A Brief Summary of Oregon Coast Range Geology, Geomorphology, Tectonics, and Climate

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Spanning 200 miles along the Pacific, the Oregon Coast Range is defined by a 30-40 mile wide swath of moderately high mountains. The range averages 1,500 feet in elevation and has a maximum elevation of 4,097 feet at Mary's Peak. Slopes and drainage basins are consistently steep through the range, approaching 50° in many localities. Pacific storms buffet the range in the wet, winter months and support thick forests of Douglas fir and hardwood species. The average annual rainfall in the range is over 100 inches per year. Several rivers flow west across the Oregon Coast Range and empty into the Pacific. These rivers generally flow across sedimentary or volcanic bedrock and do not have significant storage of sediment in river bars or banks. Once home to an abundance of trout, salmon, and other fish, rivers and streams in the Coast Range now harbor a small fraction of the original aquatic population.

The Oregon Coast Range is a belt of uplifted land lying along the Pacific Coast of Oregon. The uplift is a result of plate convergence. About 400 km west of the Coast Range lies the spreading center, which separates the Pacific plate (which extends to just east of Japan) and the Juan de Fuca plate, which descends under the North American Plate along the Cascadia subduction zone. The Coast Range overlies the subducted Juan de Fuca plate and the lies about 150 to 200 km to the east of the Cascadia subduction zone. The region seaward of the location of volcanism is referred to as the "forearc" and that the materials found in the forearc are comprised of rocks scraped off the descending the subducting slab ("accretionary wedge") and of rocks deposited within the basins ("forearc basins") created by deformation of the accretionary wedge.

The Oregon Coast Range is composed of accreted oceanic sediments. The oldest rocks, the Siletz River volcanics, are oceanic crust formed during the Paleocene to middle Eocene (about 60 to 45 million years ago). Deposited synchronously with these volcanics but also overlying them and intruded by them is a regionally extensive marine sandstone and siltstone. Commonly referred to as the Tyee formation this unit is mostly formed by repeated deposition of dense currents of sediment (turbidity currents) derived from uplifted terrestrial sources. Our study sites lie entirely within this unit. Successively younger deposits of sediments and volcanics are found to the east of the coast range and along the coast. Overall the rocks are gently folded and have a slight westward dip (Kelsey et al., 1996).

During the Oligocene (-25 million years ago), uplift of sedimentary basins in Oregon resulted in the westward migration of the coastline from as far east as Idaho towards the present position. Synchronous with uplift, giant fissures in northern Oregon brought lava flows up from the subducting plate. Dikes and sills also intruded into the Eocene and Miocene sedimentary rocks that make-up most of the Coast Range today. These isolated volcanics tend to resist weathering and erosion more than the surrounding sedimentary rocks and constitute some of the prominent peaks in the Coast Range. Continued uplift of the coast has led to the development of marine terraces along the Oregon coast. These features record the history of sea level change and uplift, and specifically they record differential uplift along the coast that may result from faulting.

The Juan de Fuca plate is being subducted at about 4 cm/yr (De Mets, et al., 1990). It dips beneath the Coast Range at about 13 to 16 degrees (Trehu et al., 1994). One of the most peculiar and troubling aspects of the Coast Range is the low seismicity of the region in recorded time. Concerns about potential seismicity associated with the Cascadia subduction zone has prompted many researchers to search for evidence of historical earthquakes in the region (e.g. Atwater, 1987). Deformation of local coastal marshes and Quaternary terraces has been interpreted as a response to pre-historic earthquakes. Geological evidence now suggests that instead of frequent lower magnitude events the Coast Range occasionally experiences very high magnitude earthquakes (order 9.0), the most recent perhaps having occurred 300 years ago (Verdonck et al., 1995). One question we will consider is whether these rare, but very large magnitude earthquakes leave a geomorphic imprint on the landscape.

Studies of fluvial strath terraces (Personius, 1995) and marine terraces (Kelsey et al., 1996) have been used to examine the spatial and temporal pattern of Quaternary rock uplift of the Coast Range. Inerred patterns of stream incision rates appear to roughly balance rock uplift rates, i.e. the rivers keep pace with uplift during the late Quaternary. A complex pattern is suggested, with generally more rapid incision in the north. Resurveys of targets and analysis of tide gauge records during the past 50 years enables an estimate of contemporary vertical deformation. These rates are in the south as much as 10 times higher than late Quaternary rates inferred from stream incision rates. As Mitchell et al. (1994) argue these data, which represent a period of little seismicity record significant strain accumulation, which implies the build up of a large seismic hazard.

