Luminescence Geochronology

EarthScope Short Course

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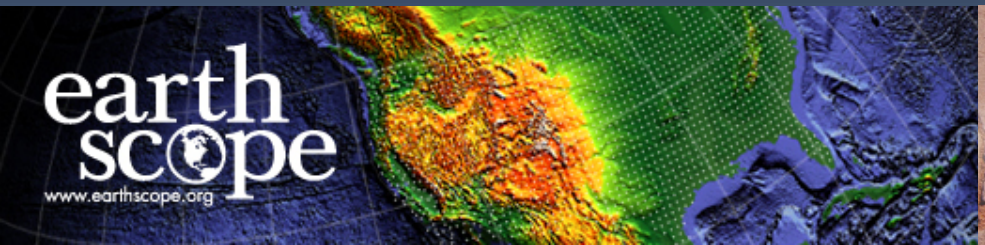
October 17, 2014



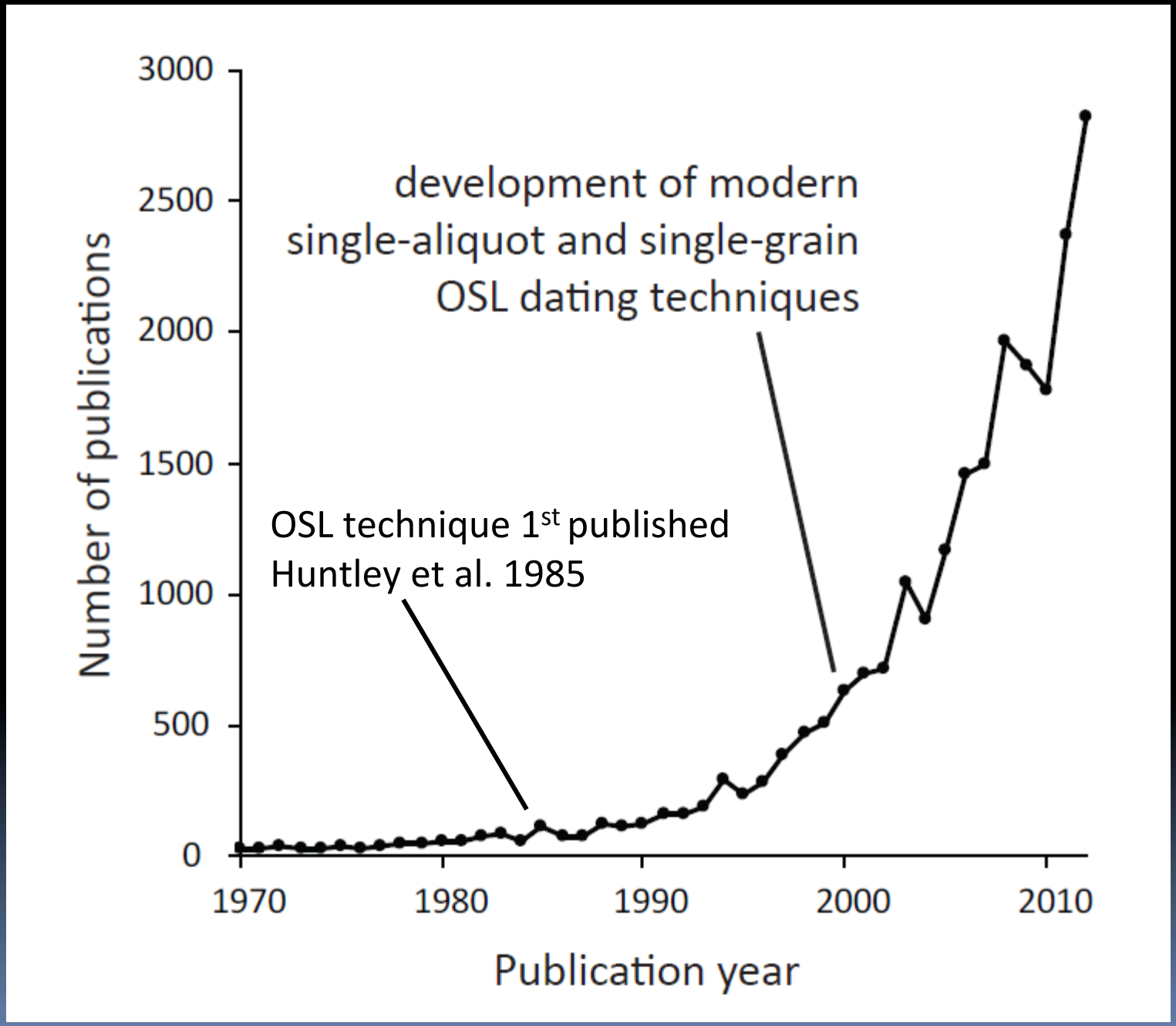
Luminescence techniques (OSL and TL)

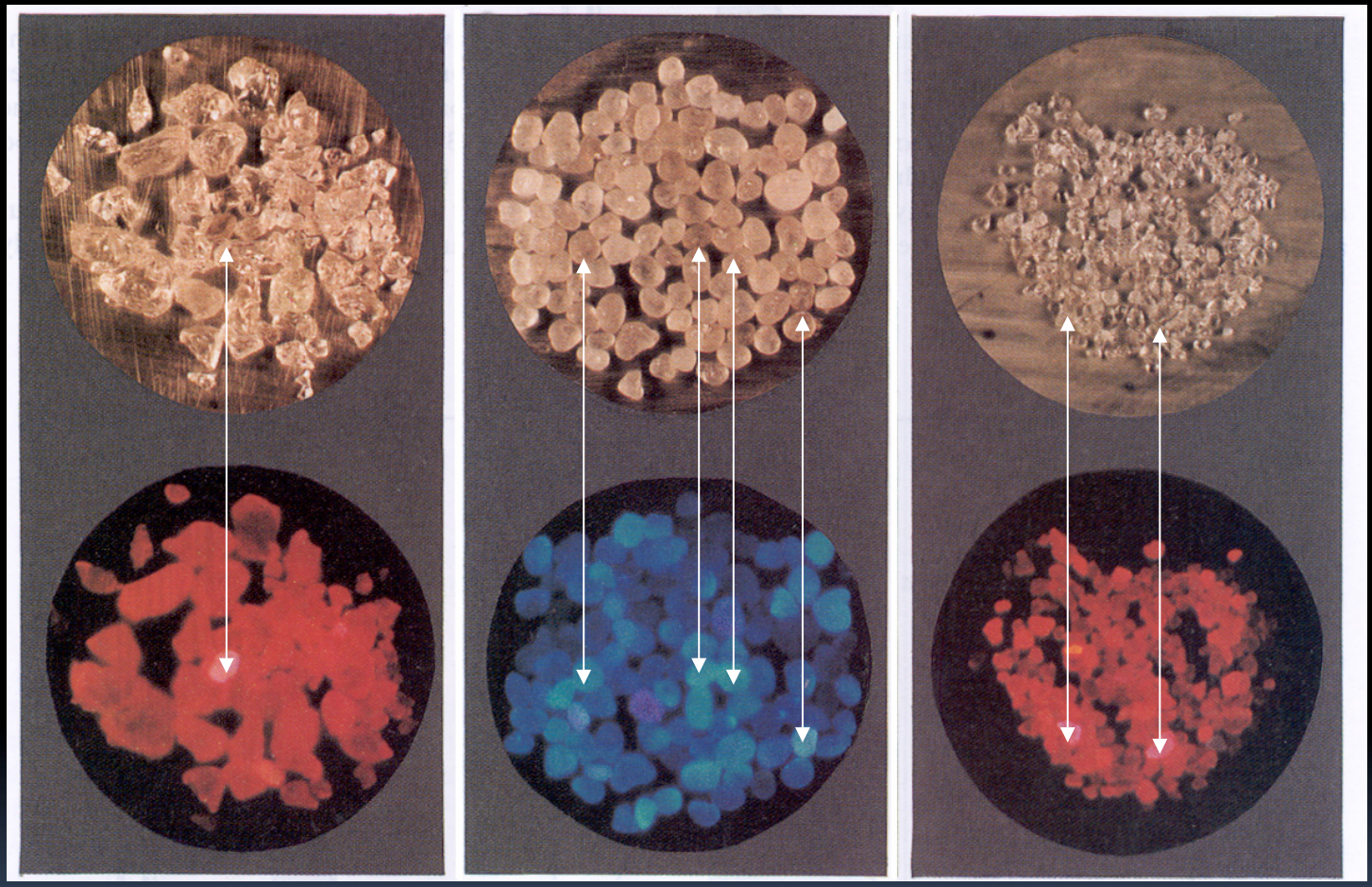
Optically stimulated luminescence, OSL

- Production of light through stimulation by photons of any wavelength

Thermoluminescence, TL

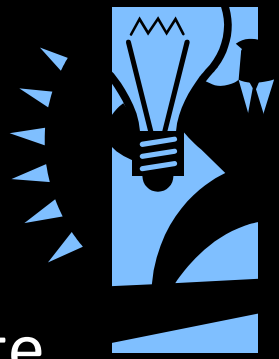
- Light production through stimulation by heat.


3000
2500
2000
1500
1000
500
0
Number of publications
development of modern
single-aliquot and single-grain
OSL dating techniques
OSL technique 1st published
Huntley et al. 1985
1970
1980
1990
2000
2010
Publication year



Luminescence (bottom) in quartz grains. Note the variation in luminescence between grains. In sample 1 most of the signal would be generated by a single grain (Ganzawa et al., 1997).

The General Idea:

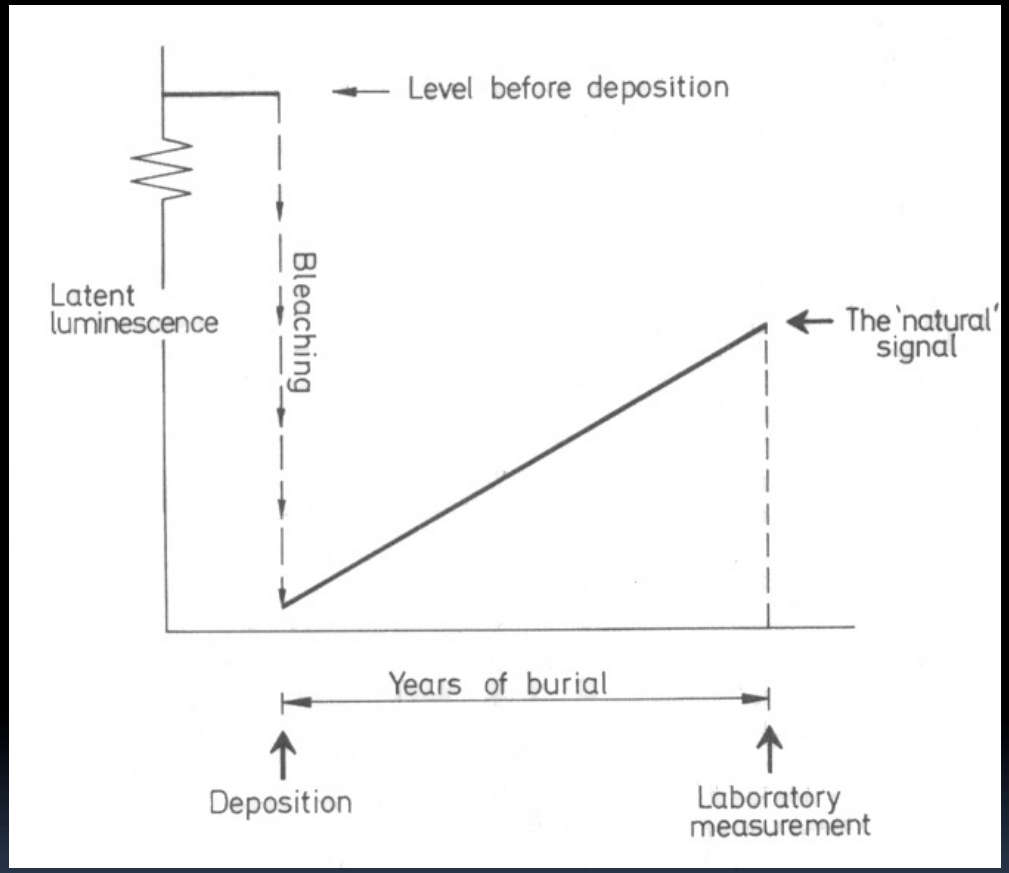


Luminescence techniques provide an estimate of the time since sediment was last exposed to light/heat (which zeros the luminescence signal).

