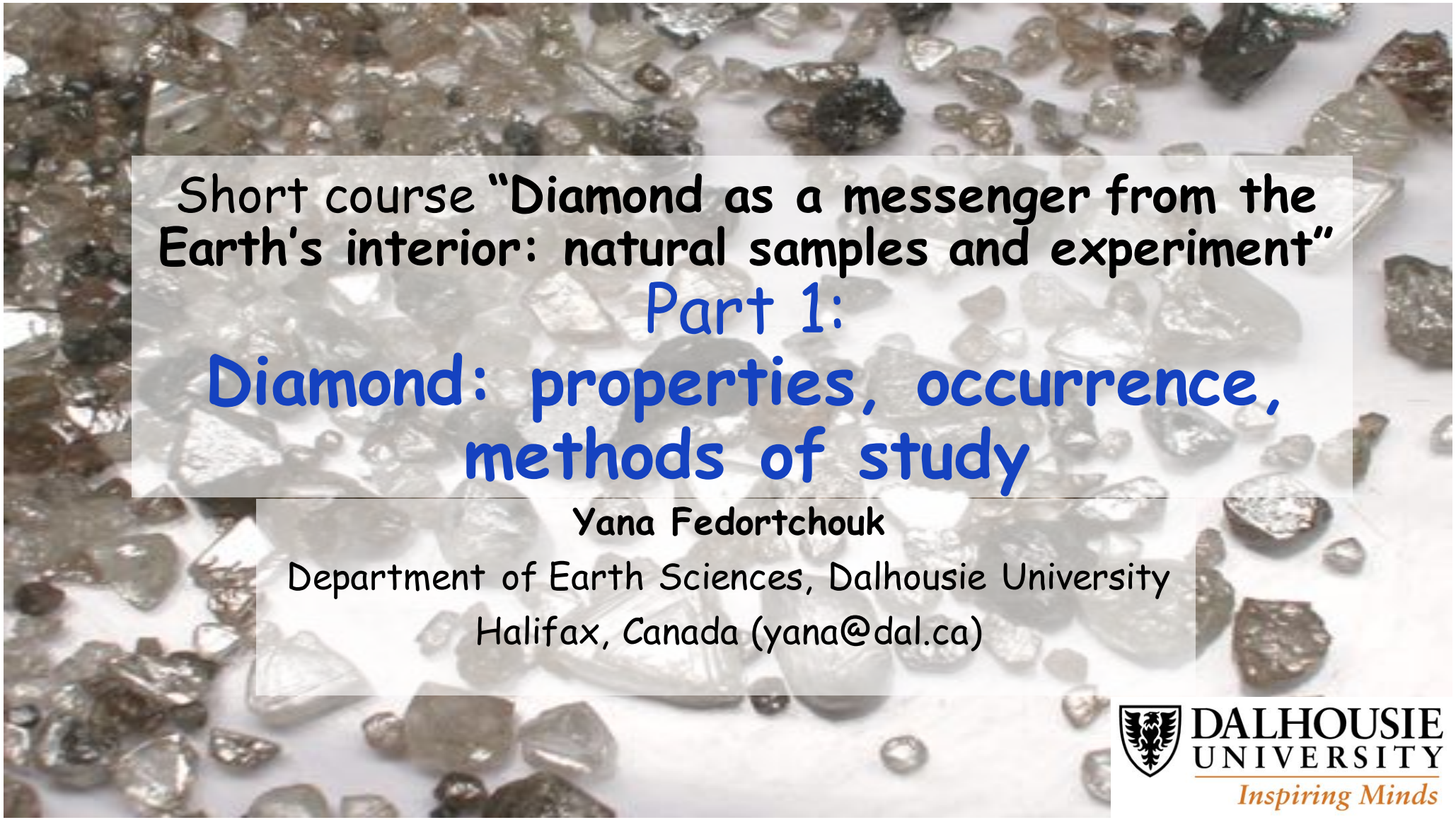

Short course "Diamond as a messenger from the Earth's interior: natural samples and experiment"

Part 1:
Diamond: properties, occurrence, methods of study

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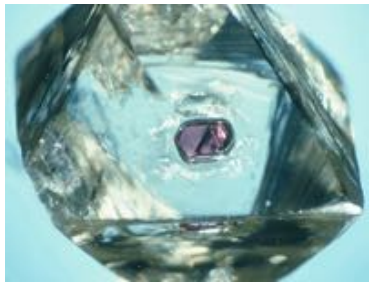
DALHOUSIE UNIVERSITY

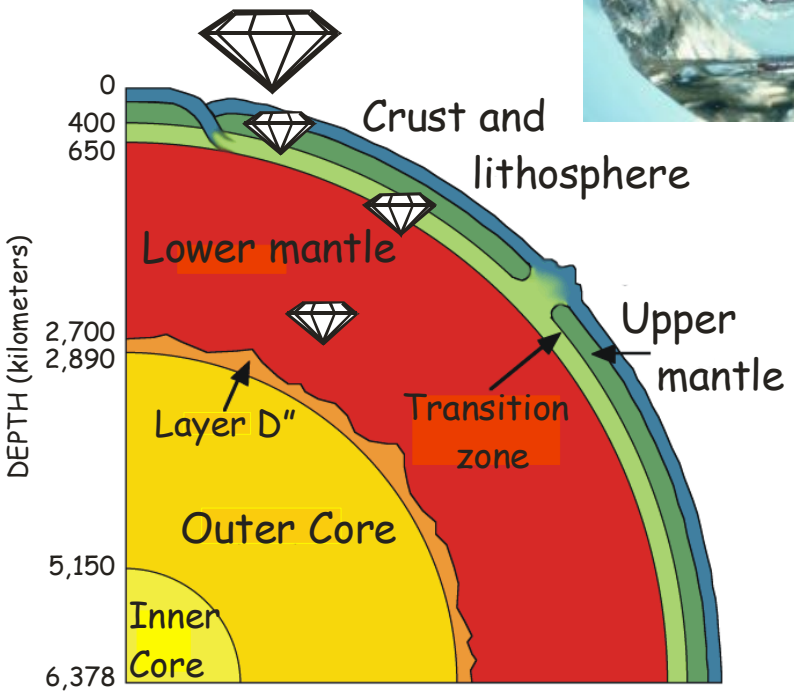
Inspiring Minds

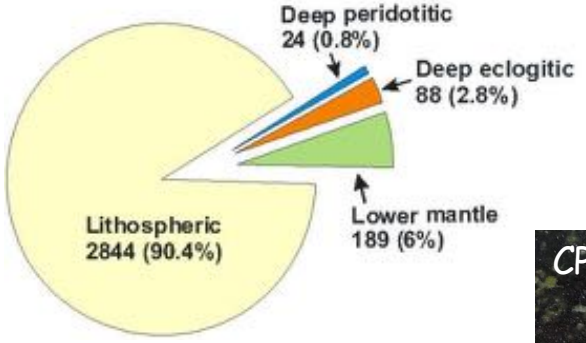
Outline

- Why do we study diamonds? What makes it a unique mineral?
  - age, occurrence, properties
- Where do we find diamonds?
  - Primary sources (kimberlites, lamproites) and placers
  - Unconventional diamond sources
  - Ultra-high pressure metamorphic rocks
- What can we learn from diamonds?
- Review of diamond properties and modern analytical techniques used in diamond studies
  - Composition (impurities) – nitrogen
  - Carbon and nitrogen isotopes
  - Inclusions: mineral and fluid
  - Age dating

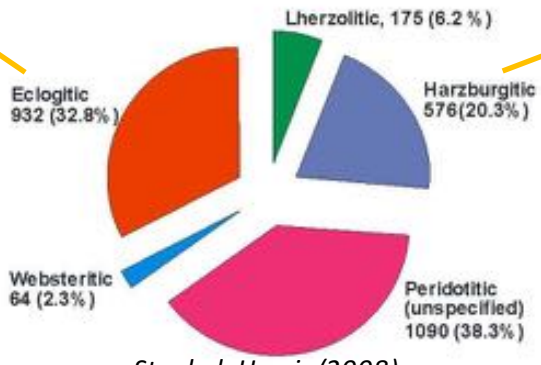
Why do we study diamonds? What makes it a unique mineral?



