Compositional Groups and Ages of the Central Atlantic Magmatic Province Relative to the End-Tr Extinction Event

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The Hypothesis: Volcanism of the Central Atlantic Magmatic Province (CAMP) caused the End-Triassic Extinction (ETE) event.
Evidence: Magmatic groups and types might be defined by chemistry, dated, and precisely correlated with the ETE.

Related Points:

- huge SO_2 and CO_2 emissions are estimated
- older CAMP dates overlap the extinction age c. 201.4 Ma
- anomalous carbon, strontium, and iridium values in sediments
- some basalts may precede the start of the ETE
- the end of the ETE event may be later than some other basalts
- basalt compositional groups have relative ages in basins
- basalt compositional groups have many imprecise absolute ages and a few very precise U/Pb zircon dates

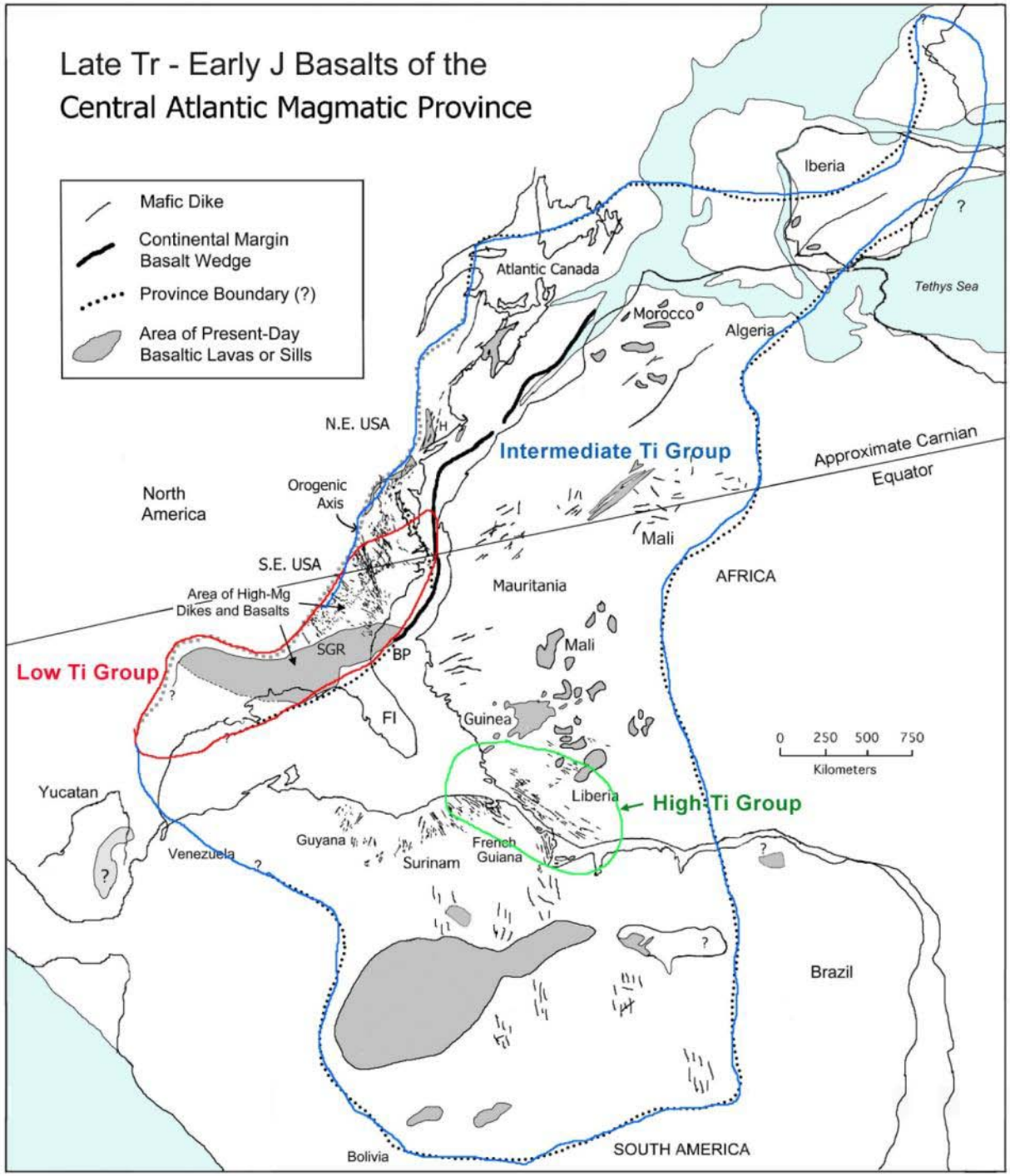
The CAMP extends over 11,000,000 km^2 of central Pangaea, in great dike swarms, sills, and surface flows of three magma groups, which can be distinguished by titanium.

Dike systems within each magma group are slightly different in composition and age from one another.

The intermediate Ti group (ITi) of quartz tholeiites is most widespread and defines the CAMP borders. This group has three subdivisions in the ENA.

In the southeastern USA, a high-Mg low-Ti (LTi) olivine basalt group is abundant.

Around French Guiana and Liberia, a high Ti (HTi) basaltic group forms dike swarms. This group appears to be substantially younger.



AVERAGES OF CAMP GROUPS

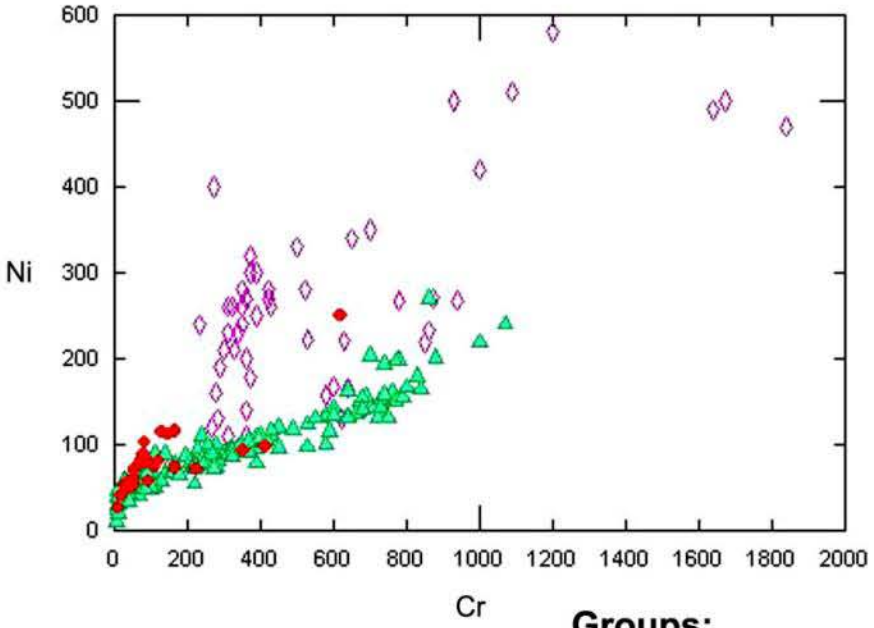
	LTi	ITi	HTi
SiO_2	47.6	52.1	51.87
TiO_2	0.45	1.05	3.21
Al_2O_3	16.12	14.27	14.32
FE_2O_3	10.87	11.36	13.49
MnO	0.17	0.18	0.19
MgO	11.29	7.63	4.11
CaO	11.29	10.7	7.64
Na_2O	1.84	2.15	2.87
K_2O	0.31	0.63	1.65
P_2O_5	0.07	0.14	0.58
H_2O+	0.87	0.67	
CO_2	0.137	0.075	
S	0.061	0.032	
F	0.012	0.022	
Cl	0.011	0.048	

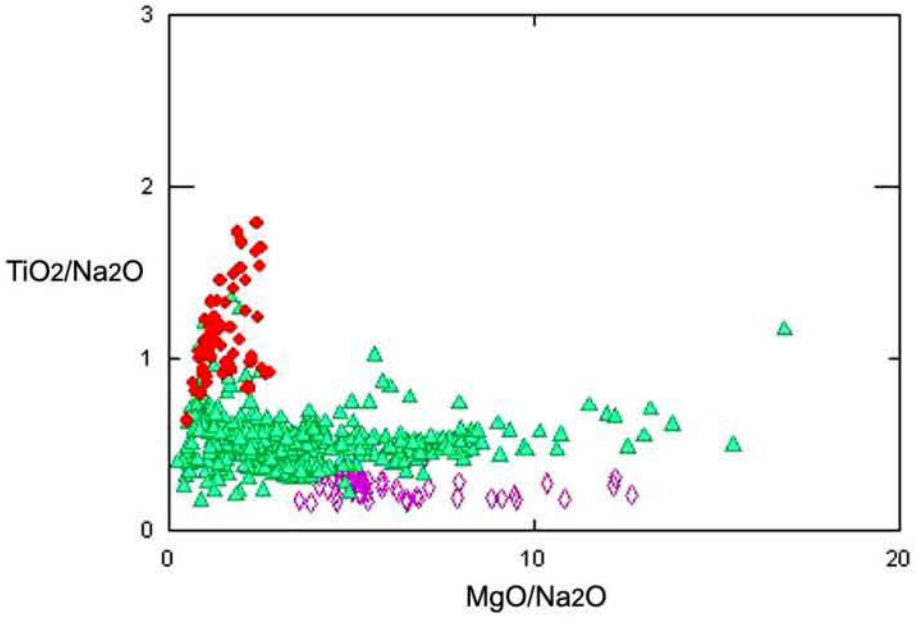
Major Sources:

LTi and ITi:
Grossman et al, 1991 USGS Open-File Report 91-322-J

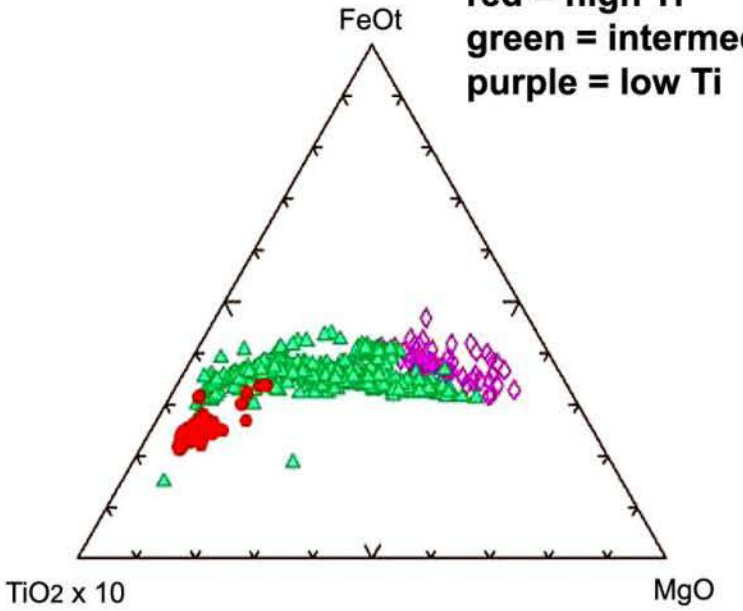
HTi:
DuPuy et al 1988, EPSL v. 87, p. 100-110.

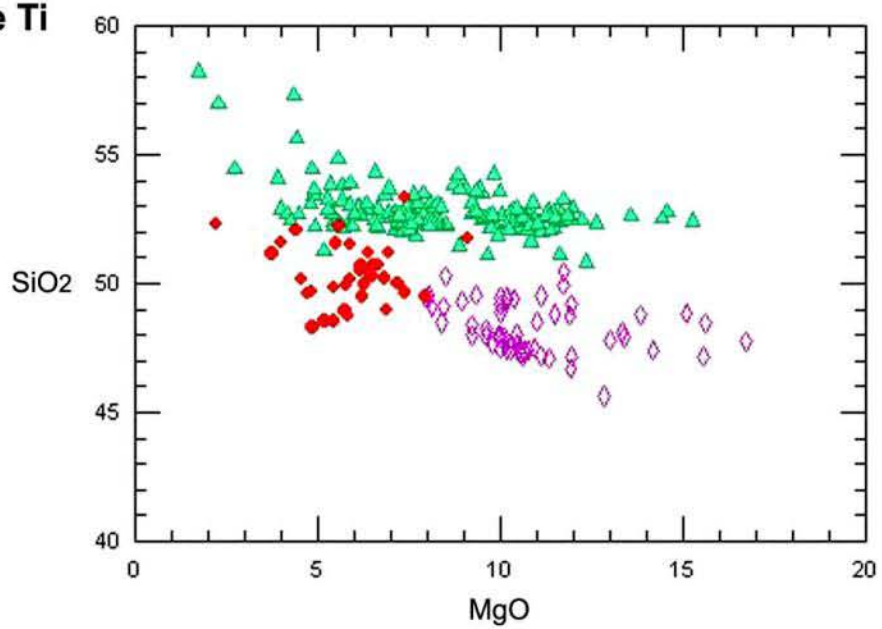
Oliviera et al. 1990, in Mafic Dykes & Emplacement Mechanisms, p. 173-183.





Groups:
red = high Ti
green = intermediate Ti
purple = low Ti



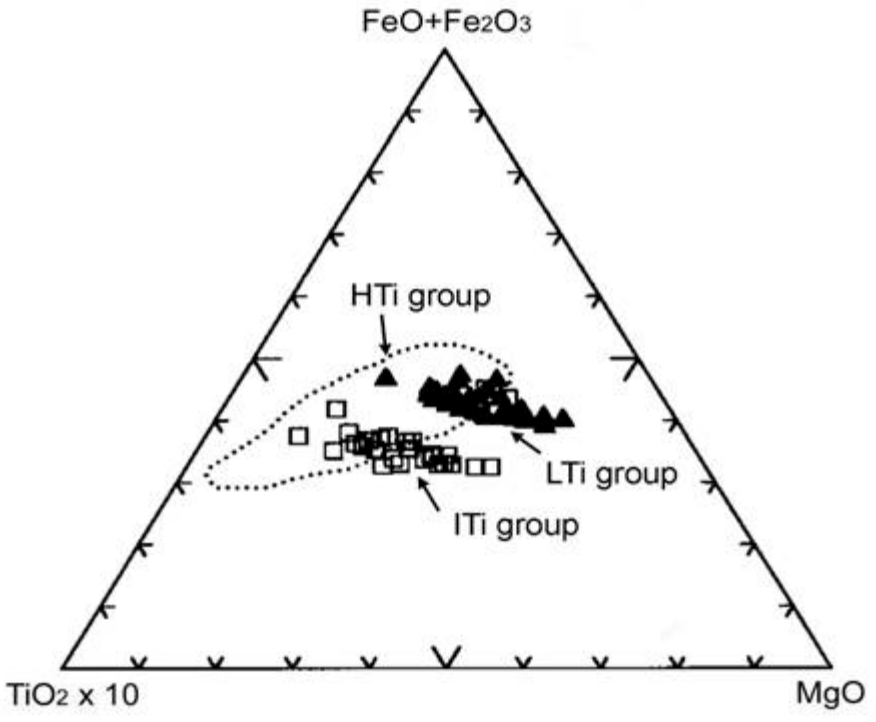


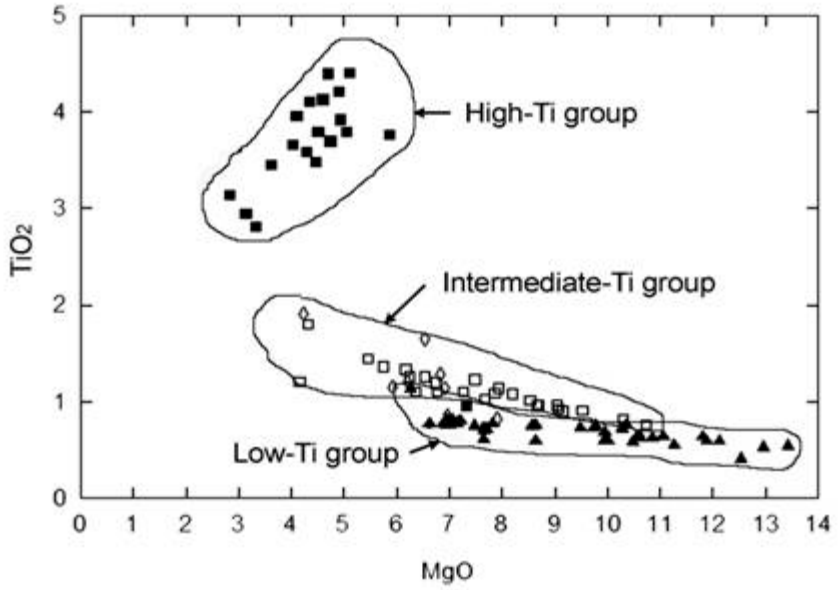
Imprecise Radiometric Ages (mainly Ar dates):

HTi: 190-195 Ma

LTi & ITI: 199-202 Ma

Except: new very precise U/Pb zircon dates for <u>one</u> of the ITi basalts: 201.38 +/- 0.02 Ma (Schoene et al., 2010, Geology, v. 38, pp. 387-390.)





