EPSC 201 LECTURE 18 MARCH 22 2016

Practice Question: The process of erosion does NOT include which of the following?

Answer: Precipitation of cement – creating the glue that holds the sedimentary rock together. The process of erosion involves taking a sediment from its origin rock (i.e. transport).

Practice Question: Sedimentary rocks formed through cementation of formerly loose grains of sediment derived from weathering of pre-existent rock are called ____________ sedimentary rocks. A very fin-grained example, which typically splits into thin sheets, is called __________.

Answer: Clastic/shale

Practice Question: Imagine a mountain stream whose fast-moving water has carried away all grains except for well-rounded pebbles, cobbles, and boulders. If such a stream gravel were lithified, it would turn into….

Answer: Conglomerate – piecing together; conglomeration of bigger pieces. Conglomerate is when you have larger pieces of rock that have been well-rounded. Breccia can also have big pieces but with sharper edges (think breccia – breaking = sharp edges). Sandstone is fine-grained.

Practice Question: Evaporites are a type of ___________ sedimentary rock. Examples can consist of ________ and/or _______________?

Answer: Chemical / gypsum / halite. Example from class was Death Valley – where the water evaporated.

Sedimentary Structures are features imparted to sediments at (or near) the time of deposition. They are extremely useful to geologists because they provide strong evidence about conditions in the depositional environment.

Bedding and stratification are prominent features of sedimentary rocks. They include surface features on bedding layers and the arrangement of grains within bedding layers, such as these subtle laminations in sands deposited by glacial meltwater in Indiana.

Sedimentary rocks are usually layered or stratified in planar, close-to-horizontal beds. The boundary between two beds is a bedding plane. Width can be uniform or can vary within a layer.

Bedding and Stratification – why does bedding form?

Bedding reflects changing conditions during deposition.

- Changes in transporting medium (velocity, volume per time)
- Changes in sediment source, etc. These may alter:
  -Sediment composition – what sediments are being transported?
  -Grain size
  -Sorting, etc.

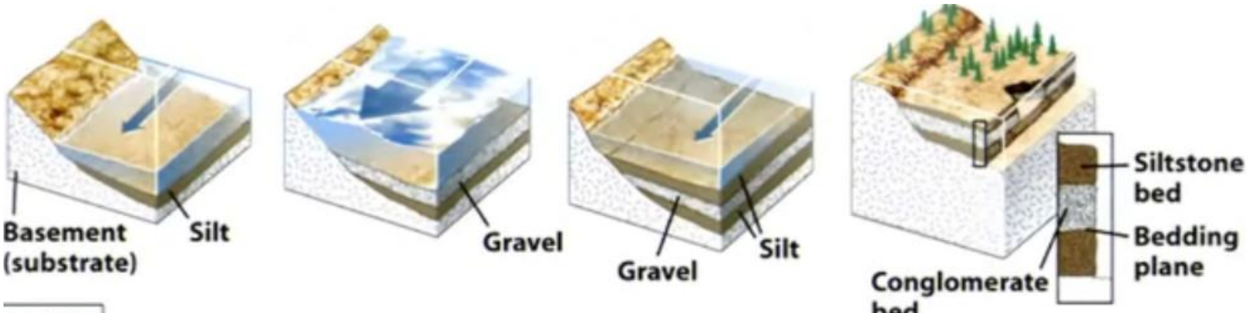


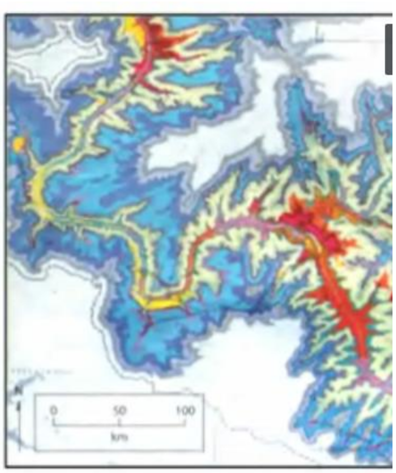
Fig. 6.10b

Maybe the rate of flow of a stream changes therefore the materials being transported will change as well. These beds reflect that something in the environment has changed – sediment composition, grain size, etc..