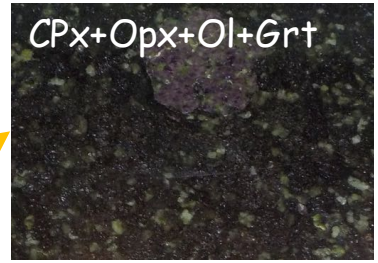


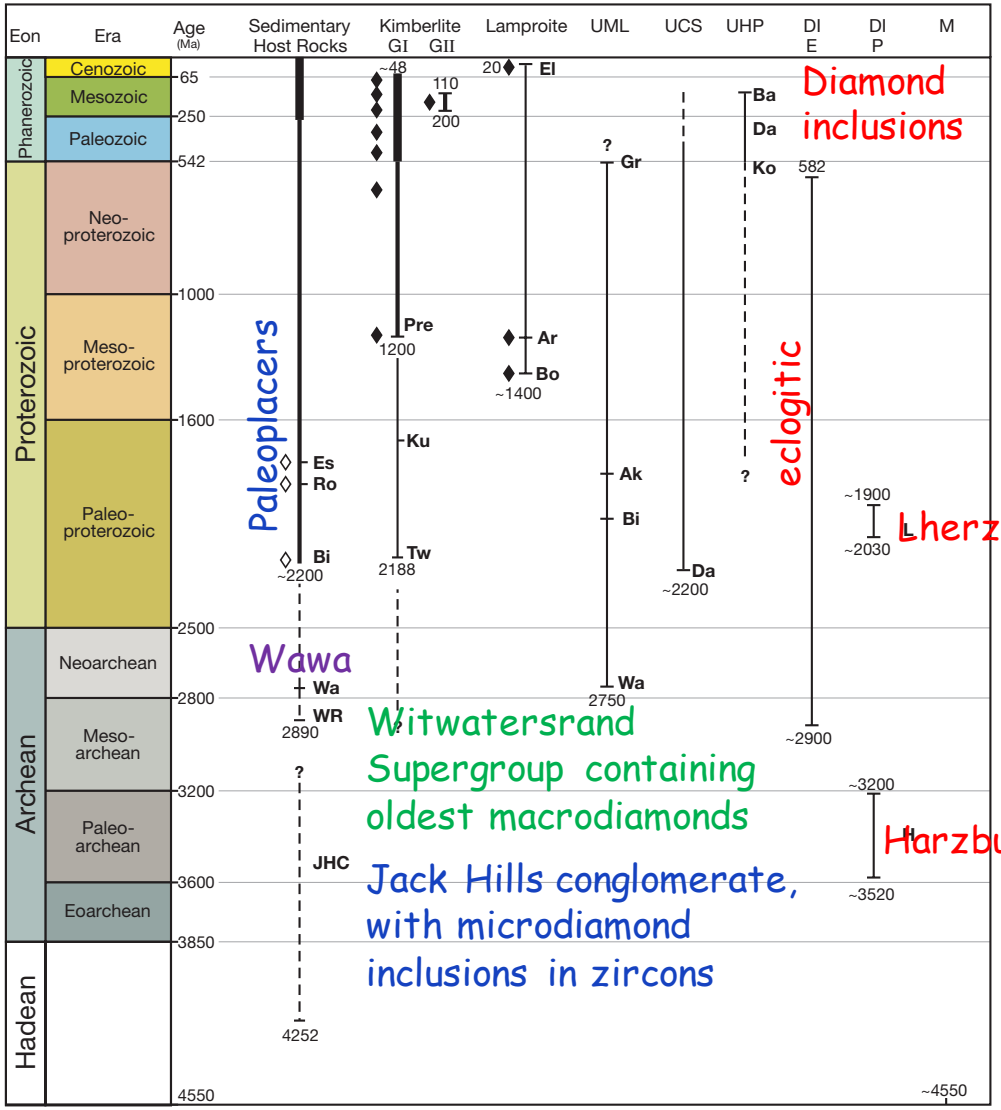


Stachel, Harris (2008)



Stachel, Harris (2008)

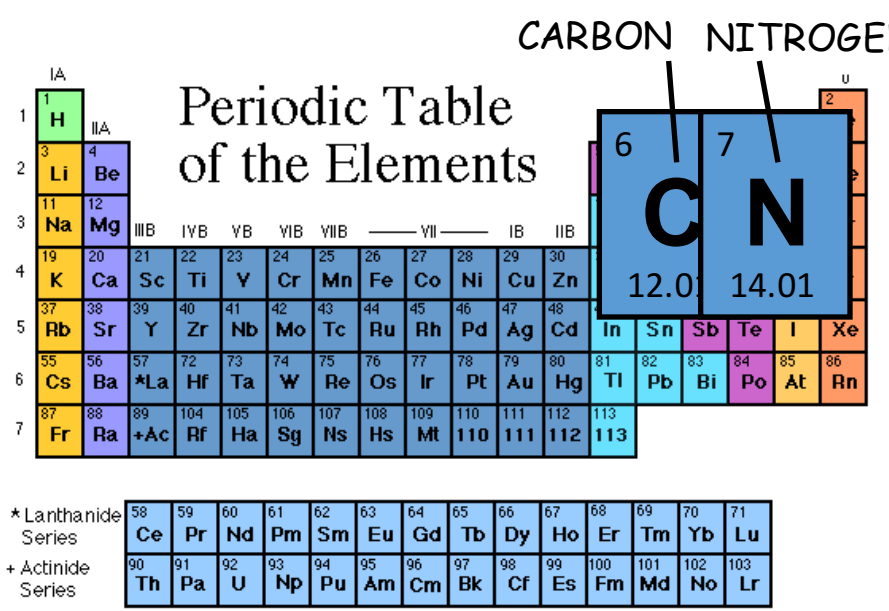


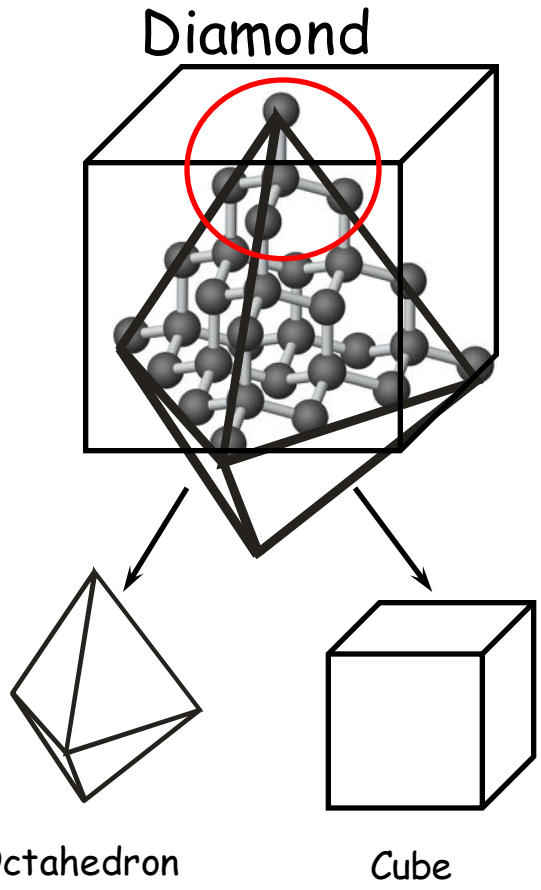


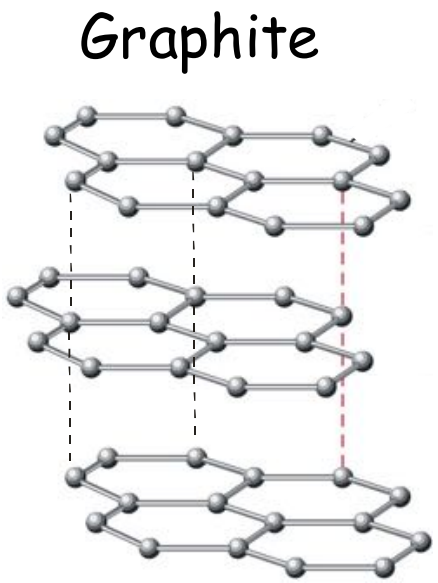
Gurney et al. (2010)

Age ranges (in Ma) of diamond deposits, diamond-bearing rocks, and diamond inclusion minerals.

Chemistry and structure

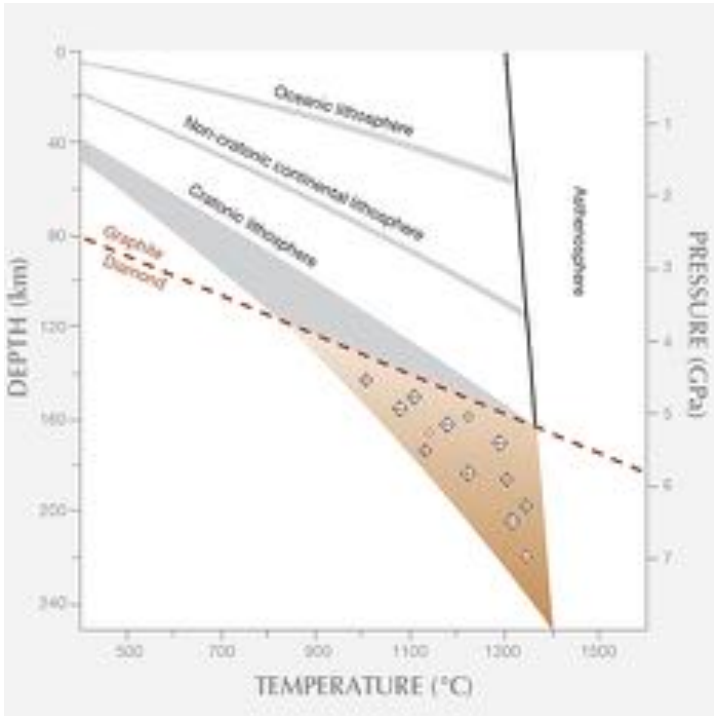




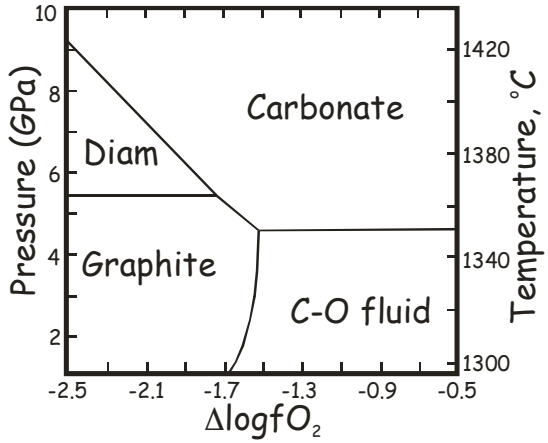


- Simple chemistry & compact structure,
- The hardest mineral
- Chemically and mechanically stable:
  - during long history in the mantle
  - During transportation in magma
  - In surface environment

Carbon in the Earth



From Tappert and Tappert (2011), Day (2012)

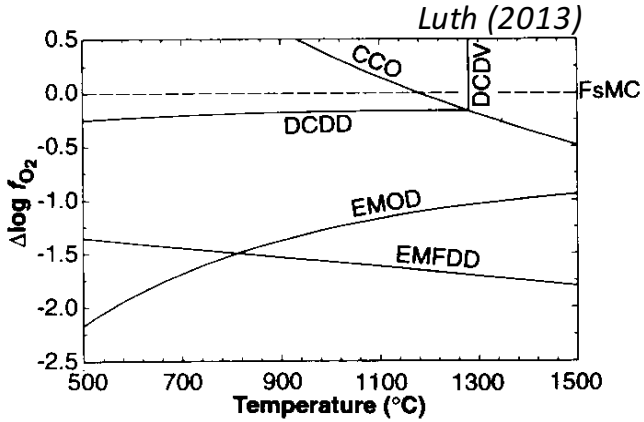


(Frost & Wood, 1997)

