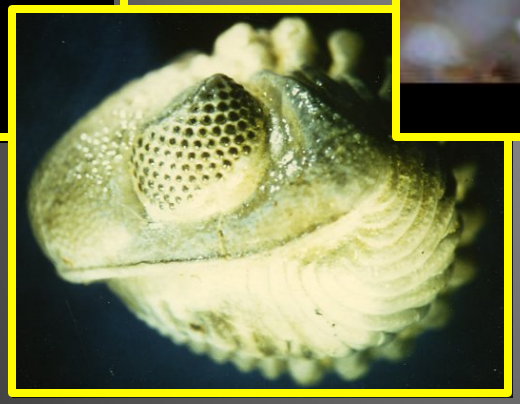
CARBON MINERAL ECOLOGY:
Predicting the "Missing" Minerals of Carbon



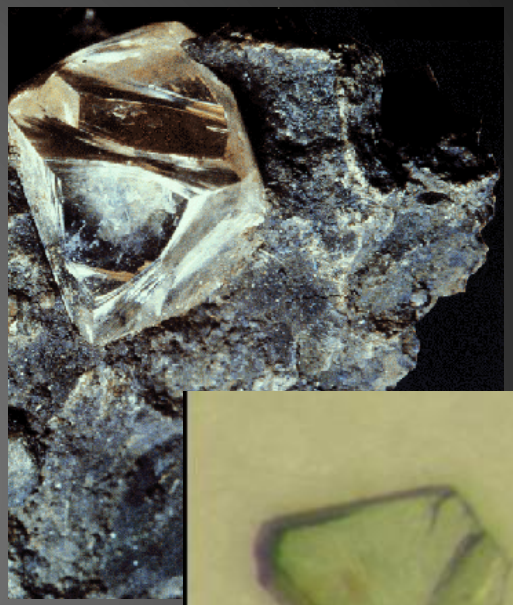
2nd Deep Carbon Science Conference
23 March 2015—R. M. Hazen
Carnegie Institution & DCO Secretariat

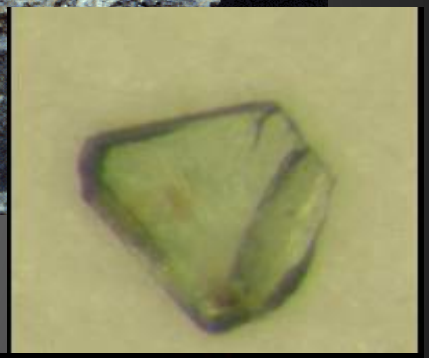
DEEP CARBON OBSERVATORY
deepcarbon.net

CARBON MINERALOGY TODAY:

403 IMA approved mineral species

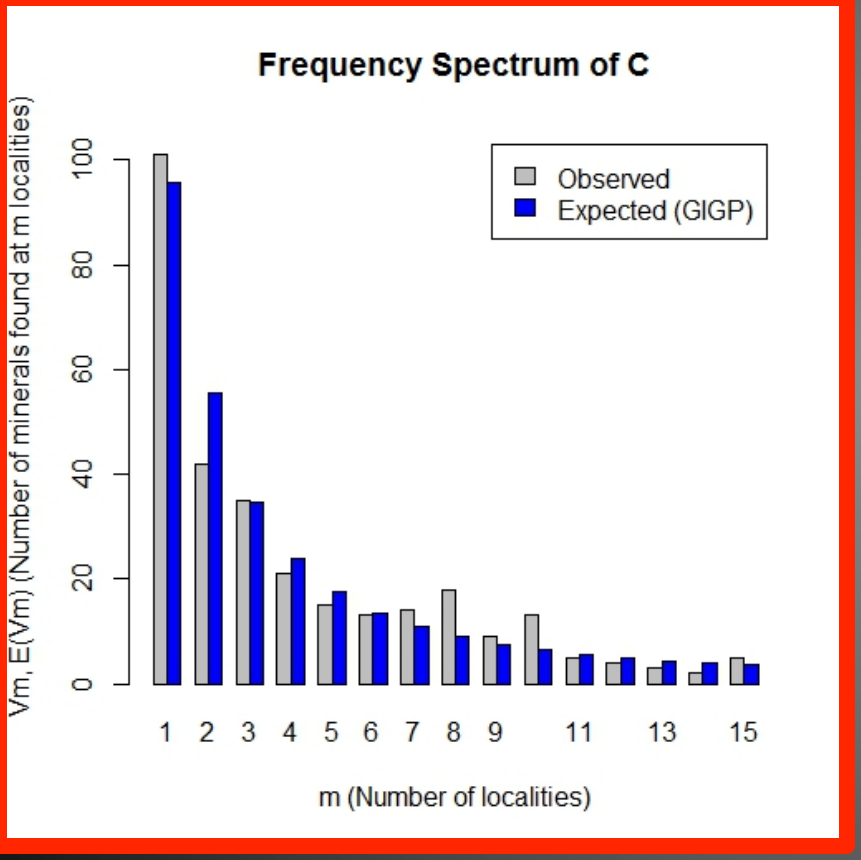
Carbon Allotropes:	4
Carbides:	10
Carbonates:	>300
Anhydrous	107
Hydrated	>200
Organic Minerals:	>50
Hydrocarbons	10
Oxalates	12