Beds have a definable thickness that can change – that thickness can tell us about the environment at that time. Bedding forms due to changes in:

- Climate
- Water depth (if looking at sediments deposited in a source of water)
- Current velocity
- Sediment source (example: 2 streams merging carried different sediment types)
- Sediment supply

Looking at a big area, different colored bedding is representative of one particular sediment at a given time – representing that this environment was a particular way at that time. When the color changes, this indicates that the environment changed.



Depositional changes vary the stacking of rock features and create unique packages of rock that are recognizable over a region.

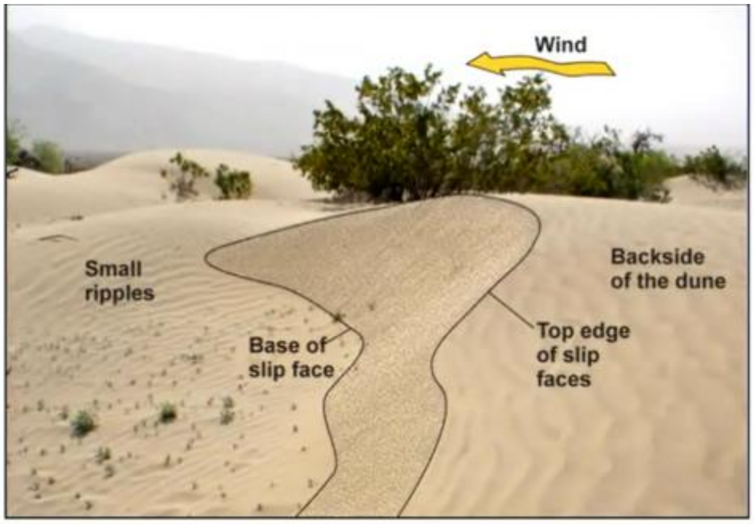
Distinct rock units that are so unique that they can be recognized – and mapped – over large regions, are termed **formations.** Formations are names for places where that are best exposed. Geologic maps display the distribution of formations.

We can use this distinct large areas, formations, to determine what has happened environmentally at that time. We can determine how they formed or what brought those sediments there.

Current Deposition

Water or wind flowing over sediment creates bedforms (looks like "waves" in the sand – like early morning on a beach). Bedform character is tied to flow velocity and grain size.

- Ripple marks created by water flowing over an area – cm-scale ridges and troughs
  -Develop perpendicular to flow
  -Ripple marks are frequently preserved in sandy sediments
  -Found on modern beaches
  -Found on bedding surfaces of ancient sedimentary rocks

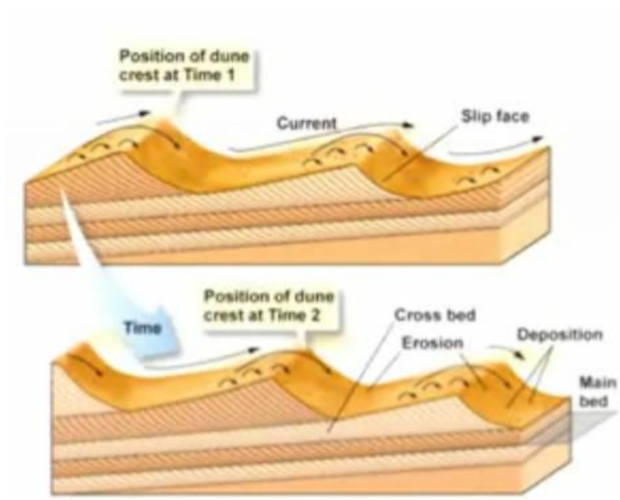


We can look at the marks left behind on the bedform to look at how the stream was flowing.