After burial, the luminescence signal grows with exposure to radiation in the surrounding sediments (K, U, Th, Rb) plus cosmic radiation

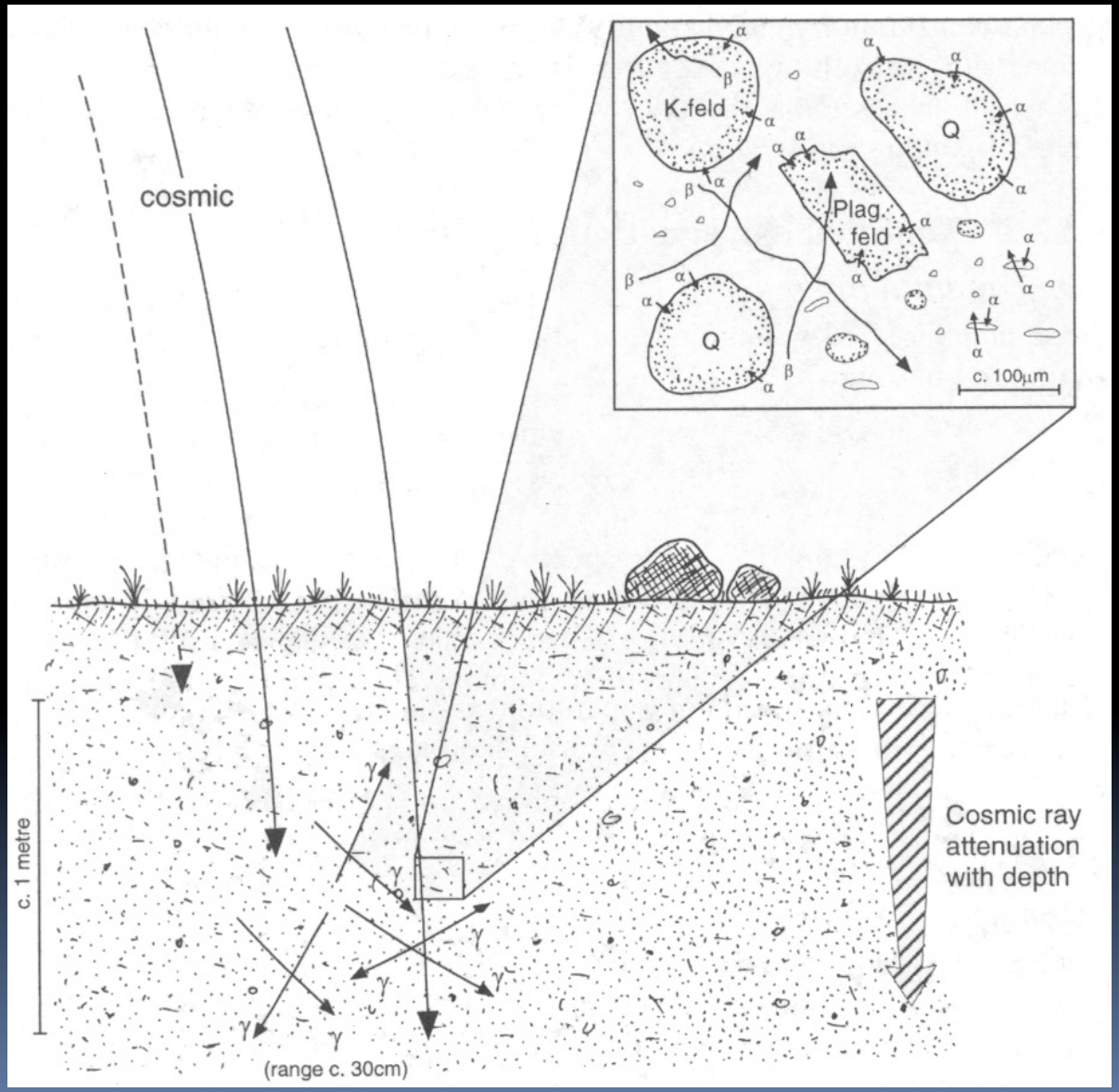
Measured luminescence signal is related to the length of burial and radioactive environment

Bleaching and Signal Generation



Bleaching (exposure to light) sets the signal to zero; the 'natural' signal regenerates over time by exposure to natural radiation. The strength of the signal is related to the number of years of burial and the flux of radiation

Generation of the burial dose:



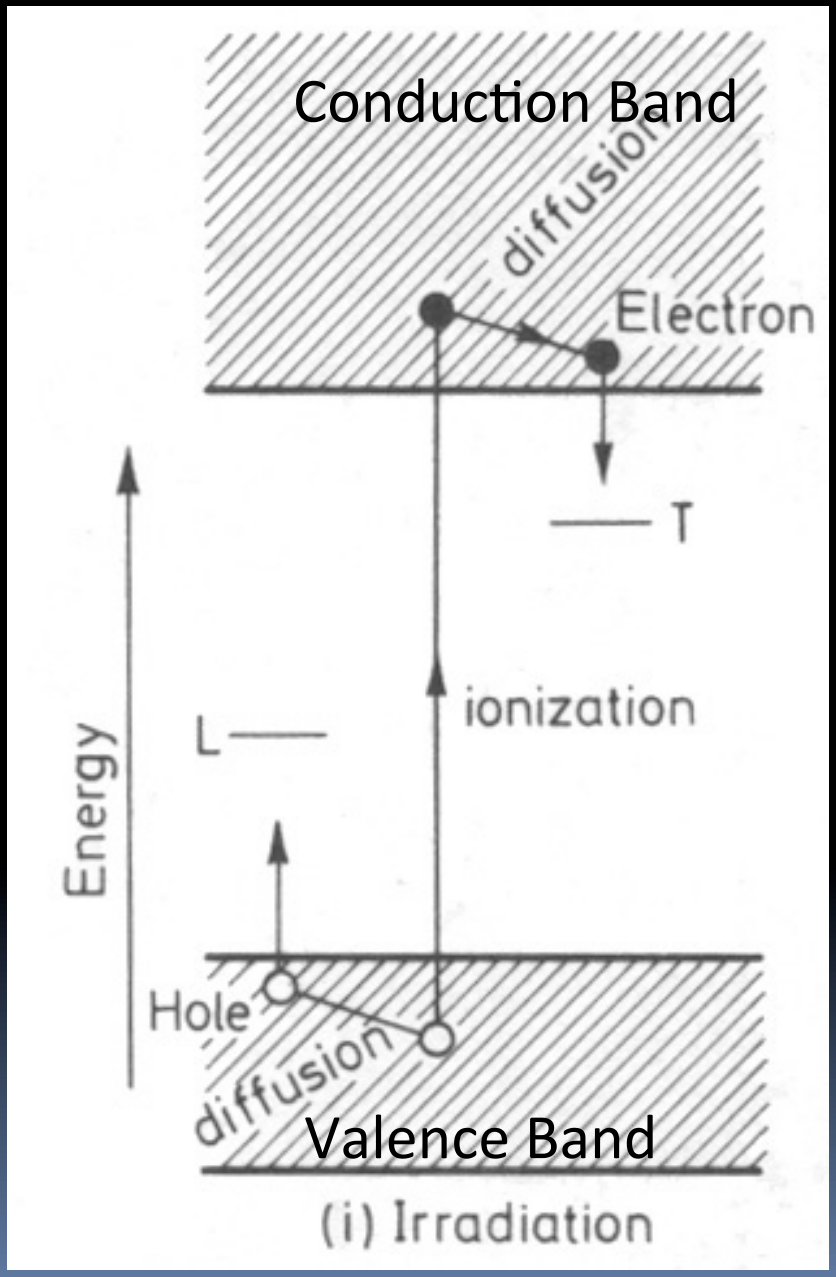
The 'natural' signal is produced by the flux of α, β, γ and cosmic radiation.

Generation of the Luminescence signal-

Ionizing radiation ejects electrons from atoms in the crystal lattice

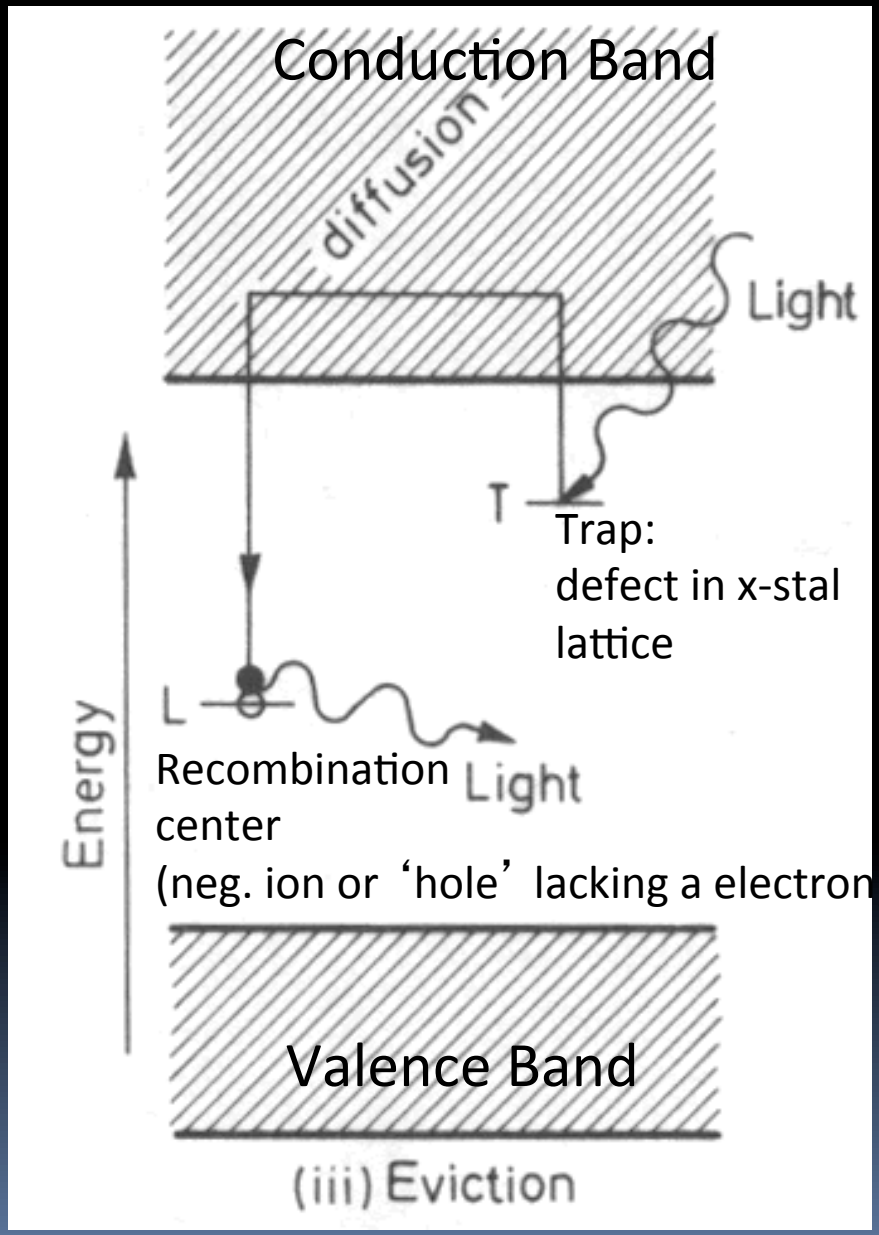
These electrons are trapped in ‘positive’ defects in the crystal lattice (holes or traps) and stored here over geological time until stimulated by external energy (light, heat)

