Phyllosilicates produced by impact-generated hydrothermal systems on Mars.

Susanne P. Schwenzer and David A. Kring

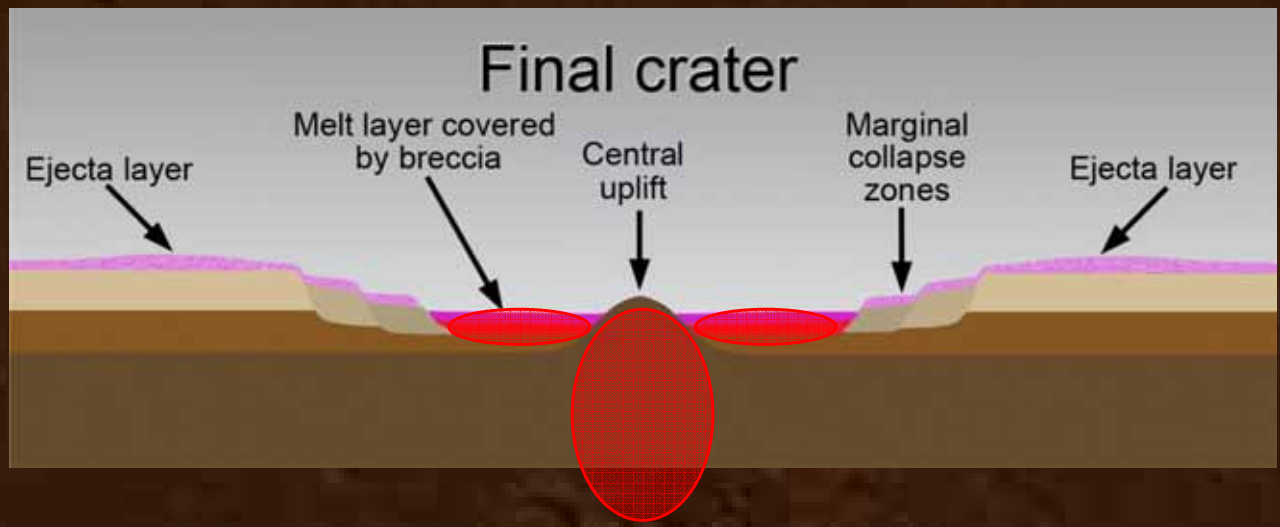
Arabia region with Cassini crater, picture credit: NASA

Impact ... in principle

terrestrial scale!

pre-impact:
- local geology
- water may be
  - groundwater
  - ice
  - in minerals

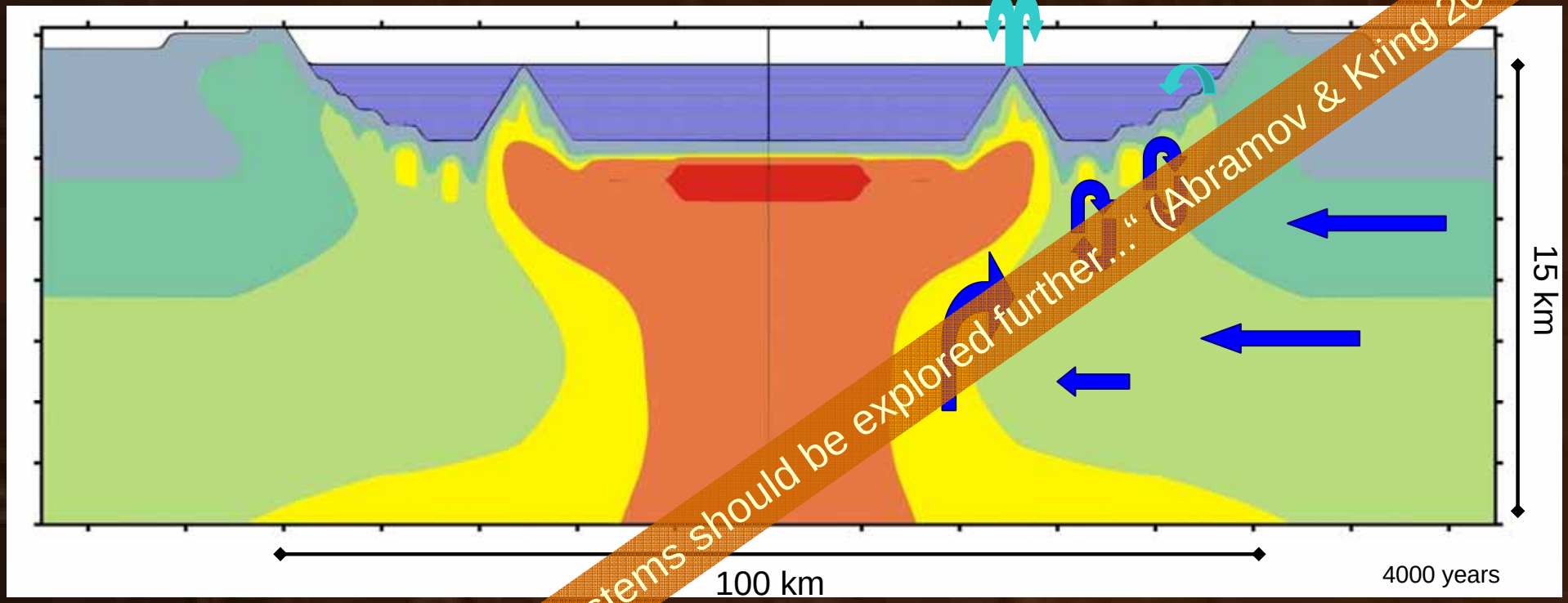
post-impact
- crater
- central heat source
- water will be
  - liquid
  - steam