Dunes are similar to ripples except that they are much larger (tens of cm to hundreds of m). They occur in streams and desert or beach regions from water or wind-transported sand. Dunes often preserve large internal cross beds.

As the wind blows, there is a plane that forms, so we can determine how the wind was blowing at a particular time. So if the wind was blowing less strongly, then the plane might be titled in a different way…

Cross beds – created by ripple and dune migration.

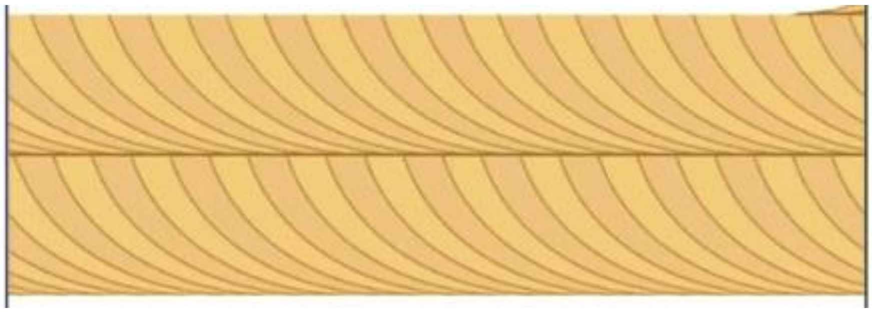


- Sediments move up the gentle side of a ripple or dune.
- Sediment piles up, then slips down the steep face
  -The slip face continually moves downcurrent
- Added sediment forms sloping cross beds.

How do cross beds form?

1. Wind blows sand over the crest of a dune and deposits it on the sloping, leeward, side of the dune to form a cross bed.
2. Over time, many cross beds accumulate in sequence, building the dune out in the direct the wind is blowing.
3. The thick layer containing the cross beds is the “master bed”. Here the top and bottom surfaces of the master bed are horizontal.
4. Later, a second layer of sand builds out over the first. The second layer also contains cross beds.
5. Cross beds are abruptly truncated at the top master-bed plane and gradually curve into (i.e. are asymptopic with) the bottom master-bed.

6. Thus, by examining the shape of the cross beds, geologists can locate the top and bottom of a master bed.



7. Over time, changes in wind direction may affect the shape of the cross beds.

These layers can tell us how the wind was blowing at a specific time. The layers are pointing upwards towards where the wind was coming from – bottom and top layer in diagram above is west → east.

Bed-surface markings occur after deposition while sediment is still soft (has not quite formed a sedimentary rock yet). Mudcracks – polygonal desiccation features in wet mud. They indicate alternate wet and dry terrestrial conditions. Also, fossil footprints are evidence of past life – living things that walked across the layer while it was still forming.

Depositional environments are locations where sediment accumulates. Different environments vary in energy regime, sediment transport, and depositional processes and chemical, physical, and biological characteristics, all of which conspire to create unique sedimentary rocks. Environments range from terrestrial to coastal to marine.

Terrestrial environments: are those where sediment is deposited above sea level (could be in water but not in the ocean, i.e. glaciers, streams). In glacial environments, sediments are created, transported, and deposited by the actions of moving glacial ice. Ice carries and dumps every grain size – it is a very powerful transport medium. A common feature of this environmental is *glacial till*, a poorly sorted mixture of all grain sizes, gravel, sand, silt, and clay. The glacier comes along and melts and dumps everything is has in it.

In mountain stream environments, water carries large clasts during floods. During low-flow conditions, cobbles and boulders are immobile. Coarse conglomerate is a characteristic of this setting. When we have a low flow in the stream, the bigger pieces cannot be moved. These are often better sorted than in glacial till.