$C + O_2 = CO_2$
fluid

$CO_2 + (Ca,Mg)O = (Ca,Mg)CO_3$
carbonate

- High Pressure,
- low Temperature,
- Reduced conditions



DCO $C + O_2 = CO_2$

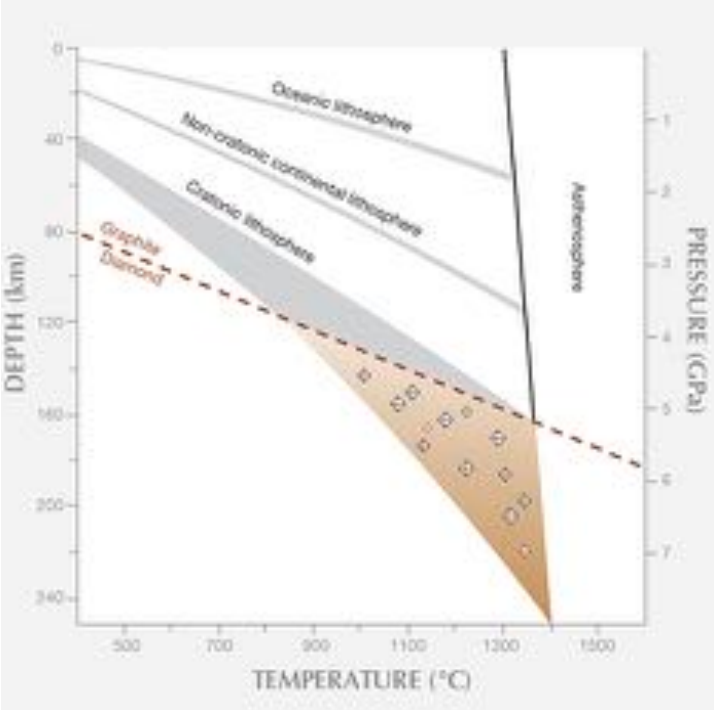
Peridotite:

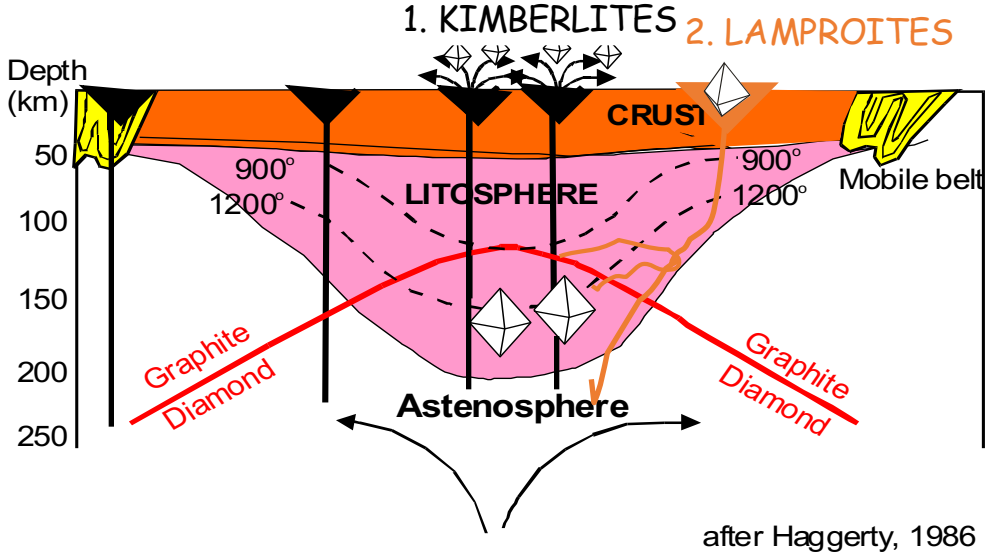
EMOD $MgSiO_3 + MgCO_3 = Mg_2SiO_4 + C + O_2$
enstatite magnesite olivine diamond

Eclogite:

DCDD $CaMg(CO_3)_2 + 2SiO_2 = CaMgSi_2O_6 + 2C + 2O_2$
dolomite coesite diopside diamond

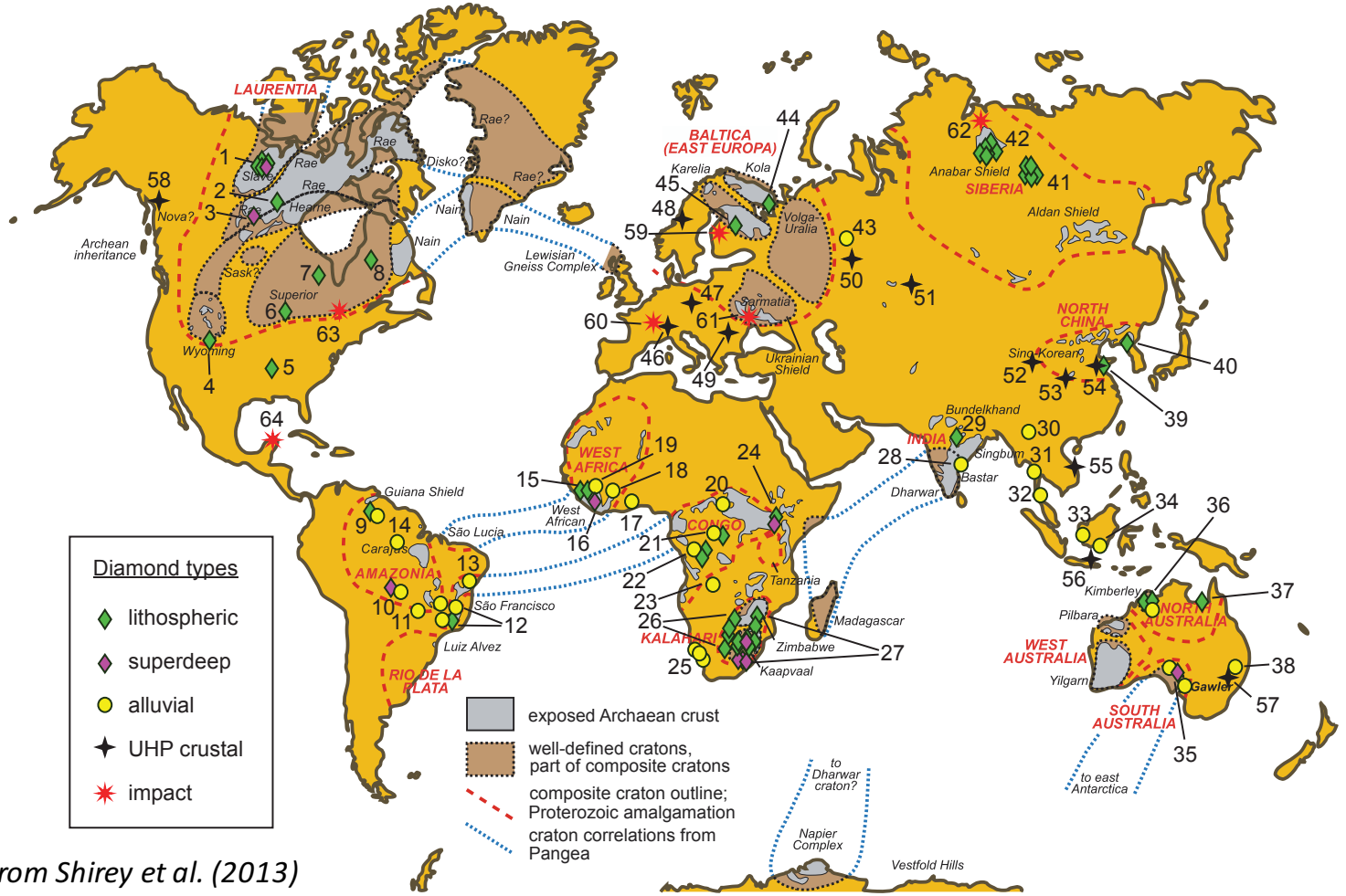
Where do we find diamonds?





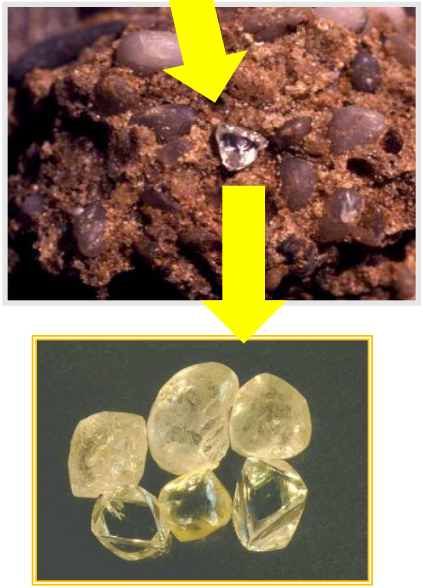
From Tappert and Tappert (2011), Day (2012)

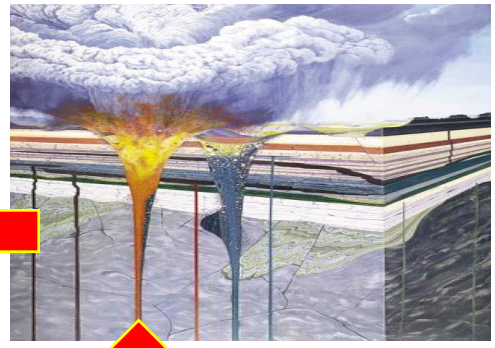
Where do we find diamonds?