Water on Mars see e. g. Clifford (1993), Carr (1996), Squyres et al. (2006)

Kring (2006) after French (1998)

Impact... on Mars



„The chemical evolution of these systems should be explored further…" (Abramov & Kring 2005)

- central, dome-shaped heat source – porosity – permeability – water
  - ➢ a hydrothermal system forms
    (for Mars: Newsom et al. 1996, Rathbun & Squyres 2002, Abramov & Kring 2005)

✓ well known from terrestrial craters, e.g. Chicxulub *(Zürcher & Kring 2004)*
✓ early Mars history cratering was very abundant *(Kring 2000)*

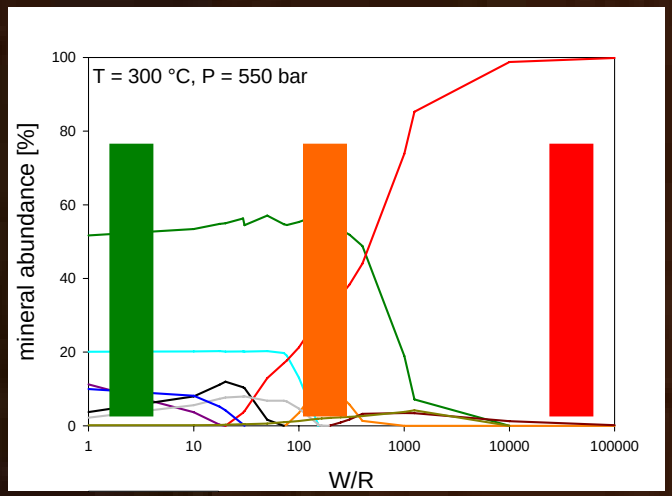
What do we know?

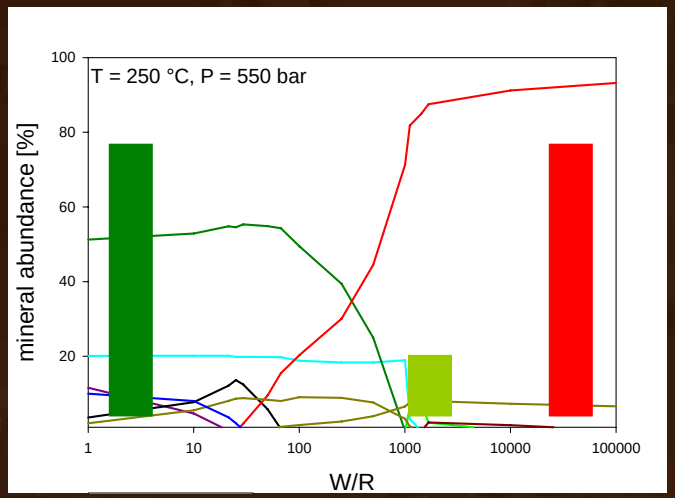
- temperature and water flux distribution and evolution from the model
- Mars‘ crust composition from Spirit and Opportunity *(e. g. Clark et al. 2005, McSween et al. 2006)*
- mineral reactions in the p-T space: CHILLER *(Mark Reed, University of Oregon)*

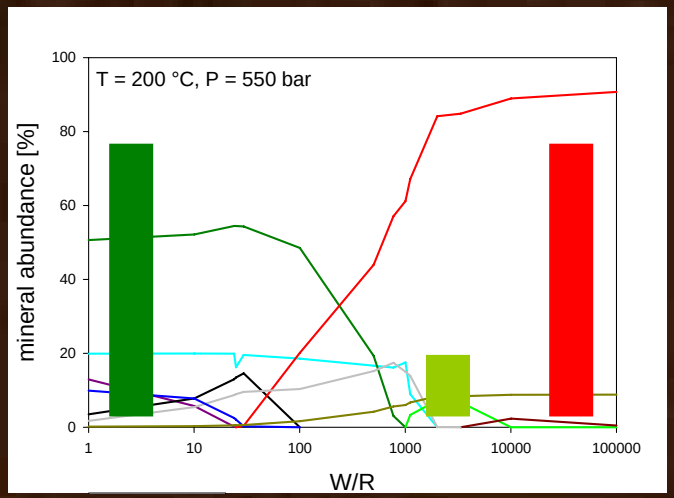
What do we have to assume?

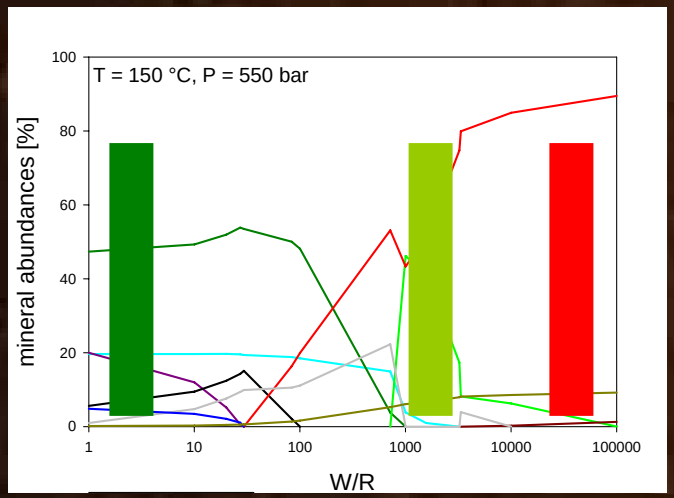
- the actual rock composition: a plutonic shergottite, LEW 88516
  (data from: Dreibus et al. 1992, Warren & Kallemeyn 1996, Gleason et al. 1997)
- initial water composition (cations: Fe^{3+}, Mg^{2+}, Ca^{2+} in the 10^{-3} mole/L-range; anions: $Cl^- >> SO_4^{2-} > HCO_3^-$, charge balanced)
- system closed to atmosphere, thus no additional supply of CO_2
- equilibrium