Upon absorption of energy, the electron is released from the trap and when it enters a recombination center (another site attractive to electrons) it releases a photon of energy (wavelength depend on trap type)



Production of Electrons and Holes

Ionization due to exposure of the crystal to nuclear radiation, with trapping of electrons and holes at defects, T and L, respectively (Aitken, 1998).



Generation of Luminescence Signal

Light of an appropriate wavelength (or heat) evicts electrons from the traps. Some reach luminescence centers, producing light (i.e. OSL)

Age Calculation:

Dependent upon:

Flux of radiation as measured in the field and/or determined by chemistry (I.e. concentrations of U, Th, K, Rb) = dose-rate

Intensity of OSL signal as related to a known flux of radiation = equivalent dose (De) (equivalent to the natural luminescence signal)

Equivalent Dose (D_E)

def:

Laboratory dose of radiation needed to induce a luminescence signal equal to the natural luminescence signal of the sample.

Unit: Gray (Gy) 1 Gy = 1 J/kg

Approximately equivalent to dose sample received in nature, the "Paleodose", P.

Dose-Rate (D_R)

def:

Dose per unit of time received by the sample while buried.

Typical unit: Grays per thousand years (Gy ka-1).

Calculated from measured concentrations of
U, Th, K, Rb and cosmic radiation, with correction
for absorption of radiation by water.

Can also be measured directly or indirectly in the field.

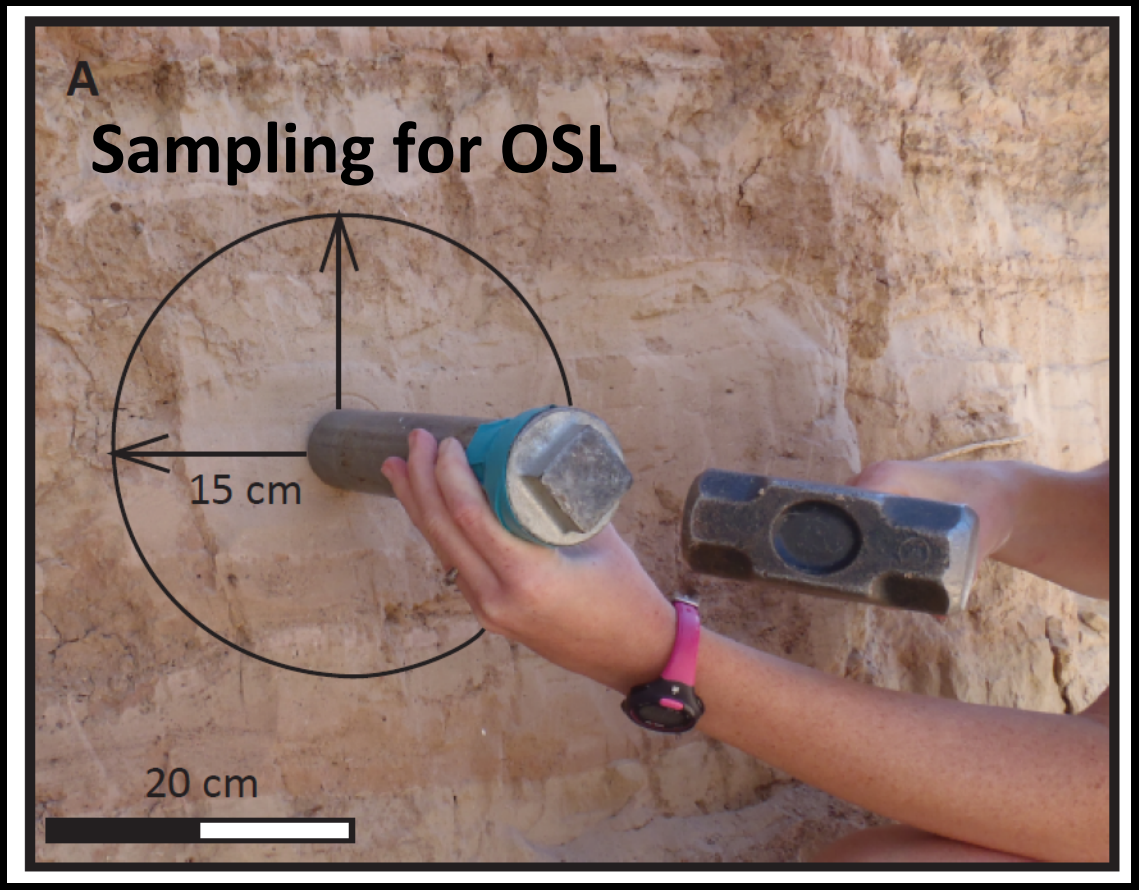
Age:

$$\textbf{Age} = \frac{\text{Equivalent Dose (Gy)}}{\text{Dose-Rate (Gy ka}^{-1}\text{)}} \textbf{ = ka}$$

Sample Collection (typical)

- Sample collected by driving metal tubes into sediment.
- Sample tube removed and ends sealed.
- Water and chemistry samples also collected for dose-rate determination.
- Sample depth, latitude, longitude recorded for cosmic contribution

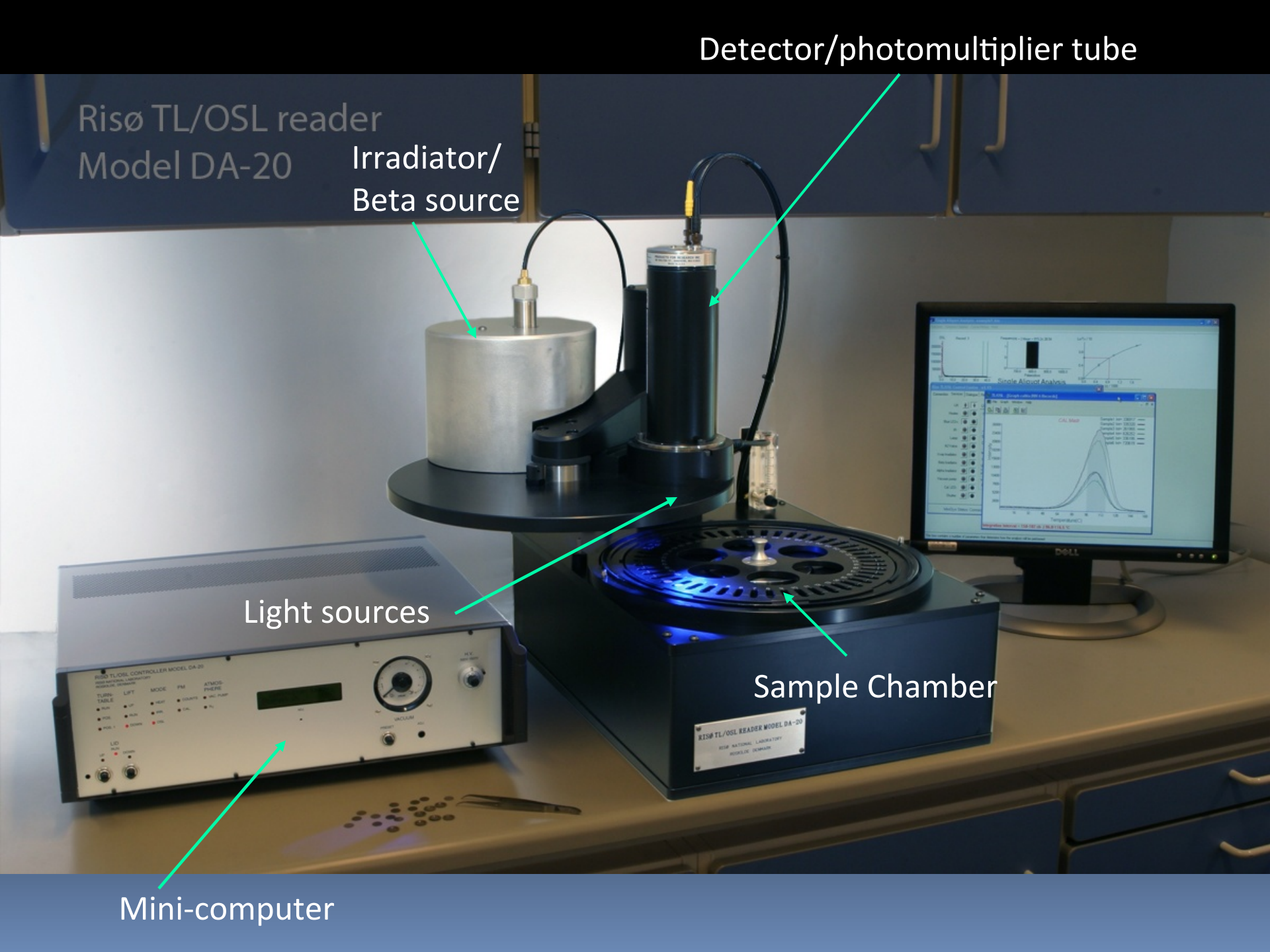
OSL Tool kit:


A
Sampling for OSL
15 cm
20 cm

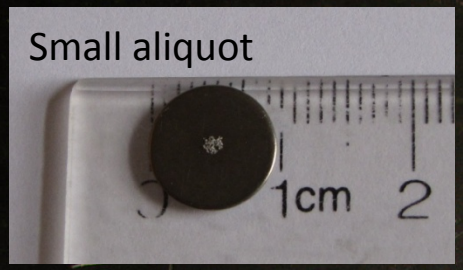

B

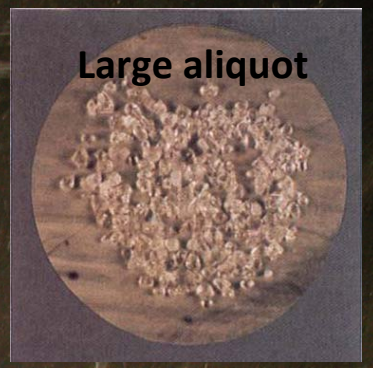

GIDDINGS

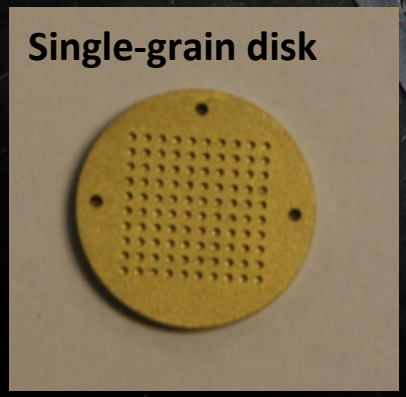
In the Lab ……


Detector/photomultiplier tube
Risø TL/OSL reader
Model DA-20
Irradiator/
Beta source
Light sources
Sample Chamber
Mini-computer

Sample holder for Risø







OSL Sample Preparation

Isolate desired grain size

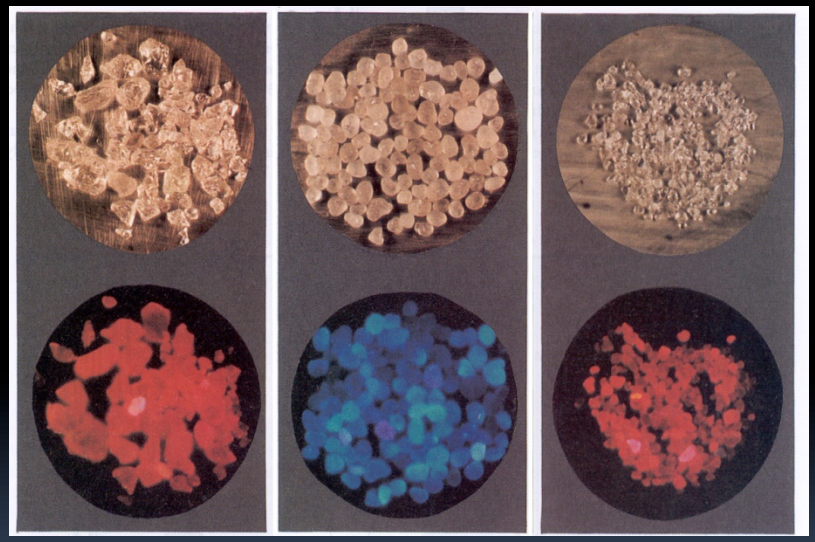
- Wet sieving (60-90, 90-125, 90-150, 150-200μ…)

Isolate desired mineral (quartz)

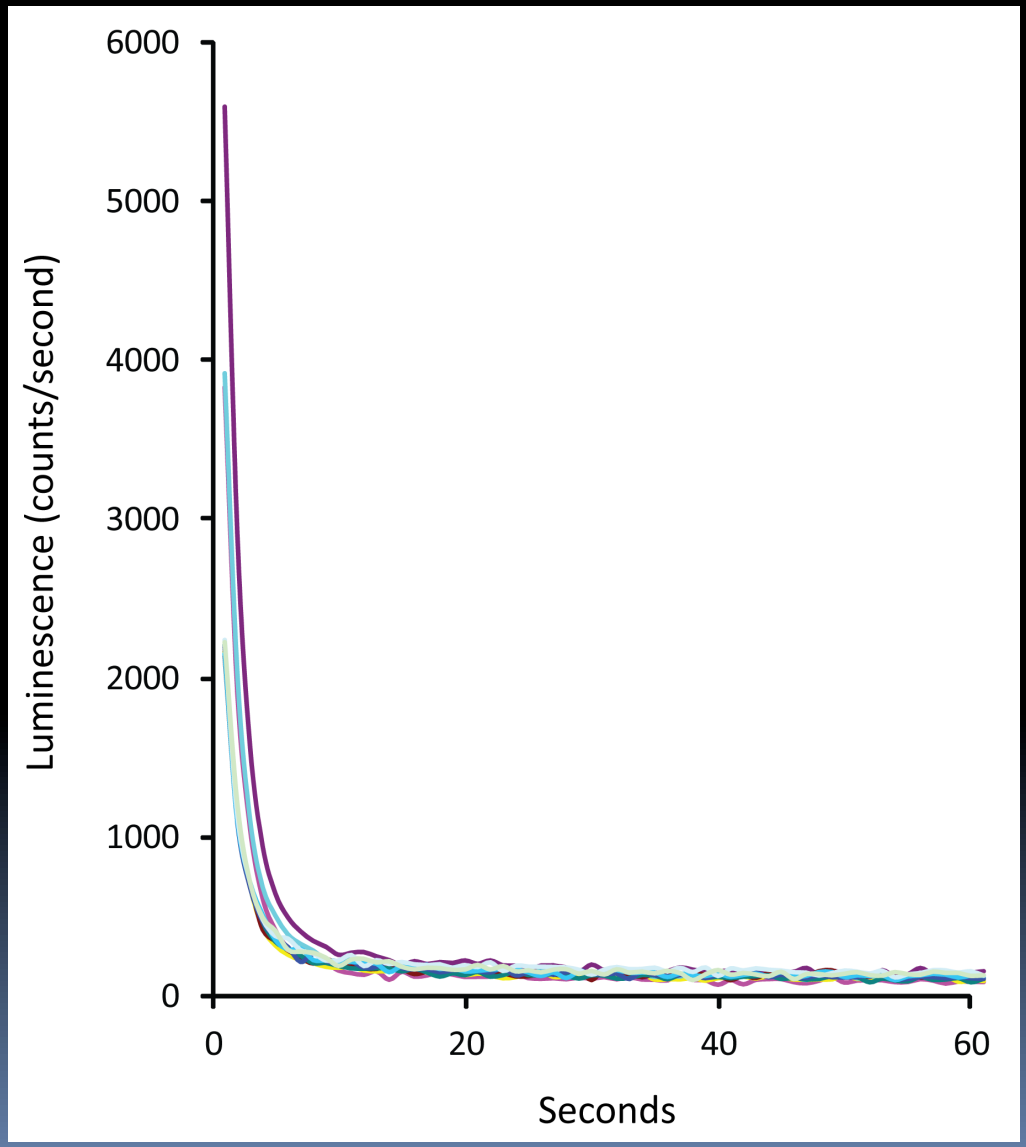
- Carbonates removed with HCl.
- Organics removed with hydrogen peroxide or bleach.
- Quartz & feldspar floated with 2.7 g cm^{-3} Na-polytungstate.
- Feldspar removed and quartz grains etched with HF.
- HCl to remove any fluorides produced.
- Re-sieve & discard fine fraction with residual feldspars.

D_E and OSL Age Determination

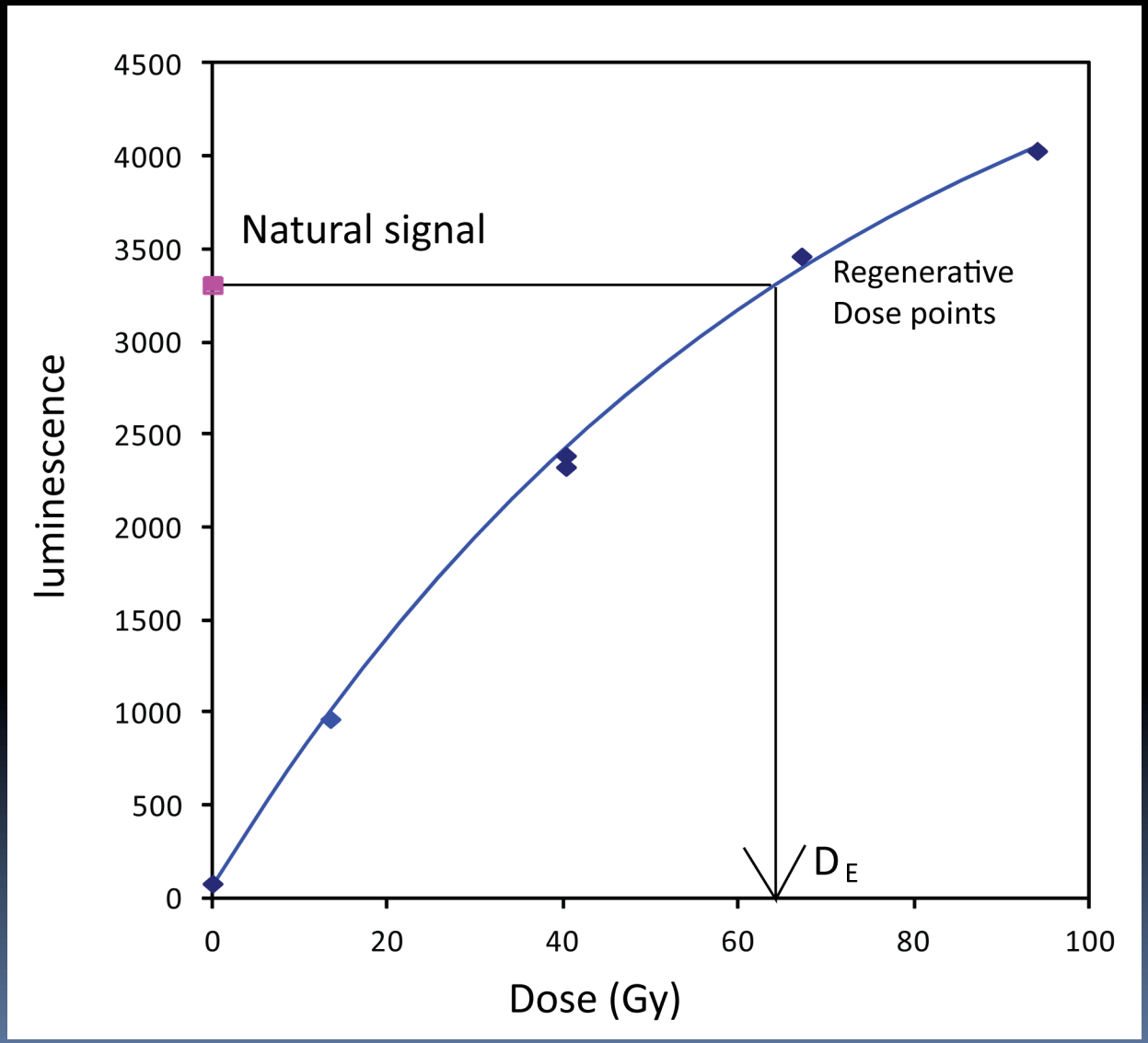
- Monolayer of quartz attached to ss disk using silicon spray or single-grain disc.
- Several cycles of preheating, irradiation, and measurement of OSL signal.

