GEOMORPHOLOGIST'S TOOL KIT

UNI – Earth and Environmental Science

Geomorphology – EarthSci 3300/5300

UNIT TWO

Characterizing the Earth's Surface

1. Optical surveys are done with a variety of instruments including levels, plane tables, and total stations; these provide fine-scale topographic data for hillslopes and river channels at relatively low cost.

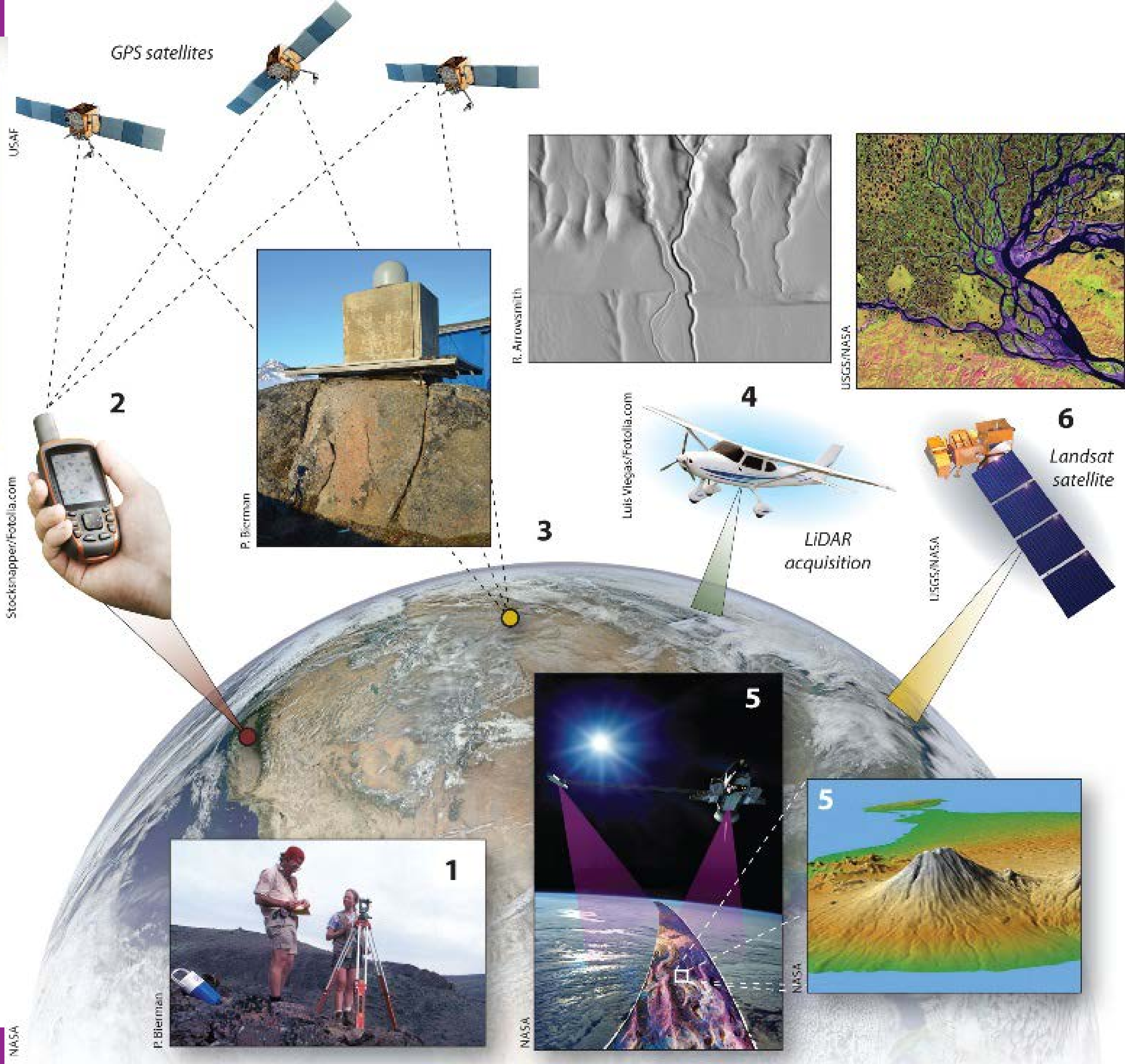
2. Handheld **GPS** receivers are used routinely to locate positions and sample sites in the field. Vertical and horizontal locations are determined to better than tens of meters by trilateration to at least four GPS satellites.

3. Recording GPS receivers anchored to stable **bench-marks** are used to make high-precision (mm-scale) measurements of lateral and vertical position change caused by plate tectonics and the isostatic response to changing glacier mass over time.

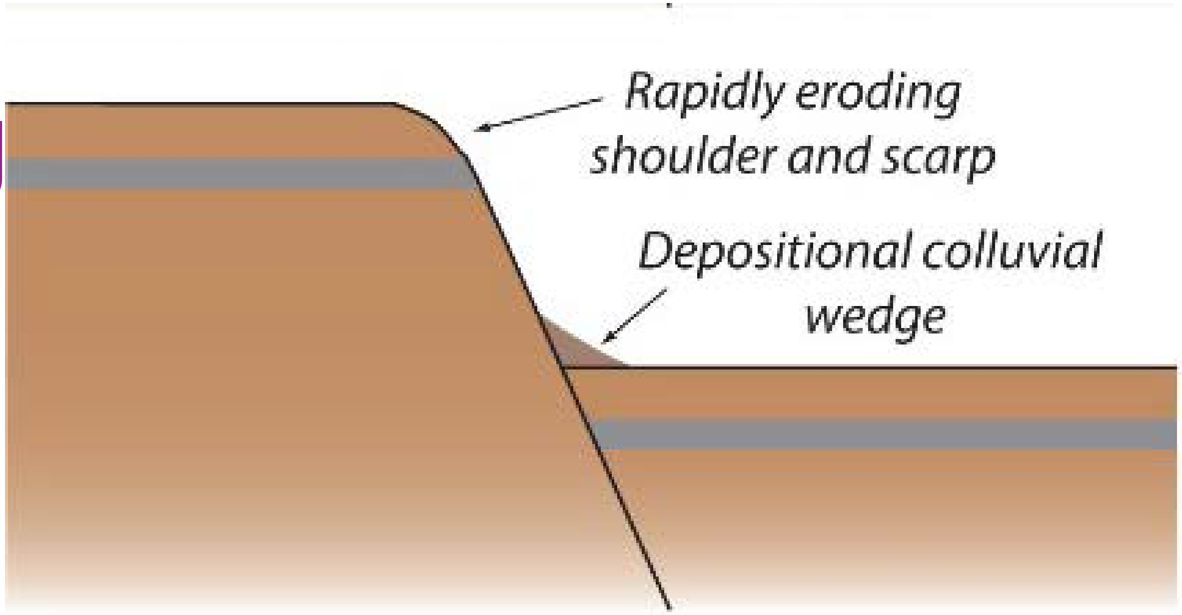
4. LiDAR data are collected from airplanes carrying lasers capable of measuring precisely the travel time of laser light to Earth's surface. High-precision GPS determines the location of the airplane when each laser pulse is sent out and received.

5. Active remote sensing data collected by the Space Shuttle include Synthetic Aperture Radar (**SAR**), used both to map the topography of Earth's surface (**SRTM**) and to determine small changes in elevation through interferometry (**InSAR**).

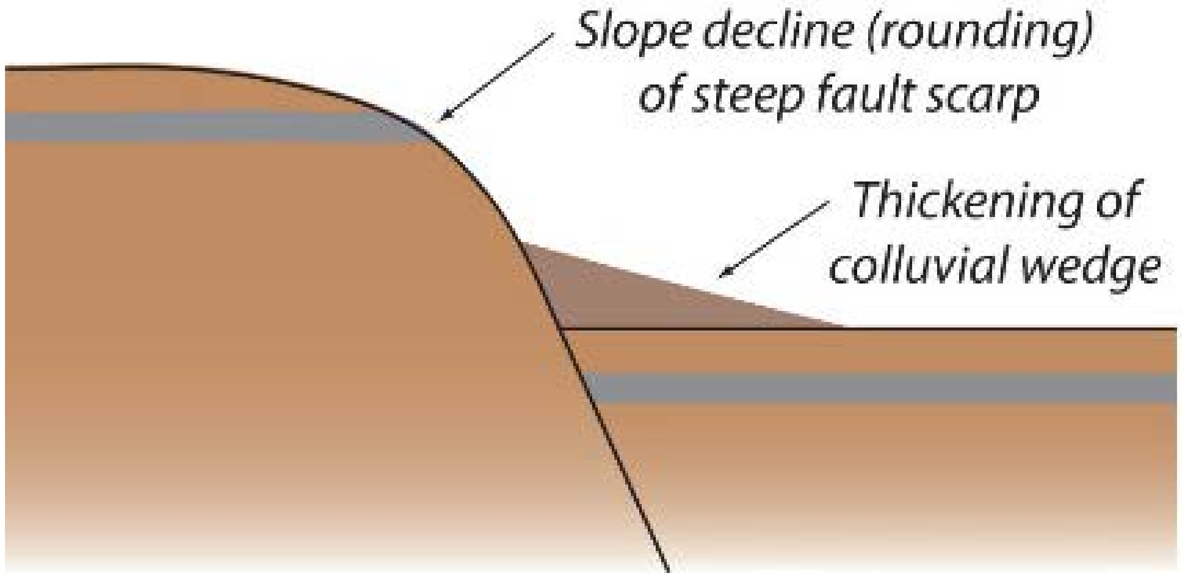
6. Landsat and other satellites collect **passive remote sensing** data. Multi-spectral sensors on the satellites quantify the amount of light at different wave-lengths reflected by the materials covering Earth's surface, such as differing vegeta-tion or lithology.



