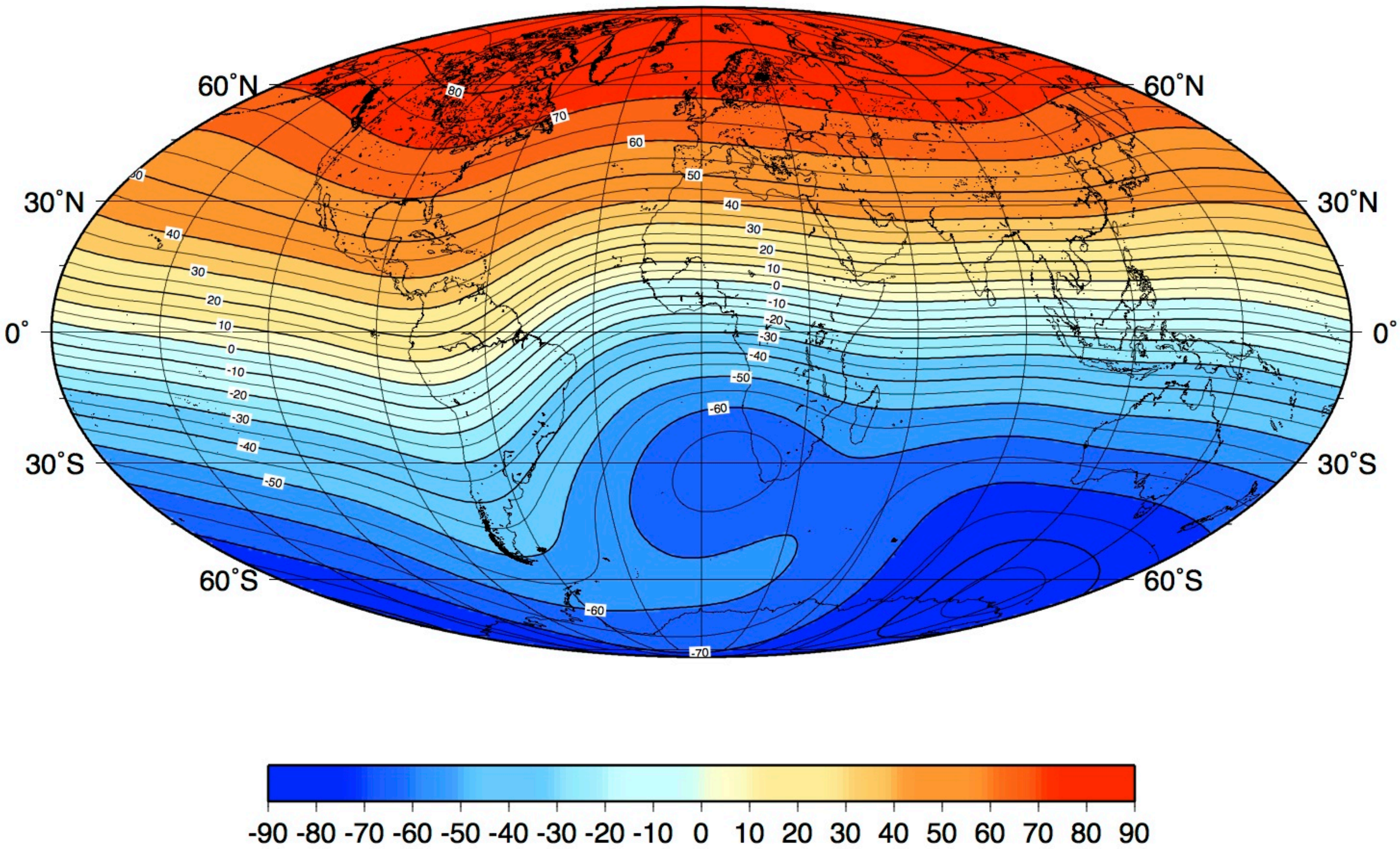
Field Directions



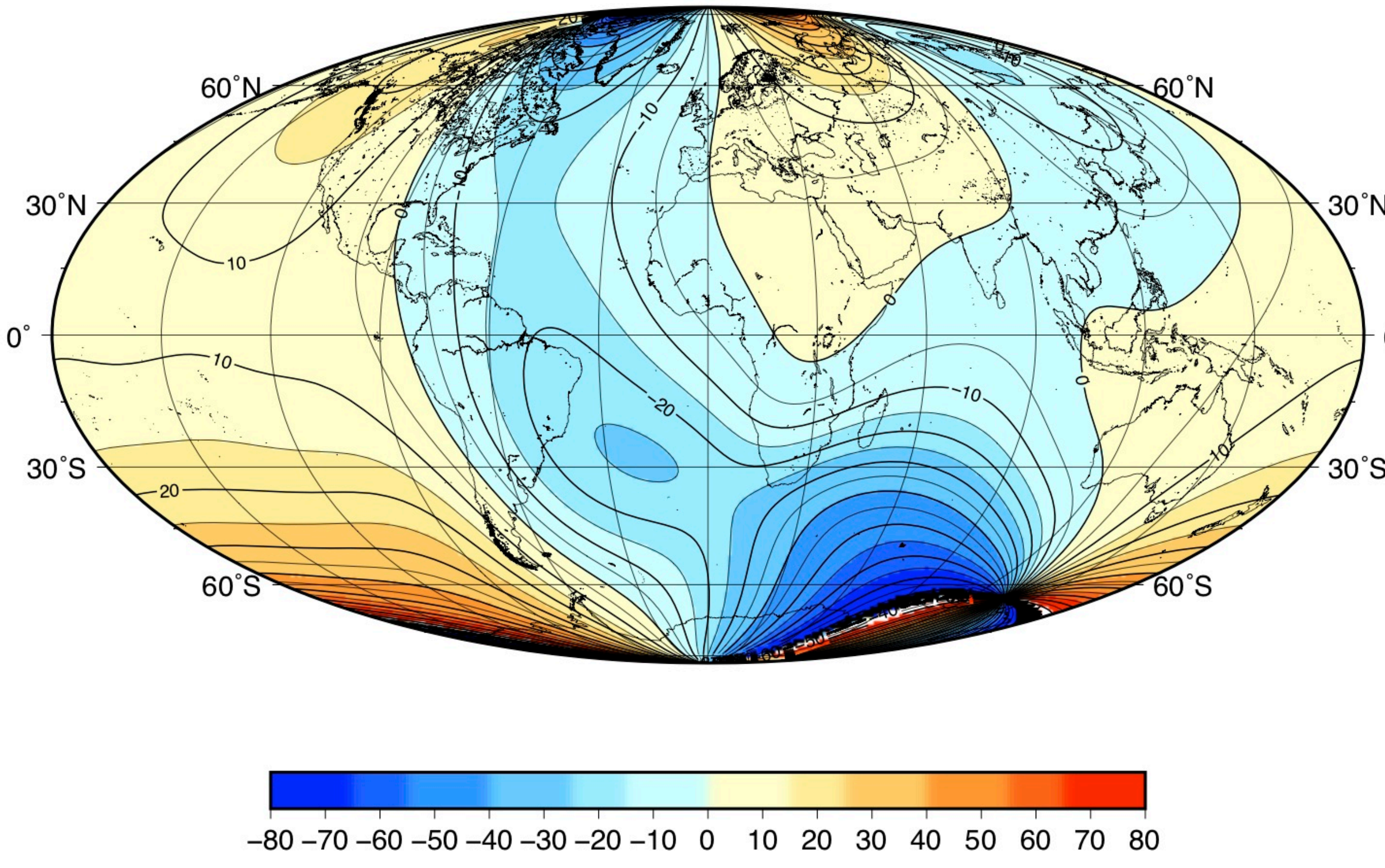
Total Field Intensity 2015



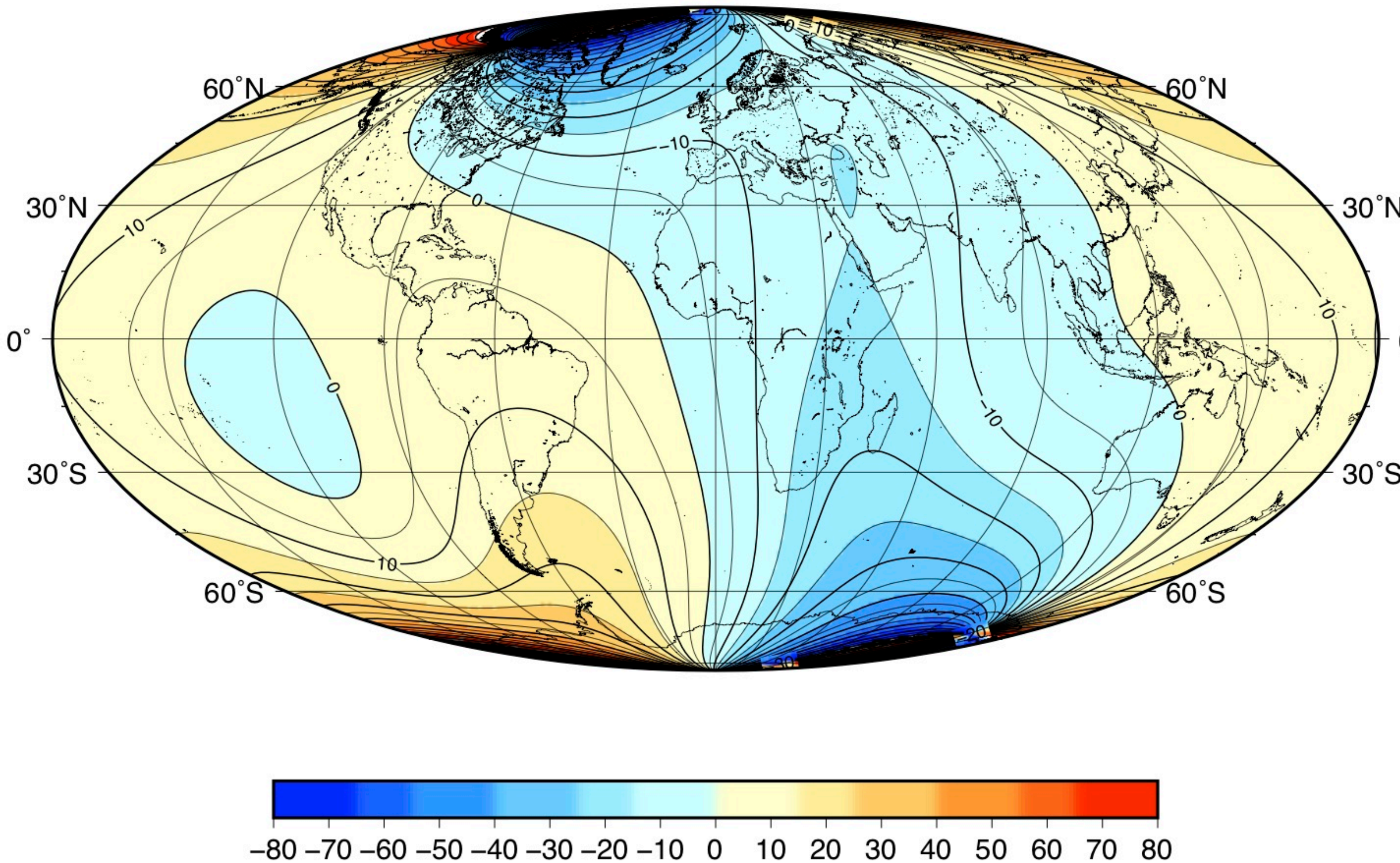
Inclination 2015



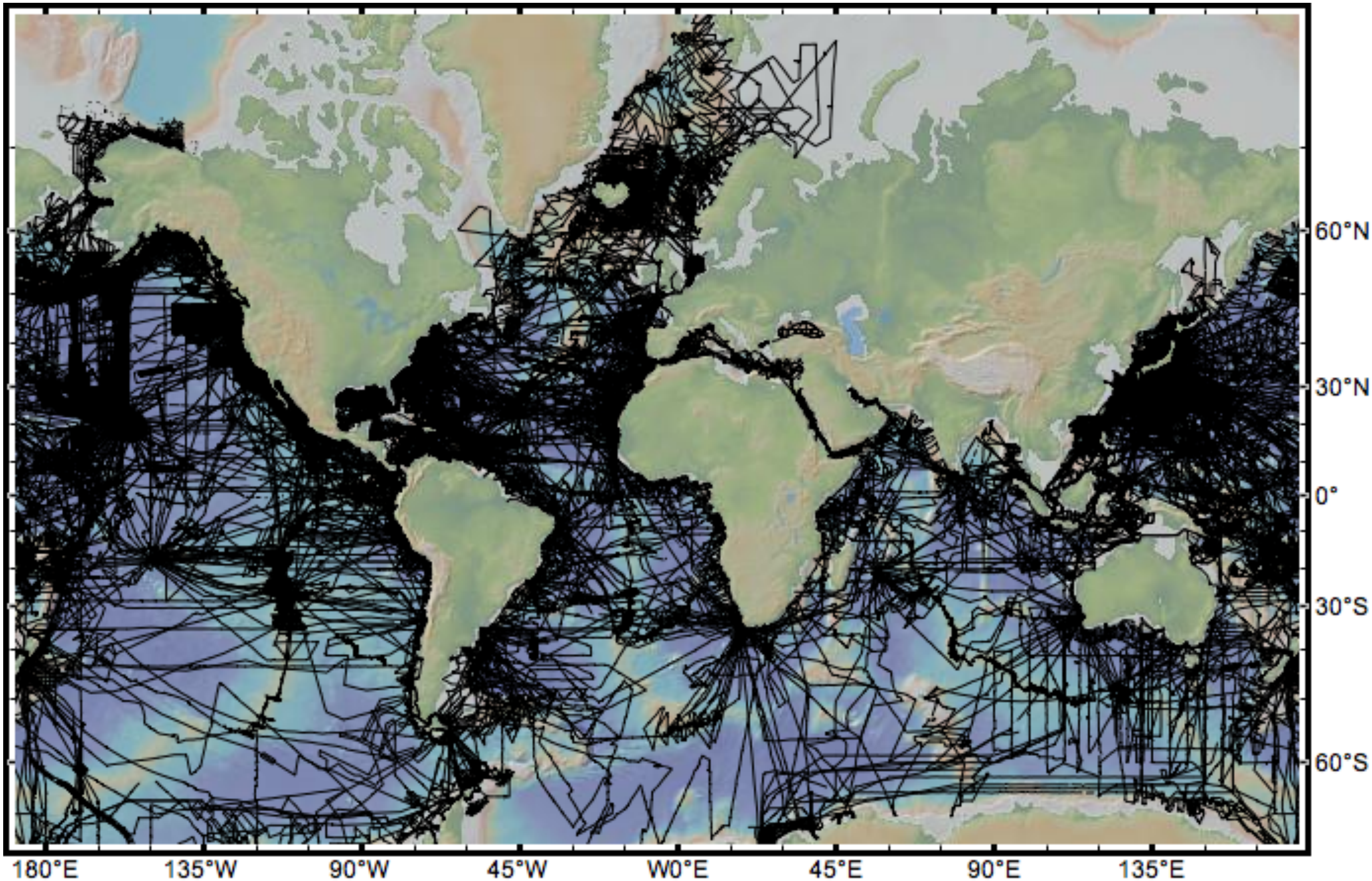
Declination 2015



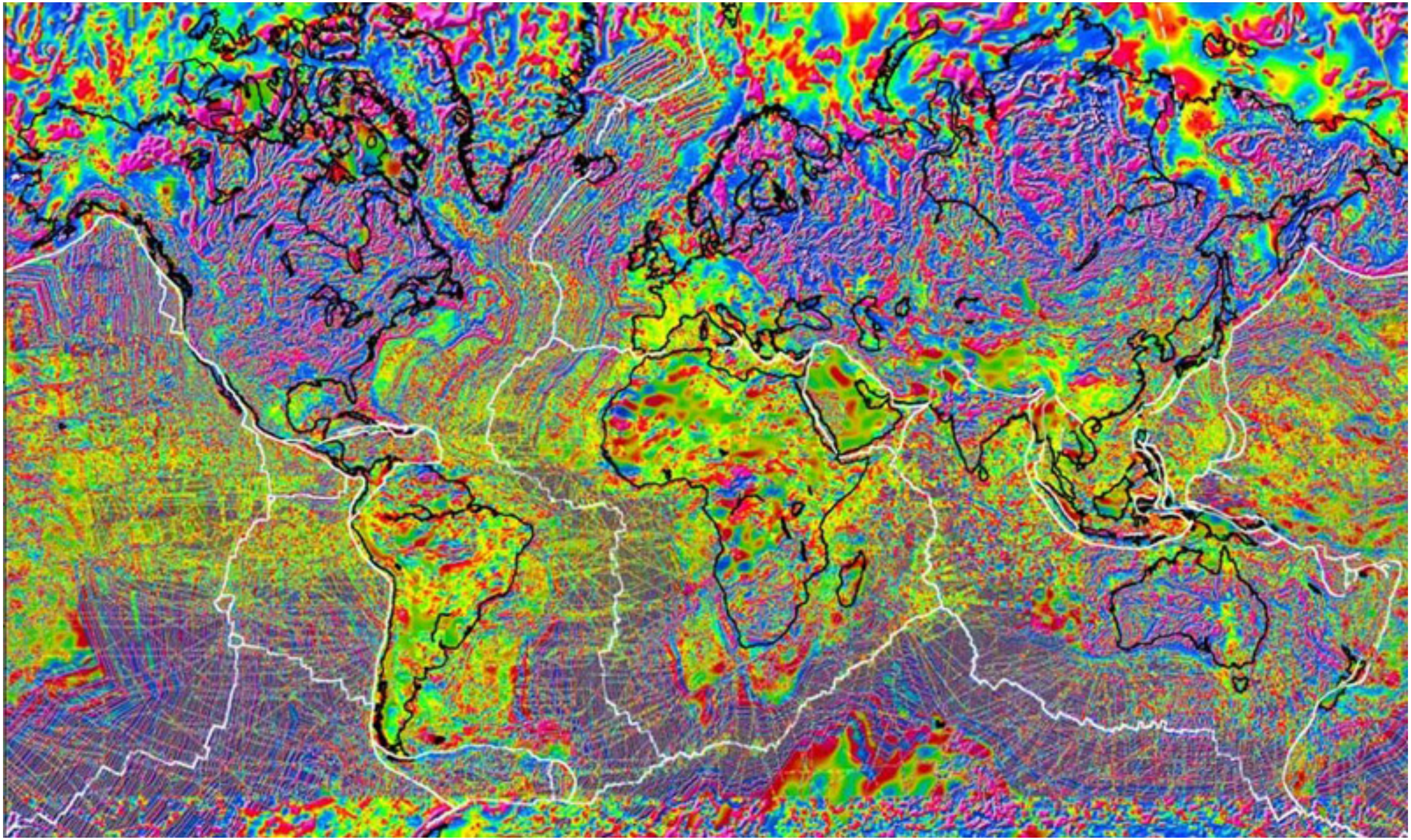
Declination 1700



NGDC (NCEI) Shiptracks with magnetic data



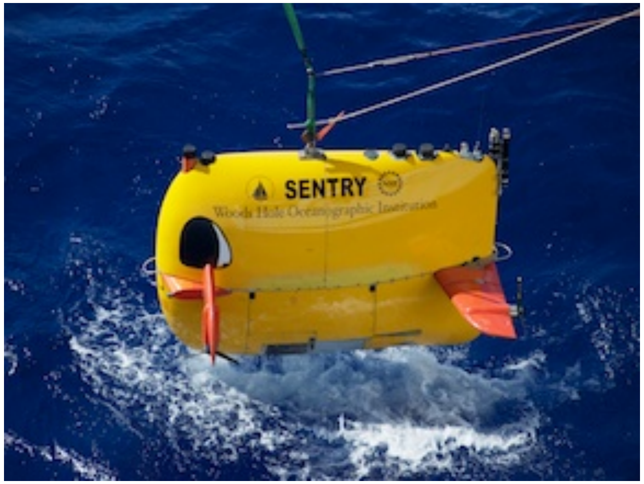