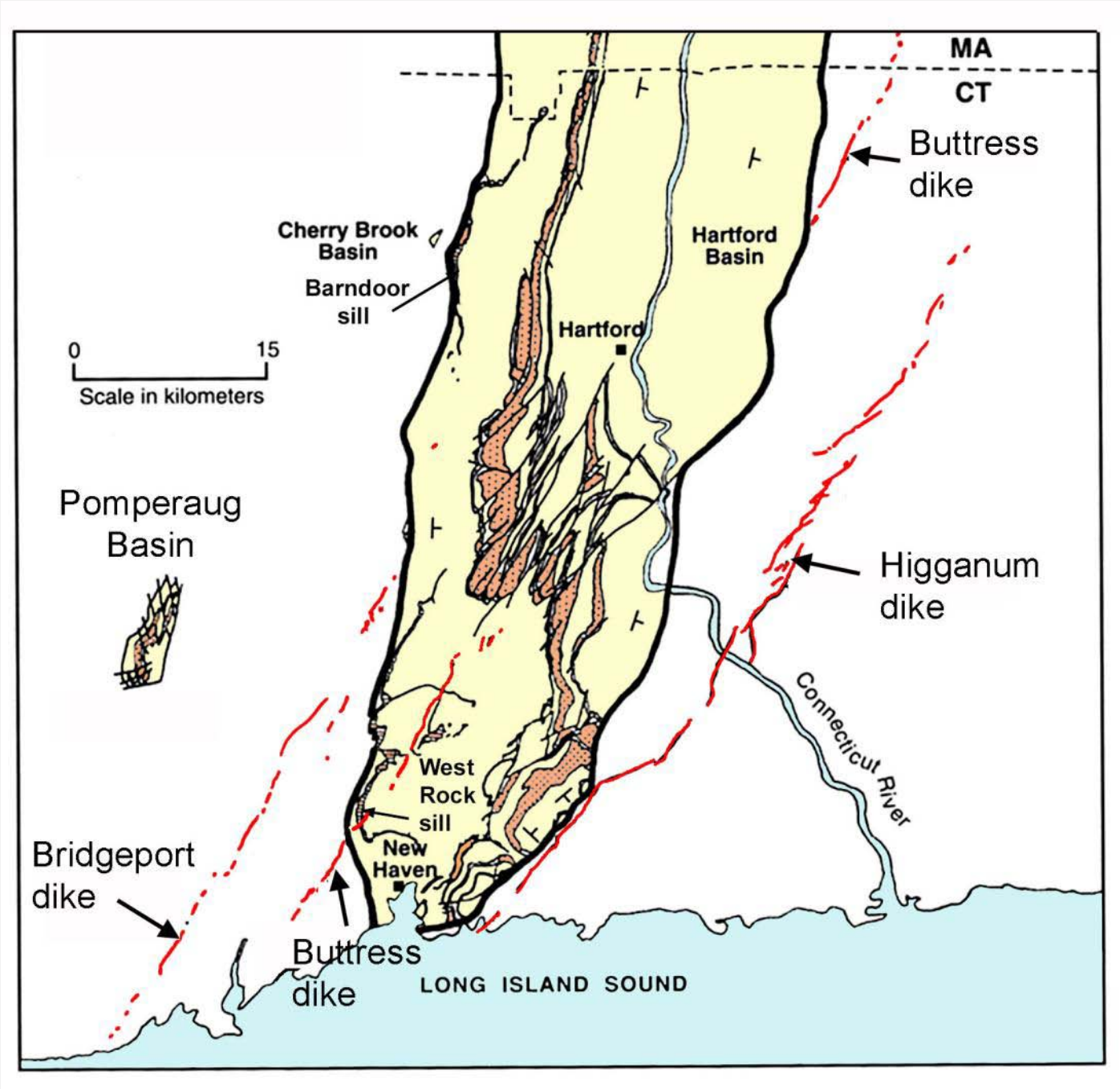
Chemical Groups, Types within Groups, and Relative Ages based on Radiometric Dates and Stratigraphic Correlation

HTi	c.190-195 Ma:	High-Ti sub-alkaline to tholeiitic NW-trending dikes of southeastern CAMP
ITi	c. 201 Ma:	“HFQ” type of Intermediate-Ti quartz tholeiite
	c. 201 Ma:	“LTQ” type of Intermediate-Ti quartz tholeiite
	c. 201 Ma:	“HTQ” type of Intermediate-Ti quartz tholeiite
LTi	c. 201? Ma:	Low-Ti High-Mg olivine tholeiite of western CAMP

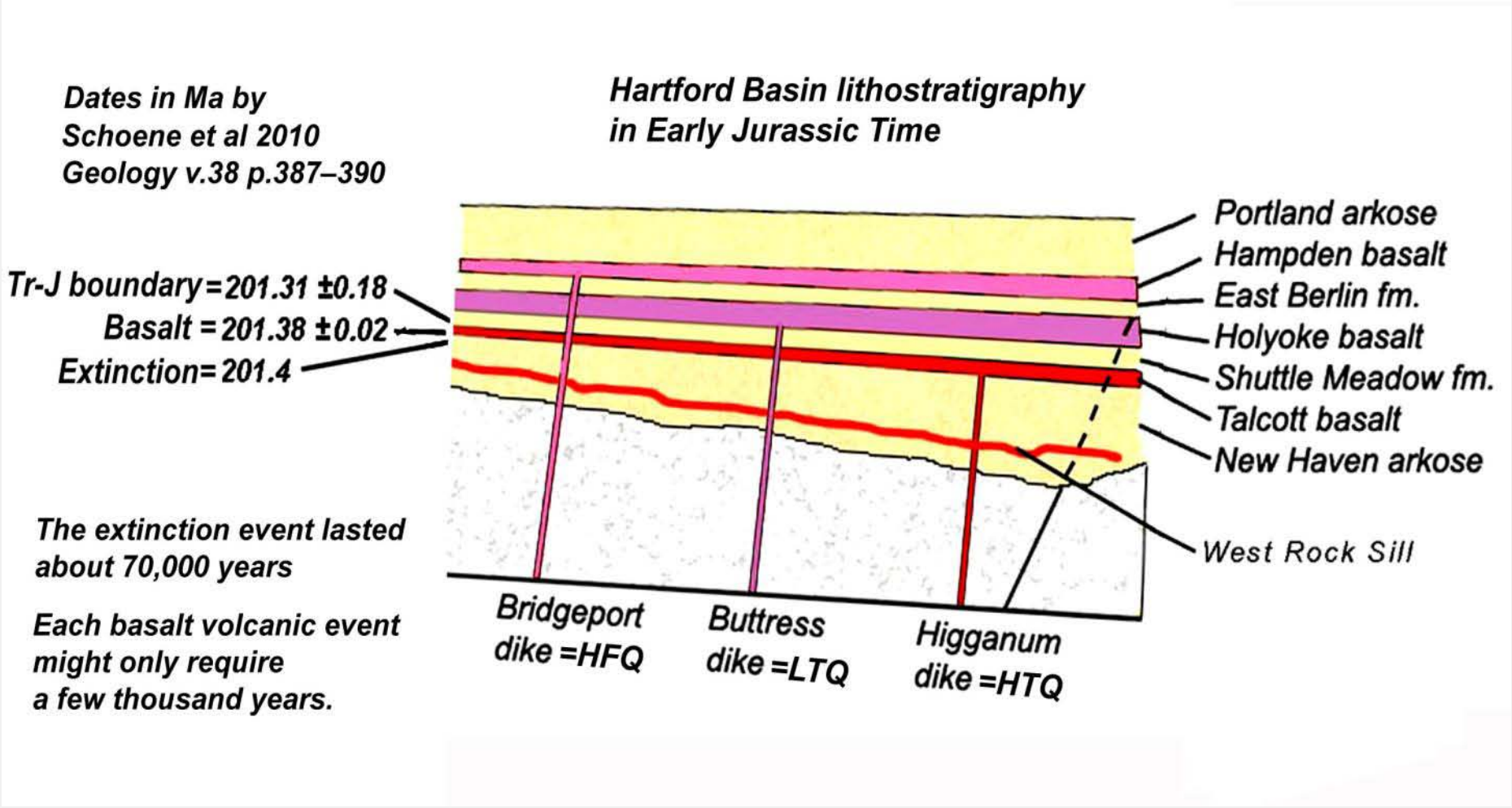
The ITi group in eastern North America is subdivided into 3 types, based on work by Weigand and Ragland (1970) and others; PUS there are slight differences within the 3 types