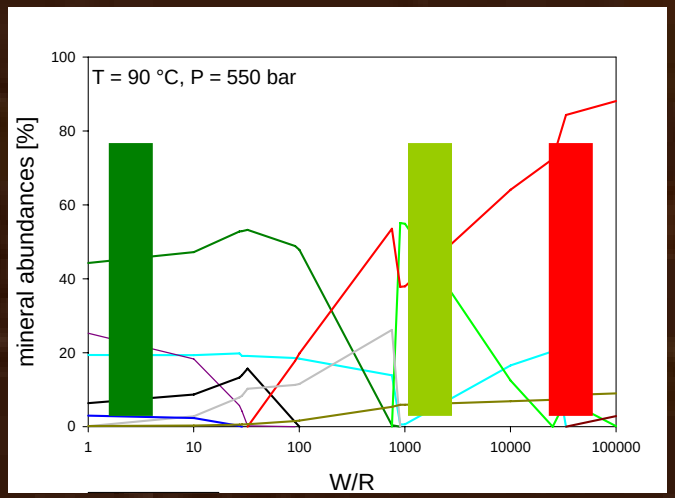
Modeling results at 5 km depth

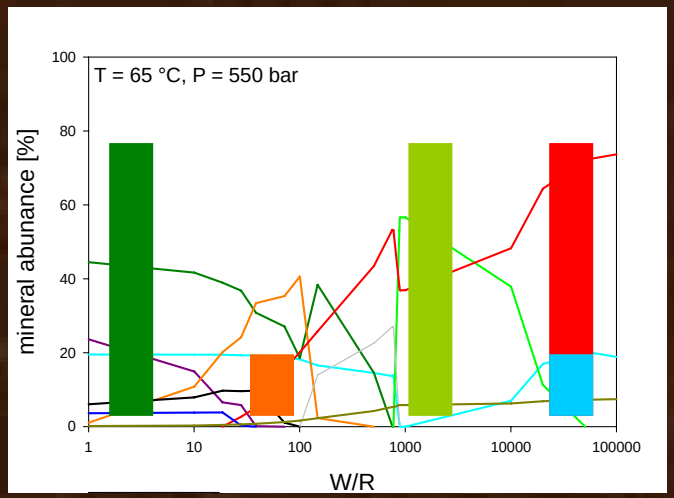












Schwenzer & Kring (forthcoming)

Serpentine-Chlorite

Hematite-Clay

Hematite-Chlorite

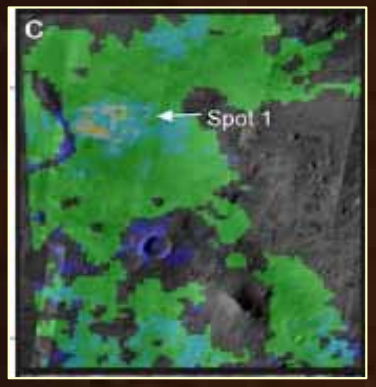
Serpentine-Hematite

Hematite

Observations?

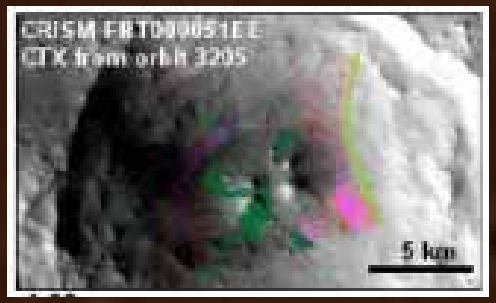
from OMEGA and CRISM

Nili Fossae Region



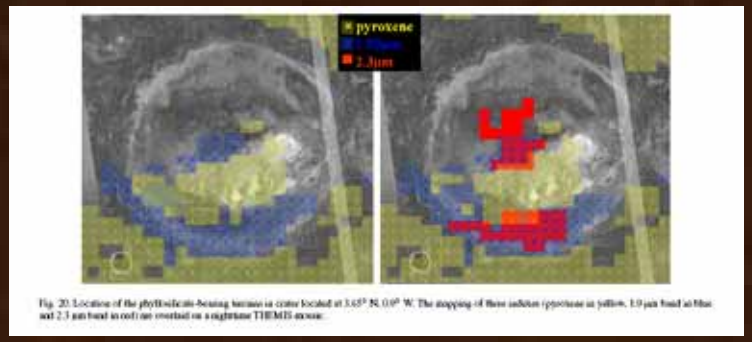
Mangold et al. (2007)

blue: hydrous signature
green: olivine



Ehlmann et al. (2008)
Western Isidis Region

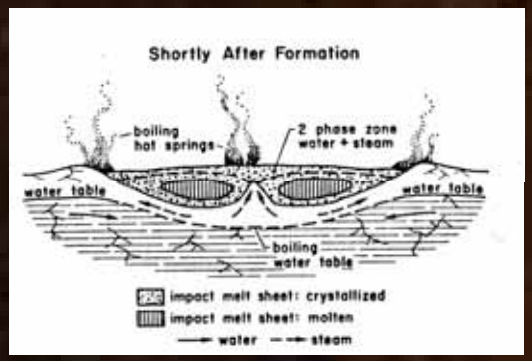
dark green: nontronite
light green: chlorite



Poulet et al. (2008) Terra Meridiani

1.93 µm band: water-bearing minerals,
2.3 µm band metal-OH (Fe/Mg-rich clay)

more crater related water dependent features



Newsom (1980)

...and:

- trigger for small outflow channels (Brakenridge 1985)
- rampart craters (Reiss et al. 2006)
- ....