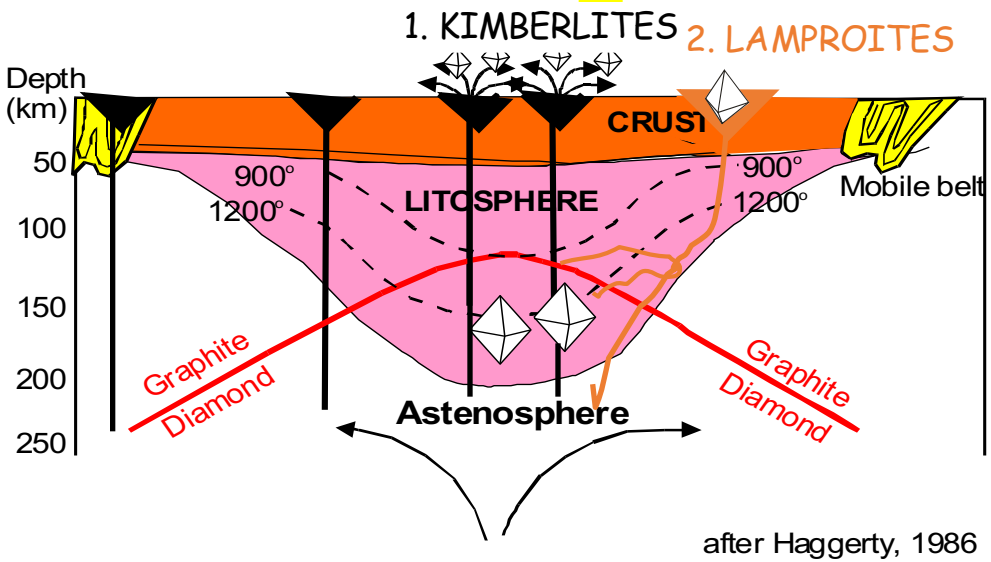


From Shirey et al. (2013)

Diamond primary sources





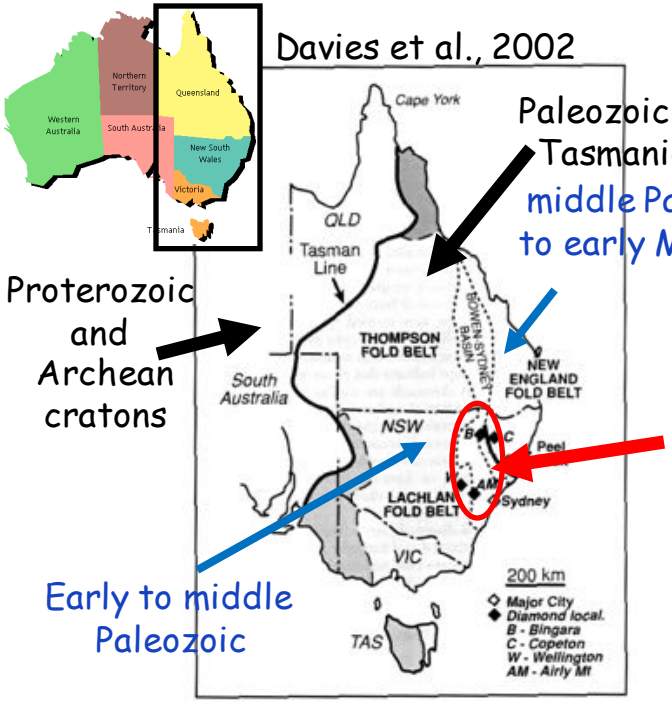


after Haggerty, 1986

Unconventional diamond sources

Headless placer diamond deposits:

East-Australian diamonds:



Paleozoic- Mesozoic Tasmanide orogen

middle Paleozoic to early Mesozoic

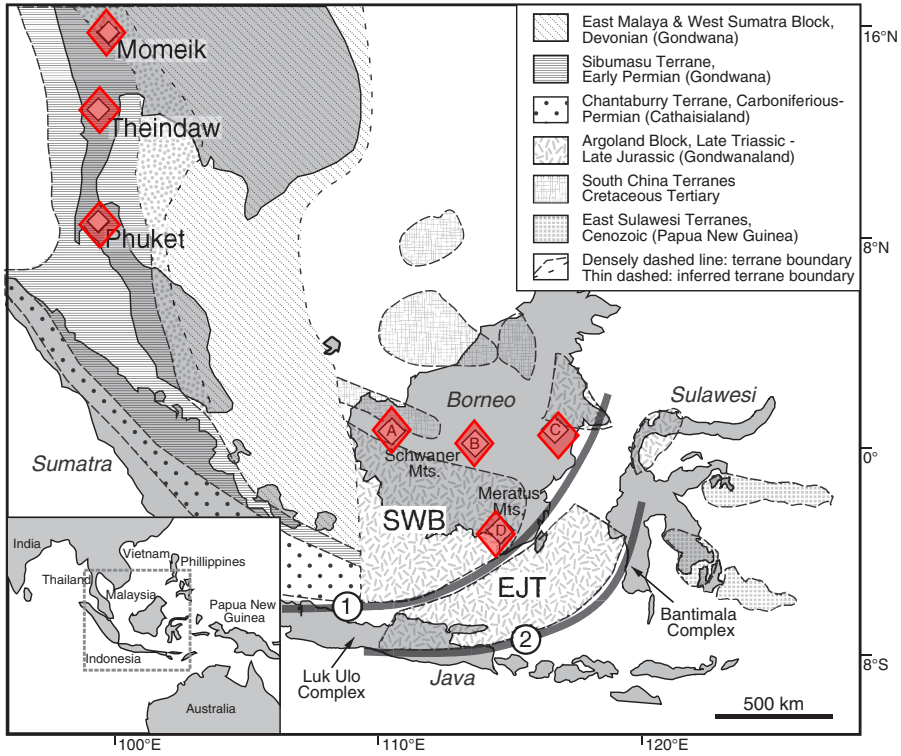
Proterozoic and Archean cratons

Early to middle Paleozoic

Diamond-bearing alluvium:

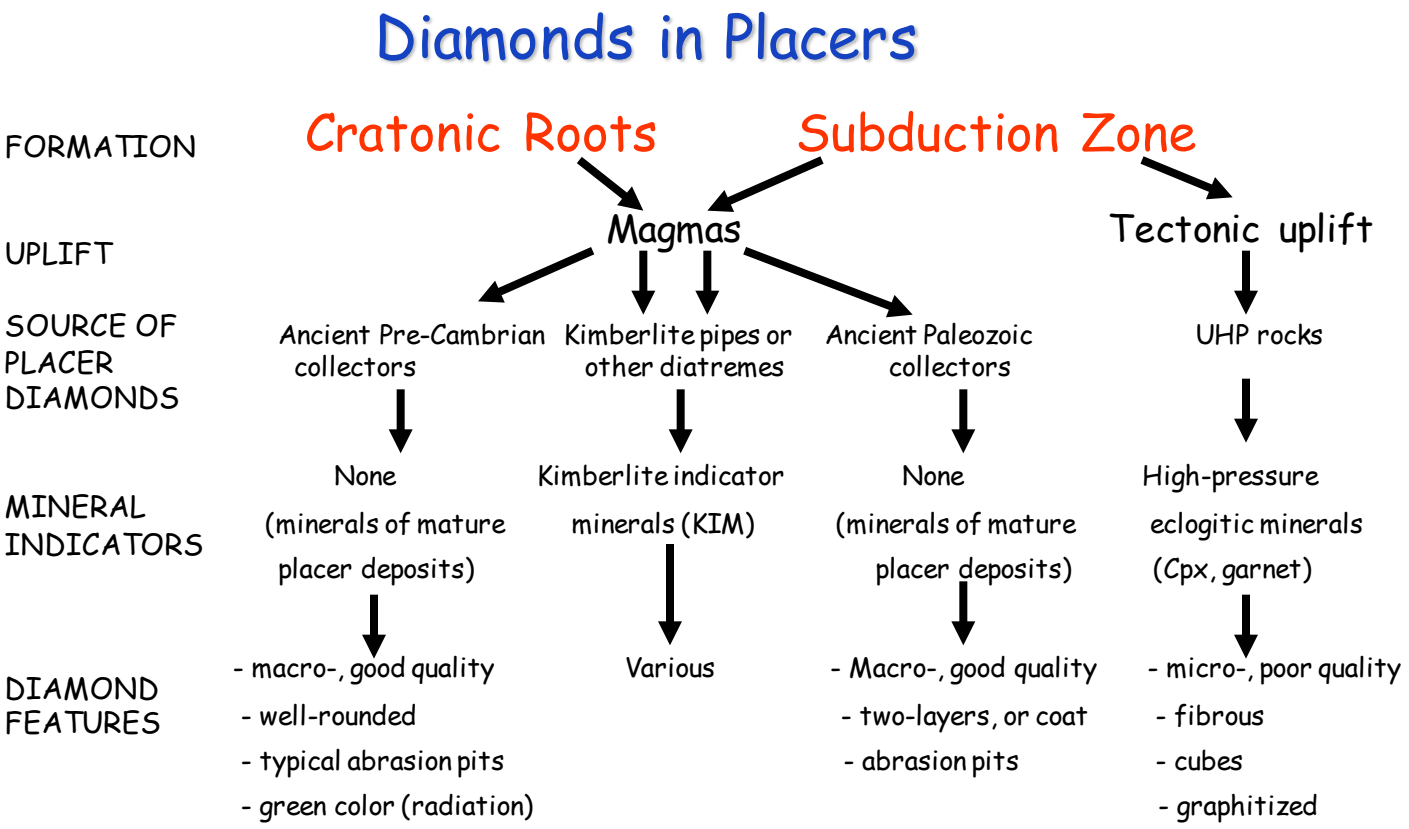
Gold, cassiterite, corunmum, topaz, almandin garnet, zircon mature placer, no Diamond Indicator Minerals

Kalimantan diamonds:

