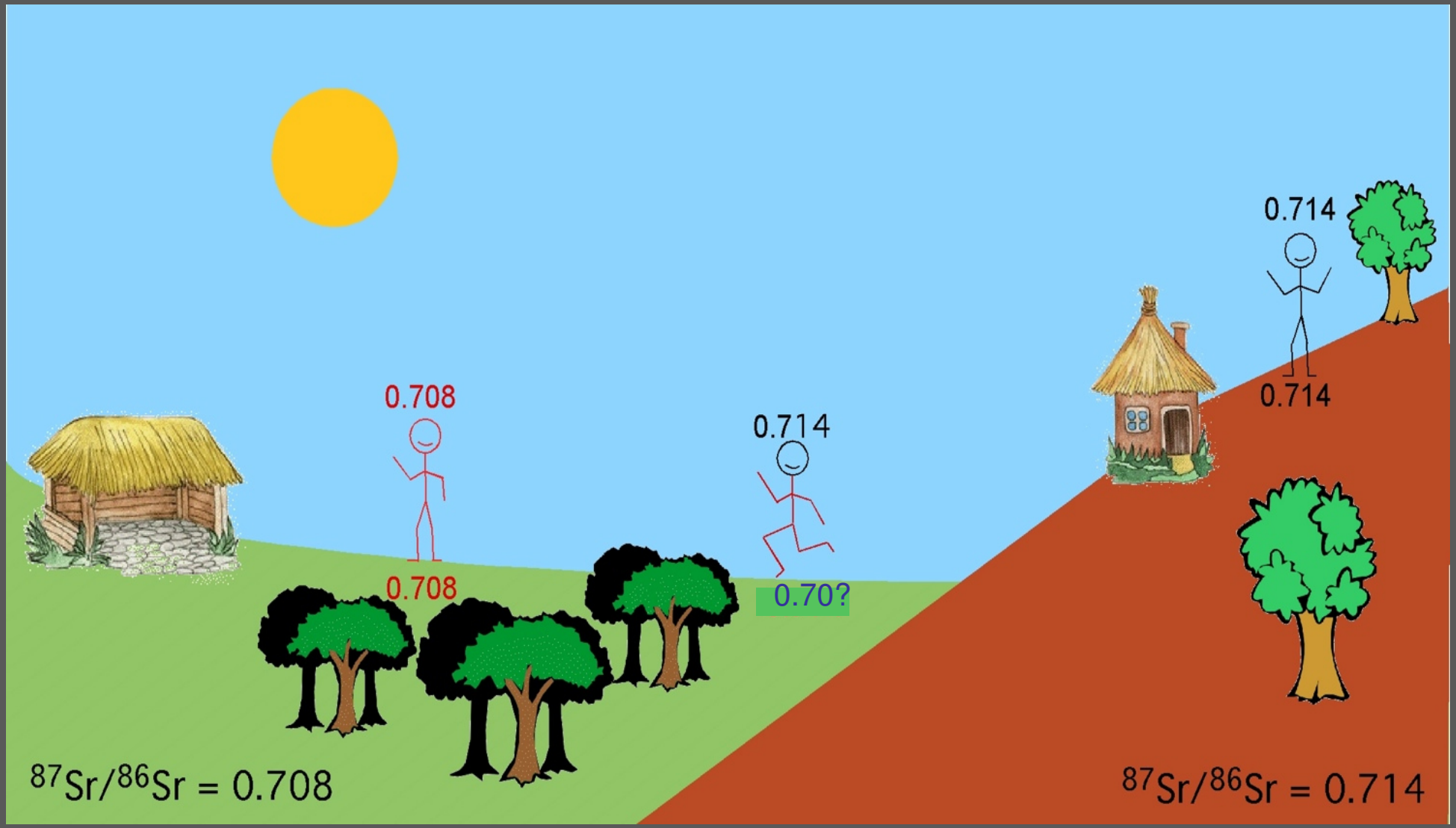
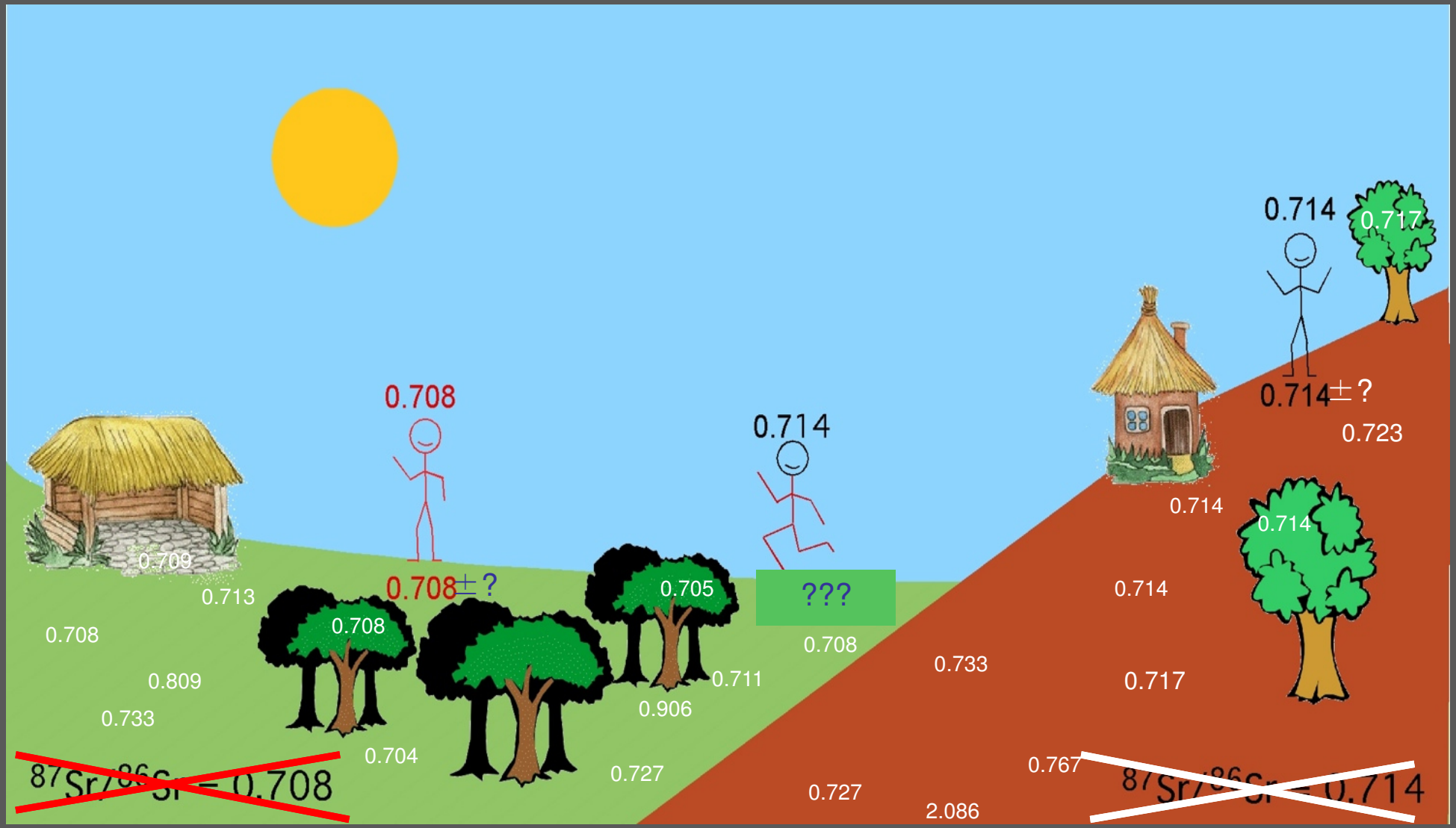
Isotopic landscapes in archaeology:
‘local' versus human 87Sr/86Sr

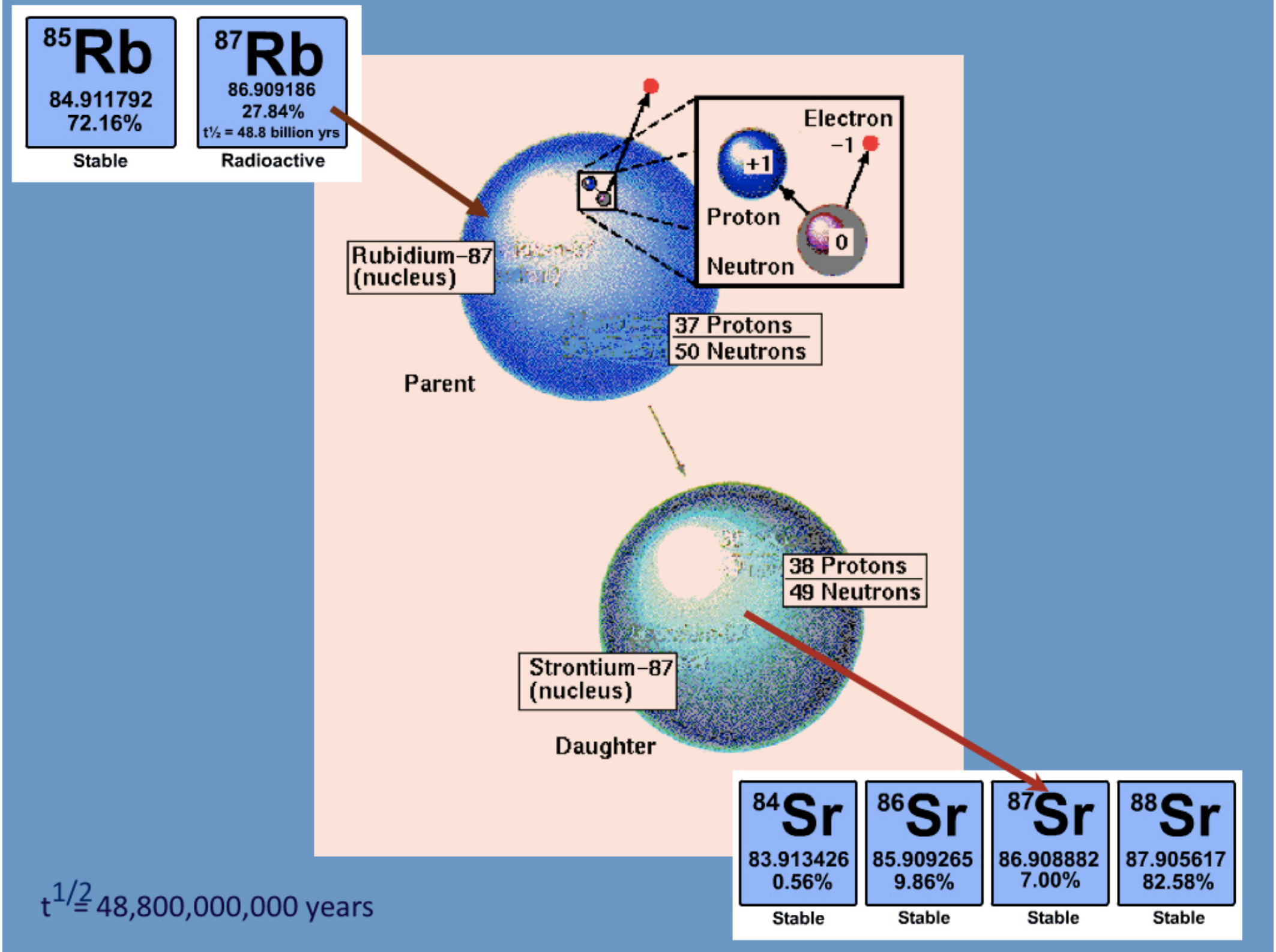
James Burton
University of Wisconsin-Madison

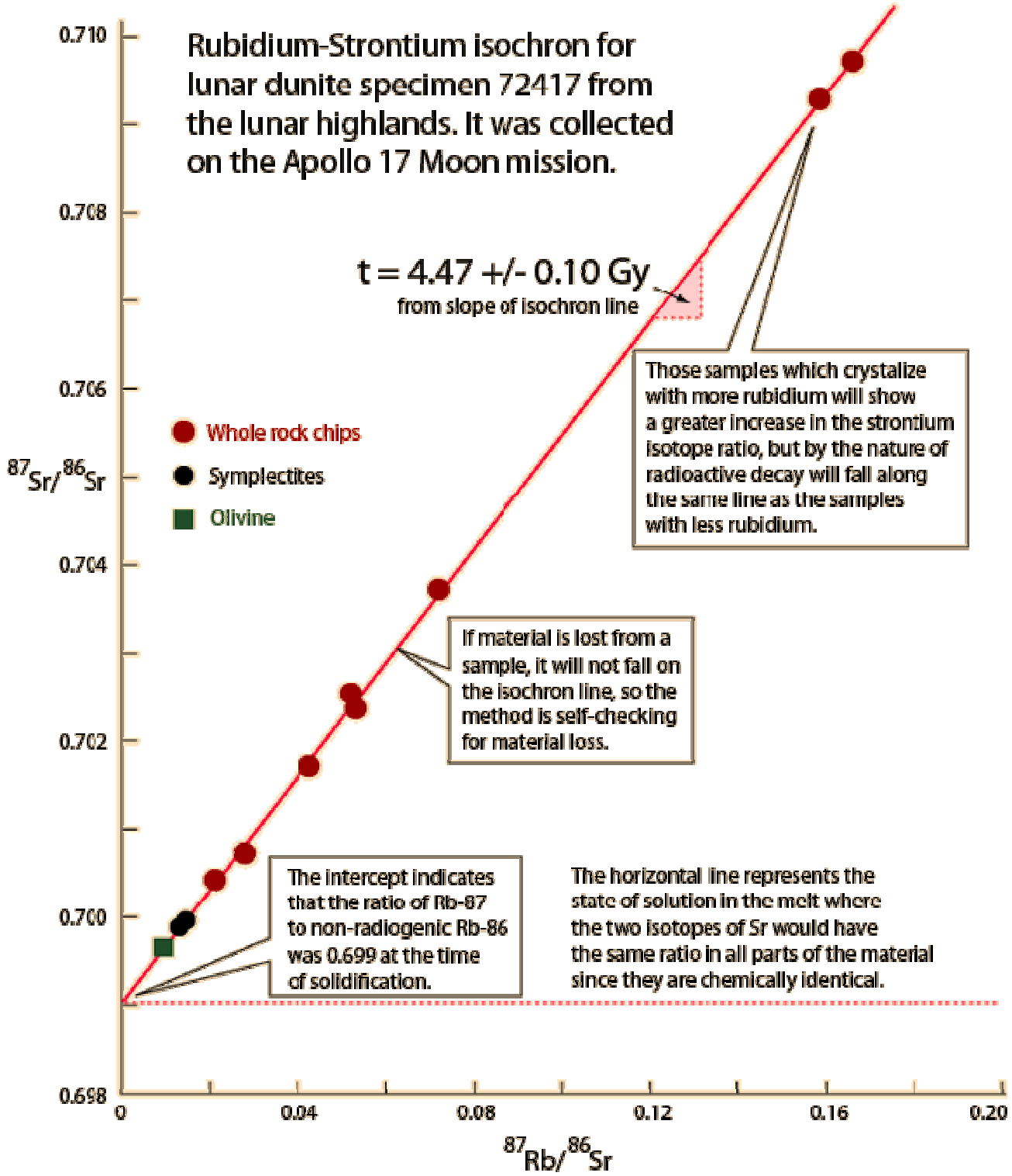
A Critical Look at the Concept of Isotopic Landscapes

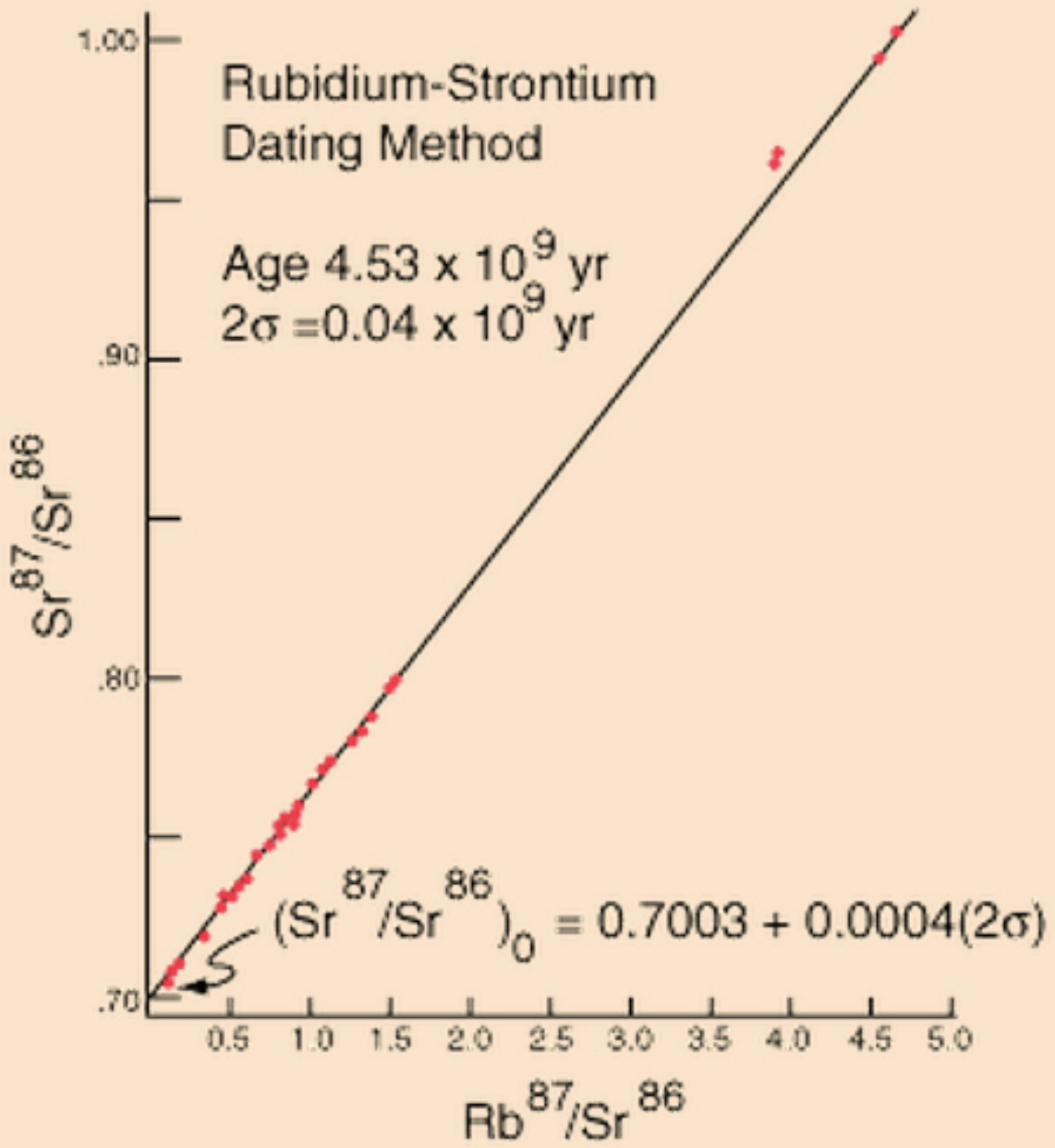
Tuesday, October 14, 2014


0.714
0.708
0.714
0.708
0.70?
$^{87}Sr/^{86}Sr = 0.708$
$^{87}Sr/^{86}Sr = 0.714$


0.714
0.717
0.708
0.714±?
0.723
0.714
0.714
0.709
0.713
0.708±?
0.705
???
0.714
0.708
0.708
0.733
0.809
0.711
0.717
0.733
0.906
0.704
0.727
0.767
0.727
2.086
87Sr/86Sr = 0.708
87Sr/86Sr = 0.714

