Tectonic Geomorphology

Dr. George E. Hilley
Prof. Dr. Manfred R. Strecker
Universitaet Potsdam

Spring 2002

Class Meeting Times:	**Wednesdays**	**10:00 - 10:50**
	Fridays	**10:00 - 10:50**
Laboratories:	**Wednesdays**	**14:00 - 17:00**
	except where noted on syllabus	

George Hilley
Phone: (331) 977-5407
email: hilley@geo.uni-potsdam.de
Office Hours: Wednesday 11:00 - 13:00
Friday 11:00 - 13:00
or by appointment

Manfred Strecker
Phone: (331) 977-5261
email: strecker@geo.uni-potsdam.de
Office Hours: by appointment

In Today's Class...

I) Course Logistics.

II) Introduction to and scope of tectonic geomorphology.

III) Deformation, surface processes, topography, and the landscape.

Tectonic Geomorphology

Organization and Scope

General Organization of Class: This course provides a working knowledge of tectonic geomorphology through general subject lectures, case studies, and extensive, applied laboratories stressing proficiency in both concepts and relevant tools.

Scope of Class:

1) Recent plate configuration reconstructions
2) Remote sensing applications
3) Use of structural, sedimentologic, and thermochronologic data in tectonic geomorphology
4) Use of geophysical data
5) landforms and landscapes in actively uplifting environments,
6) paleoseismology
7) numerical models in tectonic geomorphology

Text (to be supplemented with reading designated in syllabus):

Burbank, D. W., and Anderson, R. S., 2001, Tectonic Geomorphology, Blackwell Science, Malden, MA, USA, 274 pp.

Grading Scheme

Grades help the students and instructor communicate about a student's progress and so are important tools in the educational process. The four (4) main components of the class are given appropriate weight based on the importance of each to a student's working knowledge of the field. The three components, and their weights, are:

1) Short (1 page, single spaced) summaries of three case study articles of the student's choice (15%).

2) Laboratory reports (50%).

3) Written portion of the final project (25%).

4) Oral presentation of final project (10%).

These standards will not be altered throughout the semester, depending on the performance of the entire class in a specific category. Standard, unadjusted letter grades will be given based on the performance in these categories:

A	**=**	**90 - 100%**
B	**=**	**80 - 90%**
C	**=**	**70 - 80%**
D	**=**	**65 - 70%**
F	**=**	**< 65%**

Laboratories

Laboratory projects emphasize practical use of geologic and computer techniques to investigate problems in tectonic geomorphology. They strive to provide proficiency in interpretation of geologic, geomorphic, geophysical, and remotely sensed data in the context of recent tectonic activity. Also, the laboratories should provide a basic working knowledge of the following:

1) elementary knowledge of the UNIX operating system
2) Erdas Imagine
3) ARC/ Info
4) Generic Mapping Tools (GMT)
5) Miscellaneous Matlab tectonic geomorphology programs.

Students are encouraged to choose study areas identical or similar to their theses areas for laboratory analyses. See GEH if you would like to check the availability of various datasets for your study area. Reports will be produced after each lab session. Laboratories constitute a major portion of the course work and their grading weight is given accordingly.

Final Project

The course will culminate in a final project that synthesizes the laboratory exercise results with the concepts reviewed in class. As with the labs, diploma and doctoral students are encouraged to conduct this study on their thesis field area. We encourage use of a wide range of data and will help to acquire data sets for furthering the students' research in the area. A comprehensive report will be supplemented with a 20 - 30 minute oral presentation (in English). GEH is happy to assist with English language writing in labs and the final project.

We are believers in "learning by doing," and so the labs and final project have a large weight attached. For this reason, we strongly suggest that students work steadily on their final project throughout the semester as each laboratory will add new data to the analysis. Also, please feel free to communicate about various study areas with one of the instructors during the semester. Success in the project and course will be the thoughtful integration of prior literature, original analysis, and sound technical writing in class discussions and assignments.

Approximate Calendar

Week Number	Start Date	Subject(s)
1	7-4-02	Introduction/ Geomorphic Markers
2	14-4-02	Remote Sensing
3	21-4-02	No class (EGS)
4	28-4-02	Remote Sensing
5	5-5-02	Dating Methods
6	12-5-02	Structural Studies
7	19-5-02	Structural Studies (cont.)
8	26-5-02	Geophysical Studies
9	2-6-02	Geophysical Studies (cont.) / Rates of Erosion and Uplift
10	9-6-02	Holocene and Intermediate time-scale landscape response to deformation.
11	16-6-02	Late Cenozoic deformation and landscape response / Paleoseismology
12	23-6-02	Paleoseismology (cont.) / Numerical modeling of landscape development
13	30-6-02	Numerical modeling of landscape development (cont.)
14	7-7-02	Oral Presentations
15	7-14-02	Oral Presentations

What is Tectonic Geomorphology?

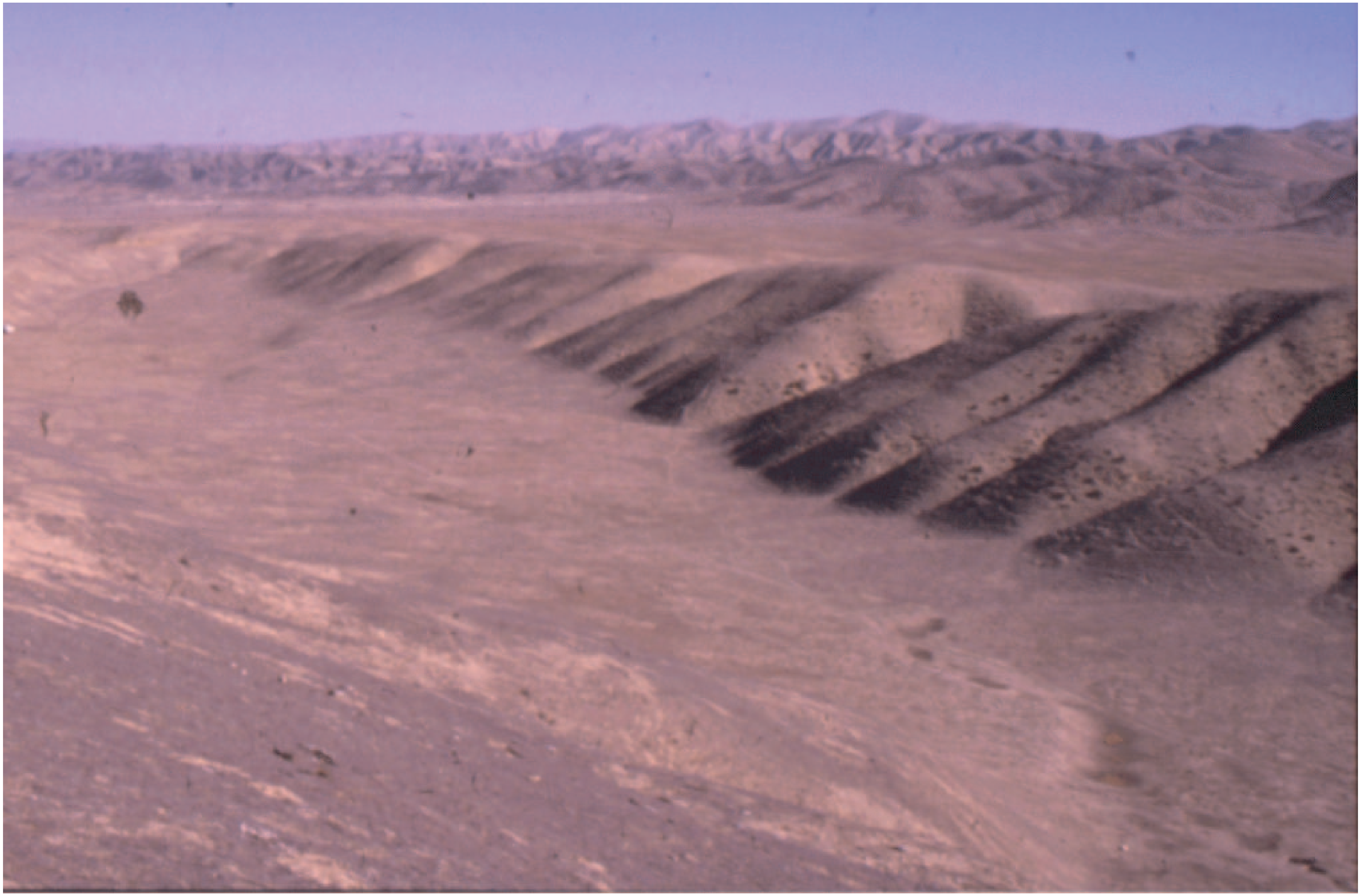
- The shape of the Earth's surface and its relation to the tectonic processes that build topography and geomorphic surface processes that tend to tear it down.

