Geog 422/522 Fans Class
Intro to Fan Morphometry Exercise

Introduction

Morphometry involves the quantitative analysis of landforms in three dimensions. Landforms are created via erosional and depositional processes, the geometry of which are controlled by the processes that shape them. Morphometric analysis provides data that yield insights into these processes. Classic fan morphometry has focused on measurements of fan and watershed geometry, including: fan shape, fan area, fan slope, drainage basin area, channel slope, and hillslope gradients. This exercise provides an introduction to morphometric approaches that have been applied to fans.

Part 1. Watershed-Fan Data Collection

Many workers have derived relationships between fan size and drainage basin area. This exercise involves analysis of the good ol' paper map of the Bat Mountain Fan in California (we will do this the old fashioned "analog" way... we look at the GIS approach later).

A. On the Bat Mountain Map, outline the fan area and the contributing watershed area. Identify the fan apex, where the fan exits the canyon mouth. Colored pencils and creativity can be applied here.

B. A digital planimeter is on reserve at Knight Library, in the Government Documents Section, first floor. Instructions are available as well. Check out the planimeter (or use other devices on campus that may be available to you), and determine the watershed drainage area and fan area (square meters or square kilometers are appropriate units of measure).

C. Using the graph paper provided, or your favorite software program, draw a tranverse topographic profile along line X-Y, as marked on the map. Label appropriately with tributaries, fan slope segments, etc.

D. Determine the average gradient of the contributing tributary and fan surface. Express the gradients as dimensionless ratios.

E. Answer the related questions in the last section.

Part 2. Introduction to Morphometric Relations

A. Troeh (1965) analyzed a number of alluvial fans and determined the following empirical relationship:

$$Z = P - SR + LR^2$$

where Z = elevation of any point on the fan, P = elevation at the apex of the fan, S = slope of the fan at the apex, R = radial distance (straight line distance) from the apex to the point where Z is to be estimated, and L = half the rate of change of slope along the radial line ($L = 0.5(\Delta S_r/\Delta D_r)$ where ΔS_r is change in slope between two points on the radial line, and ΔD_r is the change in distance between the same two points on the radial line).

Use the straight portion of line X-Y as the radial line on the Bat Mountain fan to test Troeh's relationship. Validate the equation by calculating Z values at the 2200, 2300, 2400, and 2500 ft contours on the map (i.e. you know what the z values are, according to the map, evaluate how good of a job the equation predicts the known Z values).

For each of your z-value calculations, determine the percent error with the following formula:

$$\frac{\text{Known Z - Calculated Z}}{\text{Known Z}} \times 100\%$$

B. The table below lists percent frequency of fan gradients from the United States (after Anstey, 1965). Plot a histogram of percent frequency (y-axis). If you are skilled at MS Excel, the chart wizard may help you with this...otherwise the good old fashion "paper" method will do.

Fan Gradient (degrees)	Percent Frequency
<0.5	0.5
0.5-0.9	2.0
1.0-1.4	10.0
1.5-1.9	16.0
2.0-2.4	18.5
2.5-2.9	15.0
3.0-3.4	10.0
3.5-3.9	8.0
4.0-4.4	6.0
4.5-4.9	4.0
5.0-5.4	3.0
5.5-5.9	3.0
6.0-6.4	1.0
6.5-6.9	1.0
7.0-7.4	0.5
7.5-7.9	0.5
>8.0	1.0
Total	100%

C. Answer the related questions in the last section.

Part 3. Vegetative Cover / Precipitation / Sediment Yield

As discussed in class, average annual precipitation has a strong influence on vegetative cover and sediment yield in drainage basins that feed alluvial fans. The table below shows data relating average annual precipitation to average sediment yield. Data are derived from stream gaging stations and reservoirs.