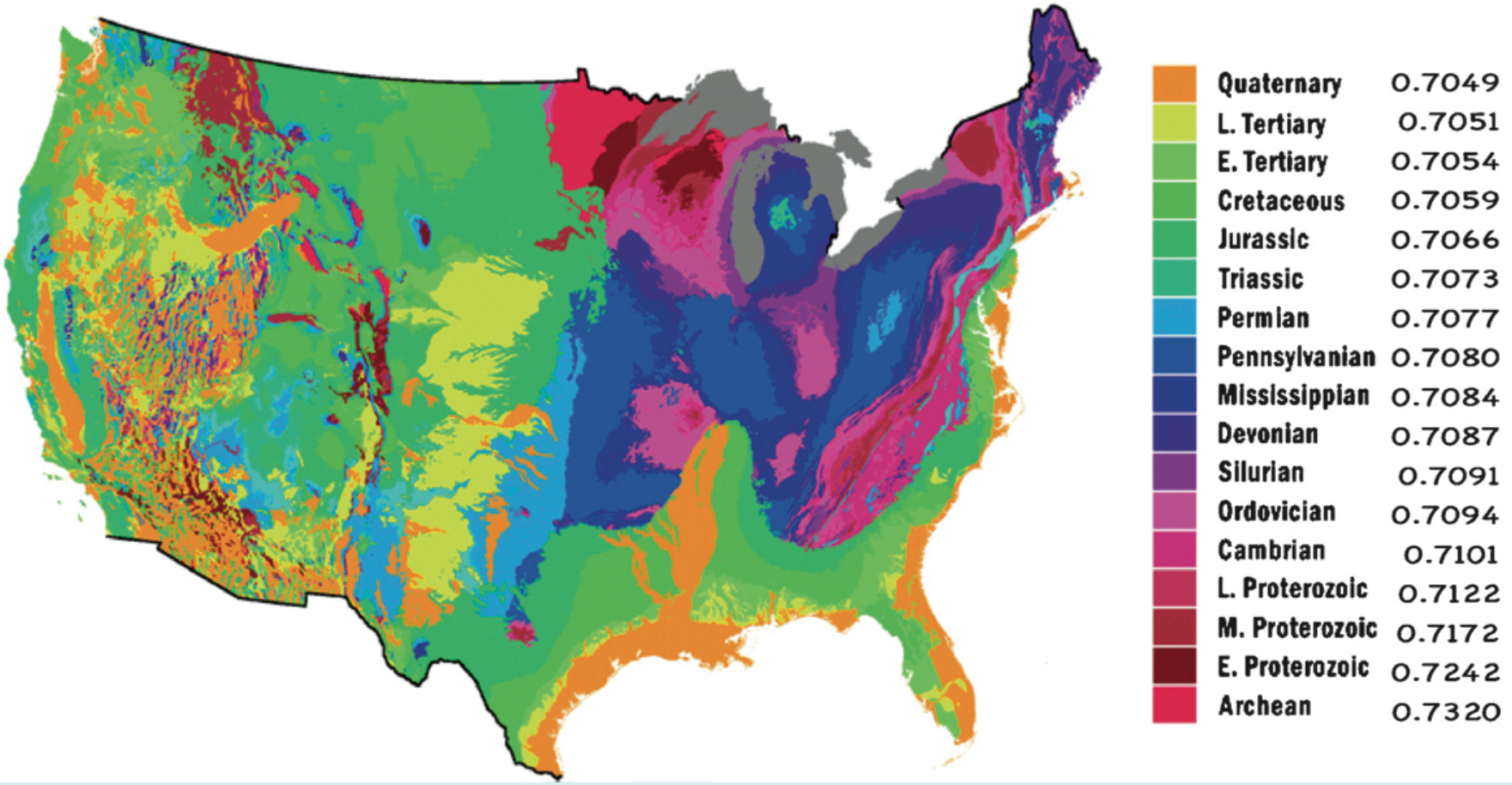

85Rb
84.911792
72.16%
Stable
87Rb
86.909186
27.84%
t½ = 48.8 billion yrs
Radioactive
Electron
−1
+1
Proton
0
Neutron
Rubidium−87
(nucleus)
37 Protons
50 Neutrons
Parent
38 Protons
49 Neutrons
Strontium−87
(nucleus)
Daughter
84Sr
83.913426
0.56%
Stable
86Sr
85.909265
9.86%
Stable
87Sr
86.908882
7.00%
Stable
88Sr
87.905617
82.58%
Stable
t1/2 = 48,800,000,000 years

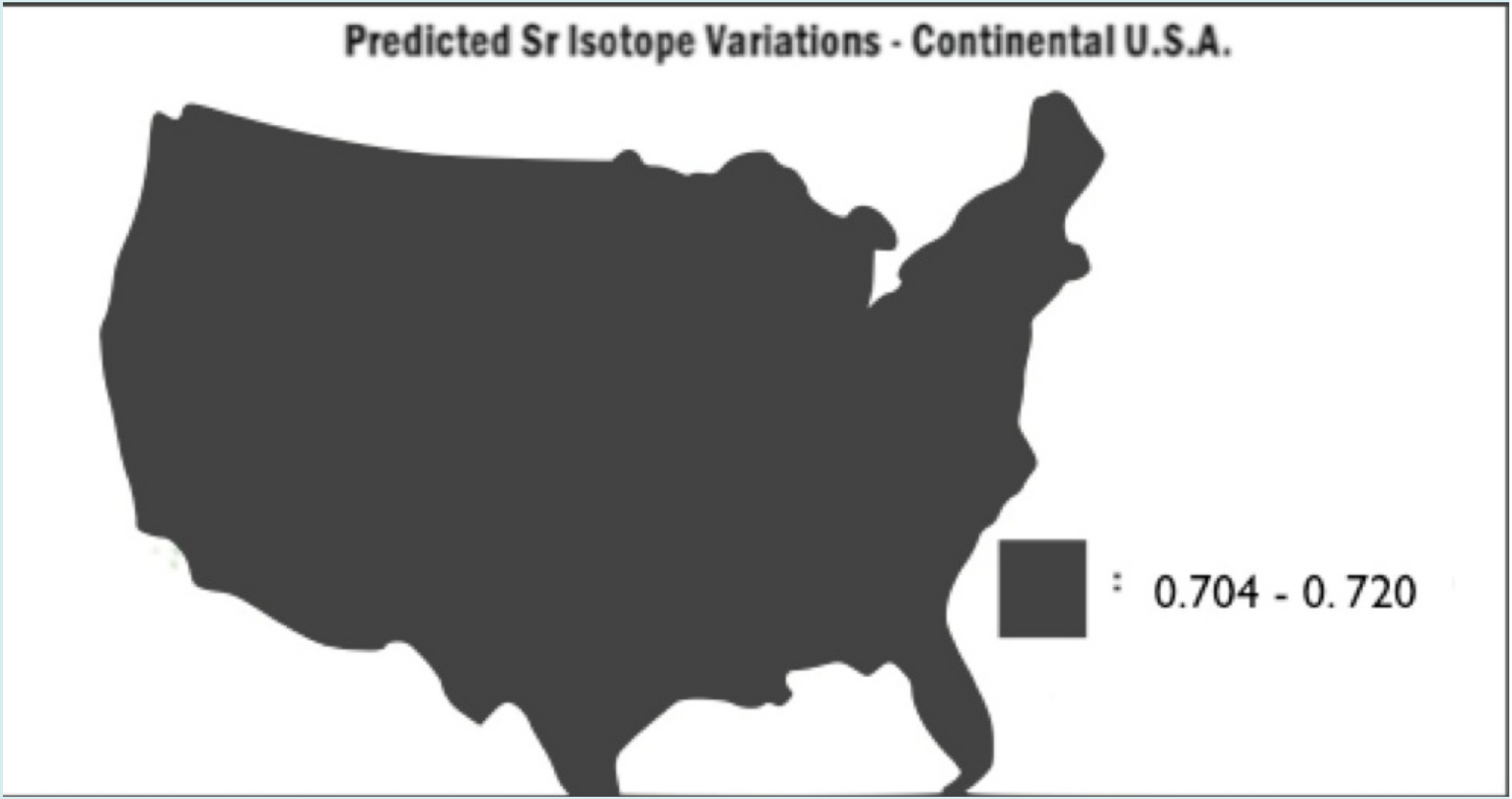

Rubidium-Strontium isochron for lunar dunite specimen 72417 from the lunar highlands. It was collected on the Apollo 17 Moon mission.
t = 4.47 +/- 0.10 Gy
from slope of isochron line
Those samples which crystalize with more rubidium will show a greater increase in the strontium isotope ratio, but by the nature of radioactive decay will fall along the same line as the samples with less rubidium.
Whole rock chips
Symplectites
Olivine
If material is lost from a sample, it will not fall on the isochron line, so the method is self-checking for material loss.
The intercept indicates that the ratio of Rb-87 to non-radiogenic Rb-86 was 0.699 at the time of solidification.
The horizontal line represents the state of solution in the melt where the two isotopes of Sr would have the same ratio in all parts of the material since they are chemically identical.
0.710
0.708
0.706
0.704
0.702
0.700
0.698
87Sr/86Sr
0
0.04
0.08
0.12
0.16
0.20
87Rb/86Sr

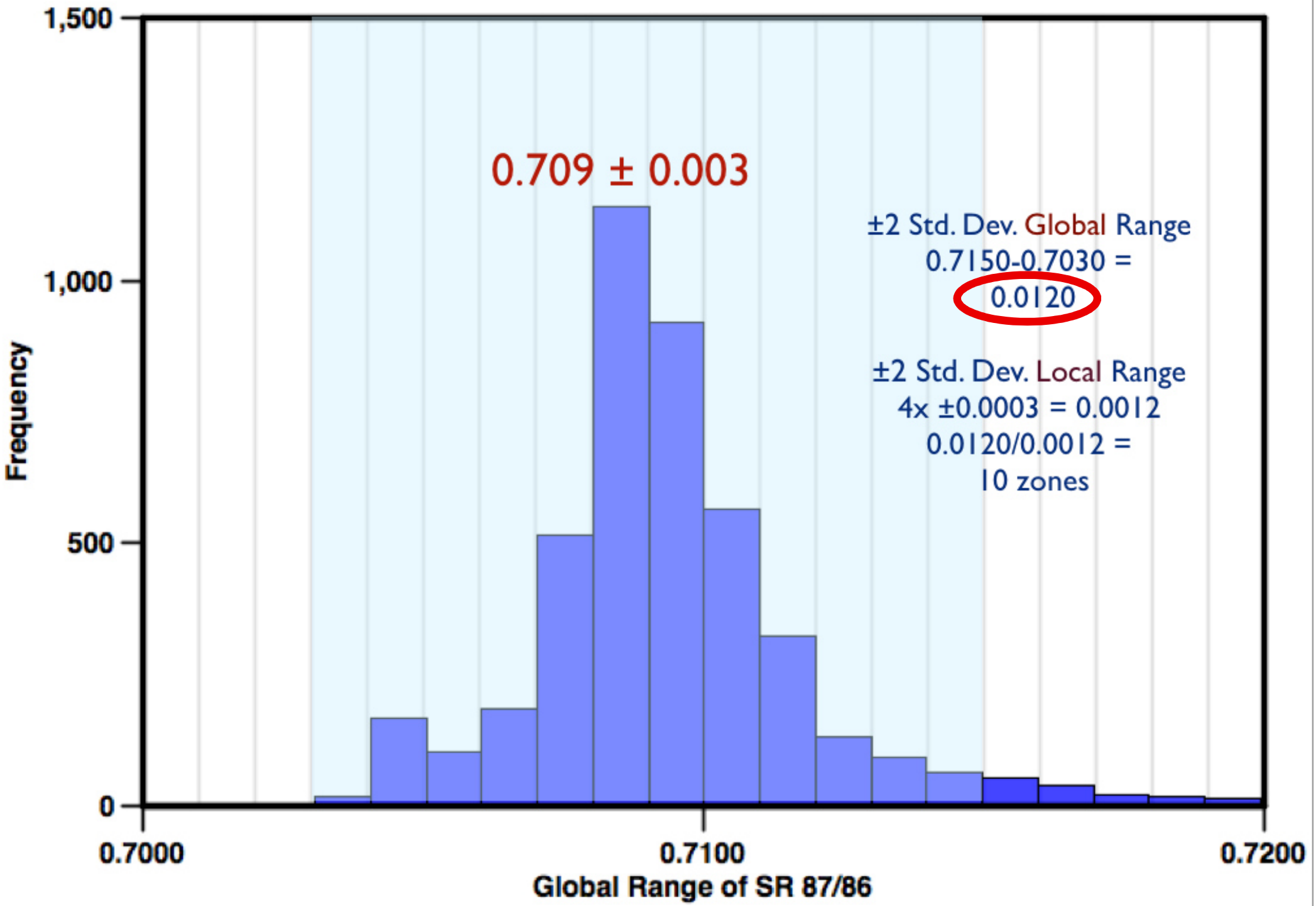


G. W. Wetherill, Ann. Rev. Nucl. Sci. 25, 283 (1975)

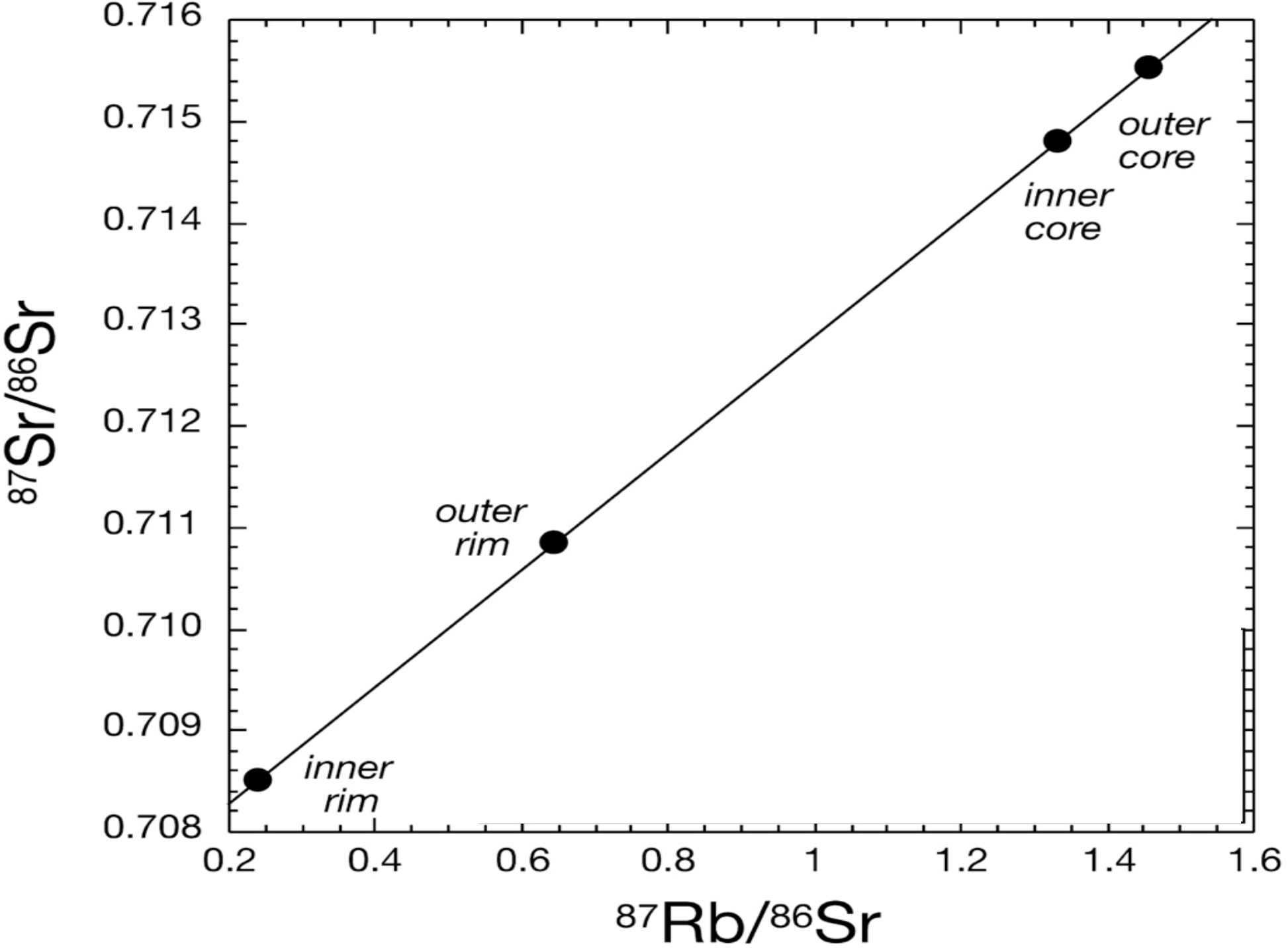
Predicted Sr Isotope Variations - Continental U.S.A.