* Lack of absolute age control plagued the field for much of its existence by making different competing hypotheses about landscape development untestable.

* Recent resurgence in field has been motivated by:

1) deformation rate determinations,
2) incision rate estimates,
3) landsliding denudation rate estimates.

Fault Scarp in Carrizo Plain



Fault Scarp Along the Pamir Mountains

figure from J R. Arrowsmith

Fault disrupted terraces in the Tien Shan

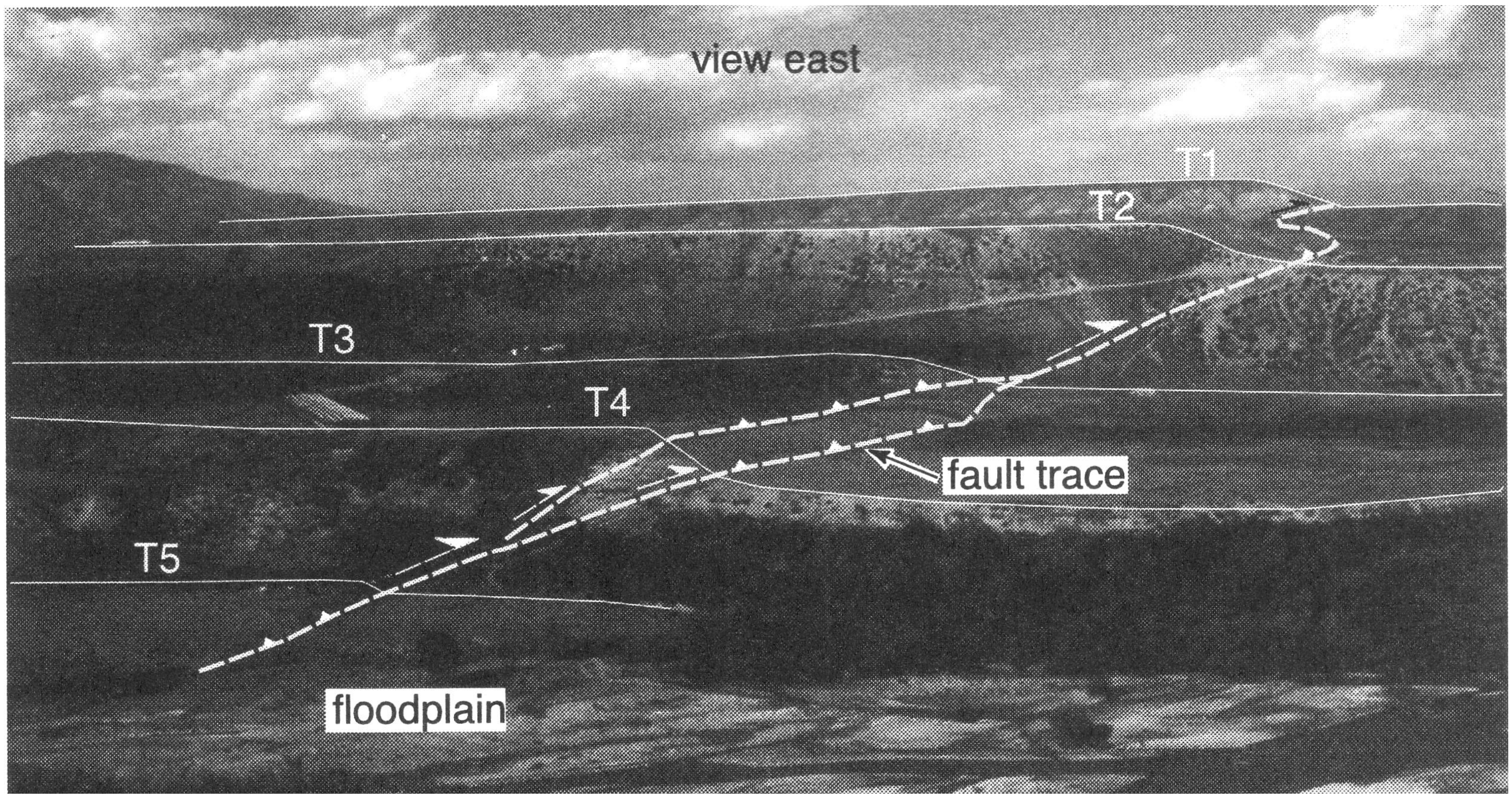


figure from Burbank and Anderson, 2001

Trans-Alai Terrace

figure from J R. Arrowsmith

Corona Image of Trans-Alai

Deflected Streams Over a Growing Anticline in the Tien Shan, Kyrgyzstan

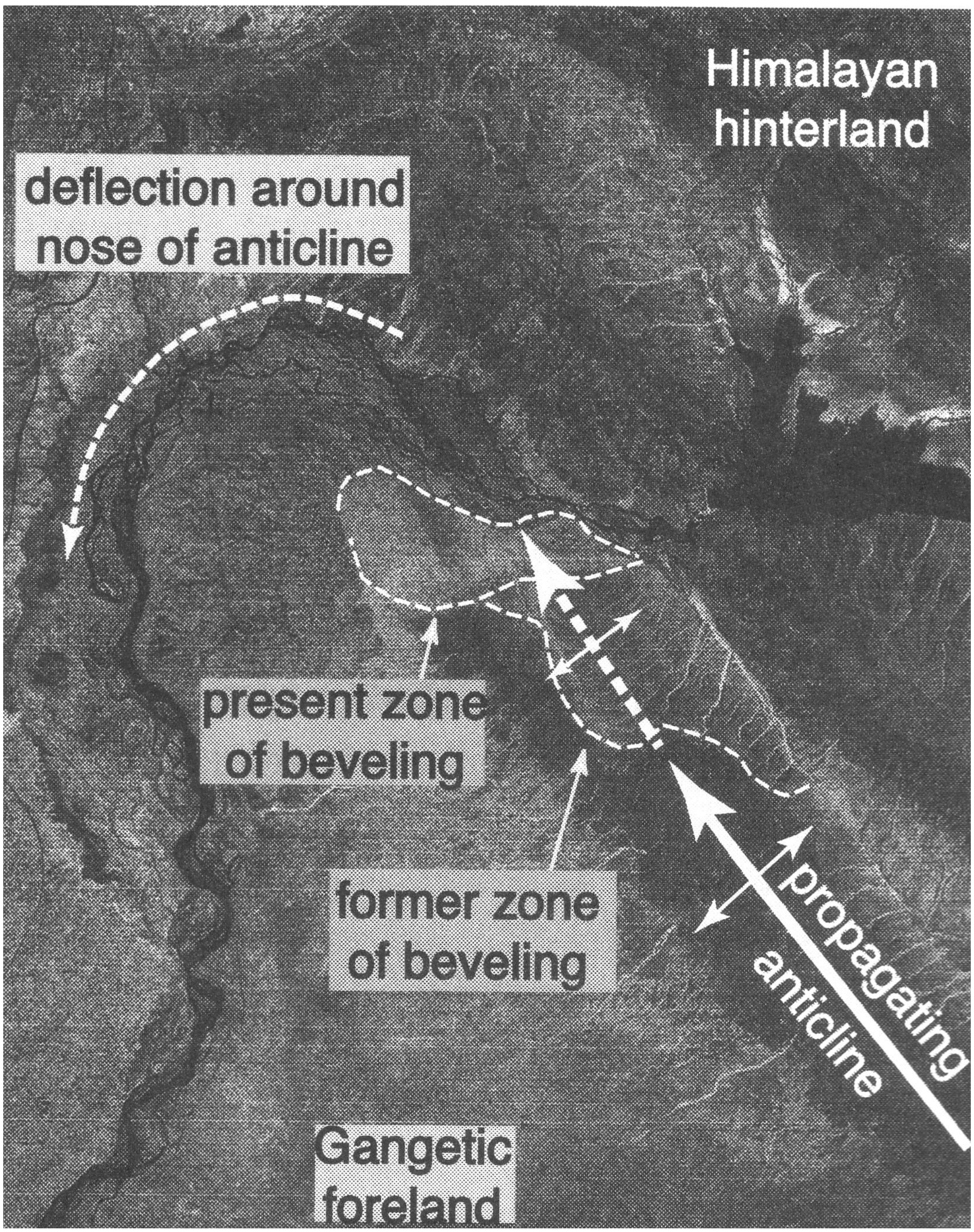
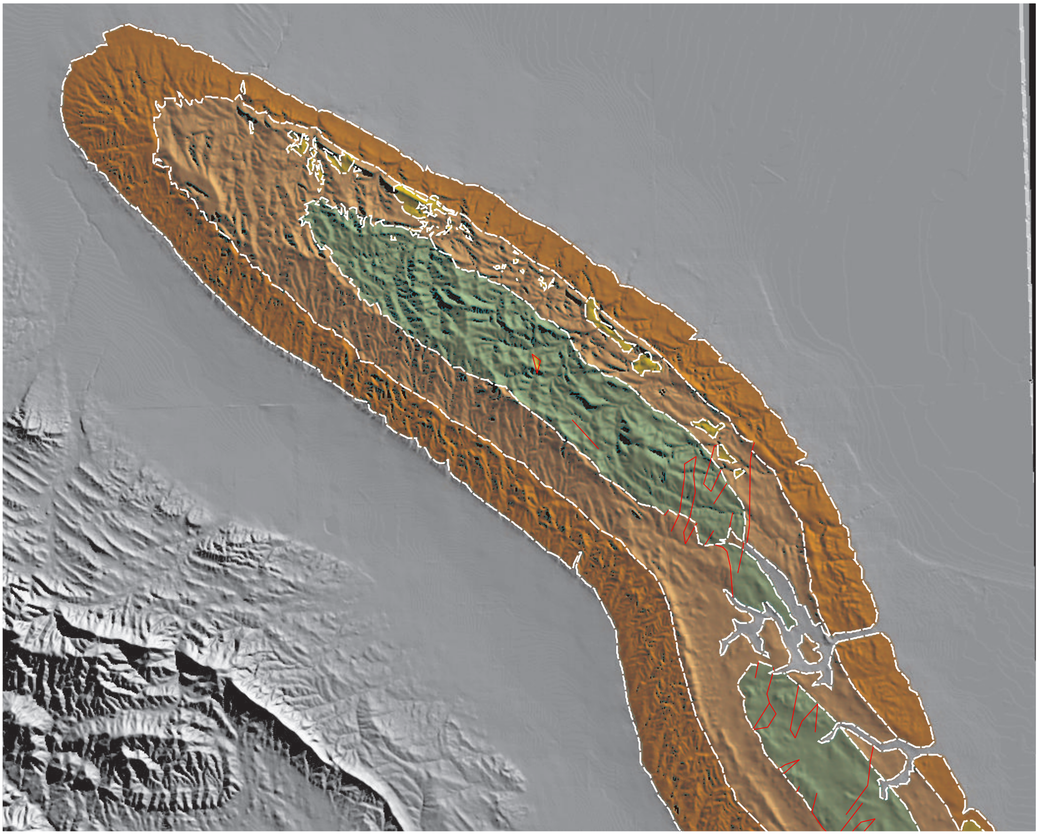
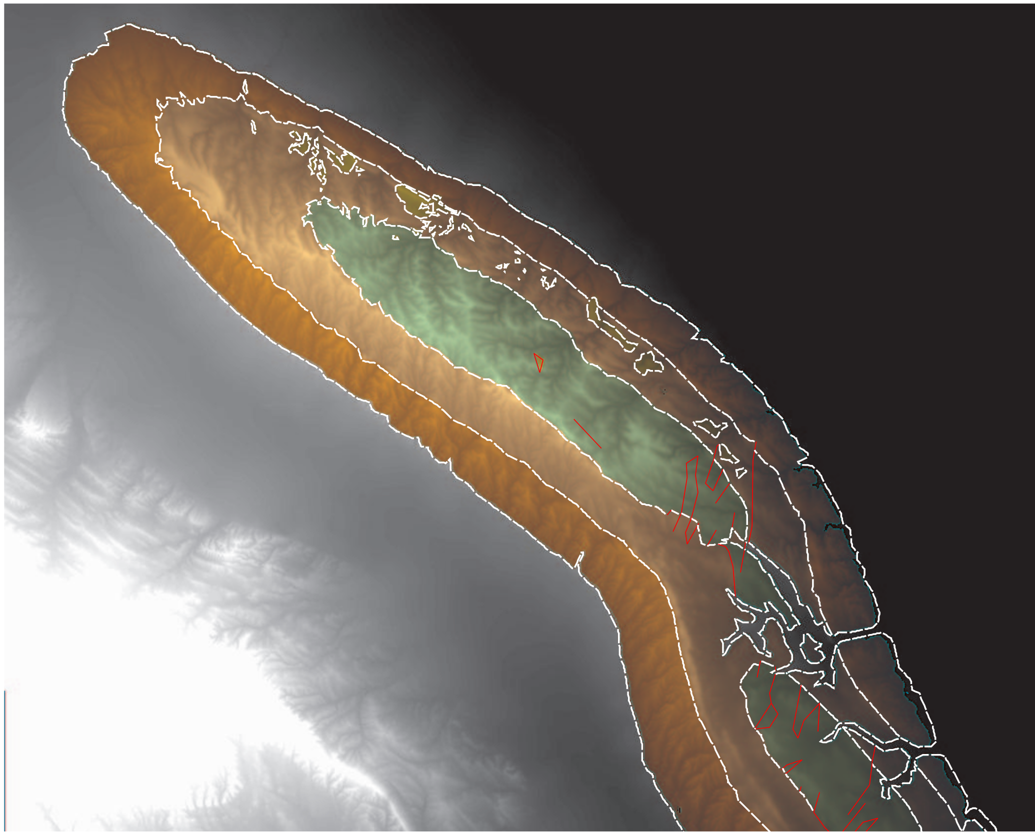


