

Sea level changes and raised beaches

By

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Currently there is frequent reference in the media to the threat of global warming which will cause the Greenland ice sheet to melt, thereby raising the sea level worldwide. As the Greenland ice sheet is entirely land-based this would indeed be the case. No doubt floating ice-packs in the Polar Regions would also melt but this would not lead to a rise of sea level as floating ice displaces its own mass of sea water. You can demonstrate this by placing an ice cube in a glass and fill the glass to the brim with water. The melting of the ice cube will not cause the water to overflow.

The converse is also true – a period of colder climate would cause water from the ocean to be deposited on land as snow forming glaciers and ice-sheets or expanding existing ones thereby causing a lowering of the sea level worldwide.

Such worldwide changes of sea level are termed eustatic changes – the process being called eustasy. If the new higher or lower sea levels persist for an appreciable period, beaches will form at levels higher or lower than the present one. Sequences of beaches formed at various times when the eustatic sea level remained constant for significant periods have been recorded on isolated volcanic islands in the Pacific Ocean. Such beaches tend to be horizontal

However, there is another factor that can influence sea level in relation to the land. This depends on the fact that the rocks that form the continents make up a ‘Crust’ that is less dense than a substrate, called the ‘Mantle’. This surrounds the core of the planet. It is much denser than the material that forms the crust so that the continents can be said to ‘float’ upon it. When the areas of continental crust are loaded by the extra weight of an ice sheet, they are depressed, thereby displacing the underlying mantle material. As a result, the sea level is ‘raised’ in relation to the ice-covered land and beaches can be formed at high levels on the margins of the continent. As the mantle is very viscous, the displaced material tends to form a raised zone around the mass of continental crust with its load of ice. This also tends to raise the sea level in relation to the ice-laden continent and during periods when the sea level is relatively constant, high level beaches can form. The changes of sea level generated by displacement of the mantle as a result of the development and decay of ice sheets are termed ‘isostatic’ - the process being termed isostasy. Beaches tend to form during periods when the isostatic and eustatic processes take place in the same direction - up or down – and at the same rate, thereby maintaining for a period a sea level that is relatively constant in relation to the deglaciating land mass. (Fig. 1)

As the ice-sheet melts, the land mass will ‘recover’ – rising upwards in relation to the sea level as the displaced mantle material flows back to its former position. Obviously, the continental mass will be raised to a greater extent towards its centre where the crust been depressed to a greater extent by the ice-load. As a result, the beaches that form during the episodes when the rate of eustatic sea level rise matches the rate of isostatic recovery of the glaciated land mass will be tilted – the older ones rising more steeply towards the centre of the land mass than the later ones. The

gradient of these beaches gives a measure of their age – the steeper the gradient, the older the beach.

When the Geological Survey carried out its initial survey of Scotland, they recognised the ancient raised beaches but assumed they were horizontal and termed them the 100-foot, the 50-foot and 25-foot Raised Beaches. It was the detailed investigation of the raised beaches by D. E. Smith, R. A. Cullingford and B. J. Sissons on the flanks of the Tay and Forth estuaries (Fig. 2) that revealed the true attitude of the features. There is an excellent account of the researches which demonstrated that the raised beaches were tilted and how they were related to the margin of the decaying ice-sheet. in 'The Evolution of Scotland's Scenery' by B. J. Sissons, 1966.

The most conspicuous of the Scottish raised beaches is the most recent one that formed about 6–8000 years ago when the sea level was about 25 feet (6-8m) higher in relation to the land than at present. It is well developed along the west coast. More enigmatic is the so-called Raised Rock-cut Platform. This extensive feature is also well developed along the west coast and on the offshore islands. Sissons maintained that it formed during the last phase of glaciation that affected Scotland – the Loch Lomond Readvance – and there are thermoluminescence dates that support this view. However, there are broad rock-cut platforms - at present sea level - on the east coast of Scotland. They clearly must predate the Loch Lomond Readvance, the glaciers of which did not extend to the East coast and must also predate the Last Main Glaciation as in places they are covered by glacial deposits.

The very extensive character of the Platform, and the caves that are associated with it, strongly suggests to me that it required an extremely long period to be formed. I suggest that the feature predates the Glacial Period and was formed during a very long period when the sea level remained constant. I further suggest that the fact that it is now 'raised' is a response to the removal of rock from northern Scotland during the Glacial Period. This raised beach may well have been reoccupied – and suffered further erosion – during the period of the Loch Lomond Readvance thereby accounting for the date determined by the thermoluminescence method.