Mars (and others...)

- For Mars the Noachian surfaces approach the crater saturation limit. (Hartmann & Neukum 2001)
- The old highlands „should have been gardened to a depth of a kilometer or so“. (Hartmann & Neukum 2001)
  - Cratering in the Noachian is a major geologic process.
  - The impacts cause re-distribution of material, fracturing etc.
- Hydrothermal systems reach even deeper. (Abramov & Kring 2005)
- Other terrestrial planets, if they contained water, faced the same processes.

Terrestrial ground truth?

Terrestrial craters with and without hydrothermal activity

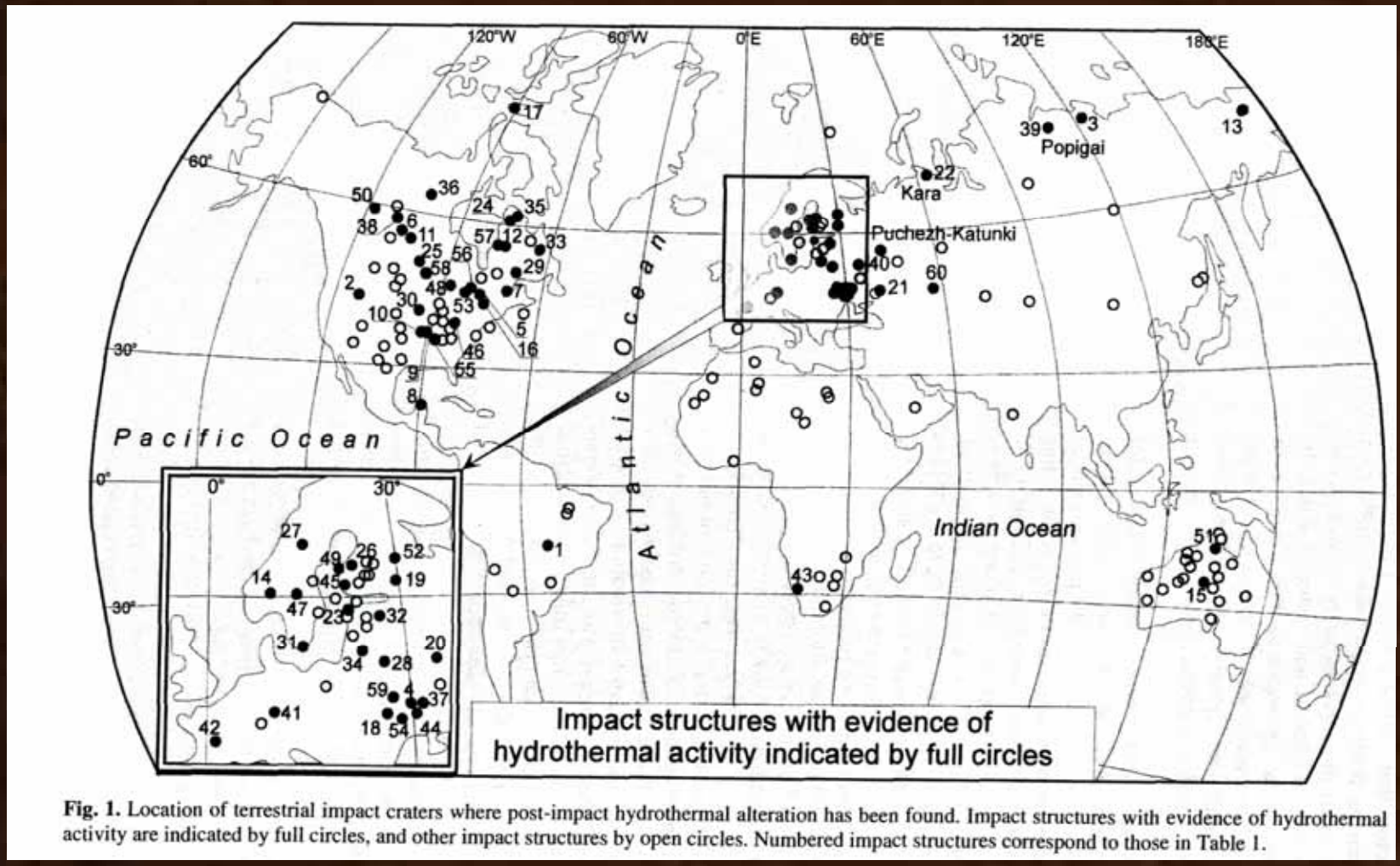
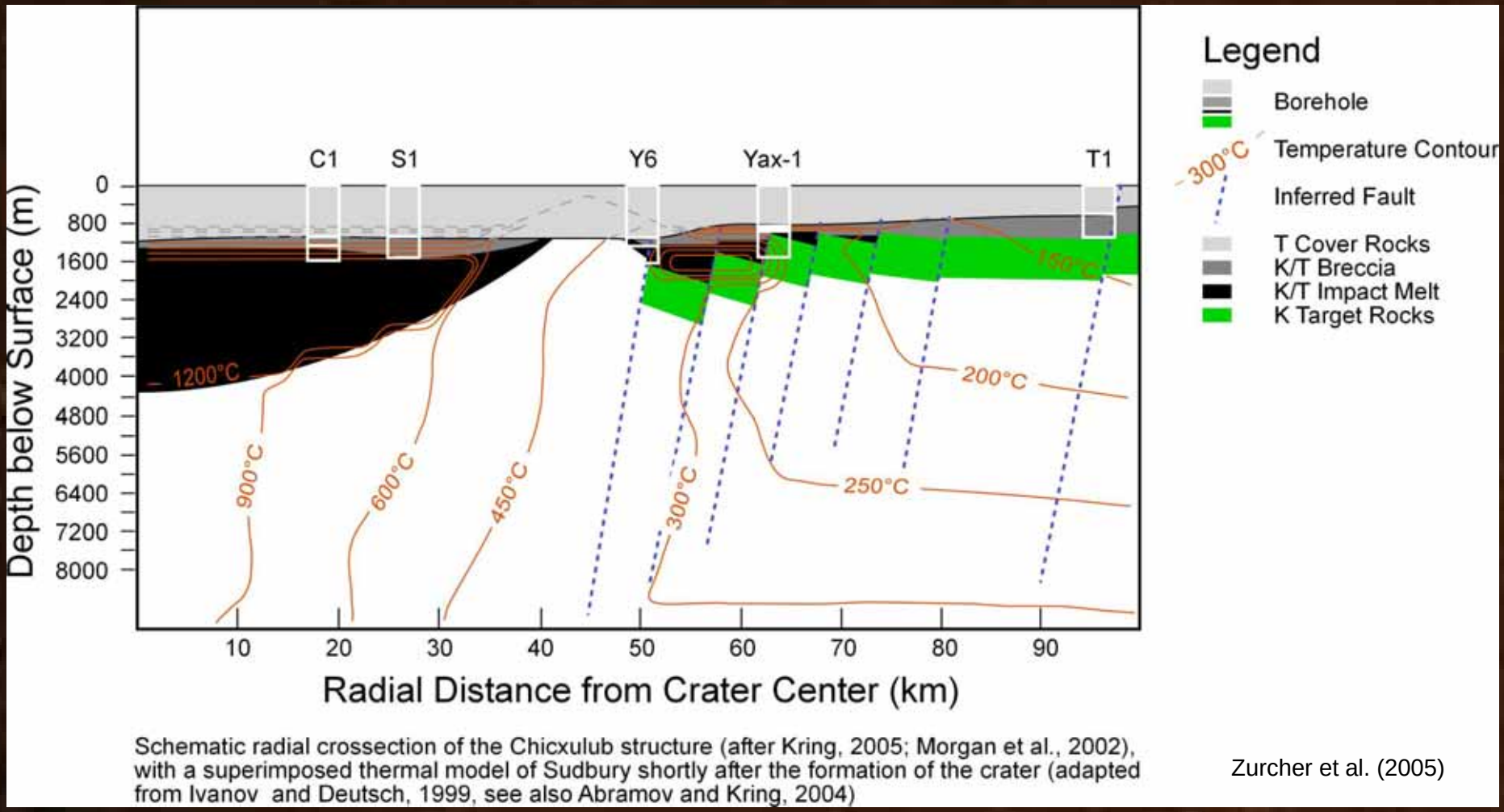