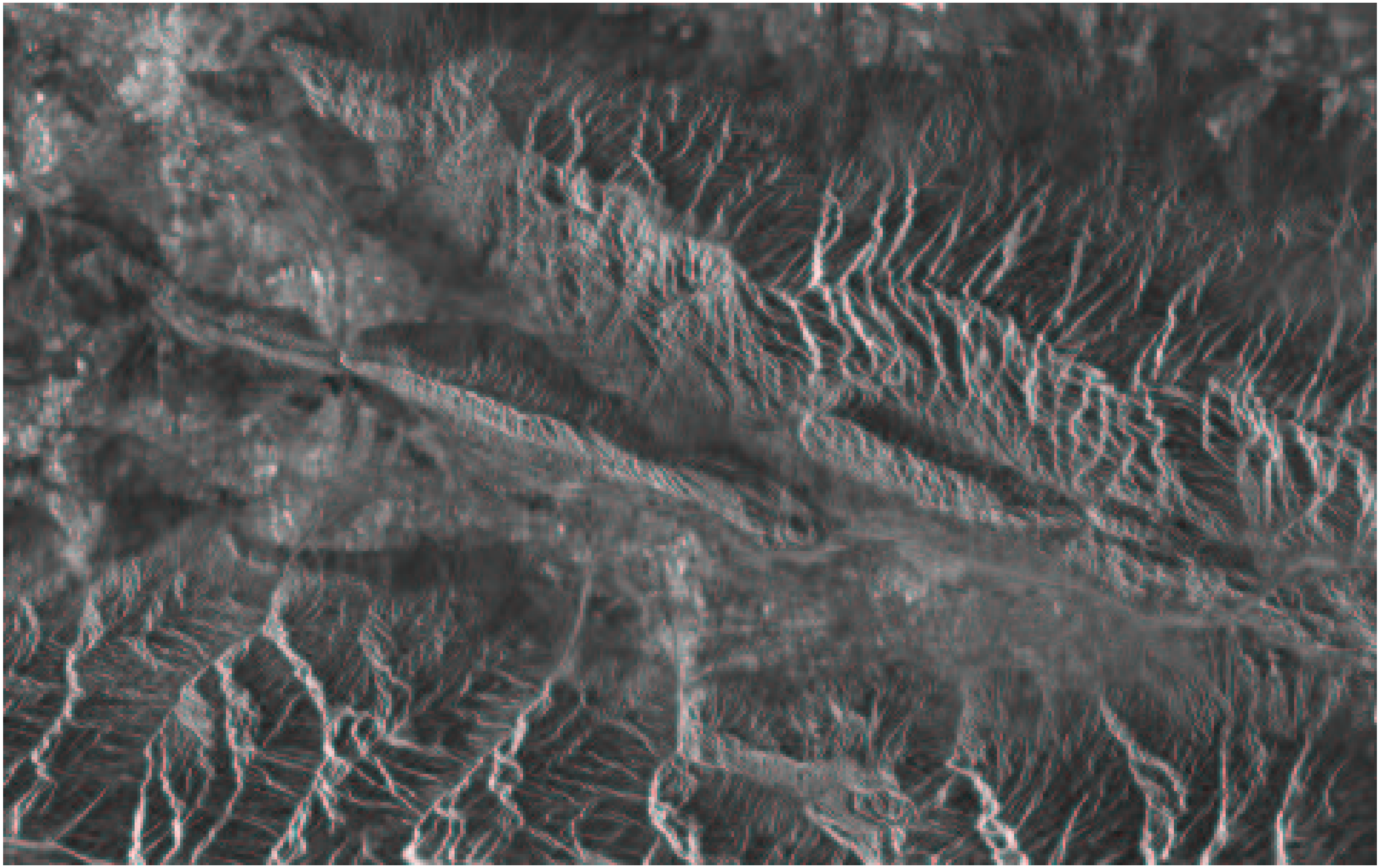
figure from Burbank and Anderson, 2001

Kettleman Hills

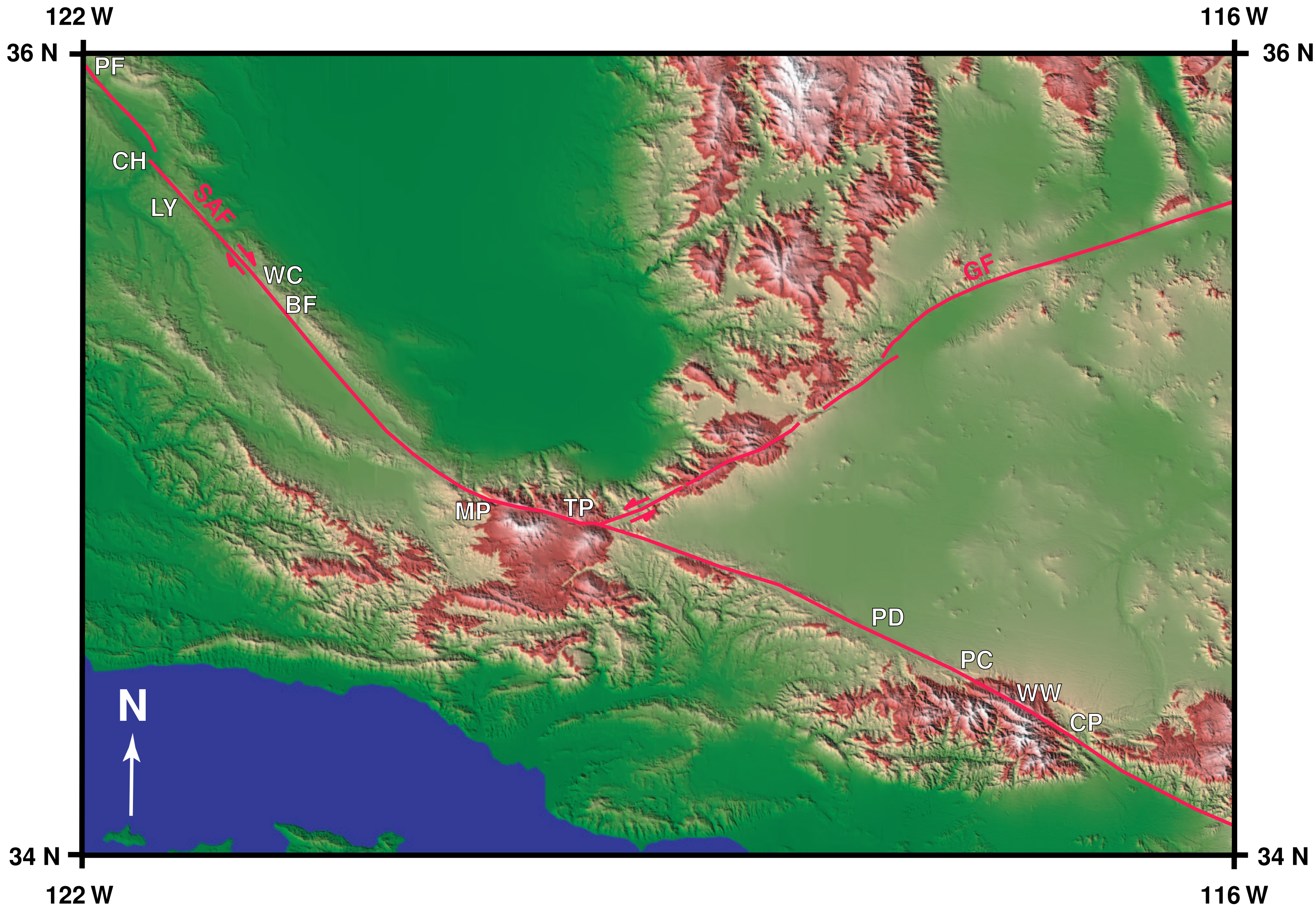




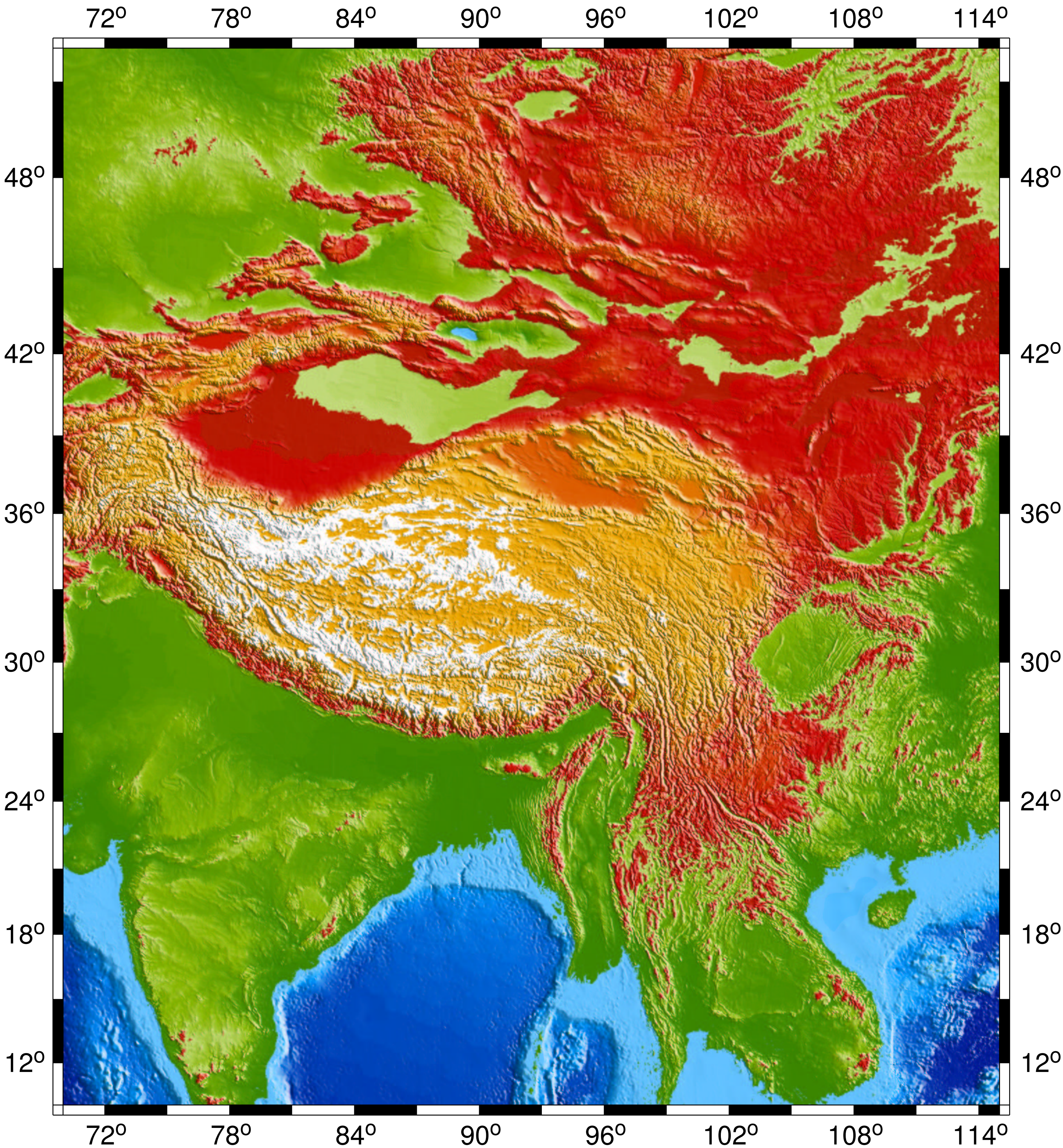
SAR of Northern Kyrgyzstan



Southern California DEM



Himalaya and Tibet DEM



Important Questions to Consider:

1) Did deformation uplift material and then geomorphic surface processes erode this material or did deformation and geomorphic surface processes act at the same time to produce topography?