Alluvial fans are cone-shaped wedges of sediments that pile up where a rapid drop in stream velocity occurs at a mountain front. If a stream suddenly stops flowing as fast, you end up with a pile of sediment that piles out at the end of the stream.

Sand-dune environments – wind-blown, well sorted sand – Aeolian deposition.

- Dunes move according to prevailing winds
- Result in uniform sandstones with gigantic cross beds

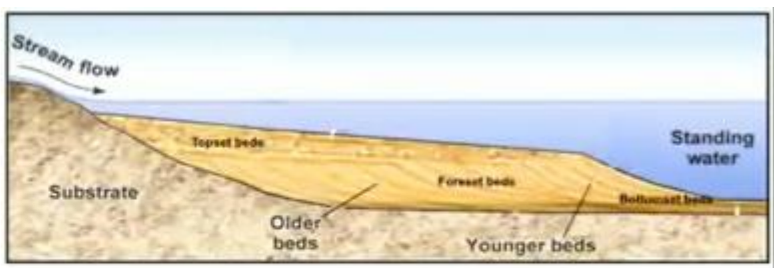
River environments preserve evidence of channelized sediment transport. Sand and gravel fill concave-up channels that often scour into previously deposited floodplain fines. Fine sand, silt, and clay are deposited on nearby flood plains.

<u>Marine environments:</u> deposited at or below sea level.

Lake – large ponded bodies of water

- Gravels and sands trapped near shore
- Well-sorted muds deposited in deeper water

Delta – sediment piles up where a river enters a lake. This depends on how the sediment is deposited into the water (flow intensity). In a marine delta environment, sediment accumulates where river velocity drops upon entering the sea. Deltas grow over time, building out into the basin. Many sub environments present.

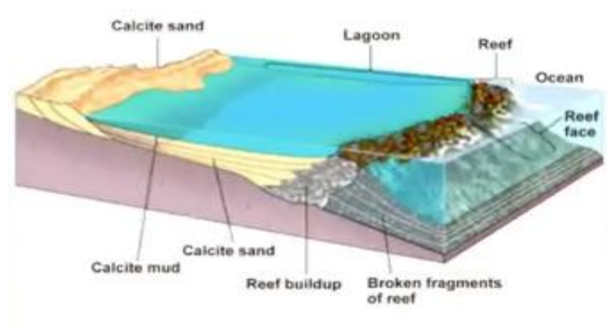


Coastal beach sands – sand is moved along the coastline. Sediments are constantly being processed by wave action. This results in well-sorted, well rounded medium sand. Beach ripples often preserved in sedimentary rocks. Beaches are above land but the sediments coming up onto them are from the ocean so it is really a buildup from the ocean. The sediments are determined by how the water is flowing…

Shallow marine clastic deposits are composed of fine sands and silts that accumulate in the quieter waters offshore. The sea-floor in these settings supports active biotic communities. Fine silts and muds turn into siltstones and mudstones.

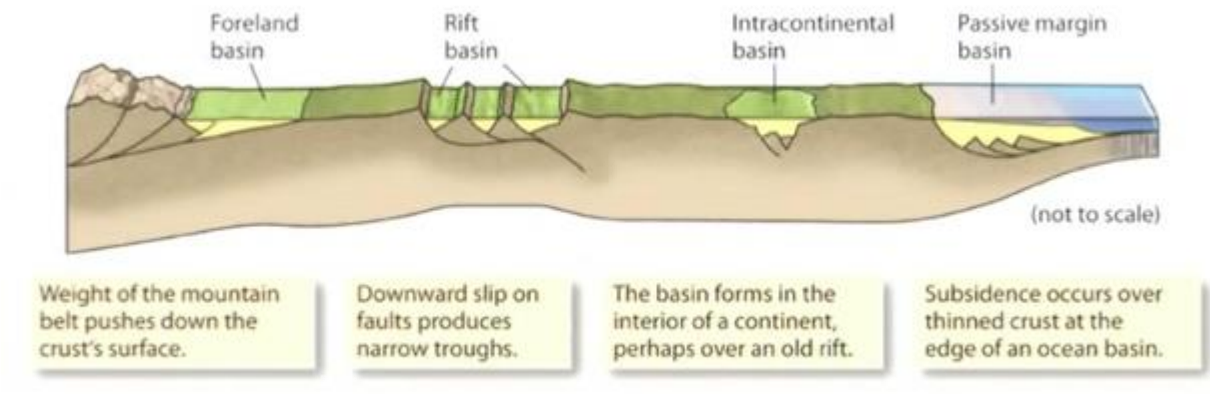
Shallow water carbonate environments: most sediments are carbonates – shells of organisms. Characteristic of equatorial regions.