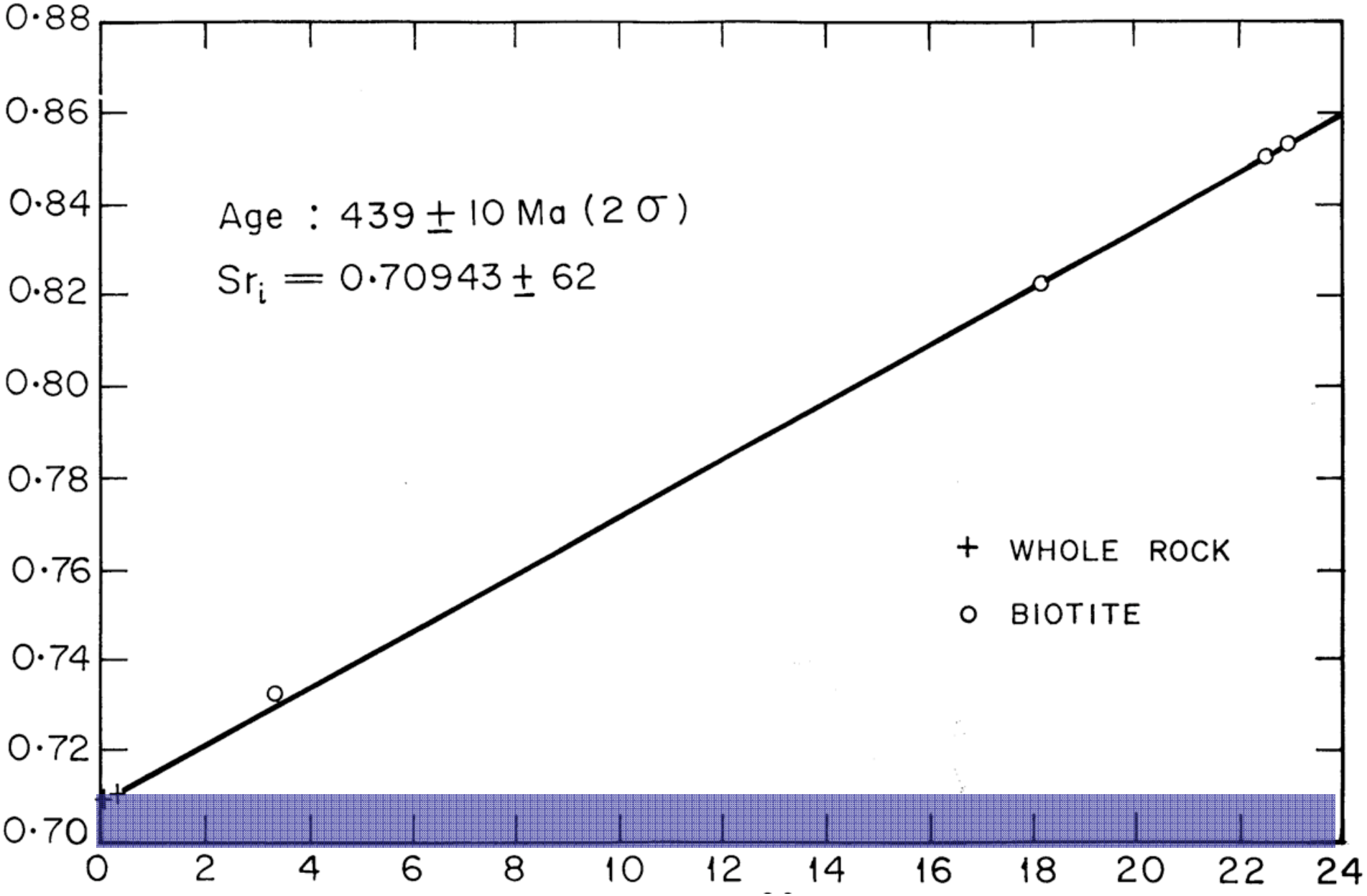

Predicted Sr Isotope Variations - Continental U.S.A.
0.704 - 0. 720



Laboratory for Archaeological Chemistry database

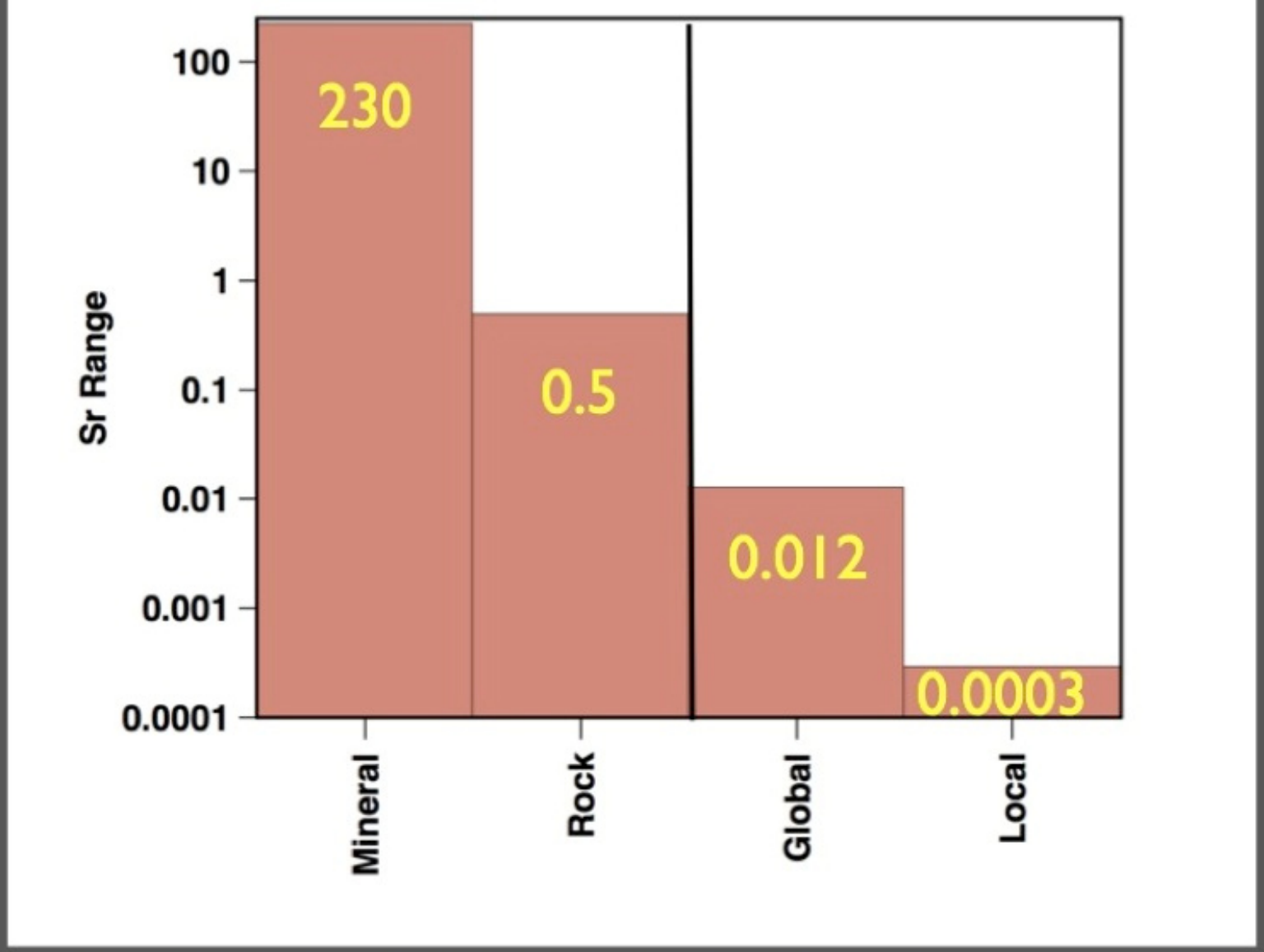


Jon Davidson, Bruce Charlier, John M. Hora, and Rebecca Perlroth
Mineral isochrons and isotopic fingerprinting: Pitfalls and promises.
Geology January, 2005, v. 33, p. 29-32.



A. M. Dayal and S. M. Hussain.
Sr–Nd isotopic composition of lamprophyre dykes from Queen MaudLand, East Antarctica
National Geophysical Research Institute, Hyderabad 500 007, India

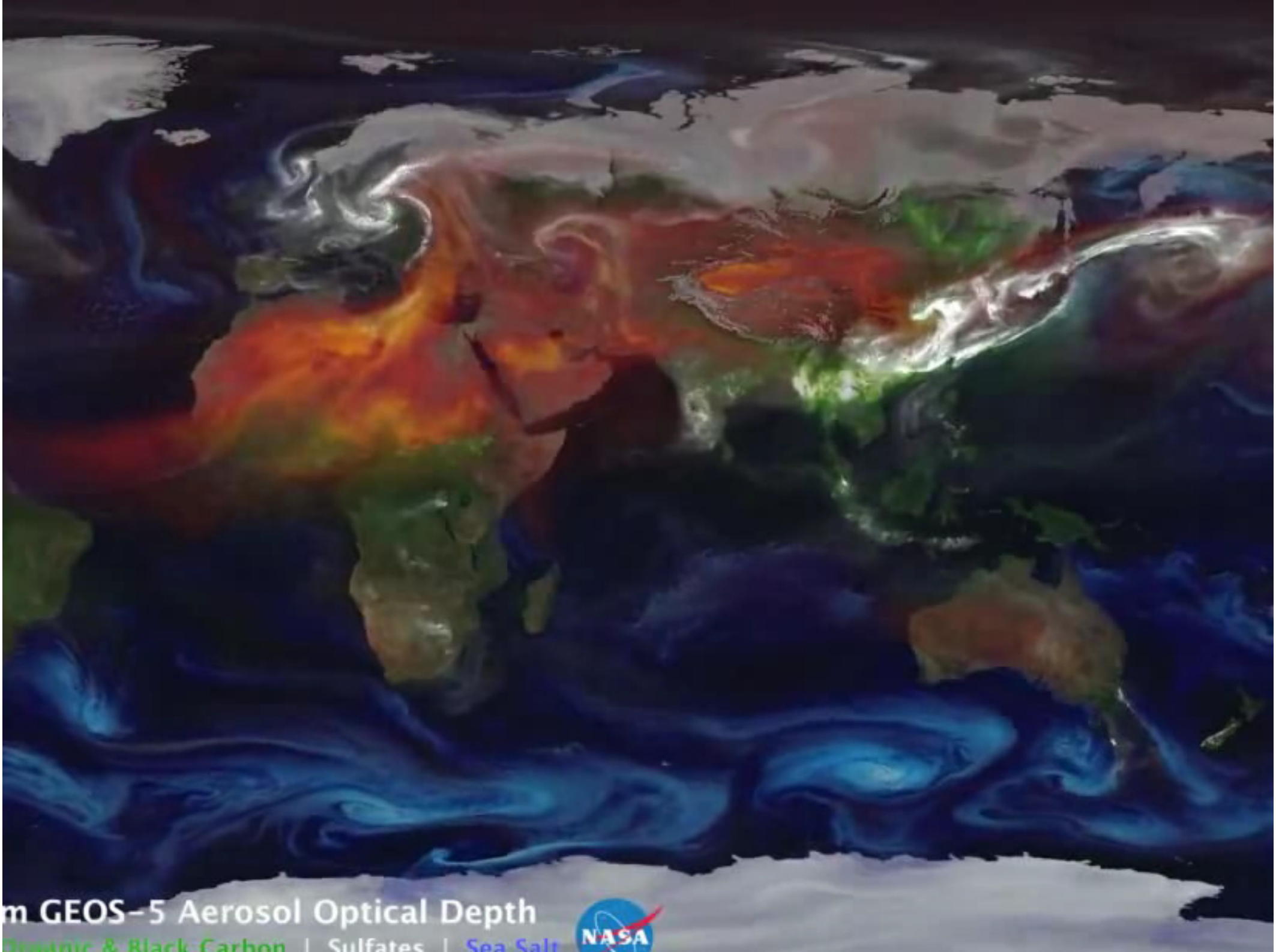
www.ias.ac.in/currsci/dec251999/articles26.htm

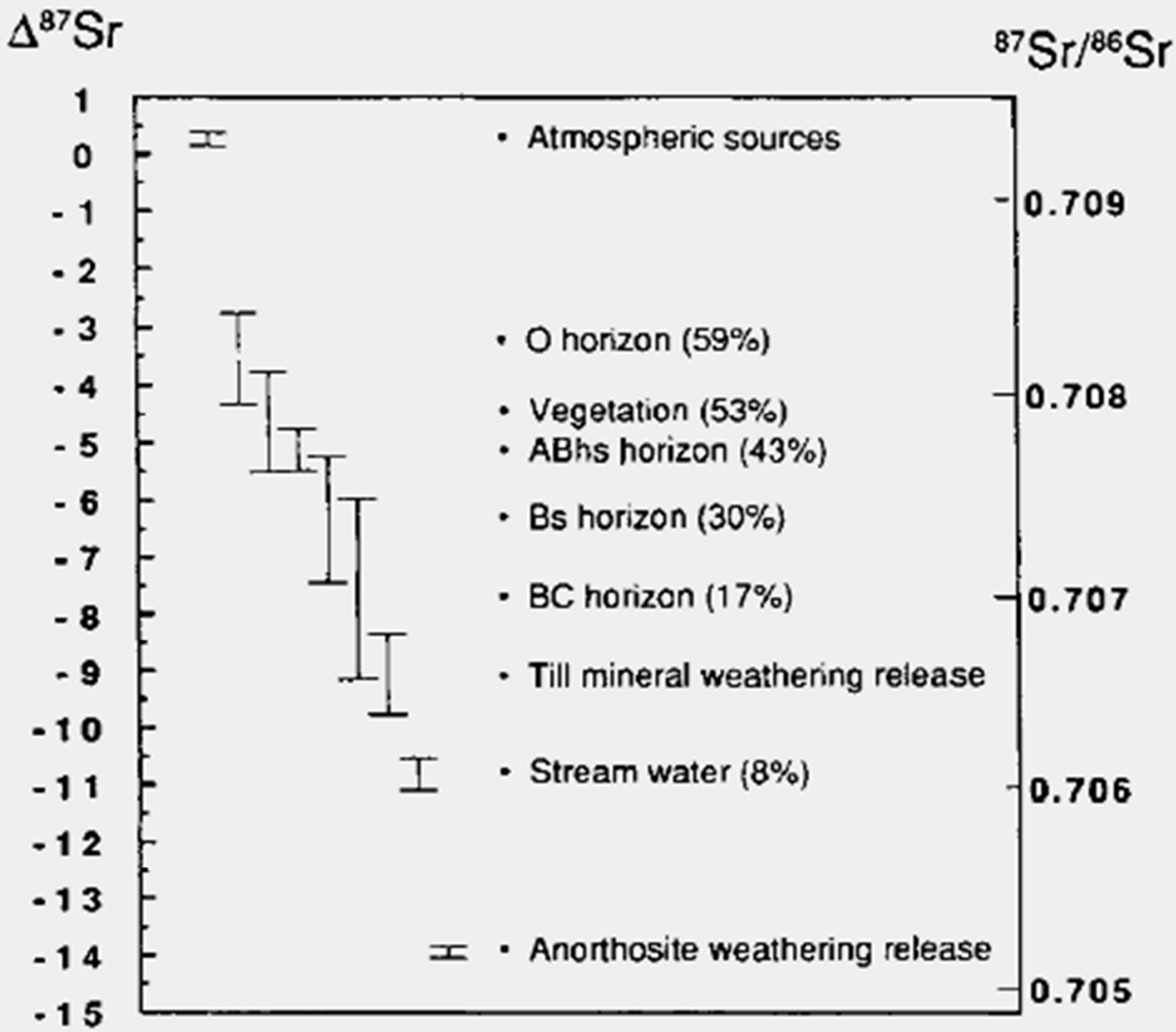


Comparison of strontium isotope ranges in geological material versus human enamel

Wyoming granodiorite: Naylor, R.S., Steiger, R.H., and Wasserburg, G.J., 1970, U-Th-Pb and Rb-Sr Systematics In 2700-Million-Year-Old Plutons From The Southern Wind River Range, Wyoming. Geochimica et Cosmochimica Acta, v. 34, p. 1133-1159.

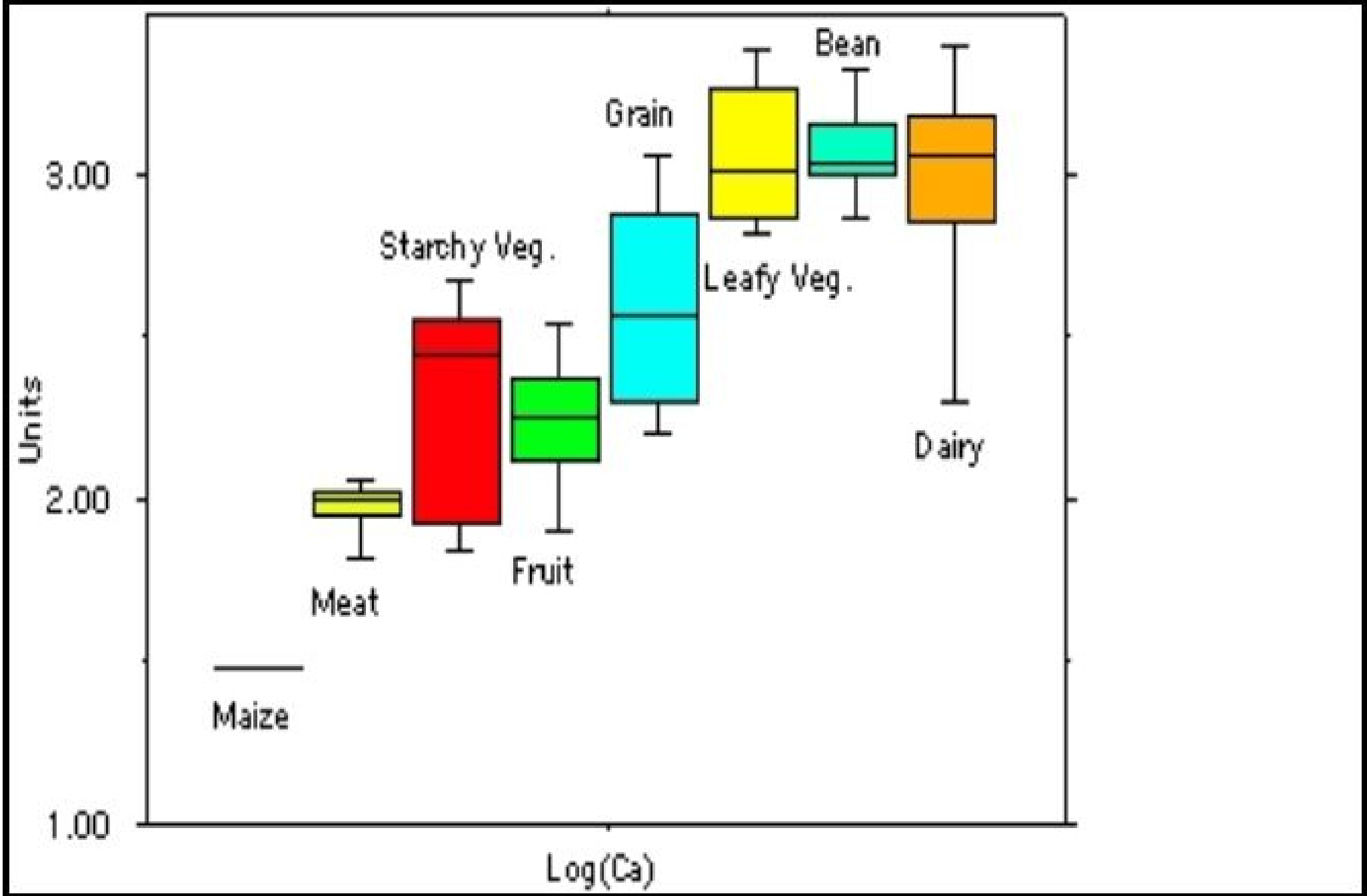
Enamel: Laboratory for Archaeological Chemistry/ UW-Madison Database

