a25 Rates of bedrock incision by rivers < strath >

> We have a chain of facts which clearly demonstrates ... that the materials of the wasted mountains have traveled through the rivers. —Hutton.[1]

A river erodes by cutting downward (incising) and sideways (strathing). These processes are naturally episodic and rarely do they operate at the same rate. In mountain streams, incising can be rapid. Straths (***Figure a25.1***) that can be dated allow for rates of incision to be known. The fastest incision rate documented by Douglas W. Burbank in 1996 [2] is 12 mm/yr or 12,000 B (bubnoffs, a unit of surface-material removal, named after Serge von Bubnoff (1888-1957) of one micrometer per year or one millimeter per thousand years) where the Indus river has maintained its course across a belt of rapid bedrock-uplift during Quaternary times. In that reach of the Indus river, between Bashu and the Raikot fault in the northwestern Himalayas, numerous straths, 10 to 200 m wide and at heights ranging from 10 to 400 m or more above the present river, are cut into metamorphic and igneous bedrock. Straths judged to be pristine (because their streamlined bedrock knobs and potholes mimic those of river-worn surfaces along the modern channel) are suitable for exposure-age dating. The dating method used measures cosmogenic ^{10}Be and ^{26}Al accumulations (cosmic ray flux is treated as a constant in the calculation) in exposed quartz minerals of the bedrock. The mean rate of uplift calculated from ^{10}Be and ^{26}Al datings of straths can be compared to the overall long-term denudation rate for this region (here equal to the uplifted massif across which the Indus kept its course) obtained from Apatite (U-Th)/He thermochronometry—apatite's helium age records when it cooled through 70 °C (its closure temperature when it stops leaking He), i.e. when the erosionally exposed rock it is in became less than 2-4 km deep in the crust.[3]

Another technique to judge rate of denudation uses fission track (FT) dating.

When a ^{238}U atom fissions, two major fragments of it fly in opposite directions with enough force to disrupt the crystalline structure of a mineral it can be in, over a track of about 10 to 20 microns. Crystals at low temperature do not anneal (heal the damage). Fission tracks, as these, can be seen under a light microscope if the mineral is ground, polished, and etched with hydrofluoric acid or potassium hydroxide. The number of tracks per unit area can be counted and averaged.

The time (cooling age) since a given naturally radioactive mineral, as apatite or zircon, in a rock-outcrop sample has been cooler than its annealing closure temperature can be known (with difficulty)[4] by comparing the fission track "density" (frequency) in it (knowing the decay constants of the radioactive isotopes present) with the fission track count found after the natural emitters in the mineral have been forced to emit all their particles. The forcing is done by placing the mineral in a cyclotron. Given (or assuming) the geothermal gradient of increasing temperature with depth for a region, the rate of uplift is the evident thickness of rock removed divided by the cooling age. ❑

Figure a25.1 **The development of a strath**[5]

The block diagrams show two instances (**a** more recent than **b**) of a mountain stream's incision into bedrock. The down cutting (bed erosion) and the lateral cutting (bank erosion) of a river channel are naturally episodic because the river as an agent of erosion has no control over variables as discharge, nick-point travel, landsliding, and the happenstance in-between-flood-stage valley floor position of its channel. An abandoned valley-floor remnant that was river-cut into bedrock and is above the level that the river in the valley can flood again, is called a *strath*.