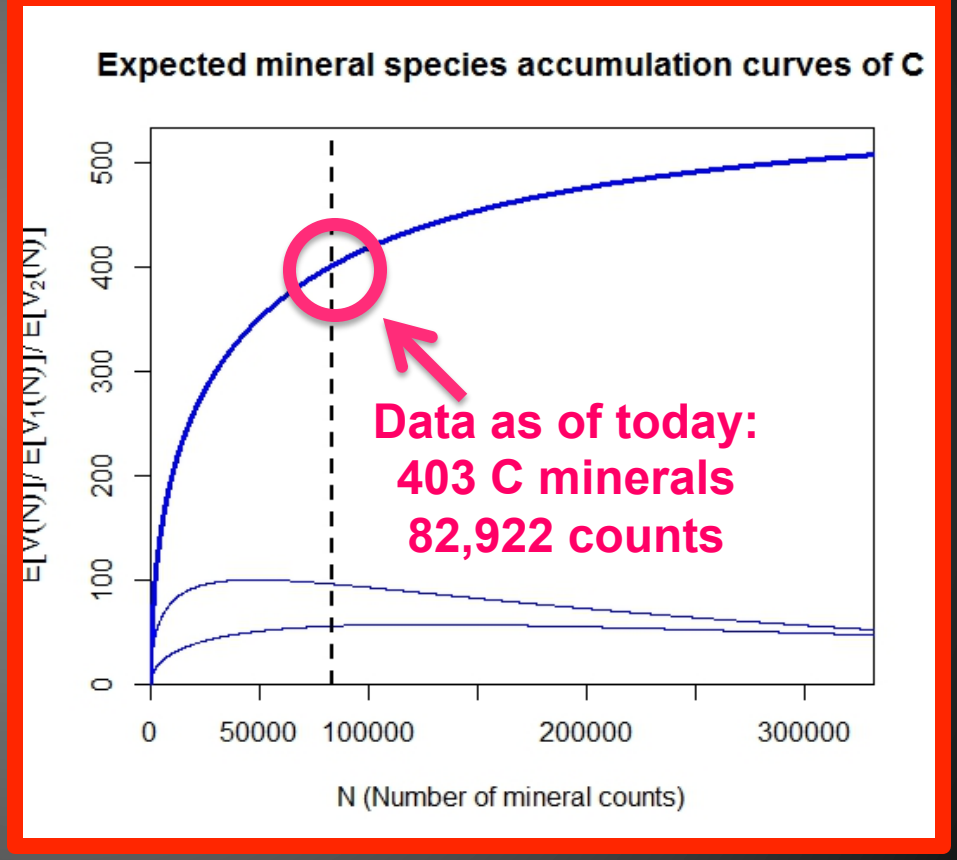




Carbon Minerals: Frequency Distribution

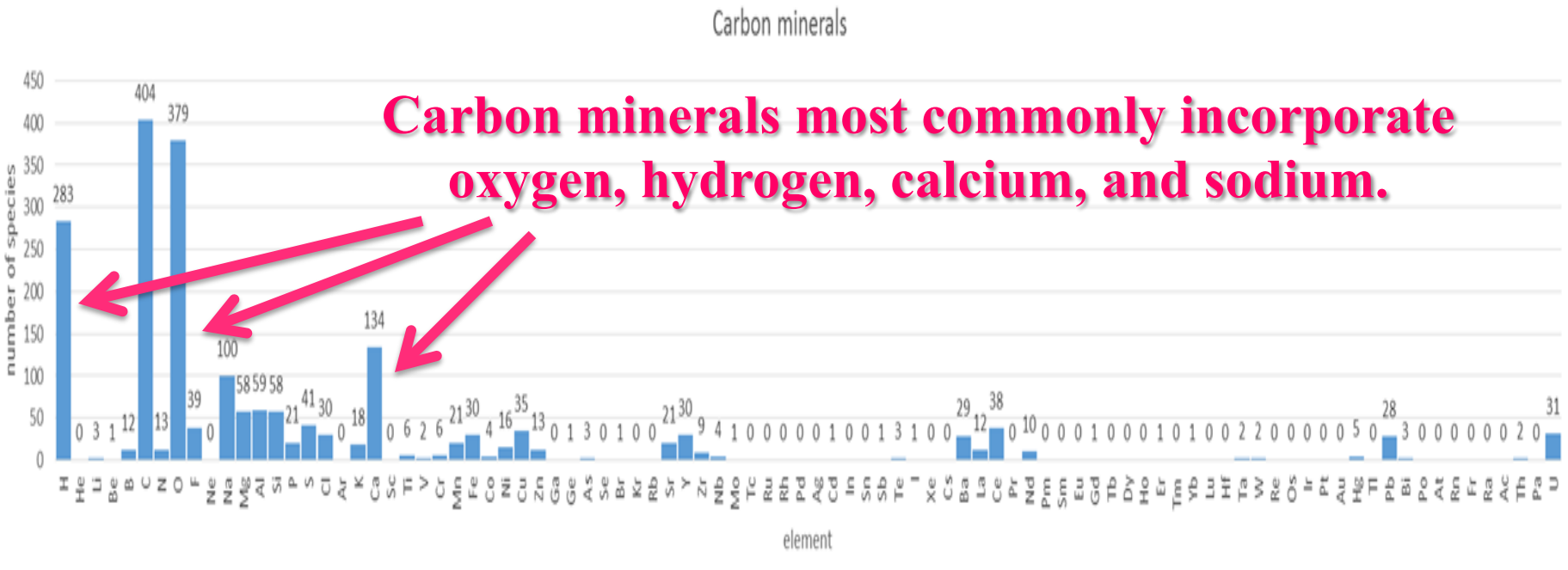
403 carbon mineral species, known from 82,922 locality data, conform to an LNRE distribution.