Relative age dating

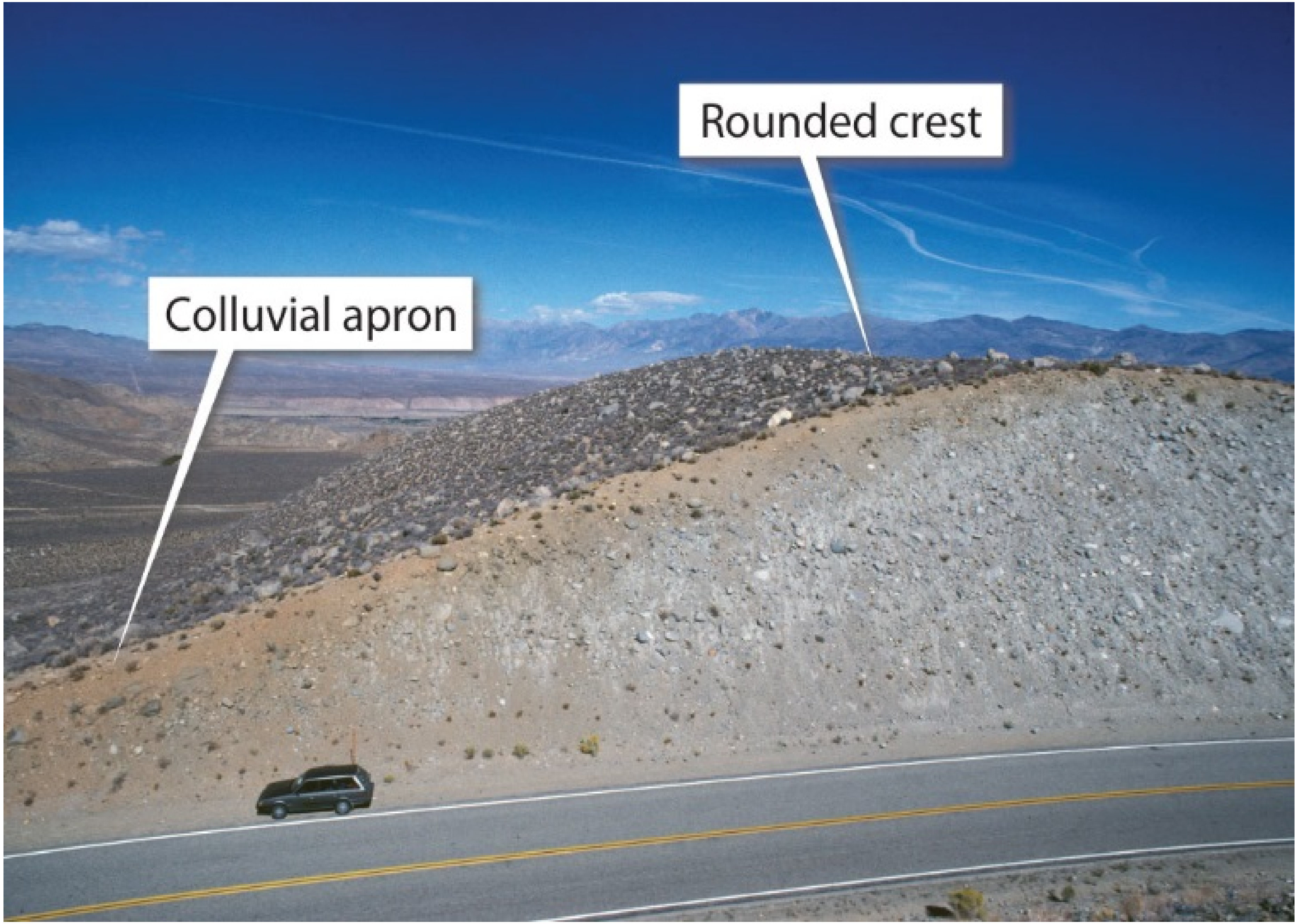


Time 3: As the steep scarp begins to erode, transported material piles up on the downthrown block, creating a **colluvial wedge.**

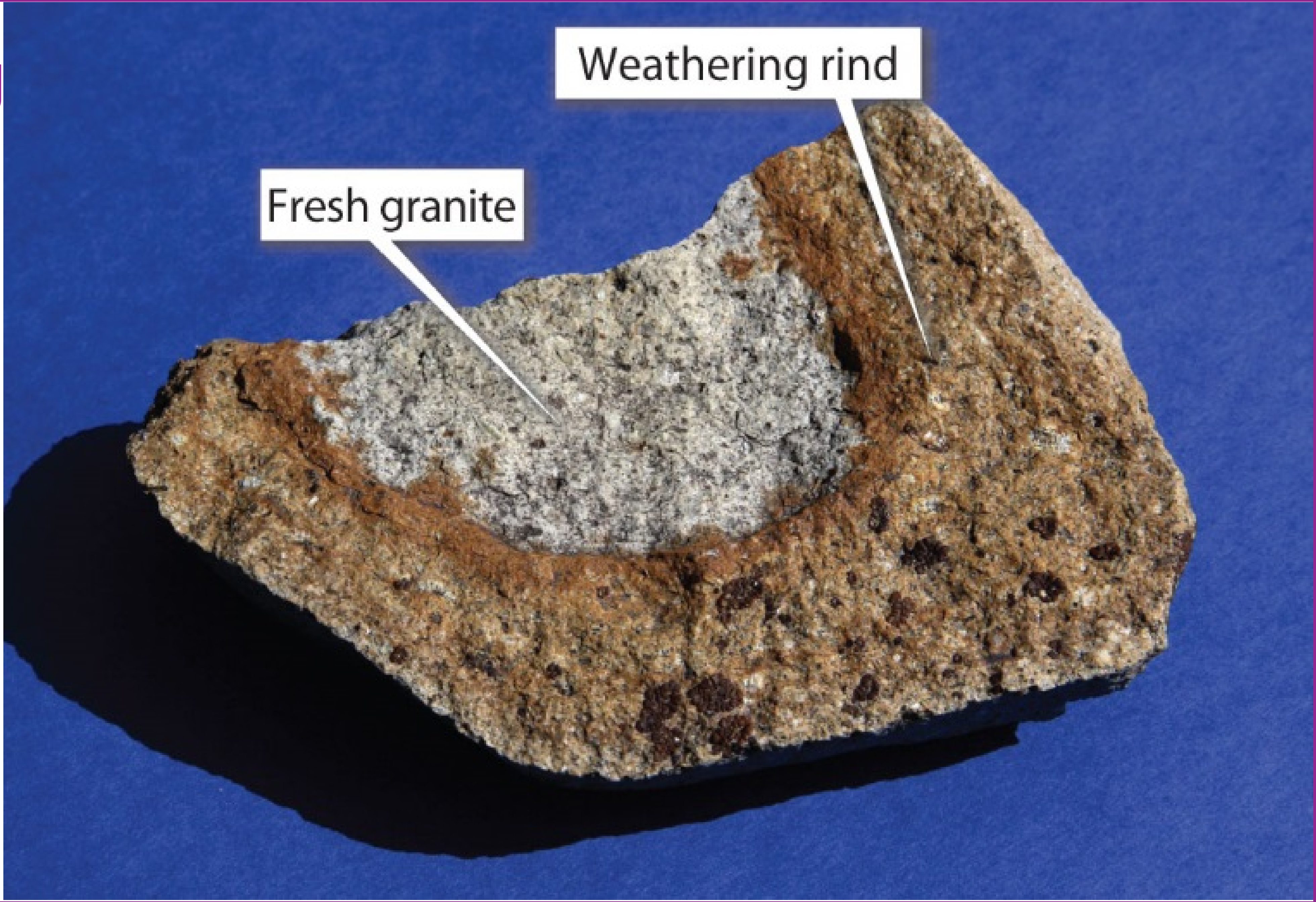


Time 4: Over time, the colluvial wedge thickens and extends. The deposit preserves a record of the timing of erosion and the volume of material shed from the scarp.