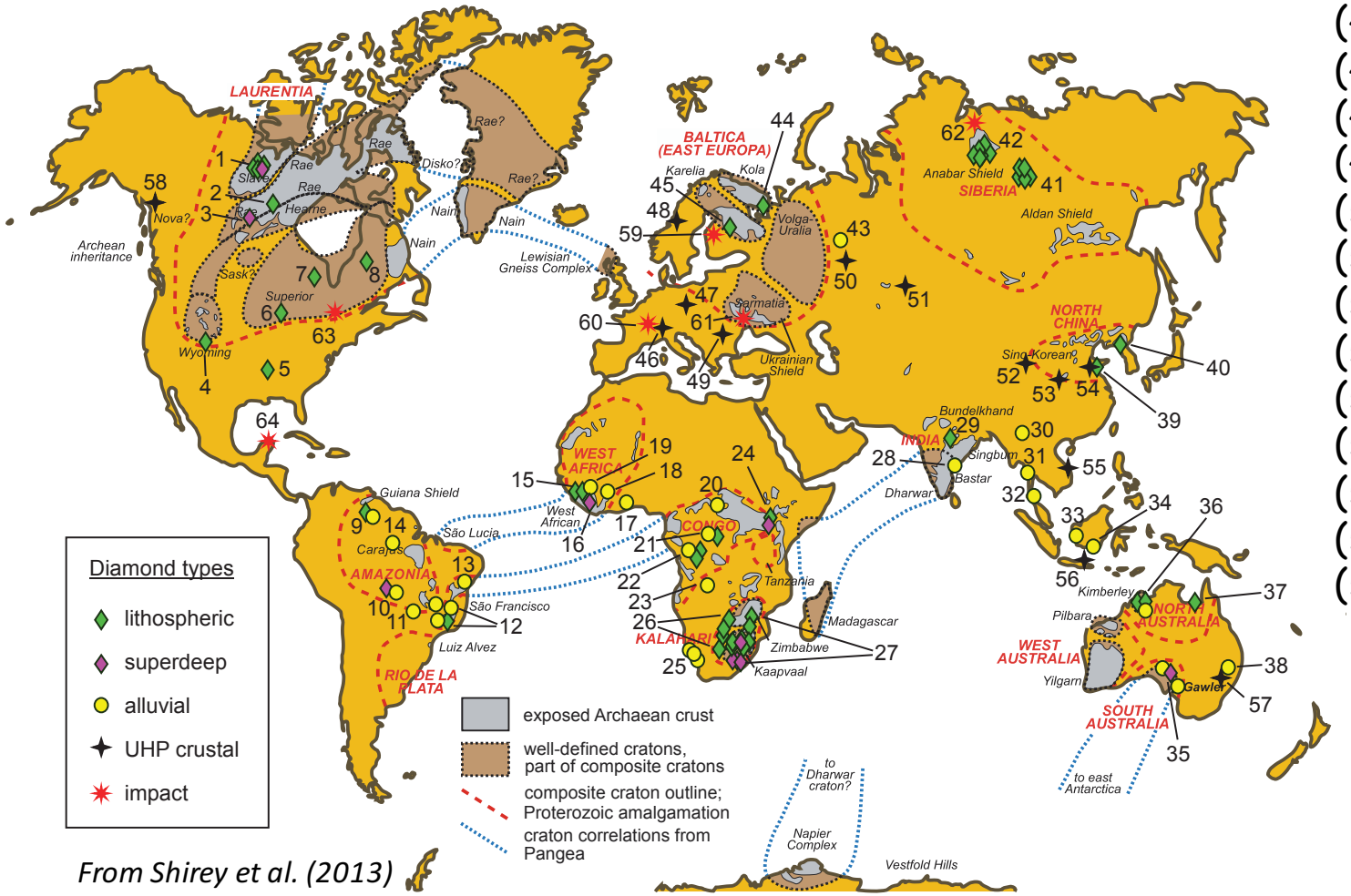


Kuter et al. (2016)

Unconventional diamond sources



Ultra-high pressure rocks

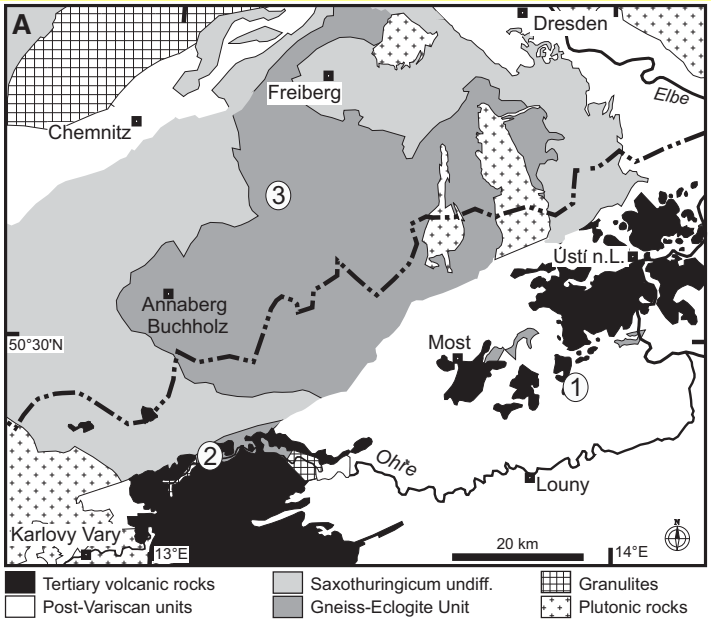


From Shirey et al. (2013)

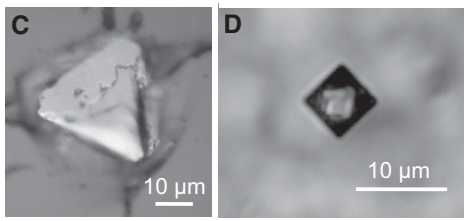
(46) W Alps;
(47) Moldanubian;
(48) Norway;
(49) Rhodope;
(50) Urals;
(51) Kokchetav;
(52) Qinling;
(53) Dabie;
(54) Sulu;
(55) Kontum;
(56) Java;
(57) New England Fold Belt;
(58) Canadian Cordillera;

Ultra-high pressure rocks

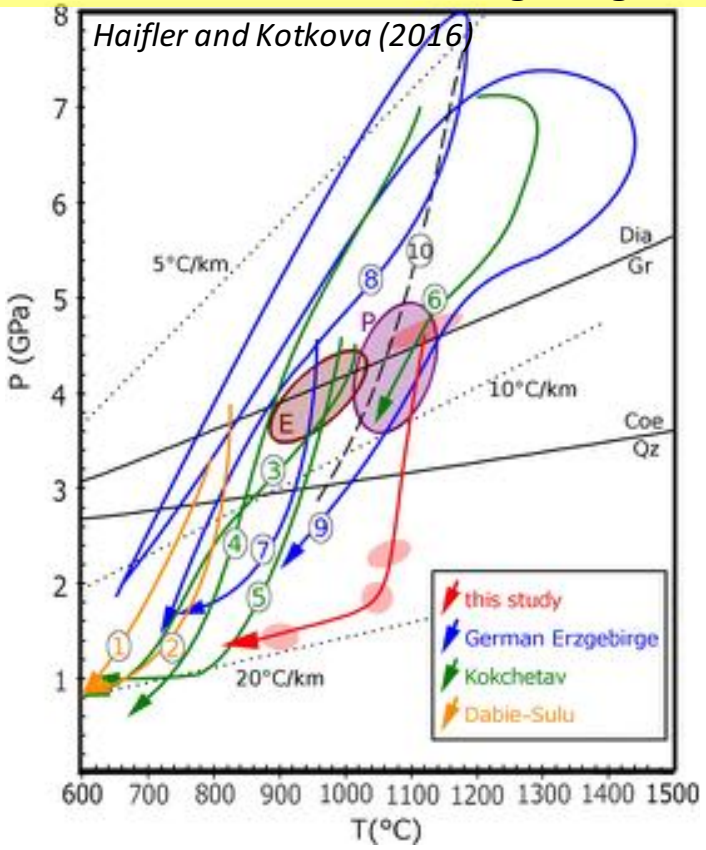
Discovery of diamond-bearing granulites in Eger Crystalline Complex of North Bohemian Massif



Kotkova et al. (2011)

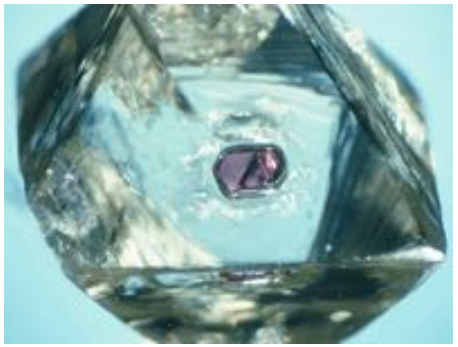


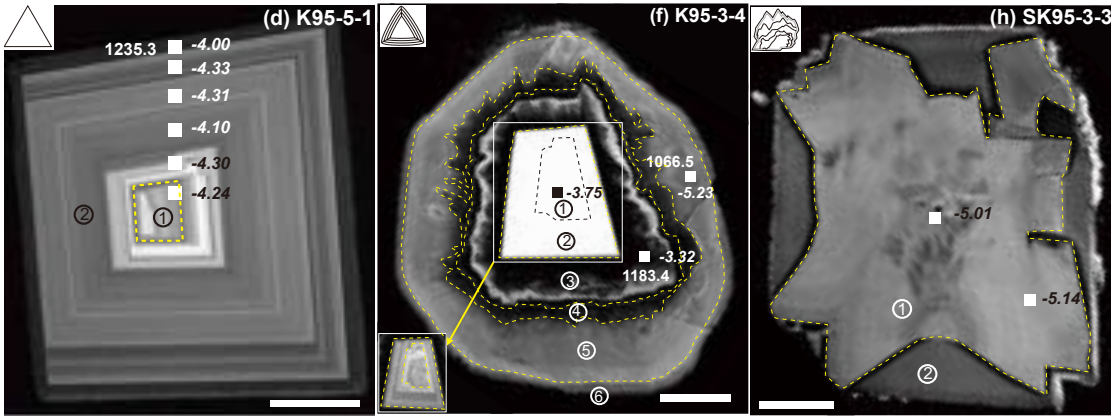
P–T evolution of garnet-clinopyroxene UHP rocks from the North Bohemian Massif, Dabie-Sulu, the Kokchetav Massif, and the German Erzgebirge.



What can we learn from diamonds?