2) What are the relative and absolute rates of "tectonic" and "geomorphic" processes acting in a landscape?

These questions can only be answered by quantifying the *rates* of the tectonic and geomorphic processes in the landscape.

Some Disciplines Integrated in Tectonic Geomorphology Studies

1) Seismology

2) Quaternary Climate Change

3) Geochronology

4) Structural Geology

5) Geodesy

6) Geomorphology

7) Fault Mechanics

Tectonic Geomorphology: A Historical Perspective

1) "The Geomorphic Cycle" - W. M. Davis (1890s).

2) "Coupled landscape evolution" - W. Penck (1950s).

3) "Steady-state landscapes" - J. Hack (1950s).

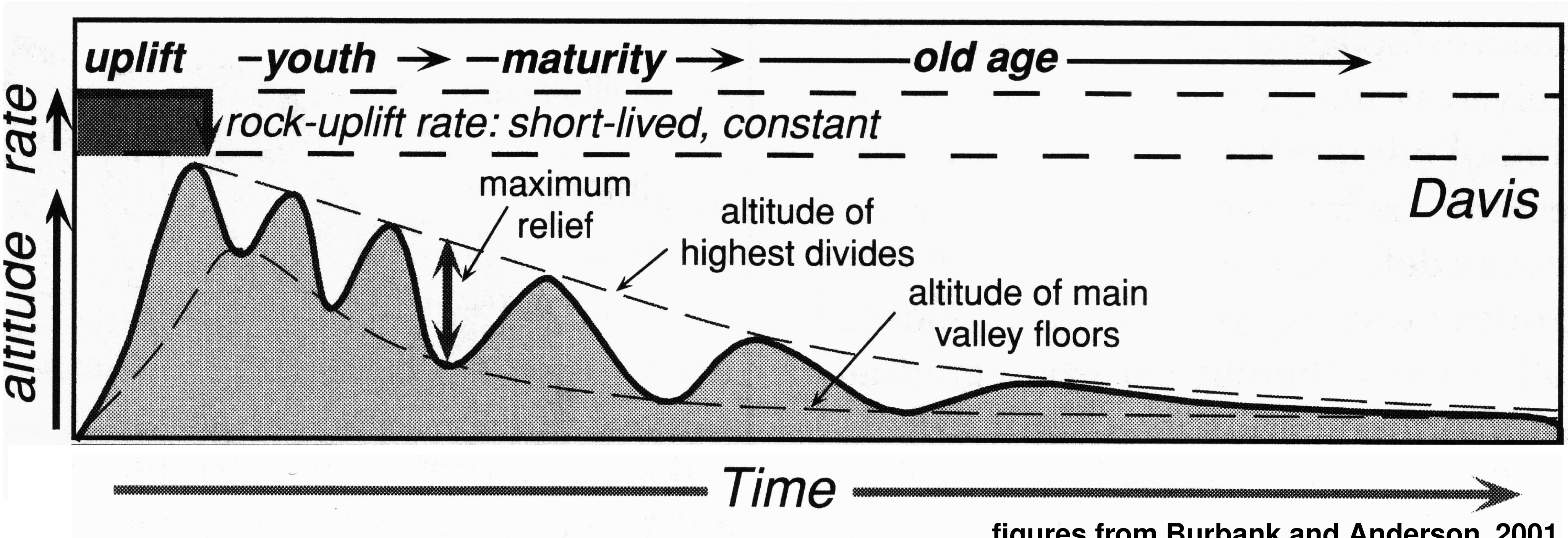
"The Geomorphic Cycle" W. M. Davis

- All landscapes "evolve" from a stage of "youthfulness" through "maturity" to "old age".

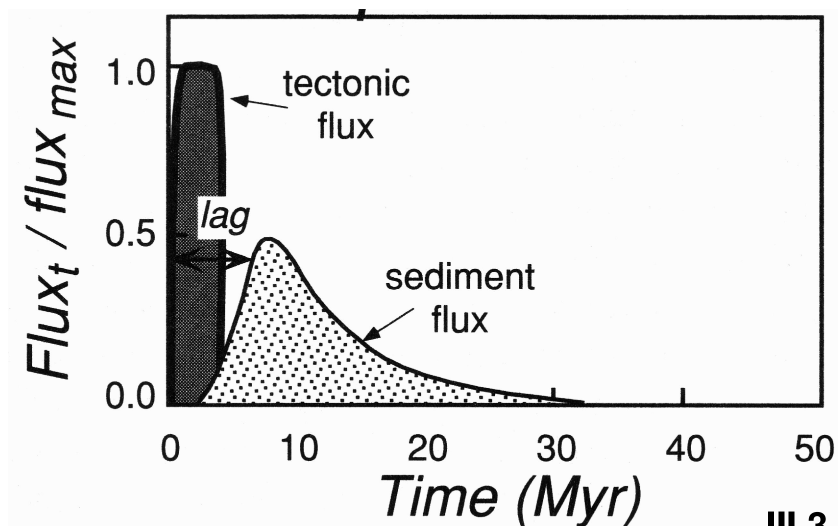
** All topography is built at the beginning of the "geomorphic cycle".*

** Geomorphic processes then attack and degrade the topography with the end result, a peneplain.*

"The Geomorphic Cycle" (Davis)



figures from Burbank and Anderson, 2001



- Short duration, high uplift rate tectonic event precedes erosion.

- Erosion wears down this uplifted landscape, resulting in "youthful", "mature", and "old age" stages.