Since the 1960's, many researchers have investigated the hypothesis that rates of tectonic deformation and long-term average erosion are strongly related. Many studies have addressed the balance of erosion and tectonic uplift in the central and southern Oregon Coast Range. In this part of the range, the topography has a characteristic morphology, with convex ridge tops dominated by soil creep processes and steep sideslopes, where small soil slips and landslides dominate (Roering et al., 1999). Near the terminus of steep, sideslopes, in steep, unchanneled valleys (topographically-defined hollows), soils accumulate and thicken over long time periods. These convergent parts of the landscape also tend to become saturated during rainfall events. The combination of thick soil and frequent saturation tends to favor these parts of the landscape for episodic shallow landsliding. As a result, hillslope erosion rate is highly stochastic over human timescales, but when averaged over thousands of years the landscape appears to be eroding at roughly the same rate, 0.1 to 0.2 mm/yr (Heimsath et al., 2001). Reneau and Dietrich (1989) estimate average hillslope erosion rates of 0.07 mm/yr over the last 4,000 to 15,000 years from analysis of colluvial deposition in hollows or topographic depressions. Sediment yield measurements from several Coast Range basins indicate similar rates of erosion between 0.05 and 0.08 mm/yr (e.g. Brown and Krygier, 1971; Beschta, 1978). These findings suggest that the portions of the landscape in the Oregon Coast Range are lowering at a similar rate of 0.05 to 0.2 mm/yr. These studies do not reflect millennial-scale variations in process rates related to climate change. Recent evidence (Long et al., 1998, Roering and Gerber, 2005) suggests that episodic fires may be a significant mechanism of sediment production because the incineration and removal of vegetation on steep slopes can cause extensive transport via dry ravel (bouncing, sliding, and rolling of grains). In the early Holocene (~8,000 ya), fires were much more frequent (~110-yr return interval) than recent times, suggesting that the soil mantle may have been much thinner and less continuous than today.

In the Oregon Coast Range, stream incision or (fluvial bedrock incision) rates are spatially variable, but approach 0.2 mm/yr to 2.0 mm/yr in regions where estimated hillslope erosion rates are 0.1 mm/yr (Reneau and Dietrich, 1991). This disparity may indicate that the Oregon Coast Range is not in strict dynamic equilibrium. Alternatively, the factor of 2 to 3 difference may reflect errors associated with measurements, dating errors, or it may reflect tectonic or climatic factors that cause these rates to be disparate on a short time scale. Although, deep-seated landslides make-up 30% of the land surface in certain portions of the Oregon Coast Range, their role in landscape evolution is unclear. In areas with a high frequency of large landslides, local topographic relief is depressed, suggesting that these features may limit topographic development. The notion of steady state topography in the Oregon Coast Range requires further examination.

Analysis of pollen and plant fossils from Little Lake, Oregon, provides a record of climatic history in the Oregon Coast Range (Worona and Whitlock, 1995). The following table indicates the climatic trends. The Oregon Coast Range supported few if any glaciers during the last major glacial period, which has important implications for geomorphic and tectonic interpretations (Baldwin, 1993). Notably, Reneau and Dietrich (1991) indicate an abundance of basal carbon dates between 4,000 and 7,500 years old, which corresponds with a period of cold and moist conditions that followed a several thousand year period of warm and dry conditions (Worona and Whitlock, 1995). This observation indicates that climatic variation may influence rates of erosion and sedimentation. The influence of climate and human factors, such as timber harvesting, on erosion is currently being investigated in the Coast Range. Recent studies have found that the coincidence of forest removal and high intensity rainfall events can significantly increase the number of shallow landslides (Montgomery et al., 2000). The results of these and other studies are important for future land management decisions.

Brief Climatic History of Little Lake. Oregon Coast Range *(Worona and Whitlock, 1995)*

Rainfall = 150 cm/yr (75-80% occurs Oct-Mar)

Unglaciated during the Fraser glaciation (ice 320 km north in Wash.)