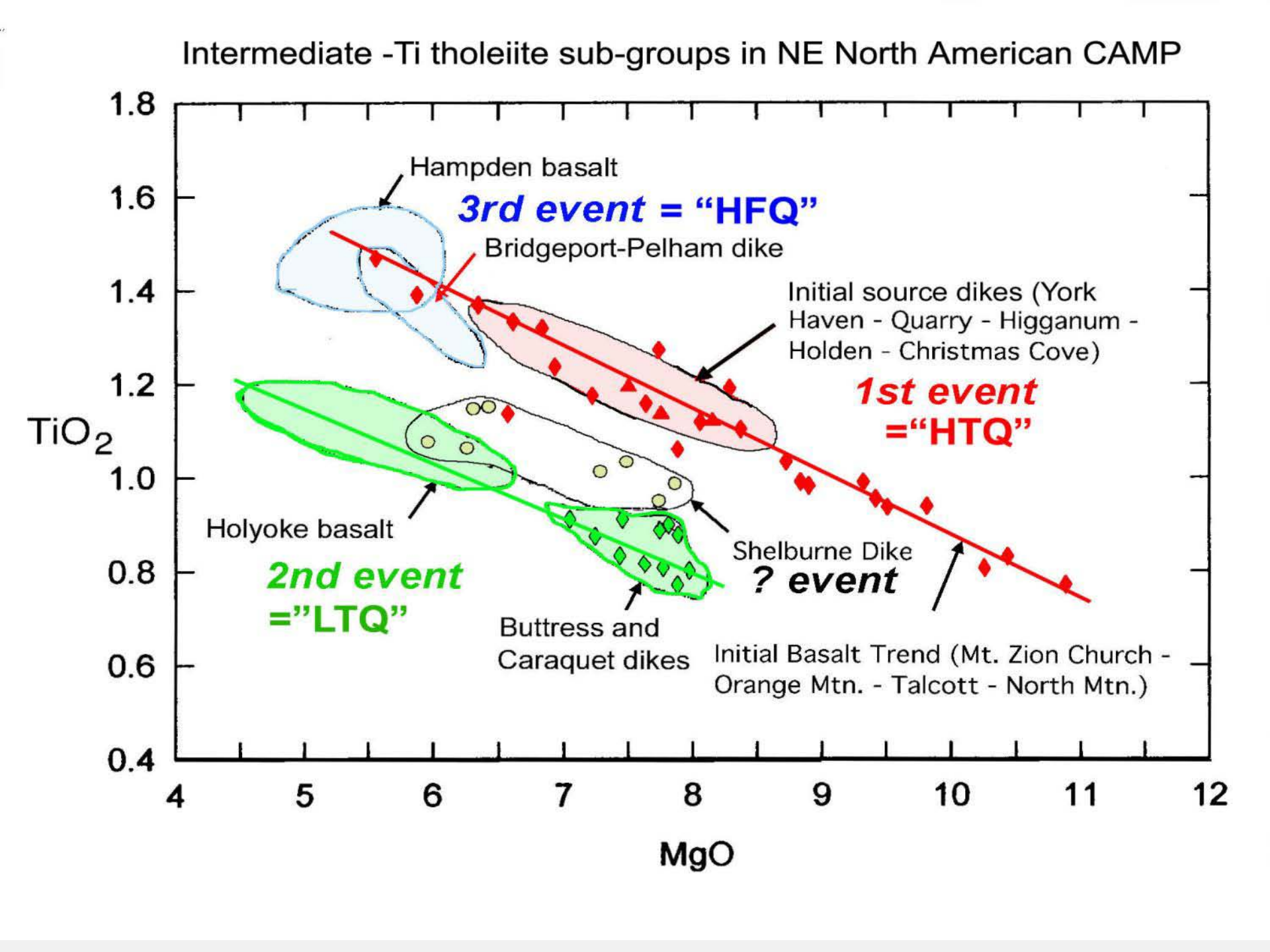
Three large dike fissures or systems were the sources for three Mesozoic basin basalts in Connecticut.

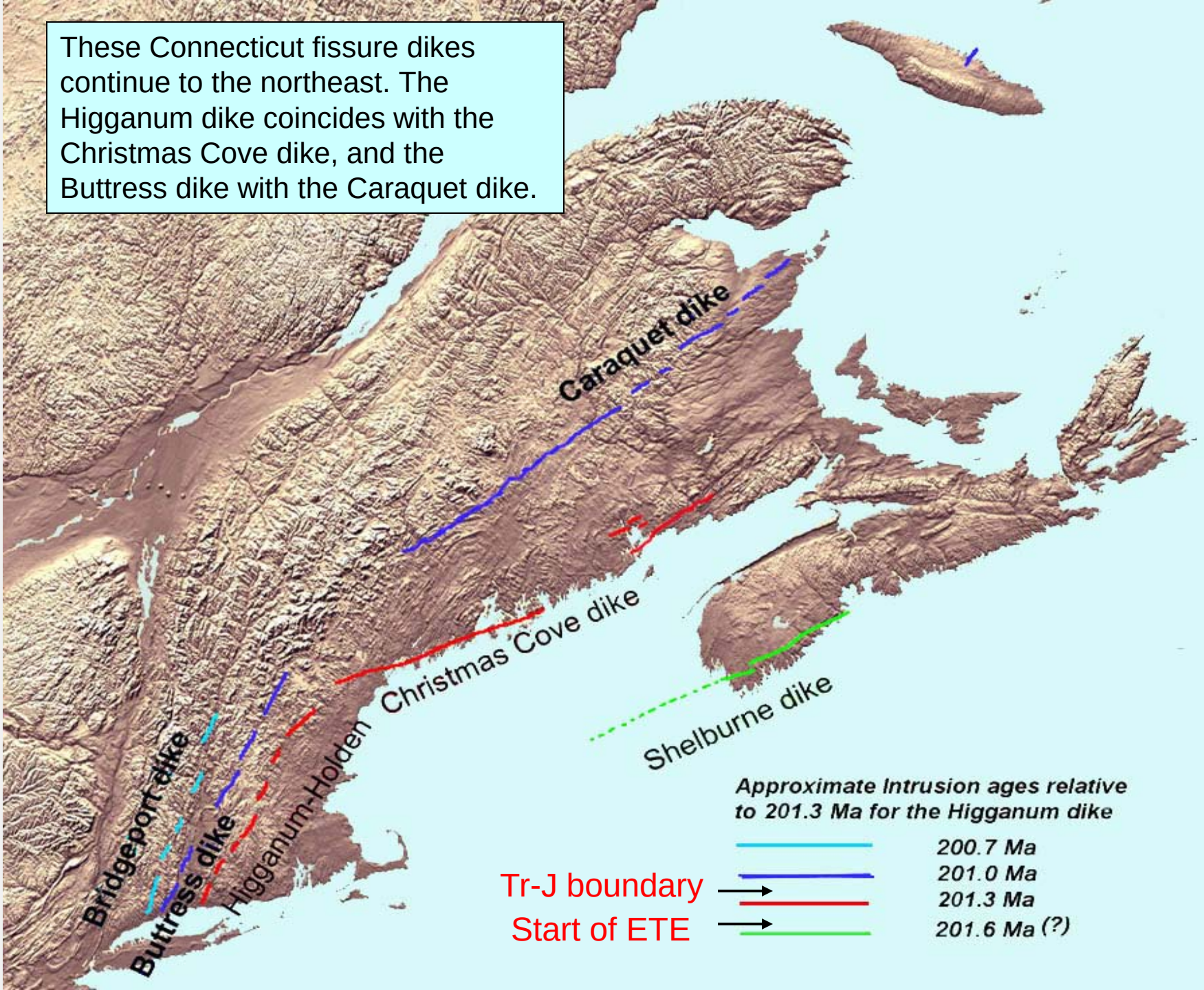
Peter Weigand based much of his classification on examples from this area.

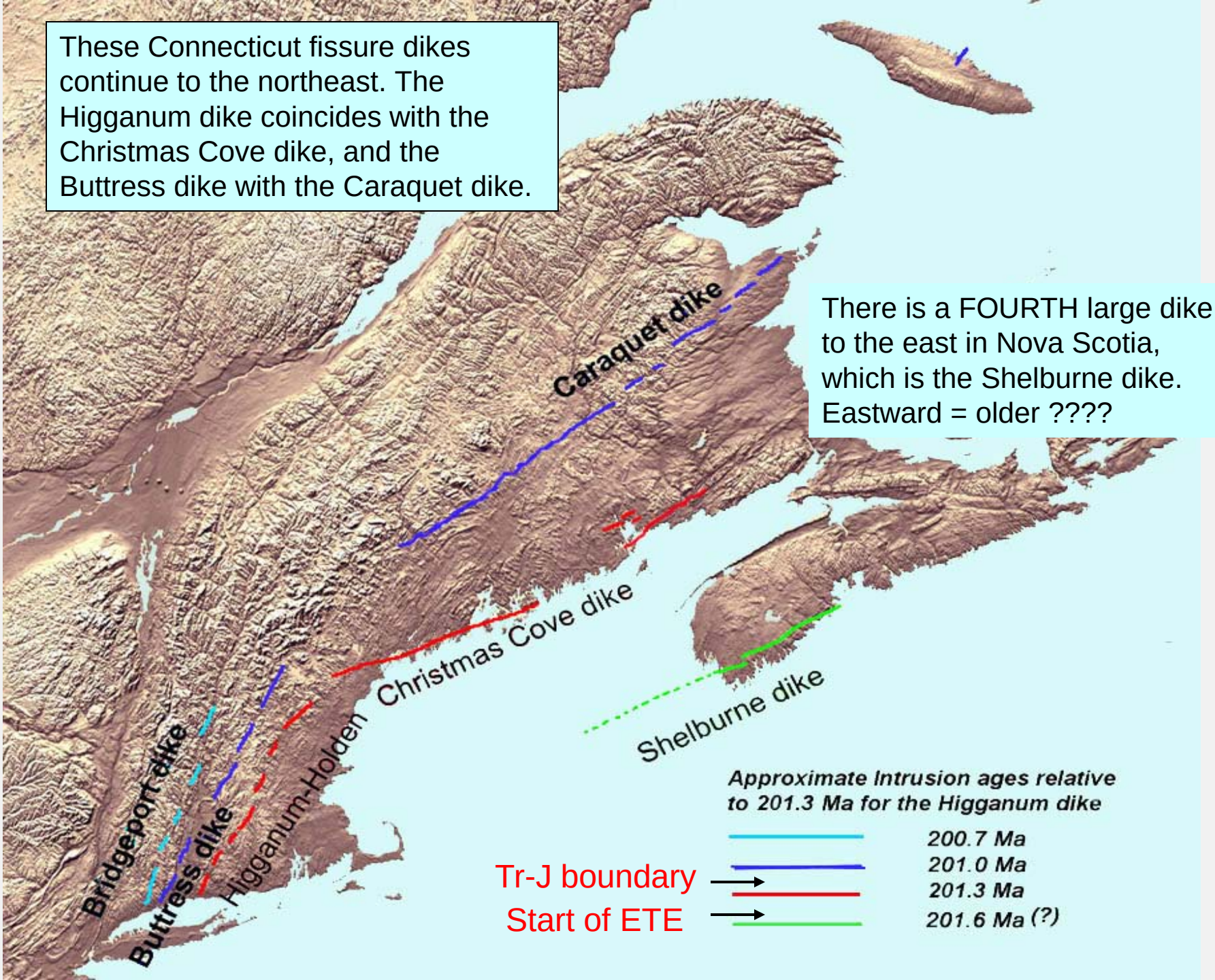


The North Mountain Basalt has a very precise U/Pb zircon date (201.38 Ma);
Talcott Basalt is co-magmatic with North Mountain basalt so must be that age;
The 3 Hartford Basalts have precise cyclo-stratigraphic relative ages;
The 3 dikes are co-magmatic with the 3 basalts, so the Higganum Dike = 201.38 Ma