- Processes in the Earth mantle
- Evolution of mantle processes through time
- Multiple diamond-growth events, sampling of different stages of mantle history (variable age of kimberlites) – snap-shots



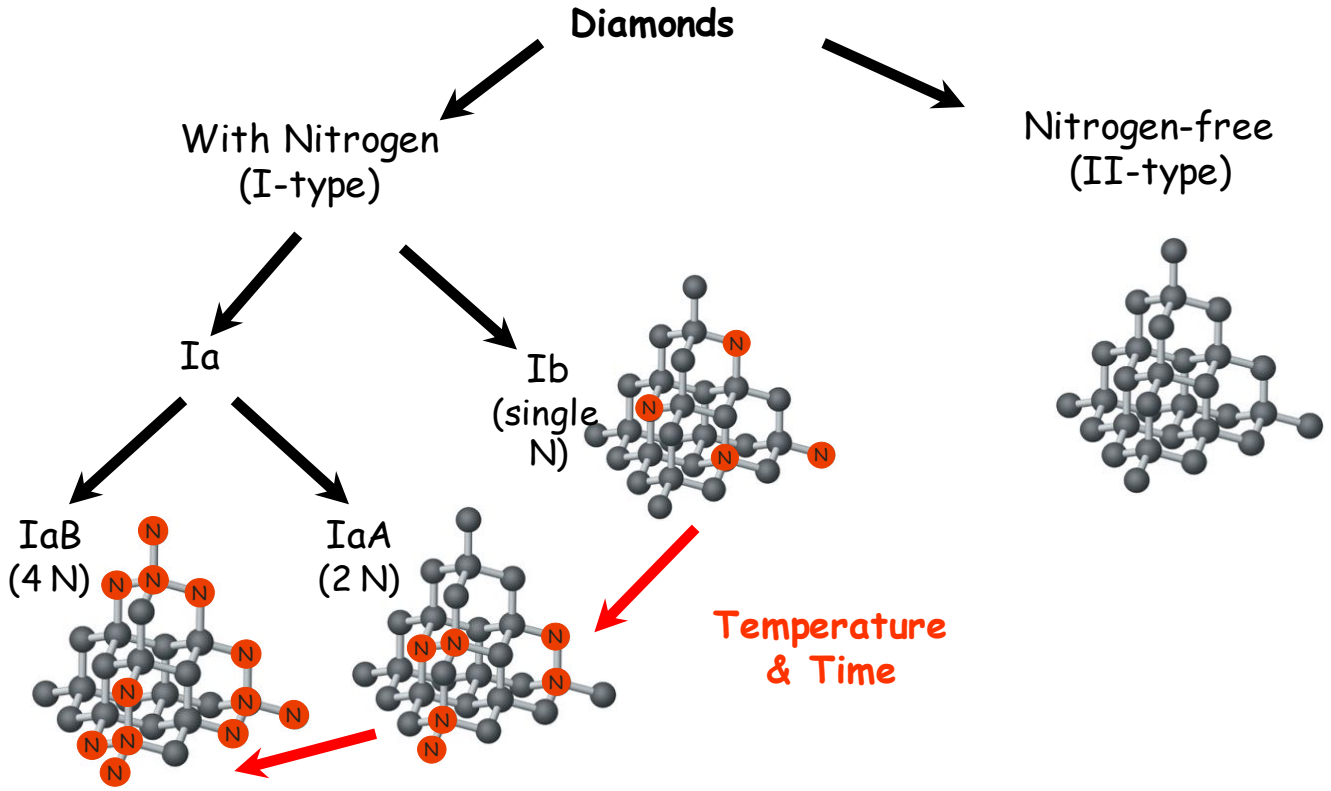


Review of diamond properties and modern analytical techniques used in diamond studies

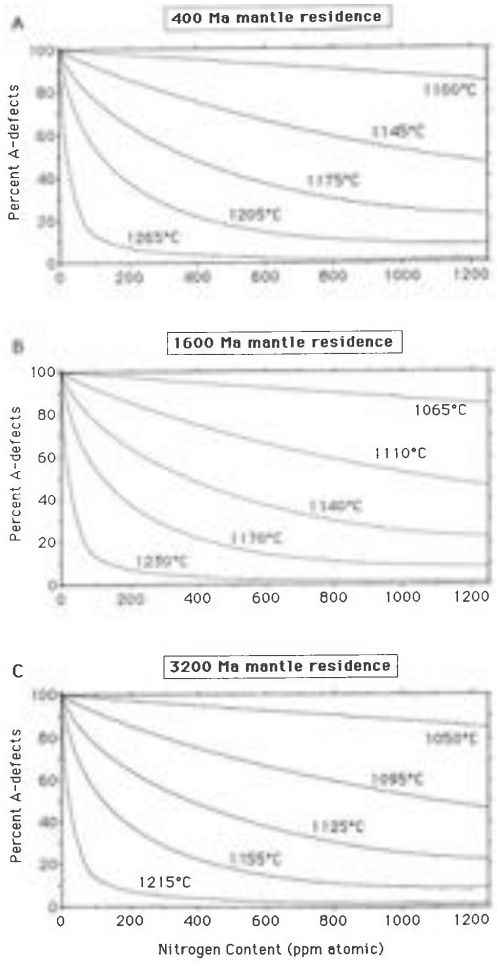
- Composition (impurities) – nitrogen
- Carbon and nitrogen isotopes
- Inclusions: mineral and fluid
- Age estimates

Nitrogen impurities in diamond

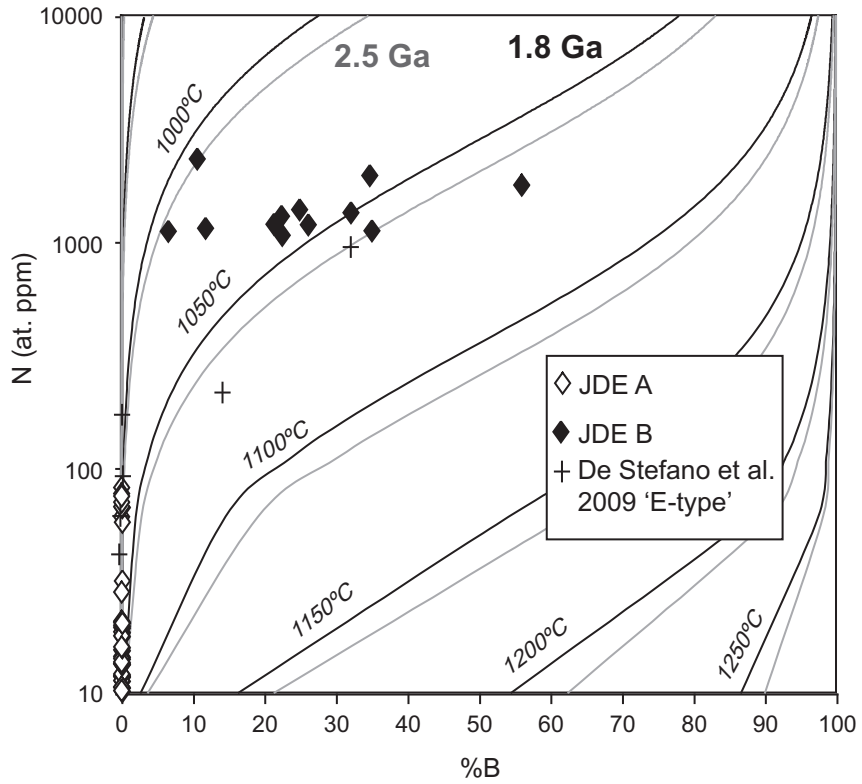
(Average 300 ppm, up to 0.2%)



Nitrogen impurities in diamond

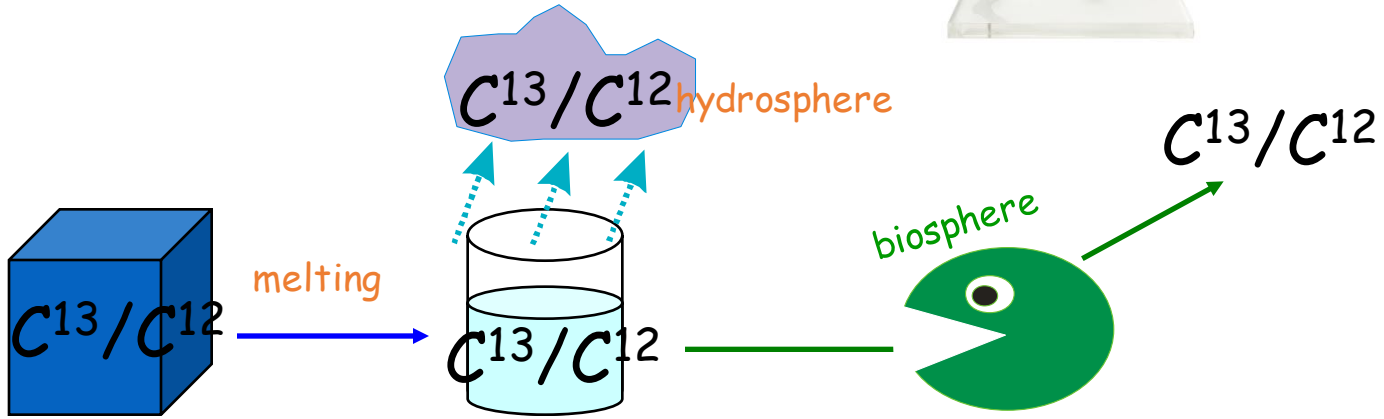


Taylor et al. (1990)



Smart et al. (2011)