- Warm, clear, marine water, relatively free of clastic sediments.
- Protected lagoon accumulate mud.
- Wave-tossed reefs are r?
- Source of limestone
- Indicative of water level in the past because often certain organisms only grow at a certain water level



Deep marine deposits: fines settle out far from land. Skeletons of planktonic organisms make chalk or chert. Fine silt and clay lithifies into shale. Example: sediment cores from the bottom of the ocean. When we had terrestrial ice sheets, we had a large amount of mass that was being lost to the ocean. The lost did not always happen smoothly, sometimes it would come in a big burst where a large piece of ice would break off into the ocean. The ice would melt and drop all the rocks into the bottom of the ocean. These deeper marine deposits can tell us how the ice sheets were losing mass very rapidly in the past.

Sedimentary basins are special places that accumulate sediment. Sediments vary in thickness across Earth's surface from zero to 20+ km in sedimentary basins. Sedimentary basins form where tectonic activity creates space.



Rift basin – divergent plates – not marine environments yet, flat area where land is being stretched out and thinning. Eventually it will be a divergent margin. Sediment fills the down-dropped troughs.

Passive margin basin – generally, when you have oceanic and continental lithosphere meeting, the oceanic is going under the continental lithosphere at a plate boundary (subduction zone). Sometimes there is not a plate boundary there, this is called a passive margin. Oceanic crust is flowing outwards and is building up forming continental crust – where there is no plate boundary or any subduction.

- Underlain by crust thinned by previous rifting
- Thinned crust subsidies as it cools
- Subsiding basin fills with sediment from rivers entering sea

Foreland basin - is associated with mountains. A mountain belt will push down on the surface and you'll end up with a foreland basin forming on the outside of it.

Inter-continental basin will form when there is already a hole in the continent. If you have a rift but it hasn't rifted all the way (it just stopped rifting) then you are left with this depressed area = intercontinental basin.

Transgression – Regression – sea level changes

Sedimentary deposition is strongly linked to sea level. Changes in sea level or commonplace geologically. Corals and old shorelines give us an idea of how sea level was at a specific time.

- Sea level rises and falls up to hundreds of meters due to changes in climate and tectonic processes
- Depositional belts shift landward or seaward in response
- Layers of strata record deepening or shallowing upward

Trangression – sea level rising ; regression – sea level lowering

During transgression, as the sea level rises, what was once a beach becomes submerged, and mud buries the sand. Eventually, an uninterrupted layer of sand accumulates across the region as the sea level rises; at any given time, though, sand is being deposited only at the beach. When the sea level falls, the coast migrates seaward and areas that has been accumulating mud become buried by sand. Millions of years later, after the land has been uplifted, erosion reveals a layer-cake succession of strata. Note that no layer formed all at once; rather, the sand in each layer was deposited gradually, as the sea transgressed and regressed. Thus, not all parts of a layer are exactly the same age.

Sea-Level Overview – Sea level change, ice sheets, and the solid Earth

Global ocean bathymetry (depth of the ocean): oceans cover ~70% of the World's surface; the average depth of the ocean if 4km (max depth 11km); 80% of the world's population live within 60km of the coast.