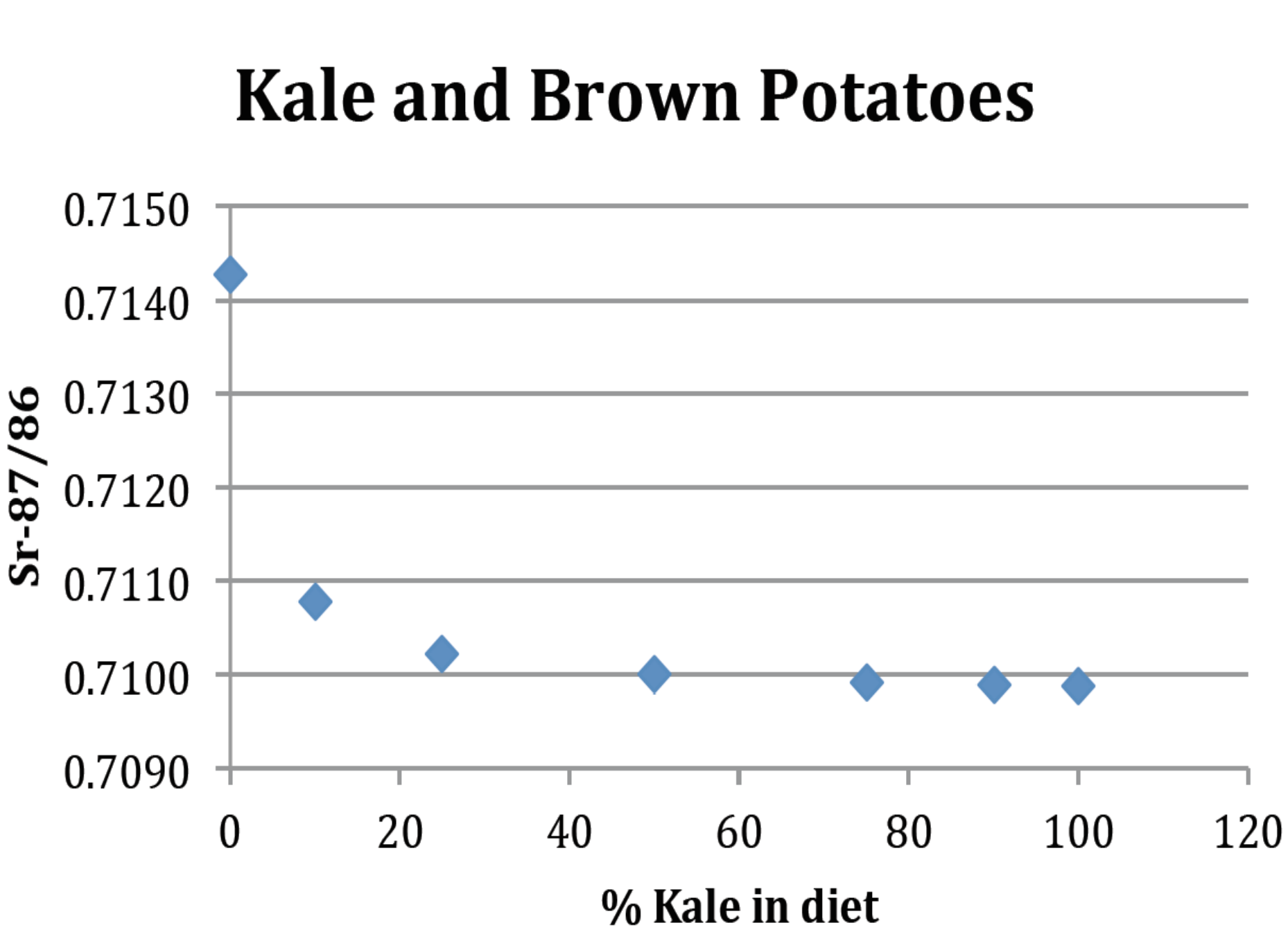

m GEOS-5 Aerosol Optical Depth
Organic & Black Carbon | Sulfates | Sea Salt
NASA

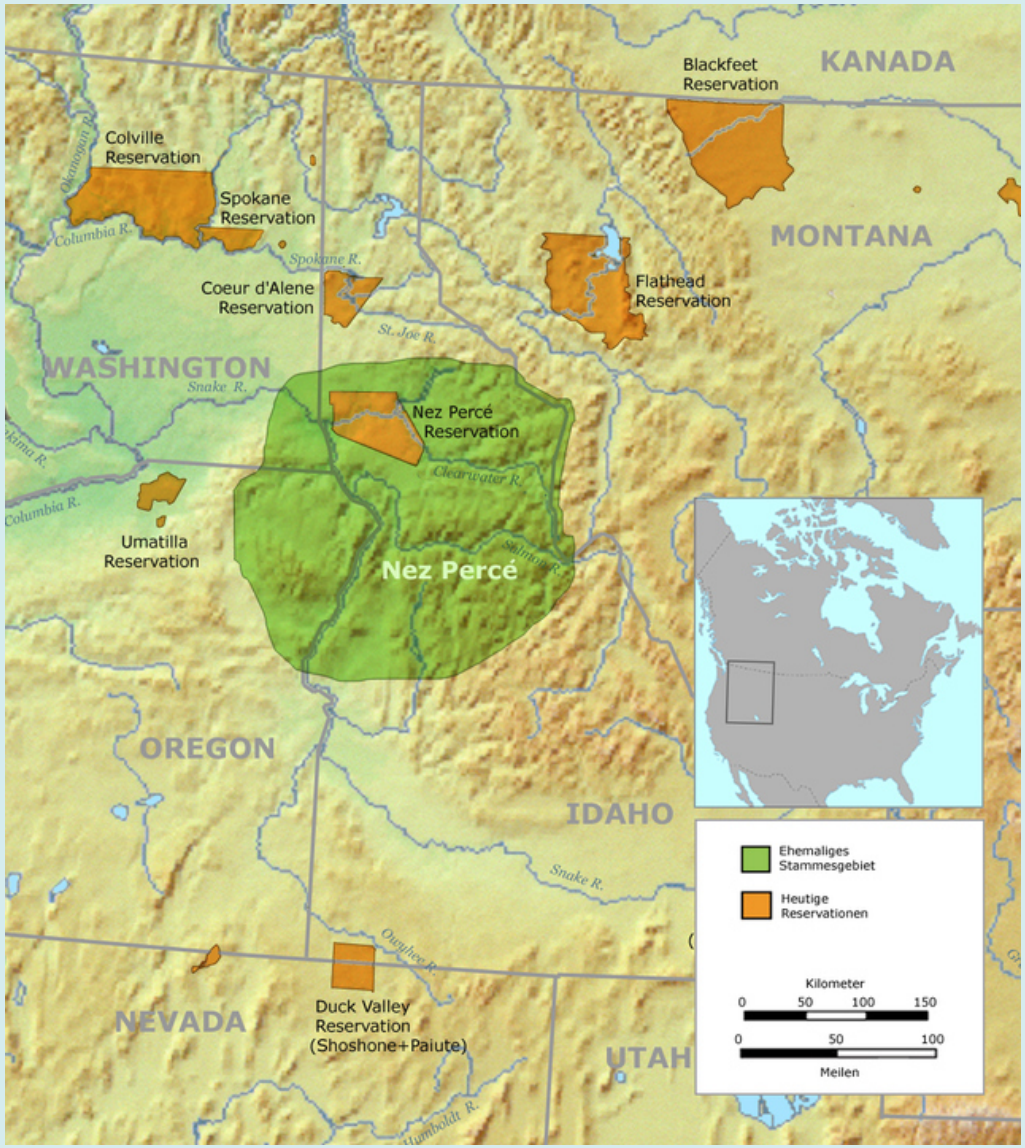

Δ87Sr
87Sr/86Sr
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
0.709
0.708
0.707
0.706
0.705
• Atmospheric sources
• O horizon (59%)
• Vegetation (53%)
• ABhs horizon (43%)
• Bs horizon (30%)
• BC horizon (17%)
• Till mineral weathering release
• Stream water (8%)
• Anorthosite weathering release

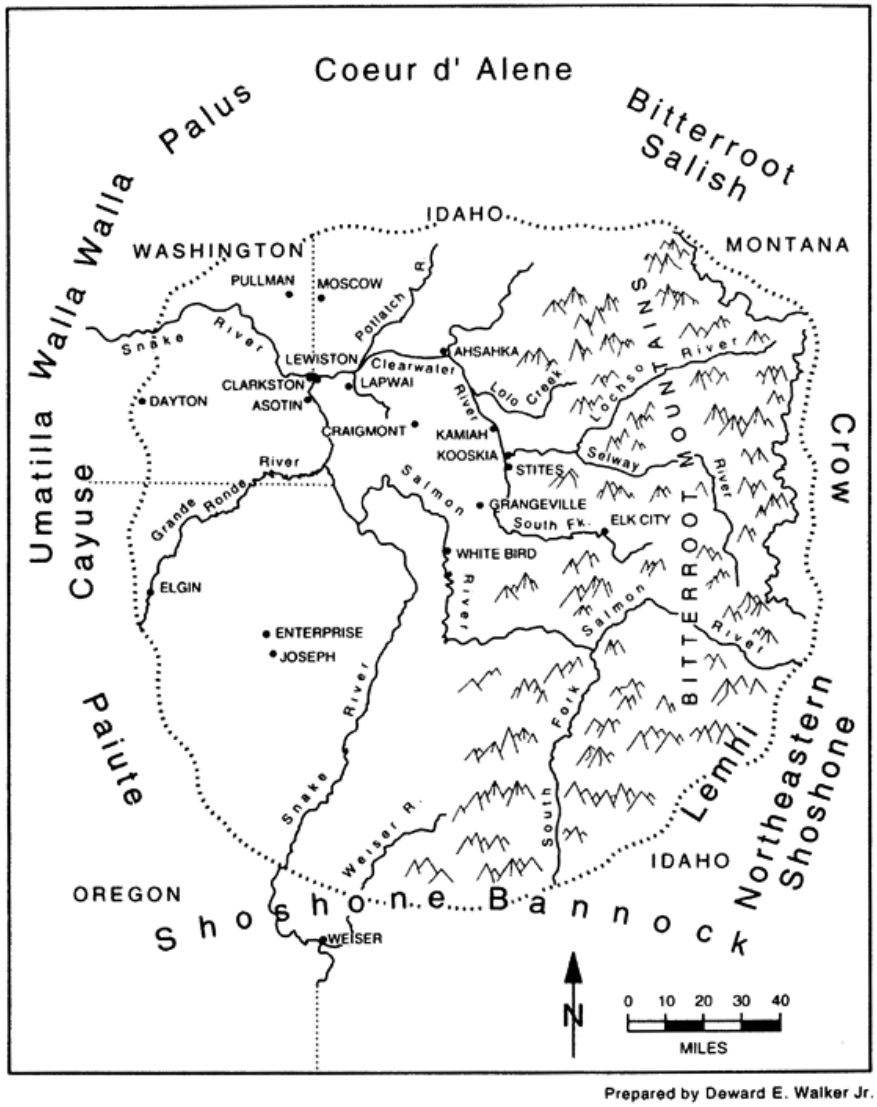
Dane County, Wisconsin, JenEhr Farm:

0.708456
0.708751
0.709324
0.709372
0.709408
0.709681
0.709703
0.709873
0.709877
0.709882
0.709957
0.710054
0.710299
0.714263
0.724807
0.734563


Bean
Grain
3.00
Starchy Veg.
Leafy Veg.
Units
2.00
Dairy
Fruit
Meat
Maize
1.00
Log(Ca)

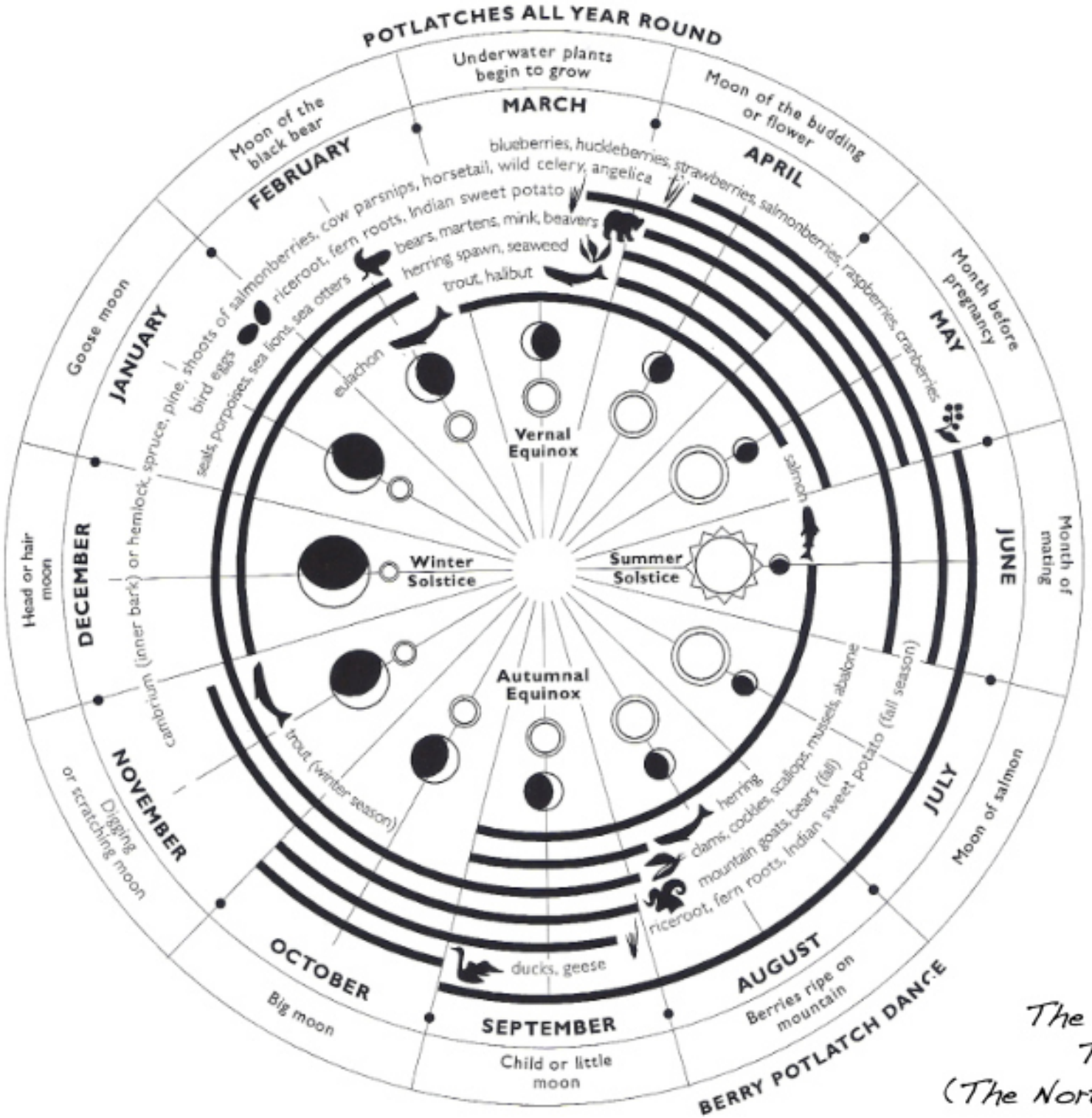

Kale and Brown Potatoes
0.7150
0.7140
0.7130
0.7120
0.7110
0.7100
0.7090
Sr-87/86
0
20
40
60
80
100
120
% Kale in diet



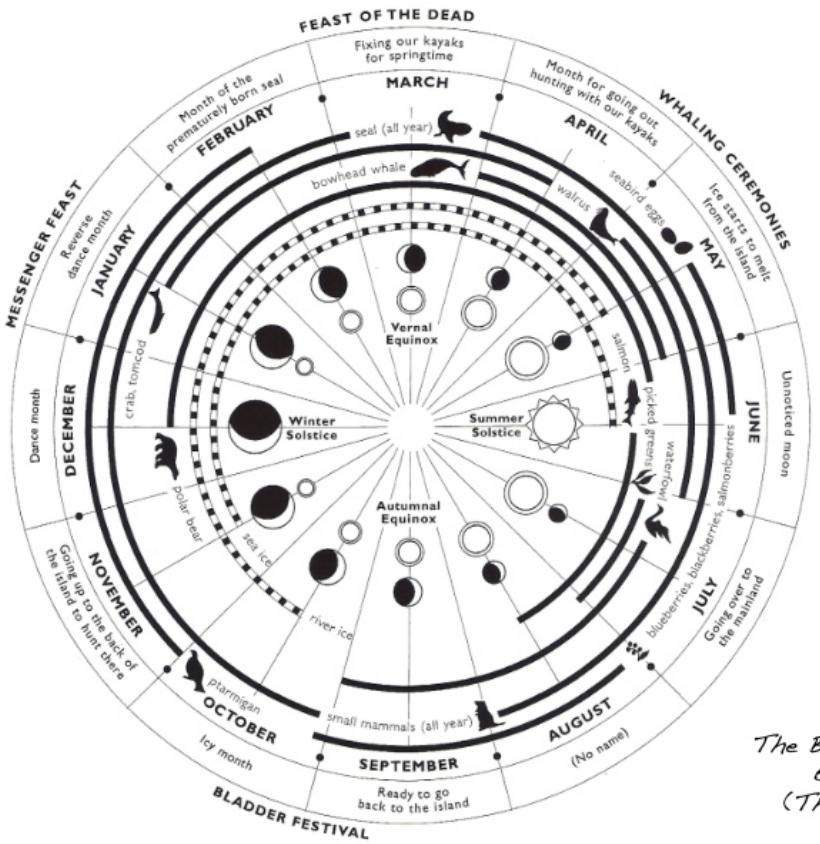


Prepared by Deward E. Walker Jr.

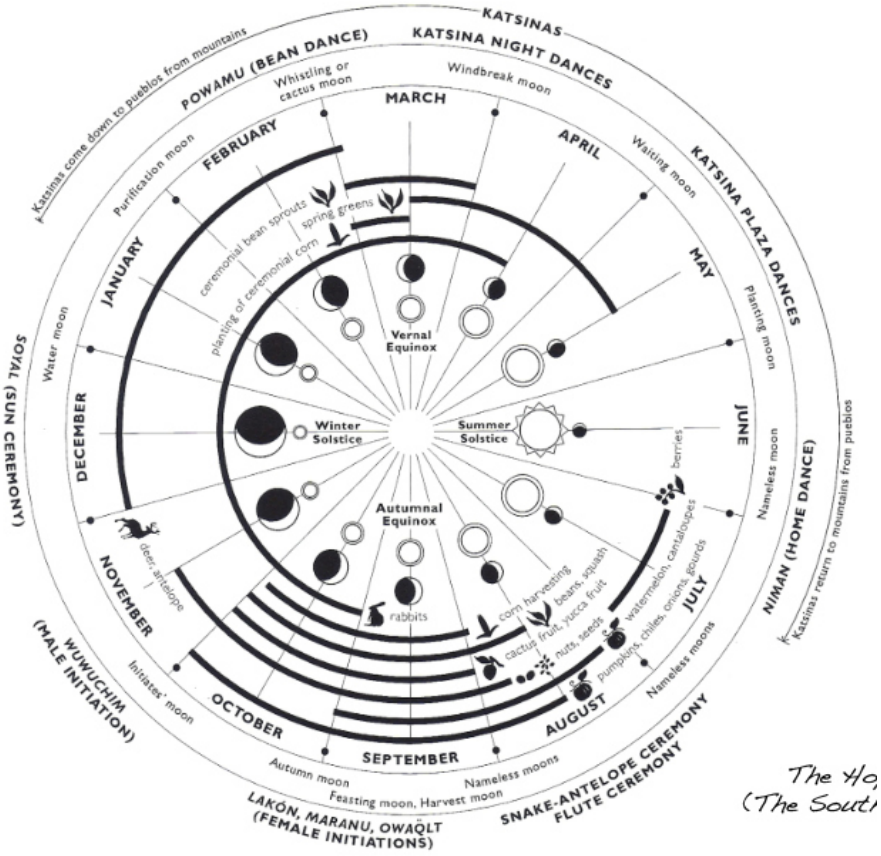
The Nez Perce Homeland and Their Neighbors



The Mainland Tlingit
(The Northwest Coast



The Bering Strait Eskimo (The Arctic)