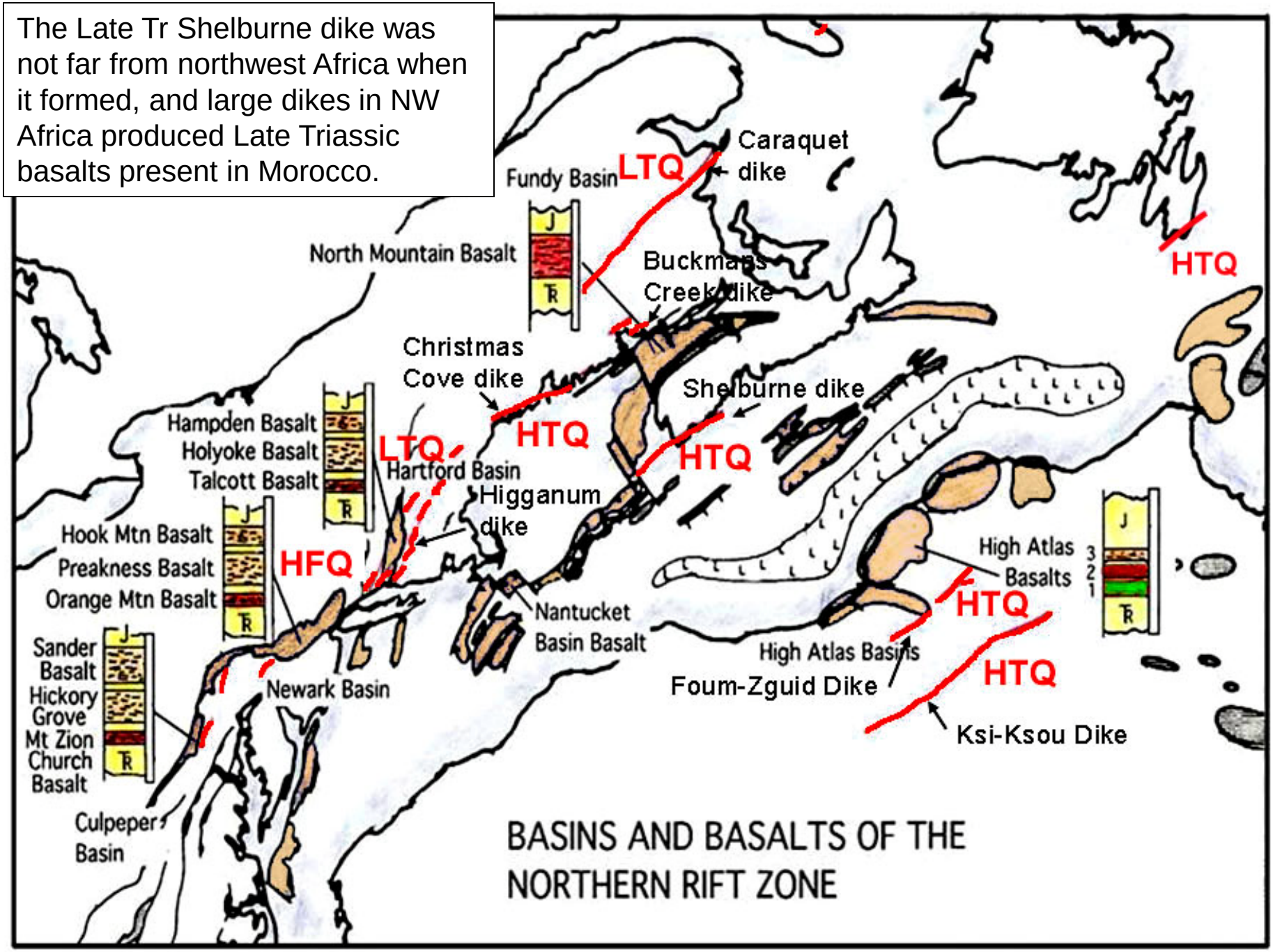


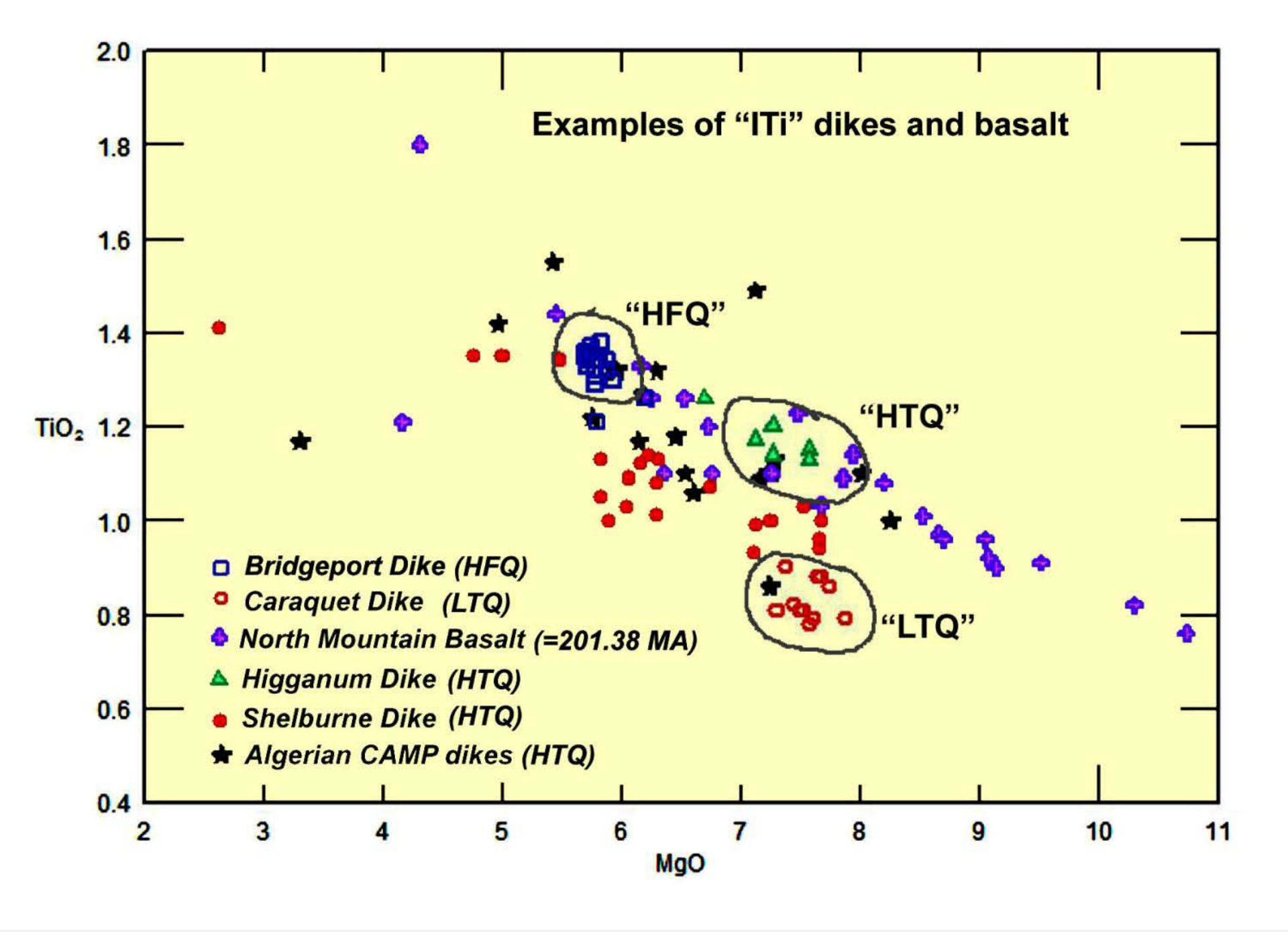

Intermediate -Ti tholeiite sub-groups in NE North American CAMP
TiO2
MgO
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
4
5
6
7
8
9
10
11
12
Hampden basalt
3rd event = "HFQ"
Bridgeport-Pelham dike
Initial source dikes (York Haven - Quarry - Higganum - Holden - Christmas Cove)
1st event ="HTQ"
Holyoke basalt
2nd event ="LTQ"
Shelburne Dike
? event
Buttress and Caraquet dikes
Initial Basalt Trend (Mt. Zion Church - Orange Mtn. - Talcott - North Mtn.)