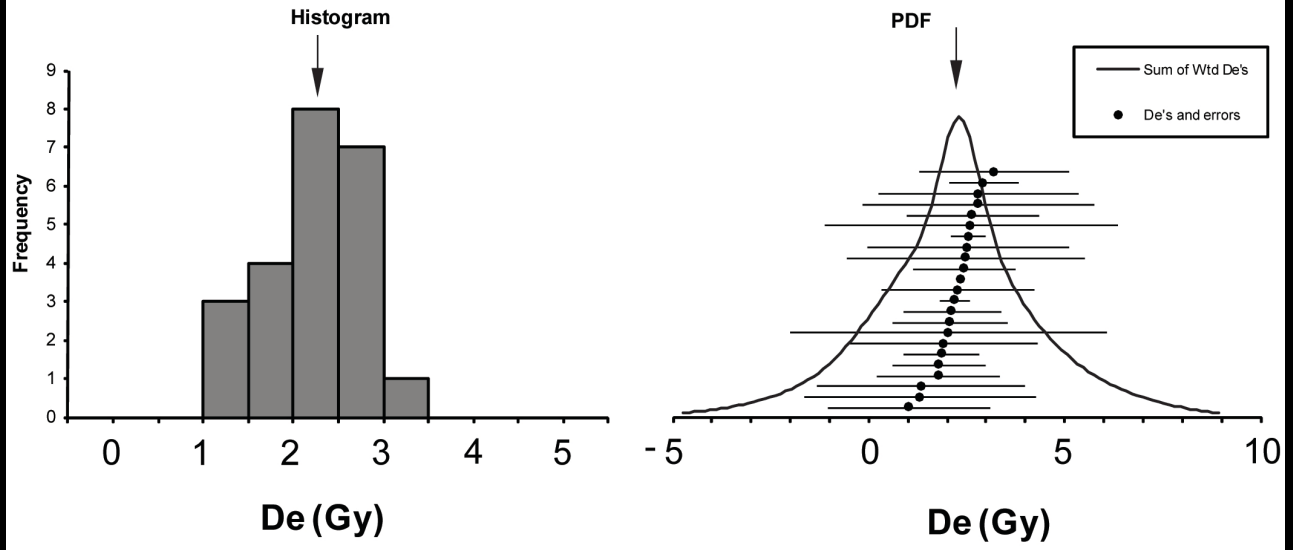


Quartz Decay Curve (OSL)