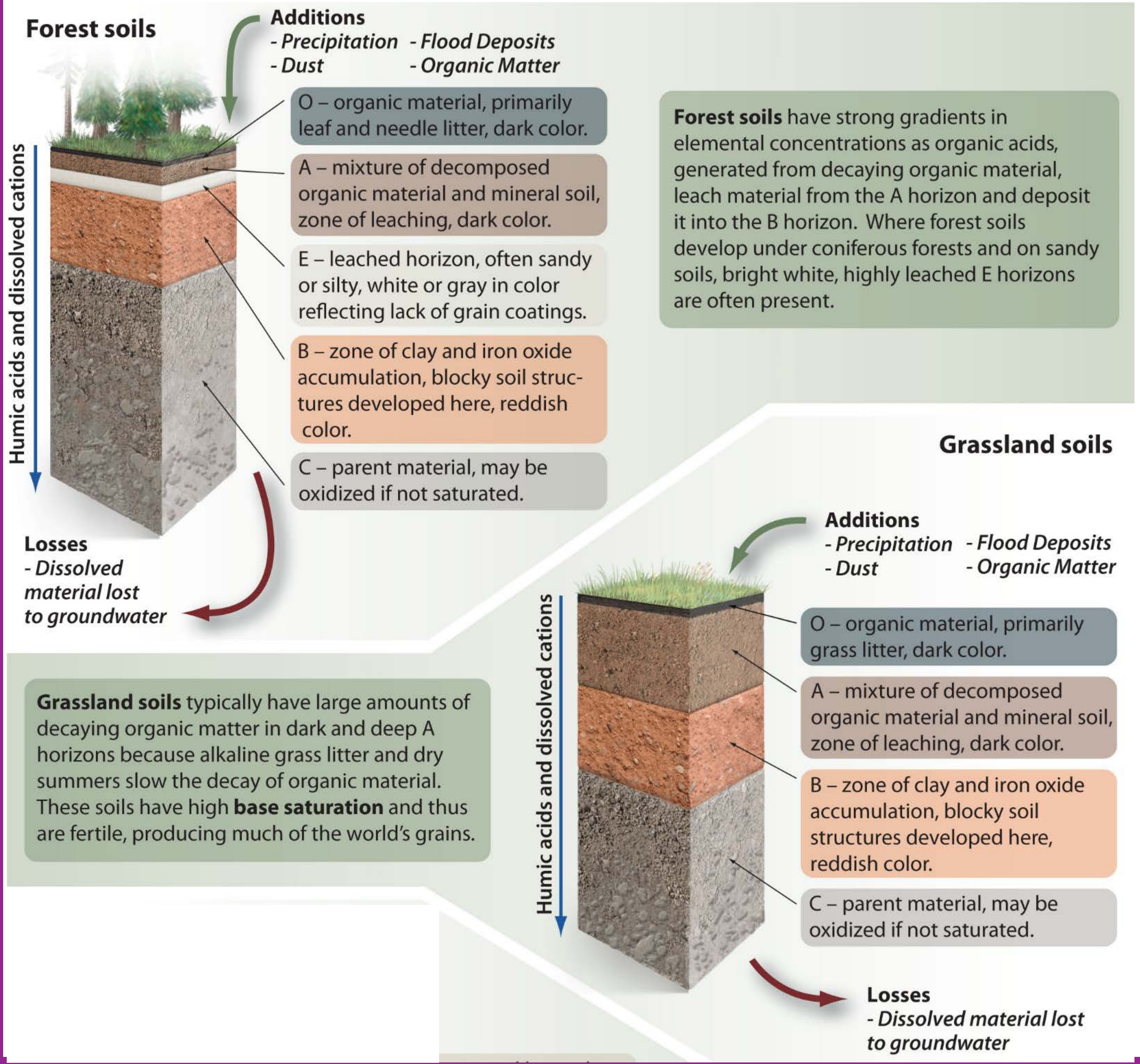
Signs of landform degradation



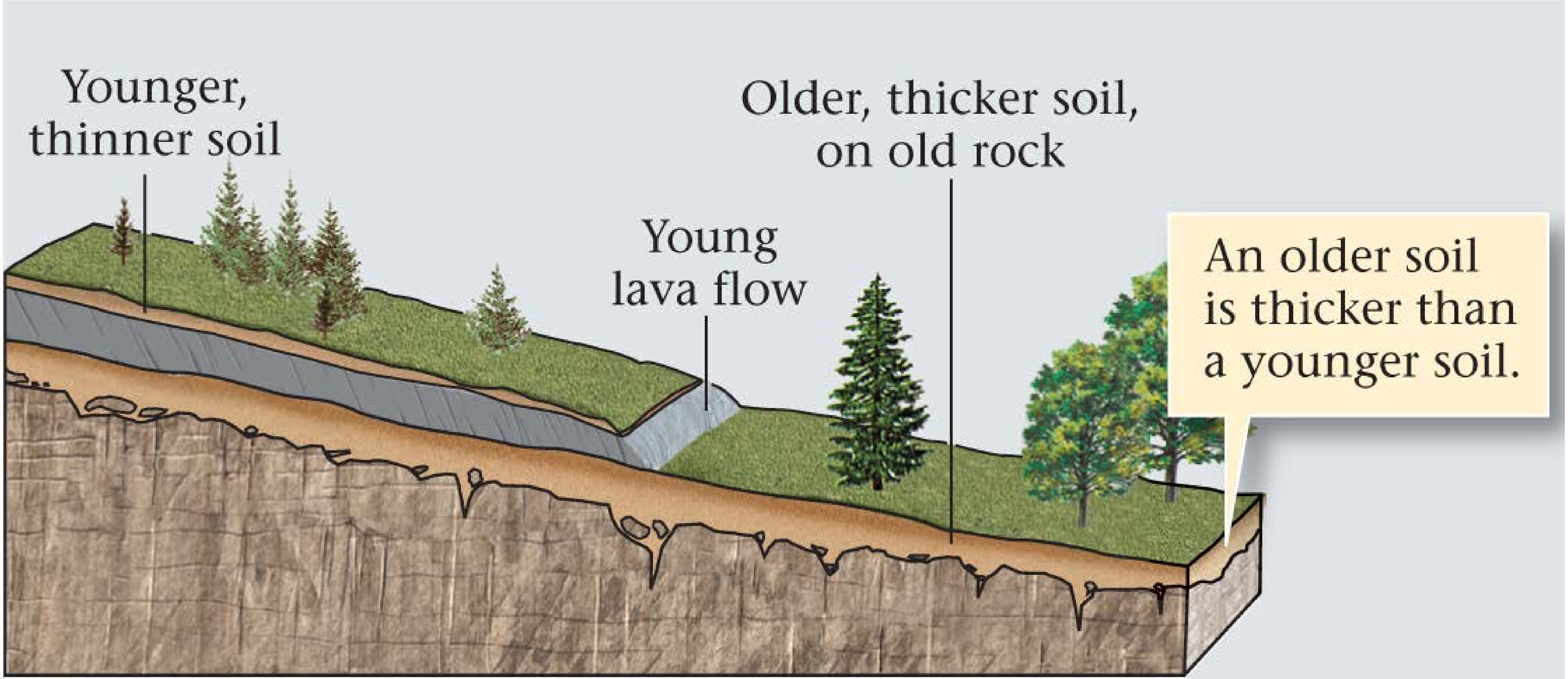
Weathering



Type and degree of soil development

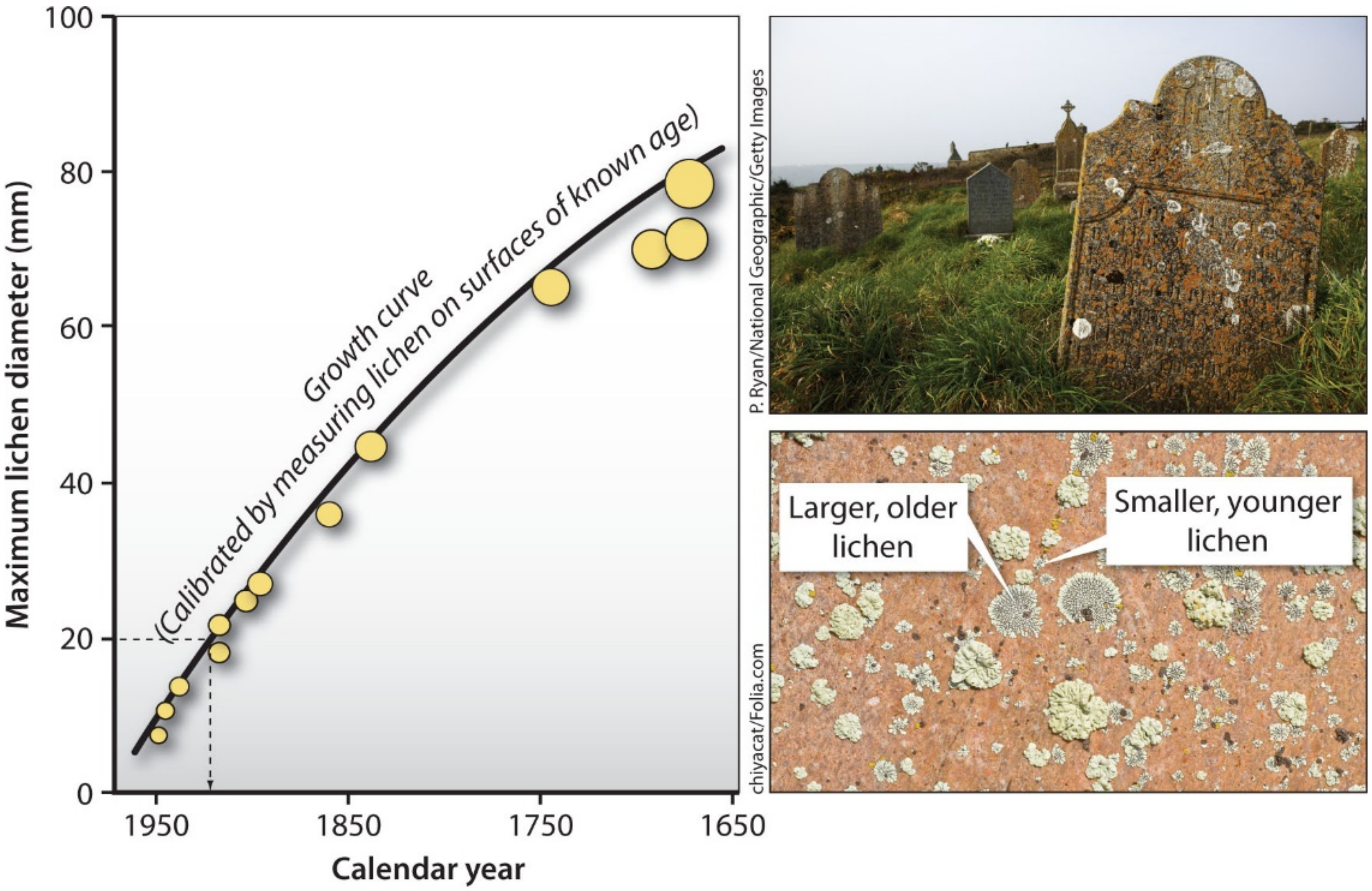


Soil development




Younger fan surface
Older fan surface
Rock varnish / Desert varnish

Calibrated Relative Dates

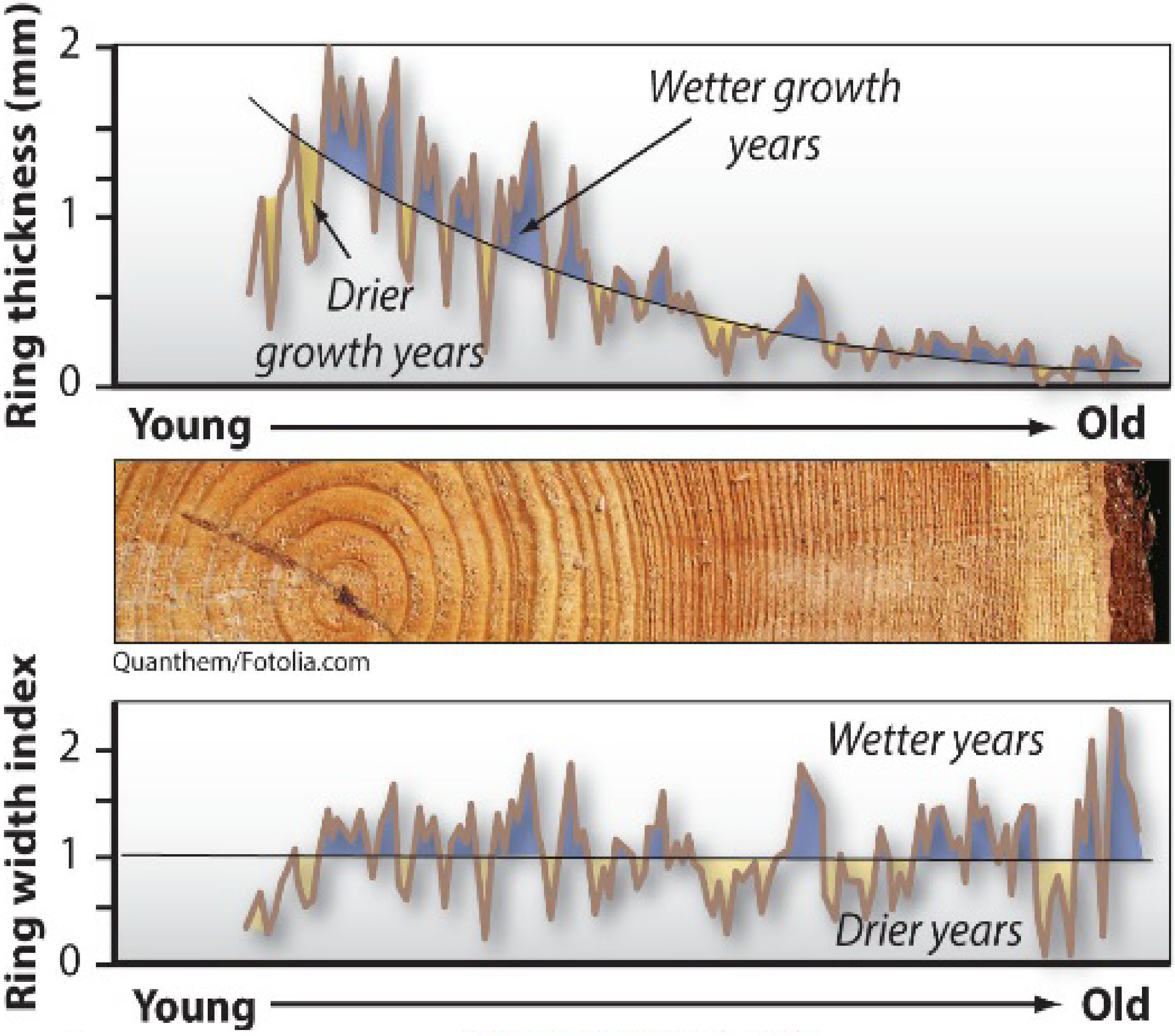


Lichenometry is a calibrated **relative dating method,** which relies on the observation that lichens of a single species have similar growth rates. Thus, by calibrating a **growth curve** on surfaces of known age, such as buildings and tombstones, the maximum width of a lichen found on a surface of unknown age (such as a glacial **moraine**) can be used for dating. Lichenometry can be used to date features between a few decades and a few centuries in age.

Dating methods frequently used by geomorphologists

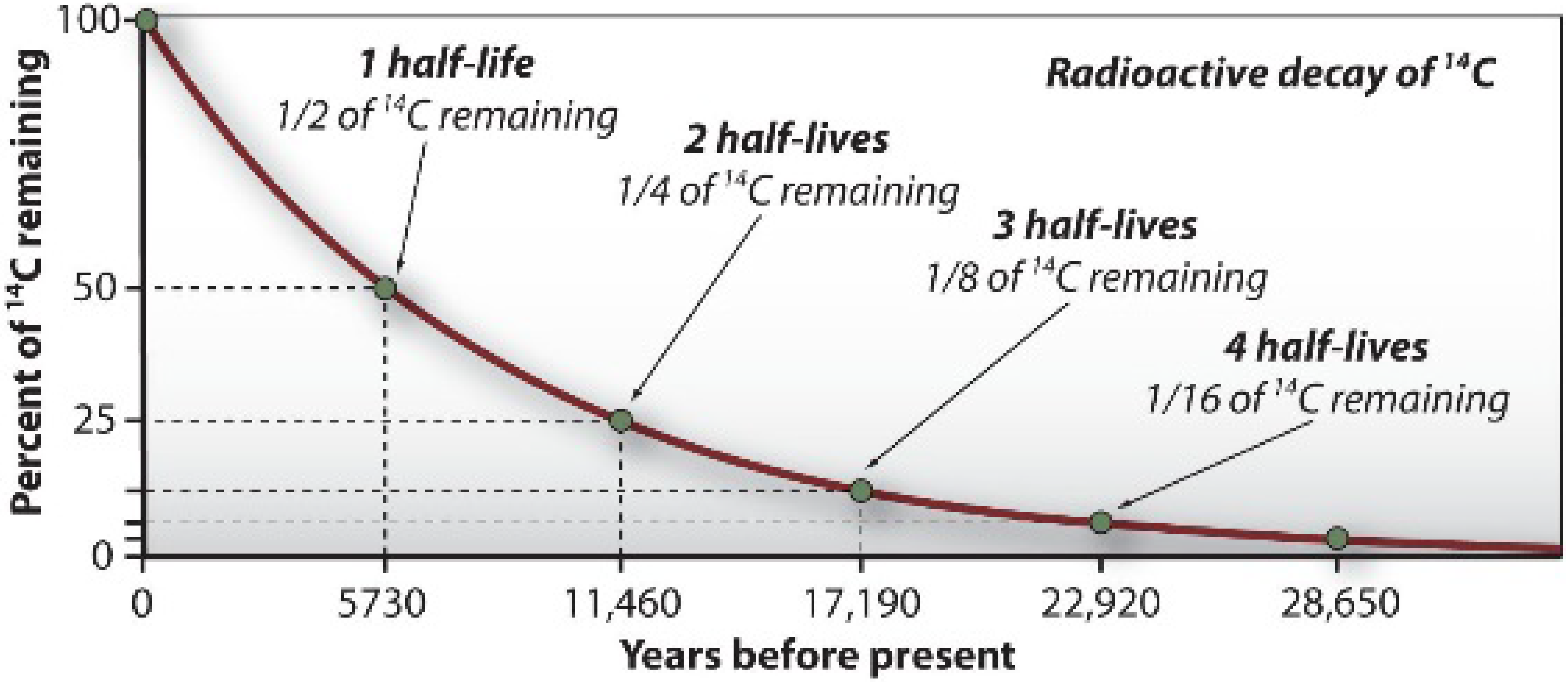
Method	Type	Age Range (years)	Requirements/Assumptions
Radiocarbon (^{14}C)	Numeric dating	10^2 to 5×10^4	Organic material present in interpretable geologic context
Cosmogenic nuclides	Numeric dating	10^2 to 10^6	Continuous exposure of noneroding surface that was free of cosmogenic nuclides before exposure
Luminescence	Numeric dating	10^3 to 10^6	Quartz or feldspar exposed to light or heat before burial
U/Th	Numeric dating	10^3 to 10^5	Carbonate minerals
Dendrochronology	Numeric dating	10^0 to 10^4	Wood from trees
K/Ar	Numeric dating	10^3 to 10^8	Potassium-bearing minerals
Lichenometry	Calibrated relative dating	10^1 to 10^3	Lichens on both unknown and dated calibration sites
Amino-acid racemization	Calibrated relative dating	10^3 to 10^5	Well-preserved shell material
Rock weathering	Relative dating	10^2 to 10^4	Dated surfaces for calibration
Soil development	Relative dating	10^2 to 10^6	Dated chronosequence for calibration