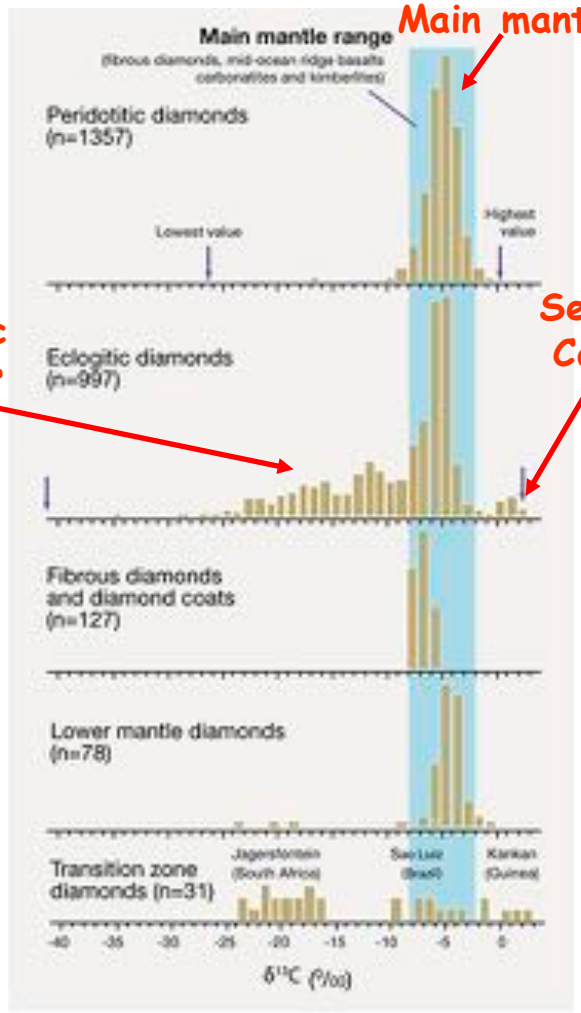
Carbon isotopes



Source of the material

primitive mantle **Recycled Earth's crust**

Carbon isotopes



Main mantle range

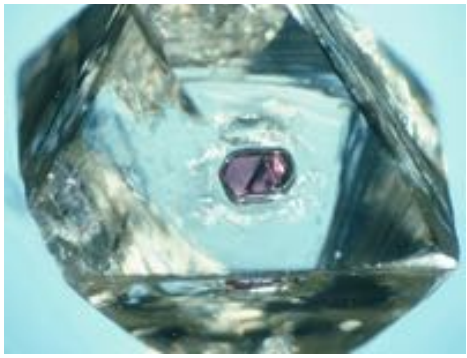
Organic Matter

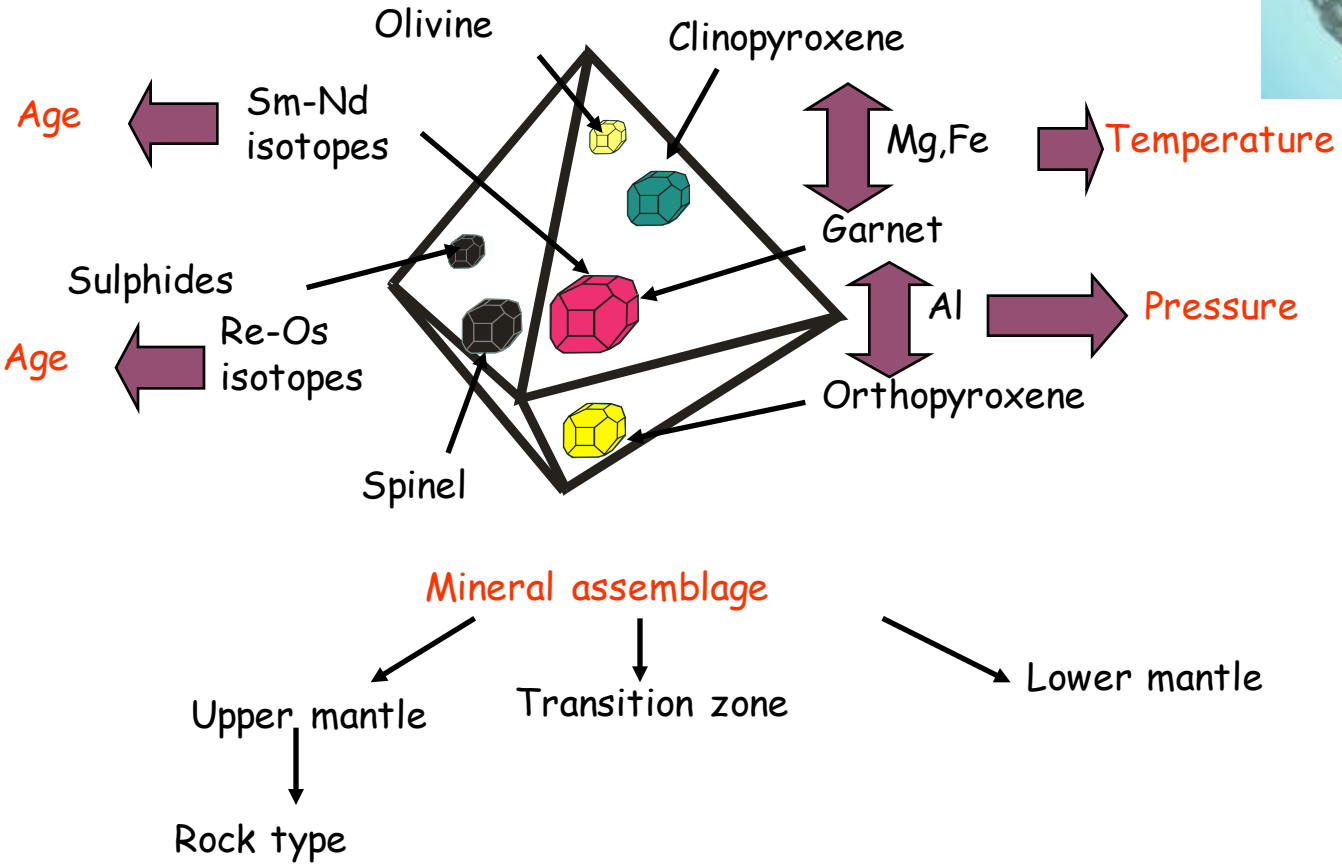
Sedimentary Carbonates

From Shirey and Shingley (2013)

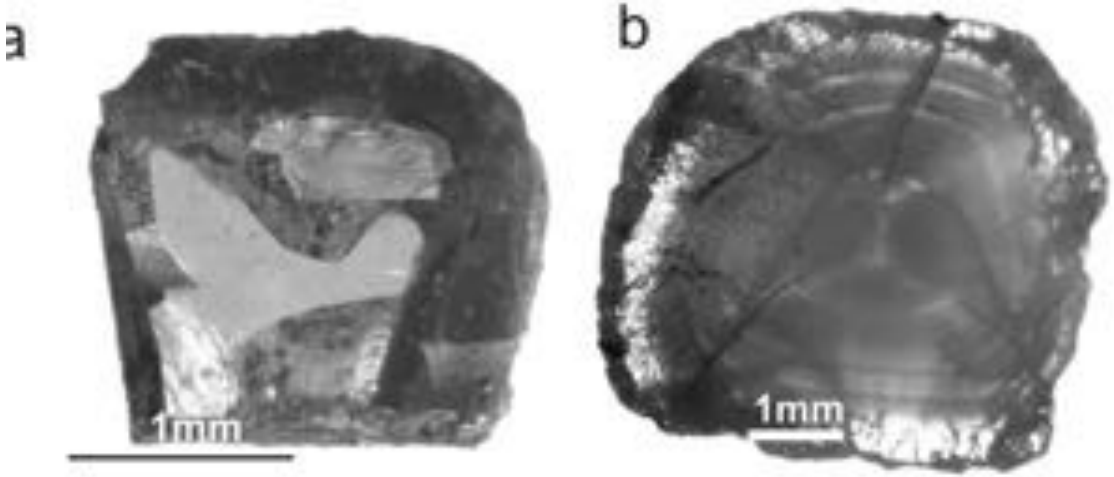
Mineral inclusions

(25 mineral species)

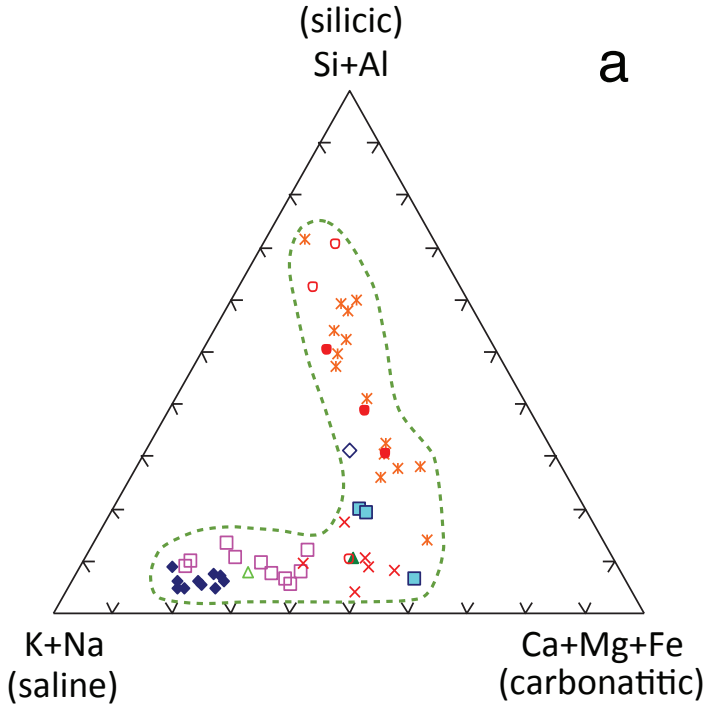




Fluid inclusions



From Klein-BenDavid et al. (2006)