Yr. B.P.	Characteristics
42,000-25,000	Cooler, wetter than today (at least 3°C cooler) consistent all along the Oregon coast.
25,000-13,000	Colder, drier, Oregon Coast Ranges supported small if any glaciers. (7-14°C cooler, 50% of today's rainfall)
16,000-13,500	Small warming trend, increased moisture 11,000-10,000 Colder, brief reversal
10,160-9,000	Warm, dry conditions; intensified summer droughts and widespread fires; increased solar radiation from increased tilt of the earth.
6,000-3,000	Cool, moist climate much like today
3,000-2,000	Reduced moisture (somewhat) and cooling 2,000-> Somewhat drier, fires?

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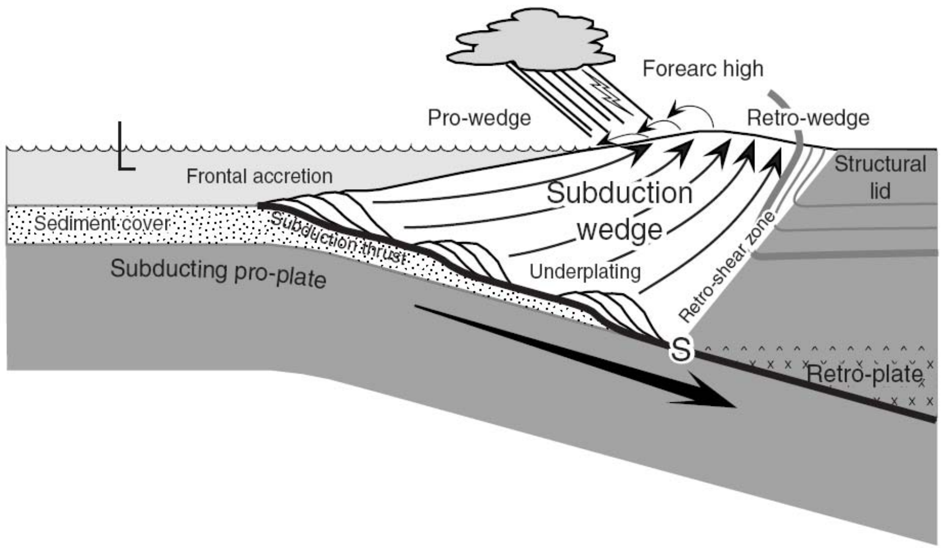
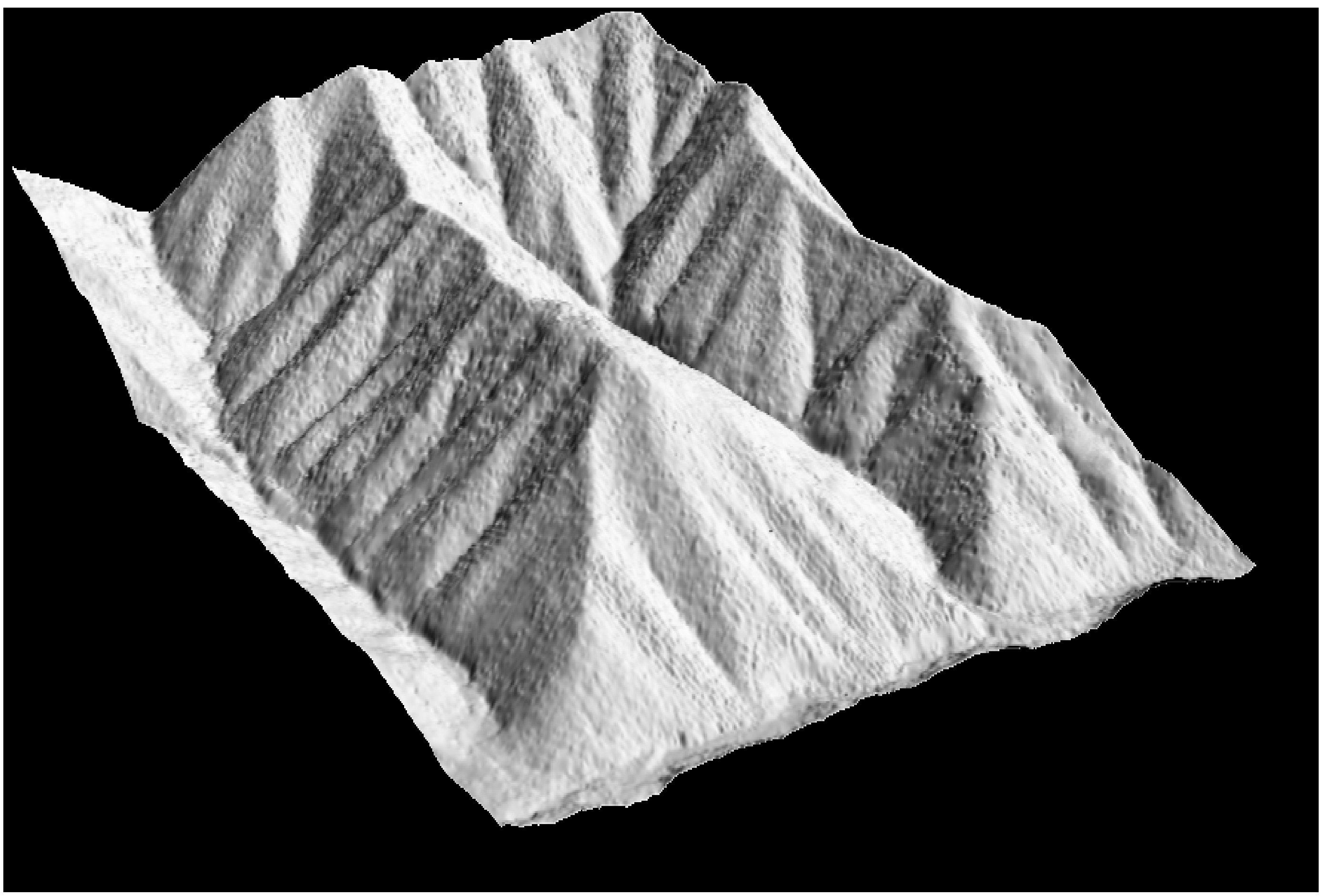
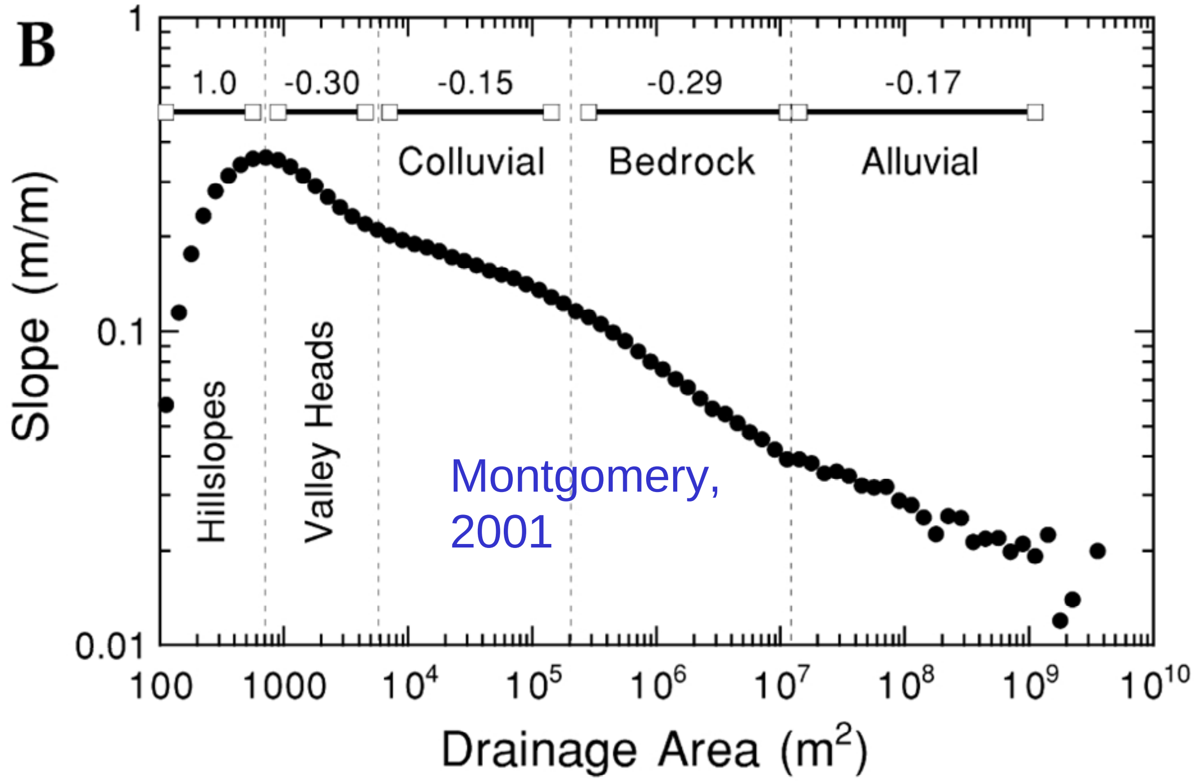
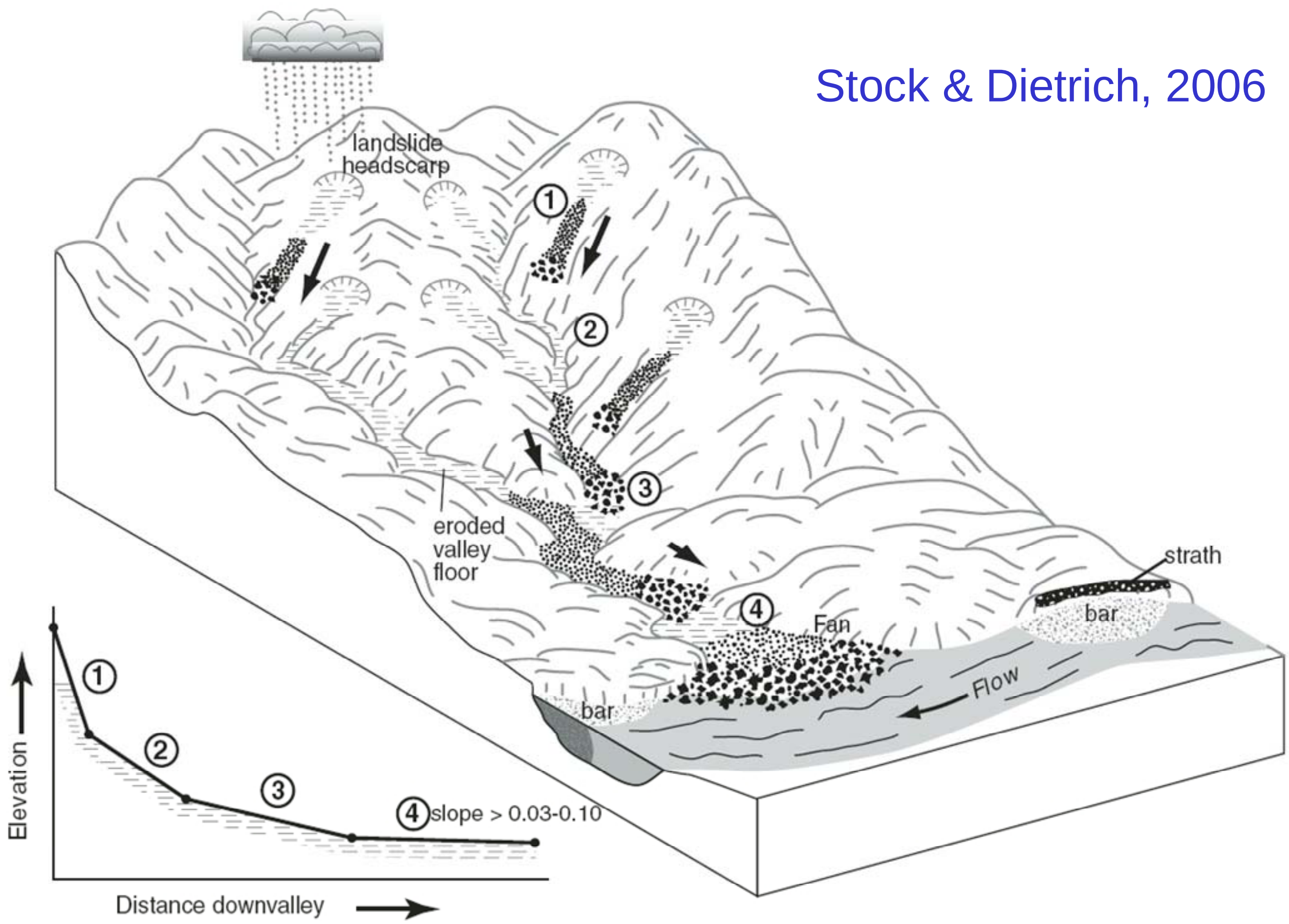
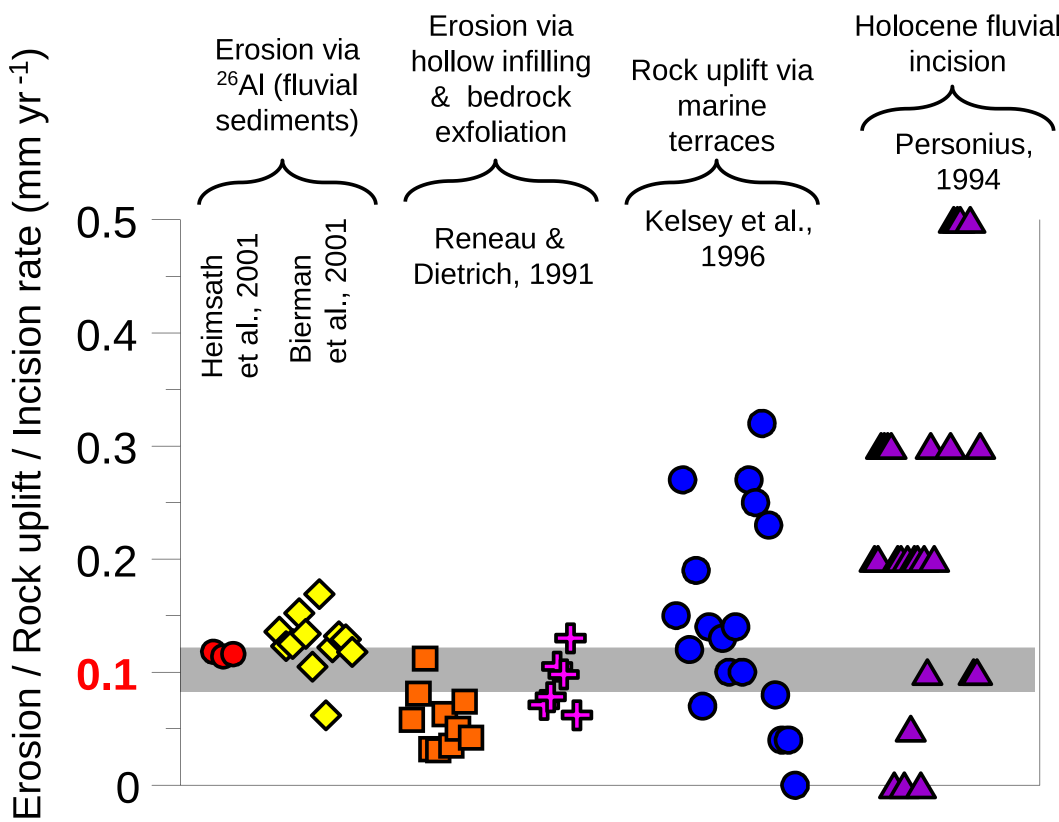