Amino-acid racemizatior



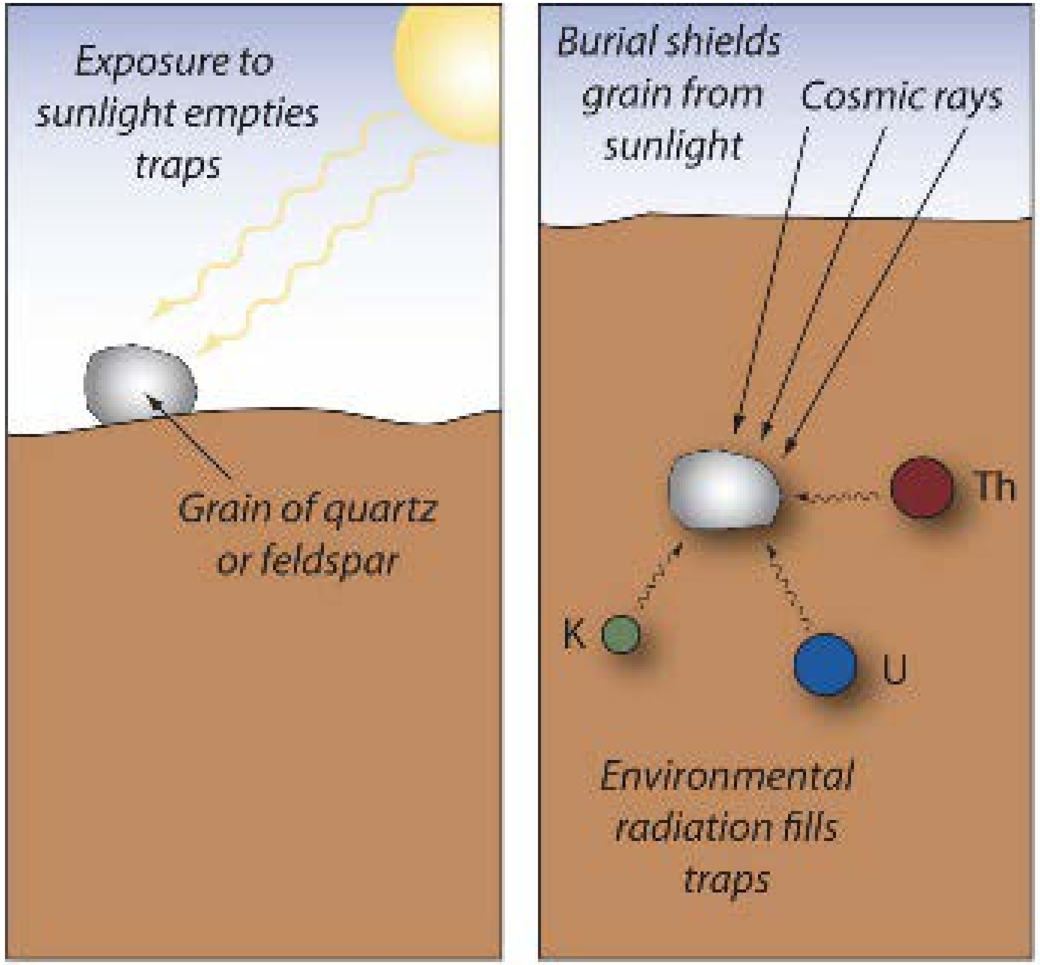
In addition to dating tree ages, **tree ring analysis** can be used to decipher changes in ring width related to climate (temperature, water, and cold stress). The thinning of rings over time needs to be filtered out, usually by detrending the data using a curve fit. The resulting deviation from the curve defines the **ring width index** and is used for **paleoclimate** interpretation, with deviations above or below the fitted trend interpreted as wetter or drier years, respectively.

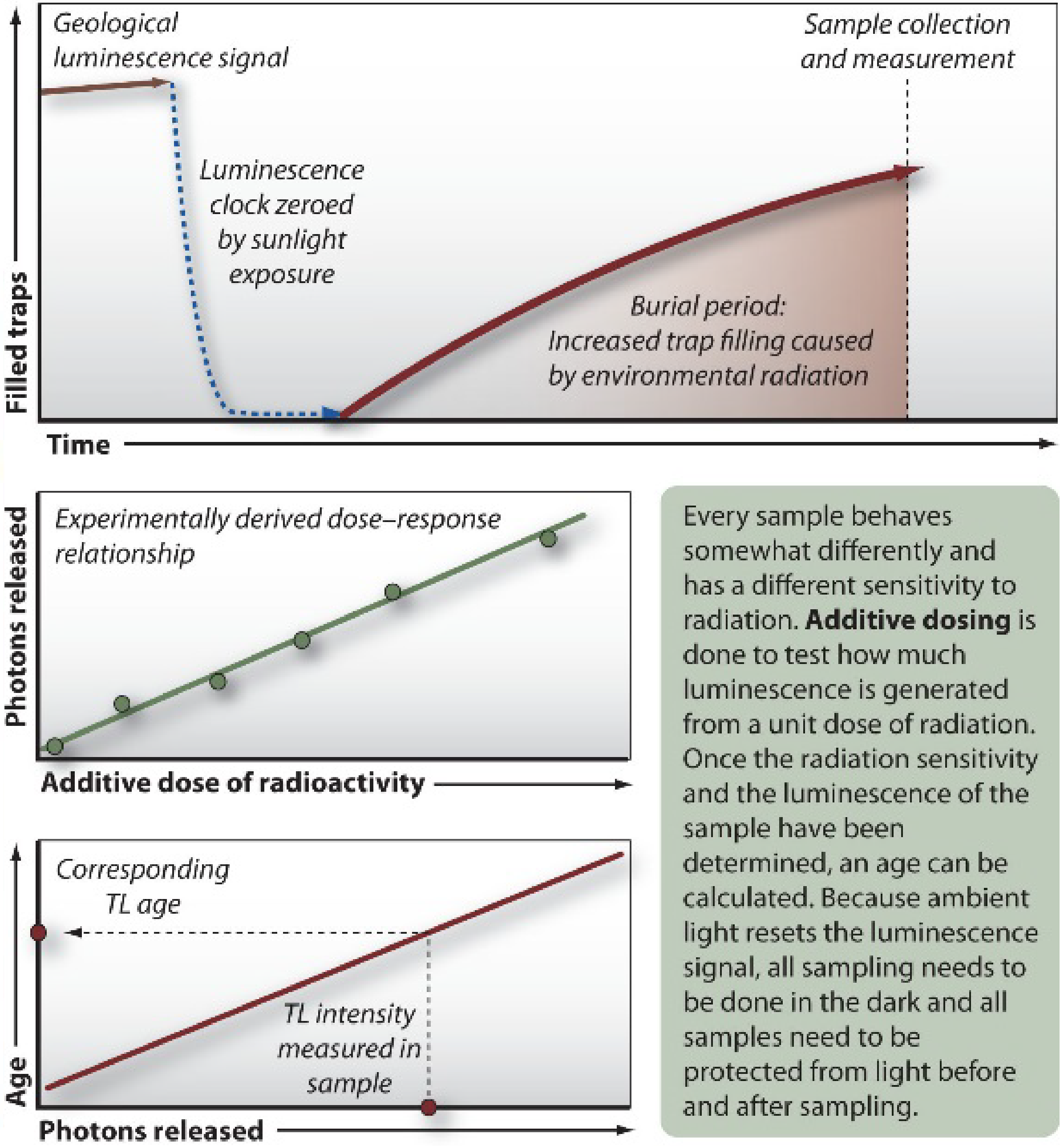
C-14 dating



The time of death of organic material can be dated using the concentration of radiocarbon (^{14}C) remaining in the material. As the object ages, radiocarbon atoms decay back to nitrogen at a steady rate; thus, the concentration of ^{14}C is reduced over time. Because the **half-life** (decay rate) of radiocarbon is well known (5730 years), one can estimate an age from a radiocarbon concentration. In practice, radiocarbon dating is useful for 7 or 8 half-lives, about 50,000 years.