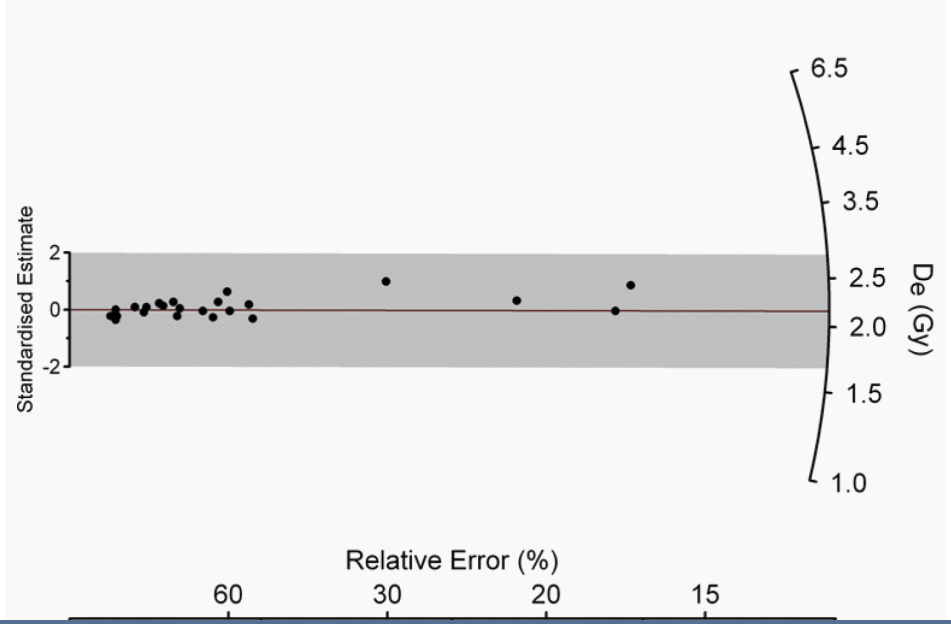


Dose-response curve

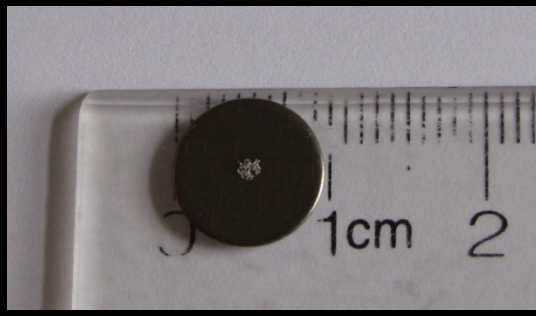




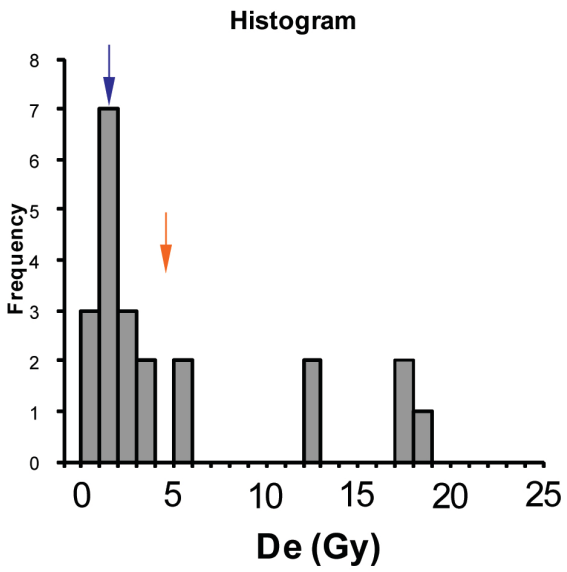
Mean De = 2.17 Gy

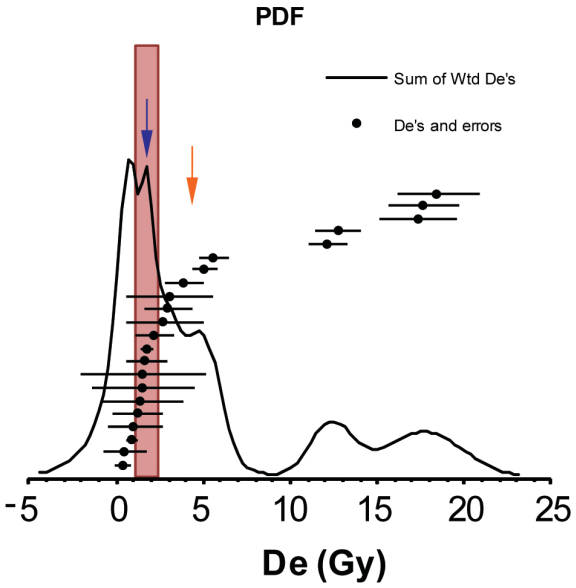


Small aliquot



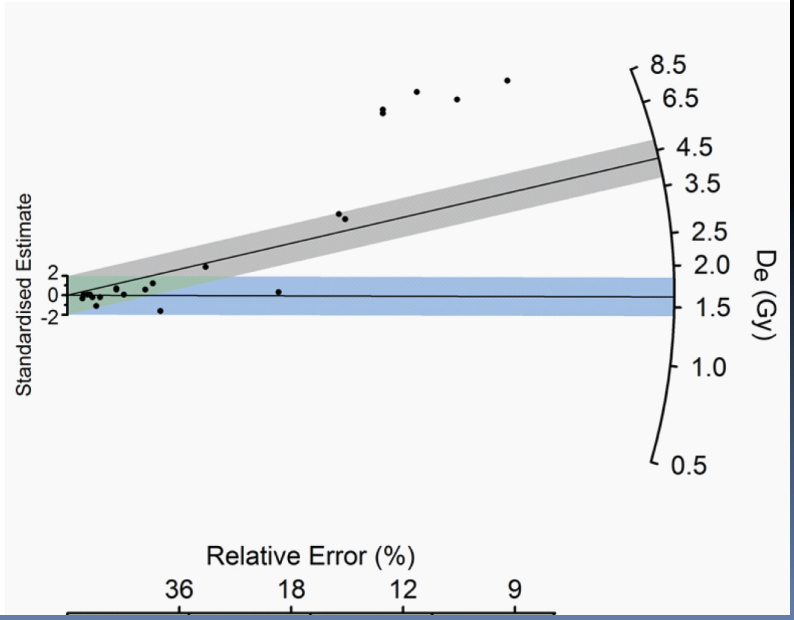
(a) USU-603



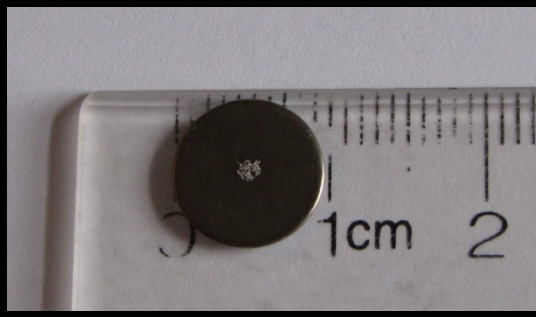


MAM De = 1.53 Gy

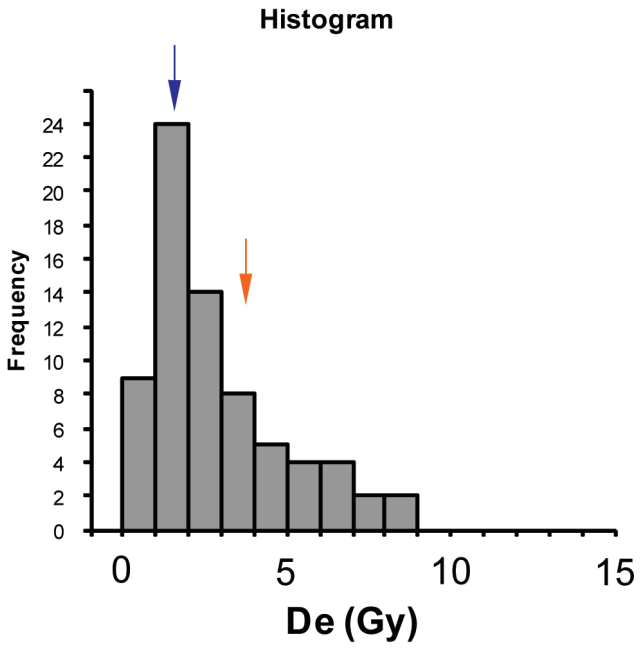
CAM De = 4.23 Gy

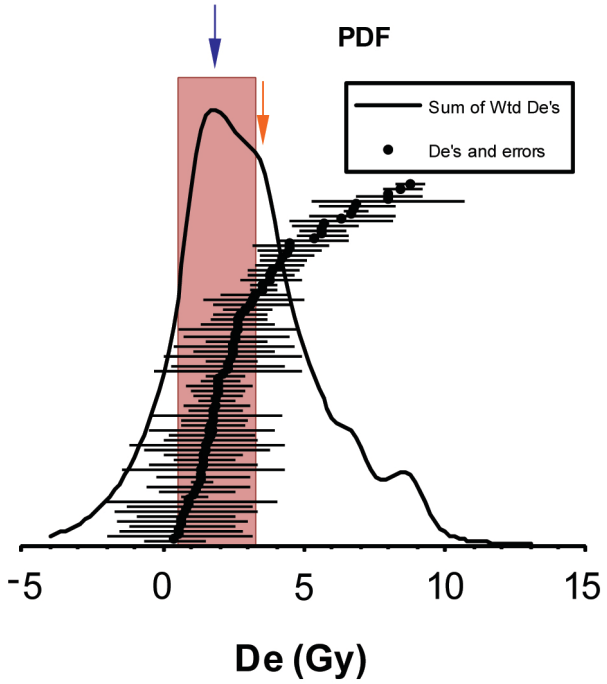


Small aliquot



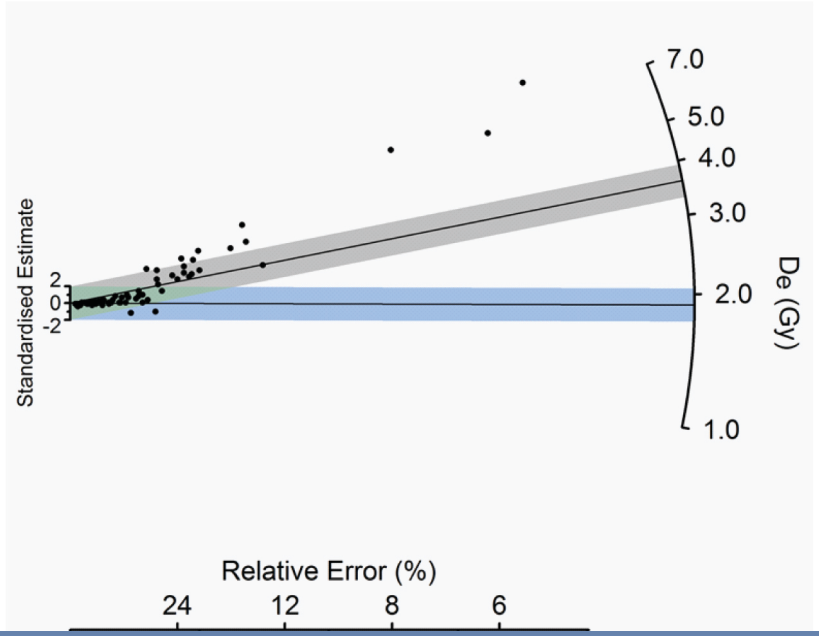
USU-815