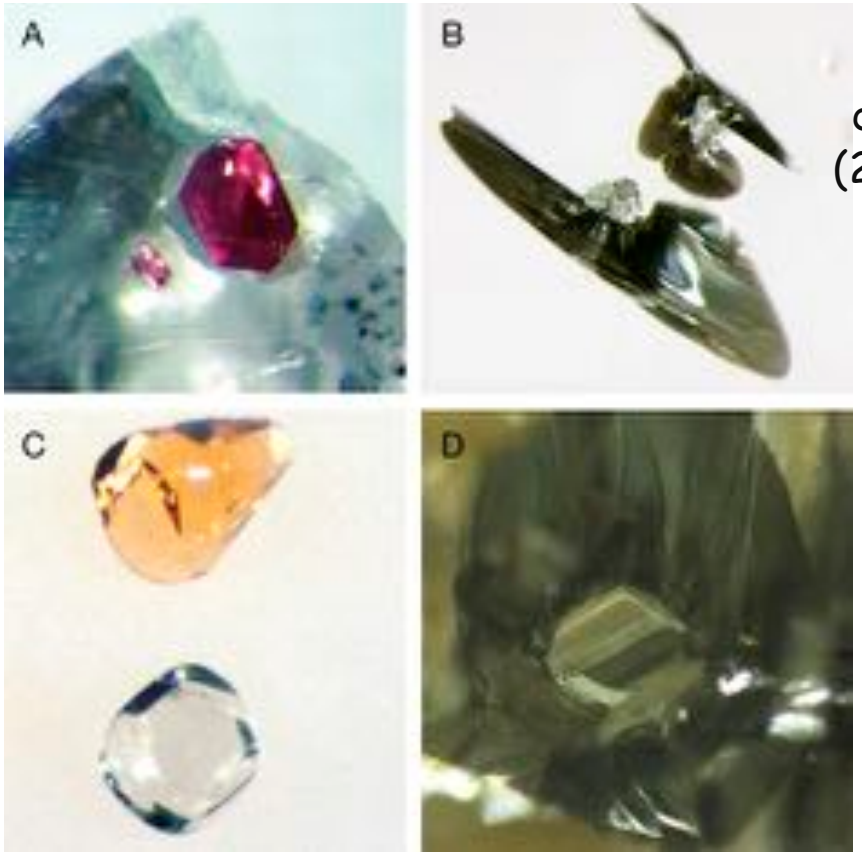
From Shirey et al. (2013) and references therein

Diamond ages

Silicate mineral inclusions in diamond used for radioisotopic Rb-Sr and Sm-Nd age dating by Richardson et al. (1984, 1986)

Peridotitic
Harzburgitic garnet
(high in Cr, low in Ca)

Eclogitic
Orange garnet
and
colorless clinopyroxene



From Shirey and Shingley (2013)

Sulfide mineral inclusions in diamond used for radioisotopic Re- Os age dating by Westerlund et al. (2006), Pearson et al. (1998). Richardson et al., (2001).

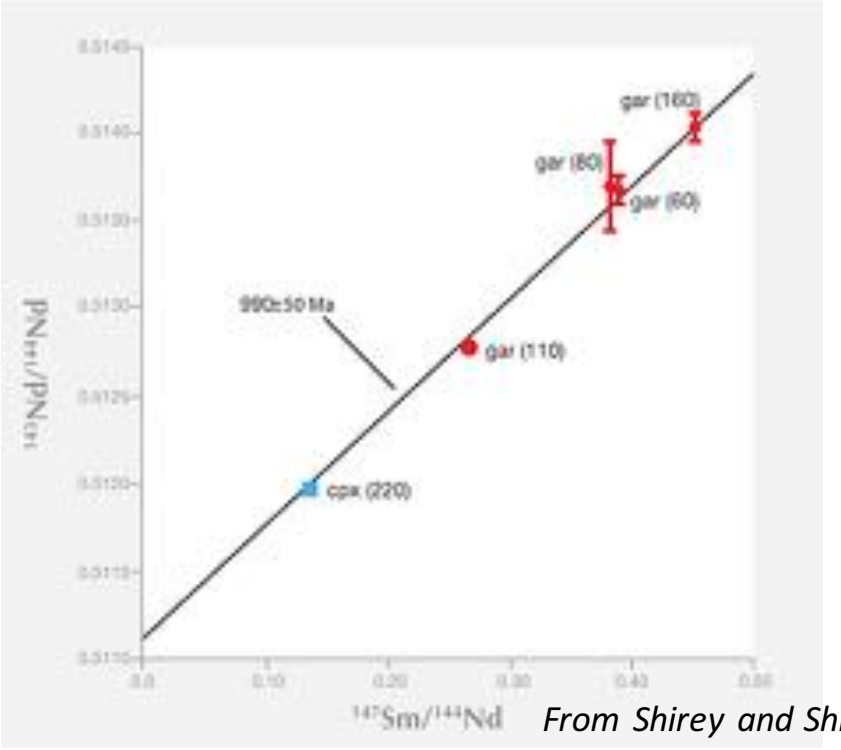
Peridotitic
Ni-rich iron sulfide
(pentlandite)

Eclogitic
Ni-poor iron sulfide
(pyrrhotite)

Diamond ages

Sm-Nd dating of silicate inclusions in diamond

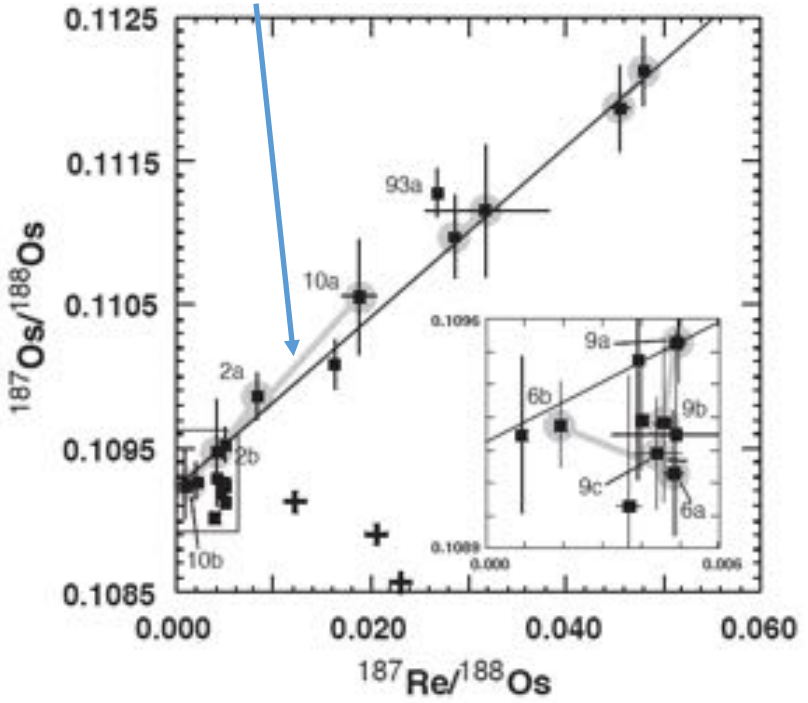
The data obtained by breaking apart 630 inclusion-bearing diamonds and grouping each set of inclusions as clinopyroxene (cpx) or garnet (gar).



From Shirey and Shingley (2013)

Re-Os dating of sulfide inclusions in diamond

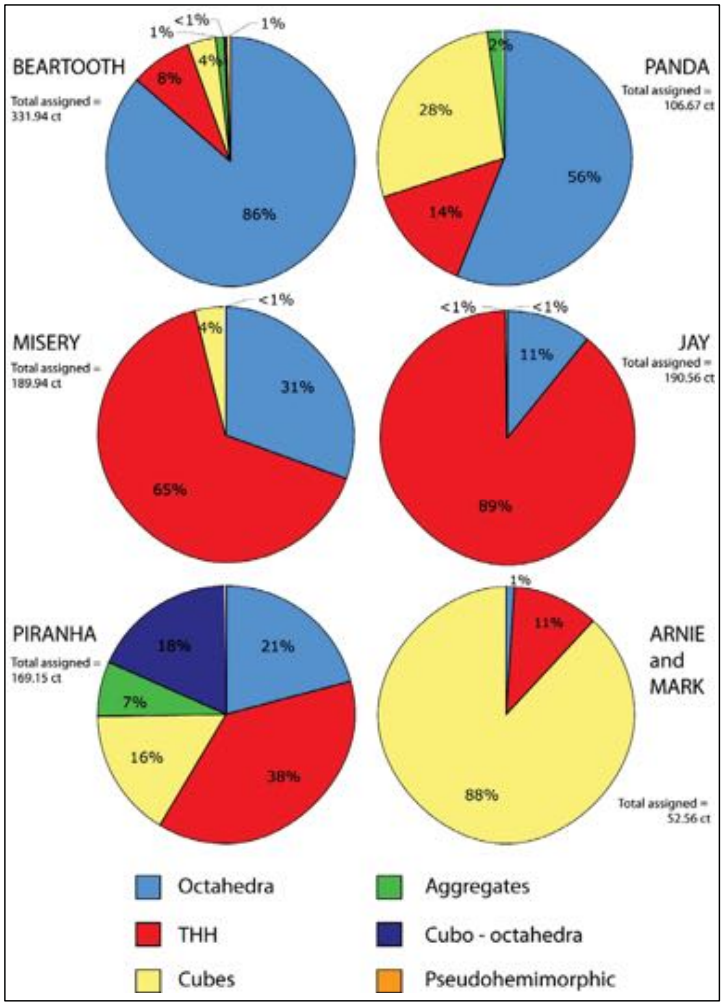
Multiple sulfide inclusions from single diamonds



Gurney et al. (2010)

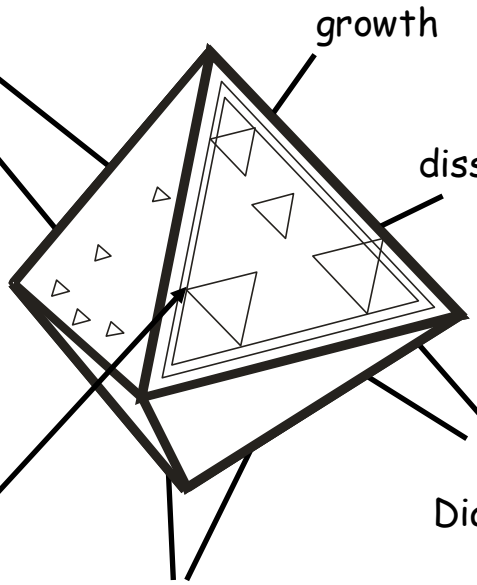
Surface features

Morphology of diamonds in six kimberlites from Ekati diamond Mine, Canada. Gurney et al. (2004, 2010).



Conditions in the mantle and in kimberlite magma

What a diamond can tell us



Inclusions

1. Where the diamond was formed:
   - rock type
   - lower mantle?
2. Age of the diamond
3. T and P during growth

C^{13}/C^{12} isotopes
source of the carbon
Diamond growth processes

Surface features -
conditions in
kimberlite magma

Nitrogen aggregation -
temperature during diamond
residence in the mantle


Thank you!