Forearc high
Pro-wedge
Retro-wedge
Frontal accretion
Structural lid
Subduction wedge
Sediment cover
Subduction thrust
Subducting pro-plate
Underplating
Retro-shear zone
S
Retro-plate

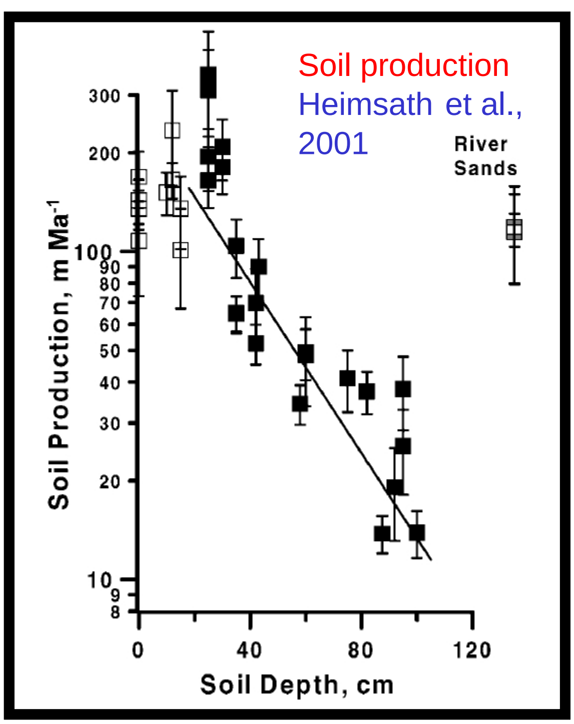


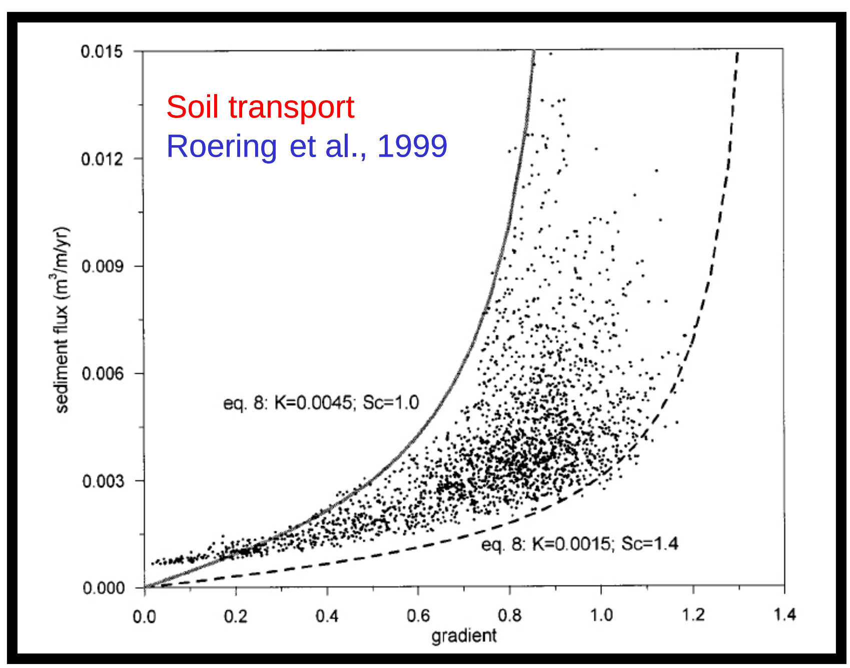

Washington
Oregon
Portland
Oregon Coast Range
Alsea River
McKenzie River
Siuslaw River
Eugene
Umpqua River
Willamette River
N
65 km


B
1.0
-0.30
-0.15
-0.29
-0.17
Colluvial
Bedrock
Alluvial
Hillslopes
Valley Heads
Slope (m/m)
1
0.1
0.01
100
1000
10^4
10^5
10^6
10^7
10^8
10^9
10^{10}
Drainage Area (m^2)
Montgomery, 2001


Stock & Dietrich, 2006
landslide headscarp
1
2
3
4
eroded valley floor
Fan
strath
bar
bar
Flow
Elevation
slope > 0.03-0.10
Distance downvalley


Erosion / Rock uplift / Incision rate (mm yr -1)
Erosion via 26Al (fluvial sediments)
Erosion via hollow infilling & bedrock exfoliation
Rock uplift via marine terraces
Holocene fluvial incision
Heimsath et al., 2001
Bierman et al., 2001
Reneau & Dietrich, 1991
Kelsey et al., 1996
Personius, 1994
0.5
0.4
0.3
0.2
0.1
0


Soil production
Heimsath et al., 2001
River Sands
Soil Production, m Ma-1
Soil Depth, cm


Soil transport
Roering et al., 1999
sediment flux (m3/m/yr)
gradient
eq. 8: K=0.0045; Sc=1.0
eq. 8: K=0.0015; Sc=1.4