Optically Stimulated Luminescence Dating



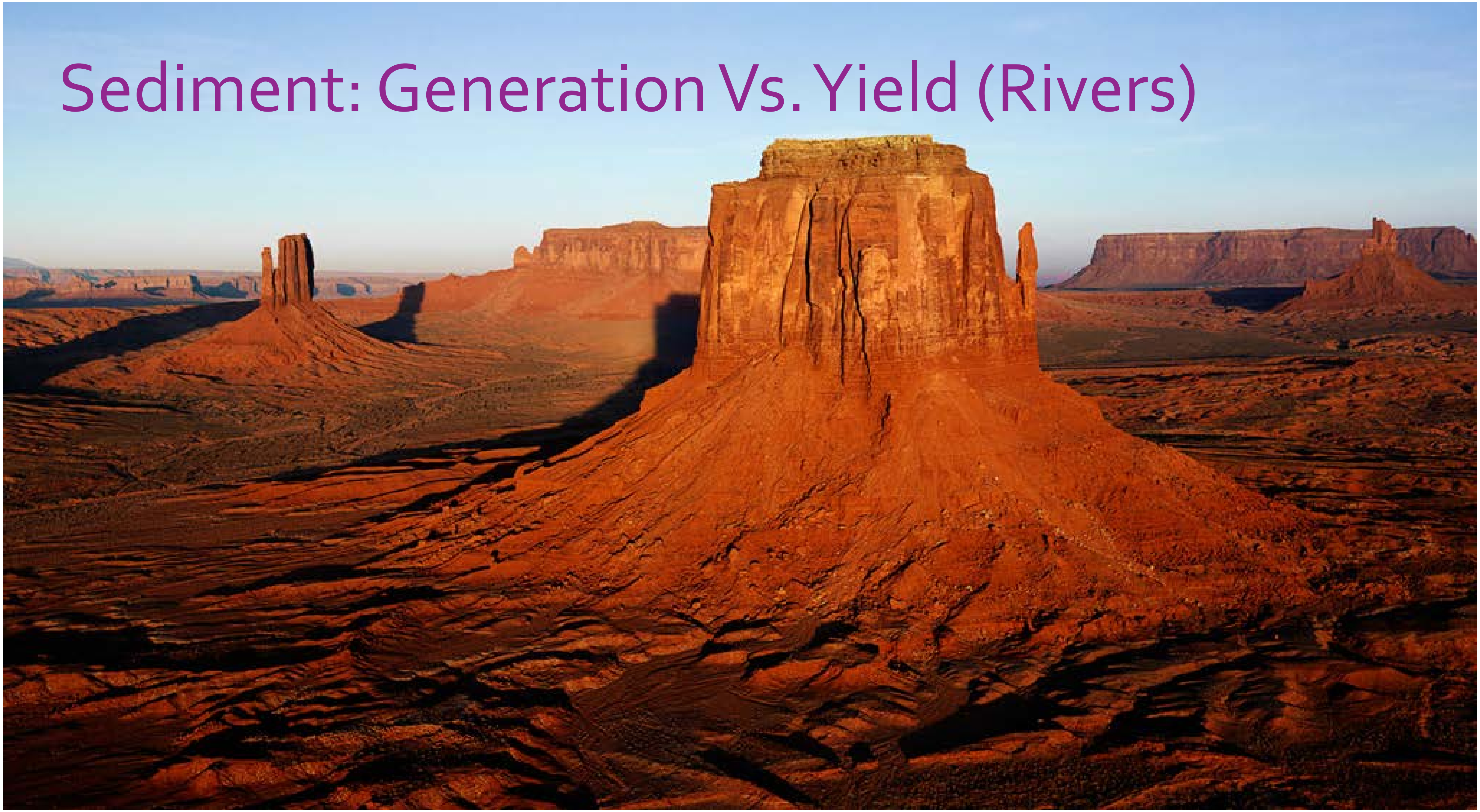


Every sample behaves somewhat differently and has a different sensitivity to radiation. **Additive dosing** is done to test how much luminescence is generated from a unit dose of radiation. Once the radiation sensitivity and the luminescence of the sample have been determined, an age can be calculated. Because ambient light resets the luminescence signal, all sampling needs to be done in the dark and all samples need to be protected from light before and after sampling.

MEASURING RATES OF GEOMORPHIC PROCESSES

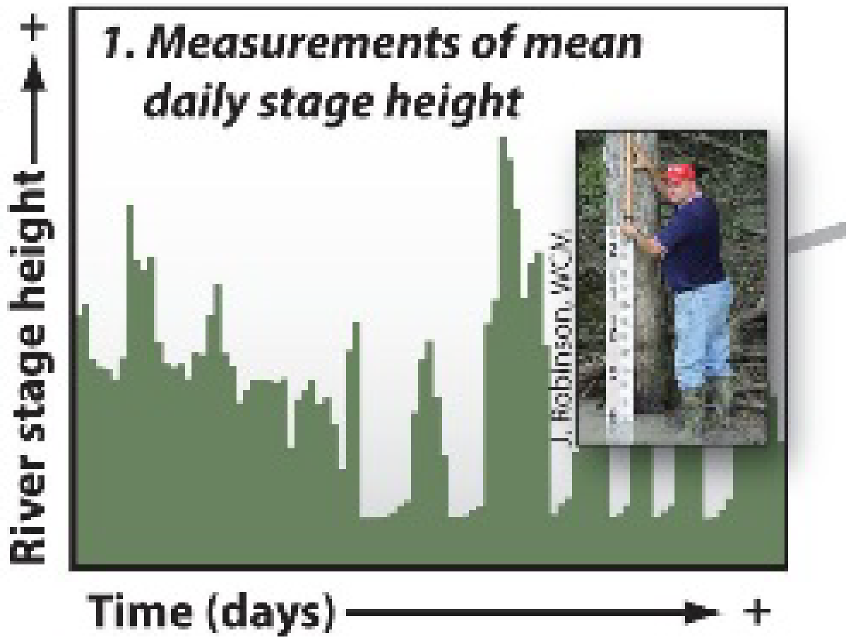
Unit 2 – Continued

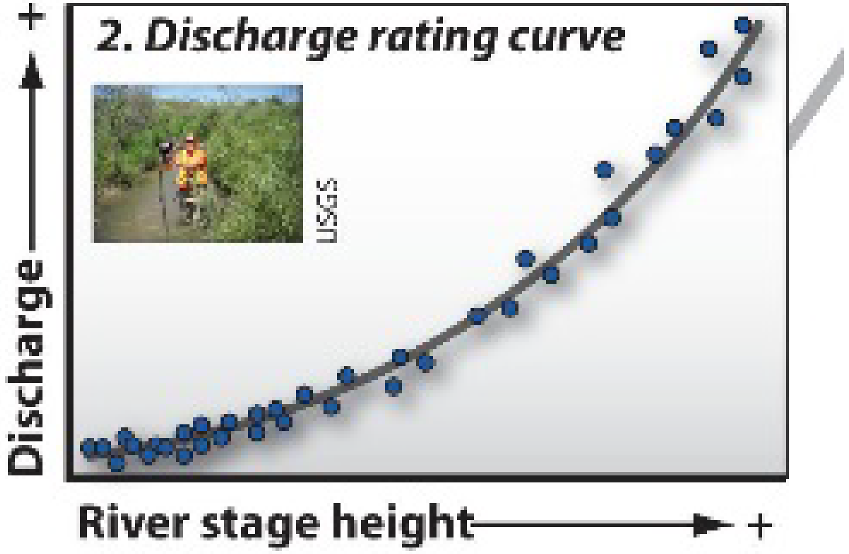
Sediment: Generation Vs. Yield (Rivers)



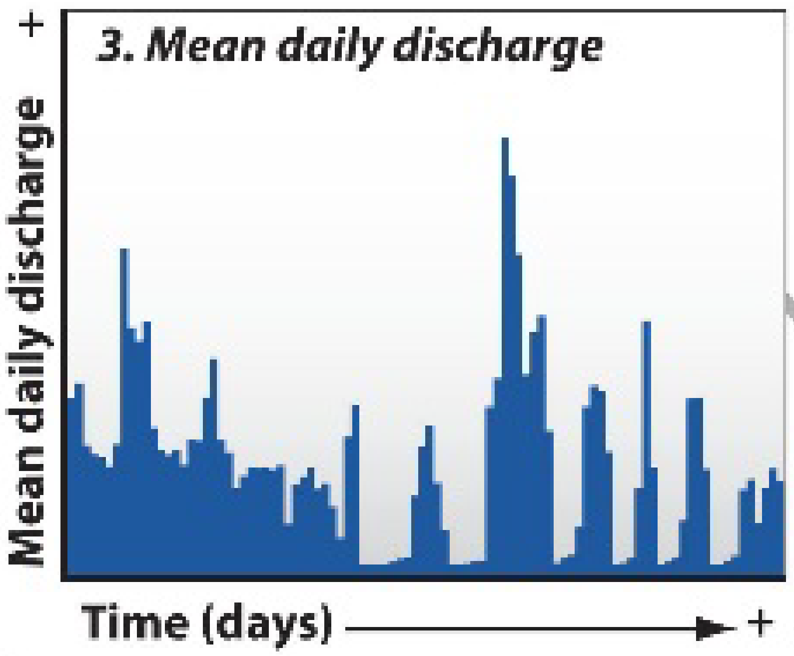
Step 1. River stages can be measured manually by reading **staff gauges** or automatically by stage recorders. Some recorders use floats that measure water surface elevation directly; others use pressure transducers that measure the mass of water overlying the sensor.