World Digital Magnetic Anomaly Map

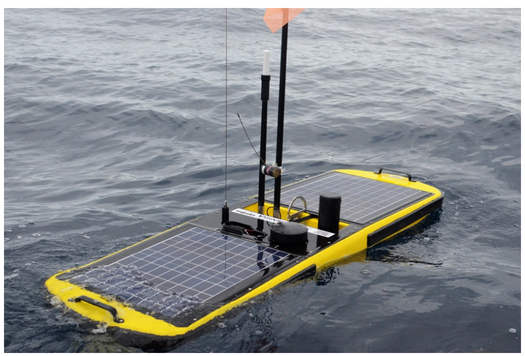


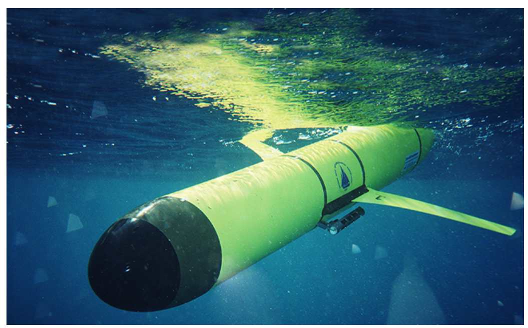
Measuring Magnetism at Sea

Magnetic Sensors for Deep Submergence

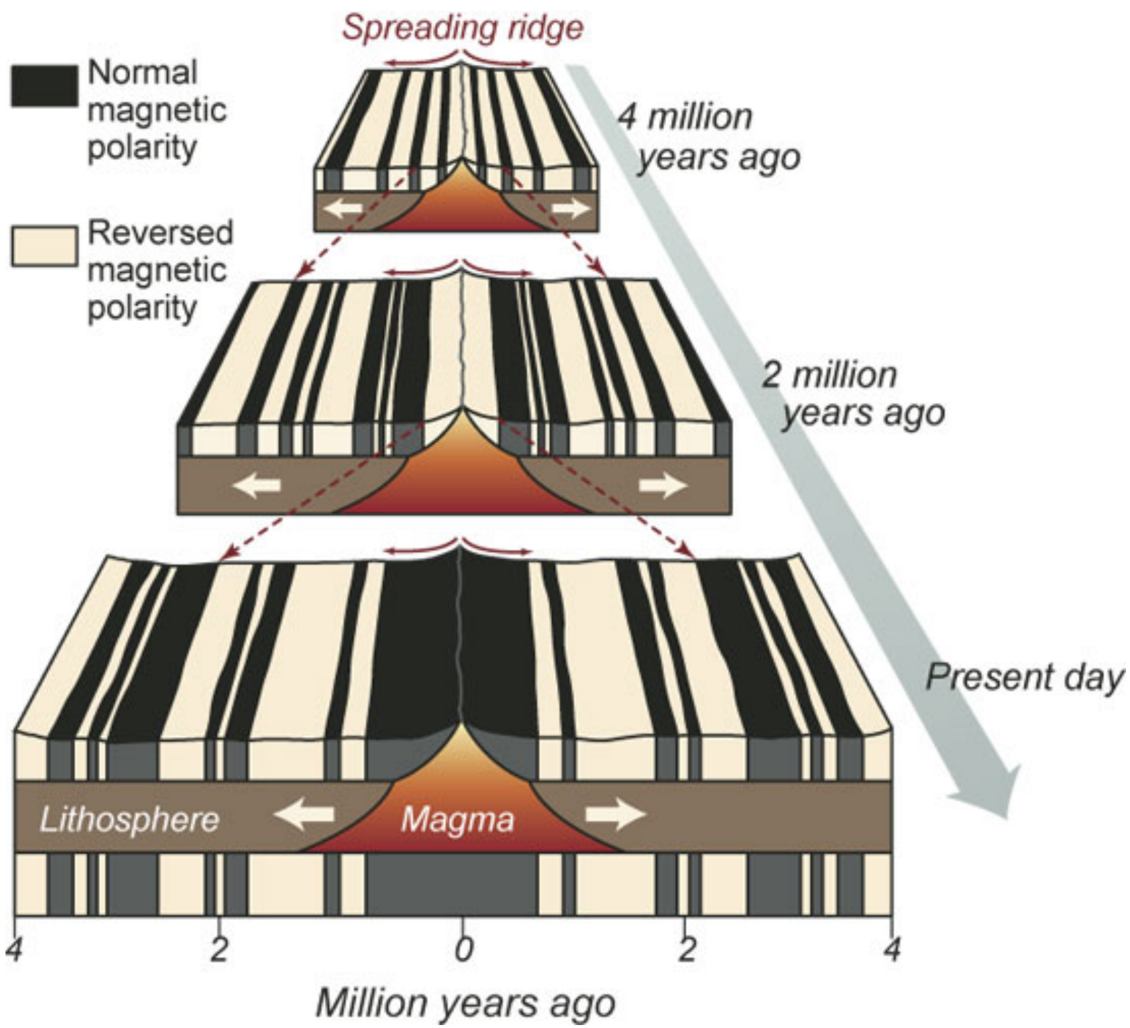
Autonomous Tech.



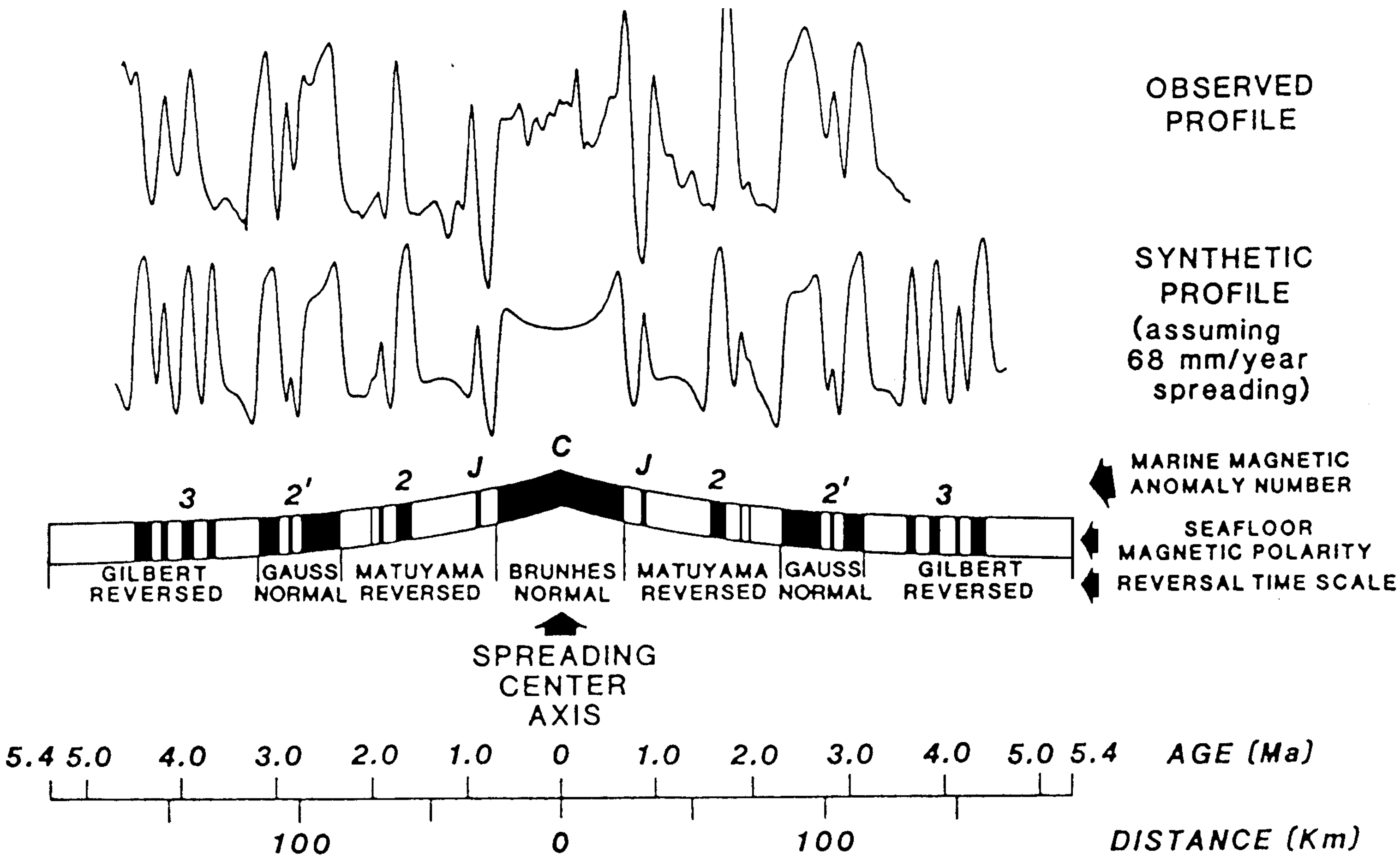




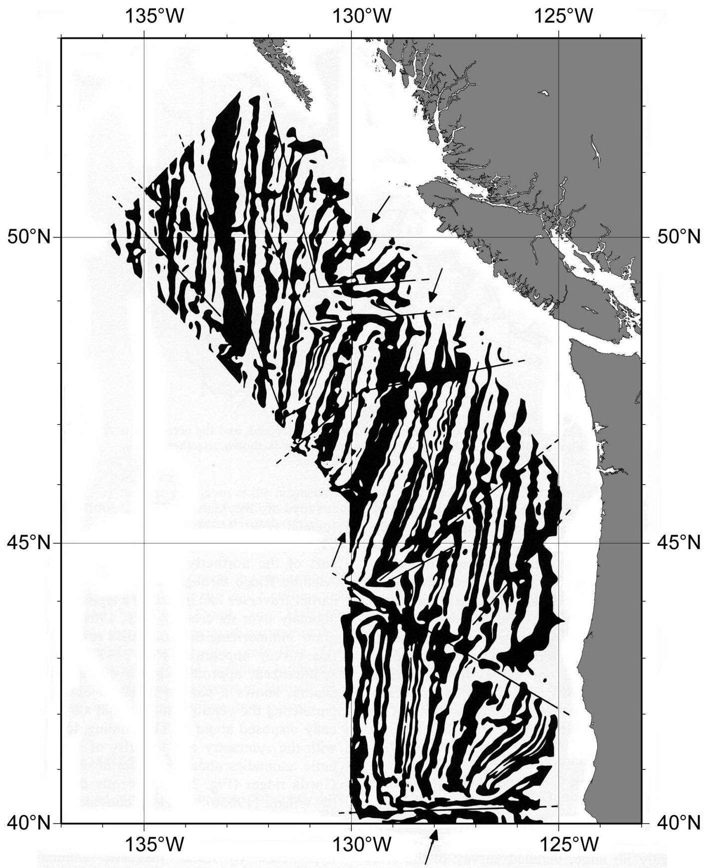
The Vine-Matthews-Morley Sea Floor Spreading Hypothesis