The Ho
(The South


LO BUENO CUESTA
$4.00
KILO
LO BUENO CUESTA
$5.00
KILO


MARINATED
CALAMARI
GREEK STYLE
MARINATED
PICKLED
OCTOPUS
OLIVE LOVERS
GREEK
BLONDE
GREEK
KALAMATA

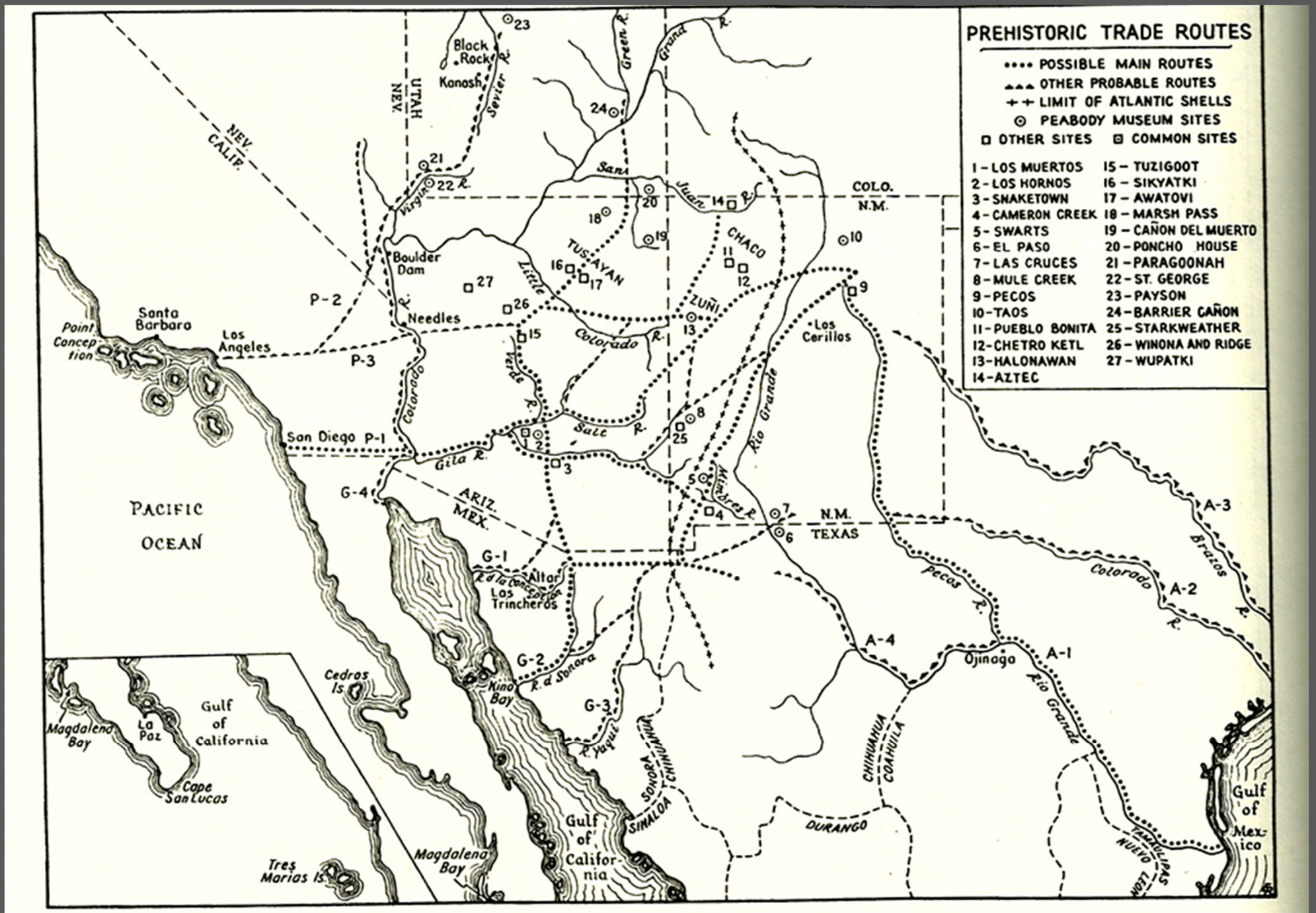
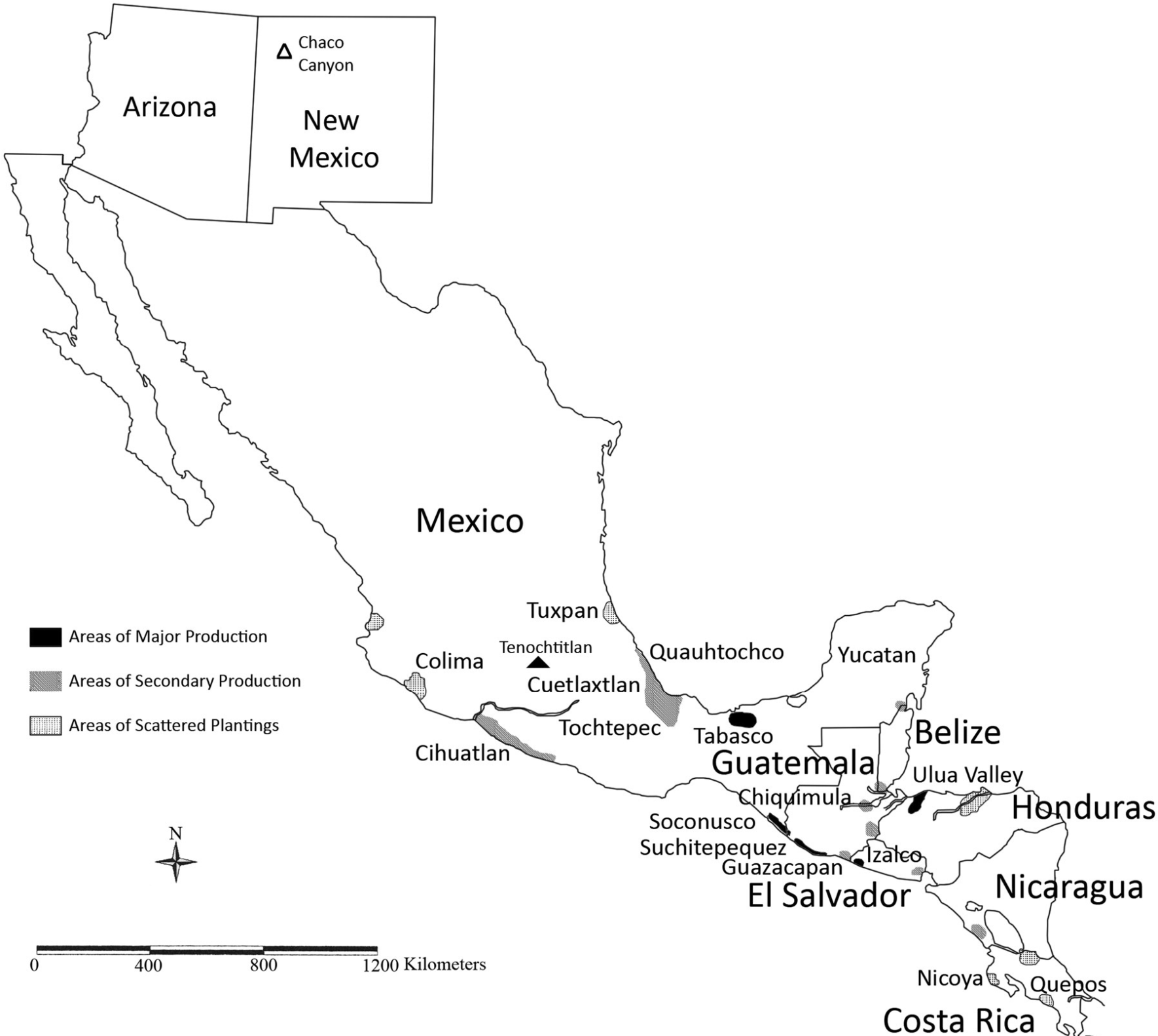
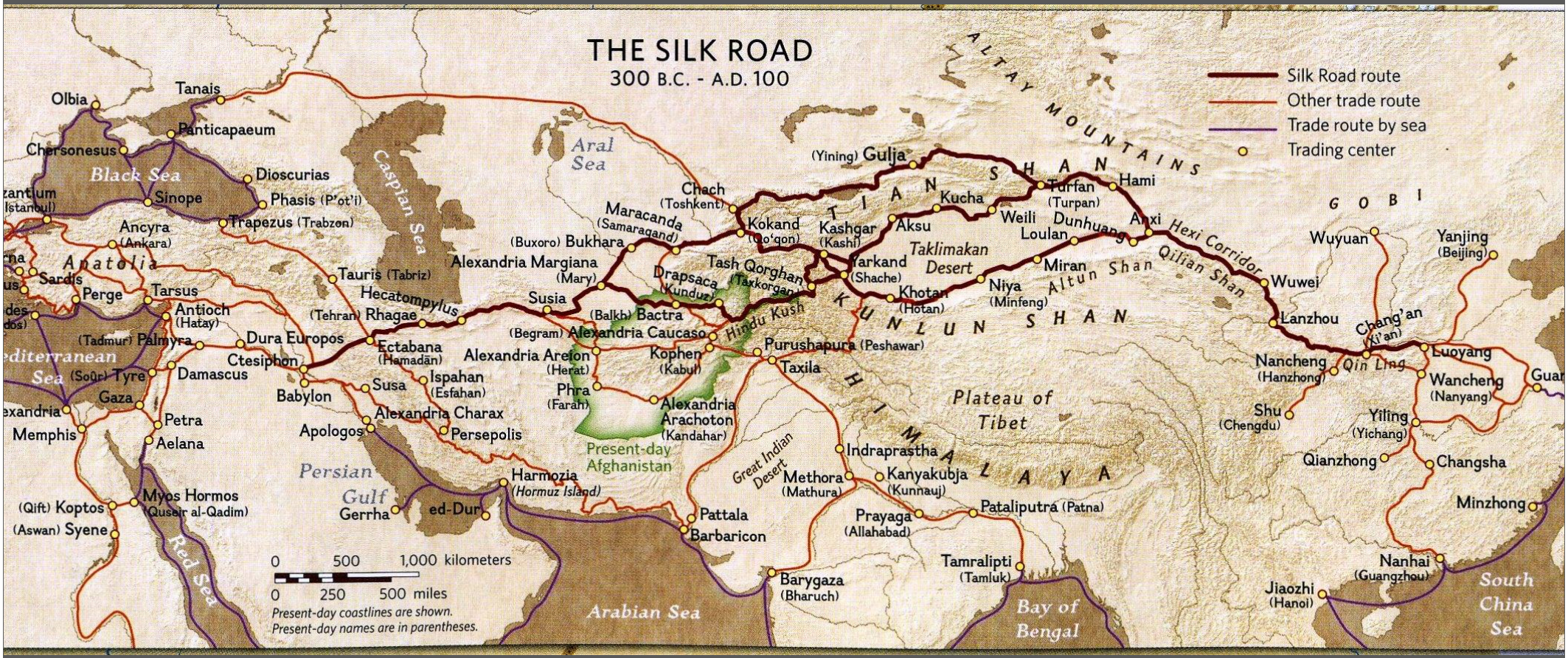


Figure 10.2. Tower's (1945) map of long-distance shell exchange routes.

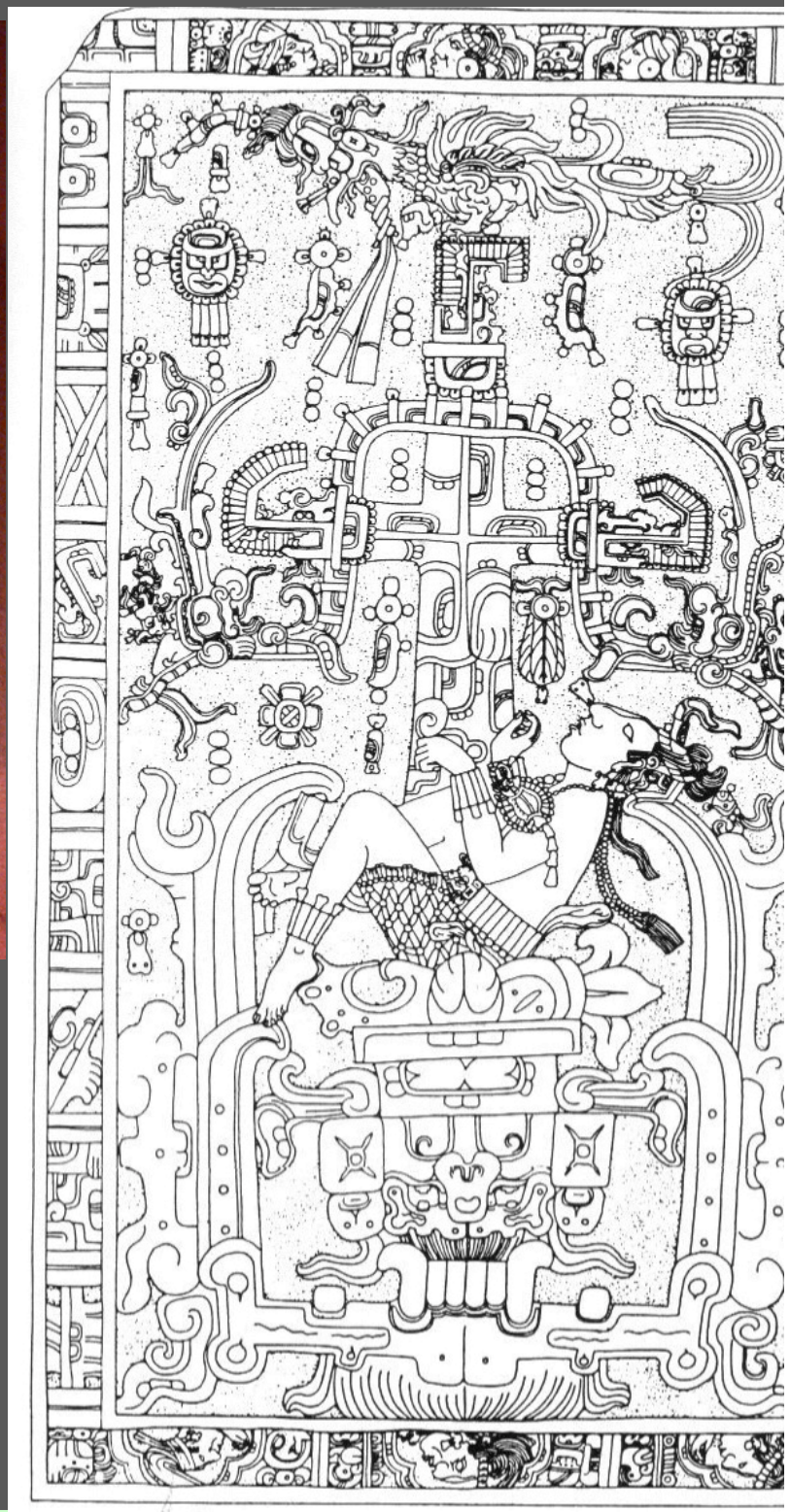

Chaco Canyon
Arizona
New Mexico
Mexico
Areas of Major Production
Areas of Secondary Production
Areas of Scattered Plantings
Tuxpan
Tenochtitlan
Colima
Quauhtochco
Yucatan
Cuetlaxtlan
Tochtepec
Tabasco
Belize
Cihuatlan
Guatemala
Ulua Valley
Chiquimula
Honduras
Soconusco
Suchitepequez
Izalco
Guazacapan
El Salvador
Nicaragua
N
0
400
800
1200 Kilometers
Nicoya
Quepos
Costa Rica

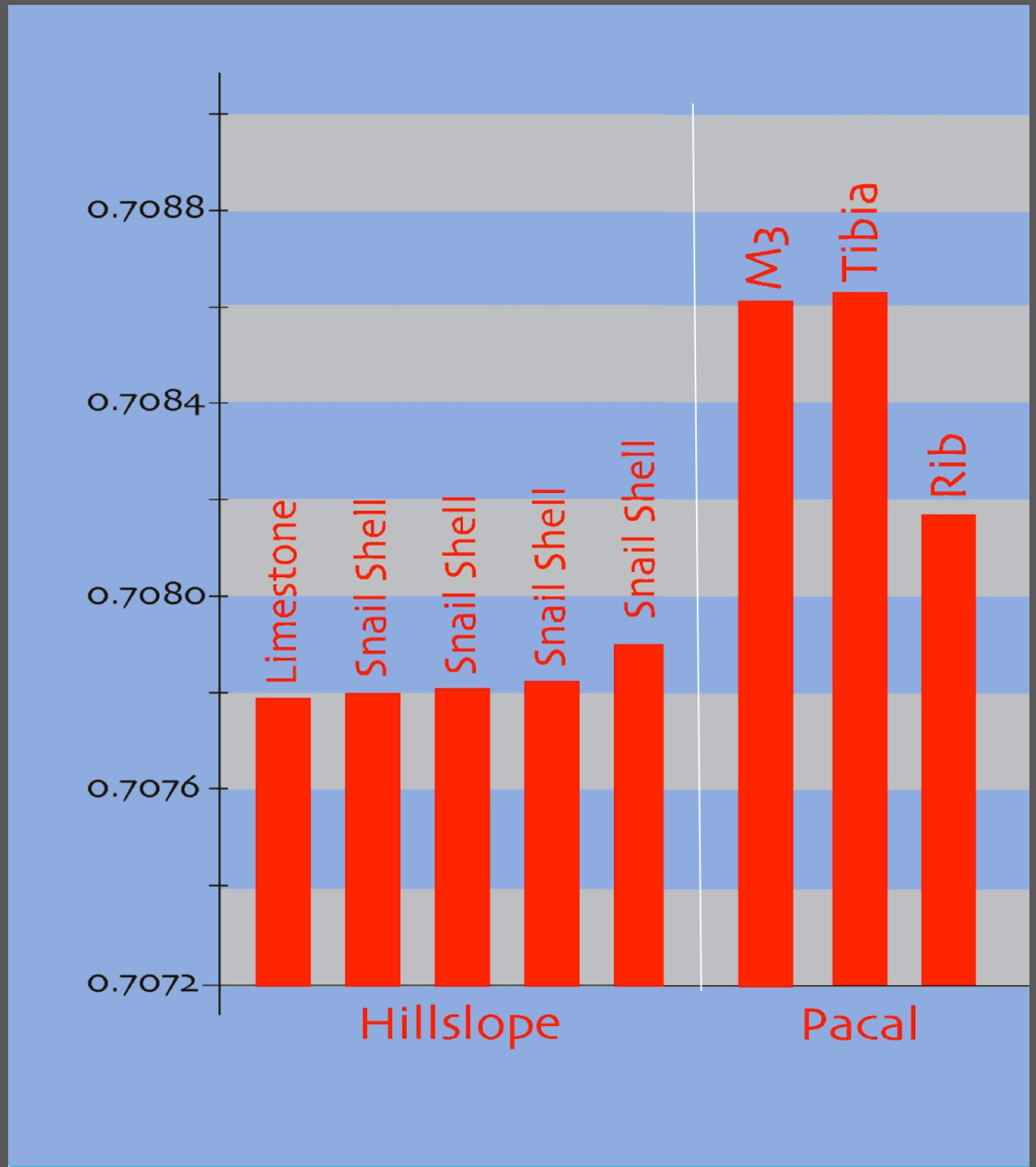

THE SILK ROAD
300 B.C. - A.D. 100
Silk Road route
Other trade route
Trade route by sea
Trading center
Olbia
Tanais
Panticapaeum
Chersonesus
Black Sea
Dioscurias
Sinope
Phasis (P'ot'i)
Trapezus (Trabzon)
Ancyra (Ankara)
Anatolia
Sardis
Perge
Tarsus
Antioch (Hatay)
(Tadmur) Palmyra
Dura Europos
Ctesiphon
Damascus
Tyre
Gaza
Petra
Aelana
Memphis
Myos Hormos (Quseir al-Qadim)
(Qift) Koptos
(Aswan) Syene
Red Sea
Caspian Sea
Aral Sea
Tauris (Tabriz)
Hecatompylus
(Tehran) Rhagae
Ectabana (Hamadān)
Babylon
Susa
Ispahan (Esfahan)
Alexandria Charax
Apologos
Persepolis
Persian Gulf
Gerrha
ed-Dur
Harmozia (Hormuz Island)
Alexandria Margiana (Mary)
(Buxoro) Bukhara
Maracanda (Samaragand)
Chach (Toshkent)
Susia
(Balkh) Bactra
(Begram) Alexandria Caucaso
Alexandria Areion (Herat)
Phra (Farah)
Alexandria Arachoton (Kandahar)
Present-day Afghanistan
Drapsaca (Kunduz)
Kophen (Kabul)
Hindu Kush
Tash Qorghan (Taxkorgan)
Pattala
Barbaricon
Arabian Sea
Barygaza (Bharuch)
Purushapura (Peshawar)
Taxila
Great Indian Desert
Indraprastha
Methora (Mathura)
Prayaga (Allahabad)
Tamralipti (Tamluk)
Bay of Bengal
Plateau of Tibet
HIMALAYA
Kanyakubja (Kunnauj)
Pataliputra (Patna)
(Yining) Gulja
Kokand (Qo'qon)
Kashgar (Kashi)
Yarkand (Shache)
Khotan (Hotan)
Aksu
Kucha
Turfan (Turpan)
Hami
Weili
Loulan
Dunhuang
Taklimakan Desert
Niya (Minfeng)
Miran
Altun Shan
Anxi
Hexi Corridor
Qilian Shan
Wuwei
Lanzhou
Chang'an (Xi'an)
Nancheng (Hanzhong)
Qin Ling
Shu (Chengdu)
Luoyang
Wancheng (Nanyang)
Yiling (Yichang)
Changsha
Qianzhong
Minzhong
Nanhai (Guangzhou)
Jiaozhi (Hanoi)
South China Sea
Wuyuan
Yanjing (Beijing)
ALTAY MOUNTAINS
TIAN SHAN
KUNLUN SHAN
GOBI
0 500 1,000 kilometers
0 250 500 miles
Present-day coastlines are shown.
Present-day names are in parentheses.