Fig. 1. Location of terrestrial impact craters where post-impact hydrothermal alteration has been found. Impact structures with evidence of hydrothermal activity are indicated by full circles, and other impact structures by open circles. Numbered impact structures correspond to those in Table 1.

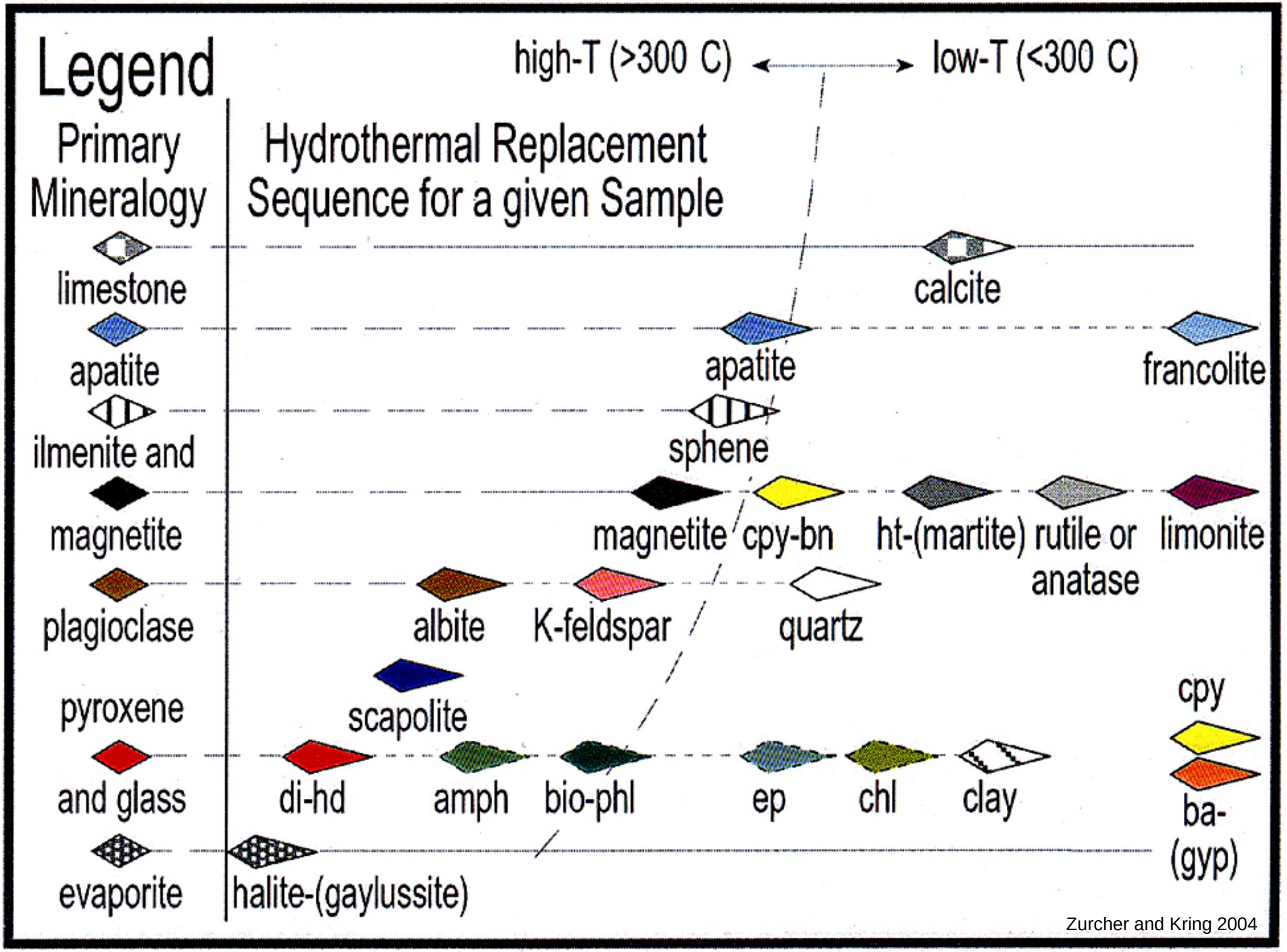
Naumov, 2002

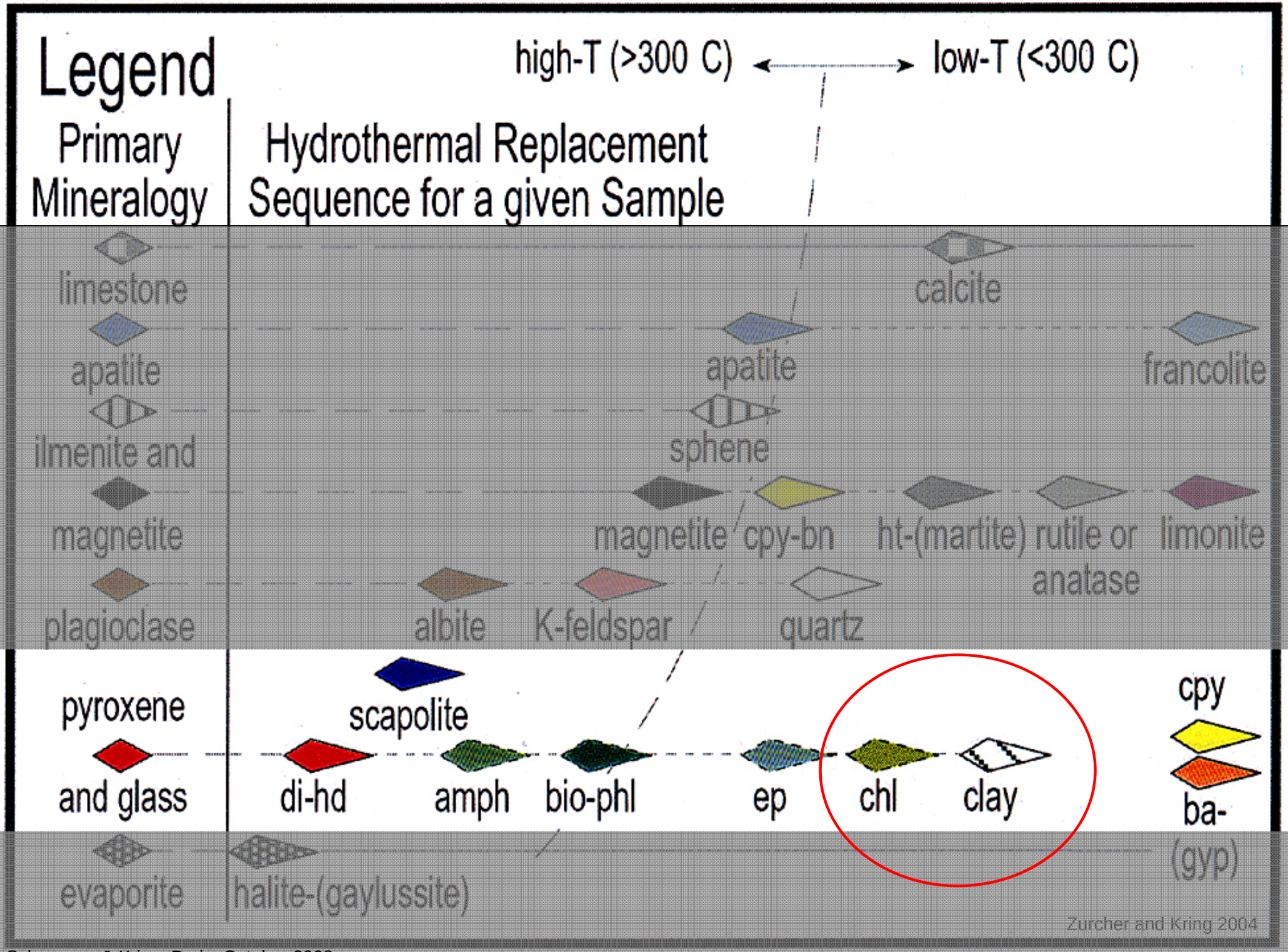
Terrestrial example: Chicxulub



Schematic radial crossection of the Chicxulub structure (after Kring, 2005; Morgan et al., 2002), with a superimposed thermal model of Sudbury shortly after the formation of the crater (adapted from Ivanov and Deutsch, 1999, see also Abramov and Kring, 2004)

Zurcher et al. (2005)


Legend