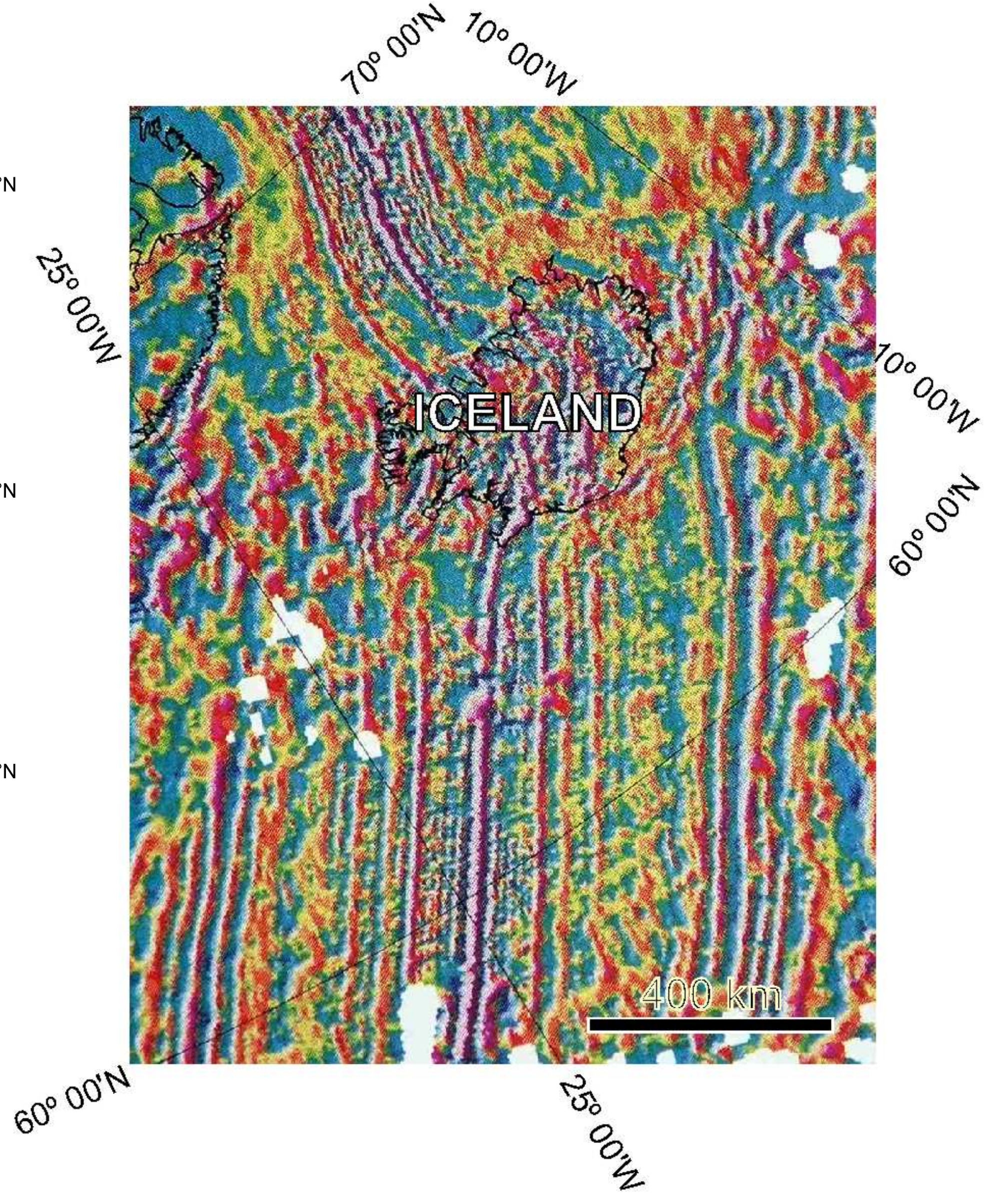


Marine Magnetic Anomalies



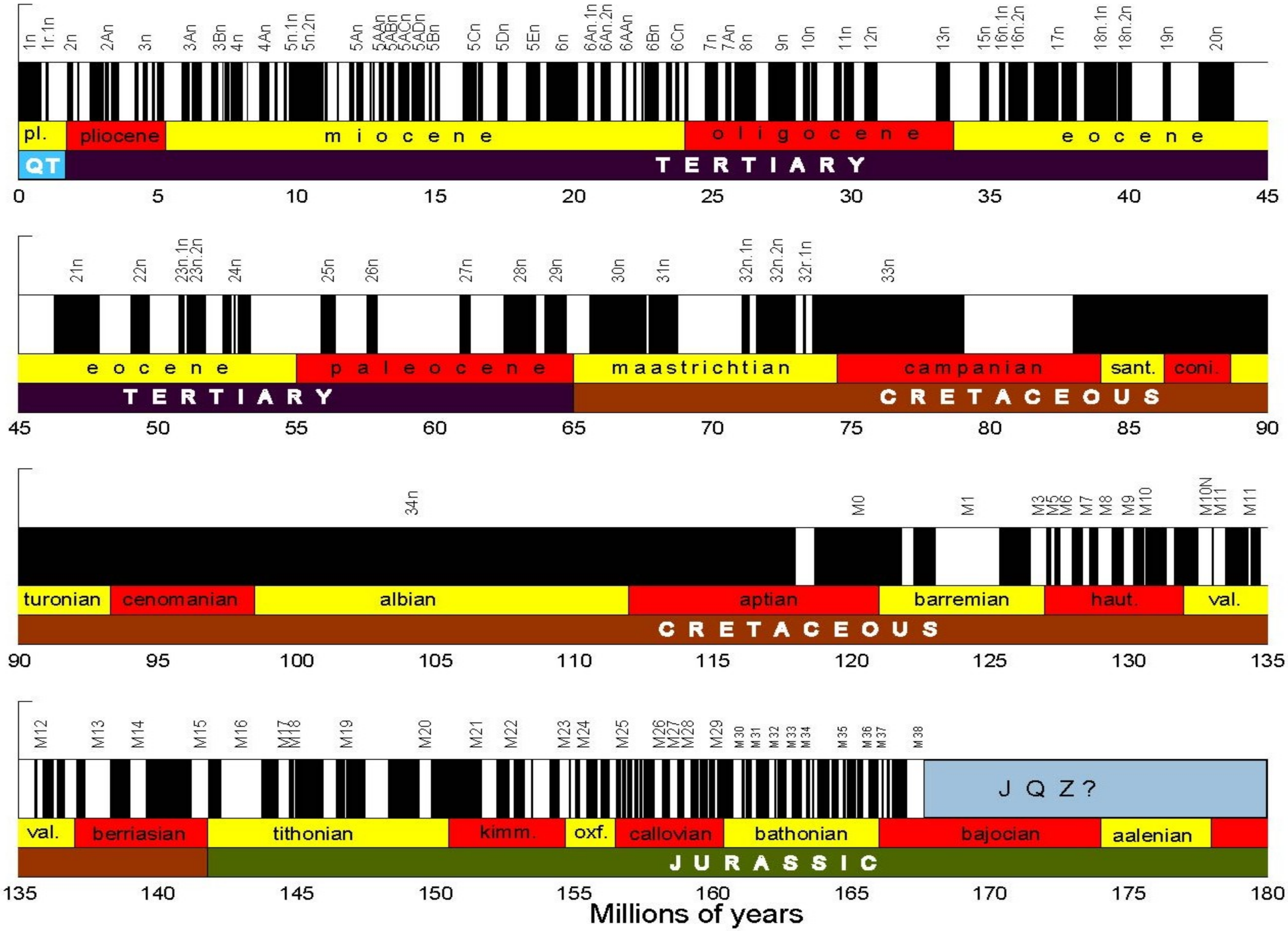
Reykjanes Ridge, Atlantic



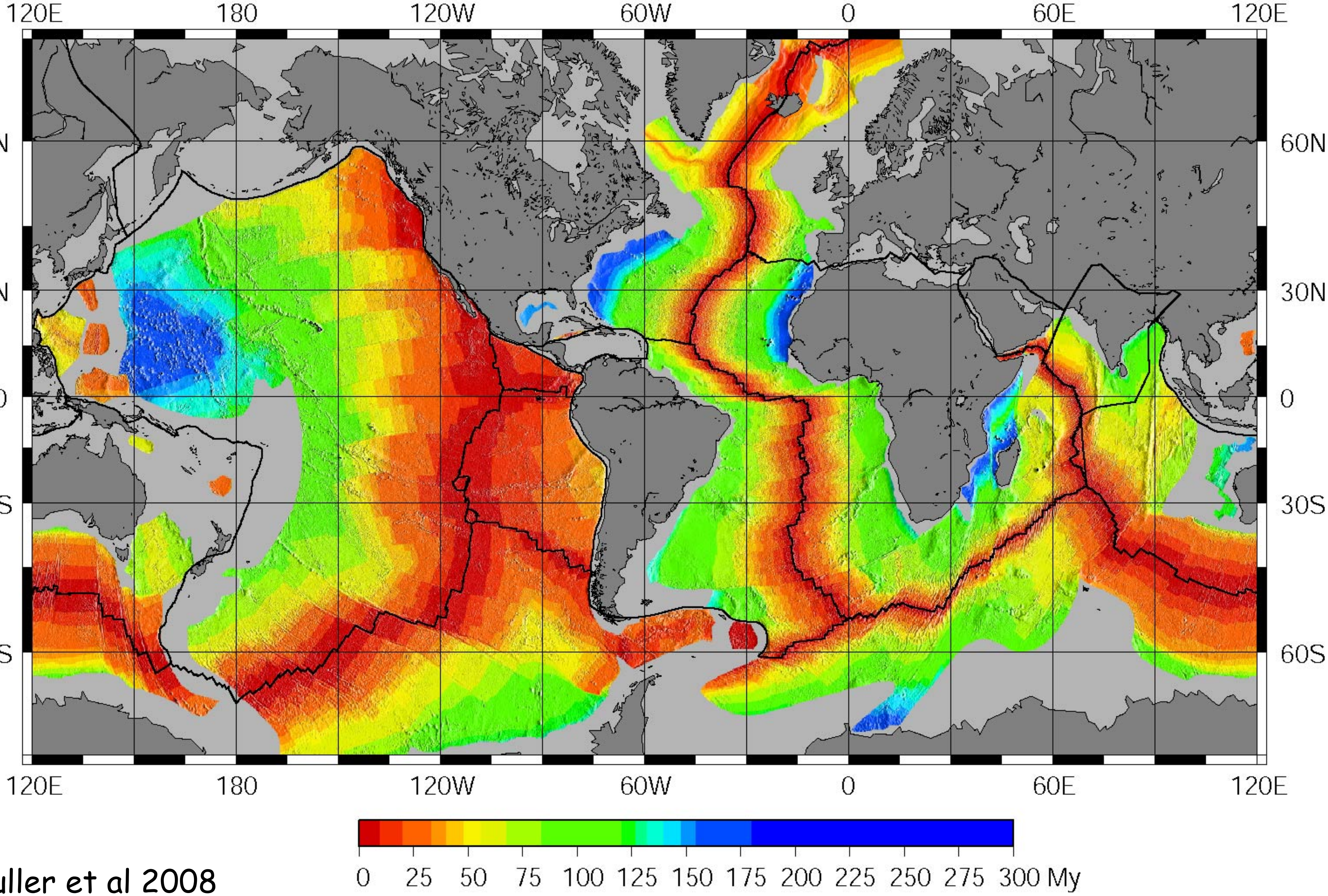


Juan de Fuca Ridge,
North East Pacific,
(Raff and Mason, 1964)

Geomagnetic Polarity Time Scale (GPTS)

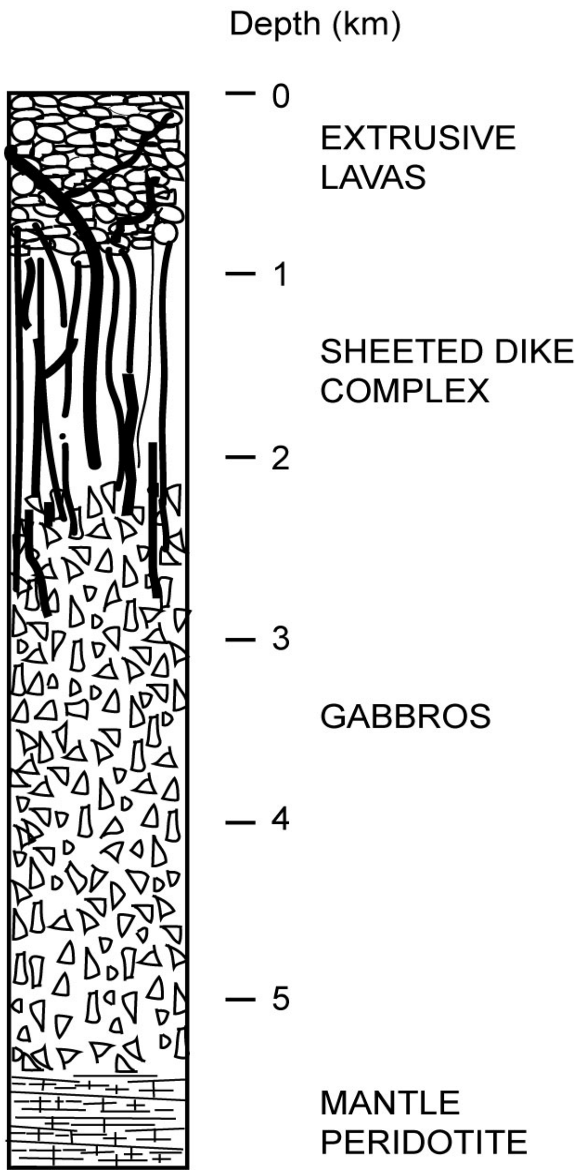


Seafloor Age



Muller et al 2008

A Magnetic Crustal Cross-section



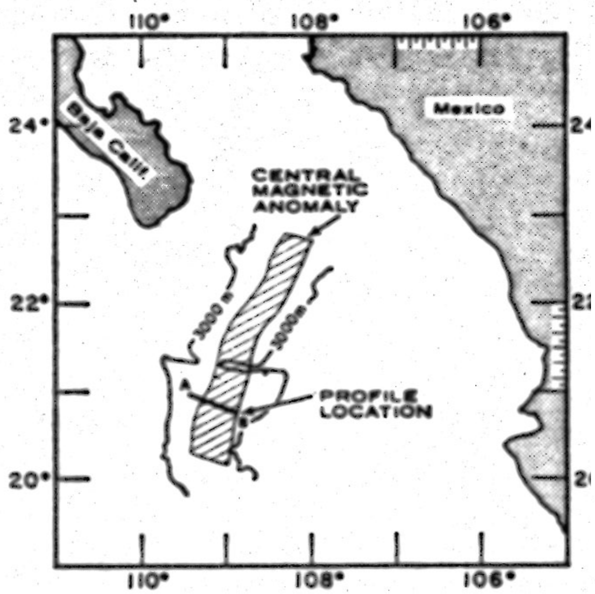
Cools fast, micro crystals, very magnetic