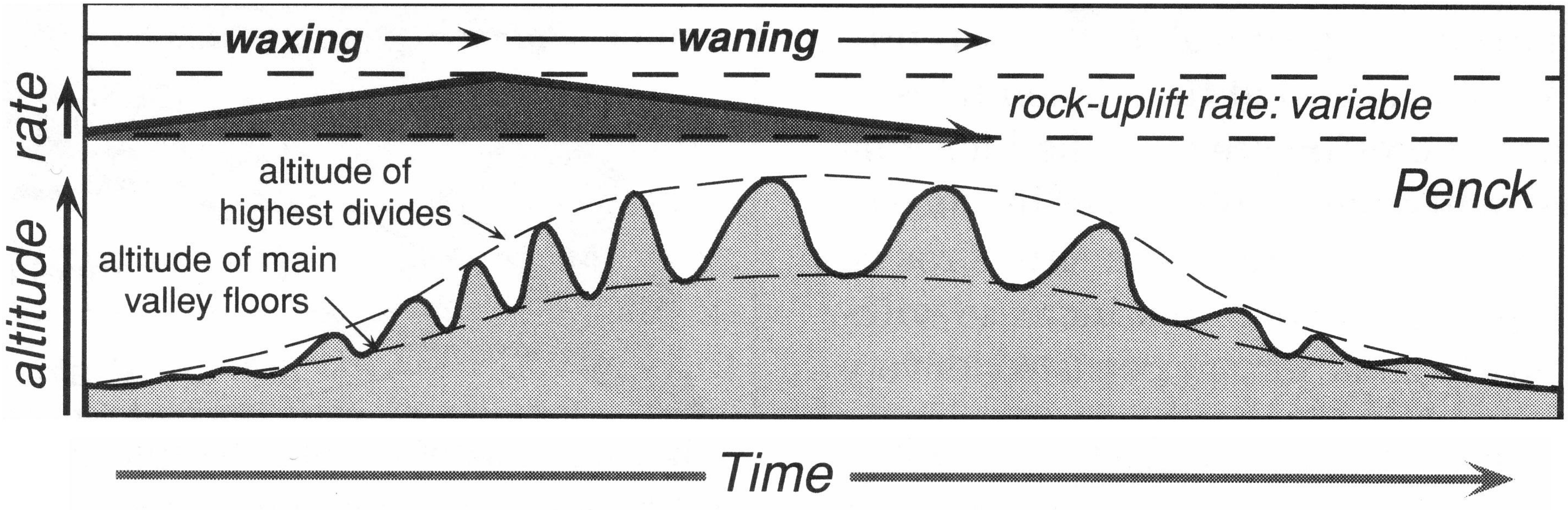
"Coupled landscape evolution"
W. Penck

- Steadily increasing rates of deformation and erosion lead to formation of observed topography.

** Topography is built steadily throughout the orogenic lifespan, and erosion "attacks" this topography that is built by slowly changing deformation rates.*

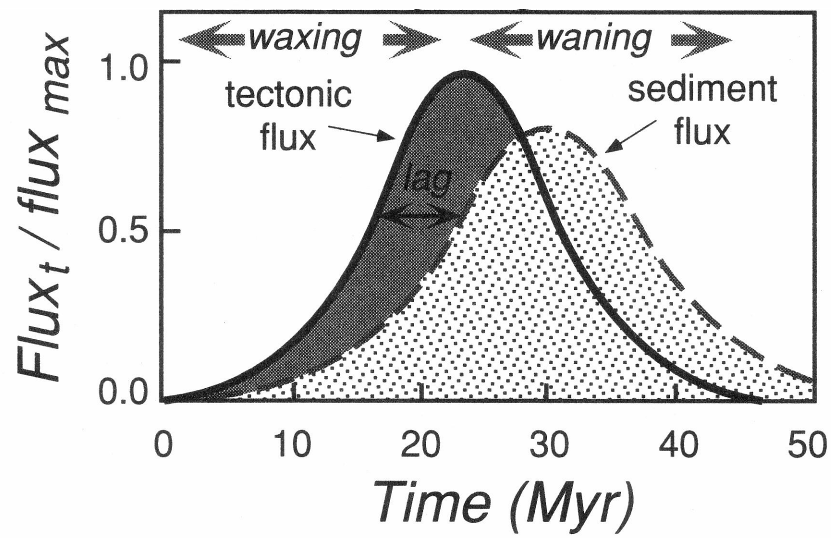
** As deformation slowed, erosion gradually degraded the residual topography.*

"Coupled landscape evolution" - (Penck)



- **Uplift gradually increases and decreases, as opposed to a sudden, short tectonic event.**

- **Erosion and uplift together contribute to the evolution of topography over time.**



figures from Burbank and Anderson, 2001

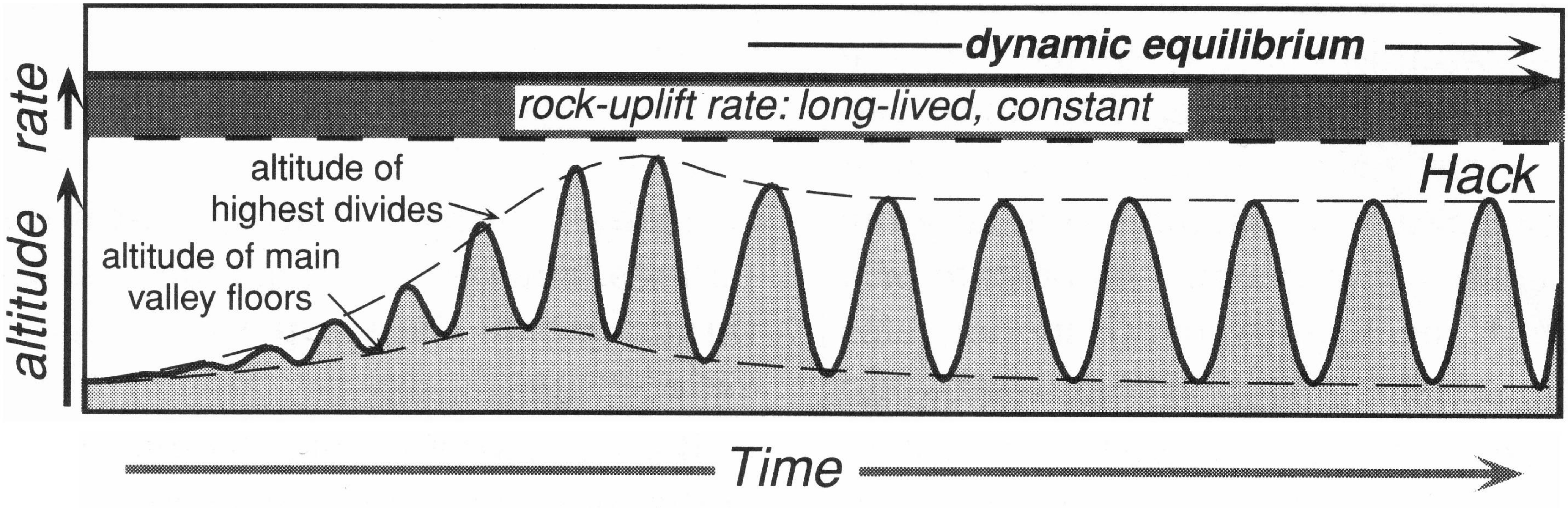
"Steady-state landscapes"
J. Hack

- Deformation and erosion rates are typically maintained for long periods of time. After some amount of time, the rates balance one another, creating a dynamic equilibrium.