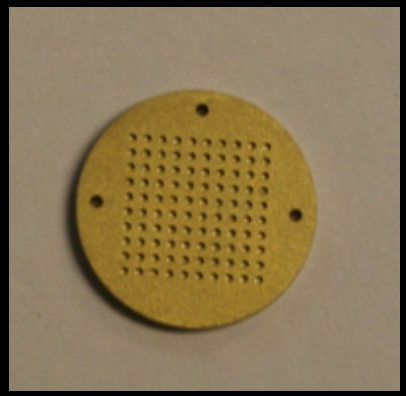


MAM De = 1.90 Gy

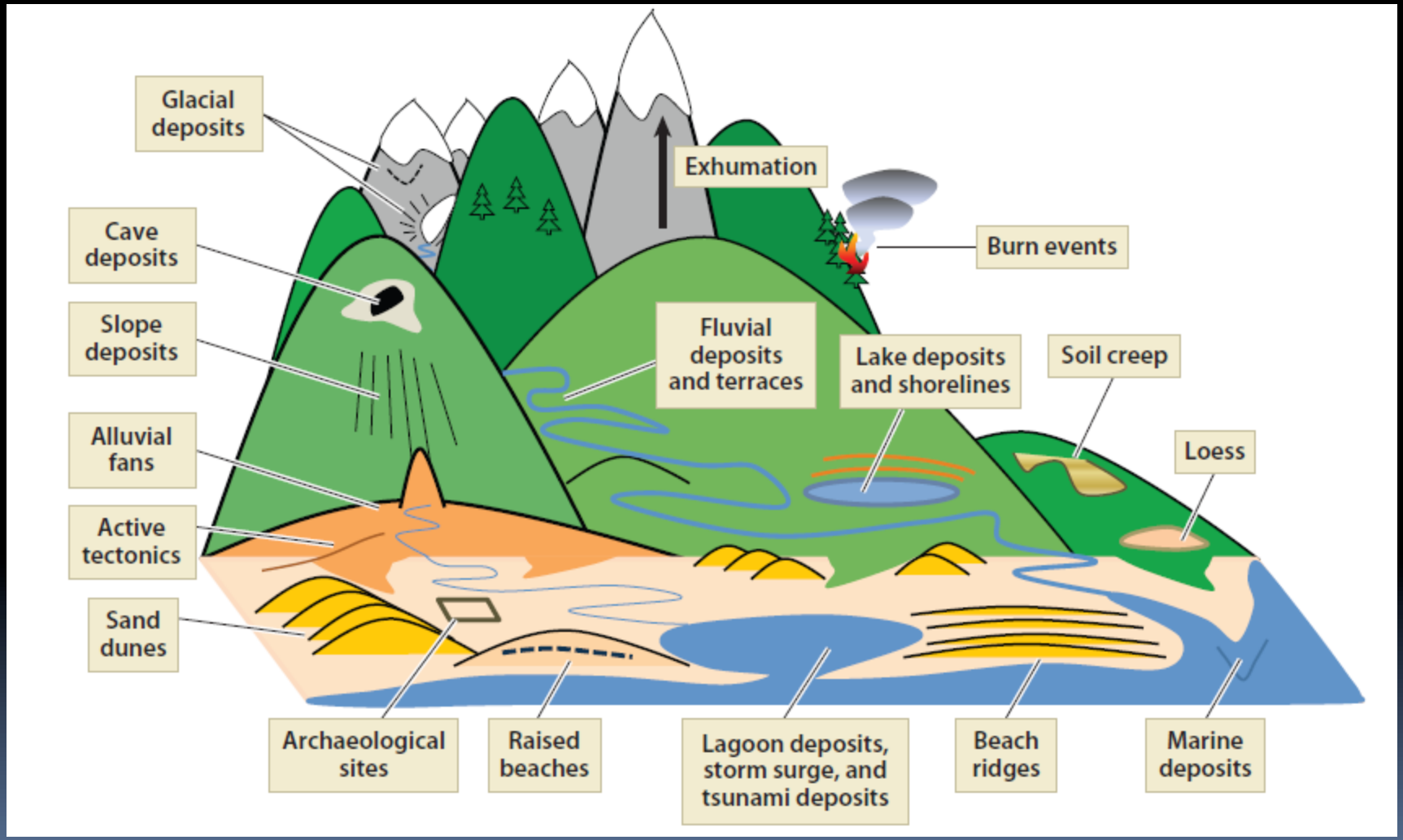
CAM De = 3.56 Gy



Single-grain

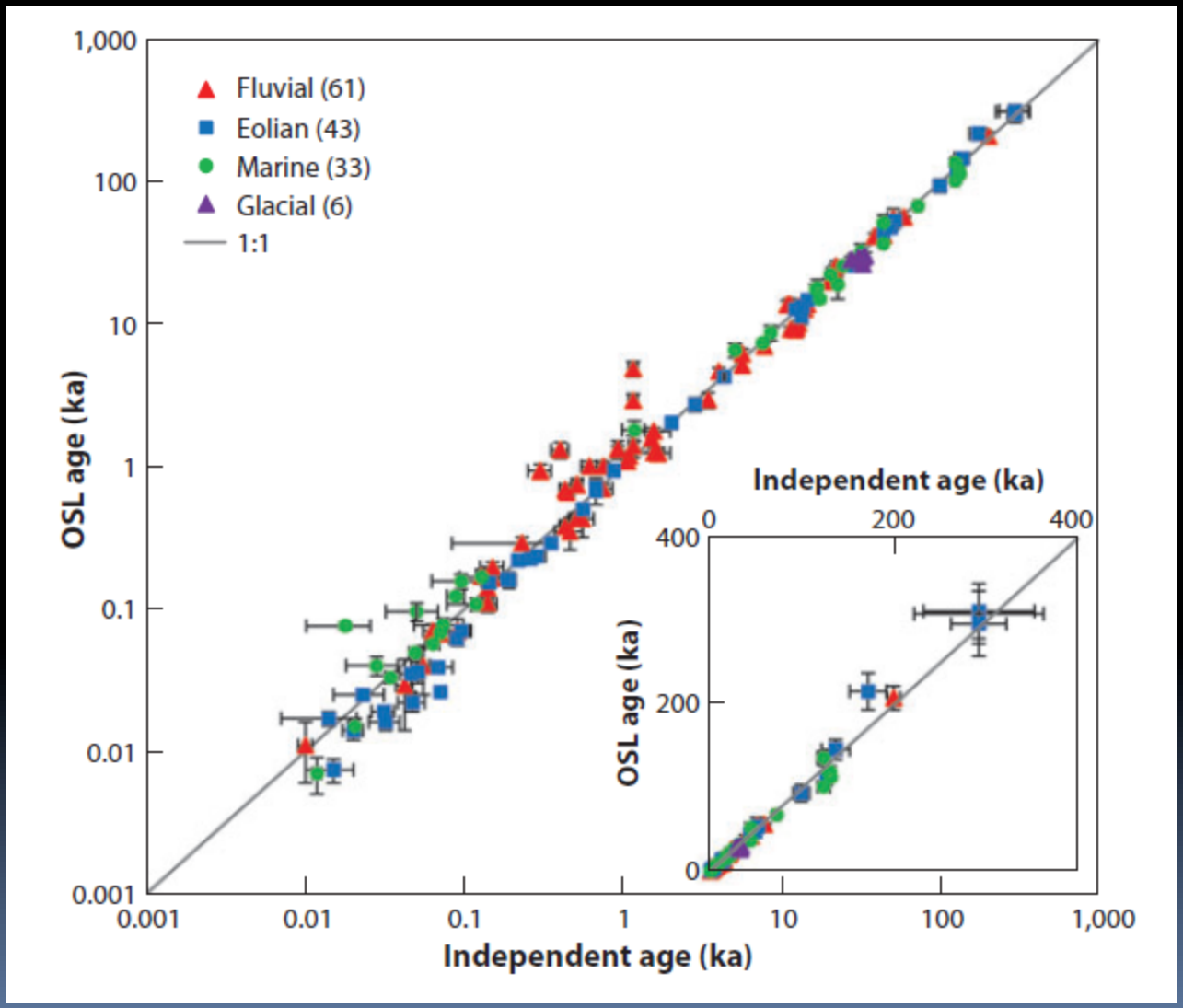


Datable deposits: nearly any…



Rhodes 2011

Age range – few decades up to 300ka with Quartz

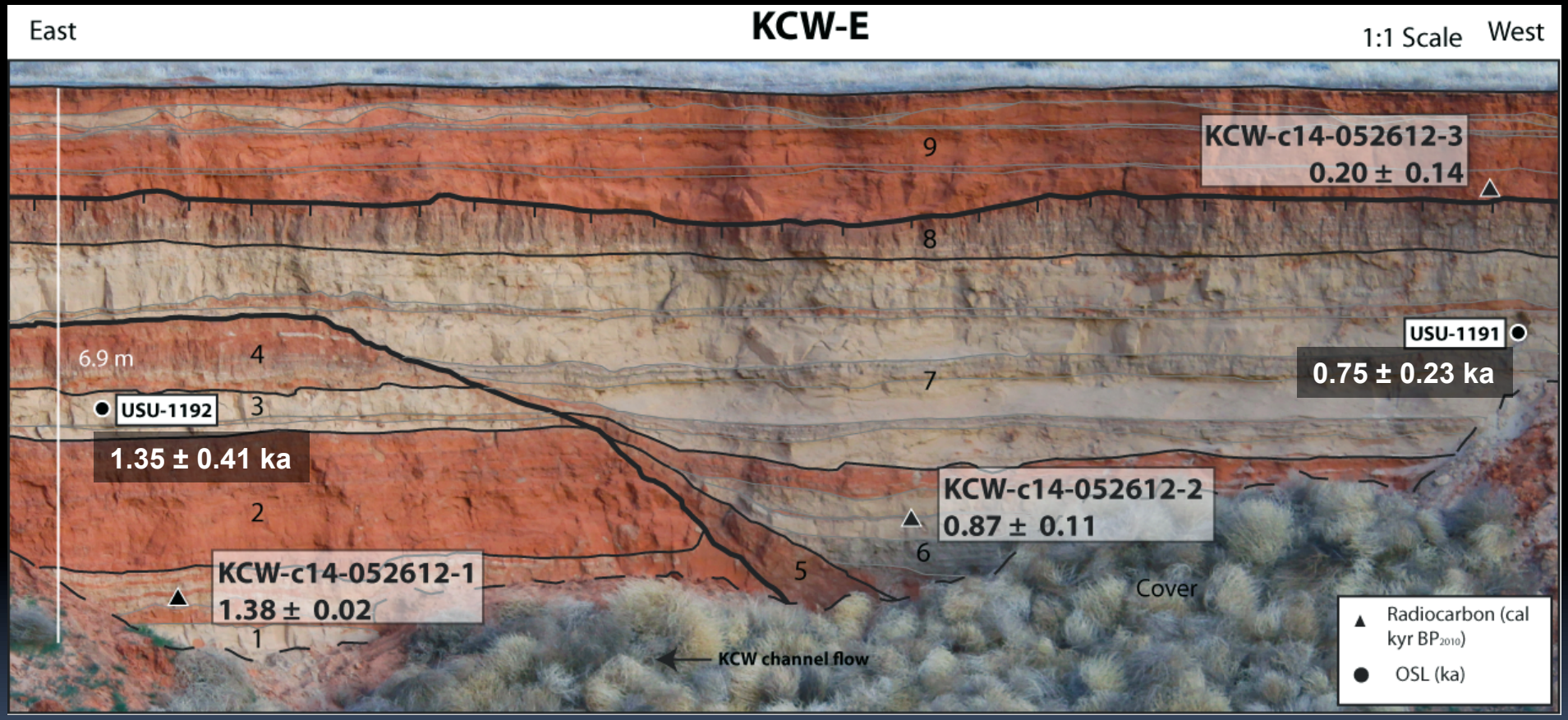


Rittenour 2008

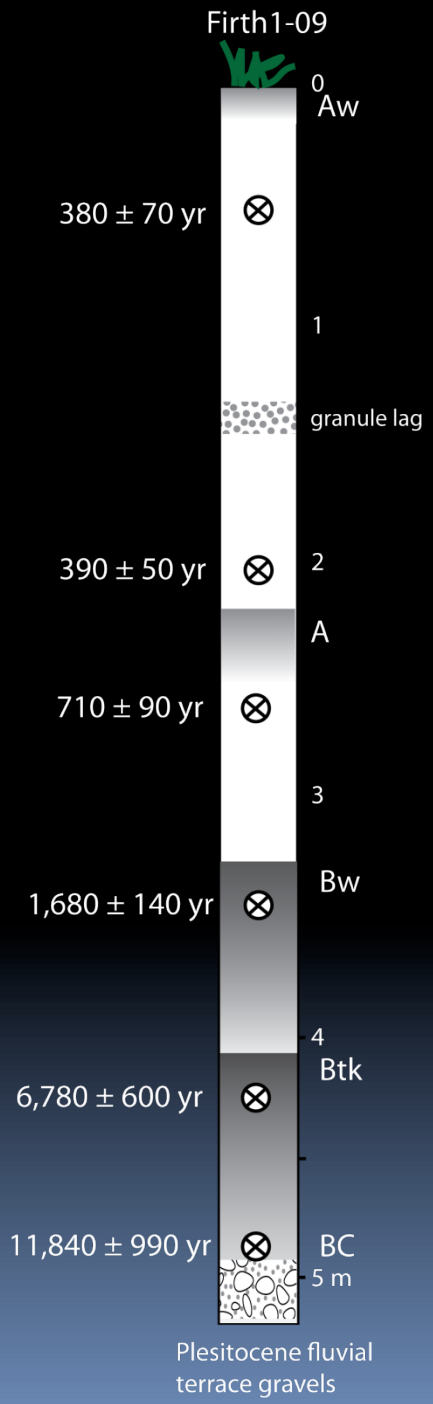
Applications:

- Dating deposits (terraces, sand dunes, glacial deposits, beach ridges, alluvial fans etc, etc)
- Dating rock surfaces
- Thermochronology