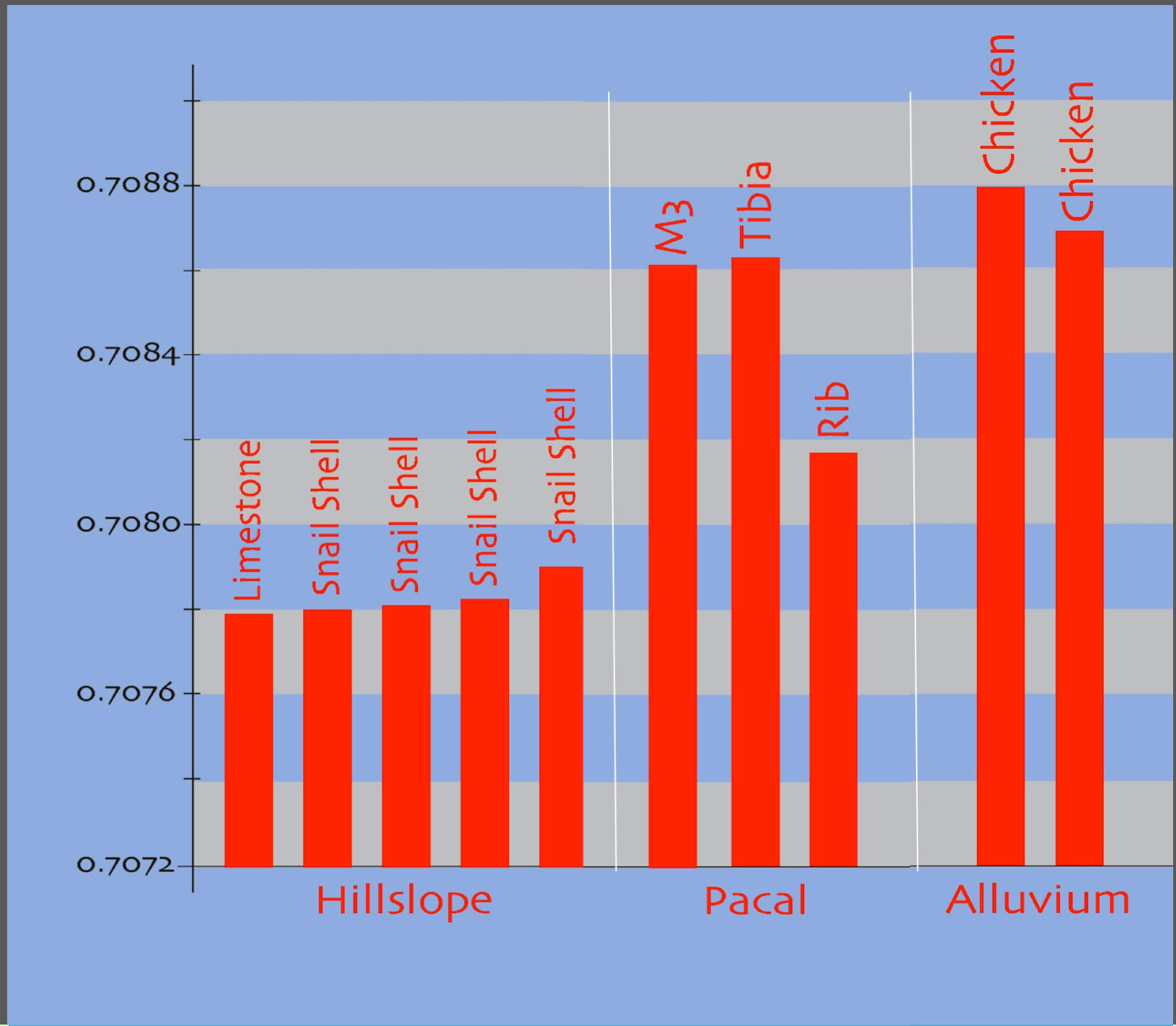
Palenque


Dzibulchaltun
Mayapan
Sayil
Comalcalco
Calakmul
Mexico
Tikal
Palenque
Caracol
Belize
Guatemala
Honduras
Copan
El Salvador

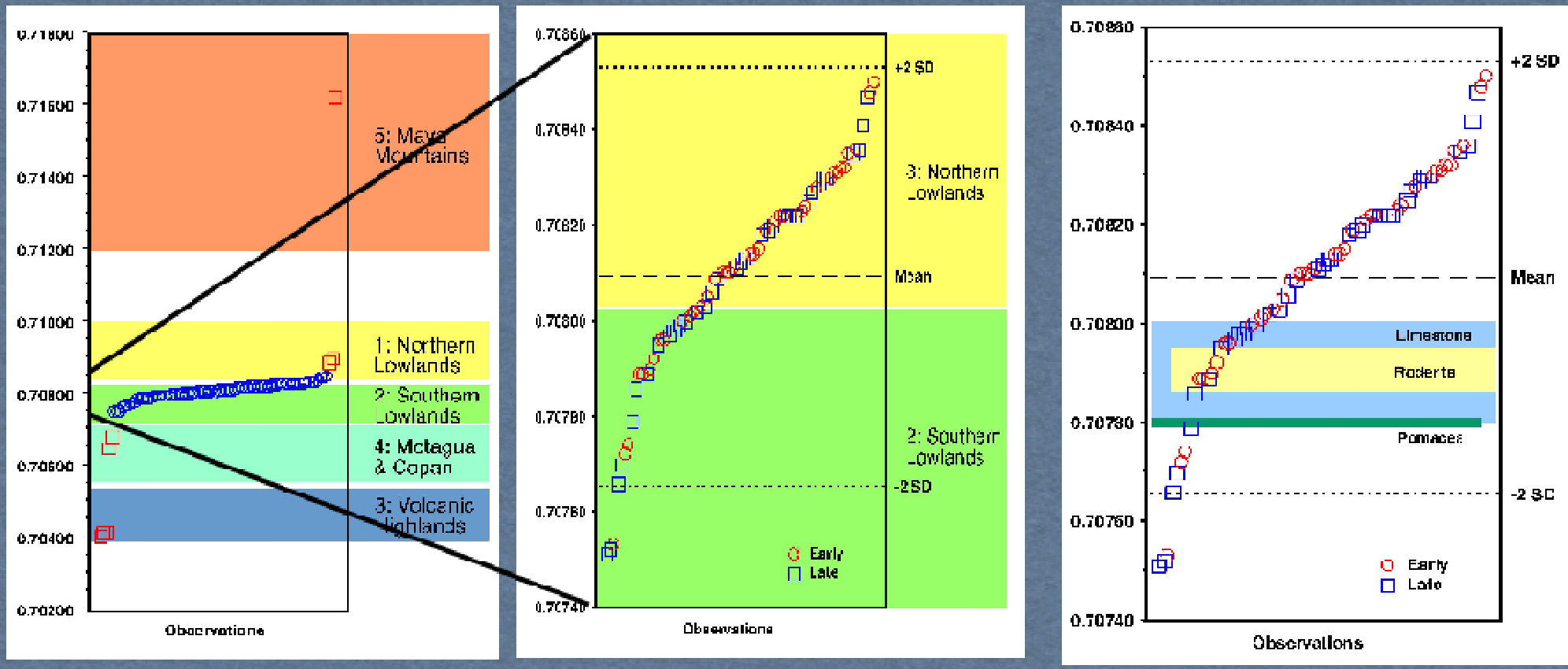
K'inich Janaab' Pakal



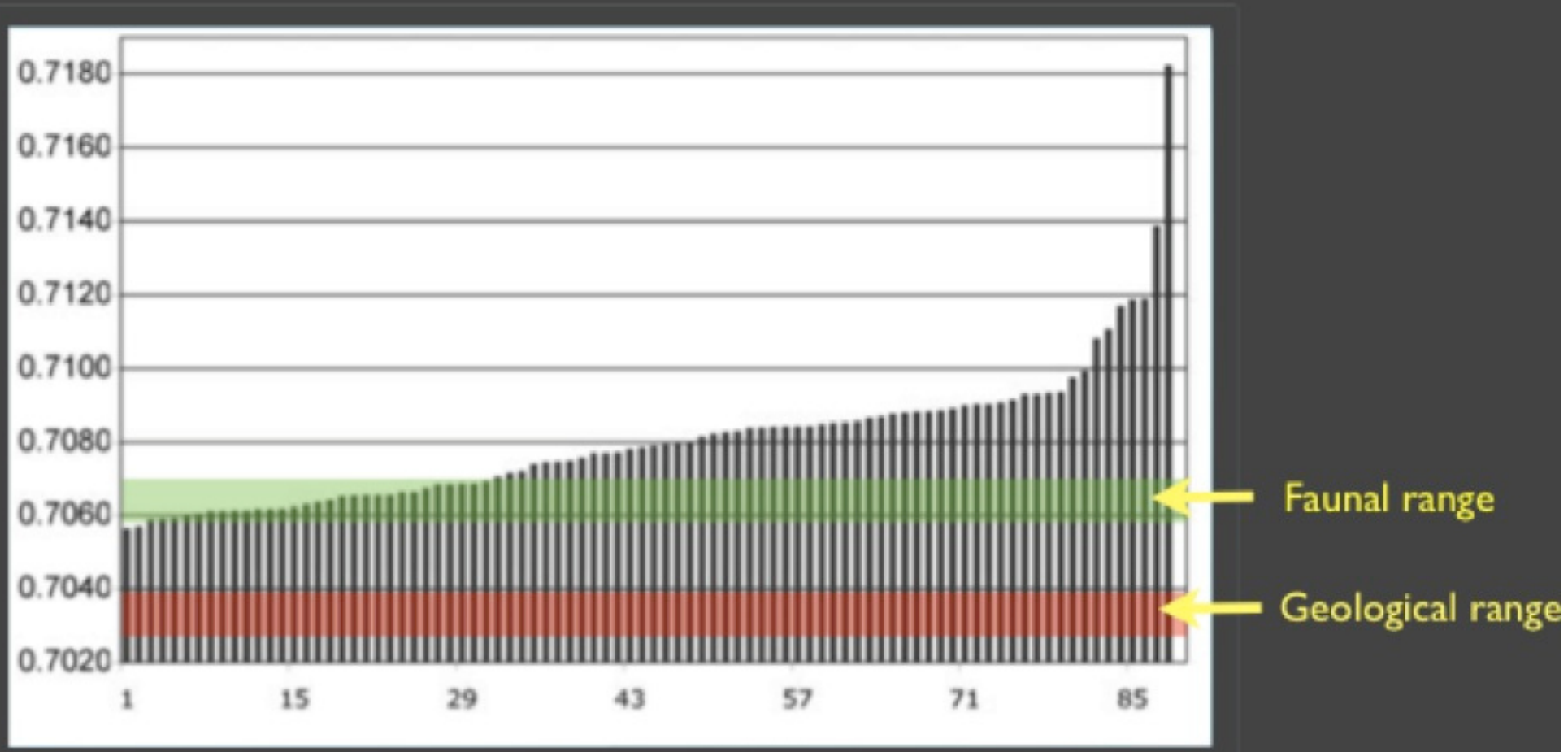

0.7088
0.7084
0.7080
0.7076
0.7072
Limestone
Snail Shell
Snail Shell
Snail Shell
Snail Shell
M3
Tibia
Rib
Hillslope
Pacal


0.7088
0.7084
0.7080
0.7076
0.7072
Limestone
Snail Shell
Snail Shell
Snail Shell
Snail Shell
M3
Tibia
Rib
Chicken
Chicken
Hillslope
Pacal
Alluvium

Tikal



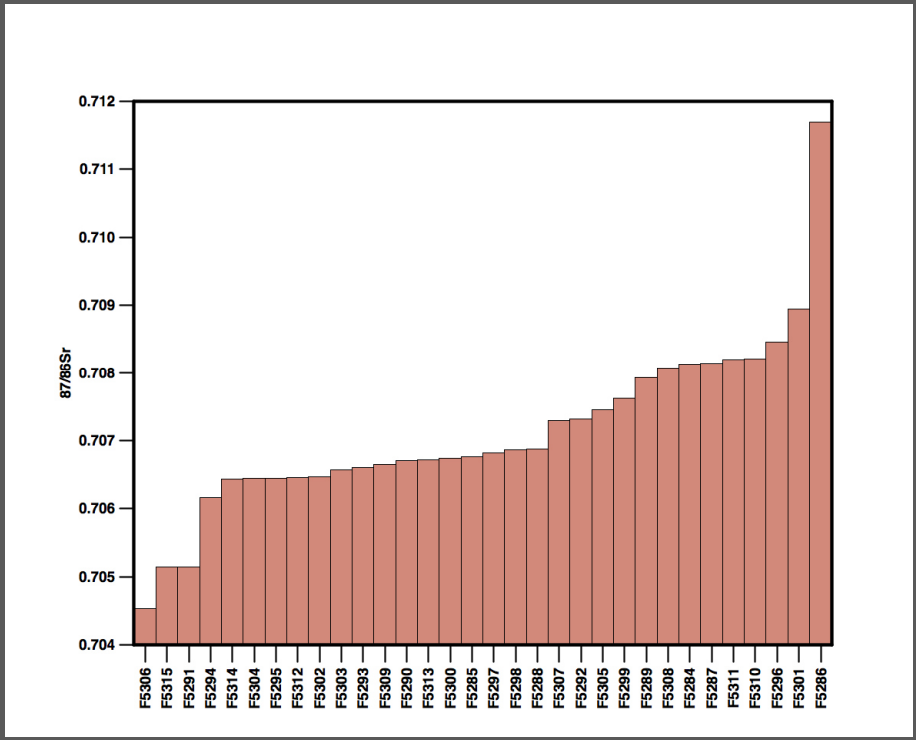
Wright, L. E. 2005
Identifying immigrants to Tikal, Guatemala: defining local variability in strontium isotope ratios of human tooth enamel. Journal of Archaeological Science 32: 555-566.



Ranked bar chart of human dental enamel from cemeteries in Iceland, compared to faunal and geological ranges

Price, T.D., and Gestsdottir, H., 2006. The First Settlers of Iceland: An Isotopic Approach to Colonization. Antiquity 80:130-144.

Copan


87/86Sr
0.712
0.711
0.710
0.709
0.708
0.707
0.706
0.705
0.704
F5306
F5315
F5291
F5294
F5314
F5304
F5295
F5312
F5302
F5303
F5293
F5309
F5290
F5313
F5300
F5285
F5297
F5298
F5288
F5307
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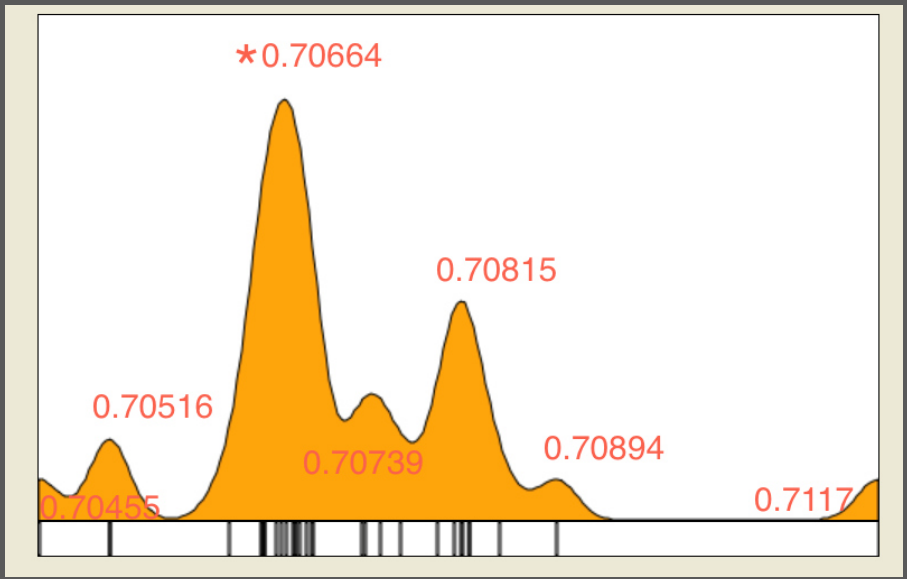
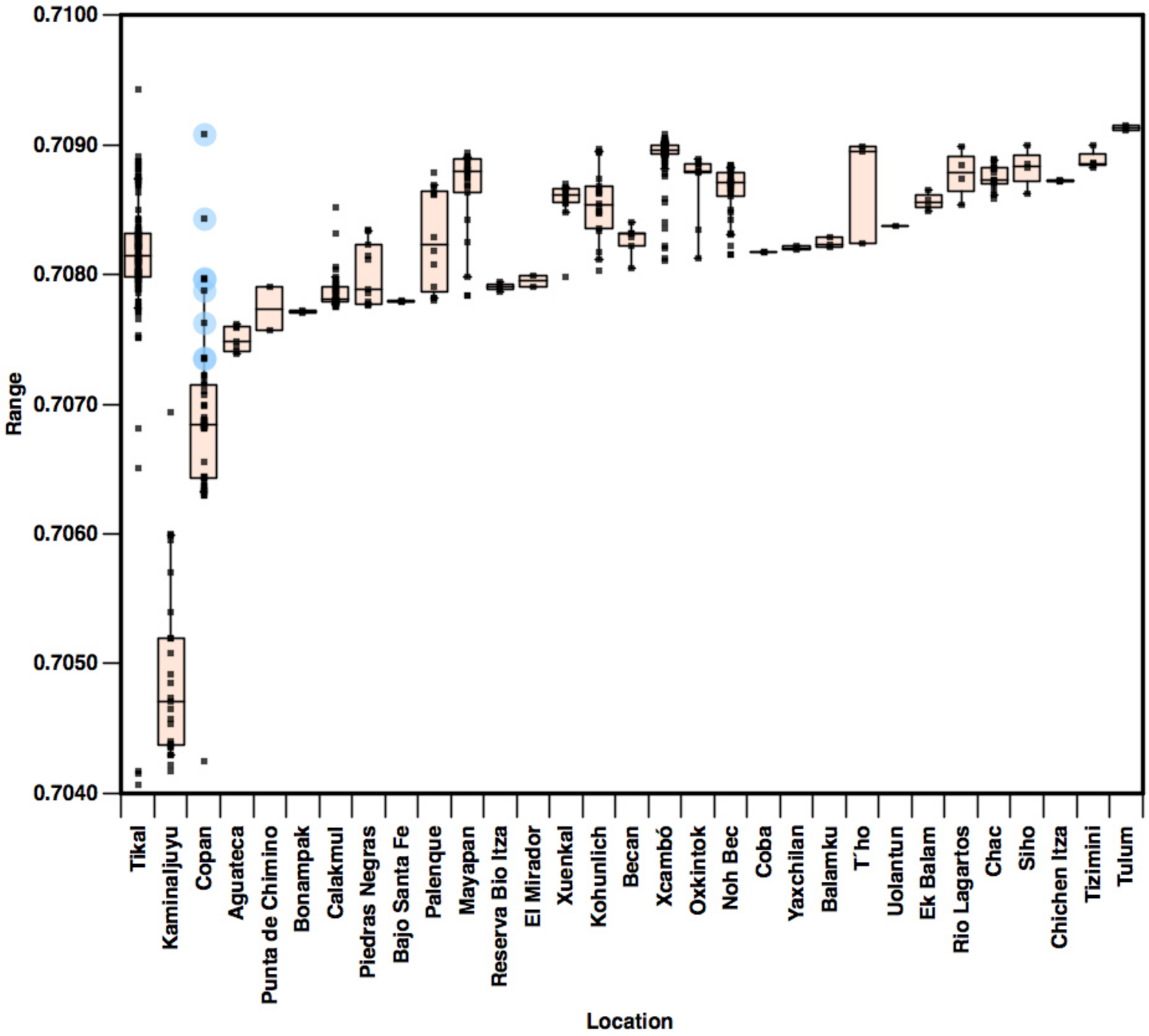
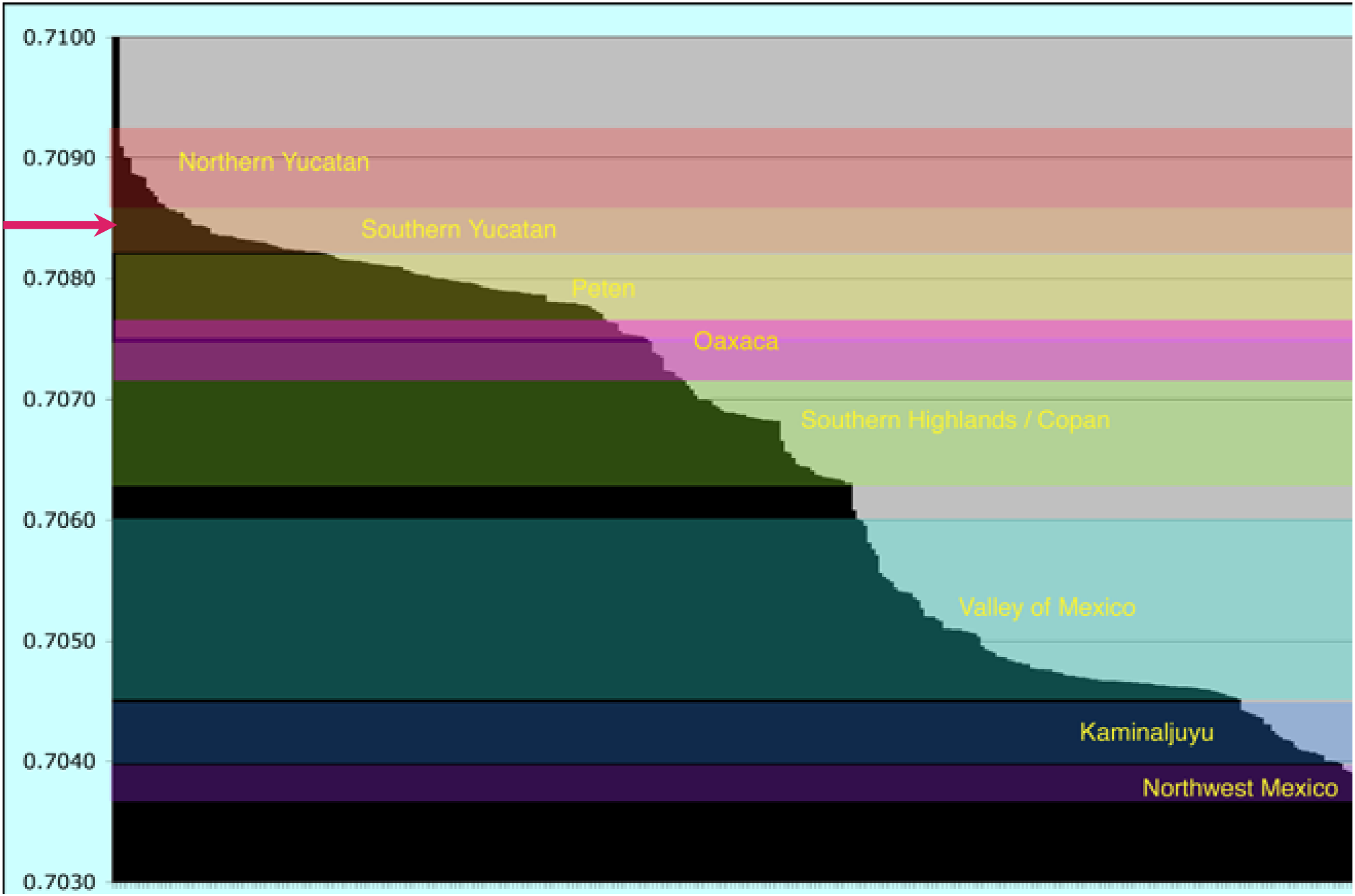
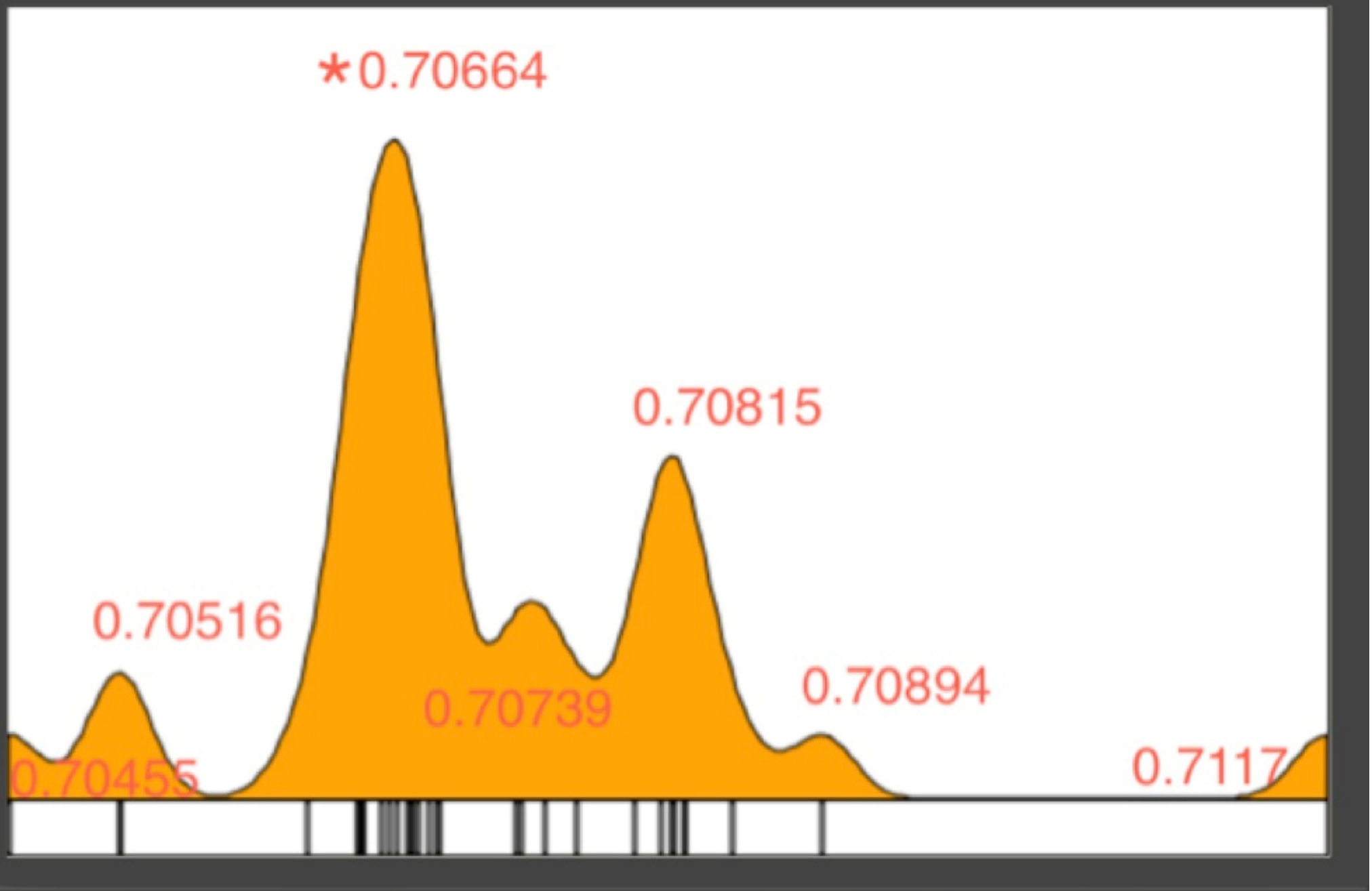
F5287
F5311
F5310
F5296
F5301
F5286


