Chalk cliff retreat in East Sussex and Kent 1870s to 2001

Article (Unspecified)

Retreat of Chalk cliffs in the eastern English Channel during the last century

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(Received 19th August 2005; Accepted 11th January 2006)

Abstract: The retreat of chalk cliffs fringing the eastern English Channel contributes shingle to the beaches which helps to protect the cliffs and slow down erosion. Conversely, cliff retreat endangers settlements and infrastructure on the clifftop. Rates of retreat have been calculated by a variety of methods over the past century, but no attempt has been made to provide a complete coverage that allows for a true comparison of retreat rates over the entire coastline. Using historic maps and recent orthophotos, cliff retreat rates have been calculated for consecutive 50 m sections of chalk cliff along the English side of the entire eastern English Channel for a period of $\sim$ 125 years. The chalk cliffs of East Sussex erode at an average rate of 0.25 - 0.3 m y^{-1} while those in Kent at a rate of $\sim$ 0.1 m y^{-1}.

ISSN 1744-5647
http://www.journalofmaps.com

1. Introduction

Accurate measurements of the retreat of coastal cliffs helps to identify the scale and threat of coastal erosion processes to settlements and transport infrastructure along vulnerable stretches of coastline. It can also aid our understanding of cliff erosion processes, and provide valuable information on the magnitude and frequency of cliff collapses. In addition, if measured on a volume basis, measurements of cliff retreat can contribute to our understanding of beach sediment budgets. Measurement of cliff retreat rates along the English coastline of the eastern English Channel has a long history (Cleeve and Williams, 1987; May, 1971; May and Heeps, 1985; Thorburn, 1977). In each of these studies, rates were determined by comparing the position of the cliff top line on maps of different ages. This was achieved by manually tracing the cliff lines from the maps and then measuring the distance between the lines at a number of points. Most researchers have applied this method to limited lengths of cliffs only, or have selected only a restricted number of points. May and Heeps (1985), for example, investigated the retreat of the $\sim$ 50 km of chalk cliffs between Dorset and Thanet, including the Isle of Wight, using only 160 points. Thorburn (1977) summarised a detailed survey of the entire Sussex coastline but, unfortunately, this study was based on maps covering the 30 year period 1925-1955. This short time frame is likely to have introduced relatively large errors because the positional error of the maps is large compared to the measured change. Similar problems of short-term measurements are present also in parts of the studies of May (1971) and May and Heeps (1985). Additionally, they based some of their measurements on maps surveyed prior to the First Edition of the Ordnance Survey "Six inch to the mile" and these are more difficult to overlay on younger maps due to a lack of suitable positional information.

The technique of manually tracing and overlaying cliff lines introduces errors associated with the accuracy of tracing the line, the pencil width and expansion or contraction of the paper (see Anders and Byrnes, 1991; Moore, 2000; Thieler and Danforth, 1994). These errors are further aggravated by the necessity of enlarging or reducing maps to facilitate the comparison of maps of different scales (e.g. to accommodate the change from imperial to metric scales). In addition, the subjectivity of selecting the points at which measurements are taken can have a significant effect on the retreat rate obtained. Only rarely, and only for short stretches of the chalk cliffs, has the area of cliff loss been measured and a mean retreat rate for individual sections of coastline been calculated (e.g. Cleeve and Williams, 1983). Previous measurements of cliff retreat rates along the Channel Coast of East Sussex, additional to those cited above, can be found in Castleden (1996) and Dornbusch et al (in press).

2. Methods

The map presented here has been compiled using a geographic information system (ESRI ArcView GIS) and is based on comparing areas of retreat rather than measuring linear retreat distances at specific points. It has been compiled from the First Edition "Six inch to the mile" Ordnance Survey maps and orthophotos based on 2001 air photos. The historic maps were first scanned and georeferenced and then the cliff top lines were digitised on screen from the historic maps and orthophotos. The area between the two cliff top positions was converted into a polygon by the following procedure. First, a third line was digitised running between the two cliff top lines. This line was split every 50m and new lines generated at right angles to this centre line. The lines at right angles to the cliff line form borders for the 50m sections into which the area of retreat was cut, creating polygons of cliff retreat that are each 50m wide along the coast, but extend for variable distances inland. The area of each polygon was calculated, and divided by 50 to obtain the average retreat in metres. Further dividing this figure by the years between the survey dates provides the mean annual cliff retreat rate shown on the accompanying map.

3. Data Sources

Orthophotos were provided by the Environment Agency from surveys flown in May 2001 at a scale of 1:5,000. The orthophotos have a ground resolution of 0.2 m and are georeferenced to the UK National Grid. No details of the positional accuracy are available but by comparing features with those in the Ordnance Survey Landline data set and with static differential GPS surveys (horizontal accuracy better than 0.05 m) carried out by the authors, the average positional accuracy has been estimated to be better than ± 0.3 m.

The earliest maps used were the First Edition of the Ordnance Survey 6-inch scale maps (1:10,560) surveyed in 1873 because these maps are the first to have been surveyed with regard to a geographical reference system (latitude and longitude) that is displayed on the map itself.

Prior to scanning, the graticule was transferred from the map frame onto the areas to be scanned as small markers using a long metal ruler so as to cause the least damage to the maps. The maps were then scanned at 300dpi using an A3 scanner and georeferenced to the National Grid in ArcView, using a combination of these markers and features that could be found on the maps and in the Ordnance Survey Landline data. Georeferencing was performed using a first order transformation with RMS-errors in most cases < 0.6 m. The georeferenced maps were then overlain with the Ordnance Survey Landline data (based on surveys carried out in the 1990s) to check the alignment of features to be found in both data sets and to check alignment with features on neighbouring maps. If alignment offset was unsatisfactory, georeferencing was repeated with other reference points until alignment errors were < 5m.