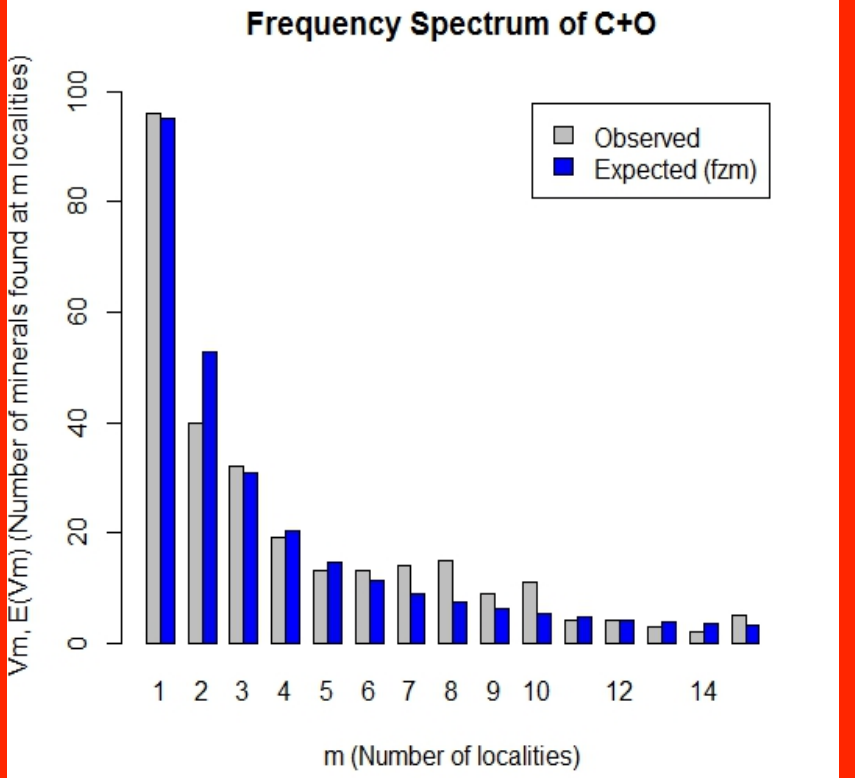


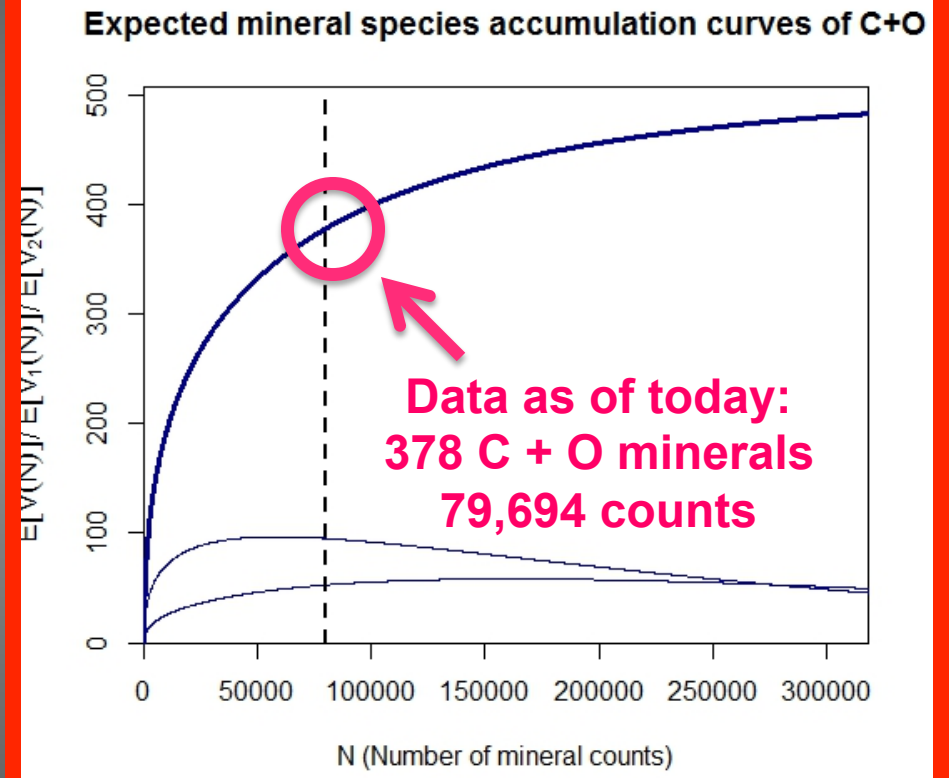
We extrapolate that **145 additional carbon mineral species exist on Earth** but have yet to be discovered.