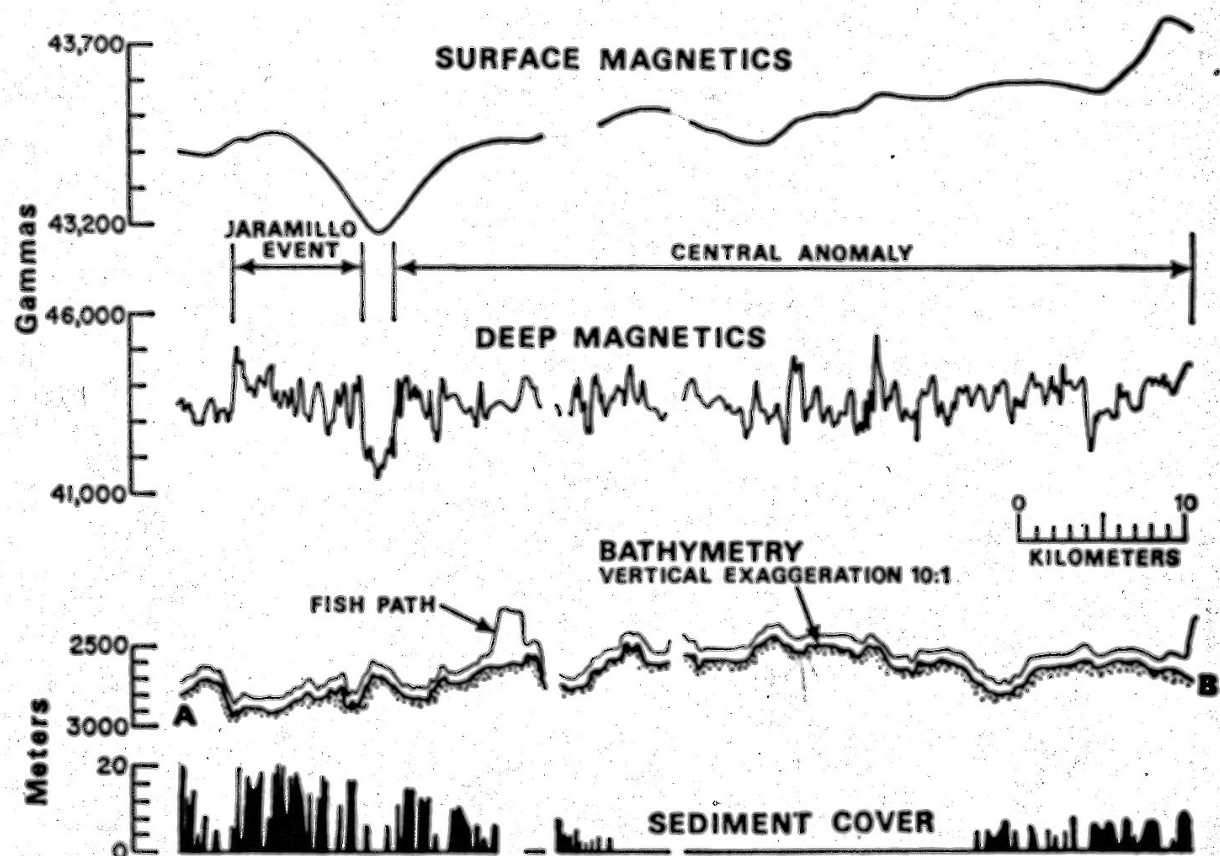
Cools slower, visible crystals, weakly magnetic

Cools slowly, large crystals, weakly magnetic but small inclusions of magnetite in crystals

Fresh Peridotite – not magnetic
Deformation, and alteration creates magnetic minerals.