Population is widely distributed, and includes "mega-cities" – ¾ which are located adjacent to oceans and island populations.

What causes the sea level to change?

-Terrestrial water storage, extraction of groundwater, building of reservoirs, changes in runoff, and seepage into aquifers. Water locked up on land and the water on land vs. the ocean can change.

-Subsidence in river delta regions (ocean and land boundary), land movements, and tectonic displacements. Both local and large scale changes, e.g. erosion (just removing land).

-Surface and deep ocean circulation changes and storm surges. Circulation changes, the strength of ocean circulation will cause swells in some areas and depressions in others.

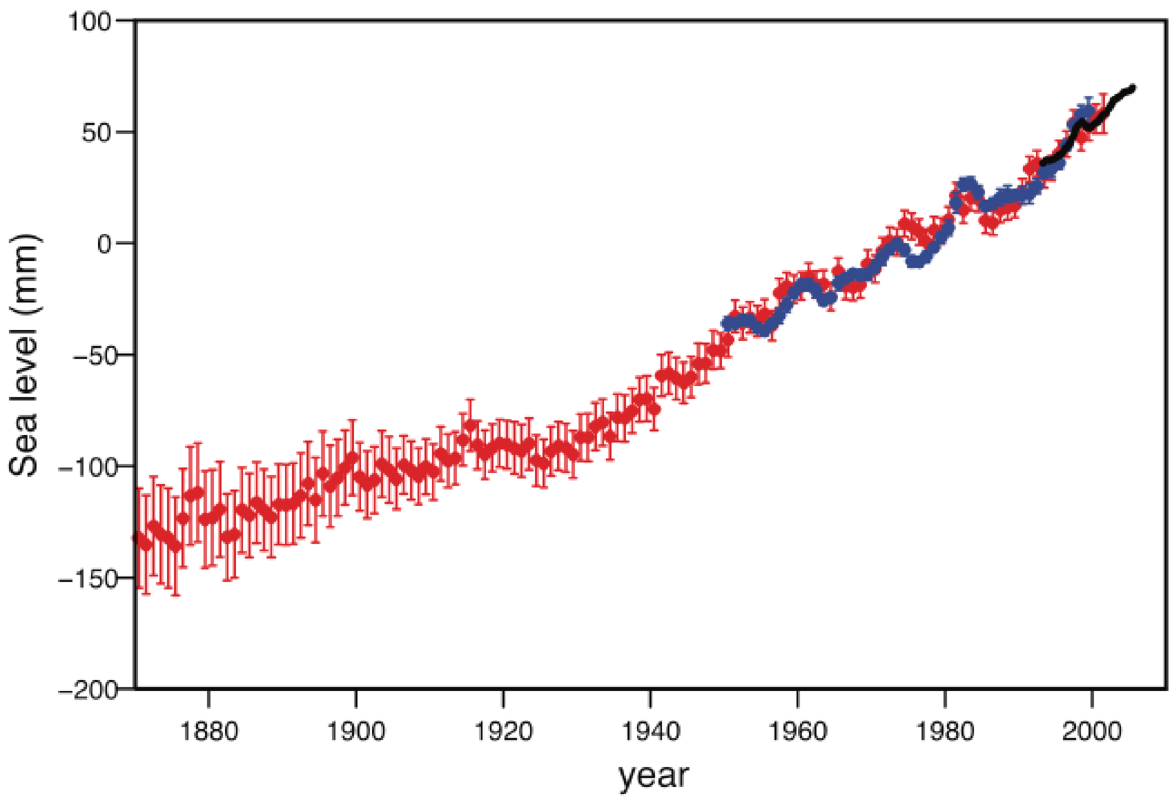
-Warming ocean causes the water to expand. Dominant source in the last century – thermal expansion, increasing the volume of the ocean.

-Exchange of water stored on land as glaciers and icecaps with ocean water. Ice locked up on land and when it melts it contributes to sea level rise.