Carbon Minerals: Coexisting Elements



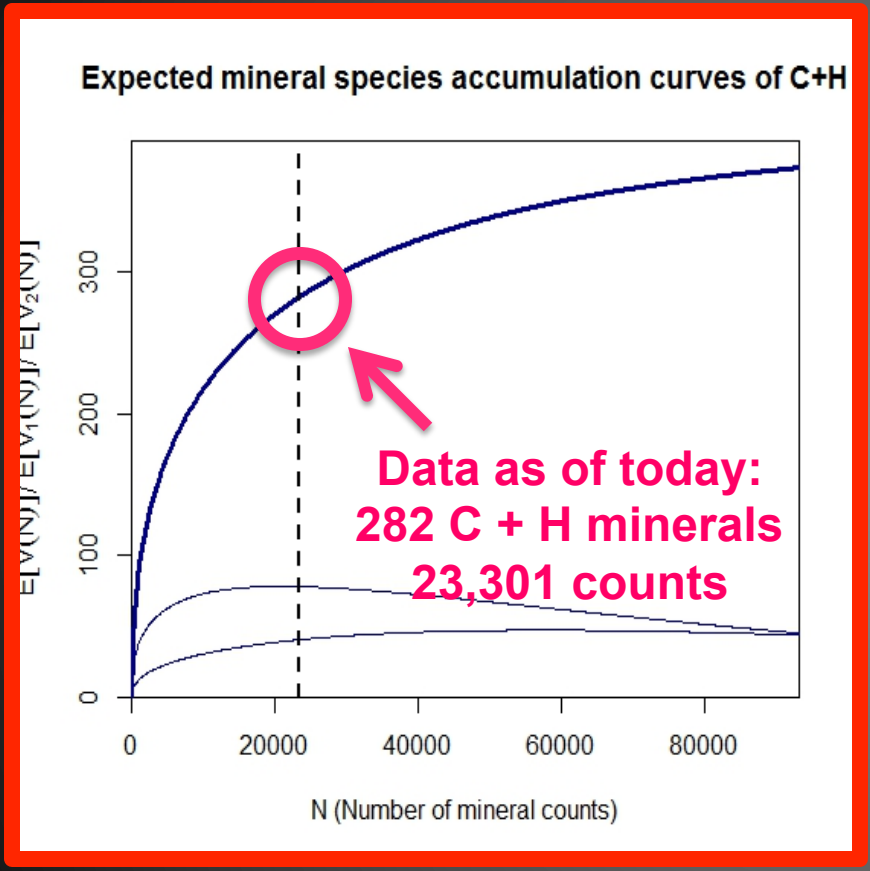
C + O Minerals: Frequency Distribution

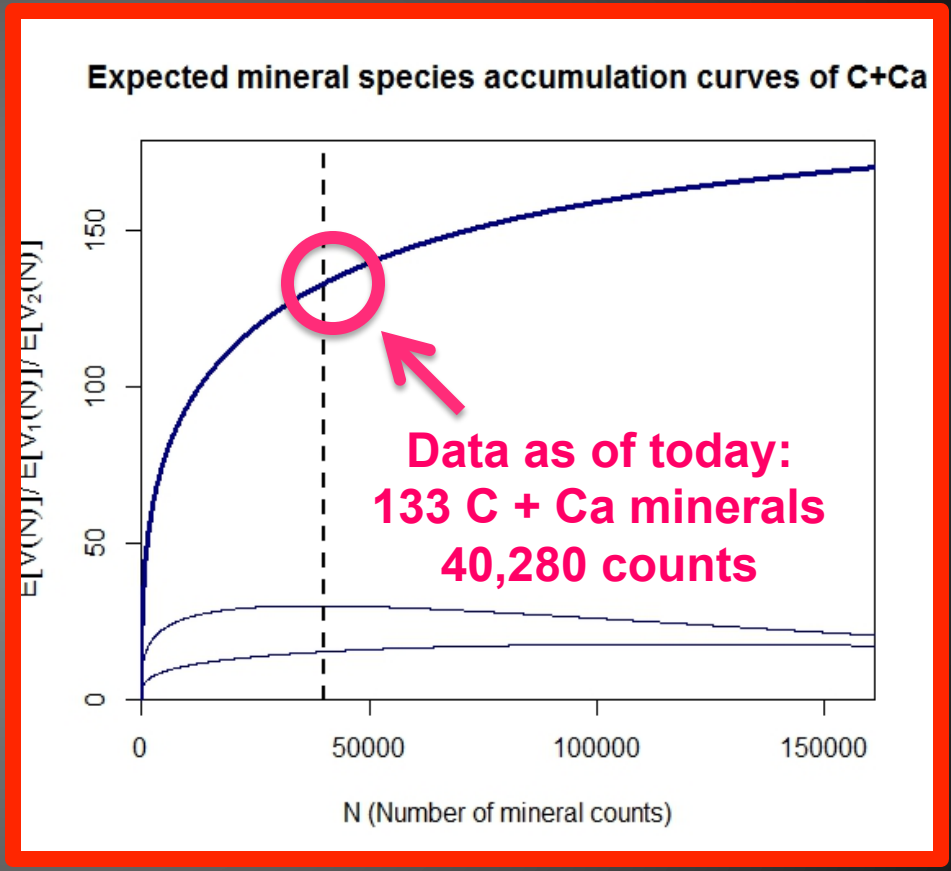




We predict that 135 of the 145 "missing" carbon mineral species are carbonates.