high-T (>300 C)
low-T (<300 C)
Primary Mineralogy
Hydrothermal Replacement Sequence for a given Sample
limestone
calcite
apatite
apatite
francolite
ilmenite and
sphene
magnetite
magnetite
cpy-bn
ht-(martite)
rutile or anatase
limonite
plagioclase
albite
K-feldspar
quartz
pyroxene
scapolite
cpy
and glass
di-hd
amph
bio-phl
ep
chl
clay
ba-(gyp)
evaporite
halite-(gaylussite)
Zurcher and Kring 2004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plagioclase
albite
K-feldspar
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scapolite
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and glass
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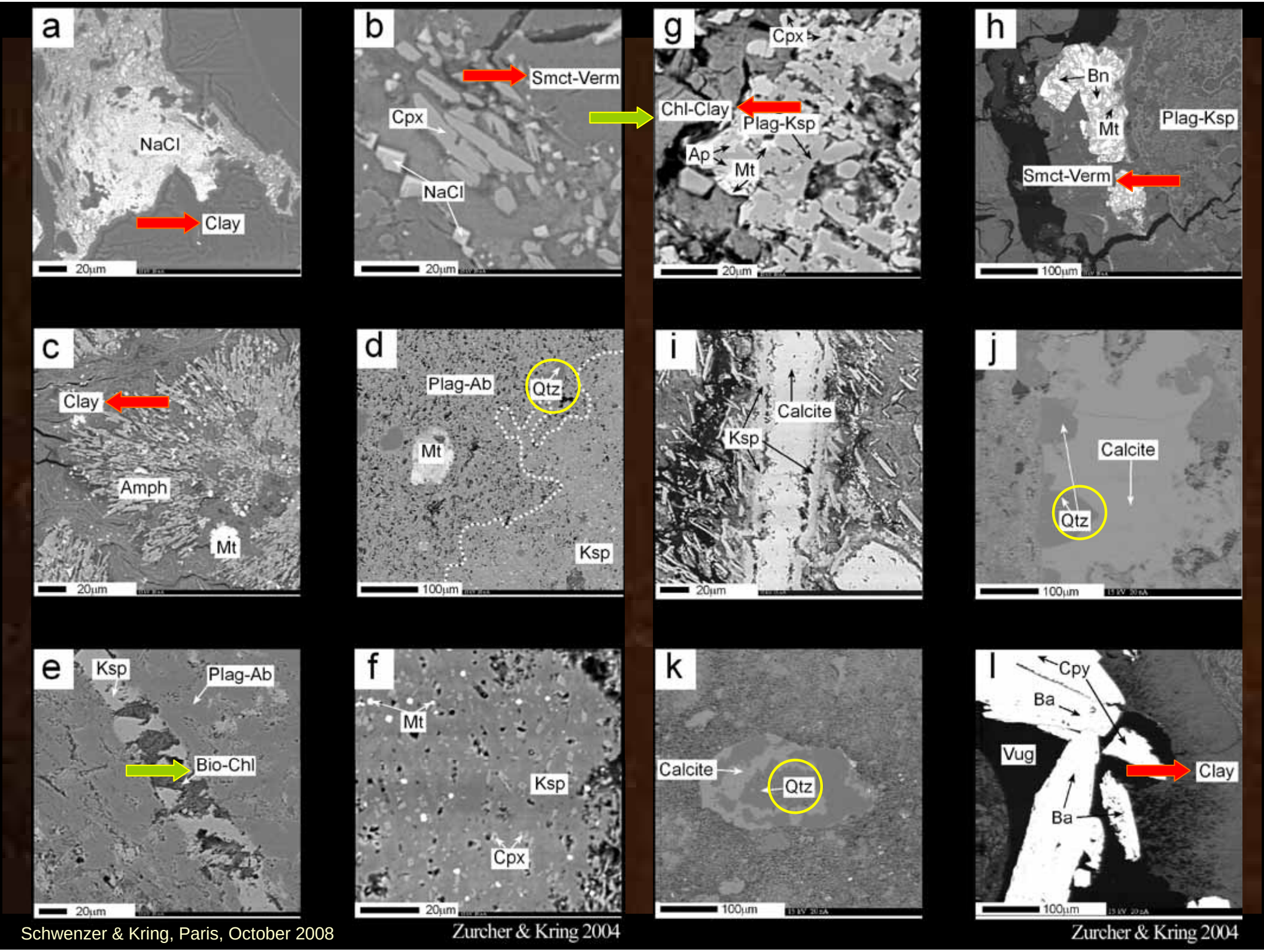
Zurcher and Kring 2004