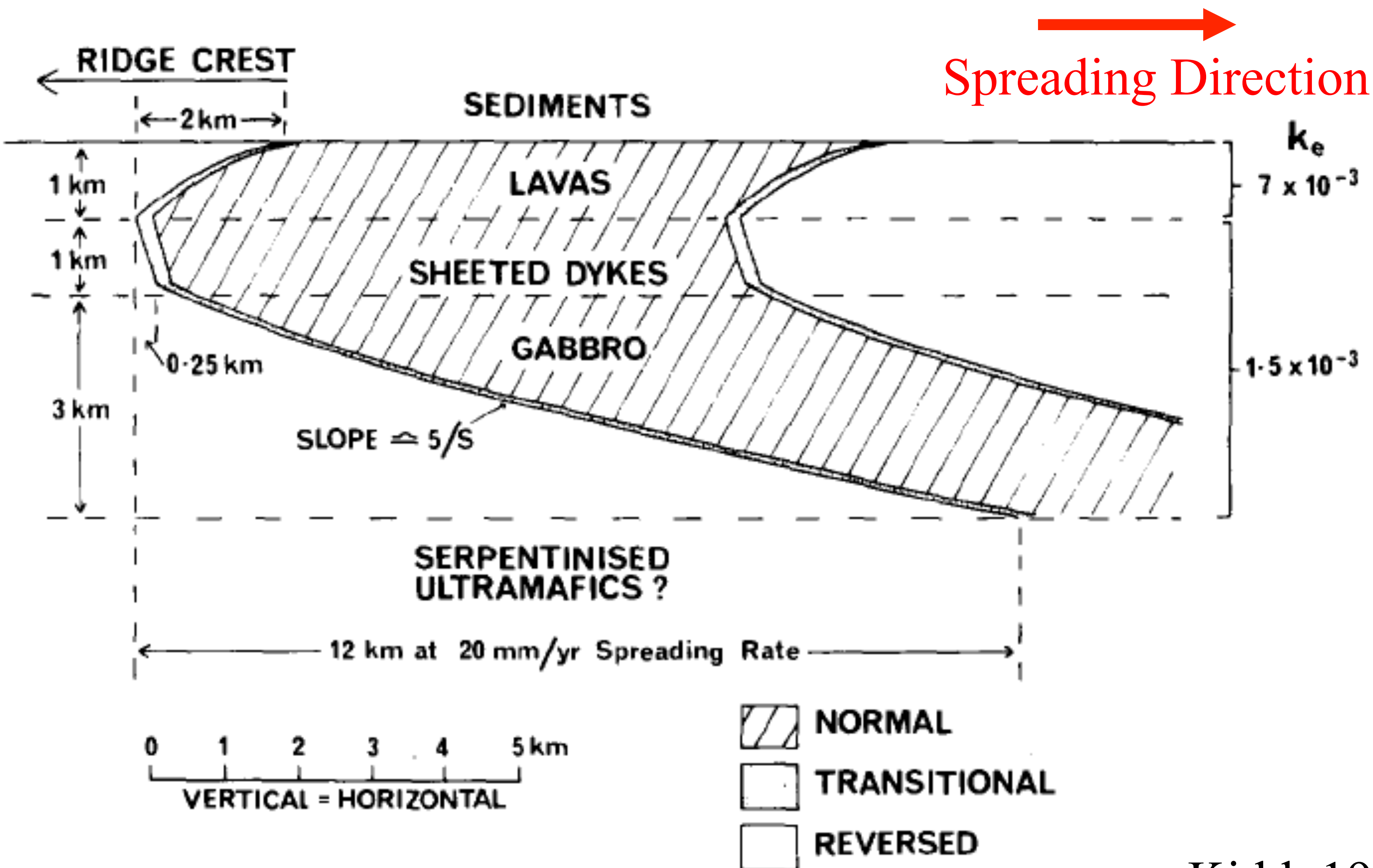
Deeptow vs Sea Surface





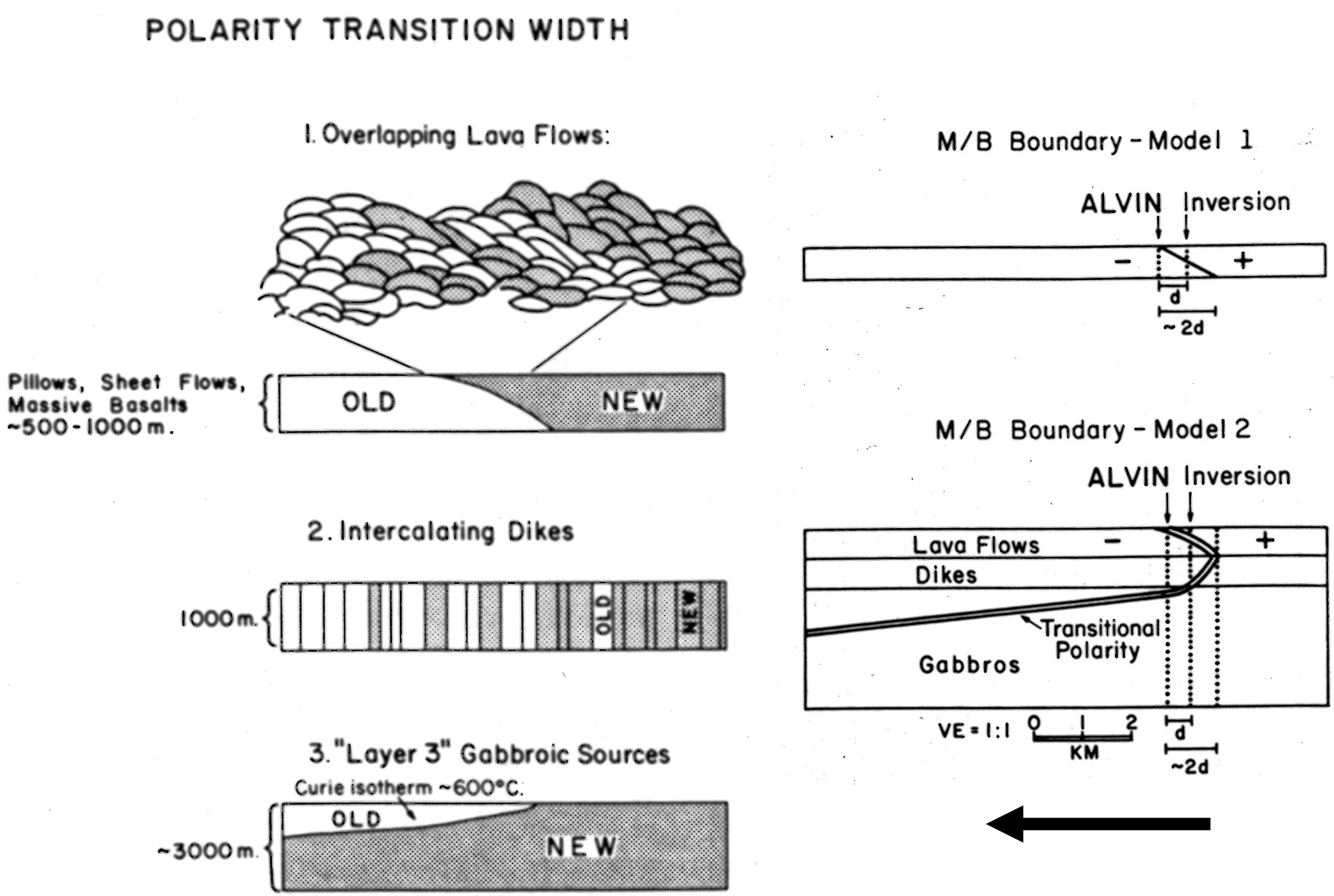
From Larson & Spiess, 1969

Magnetic Polarity Boundary



Kidd, 1977

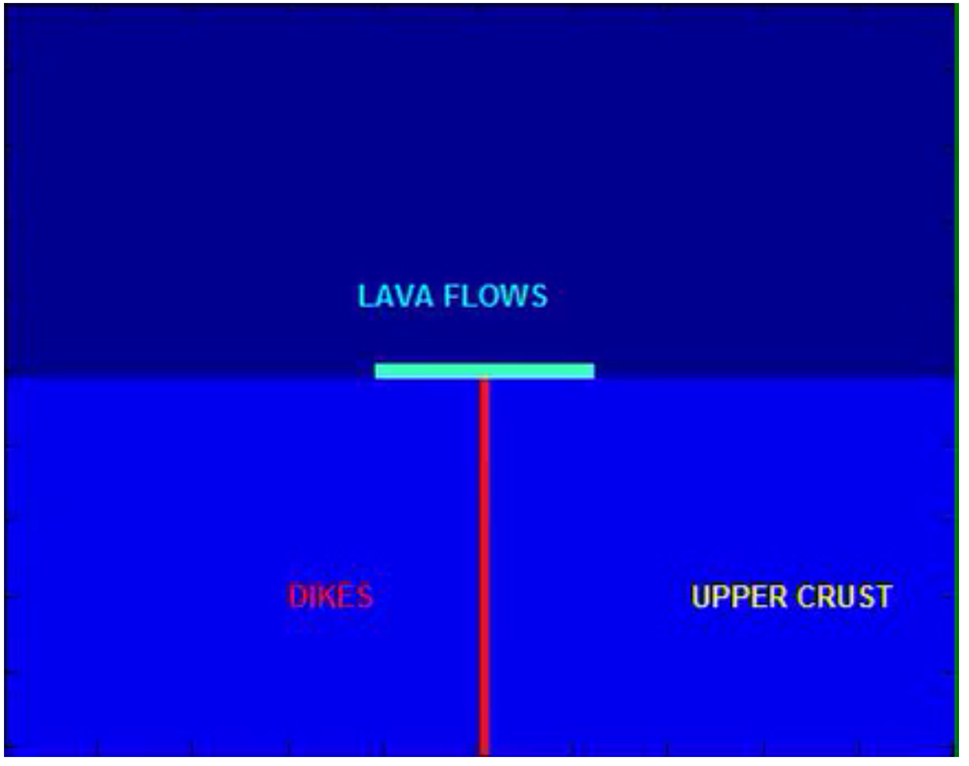
Magnetic Polarity Boundary



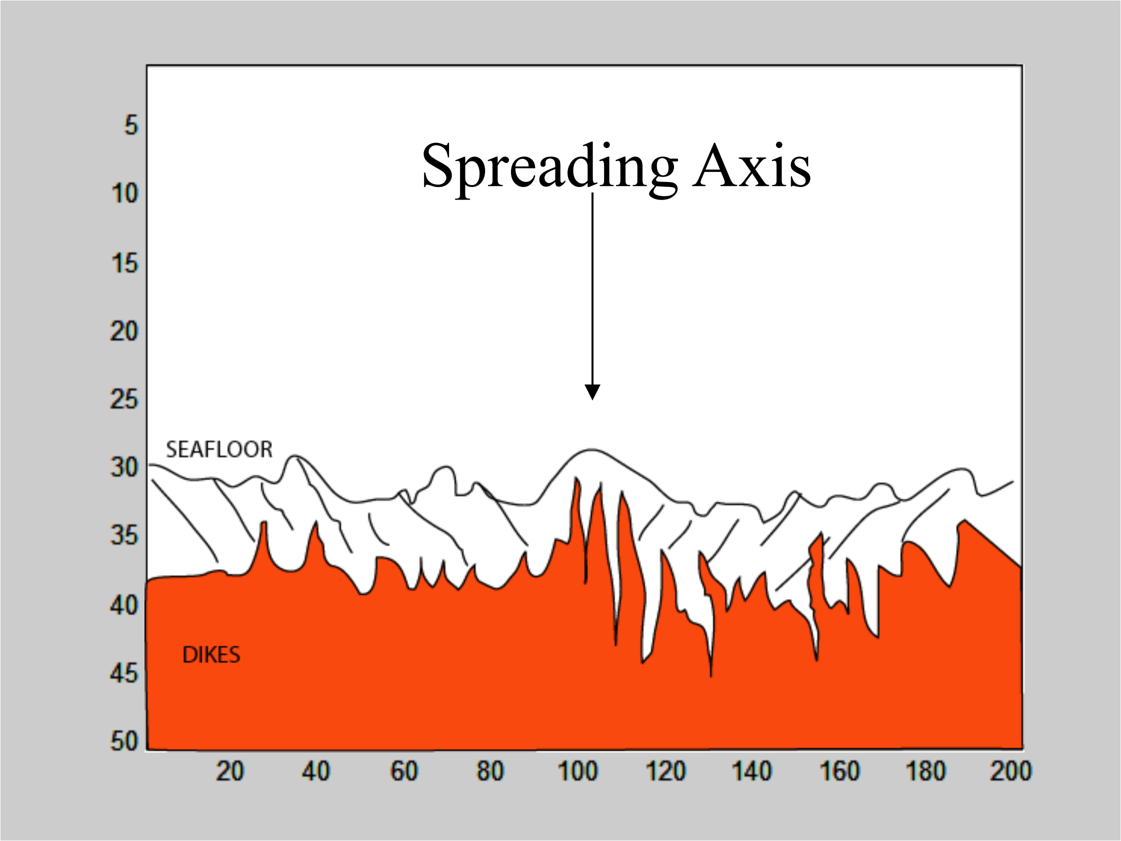
Spreading Direction

Macdonald et al., 1983

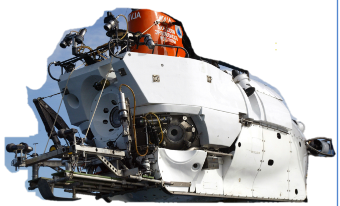
Lava & Dike Emplacement

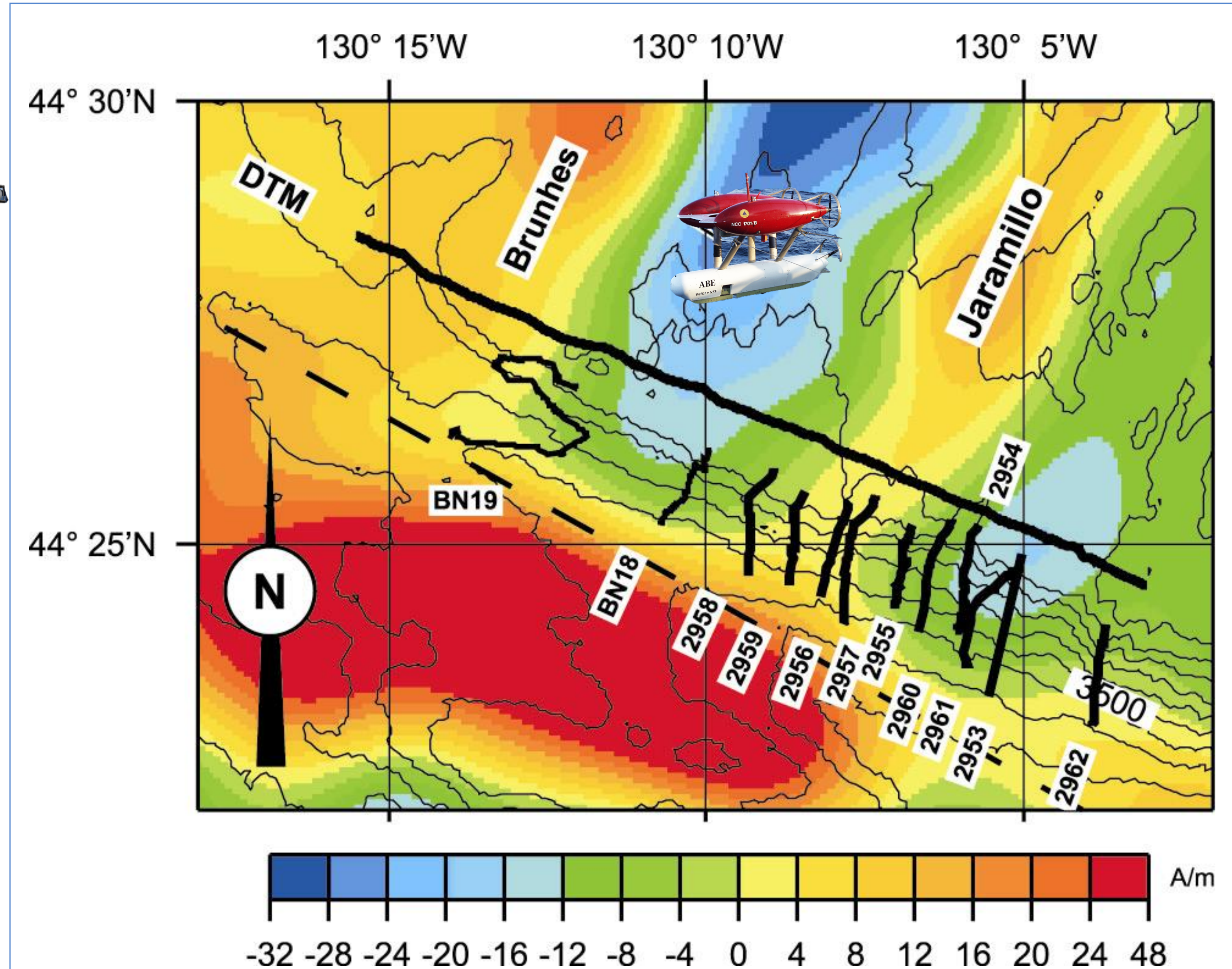


Lava & Dike Emplacement



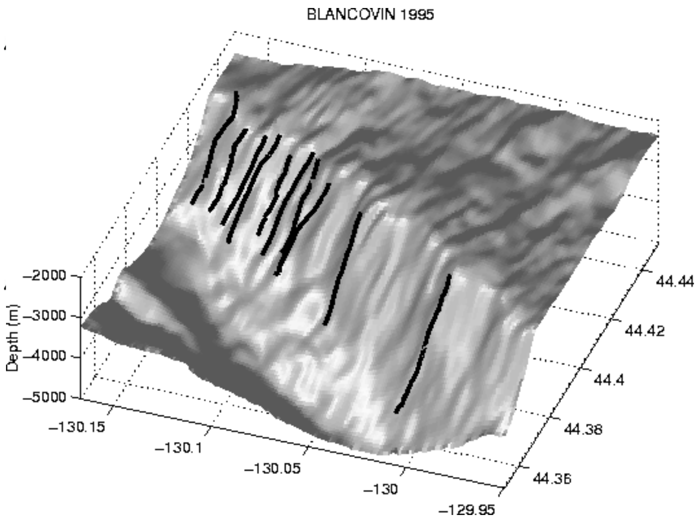
Blanco Fracture Zone Alvin Expt.



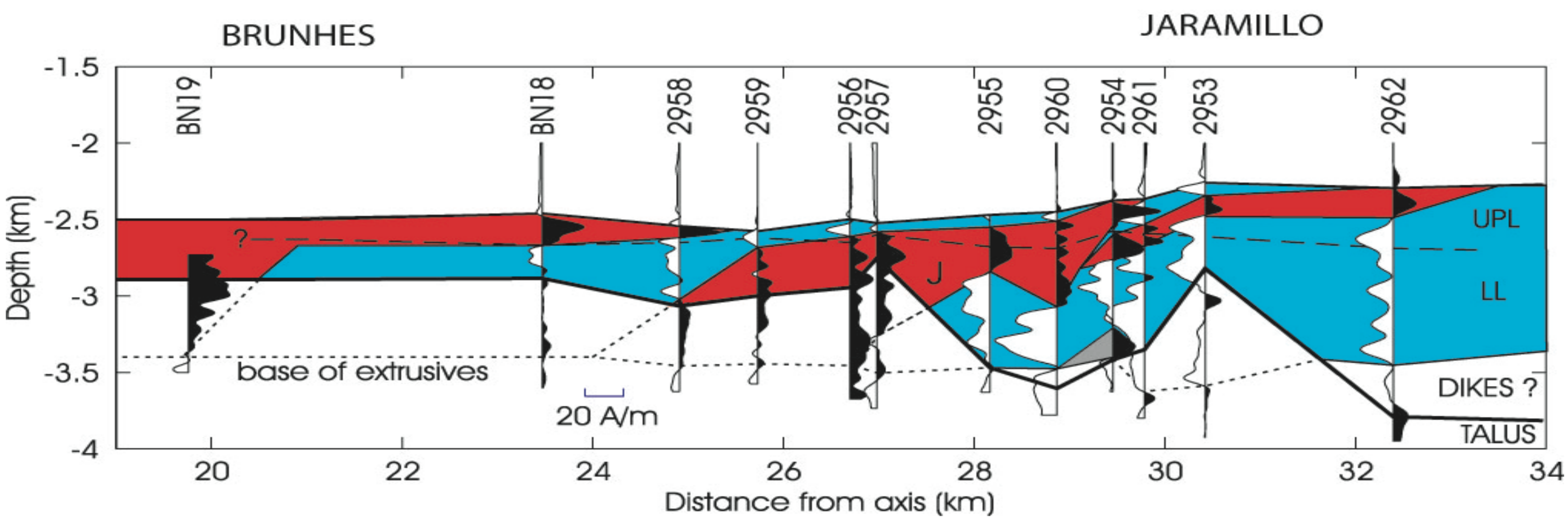


Tivey et al., 1996; 1998

Blanco Fracture Zone Alvin Expt.



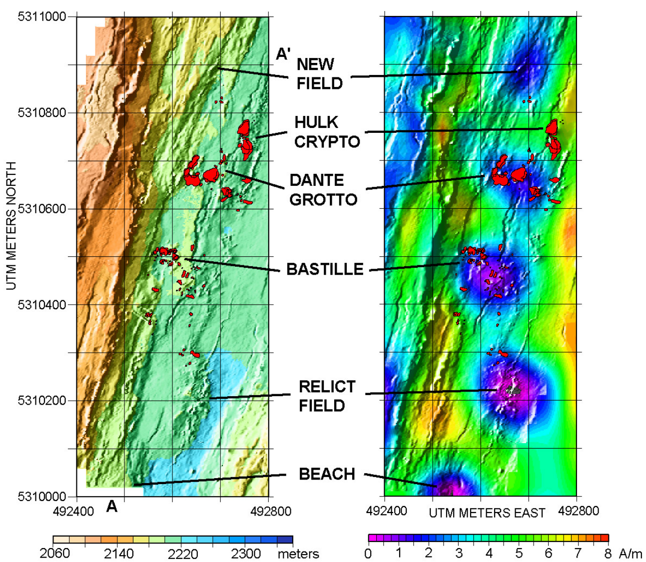
* Polarity boundaries dip towards the MOR
* Transition width 3-4 km with the largest part of the transition within the upper extrusive section
* Lavas provide 50-75% of anomaly source at surface

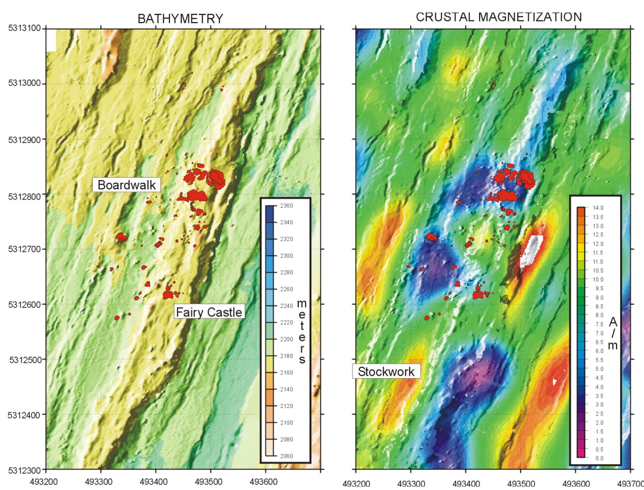


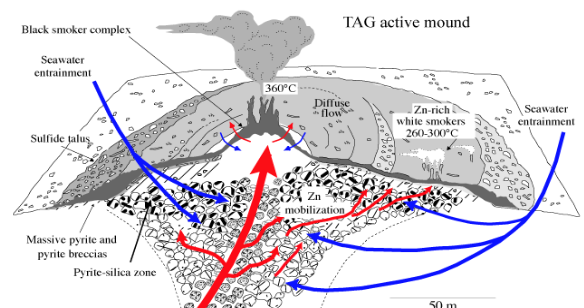
Spreading Direction →

Hydrothermal Magnetism

Juan de Fuca : Main Endeavour Field

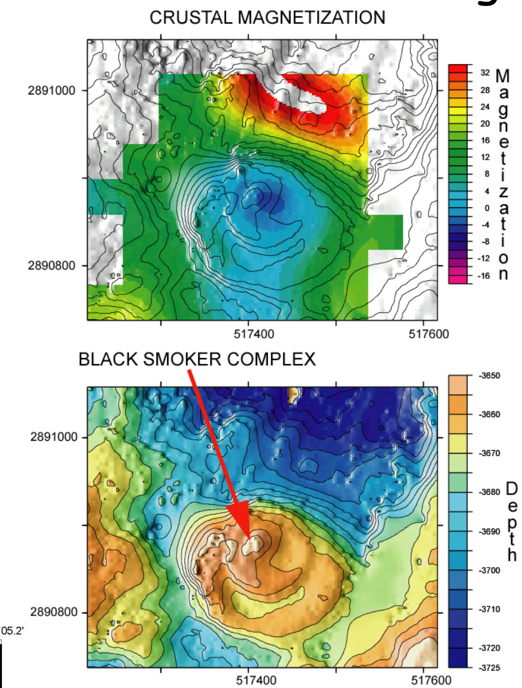


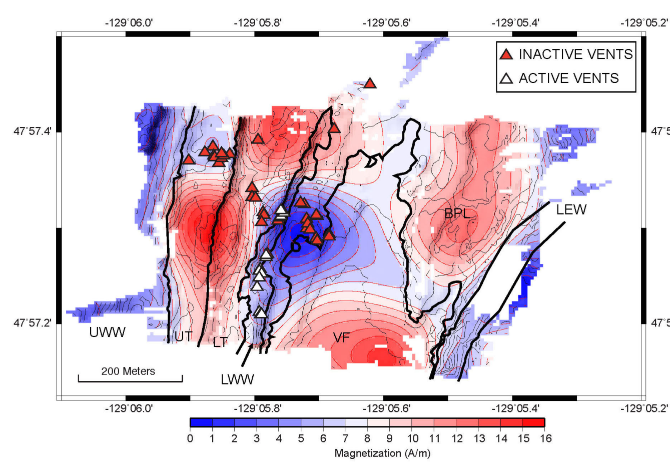




From: *Humphris and Tivey* [2000]

