

Fluvial Processes

Rivers are a ubiquitous feature on Earth.

Rivers account for most sediment transport (85%)

Very important geologically.

Throughout human history rivers have provided an important means of transportation.

River floodplains provide fertile ground for agriculture.

On the minus side flooding rivers are the most common natural disaster.

Clearly an understanding of how rivers work and sculpt the Earth's surface is important for practical reasons as well.

The Hydrologic Cycle

Water flows from land into the sea in rivers.

Where does the water come from?

Water is continually being recycled in what is called the hydrologic cycle.

River transport of water to the sea is just one part of this cycle.

Drainage Patterns

Rills take water directly from sheet flow.

Eventually, two of these join up forming a larger stream.

As one heads downstream smaller streams continue to join together to form larger streams.

The largest stream which takes the water to the sea is called the *trunk stream*.

Streams which flow into a larger stream are called *tributaries*.

At the mouth of the trunk stream it may branch off into numerous *distributaries*.

Unless controlled by structural or tectonic factors, streams form *dendritic* drainage patterns.

Tributaries merge with main stream at acute angles.

These in turn have their own tributaries forming a tree like pattern.

However, this pattern may be modified by the structure on which the river flows.

Rivers flowing off a mountain peak (e.g. a volcano) will form a radial pattern.

Rivers will tend to follow the path of least resistance—flowing through easily eroded rock while avoiding more resistant rock.

Superposed Streams

Sometimes streams seem to ignore the structures they are flowing on.

For example they cut through resistant structures.

This may occur if a river was formed initially in overlying layers.

These layers are then eroded away but the river maintains its channel structure.

A superposed stream.

Antecedent Streams

Sometimes streams cut through rock which has been uplifted.

Forming rivers should flow the other way.

Indicates that the river is older than the uplift.

The uplift occurs at a slow enough pace that erosion by the river can keep pace.

Fluvial Erosion and Transport

Water is transported from high elevations to low elevations in a river.

Thus, water loses gravitational energy as it flows.

This energy can be used for a variety of purposes:

Most is lost to friction within the river.

However, a few percent goes into eroding and transporting material within a river.

Transport

Rivers almost always carry material with them.

Material may be in solution (*dissolved load*).

Suspended load is composed of small particles suspended within the stream by turbulence.

Particles which are too big sink to the river's bed.

However, even this material may be moved along the stream bottom and form the *bed load*.

A river's *capacity* is the maximum amount of material a river can hold.

Not actually that useful a concept—a river's load is usually controlled by the amount of material available.

A river's *competence* is the largest particle which the river is capable of moving.

Competence increases rapidly with the velocity of the river (roughly as the square of the velocity).

Erosion

Over time, rivers (and other erosional forces) work to erode high regions.

Transport material to lower levels (ultimately sea level).

Given enough time, mountains will be substantially eroded away.

End state of erosion is a relatively low relief plain.

So why do we still see mountains?

River Valleys

As rivers erode their beds they cut a river valley.

Perhaps one of the most common geologic features

Rivers cut distinctive "V" shaped valleys.

Alone, rivers would cut steep walled valleys.

However, the action of overland flow, weathering, and mass movement erodes the valley walls.

Would we expect steeper valley walls in arid or humid environments?

As a river cuts (or flows) down close to its *base level* (usually sea level) its ability to erode downwards decreases.

At this point rivers erode more laterally creating flood plains.

Thus up in the mountains rivers create river valleys.

Near the mouth of the river they flow over broad flood plains.

If a river is moving fast enough it will be able to erode material from its bed.

Ability to erode is a strong function of velocity.

Most erosion also occurs in the small streams at the head of a river system.

Larger rivers downstream more involved in transport of material.

Graded Stream

Suppose a stream moves fast enough to erode its bed. What will happen?

It will then scour material off its bottom, lowering the elevation.

Reduces the slope ==> lowers the velocity.

The bed will continue to be eroded until the slope (and velocity) is decreased enough to stop erosion.

Conversely, suppose a fast moving river suddenly reaches a flat region and slows down. What will happen?

Initially, a stream may have a number of points where erosion or deposition occurs.

However, given enough time it will modify its slope until it is in equilibrium such that no net deposition or erosion takes place along the river.