Kitchen Corral Wash



Sand Dune Records - Idaho



Timing of Fault Rupture or displacement

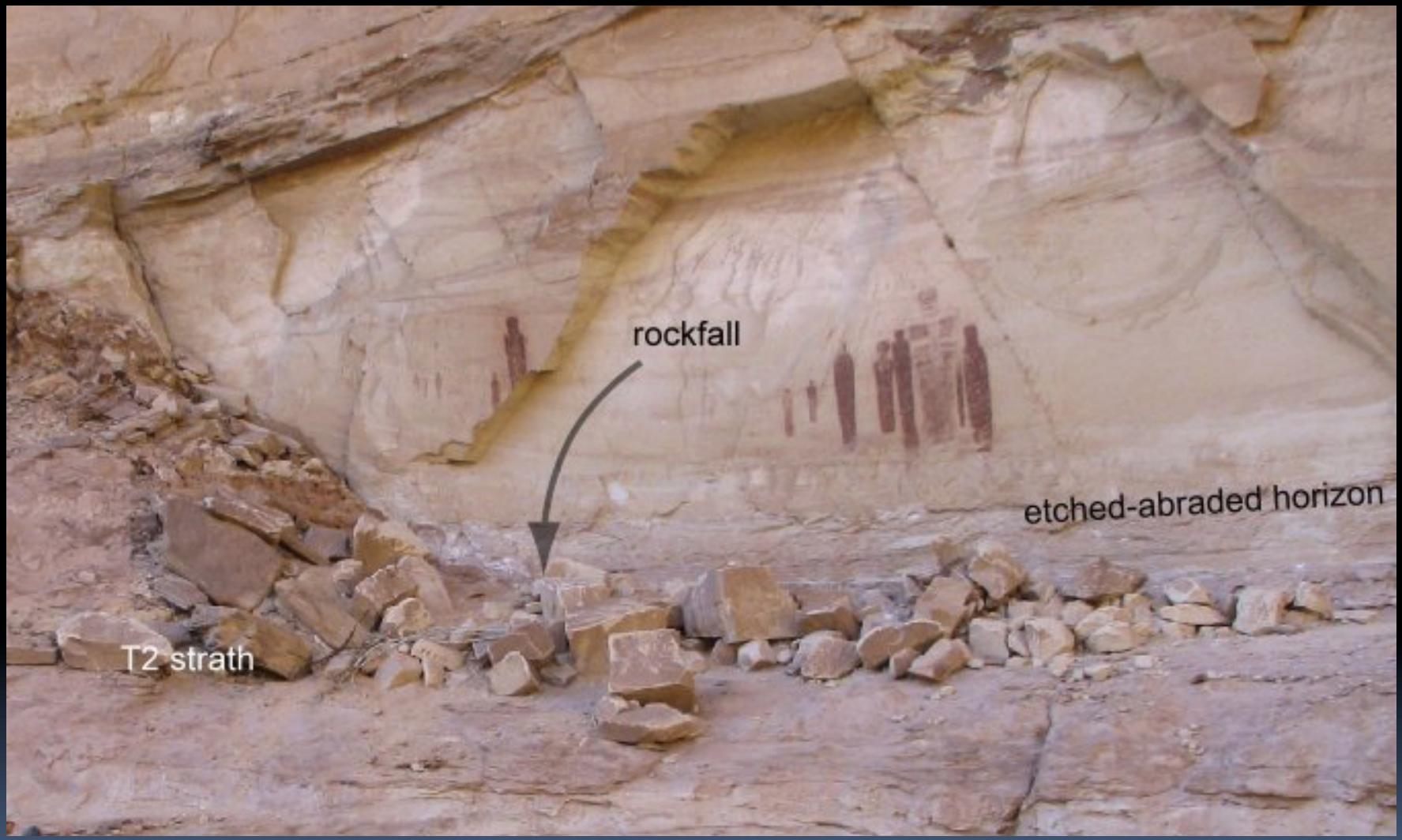
Archaeological Research

Slab-lined hearth

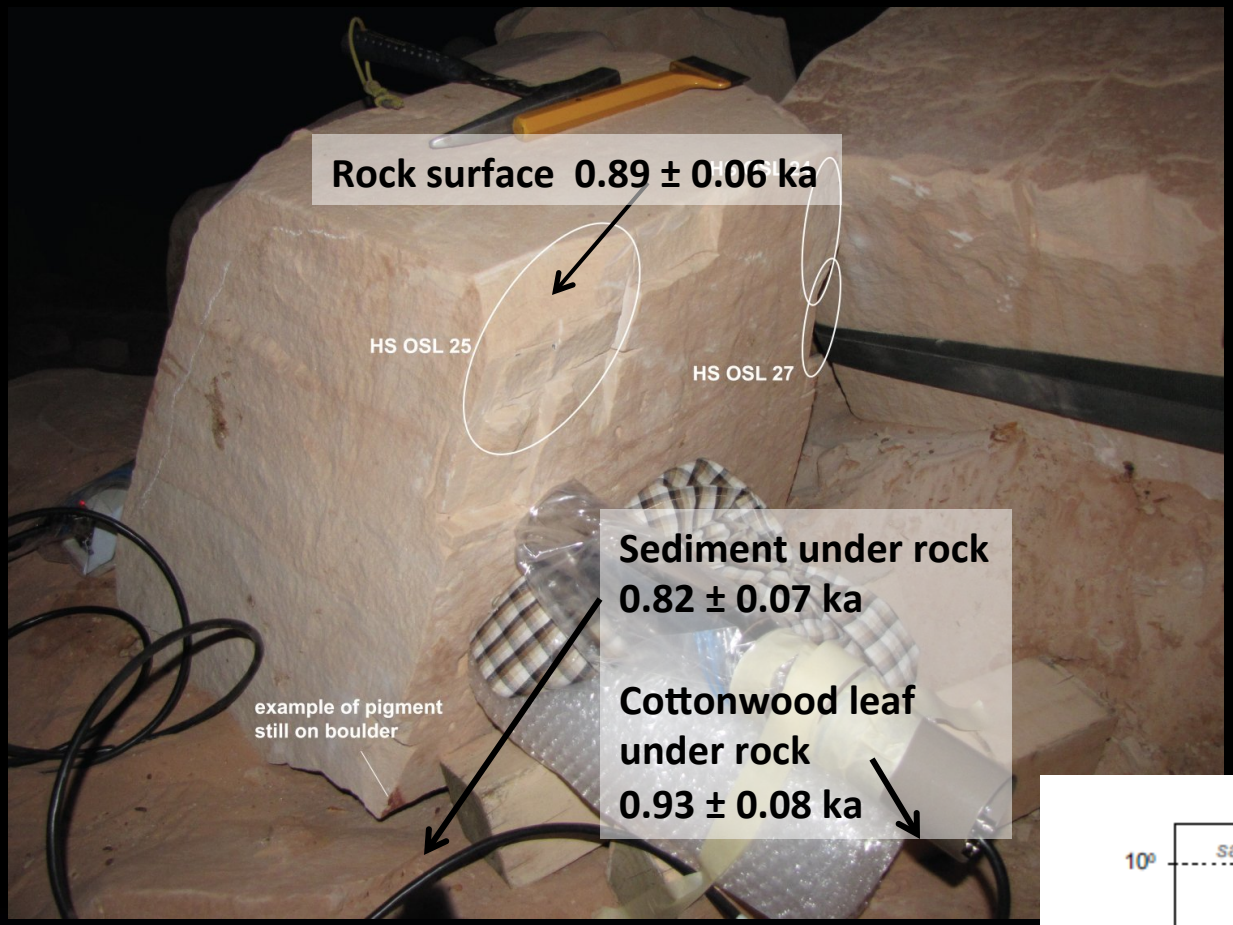
^{14}C sample = 1520-1330 cal yr BP

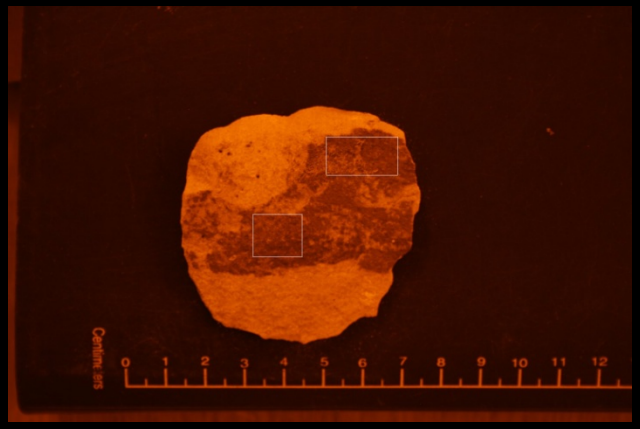
OSL sample = 1480 ± 130 ka

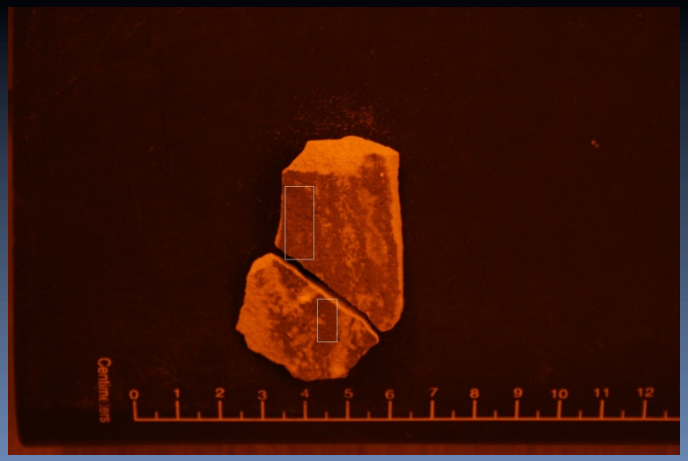
Dating Rock surfaces (exposure dating)

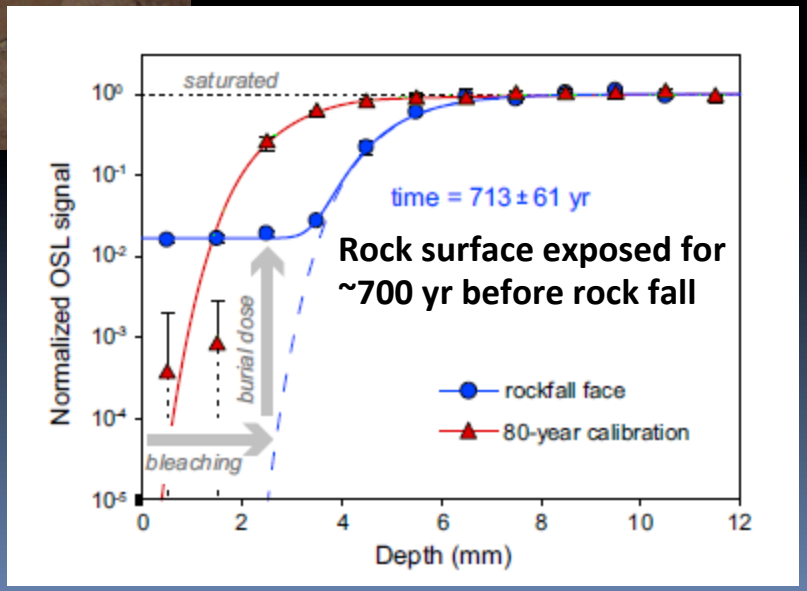


Pederson et al. 2014 PNAS

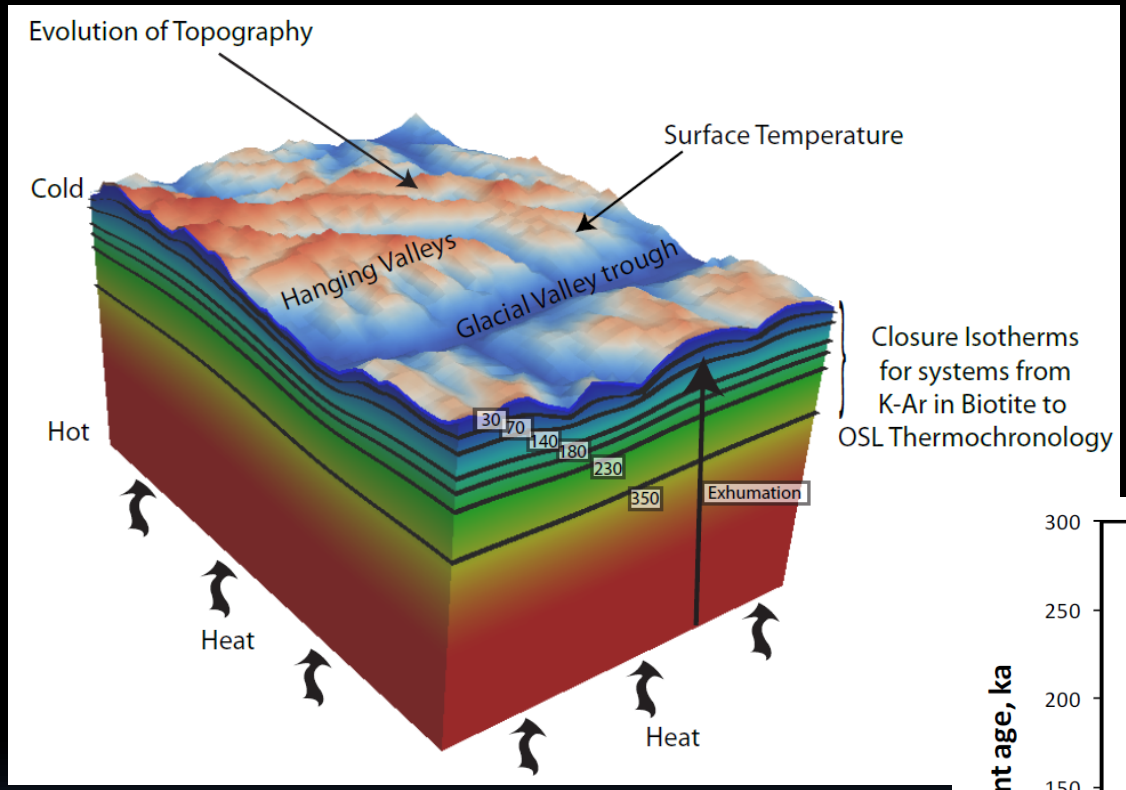

Rock surface 0.89 ± 0.06 ka
HS OSL 25
HS OSL 27
Sediment under rock
0.82 ± 0.07 ka
Cottonwood leaf
under rock
0.93 ± 0.08 ka
example of pigment
still on boulder

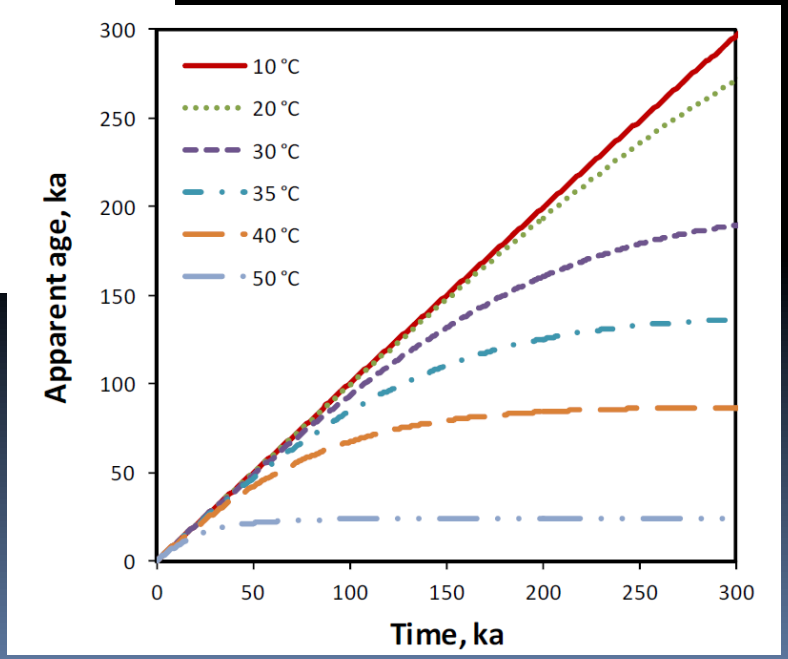





saturated
time = 713 ± 61 yr
Rock surface exposed for
~700 yr before rock fall
burial dose
bleaching
rockfall face
80-year calibration
Normalized OSL signal
Depth (mm)

OSL Thermochronology





Li and Li, 2012