C Mineral Subsets: Frequency Distribution

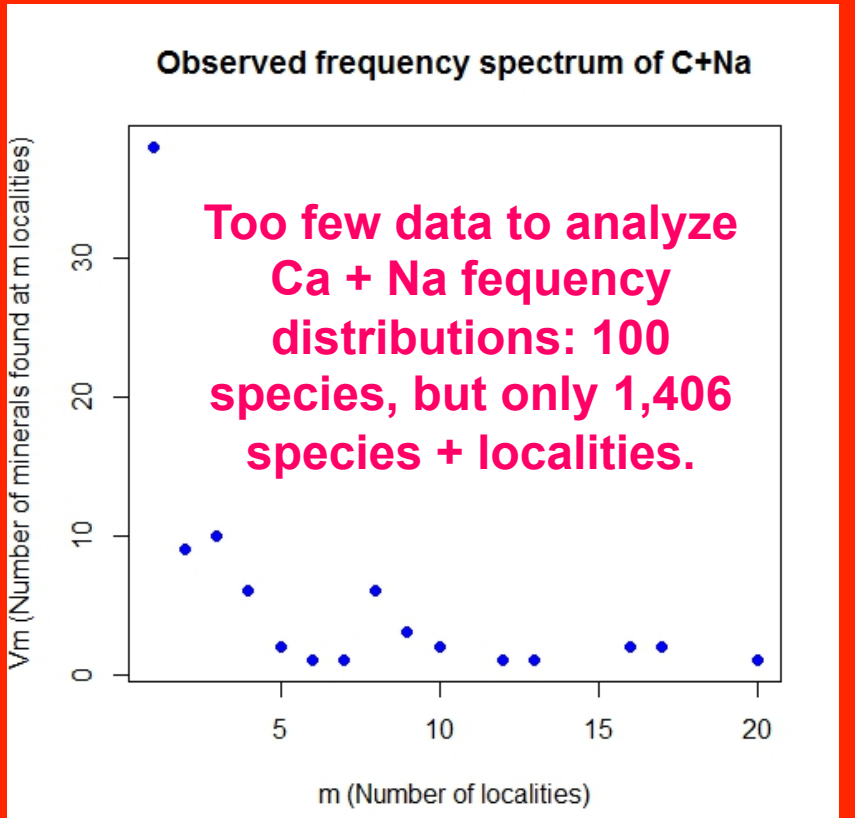


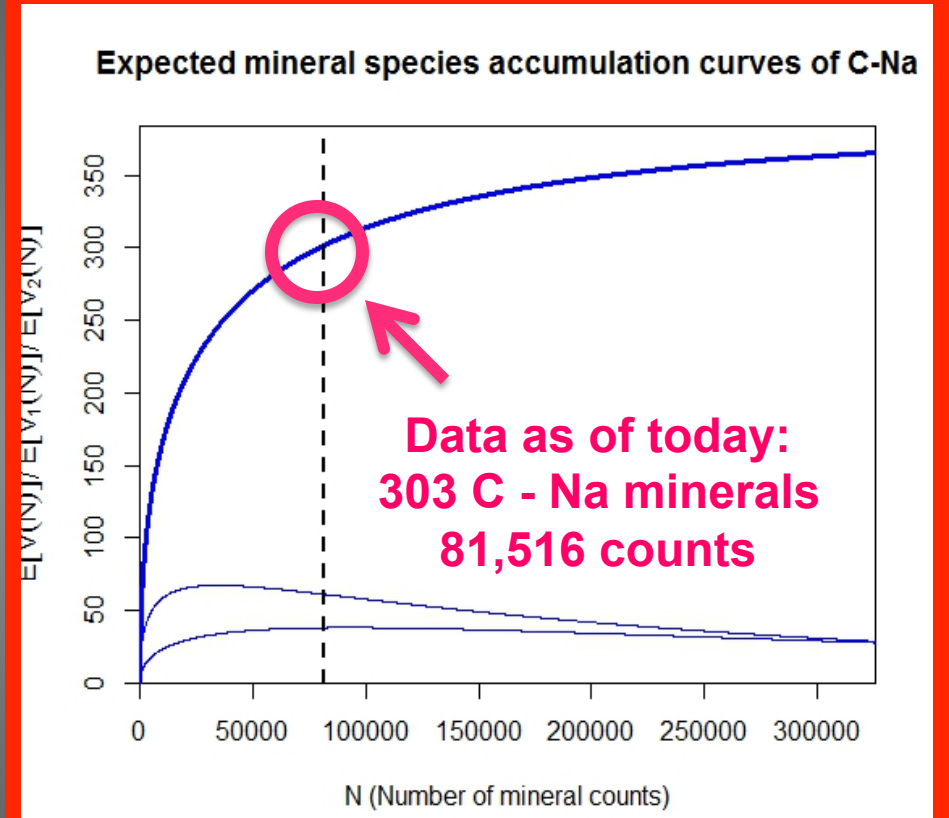


118 of the 145 "missing" carbon mineral species incorporate H.
52 missing C minerals incorporate calcium.

C + Na Minerals: Frequency Distribution

We predict that 82 of the 145 "missing" carbon mineral species do not incorporate Na. Therefore 63 missing Na + C minerals.





Analysis of other subsets, including other coexisting elements, tectonic