A stream which has reached this situation is said to be a *graded stream*.

Of course such a stream could be thrown out of equilibrium if an event changes the landscape.

Then the river would work to regain equilibrium.

Channel Patterns

Longitudinal Profile:

Usually, rivers are more steeply sloped at their headwaters and become less so at their mouths.

That is, they are concave upwards in profile.

Why?

Streams tend to flow in two main patterns:

1. Braided Streams

2. Meandering Streams

Two patterns appear to be separate and distinct modes of fluvial motion—one doesn't see a meandering, braided river.

Experiments show abrupt change from braided to meandering behavior.

Braided Rivers

Braided rivers have sediments (bars) laid down in the middle of the stream.

Streams break into two or more rivers only to rejoin later.

Rivers which are carrying a large load, especially of coarse material are often braided.

Tend to have broad but shallow channels.

Meandering Rivers

Meandering rivers flow in a back and forth manner.

Rivers which carry mostly mud (silt and clay) tend to form deeper channels and form meandering streams.

As a river enters a bend the water on the outside of the bend moves faster than the inside:

Increases the bend creating meanders.

Floods

Usually, water in a river stays within its channel.

However, the amount of water entering the river system is highly variable.

If rains are heavy, lots of water enters rivers *immediately*.

Raises the level of the river.

If the level is raised too much the water may overflow the river's banks:

Flood.

Most water infiltrates the ground.

About 7/8ths of surface water has spent some time underground.

However, during heavy rains the ground may saturate.

Most of the water runs off as sheet flow.

Leads to an even larger increase in the amount of water entering rivers than one might expect.

Therefore heavy rains in a region increase the risk of future flooding.

Floodplains

Floodplains are broad strips of land on either side of a river built up by sedimentation by the river.

It may be material from point bars of meandering rivers as it sways back and forth across the plain or it may be material laid down during floods.

As the river overflows its banks it flows out onto the flood plain.

During a flood the river is flowing at high velocities—carrying lots of sediment.

As the water overflows its banks it will slow down:

Near the channel the coarsest sediment is dropped forming natural levees.

Finer sediments are carried further over the floodplain before being deposited.

The region behind the levees where fine silt and clay are deposited is called the *backswamp*.

Sometimes floods can lead to a cut off of a river's meander: called a *meander cutoff*.

Creates a shorter path for the river.

Former meander which has been cutoff is called an *oxbow lake*.

Deposition

We have already discussed some forms of deposition which may take place.

Most streams flow into the sea or large lakes and ultimately deposit their sediment there.

As a stream enters the sea the water quickly slows down leading to deposition of sediments.

Usually this leads to the formation of a *delta*: a fan shaped region of deposited material.

The size, shape, and extent of a river's delta depends on a variety of factors:

Rivers which carry a substantial load into relatively quiet waters have well developed deltas.

Mississippi and Nile are examples.

Deltas less well developed where vigorous coastal processes take the sediment away.

For example, the Amazon.

Some rivers carry little sediment and thus have essentially no deltas—St. Lawrence.

Alluvial Fan

Sometimes rivers don't reach the sea.

Particularly in arid environment rivers may lose water to evaporation and dry up before reaching the sea.

These may form *alluvial fans* rather than deltas.

Similar to deltas except on land.

Develop in regions where a river suddenly slows down.

Geology of the Olympic Peninsula

We live near a subduction zone boundary between the Juan de Fuca plate and the North American plate.

What does this mean for earthquakes in our region?

Volcanoes?

20 to 30 million years ago the olympic peninsula was not here:

the coastline was near present day Seattle.

Over time material has been brought to the subduction zone and scraped off forming the olympic peninsula.

What kind of feature is the olympic peninsula?

The subduction zone boundary leads to current uplift of our region. Evidence for this?

If the olympic peninsula was created by rocks scraped off of the oceanic plate, what types of rocks would you expect to see?

Evidence for this period of glaciation seen in numerous U-shaped valleys throughout the olympics.

Lake Quinalt and Crescent lake both currently occupy such glacial valleys.

U-shaped valleys are quite steep—mass wasting currently moving material downhill.

Eventually valleys will be “evened out” and take on a more “V”-shape.