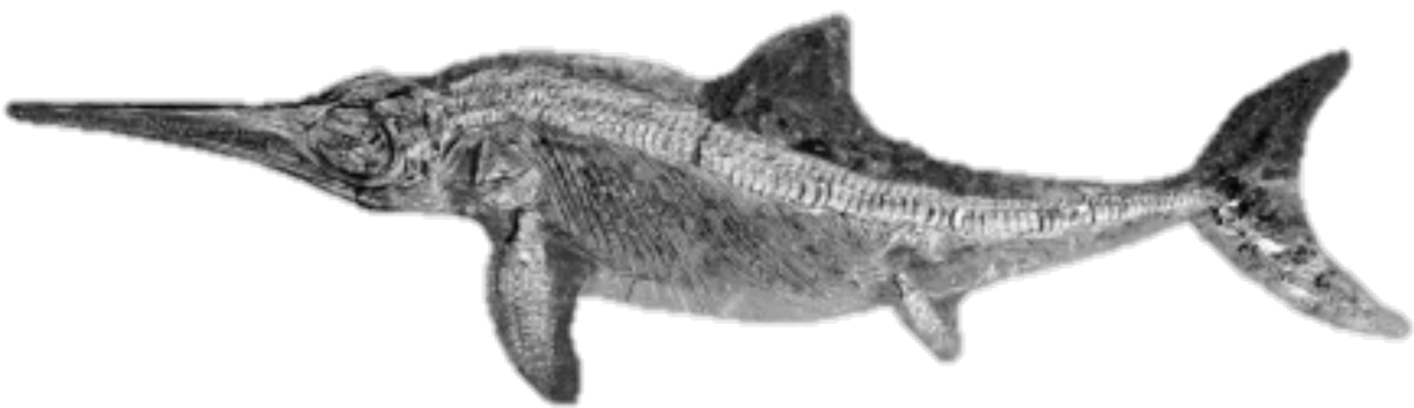
TAG : Mid Atlantic Ridge



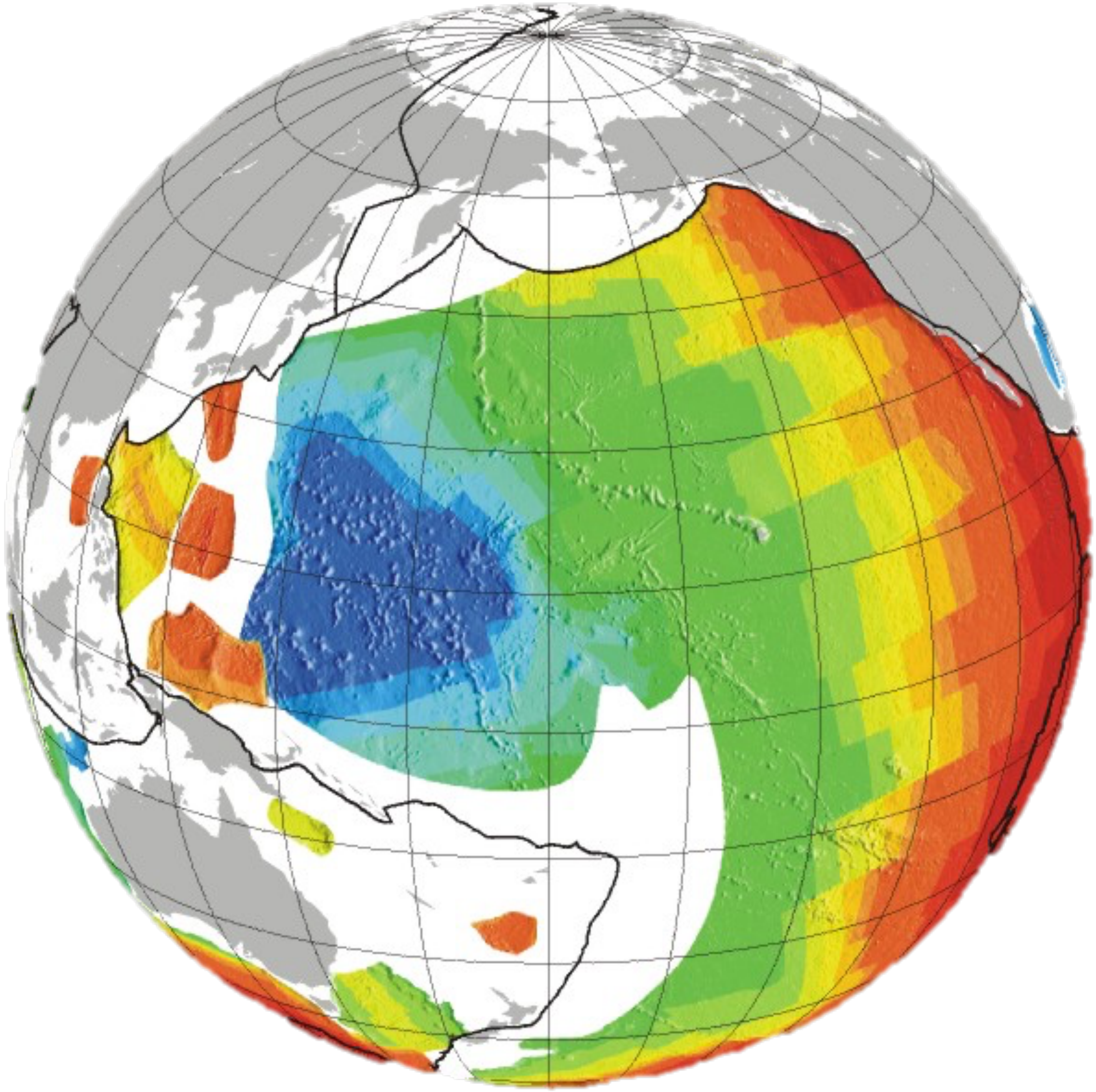


Juan de Fuca Raven Field

The JURASSIC Quiet Zone

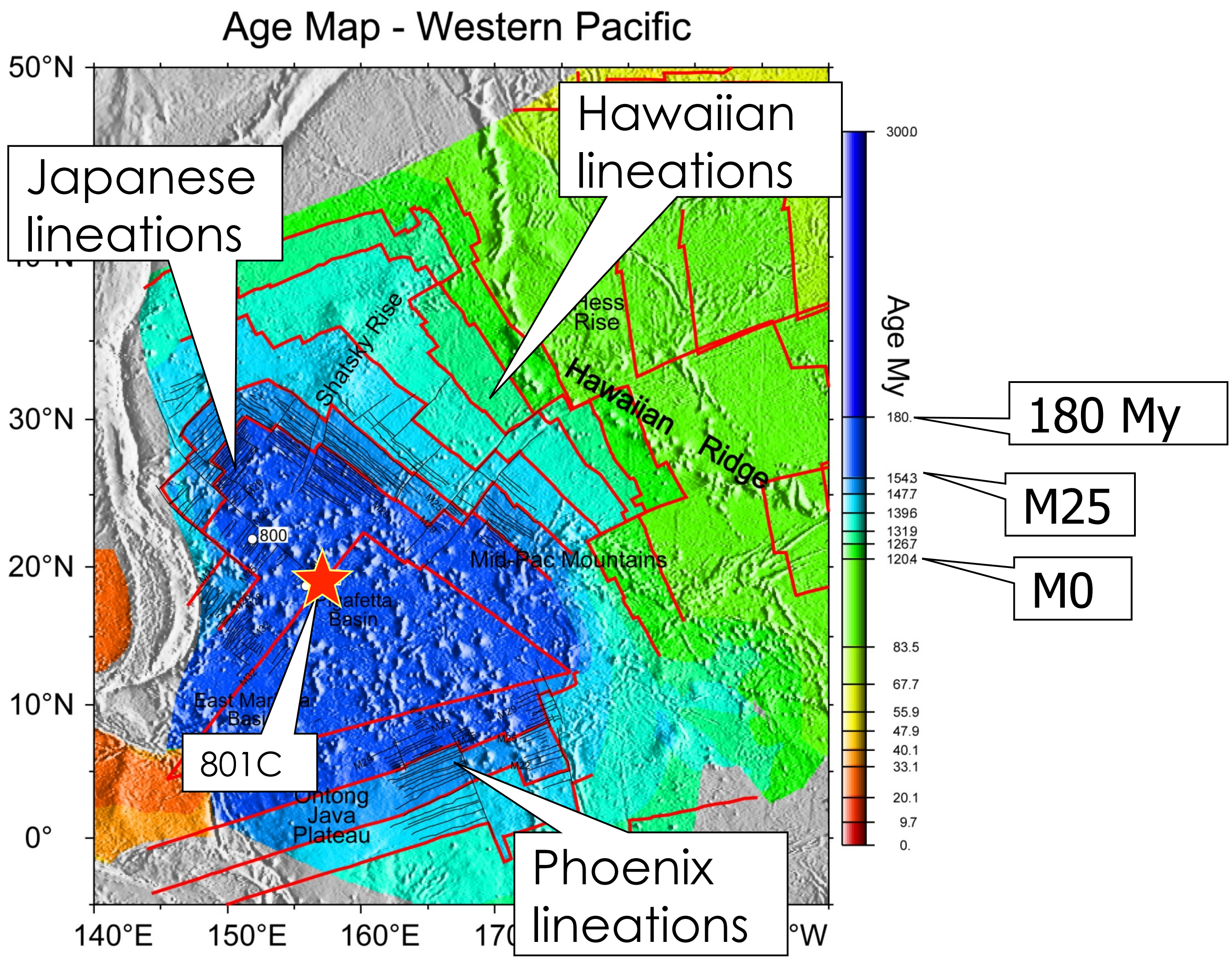


The Pacific Jurassic



Seafloor age: Muller et al 2008

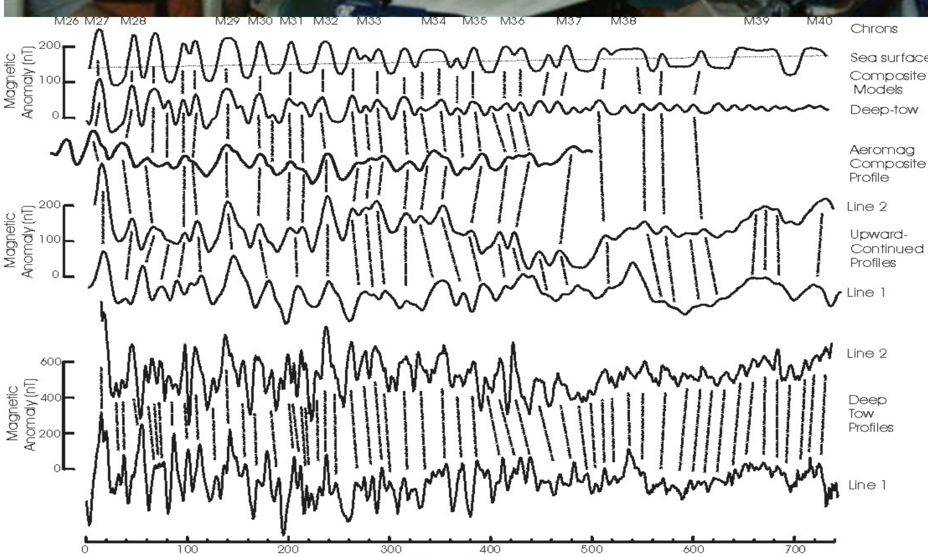
Western Pacific Jurassic Seafloor

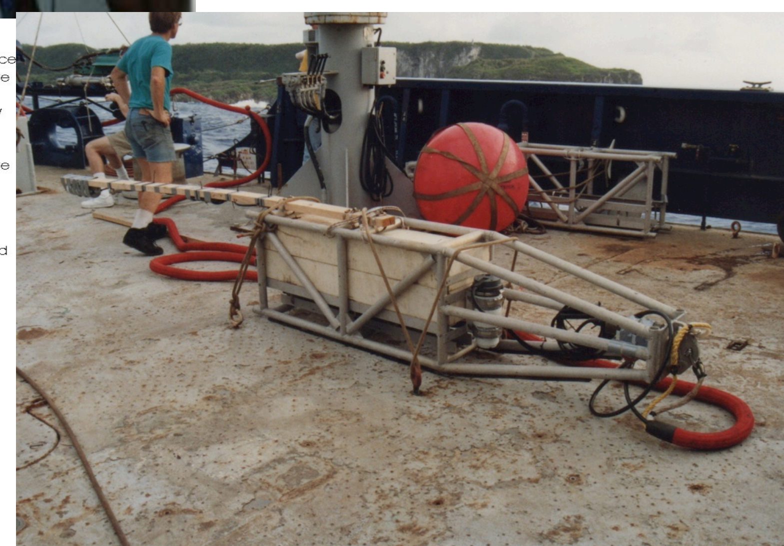


JQZ 1992 Japanese Lineations

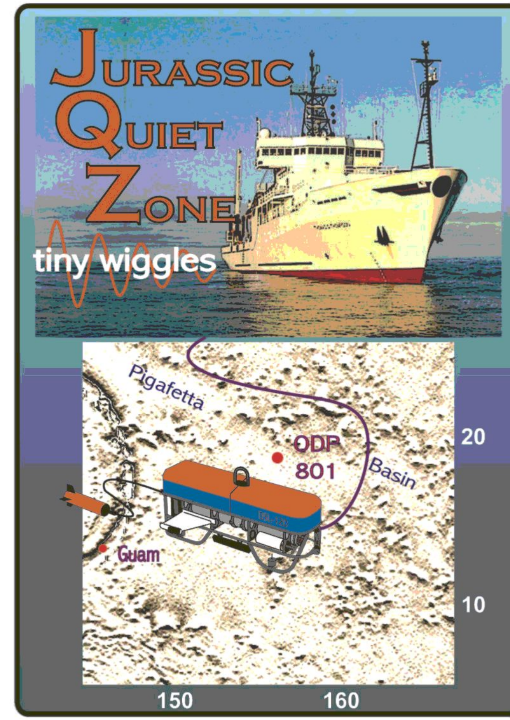
Is the JQZ really a quiet zone?

Can we correlate anomalies?