settings, age, and lithological contexts, will pinpoint where to look for these missing minerals!

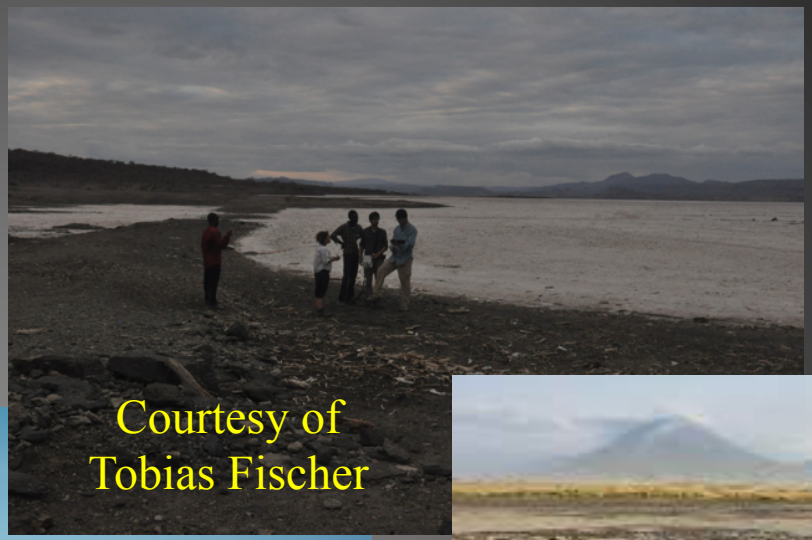
Hydrous sodium carbonates

Nahcolite	$NaHCO_3$
Natron	$Na_2CO_3 \cdot 10H_2O$
Thermonatrite	$Na_2CO_3 \cdot H_2O$
Trona	$Na_3(HCO_3)(CO_3) \cdot 2H_2O$
Wegscheiderite	$Na_5H_3(CO_3)_4$
Predicted	$Na_2CO_3 \cdot 7H_2O$

New phases in the system Na-C-O-H$^{\pm}$Ca$^{\pm}$REE

Why are several hydrous Na carbonates as yet undiscovered? They are boring!