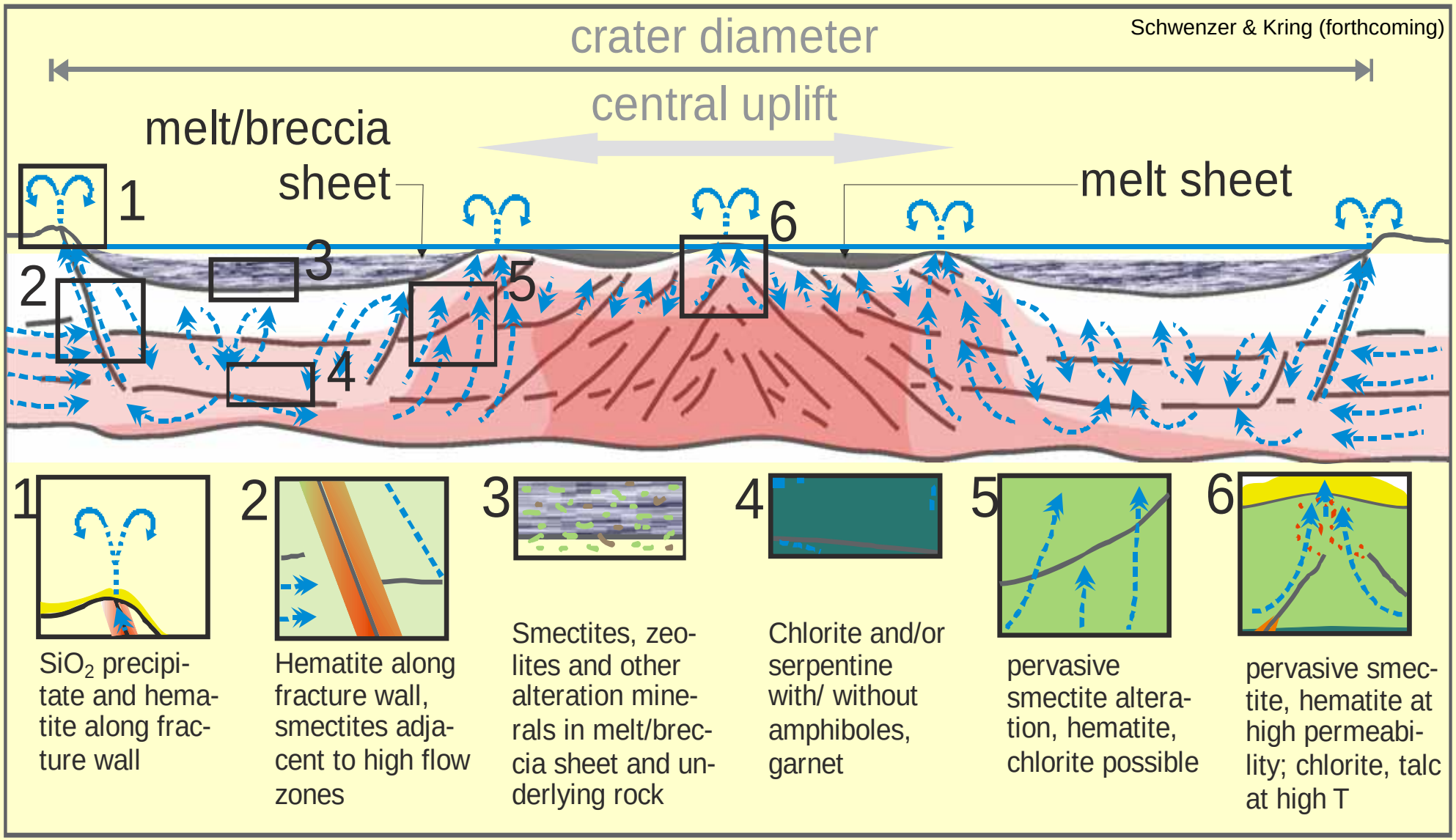


Schwenzer & Kring, Paris, October 2008

Zurcher & Kring 2004

Zurcher & Kring 2004

Still more smectites!



Conclusions

- Mars shows a highly cratered Noachian surface. Impact heating was an important heat source during the period of heavy bombardment *(Kring 2000).*

- Life times for impact-generated hydrothermal systems range from *(Abramov & Kring 2005)*
  - 67000 years (30 km crater) to
  - 290000 years (100 km crater) and
  - 380000 years (180 km crater) and
  - potentially ~ 10 Ma for a Hellas sized (2000 km) basin.

- These systems could have formed distinct types of alteration assemblages:
  - Serpentine-Chlorite-Amphibole-Garnet (low W/R)
  - Clay (Nontronite)-Hematite- ±Serpentine ± Chlorite (intermediate W/R)
  - Hematite- ± Pyrite ± Diaspore ± Clay (Kaolinite) (high W/R)
  - SiO_2 is precipitated by the fluids

✓ The occurrence of alteration phases is spatialy variable!

➢ The Noachian crust could be widespread but not necessarily uniformly overprinted by impact-generated hydrothermal systems.