Topic: Changes in relative sea level and associated features
3.1.3.3 Coastal landscape development

What you need to know
Eustatic, isostatic and tectonic relative sea level changes
Landscapes associated with emergent coastlines
Landscapes associated with submergent coastlines

Introduction:

The relative position of land to sea is rarely consistent. The land can rise or fall over:

- very short time scales (tectonic uplift or downthrust)
- over the medium term measured in thousands of years (isostatic change) and
- over millions of years (continental separation and collision)

Similarly, sea level can rise or fall:

- relatively rapidly (thermal expansion)
- over the medium term (global climate change and melting ice) and
- over the very long term of millions of years (tectonic plate movement)

As different regions of coastline may be subject to different processes the consequence is that while some coastlines may be 'emerging' from the sea, others may be 'submerging' while others are changing in balance with any sea-level change so that there is no apparent alteration in the level of the sea.

Tectonic factors (short term)

A coastal region experiencing seismicity may experience land being shifted upwards (uplift) or downwards (downthrust) as geological pressures are released and adjacent rocks adjust at fault lines. As a result, there can be a rapid change in relative sea-level depending on whether land has been shifted up or down. Some notable land/sea level changes are:

- The Great Alaskan earthquake of 1964 with a magnitude of 9.2 (the second most powerful earthquake ever recorded) had a tilting effect such that the coastline 200 miles south-west of Anchorage was left 9.1 m. higher, while south-east of the city the coastline dropped by 2.4 m.

- Over 200 miles of the eastern coastline of Honshu, northern Japan, dropped by 0.6 m. as a result of the Tohoku earthquake of 2011, known for its destructive tsunami.

Isostatic changes (medium term)

Isostasy is the state of crustal material floating on top of more pliable mantle material beneath. The natural buoyancy of crustal rocks may see them depressed by the weight of accumulating ice on top, or released if long-existing surface ice subsequently melts. Isostatic sea level change most commonly arises from movement of the land relative to the sea.

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- **Submerging land**: during periods of ice advance land masses in higher latitudes have been weighted down, sinking deeper into the mantle, a process called compression. (While this might be expected to raise sea level relative to the land, so much water was locked in ice sheets that sea level dropped at a faster rate than the land was depressed during the glacial maximum).

- **Emerging land**: at the beginning of the current warmer interglacial ice sheets started to rapidly melt after 18, 000 BCE and land masses began rising in a process known as decompression. This is thought to take place in two phases:

    - Increased buoyancy: the early stages of isostatic uplift occur as the weight of ice is suddenly released and, like a cork that has been pushed down, it 'bounces back up'.

    - Mantle readjustment: a more extended phase of uplift (that is still going on in northern Scotland as it continues to rise after the last ice advance) as viscous mantle that had been forced away from beneath the depressed crust very slowly flows back to its former location.

Eustatic changes (short, medium and very long-term)

These processes influence the level of the sea itself and are often the result of either the volume and/or mass of sea water changing due to climatic factors, or a given volume being redistributed over a changing surface area as a result of tectonic plate movements.

- **Thermal expansion/contraction**: the biggest single factor responsible for sea-level rise in the last 300 years is thought to be the expansion of sea water as it becomes warmer due to global climate change since the start of the Industrial Revolution. Warmer water occupies a larger volume (despite an unchanged mass).

- **Melting ice**: the second largest factor (which may become the most significant in the next century or two) is the increasing mass (and also volume) of the world's oceans as water is redistributed from polar ice sheets and continental glaciers as they melt at an increasingly rapid rate.

- **Ocean basin expansion**: as continents shift apart opening ocean basins, such as the expansion between Africa and South America, the larger area to be occupied by a fixed mass/volume of sea water may cause sea level to fall. (Effectively, it is spread out thinner.) If, however, submarine volcanoes and ocean ridge expansion occupies a greater area, sea level rises to reflect the larger lithological mass within it. (The same as happens to your bathwater when you get in it).

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Key point: isostatic factors are specific to particular regions of coastline while eustatic factors operate globally across the world's oceans. As a consequence, some coastlines may be emerging while at the same time some are submerging, and others achieving a state of dynamic equilibrium with a changing sea level.

Historic sea level changes

- 18 000 BCE the global sea level was around 120 m below current levels as so much water was locked up in ice sheets and glaciers.
- Sea levels rose very rapidly as ice sheets melted with as much as a 10 m rise in just 500 years after 17,000 BCE. (equivalent to 20 mm per year on average)
- A slower general rise was punctuated by pulses of much faster melting and sea level rise. The pulse of 6 000 BCE is thought to have added 6.5 m in less than 140 years and finally separated the British Isles from the European continent.
- Sea level stabilised around 1000 BCE until the 19th century. Since then it has been rising, with an average rate of 1.8 mm per year during the 20th century.
- Projections of likely sea level rise by 2100 range from a low estimate of 0.28 m to a high of 0.98 m on 1990 baseline level, building on the current 3.4 mm./yr rise.

Features of emergent coastlines.

Feature	Description	Where seen
Raised beach	A beach that was at sea level but is now well above it.	Common on the west coast of Scotland as a result of isostatic recovery
Elevated marine platform	A wave cut platform that now exists as an extensive flat area in front of a relict cliff above active wave action.	(as above)
Sea cave and/or arch	Features of past coastal erosion that are now well above the active coastal zone.	(as above)

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Features of submergent coastlines

Feature	Description	Where seen
Ria	A river valley at the coast that has been inundated by the sea as relative sea level has risen, resulting in a 'drowned valley'.	South coast of Devon (Dartmouth)and Cornwall (Falmouth)
Fjord	A glaciated valley at the coast that has been inundated by the sea. Has steeper rising walls, a straighter long profile and is deeper than a ria due to glaciers over-deepening the valley.	West coast of Norway.
Dalmation coastline	A series of longitudinal river valleys next to the coast that have been inundated leaving parallel ranges of watershed ridges as islands.	Along the coast of Croatia in the north-eastern Mediterranean.

Human uses of these features:

- Rias and fjords often offer sheltered estuaries of relatively deep water in which ships, fishing vessels and pleasure-craft may find safe harbour.

- Evidence of past relative sea level changes so that current rates of change may be understood and measured.

Coastal management issues

- Relatively rapid short-term rises in sea level as a result of thermal expansion and ice-sheet melt are likely to cause more frequent flooding of low-lying coastal areas. Future coastal planning has to consider the impacts this may have and whether adaptation policies are required.

- As different coastlines may be affected by relative eustatic sea level rise at different rates according to their isostatic context, coastal management policies need to assess the rate of likely future rise on a coastal region-by-region basis. Around the coasts of member countries of the EU relative sea level rise takes place at different rates so policy is geared to identifying coastlines in greatest need of protection and prioritising action for those areas.