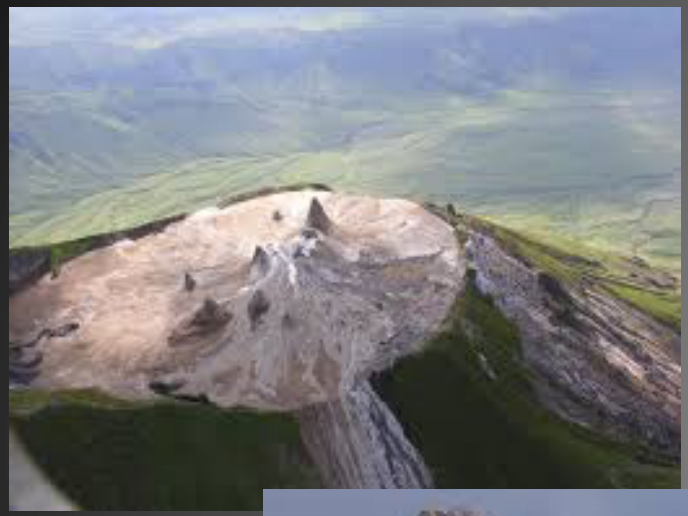
Where should we look?
Lake Natron, Tanzania



Courtesy of
Tobias Fischer

Saline lake evaporites; efflorescence/fumarolic on alkali lavas associated with carbonatites.

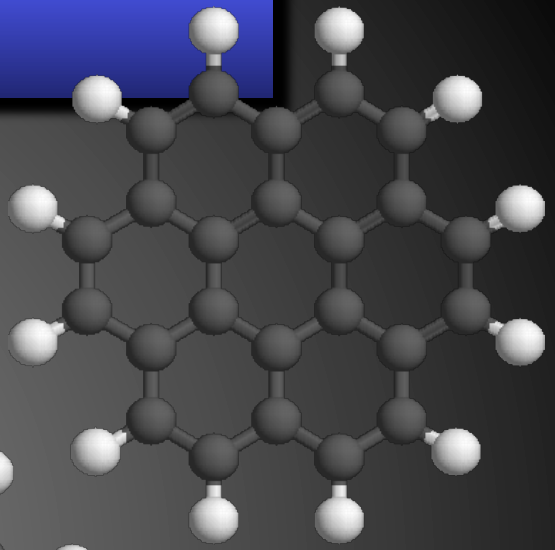
Where should we look?
Oldoigno Lengai, Tanzania



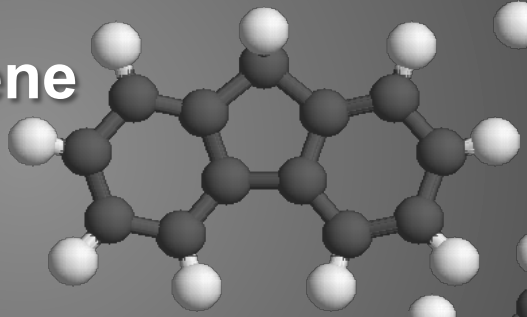
Saline lake evaporites; efflorescence/fumarolic on alkali lavas associated with carbonatites.

Known hydrocarbon minerals PAHs

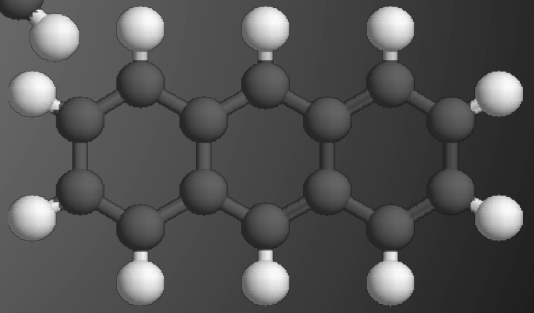
Carpathite ($C_{24}H_{12}$) = Coronene



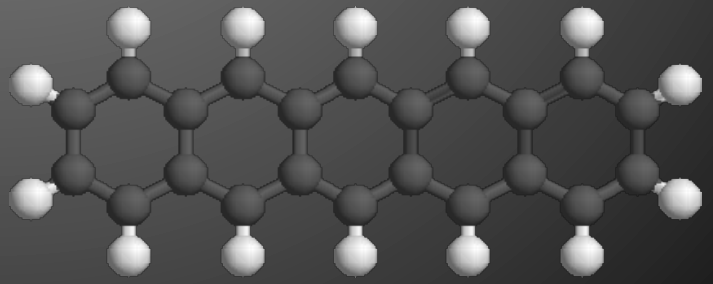
Kratochvilite ($C_{13}H_{10}$) = Fluorene