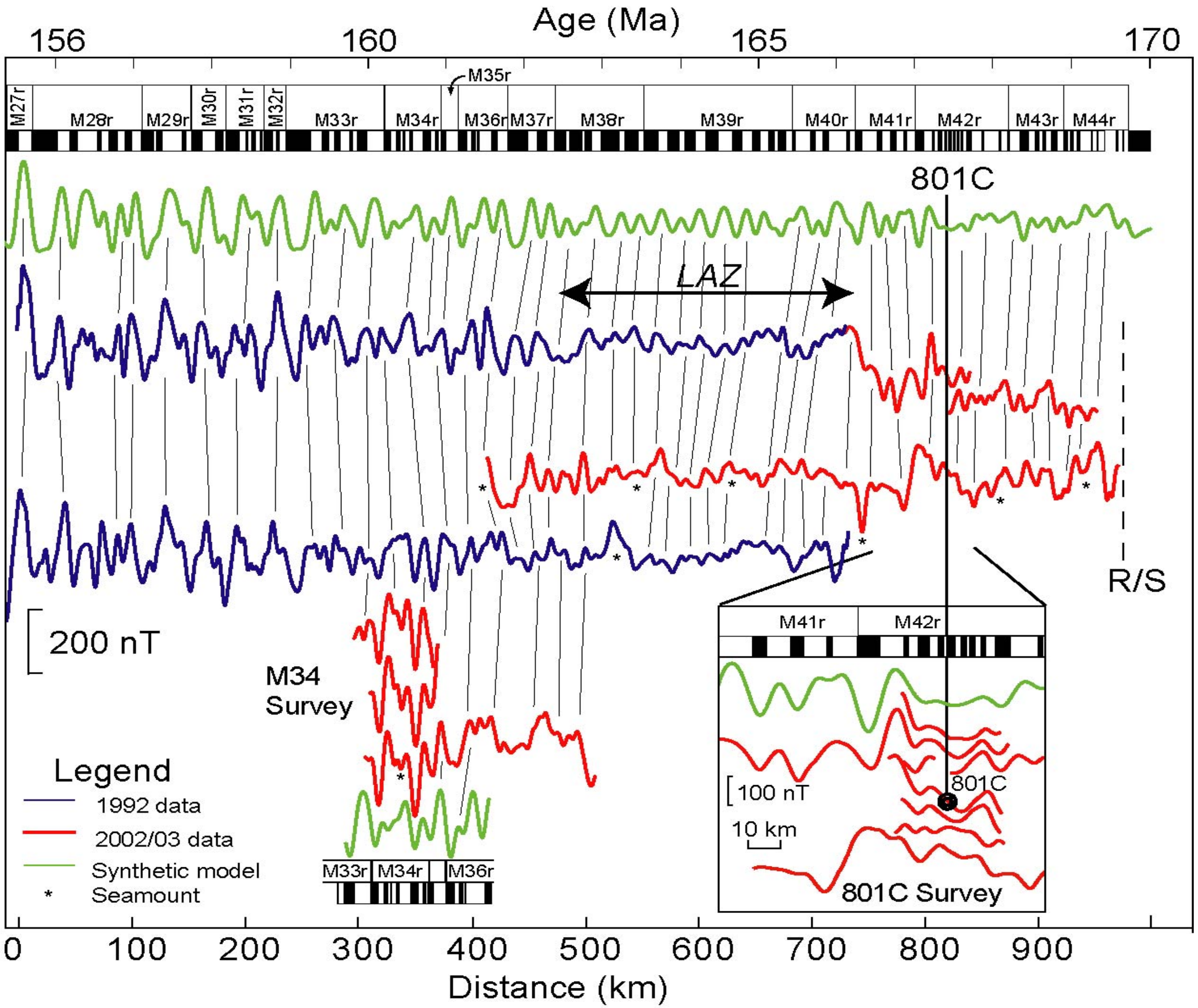


JQZ 2002 Japanese Lineations revisited

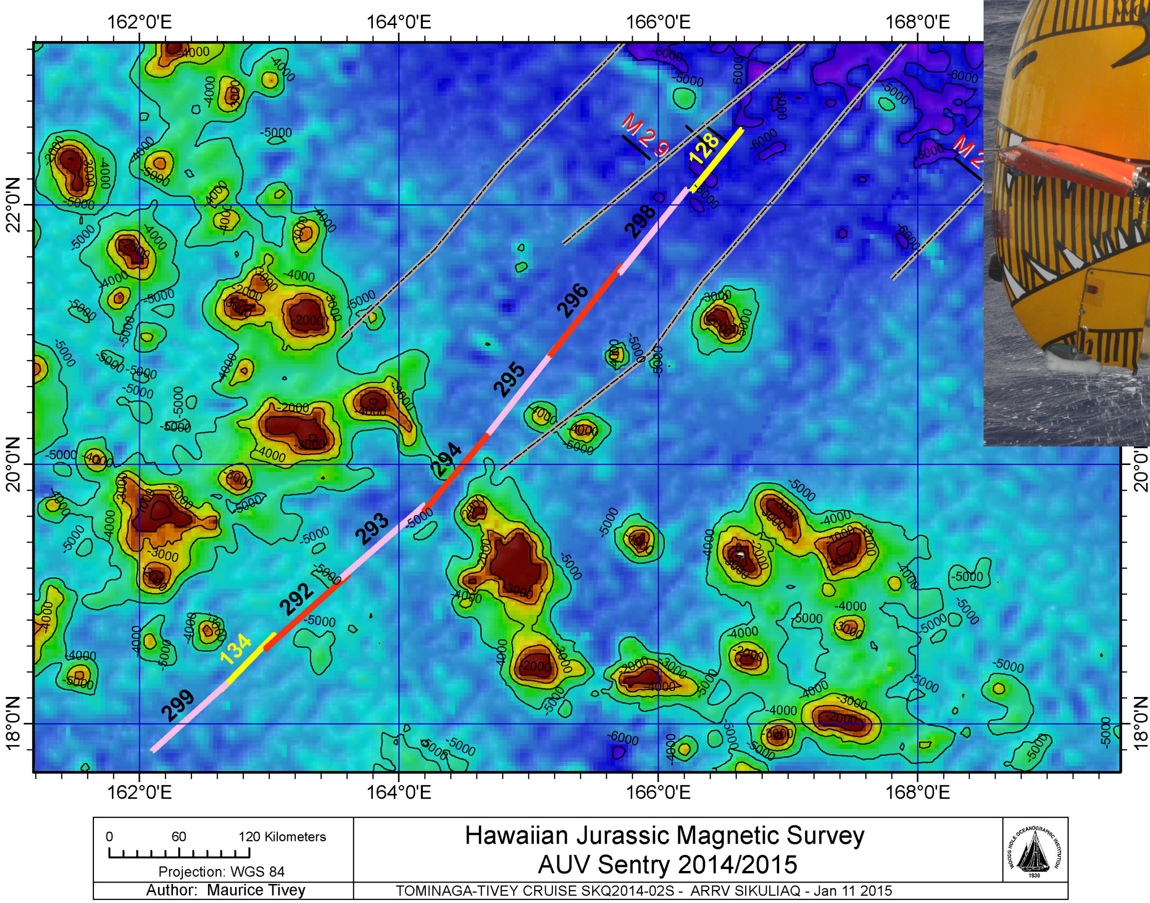


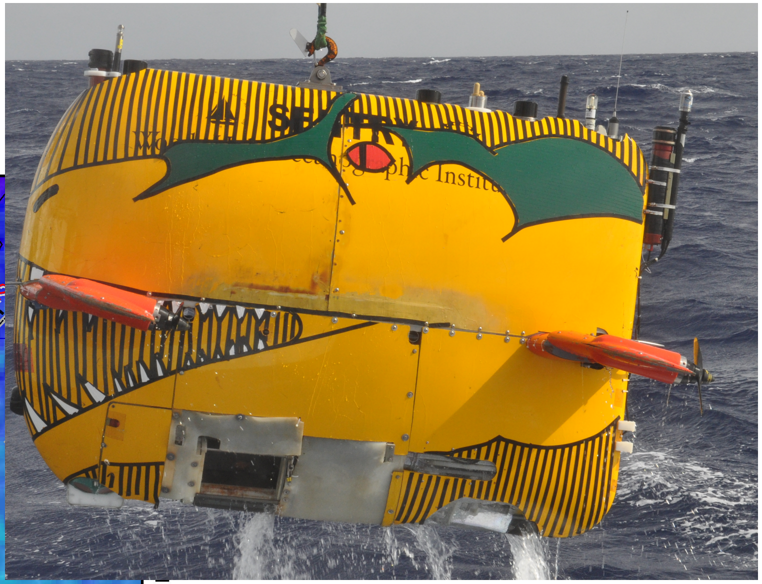
Extend survey and tie in ODP 801C
Confirm 1992 survey results – high frequency reversals
Anomaly linearity around 801C