** Relief is initially built as uplift begins and rates are sustained.*

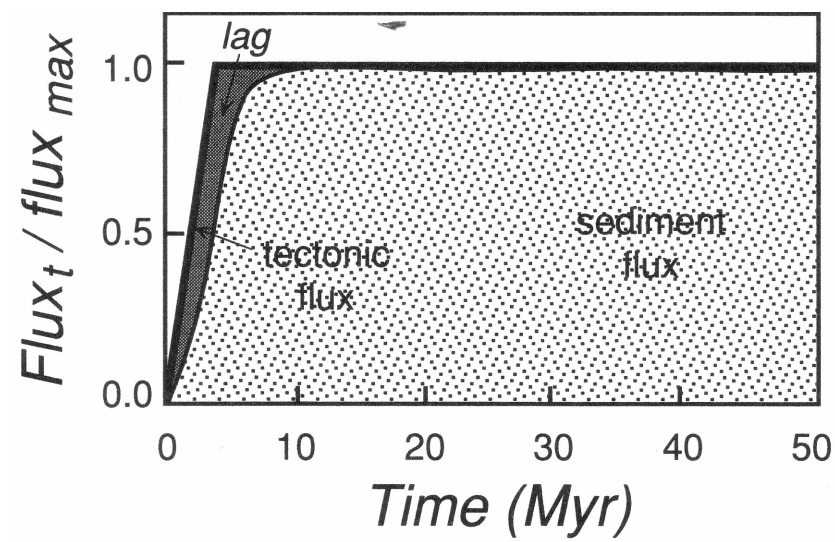
** As relief increases, erosion accelerates until a balance is reached between uplift and erosion.*

"Steady-state landscapes" - Hack



- Uplift is long lived and geomorphic processes quickly respond to this uplift.

- Topography tends towards a steady-state form that is the product of the tectonic and geomorphic rates.



figures from Burbank and Anderson, 2001

Reconciling the three models

- The three hotly debated models probably represent three different end-members of the same sets of processes.

** When tectonic rates are high and short-lived, initial topographic construction is only slightly modified by erosion. Upon cessation of uplift, erosion gradually wears the topography down. --- **Davis!***

Reconciling the three models

** When the duration of the tectonic deformation is on the order of the amount of time it takes for erosion to effectively exhume the landscape, topography will be a combination of deformation rates, erosion rates, and the time since commencement and duration of deformation --* ***Penck!***

** When the duration of deformation is long relative to the time it takes for erosion to exhume the landscape, topography will be the product of uplift and erosion rates --* ***Hack!***

Reconciling the three models

Duration of Deformation
Response time of Erosion

small → **large**

Davis

Important factors: *Time since uplift stopped, erosion rates*

Penck

Important factors: *Time since uplift started, erosion rates, uplift rates, duration of uplift*

Hack

Important factors: *Erosion rates, uplift rates*

When Does the Landscape Record Climate Fluctuations and When Does it Average Them?

Short time-scales (Holocene): Climatic shifts >> time-frame considered -- CLIMATE IS ESSENTIALLY STEADY!

Intermediate time-scales (100s kyr): Climatic shifts = time-frame considered -- CLIMATE IS IMPORTANT CONSIDERATION OF LANDSCAPE DEVELOPMENT!

Long time-scales (Cenozoic): Climatic shifts << time-frame considered -- LANDSCAPE RECORDS INTEGRATED EFFECT OF CLIMATIC FLUCTUATIONS!

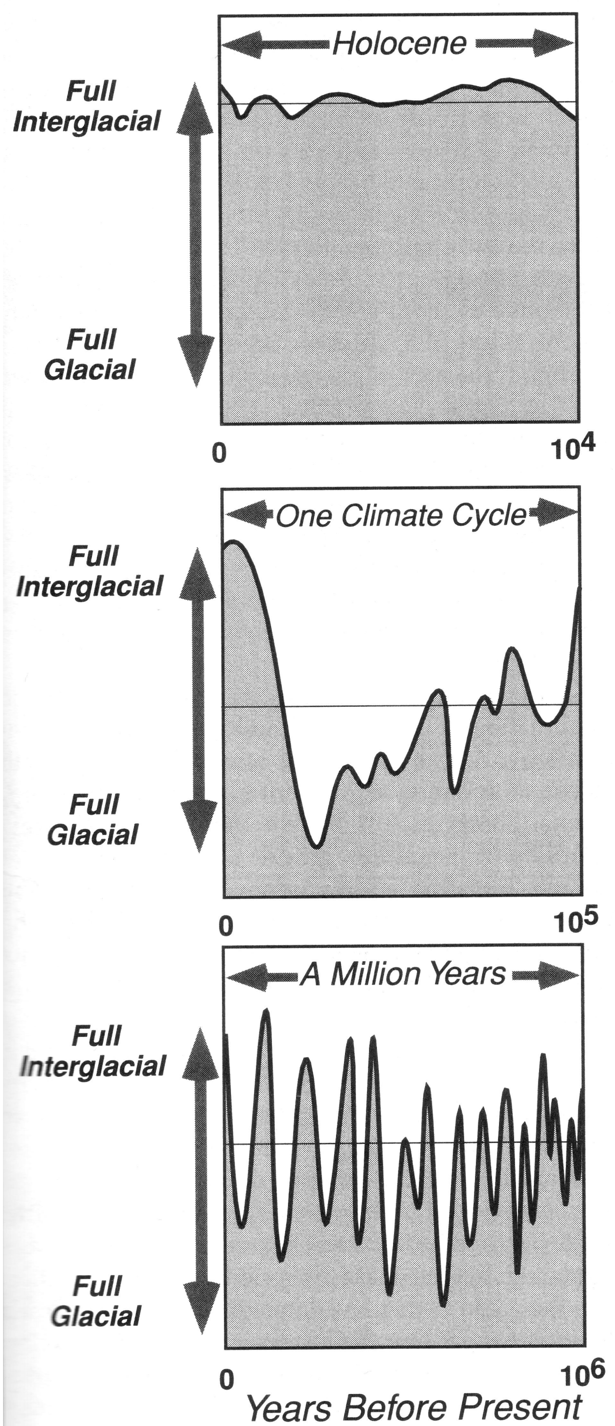


figure from Burbank and Anderson, 2001

Important Points:

** Tectonic geomorphology is the study of the shape of the Earth's surface and its relation to the tectonic processes that build topography and geomorphic surface processes that tend to tear it down.*

** Important disciplines that contribute to tectonic geomorphology are seismology, Quarternary climate change, geochronology, structural geology, geodesy, geomorphology, and fault mechanics.*

Important Points:

** Three historical perspectives on tectonic geomorphology are the "Geomorphic cycle" (W. M. Davis), "Coupled landscape evolution" (W. Penck), and "Steady-state landscapes" (J. Hack).*

** These three perspectives can be reconciled by looking at the rates and durations of the tectonic and erosional rates in each model. This again stresses the importance of age control in tectonic geomorphology as a means of discerning between different geomorphic models.*

Next Class:

Geomorphic markers and their relation to deformation and climate change!