Ratavite ($C_{14}H_{10}$) = Anthracene

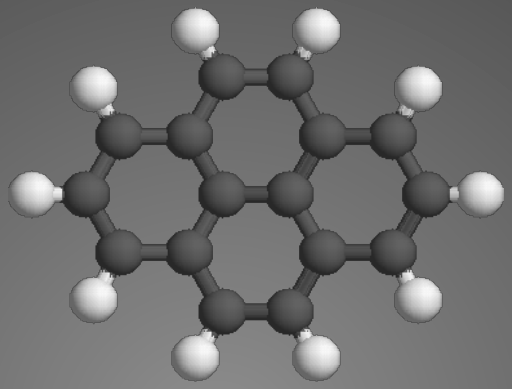


Idrialite ($C_{22}H_{14}$) = Pentacene

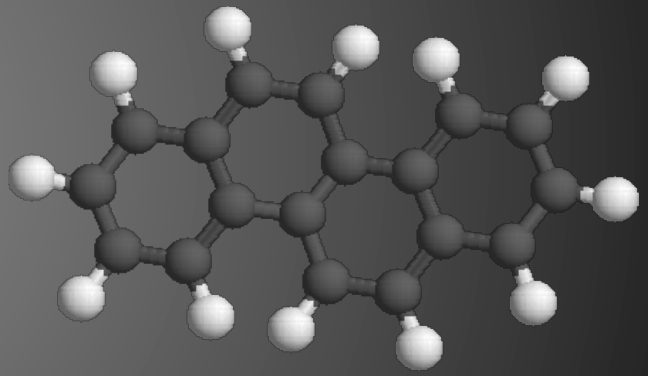


Predicted hydrocarbon minerals PAHs

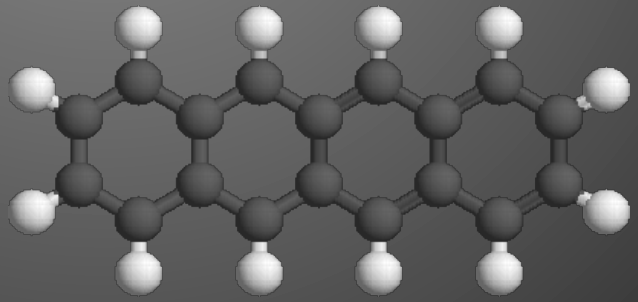
Pyrene ($C_{16}H_{10}$)



Chrysene ($C_{18}H_{12}$)

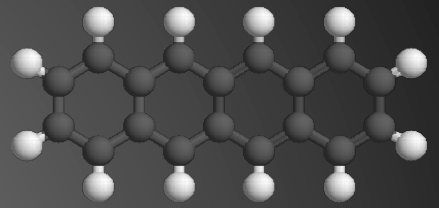


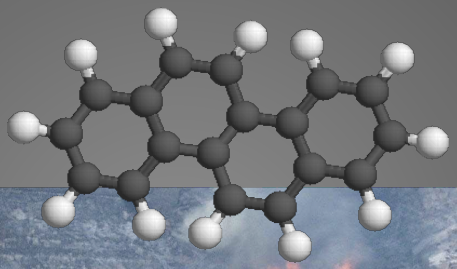
Tetracene ($C_{18}H_{12}$)

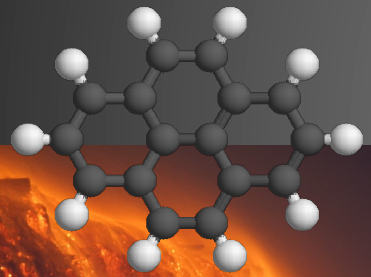


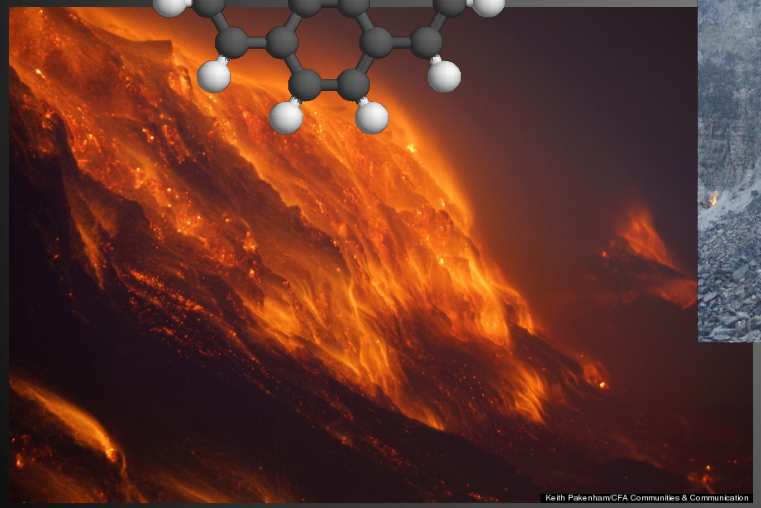
Search for these in thermally altered coal.

Predicted hydrocarbon minerals: PAHs









Search for these phases in thermally altered coal deposits, such as coal mine fires.