*0.70664
0.70815
0.70516
0.70739
0.70894
0.70455
0.7117


Santa Luisa .7077
N Yucatan .7089
Xcambo .7088
Tizimin .7089
Dzibichaltun .7089
Ek' Balam .7086
Chichen Itzá .7087
Oxkintok .7088
Cobá .7082
Siho .7087
Chac .7088
Mayapán .7088
Tulum .7080
El Tajin .7077
Chalahuites .7060
Limoncito .7061
Campeche .7082
L. Chichancunab .7078
Cerro de las Mesas .7076
Chingu .7060
Zumpango .7047
Tula .7065
Chapantongo .7052
Champot'on .7083
Chuatitlan .7047
Teotihuacan .7046
Otumba .7046
Cempoala .7079
Tres Zapotes .7042
Balamku .7083
Escárcega .7081
Becán .7082
Chapultepec .7047
Xico .7045
Tlalancaleca .7058
Maltrata .7062
Tlapacoya .7048
Tlaxcala .7052
Cacaxtla .7054
Nohmul .7086
Chalco .7064
Cholula .7067
Matacapan .7036
Comalcalco .7074
Ixtapa .7049
Xochicalco .7064
Tecali .7067
Calakmul .7077
Colha .7082
Chalcatzingo .7047
Las Bocas .7070
La Venta .7081
El Mirador .7079
Buenavista .7084
Tehuacan .7074
San Lorenzo .7083
Palenque .7079
Barton Ramie .7087
Piedras Negras .7080
Tikal .7080
Xunantunich
Etlatango .7072
Tonina .7079
Trinidad .7074
Yaxha .7079
Stann Creek .7127
San Jose Magote .7074
San Cristobal .7076
Yaxchilán .7082
Caracol
Monte Alban .7079
Aguateca .7075
Mitla .7055
Mirador .7072
Seibal .7075
La Zanja .7095
Chiapa de Corzo .7074
Bonampak .7077
Lubaantun .7070
Ejutla .7083
Rio San Pedro .7075
Pijijapa .7076
Izapa .7047
Atitlan .7042
Quirigua .7073
Paso de la Amada .7048
Ojo de Agua .7047
Abaj Takalik .7041
El Chayal .7061
Copan .7069
Kaminaljuyu .7052
Victoria .7059
Cocales .7042
El Baul .7040

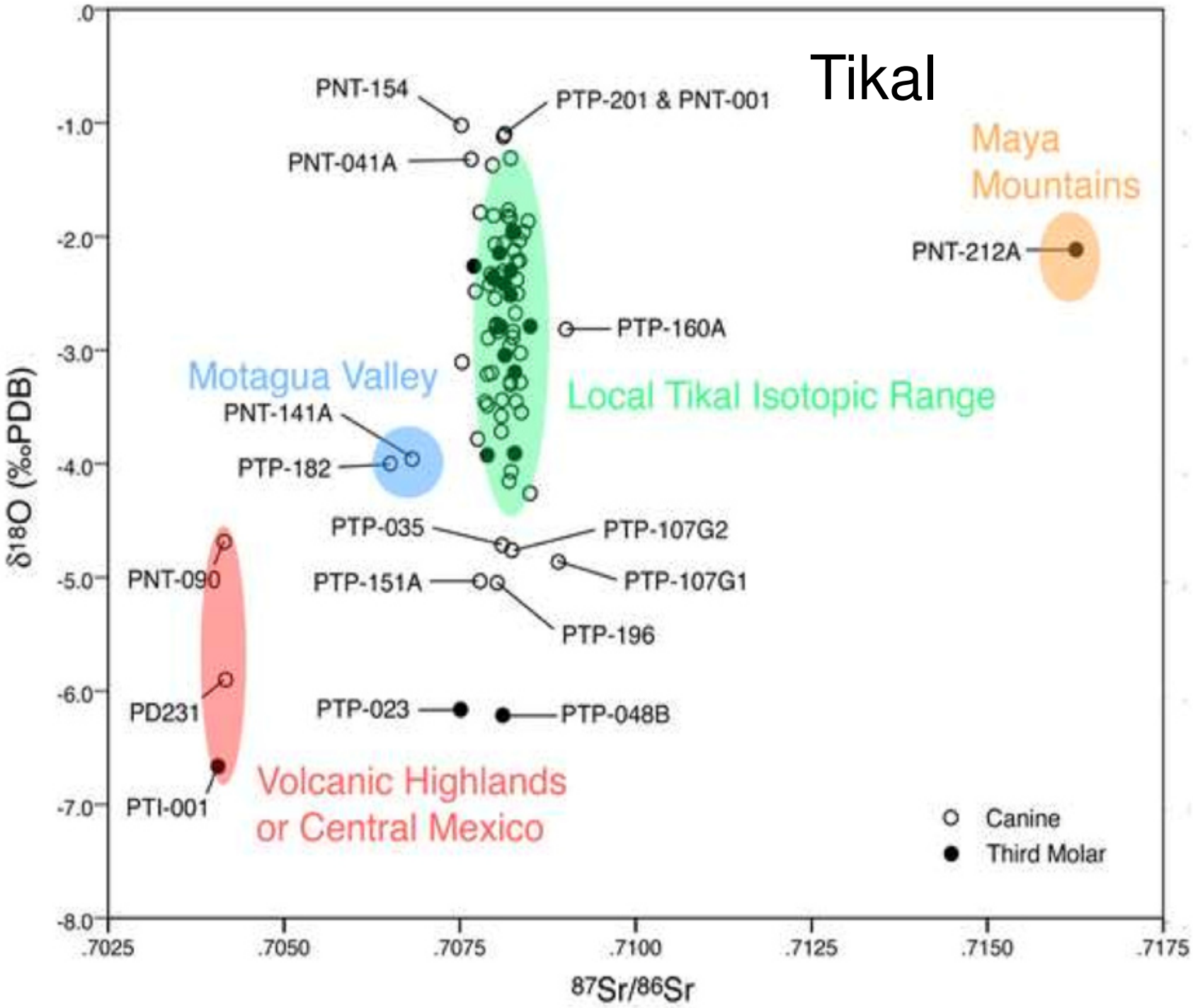

0.7100
0.7090
0.7080
0.7070
0.7060
0.7050
0.7040
Range
Tikal
Kaminaljuyu
Copan
Aguateca
Punta de Chimino
Bonampak
Calakmul
Piedras Negras
Bajo Santa Fe
Palenque
Mayapan
Reserva Bio Itza
El Mirador
Xuenkal
Kohunlich
Becan
Xcambó
Oxkintok
Noh Bec
Coba
Yaxchilan
Balamku
T´ho
Uolantun
Ek Balam
Rio Lagartos
Chac
Siho
Chichen Itza
Tizimini
Tulum
Location


0.7100
0.7090
0.7080
0.7070
0.7060
0.7050
0.7040
0.7030
Northern Yucatan
Southern Yucatan
Peten
Oaxaca
Southern Highlands / Copan
Valley of Mexico
Kaminaljuyu
Northwest Mexico



Kernel density estimate* of data from Copan, Honduras, clearly revealing multiple modes .

*using an optimization algorithm from **Shimazaki** H. **and Shinomoto** S., Kernel **Bandwidth** Optimization in Spike Rate Estimation. Journal of Computational Neuroscience (**2010**) Vol. 29


Tikal
PNT-154
PTP-201 & PNT-001
PNT-041A
Maya Mountains
PNT-212A
PTP-160A
Motagua Valley
Local Tikal Isotopic Range
PNT-141A
PTP-182
PTP-035
PTP-107G2
PTP-107G1
PNT-090
PTP-151A
PTP-196
PD231
PTP-023
PTP-048B
PTI-001
Volcanic Highlands or Central Mexico
Canine
Third Molar
δ18O (‰PDB)
87Sr/86Sr
.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
-7.0
-8.0
.7025
.7050
.7075
.7100
.7125
.7150
.7175

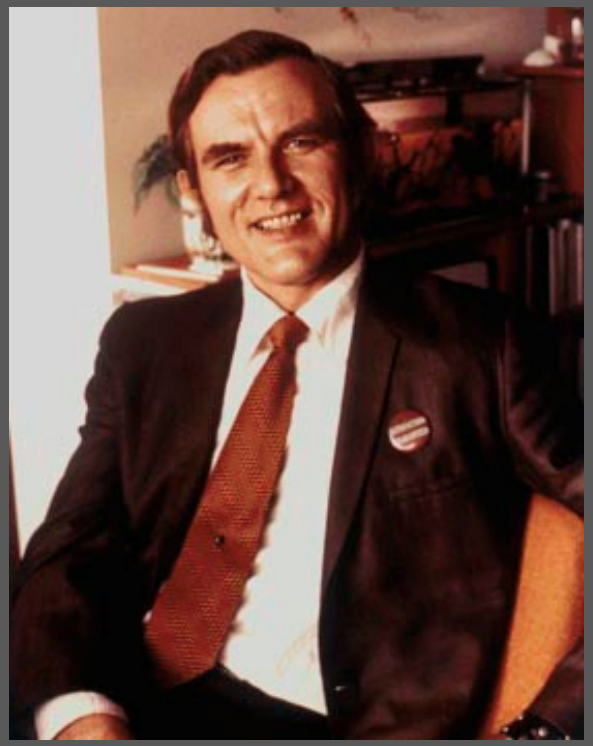
Jonathon E. Ericson
1942 -2009

Professor of Environmental Health Science and Policy
UC Irvine

J. E. Ericson, H. Shirahata, and C. C. Patterson 1975
Skeletal concentrations of lead in ancient Peruvians
New England Journal of Medicine 300:949-51.

J. E. Ericson 1985
Strontium isotope characterization in the study of prehistoric human ecology
Journal of Human Evolution 14: 503-514

Ericson (1985) stated explicitly that “There is no "magic circle" (now called an “Isoscape”) of containment that can be drawn around any group without a high degree of uncertainty.” His primary proposal was to use human strontium isotope data, empirically, to assess human dietary catchment zones, including the consumption of marine resources.



Harold W. Krueger 1935-1997

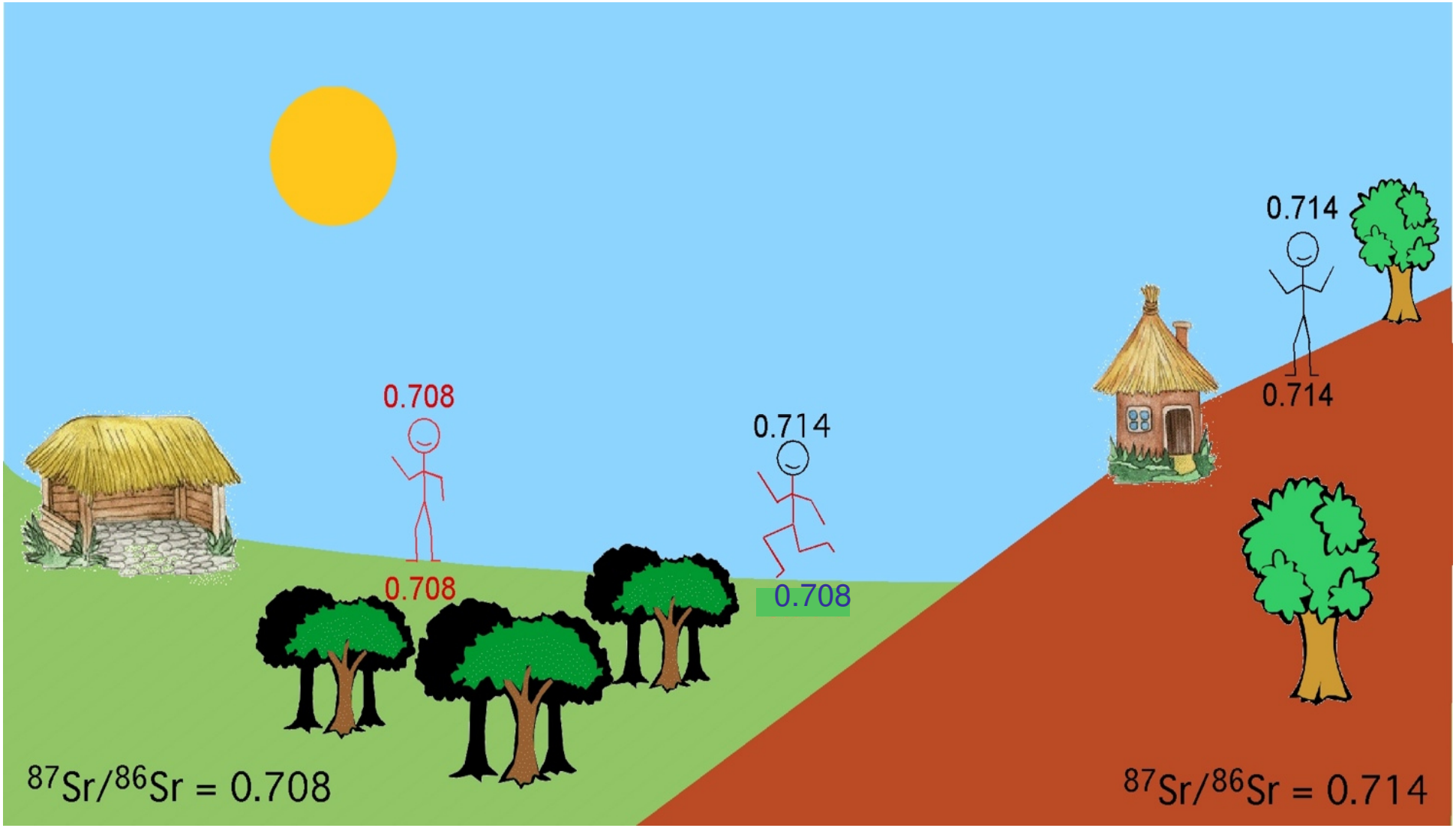
Geochron Laboratories of Cambridge, Massachusetts