Average Annual Precipitation (mm)	Average Sediment Yield (metric tons / sq. km)	Vegetative Regime
0	0	The depths of hell
203	235	Desert Shrub
318	274	Desert Shrub
444	193	Grassland
610	193	Grassland
889	140	Forest
1270	77	Forest
216	491	Desert Shrub
254	414	Desert Shrub
279	526	Desert Shrub
483	397	Grassland
698	502	Grassland
902	277	Forest
991	197	Forest
1143	165	Forest
1854	154	Forest

On the graph paper provided, or on your favorite graphing software, plot sediment yield (y axis- linear) vs. annual precipitation (x axis - linear). Fit a curved line through the data, and label vegetative type accordingly.

Answer the related questions in the last section.

Part 4. Related Questions (in the last section).

A. How does the Bat Mountain fan area compare to it's drainage area. Determine the ratio of Fan Area to Drainage Area. Think of all the geologic factors that have a controlling influence on fan geometry. Very explicitly describe your conditions and they (hypothetically) influence fan geometry, give examples of the relationships you see.

B. Describe the essential elements of the fan mapping criteria that were used to the produce the Bat Mountain Fan geologic map. How were the various map units identified in the field.

C. Compare the watershed gradient to fan gradient. Discuss the fluvial processes that result in alluvial fan formation, in the context of the gradient relations you observed.

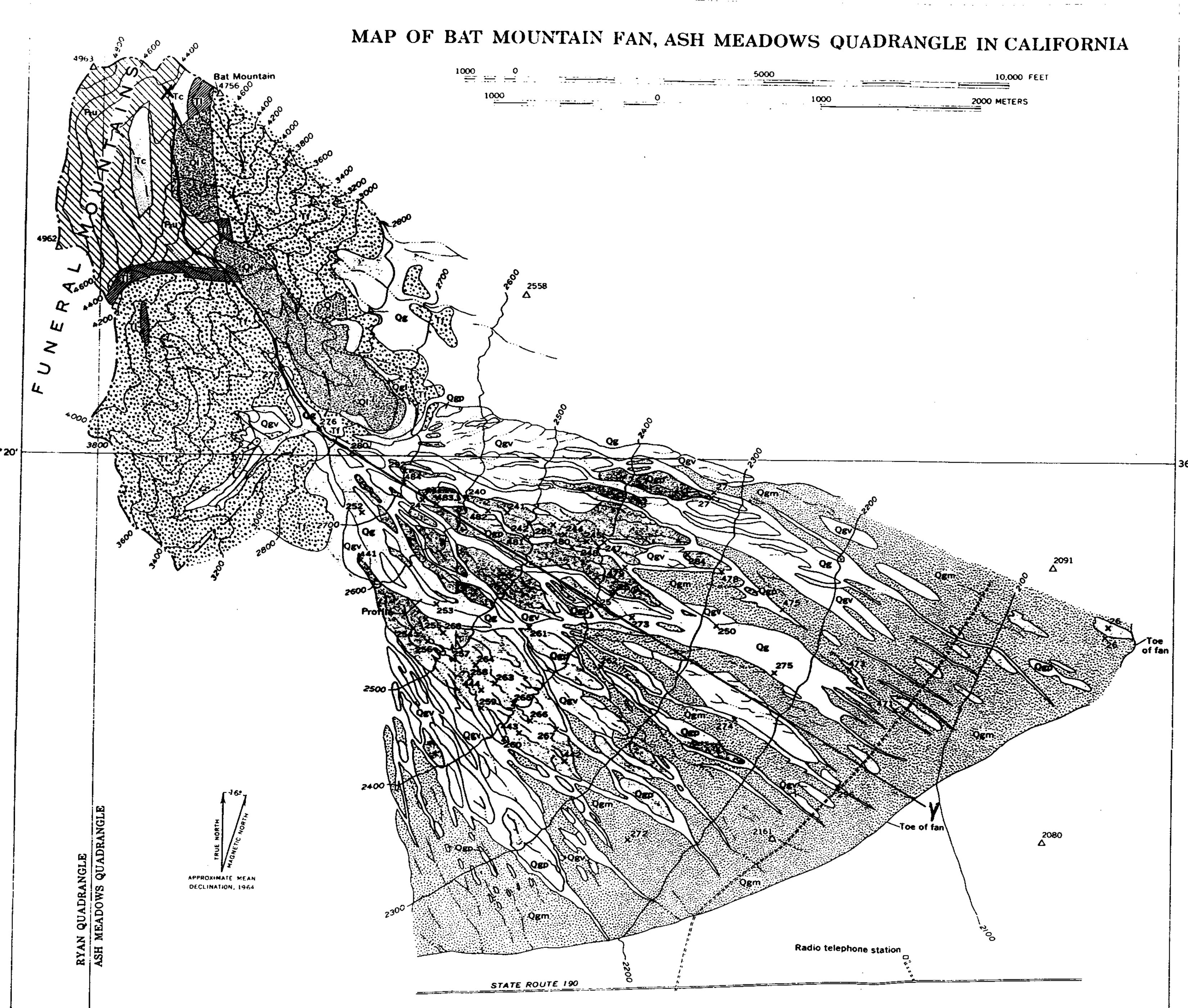
D. How well did the empirical relations of Troeh predict fan surface elevations? Think of reasons to explain the actual vs. predicted relationships that you observe. (if there are descrepancies, what might the sources of error be?)