We measure sea level using tide gauges. They are like meter sticks and measure where the sea surface is compared to the solid (land) surface. Tide gauges are mostly on the coast all around the world. There are more gauges in the Northern hemisphere than the Southern hemisphere. Also, we have a lot fewer time gauges through time and they have not been "corrected" through time.

Tide gauges measure: (Relative) Sea level = ocean surface – ocean floor

We can compile the data from the gauges and obtain a plot of sea level over the last ~100 years:



If we take the slope of the first half, we get ~0.7mm/year. If we take the slope of the latter half after the industrial revolution, the rate is ~2mm/year. The black line in the past few decades in the graph is from satellite altimetry.

Altimeter satellites send signal toward the sea surface to measure the two-way travel time of the reflection. The time to reach the satellite can then be used to calculate the distance of sea surface height. It tells us accurately where the sea surface is over time. From the satellite altimetry records, the rate of sea level rise is ~3.2mm/year for the last 2 decades. From this, we can say that the global sea level rise has been accelerating over the last 100 years.

What will happen in the future if we continue to warm the world? But what we care about is more on a local perspective – how are sea level changes going to affect a specific site, like NY city. Local measures of sea level are very different from the global average.

Sea-level change is geographically variable. We can observe that in certain areas where there is a tide gauge measurement, sea-level might be going up and in another area, it may be going down. Locally does not reflect the global average of ~3.2mm/year. These local patterns are often related to ocean circulation changes likes El Nino, La Nina, etc.

Ocean warming has been the largest contributor to sea level rise in the last century. The amount that you can expand water as you warm it is limited. The main focus for the future is that the largest contributor will be the melting of glaciers and ice caps/sheets (Greenland and Antarctic). The ice sheet that covered NA was also a major contributor to sea level rise when it retreated, thus the melting of ice sheets is a large contributor over time as well.

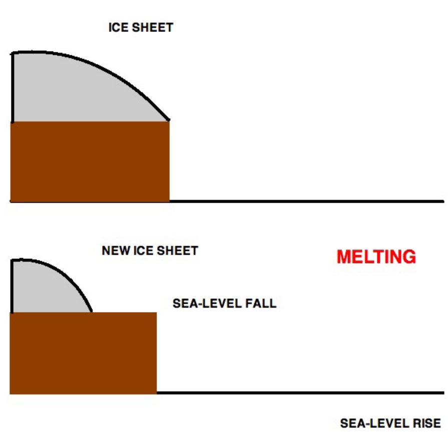
We have two ice sheets on the land today. Greenland ice would raise sea level by ~7 meters (if melted and spreaded evenly all over the world). Antarctic ice would raise sea level by ~57 meters. The area of the Antarctic ice sheet = 7.5 billion hockey rinks. West Antarctic, point with a tail at the end, is currently very unstable. Once this starts retreating, there is no stopping it unless it reaches something that has changed.

Future Sea-Level Rise? What would sea level look like if you melted all ice on Earth? Much of NA coast time would be wiped out. Even a small amount (0.5m) near a city who is not prepared for these types of floods then a tsunami or hurricane hits, this could be disastrous.

The last IPCC report mad estimates for the next century on where global sea level will go and the range of uncertainty: "Only the collapse of the marine-based sectors of the Antarctic ice sheet, if initiated, could cause GMSL to rise substantially above the likely range during the 21^{st} century". – We know this is a possibility but we do not know how this retreat will happen, but if it happens, it will surpass our estimations.

What happens to water level when an ice melts?

The bath-tub model:



The sea level will rise everywhere!

It is in fact more complicated than that and this is not how it works.

In fact, if Greenland melts, the Southern hemisphere will experience sea level rise and the Northern hemisphere will see a sea level fall. The opposite is true for Antarctica. Why does this happen – why would sea level fall at the edge of the retreating ice sheet?