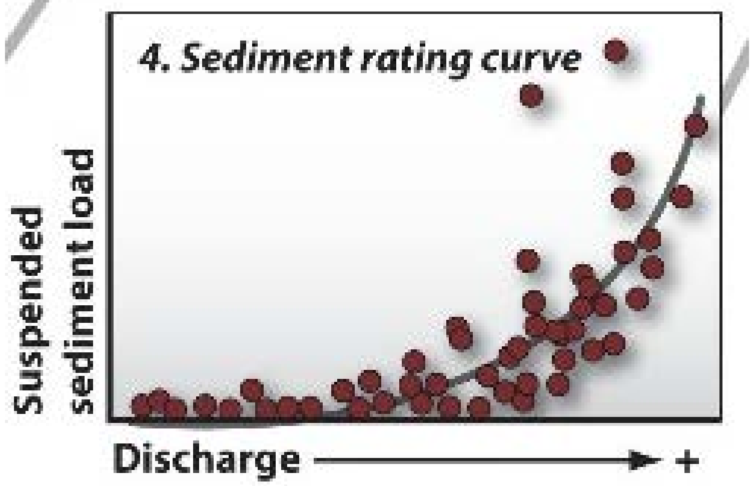
Step 2. Water discharge rating curves are created from numerous measurements of discharge at a gauging station These measurements are made at different river stages using velocity meters and measured channel cross sections or by damming the river and forcing flow over a **weir** for which the stage-discharge relationship is known. Discharge rating curves are remeasured to ensure accuracy as channel dimensions and thus the rating curve can change over time.





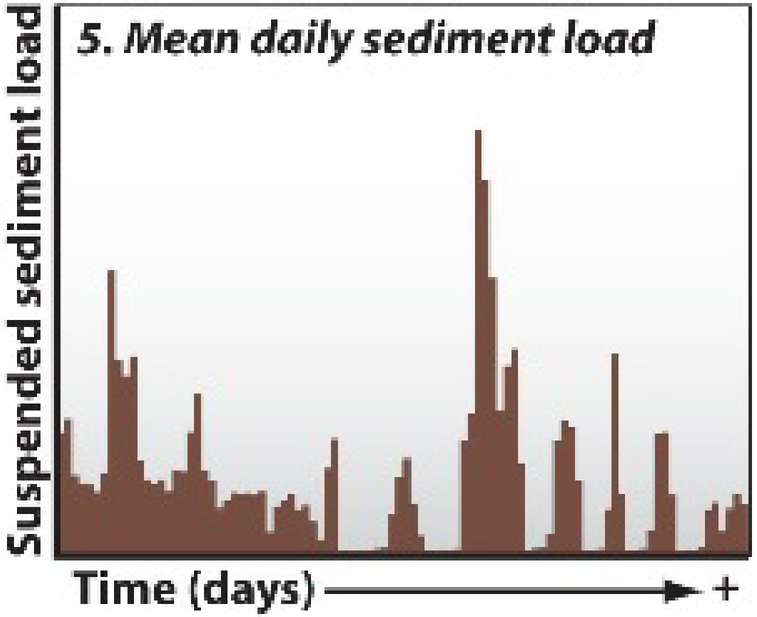
Step 3. Convolving measurements of stage with the discharge rating curve allows for calculation of discharge over time. Data are collected at different time intervals and are often reported as mean daily discharges.





Step 4. Sediment rating curves compare sediment concentration and water discharge and are often quite noisy, due to variations in sediment supply to the river. They are constructed by measuring sediment concentrations at different water discharges. Sediment concentrations can be measured discretely by sampling river water or continuously using recording **turbidity** meters.

Step 5. Sediment loads (mass/time) are calculated by multiplying sediment concentrations (mass/volume) and water discharge (volume/time). Often, daily data are used for this calculation and then summed to give annual sediment fluxes out of a drainage basin. Since most sediment moves in large runoff events, there can be great variability in sediment yields year to year.



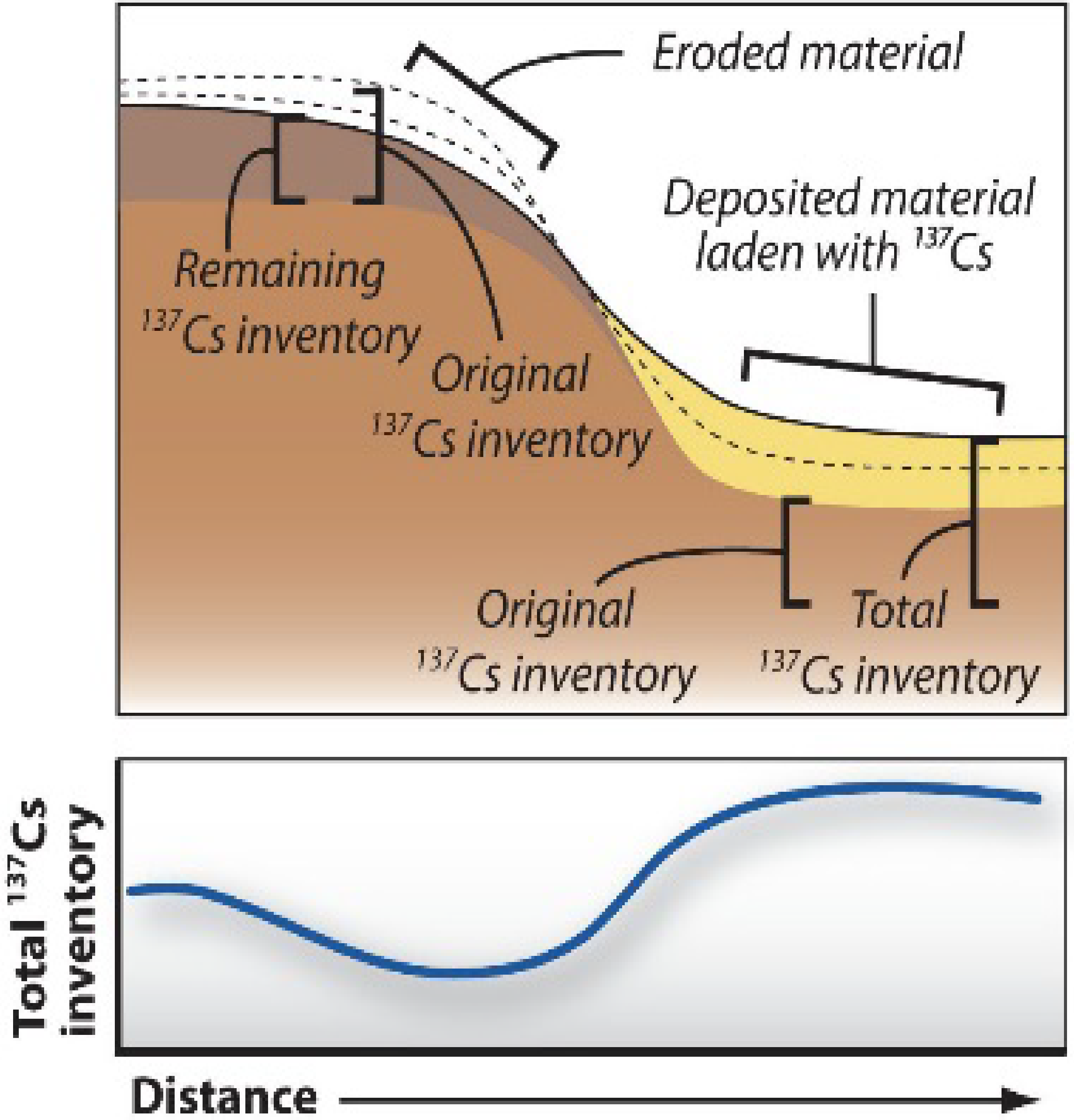
Global Warming Images / Alamy

Contemporary sediment yields, calculated from measurements of riverine sediment flux over only years to decades, may either over- or underestimate long-term erosion rates due to human impacts or climate variability.

Topographic surveys

Soil erosion

^{137}Cs is a useful monitor of erosion and deposition since the early 1960s, when the isotope was delivered to the soil surface by precipitation. ^{137}Cs sticks to soil and thus migrates no more than a few tens of centimeters below the ground surface. Using decay counting, geomorphologists measure the inventory of ^{137}Cs. If the measured inventory is greater than the amount delivered by nuclear weapons testing, then the measured profile is a depositional zone where eroded soil and the attached ^{137}Cs have accumulated. If the measured inventory is less than the amount delivered by nuclear weapons testing, the sampled profile is in an area that has eroded since the 1960s.