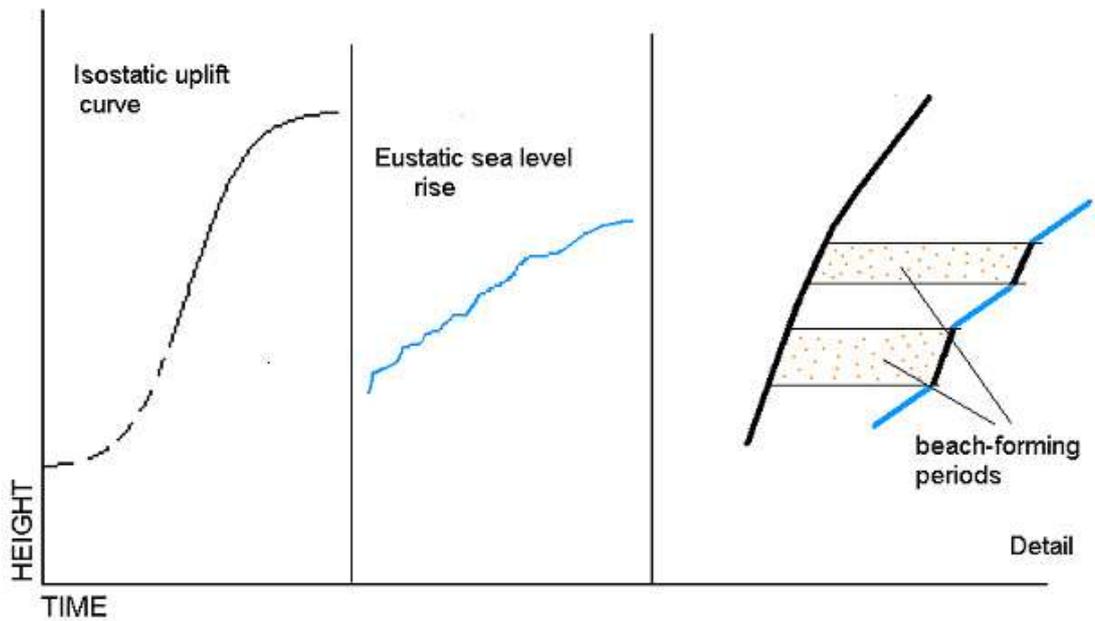


Fig. 1 Diagram illustrating the opportunities for the formation of shoreline features in response to changes of sea level during periods of ice-sheet decay.

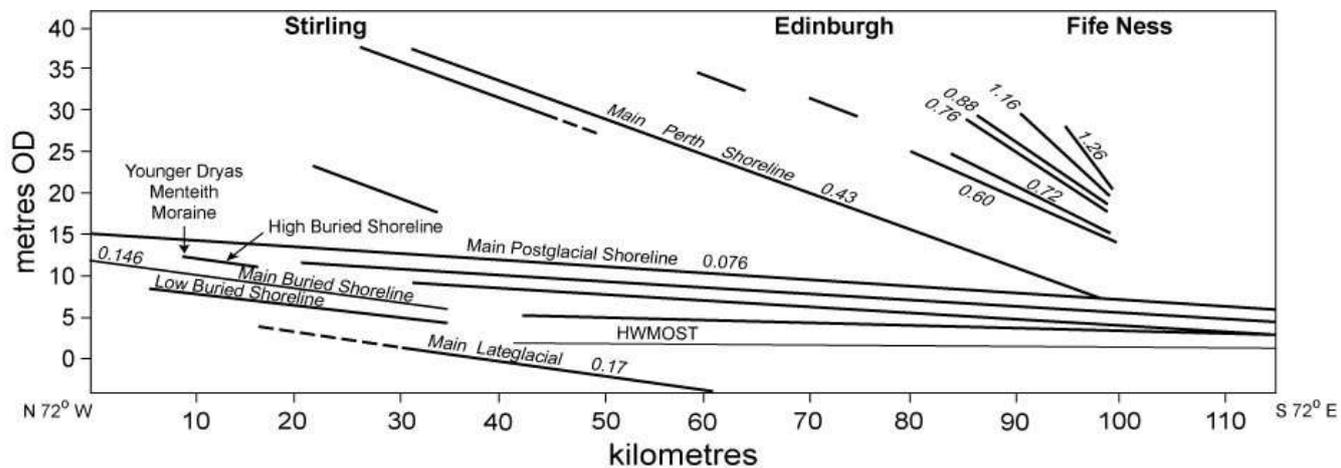


Fig. 2 Raised beaches along the Firth of Forth - one of the most closely studied raised beach sequences in the world. (HWMOST = high water mark of Spring tides).