These Connecticut fissure dikes continue to the northeast. The Higganum dike coincides with the Christmas Cove dike, and the Buttress dike with the Caraquet dike.
Caraquet dike
Christmas Cove dike
Shelburne dike
Bridgeport dike
Buttress dike
Higganum-Holden
Approximate Intrusion ages relative to 201.3 Ma for the Higganum dike
200.7 Ma
201.0 Ma
201.3 Ma
201.6 Ma (?)
Tr-J boundary
Start of ETE


These Connecticut fissure dikes continue to the northeast. The Higganum dike coincides with the Christmas Cove dike, and the Buttress dike with the Caraquet dike.
There is a FOURTH large dike to the east in Nova Scotia, which is the Shelburne dike. Eastward = older ????
Caraquet dike
Christmas Cove dike
Shelburne dike
Bridgeport dike
Buttress dike
Higganum-Holden
Approximate Intrusion ages relative to 201.3 Ma for the Higganum dike
200.7 Ma
201.0 Ma
201.3 Ma
201.6 Ma (?)
Tr-J boundary
Start of ETE

The Late Tr Shelburne dike was not far from northwest Africa when it formed, and large dikes in NW Africa produced Late Triassic basalts present in Morocco.




Examples of "ITi" dikes and basalt
"HFQ"
"HTQ"
"LTQ"
Bridgeport Dike (HFQ)
Caraquet Dike (LTQ)
North Mountain Basalt (=201.38 MA)
Higganum Dike (HTQ)
Shelburne Dike (HTQ)
Algerian CAMP dikes (HTQ)
TiO2
MgO
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
2
3
4
5
6
7
8
9
10
11

North Mountain basalt over Blomidon siltstone at Economy Mountain, Nova Scotia (northern end of the Fundy Basin)

Mesozoic Basin Basalt Correlation

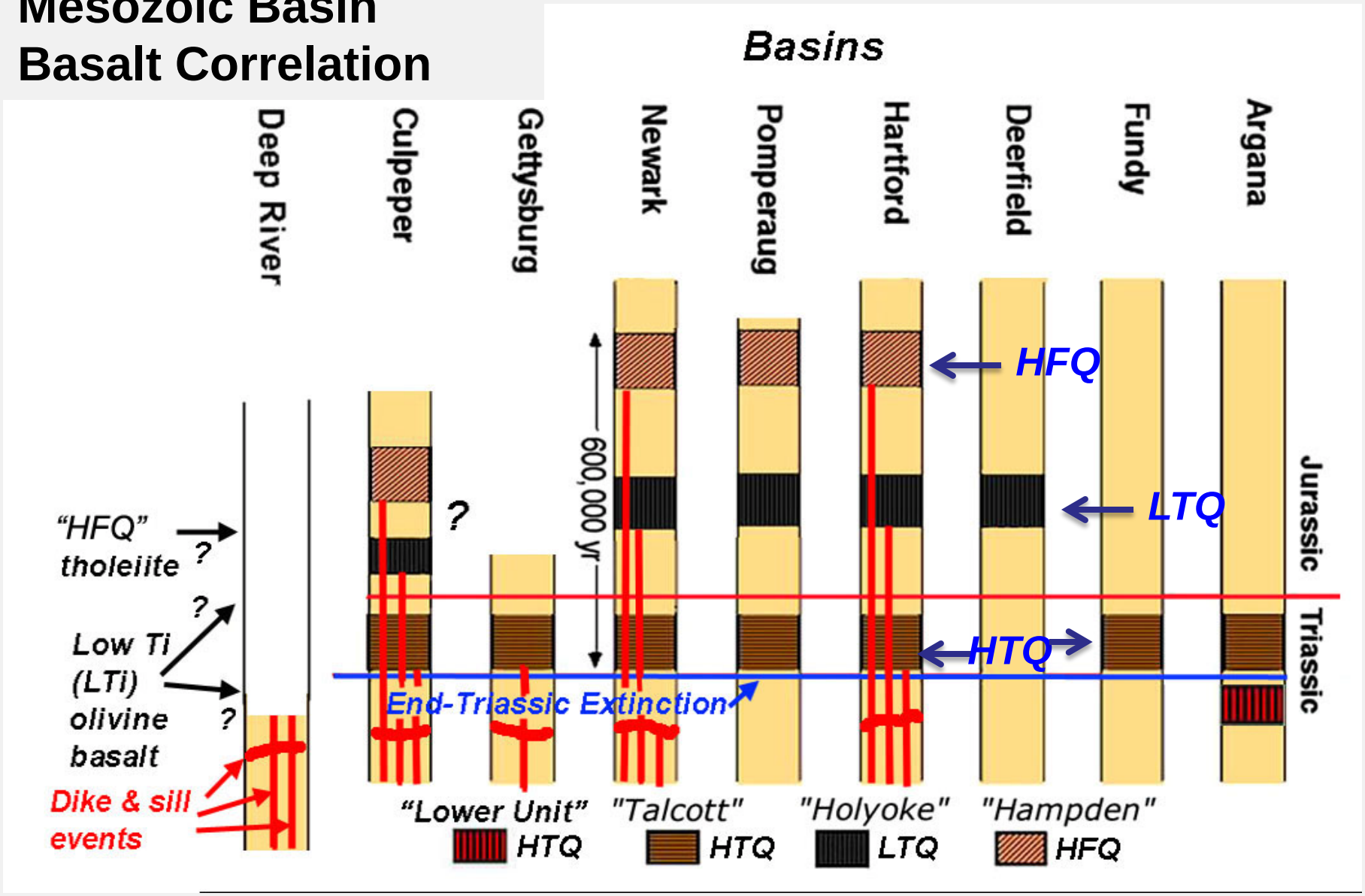
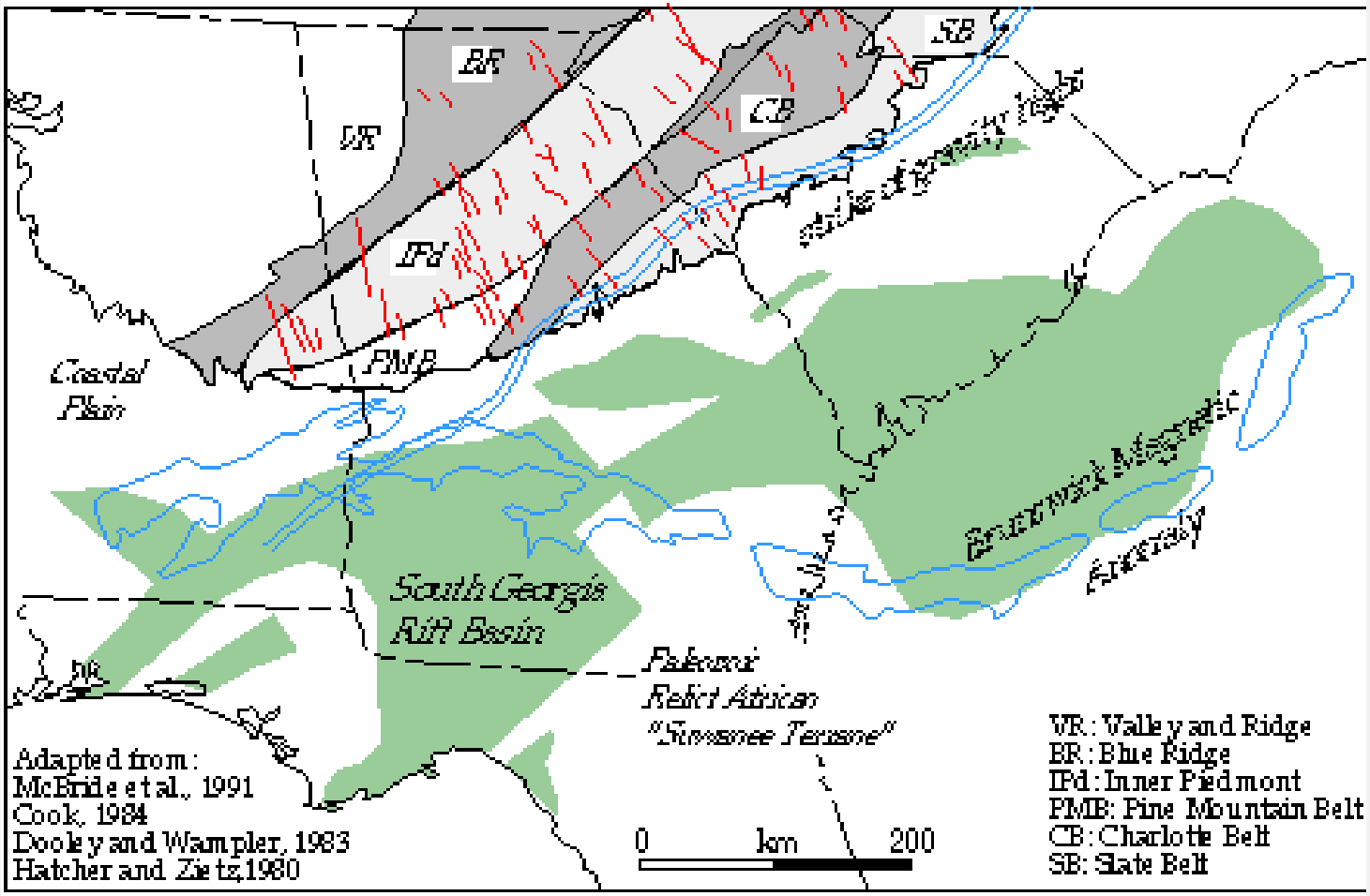