JQZ 1992/2002 – Japanese Lineations

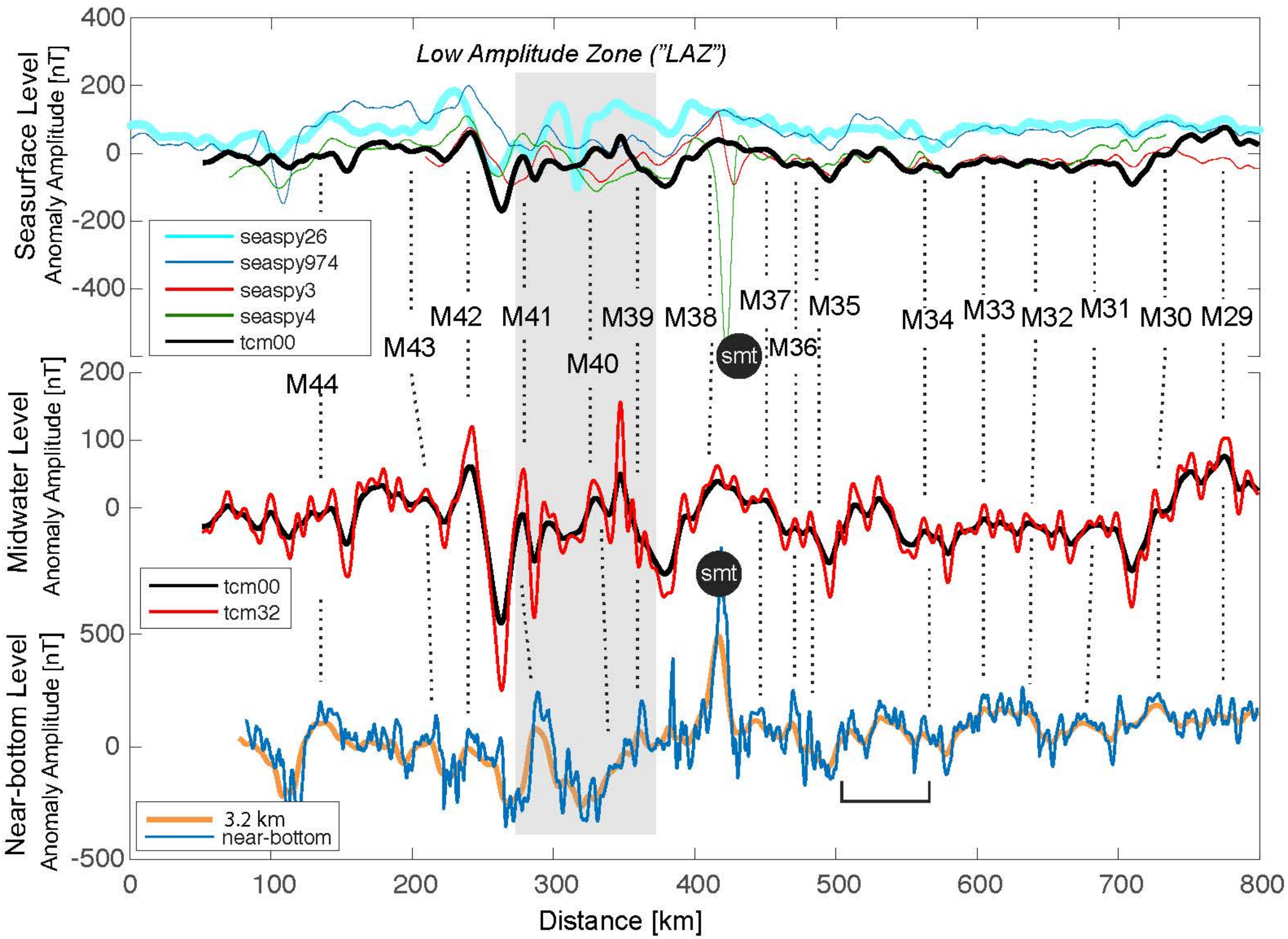


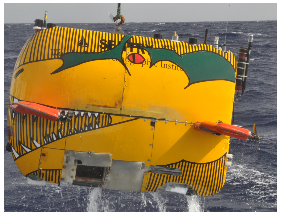
JQZ 2014/15 - Hawaiian Lineations



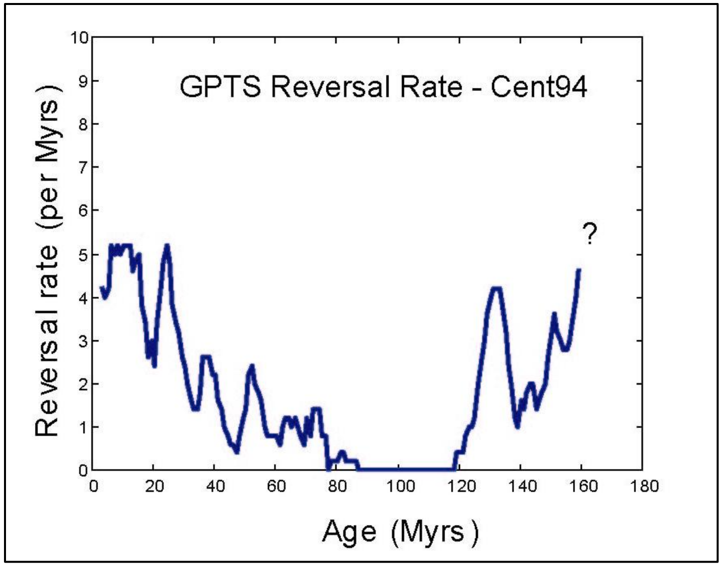


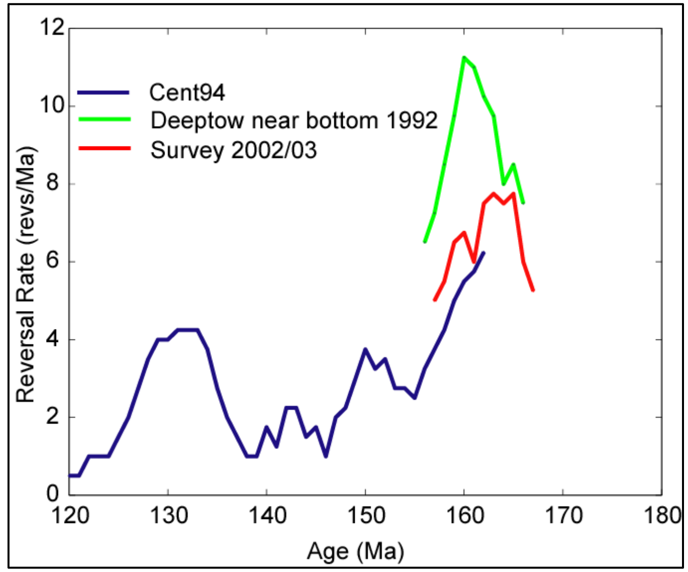
JQZ 2014/15 – Hawaiian Lineations





Jurassic Field Reversal Rate

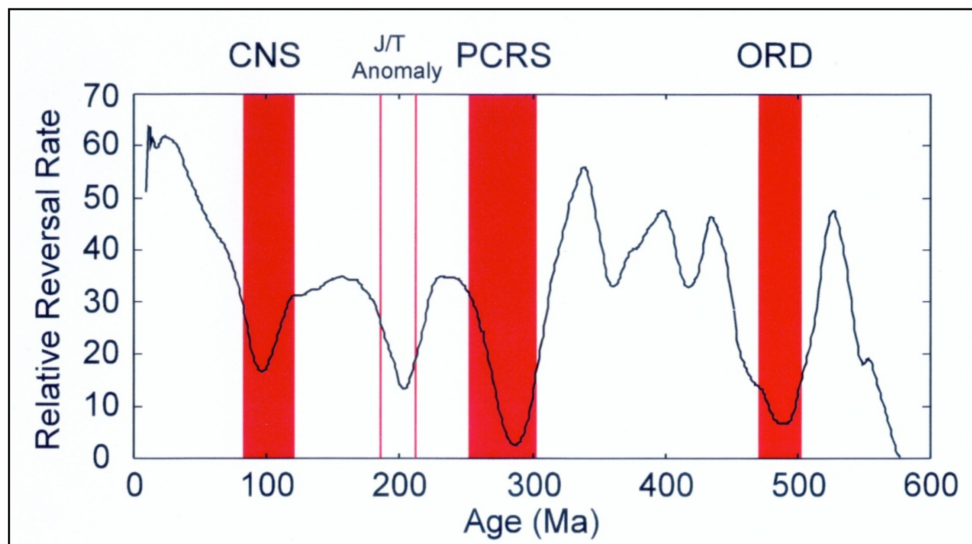




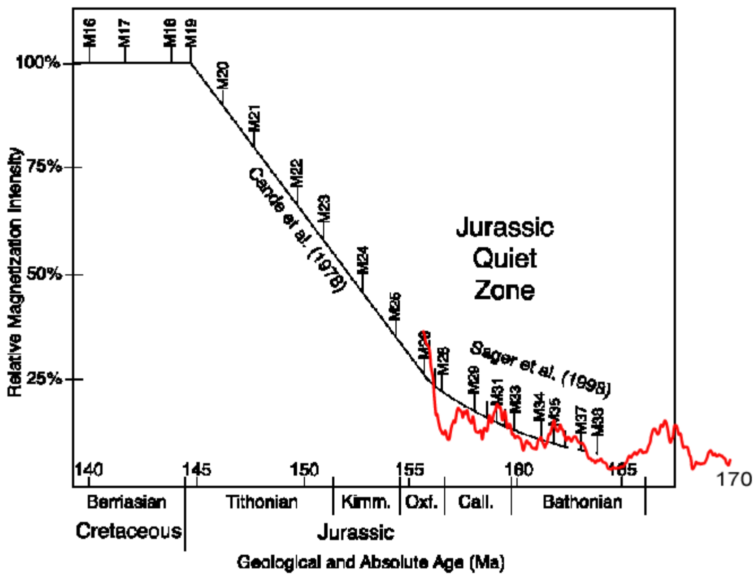
Merged GPTS:
CK95 [Cande and Kent 1995]
CENT-94 [Channel et al., 2003]
Handschumacher et al., [1988]

4 Million year window, step 1 Ma

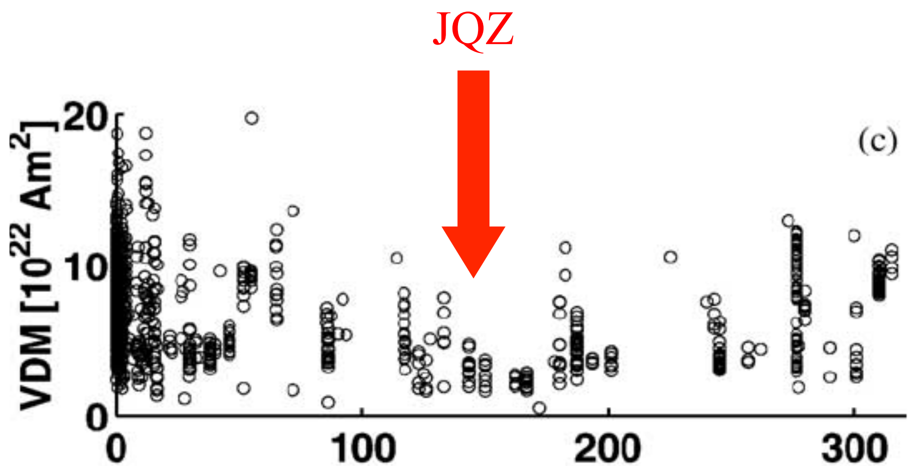
Red : Superchrons

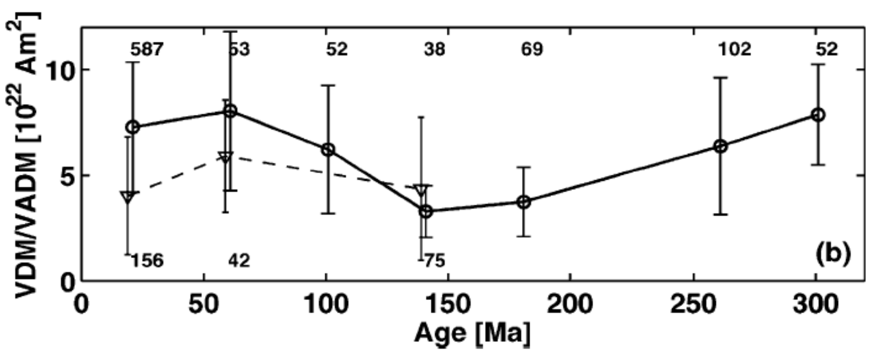


Jurassic Field Intensity

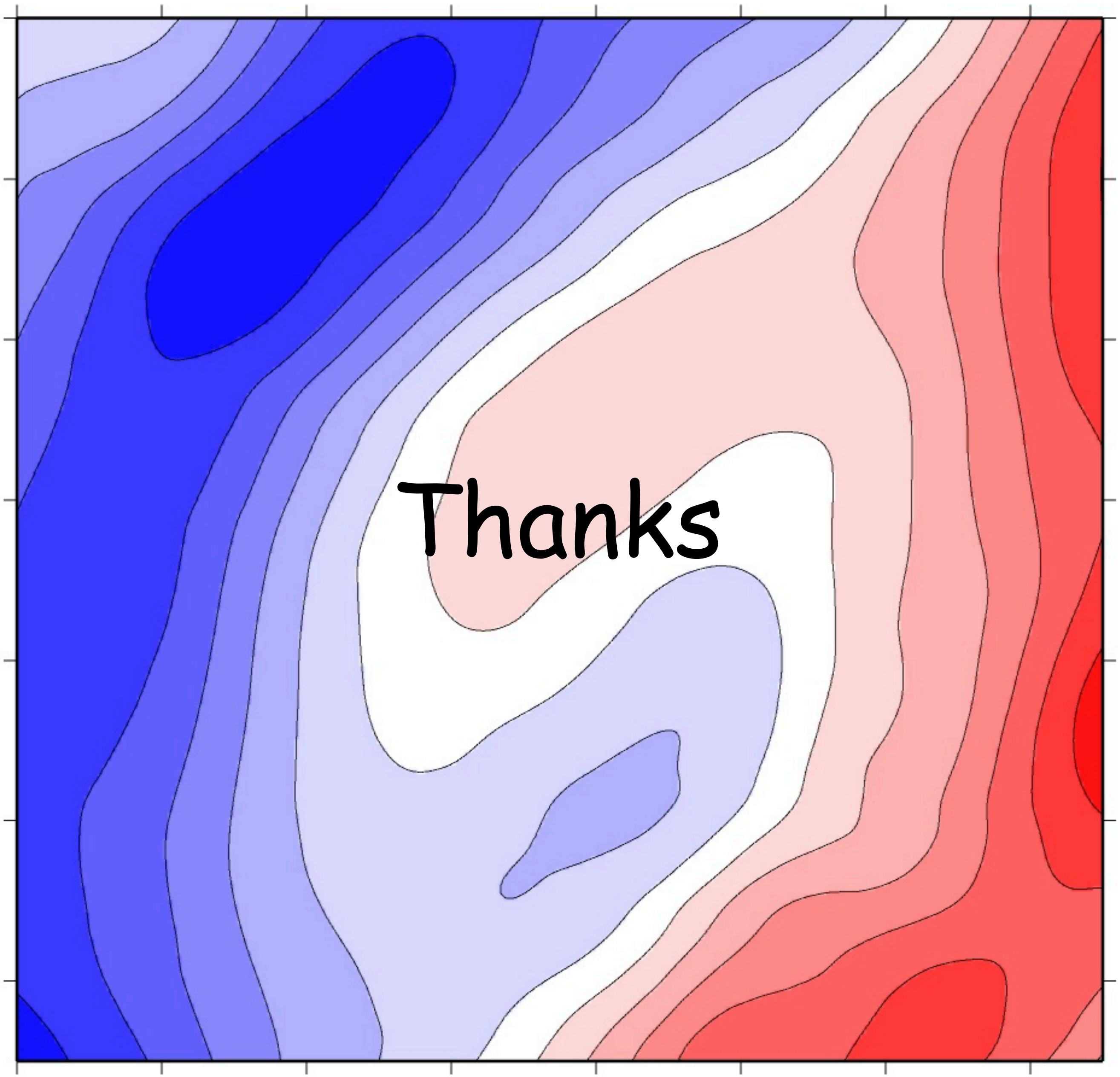


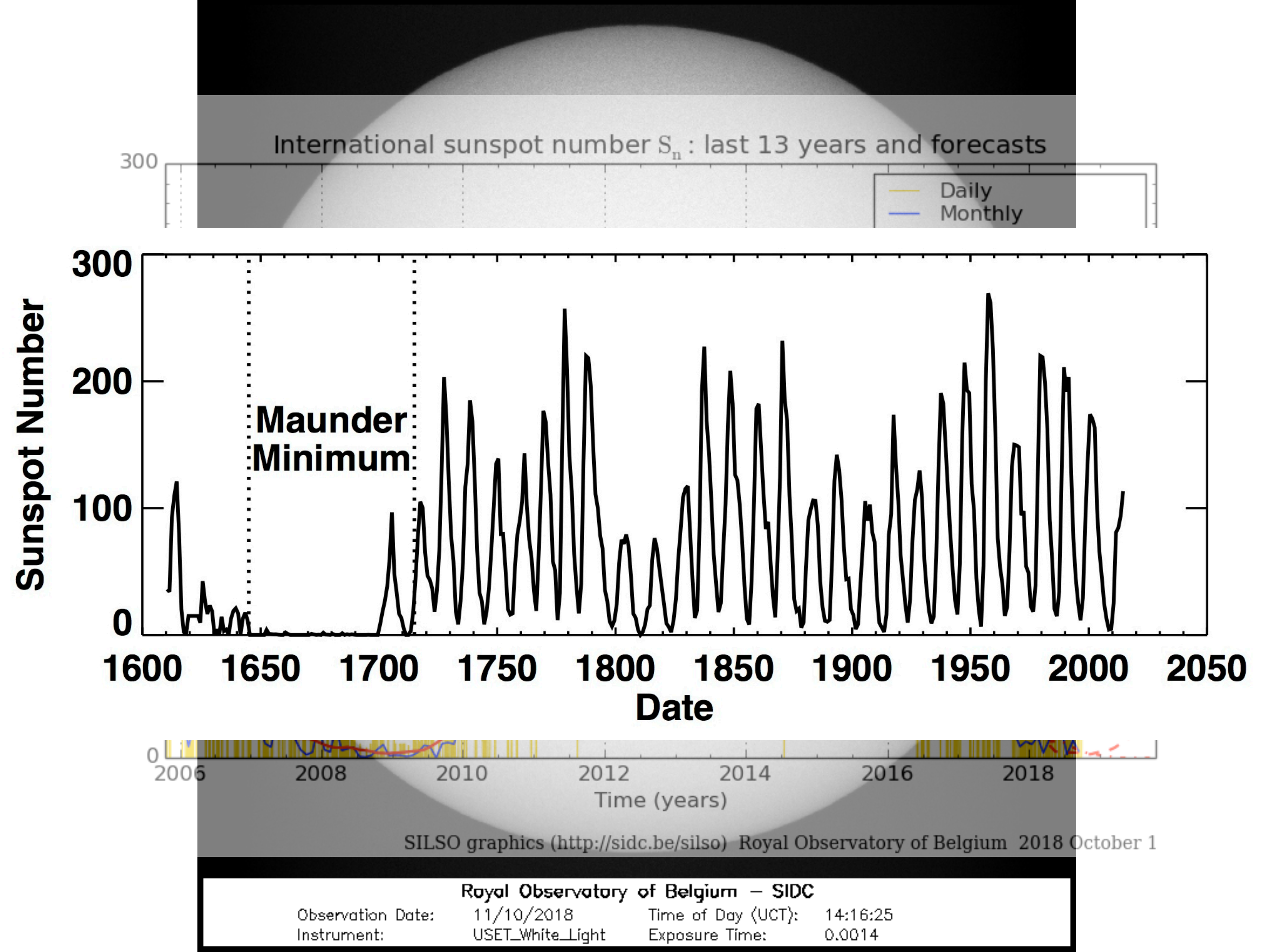
Sea surface anomaly amplitudes after
Larson and McElhinny, 2003
Red JQZ deeptow anomalies





Based on rock measurements


Thanks



International sunspot number S_n : last 13 years and forecasts
300
Daily
Monthly
0
2006
2008
2010
2012
2014
2016
2018
Time (years)
SILSO graphics (http://sidc.be/silso) Royal Observatory of Belgium 2018 October 1
Sunspot Number
300
200
100
0
Maunder
Minimum
1600
1650
1700
1750
1800
1850
1900
1950
2000
2050
Date
Royal Observatory of Belgium – SIDC
Observation Date: 11/10/2018
Time of Day (UCT): 14:16:25
Instrument: USET_White_Light
Exposure Time: 0.0014

Magnetic Units

Parameter	**SI Units**	**cgs Units**	**Conversion**
Magnetic Moment (**m**)	Am^2	emu	1 Am^2 = 10^3 emu
Magnetization (**M**)	Am^{-1}	emu/cm^3	1 Am^{-1} = 10-^{3} emu
Magnetic Field (**H**)	Am^{-1}	Oersted (oe)	1 Am^{-1} = $4\pi/10^3$ oe
Magnetic Flux (ϕ)	Weber (Wb)	Maxwell	1 Wb = 10^8 maxwells
Magnetic Induction (**B**)	Tesla (T)	Gauss (G)	1 T = 10000 G
Permeability of free space (μ_o)	Hm^{-1}	1	$4\pi \times 10^{-7}$ Hm^{-1} = 1
Susceptibility (χ)			1 SI = $1/4\pi$ emu
total (**m**/**H**)	m^3	emu/oe	1 m^3 = $10^6/4\pi$ emu/oe
volume (**M**/**H**)	-	emu $cm^{-3}oe^{-1}$	1 S.I.= $1/4\pi$ emu cm^{-3} oe^{-1}
mass (**m**/*m*).(1/**H**)	m^3kg^{-1}	emu g^{-1} oe^{-1}	m^3kg^{-1} =$10^3/4\pi$ emu $g^{-1}oe^{-1}$

Magnetic Field Numbers

Field	**S.I. units**	**cgs units**	
Earth's field @ equator	0.03 mT	0.3 oe	30000 nT
Earth's field @ pole	0.06 mT	0.6 oe	60000 nT
Sunspot	0.1 - 4 mT	1 - 40 oe	100000 nT
Lab bar magnet	20 mT	200 oe	20×10^6 nT
Electromagnet	1 T	10,000 oe	10^9 nT
Strongest continuous field	10 T	100,000 oe	
Strongest pulsed field	50 T	500,000 oe	
Magnetic field at nucleus of atom	45 T	450,000 oe	