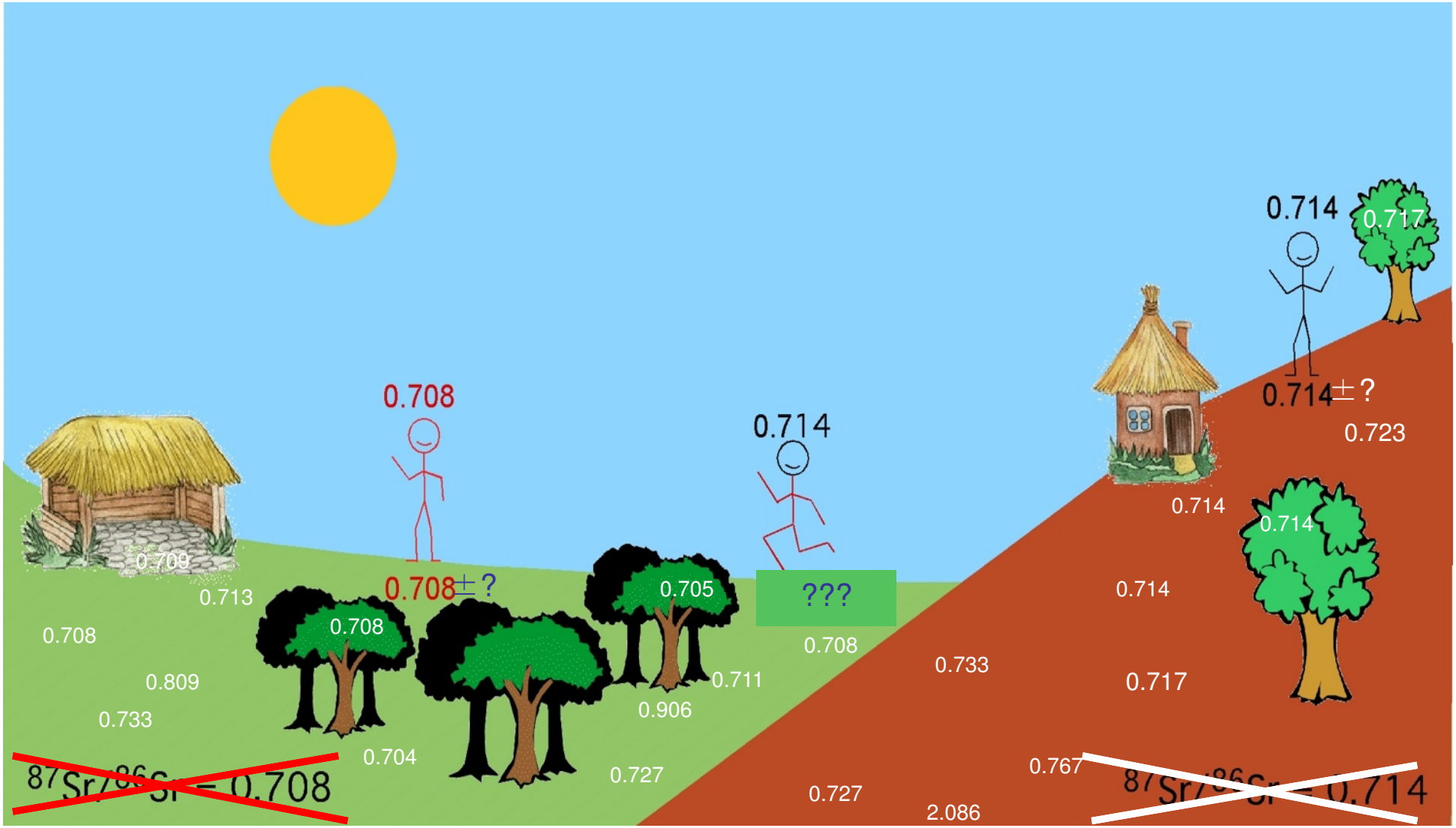
Sr Isotopes and Sr/Ca in Bone
Poster paper presented at Biomineralization Conference, Airlie House, Warrenton, VA.
April 14, 1985

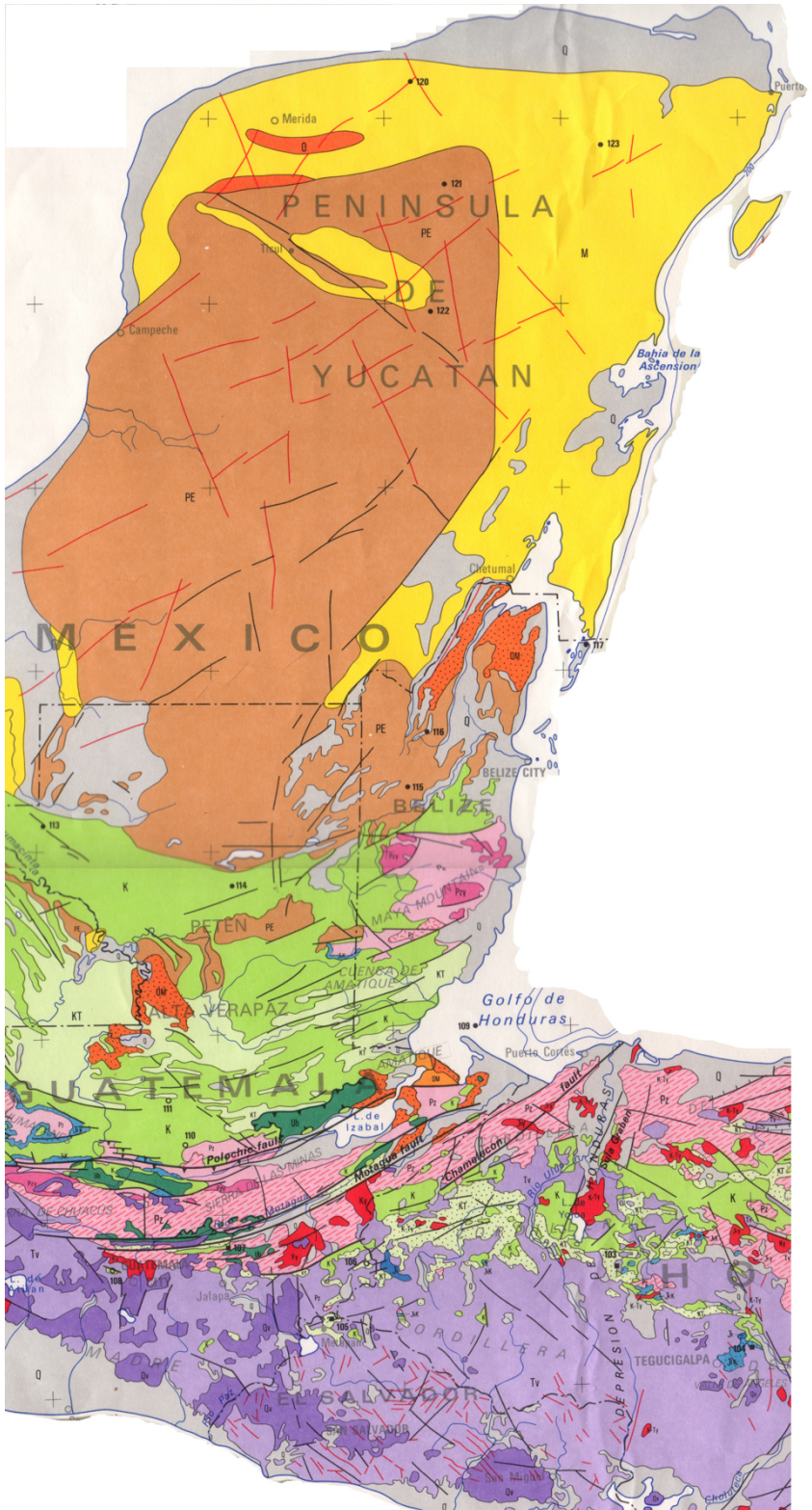
"the generations-old community of scientific minds."

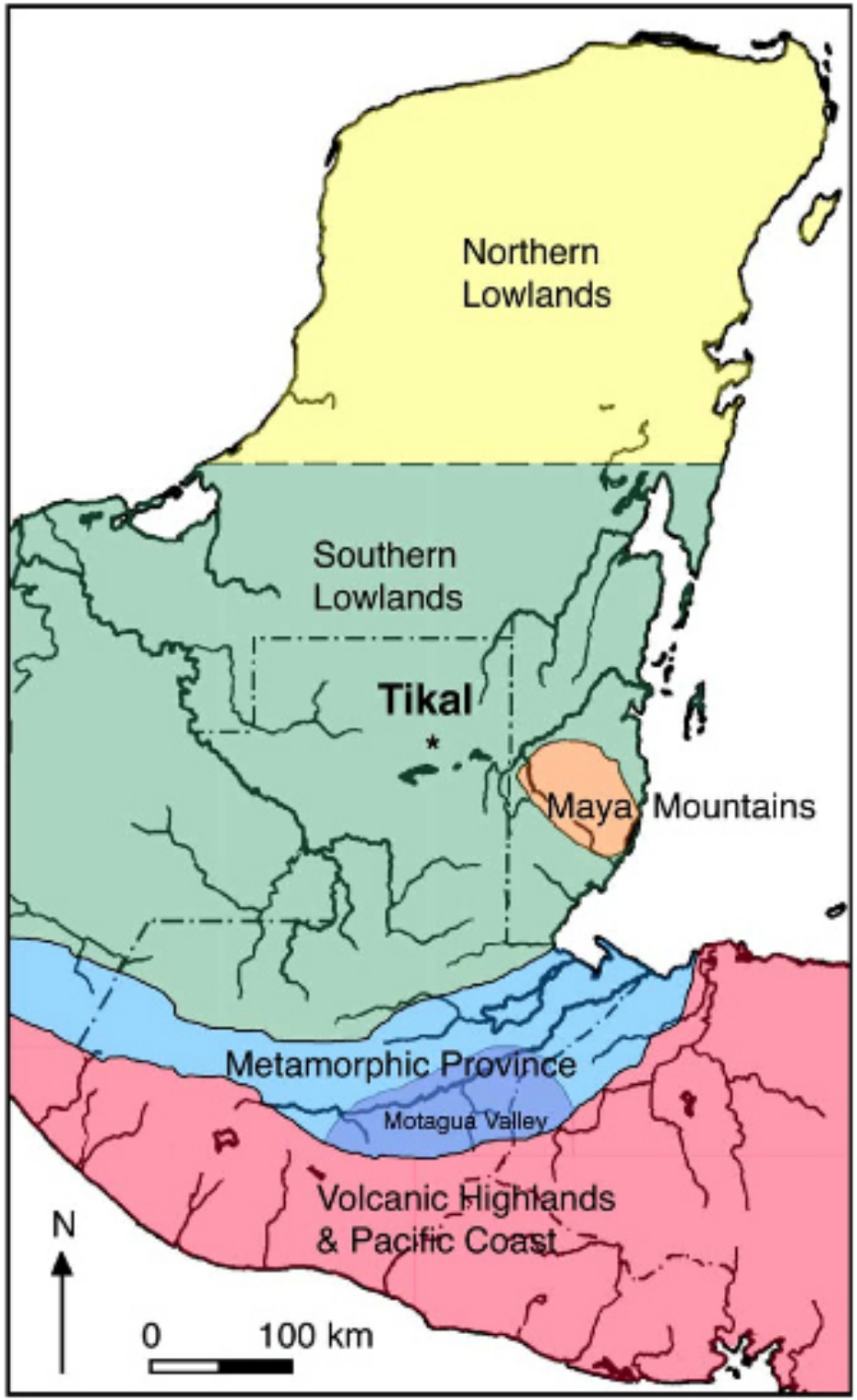
Clair Cameron Patterson
1922 - 1995

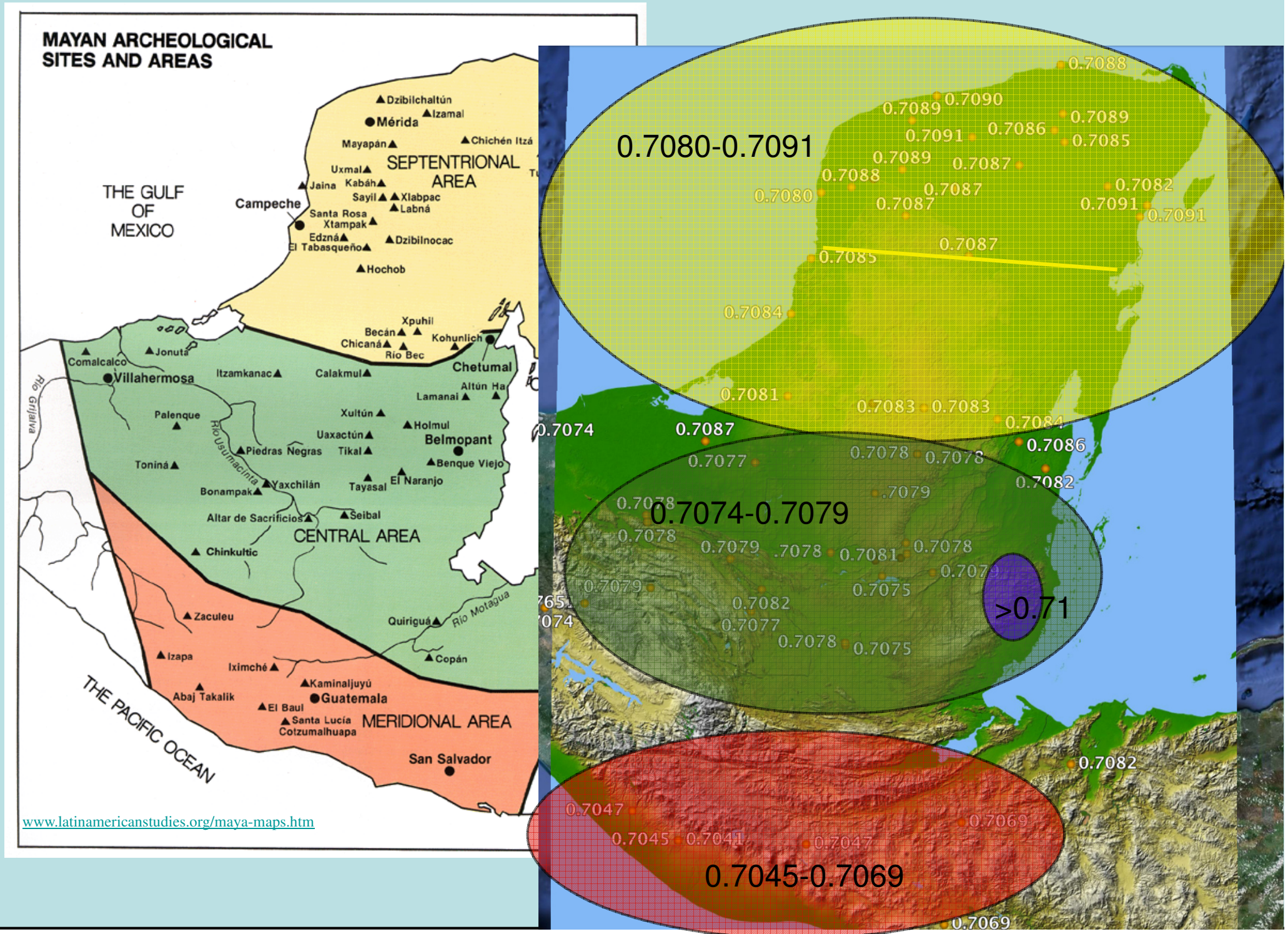
Geological and Planetary Sciences at the California Institute of Technology

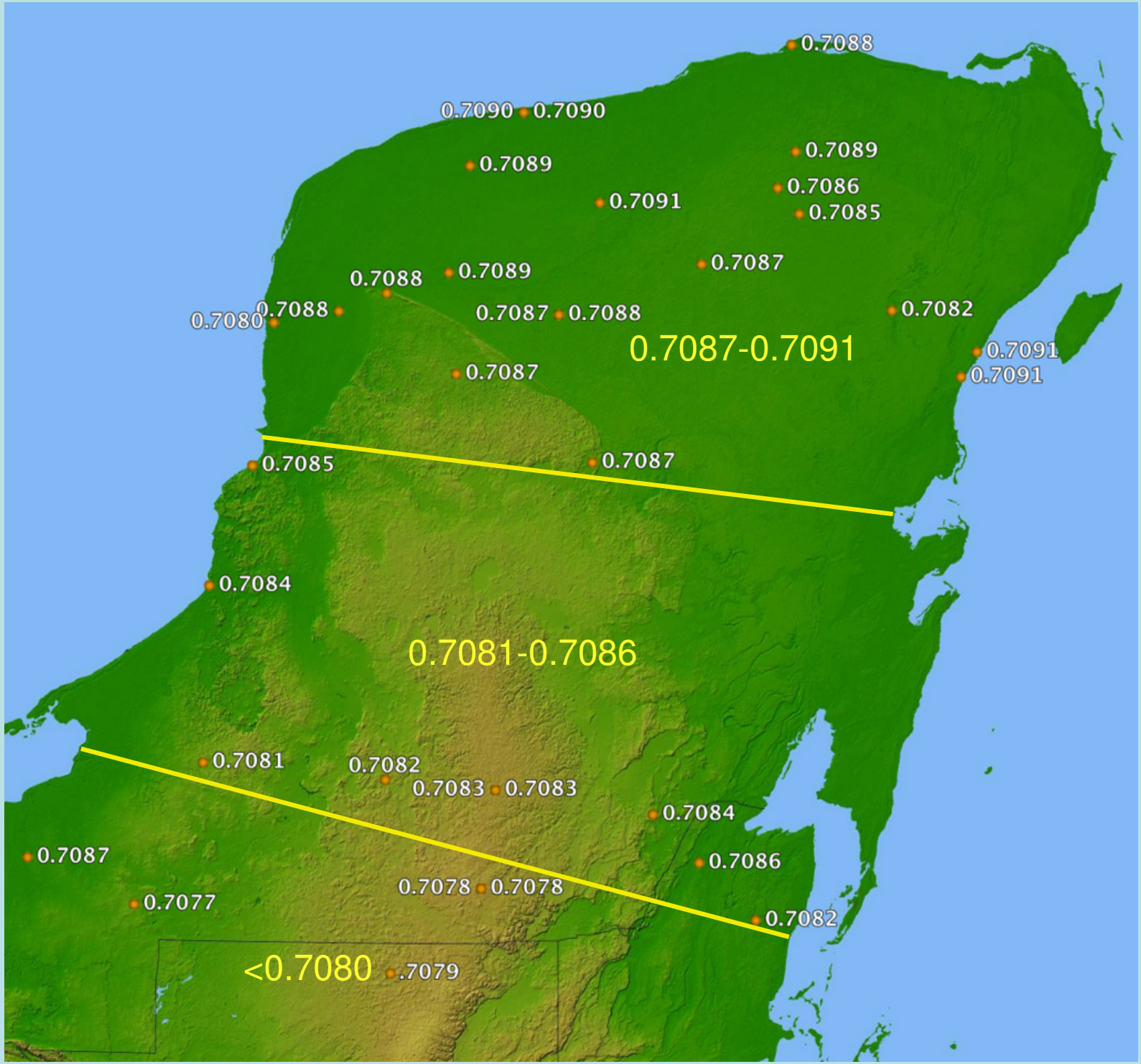

0.714
0.708
0.714
0.708
0.708
$^{87}Sr/^{86}Sr$ = 0.708
$^{87}Sr/^{86}Sr$ = 0.714


0.714
0.717
0.708
0.714±?
0.723
0.714
0.714
0.709
0.713
0.708±?
0.705
???
0.714
0.708
0.708
0.733
0.809
0.711
0.717
0.733
0.906
0.704
0.727
0.767
0.727
2.086
87Sr/86Sr = 0.708
87Sr/86Sr = 0.714


PENINSULA
DE
YUCATAN
MEXICO
BELIZE
PETEN
GUATEMALA
Merida
Campeche
Chetumal
BELIZE CITY
Golfo de Honduras
Puerto Cortes
TEGUCIGALPA
EL SALVADOR
SAN SALVADOR
Polochic fault
Motagua fault
Chamelecon fault
Jalapa


Northern
Lowlands
Southern
Lowlands
Tikal
Maya Mountains
Metamorphic Province
Motagua Valley
Volcanic Highlands
& Pacific Coast
N
0
100 km


MAYAN ARCHEOLOGICAL SITES AND AREAS
THE GULF OF MEXICO
THE PACIFIC OCEAN
SEPTENTRIONAL AREA
CENTRAL AREA
MERIDIONAL AREA
Dzibilchaltún
Izamal
Mérida
Mayapán
Chichén Itzá
Uxmal
Jaina
Kabáh
Campeche
Sayil
Xlabpac
Labná
Santa Rosa Xtampak
Edzná
Dzibilnocac
El Tabasqueño
Hochob
Xpuhil
Becán
Chicaná
Kohunlich
Río Bec
Chetumal
Comalcalco
Villahermosa
Jonuta
Itzamkanac
Calakmul
Altún Ha
Lamanai
Palenque
Xultún
Holmul
Uaxactún
Piedras Negras
Tikal
Belmopant
Benque Viejo
Toniná
Río Usumacinta
Yaxchilán
Tayasal
El Naranjo
Bonampak
Altar de Sacrificios
Seibal
Chinkultic
Río Grijalva
Zaculeu
Quiriguá
Río Motagua
Copán
Izapa
Iximché
Kaminaljuyú
Guatemala
Abaj Takalik
El Baul
Santa Lucía Cotzumalhuapa
San Salvador
0.7080-0.7091
0.7074-0.7079
0.7045-0.7069
>0.71
www.latinamericanstudies.org/maya-maps.htm



Laboratory for Archaeological Chemistry database