Figure 3: Distribution of Exposed Dikes in the Southeastern U.S. in Relation to Major Geologic Provinces and Geophysical Anomalies



(map by Bill Hames)

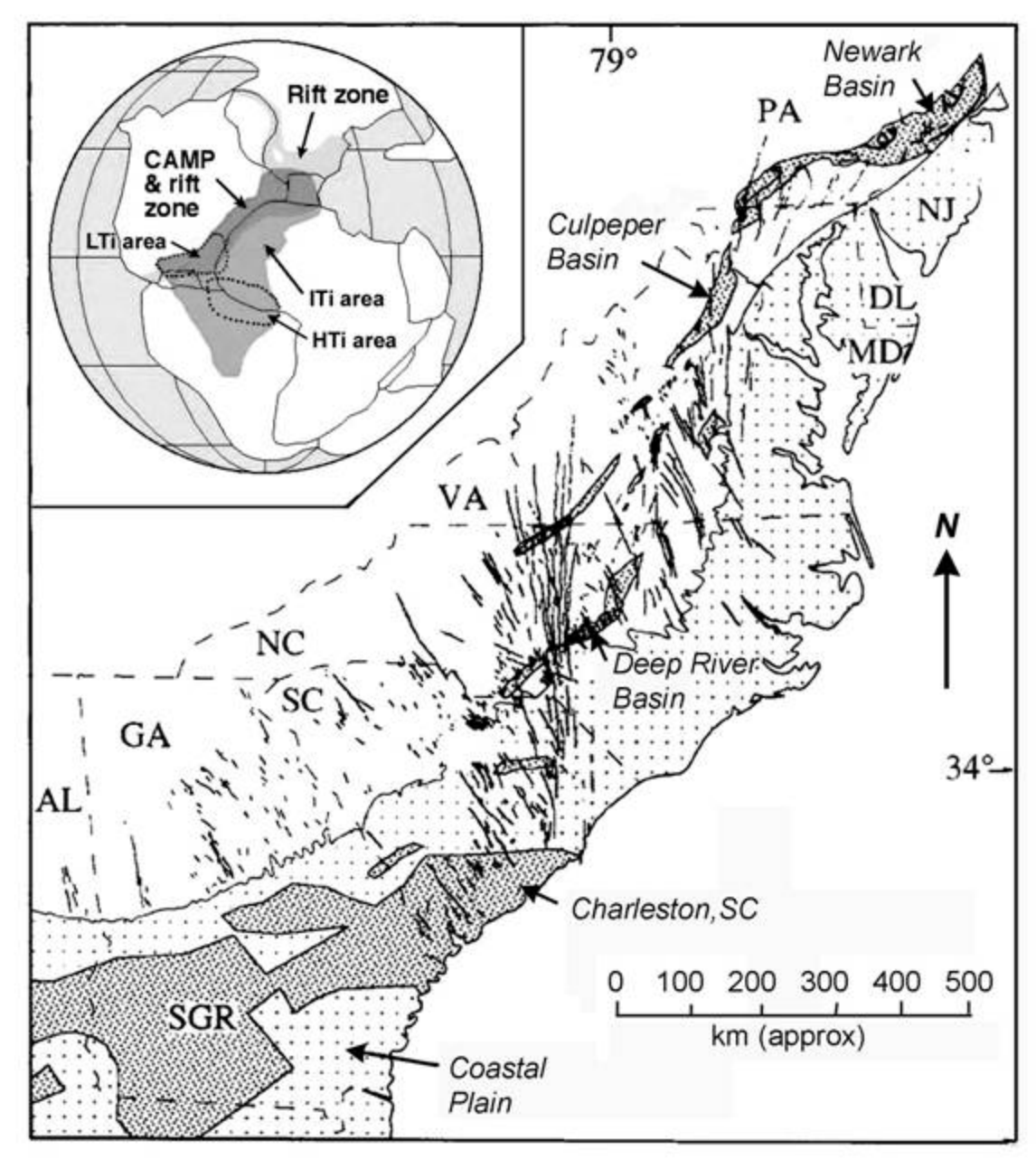
ITi dikes of the northeastern rift regions have mainly NE-SW trends from Virginia northward.

LTi dikes in the deep south, and under the Coastal Plain, trend mostly NW-SE. They include some “LTQ” dikes but these appear to be fractionates of LTi olivine tholeiite.

ITi dikes of the “HFQ” and “HTQ” sub-groups trend N-S from South Carolina to Virginia.

Ar/Ar dates for all three dike trends and the two magma groups fall within analytical precision, about 200 +/- 1 Ma.

(map by Bill Hames)

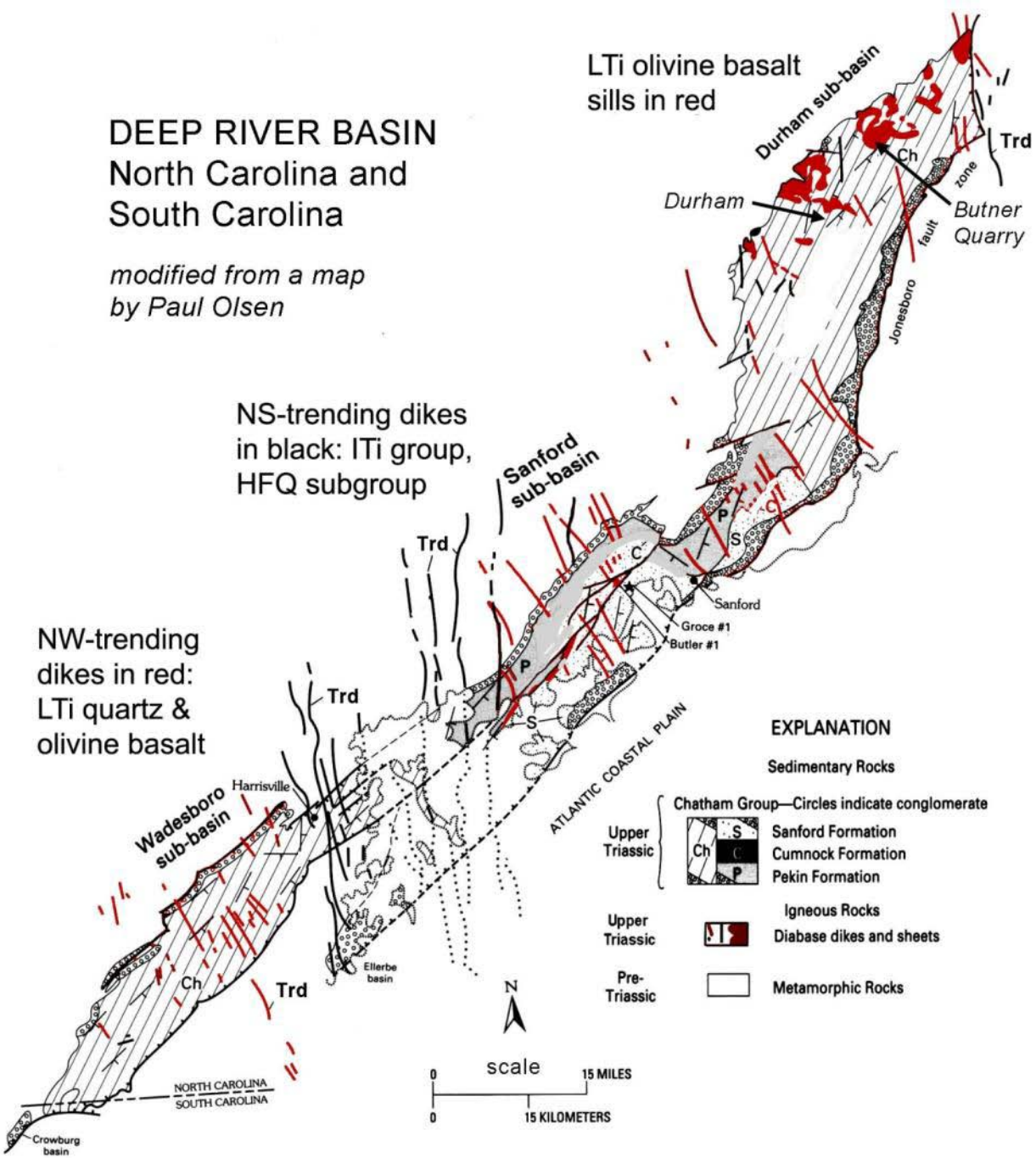


In and around the Deep River Basin of North Carolina, cross-cutting dikes indicate that NW-trending LTi dikes are older than N-S ITi dikes.

Paleo-magnetic patterns for the two types also indicate that the NW LTi group is relatively older.