E. Comment on the frequency of occurrence of fan gradients. Discuss the processes that might control these relationships.

F. Based on your sediment yield-precipitation plots, what types of climate regimes supply the greatest sediment load to fans and why? Explain your graph results in terms of climate change over time. What types of climate conditions will likely trigger fan aggradation? How about fan degradation / erosion. Explain your line of reasoning.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

MAP OF BAT MOUNTAIN FAN, ASH MEADOWS QUADRANGLE IN CALIFORNIA



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EXPLANATION

QUATERNARY

Recent

Qg

Unweathered gravel

Bouldery to pebbly gravel and sand. Fragments both slab-shaped and blocky with angular to slightly rounded edges

Surface form of deposit

Braided channels and ridges—the modern washes—with a microrelief ranging from 1 to 3 feet

Pleistocene and Recent

Qgv | Qgp

Bouldery to pebbly gravel and sand

Fragments dominantly limestone, dolomite, sandstone, and quartzite; commonly cemented by caliche

Surface form of deposit

Qgv, *abandoned washes floored with layer of varnished fragments. Surface consists of broad ridges and swales, with a microrelief of about 1 foot, that are the somewhat subdued remnants of braided channels and of bars*

Qgp, *desert pavement. Armor of fragments forming a nearly plain surface. Fragments range from pebbles to boulders and touch each other; commonly angular and considerably weathered. Quartz-rich rocks varnished; carbonate rocks faceted or pitted; many are thin slabs*

Qgm

Gravel and sand, undifferentiated

Surface of deposit is a mosaic of modern and abandoned washes and desert pavement. Microrelief not more than 2 feet. Individual patches too small to map

Ql

Landslide

Tabular bodies of limestone and fanglomerate, highly brecciated. In large part mantled by rubble

Qgl

Gravel beneath landslide

Pebble, gravel, and sand

MAJOR UNCONFORMITY

TERTIARY

Miocene and older(?)

Tf

Fanglomerate

Reddish-brown cobble fanglomerate; includes some pebble conglomerate and sandstone

Tl

Limestone

Yellowish-gray thick-bedded limestone and reddish shale; subordinate sandstone and tuff

Tc

Conglomerate

Red pebble conglomerate, subordinate sandstone and siltstone

DEVONIAN AND MISSISSIPPIAN

Pzu

Cherty limestone, limestone, and dolomite

Subordinate sandstone, siltstone, and quartzite

Contact

Generalized or approximate; includes fault contacts

Outline of drainage area

Shown only in mountains

3200

Generalized contours

100-foot interval on fan; 200-foot interval in mountains (above 2800 feet)