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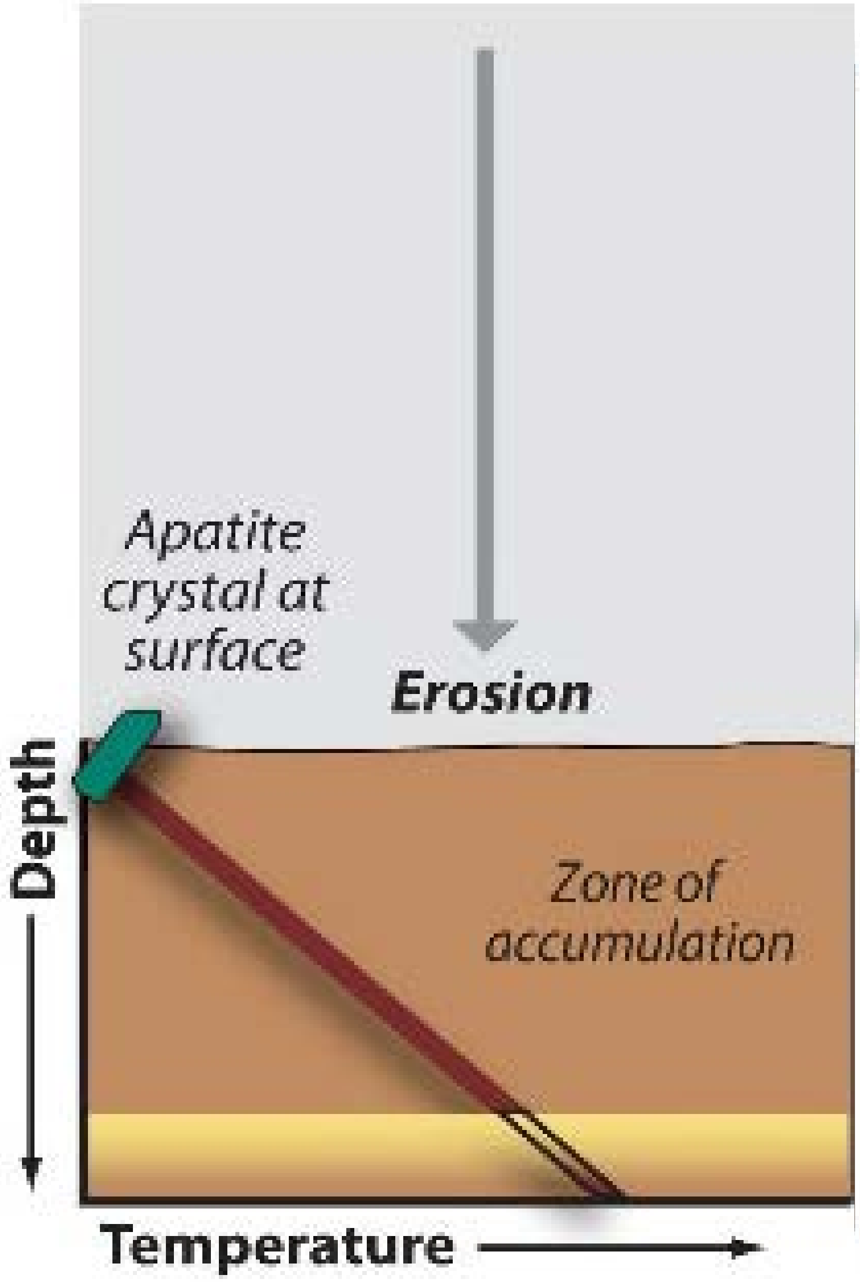
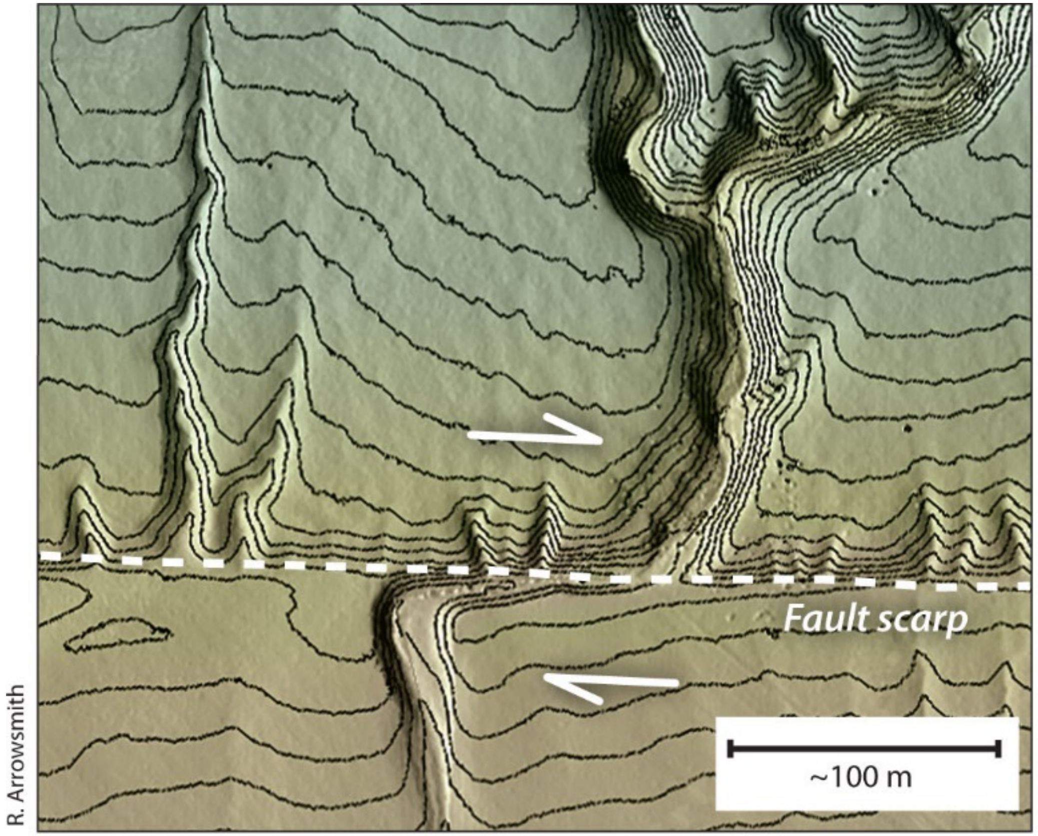
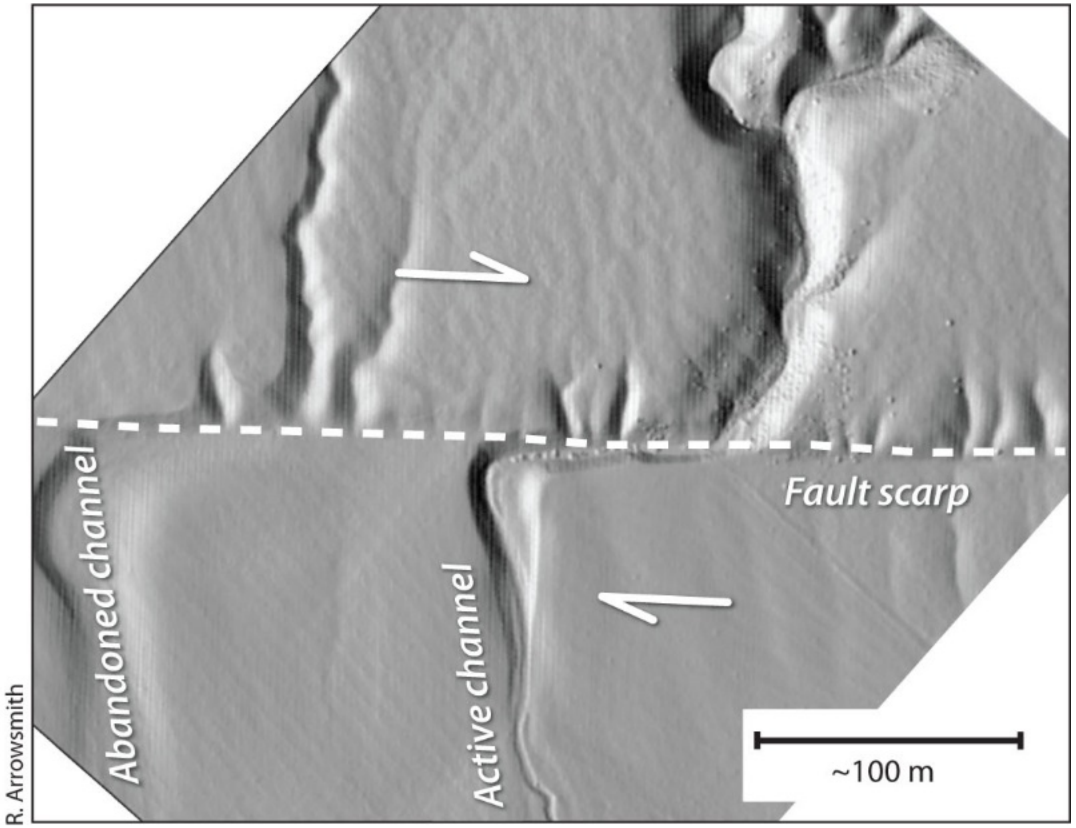


Once the crystal moves above the closure temperature range, fission tracks cease to anneal and radionuclides are retained. The fission track or radiometric age of the crystal reflects the time it took erosion to remove the depth of rock overlying the closure temperature range. Using a geothermal gradient appropriate for the study area, this depth/time relationship can be interpreted as a long-term erosion rate.

Remote-Sensing (e.g. LIDAR)



A detailed topographic map with a 2-meter contour interval shows the offset of Wallace Creek by the San Andreas Fault.



High-resolution **LiDAR** image shows both the current (active) and abandoned channels of Wallace Creek as well as the San Andreas Fault **scarp.**

The bottom line

Geomorphologists MUST be able to choose the right tool for the job AND understand the geomorphic context in which the tool is used.

Because each tool has limitation due to unique field conditions AND each tool brings underlying assumptions and biases, that if not accounted for will likely produce incorrect results/interpretaions/predictions!