For the coast at Peacehaven, which is presently defended by a sea wall, maps surveyed prior to the installation of sea defences and the trimming of the cliffs were used in place of the orthophotos. These comprise ground surveys carried out on behalf of Lewes District Council in 1970 and 1996. These maps were scanned and georeferenced as described above.

The survey accuracy of historic maps can be established only by comparison with modern data. After georeferencing the historic maps to the Landline data set, which has a positional accuracy of 1.1 m for maps surveyed at 1:2,500 (Ordnance Survey, 2005), positional errors close to the coast are small and generally less than 5 m. However, where the cliff top has not retreated at all, the position of the historic cliff top line can sometimes be found landward of the present line. These 'cliff advances' are most often associated with geometry offsets of the two lines and only rarely is the absolute offset more than 10 m. It is therefore thought to be reasonable to attach a mean positional error for the historic cliff line of ± 5 m (this value is generally better that those suggested in the literature for maps from the US (e.g. Anders and Byrnes 1991, Moore 2000). Over the time period of 124 years between the historic maps and the orthophotos this amounts to an error for the retreat rate of 0.04 m y^{-1}, similar to the values found by Valentin (1954).

4. Results

Figure 1 and the accompanying map show rates of cliff retreat along the Eastern Channel coast of the UK for the period 1870s to 2001 (except at Peacehaven where the period is shorter). Examination of the map and graph shows distinct patterns of variation. The chalk cliffs of East Sussex exhibit relatively high rates of retreat (0.25 - 0.3 m y^{-1}), with the maximum occurring along the eastern section of the Seven Sisters where rates are in excess of 0.7 m y^{-1}. Changes in retreat rates between different sections of the East Sussex coast are in most cases gradual in nature indicating that they are not the result of the occurrence or non-occurrence of individual large scale falls, but rather the sum of many small scale / high frequency events. Retreat rates in Kent are generally low (0.1 m y^{-1}) with significant sections that show no retreat at all. This supports the findings of May and Heeps (1985). Retreat along these sections of coast seems to be linked to individual large scale events with return periods longer than the time covered by the survey data i.e. > 124 years.

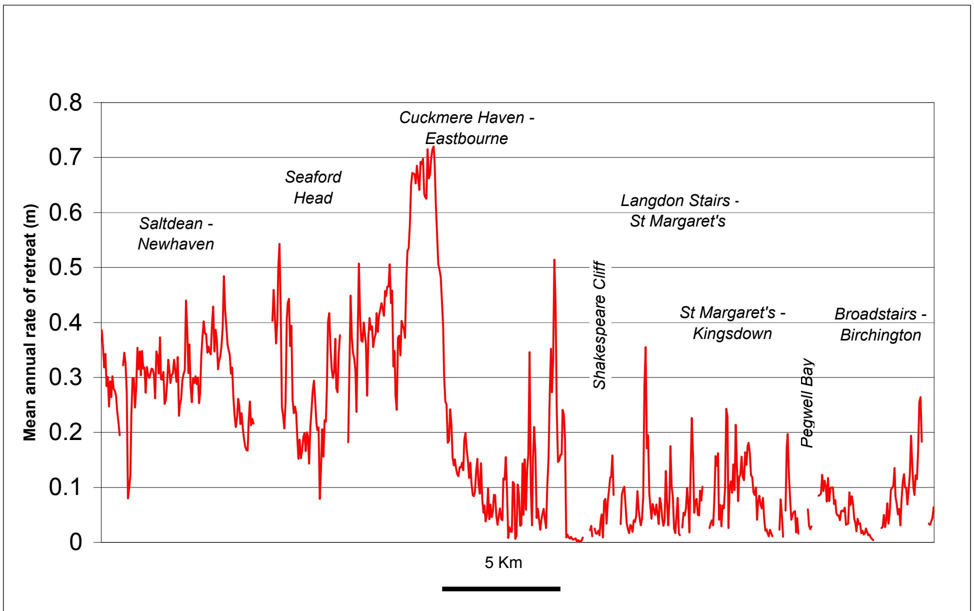

Figure 1 Mean annual rate of chalk cliff retreat along the East Sussex and Kent frontage for the period 1870s to 2001. Names refer to the start and end point of the cliff section; gaps between sections not to scale. See accompanying map for locations.

5. Conclusions and Future Work

Cliff retreat shows significant variations along the coast on different spatial scales that also suggest different frequencies of cliff falls. Future work will split the observation period into smaller phases by using maps from the 1930s and air photographs from the 1970s to investigate whether rates of retreat have remained constant over the past 124 years or have increased or decreased. Comparisons will than be made with similar work carried out on the French chalk cliffs between Cap d'Antifer and Ault in Normandy that cover the period 1966 to 1995 (Costa et al., 2004). In addition, investigations into the factors controlling the different rates of retreat are underway.

Acknowledgements

The authors would like to thank the Environment Agency, Southern Region, for the 2001 orthophotos, and Evelyn Dodds for assistance in providing the historic maps. We would also like to thank the three referees for highlighting improvements to the paper and map. Research has been carried out within the Beach Erosion in the Rives Manche (BERM) and Beaches at Risk (BAR) projects funded in part by the European Union Regional Development Fund, under the INTERREG II and III programmes.

Software

Data analysis and production of the map panels was carried out using ArcView 3.2a. The ArcView layouts were subsequently exported to wmf-format and imported into CorelDraw 7.0 for final map composition.

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