Both ITi and LTi dike types cross the Deep River Basin, but sills in the basin are all of the LTi olivine tholeiite. By the magma relationships in Connecticut, the LTi dikes and sills must be older than the southern ITi group.

But – older than which <u>type</u> of ITi tholeiite?

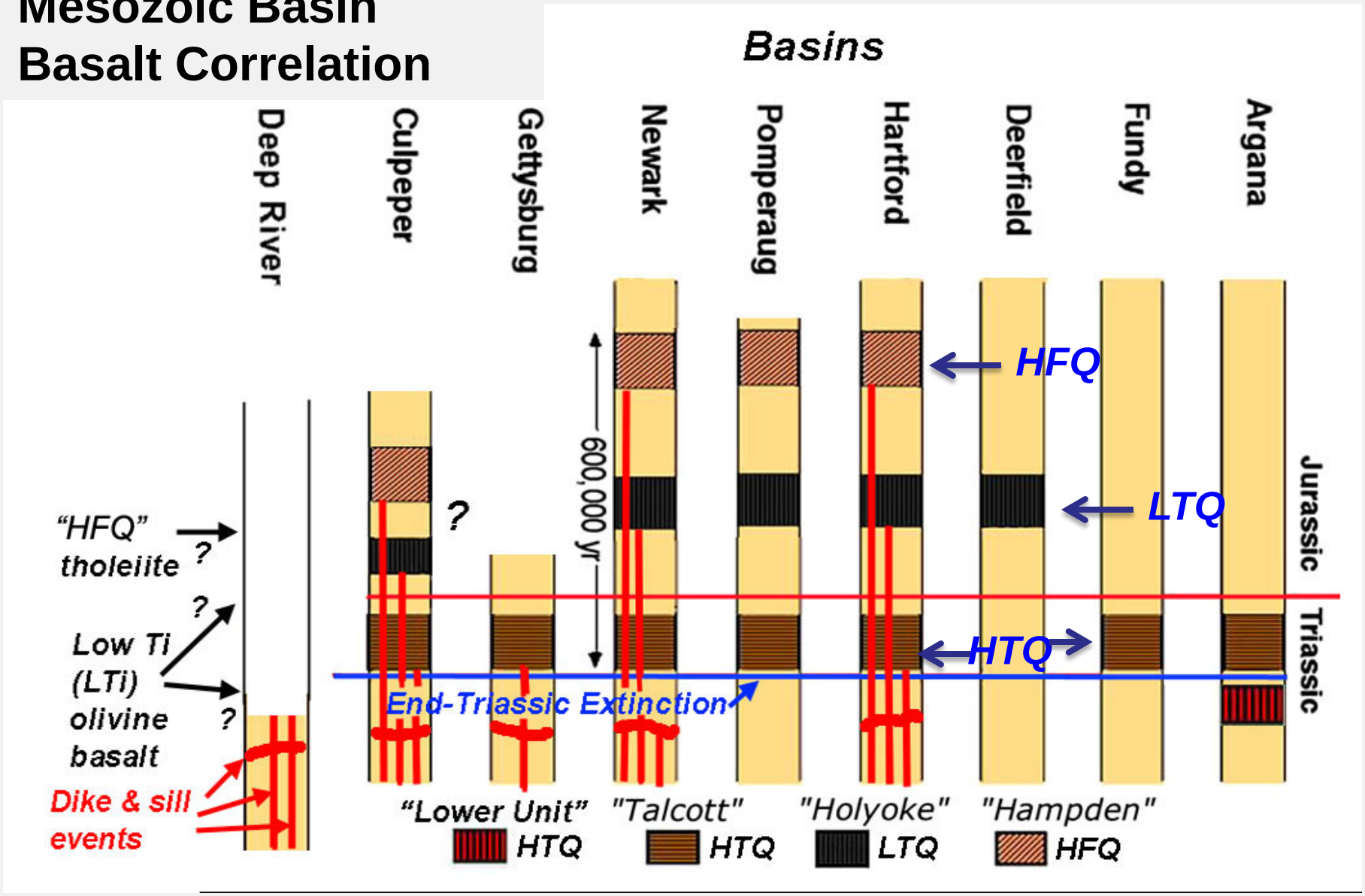


The Butner Quarry north of Durham, NC is a source for trap rock of olivine tholeiite, part of the large 170-m thick Durham Sill in the Deep River Basin. The sill is co-magmatic with NW-SE olivine dolerite (OLN) dikes that cut the Triassic strata of the basin. Jurassic strata and lavas are no longer present in the basin.

A substantial N-S dike of quartz tholeiite cross cuts the sill. It appears to be the “HFQ” quartz tholeiite type –- youngest of the ITi magmas in eastern North America.

Photo by Phil Bradley

Mesozoic Basin Basalt Correlation



Look again at the average compositions of the CAMP magma types. The LTi type has plenty of sulfur and carbon dioxide, as well as halogens. In large enough volumes, these volcanic gases are responsible for environmental catastrophes.

Generalized CAMP Types (averaged)

(wt.%)	ITi	LTi	HTi
SiO2	52.61	48.84	51.87
TiO2	1.26	0.62	3.21
MgO	6.72	9.46	4.11
CO2	0.124	0.091	(0.148)
S	0.034	0.067	(0.111)
F	0.030	0.023	(0.066)
Cl	0.064	0.030	(0.031)
Mg#	50.19	61.98	37.65

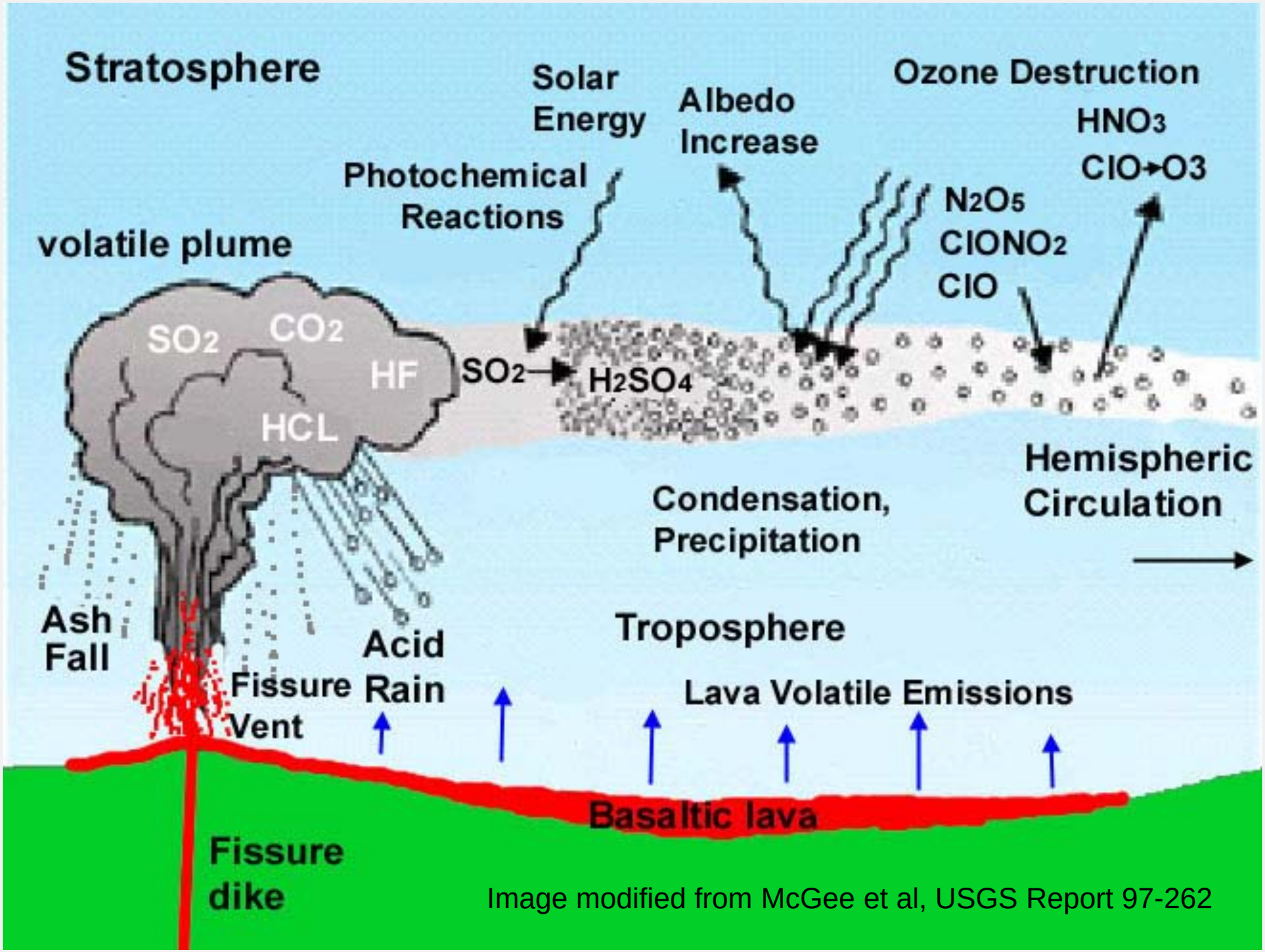


Image modified from McGee et al, USGS Report 97-262