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Research paper

A composite fall-slippage model for cliff recession in the sedimentary coastal cliffs

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ABSTRACT

A composite fall-slippage model is proposed in this study for the Tertiary sedimentary coastal cliffs of Varkala in the western coastal tract of Peninsular India which are retreating landwards due to the combination of several factors. The fall model in the present study accounts both spring seepage and wave action, resulting in undercutting and this fall affects only the topmost laterite and the just below sandstone in the cliff. Slippage in this area affects all the litho-units and hence the geologic characteristics of all the litho-units are considered for developing the slippage model. This mathematically derived model can be used in other cliffs exhibiting the same morphology as well as the one controlled by the same influencing factors. This model differs from other models in incorporating multi-lithounits as well as multi-notches. Varkala cliffs form a part of the aspiring geopark in the Global Geopark Network and hence a study on the cliff recession is a pressing requirement.

1. Introduction

Various cliff recession models have been proposed &by different authors to study the retreat of coastal cliffs. The Bruun-rule model (Bruun, 1962; Bray and Hooke, 1997) deals with sea level fluctuations. Models based on historic data (Hall et al., 2002; Drake and Phipps, 2007; Fall, 2009) often use statistical analysis. The CLIFF-PLAN model of Lee et al. (2002) uses Monte Carlo simulation to represent uncertainty in the cliff recession process. Process-response models (Walkden and Hall, 2005, 2011; Trenhaile, 2009; Castedo et al., 2012, 2013) incorporate geology, environment, hydrodynamic regime and climate. In addition, the Castedo et al. (2012) model incorporated geotechnical parameters too. A composite fall-slippage model, based on geological, geotechnical, tidal, wave, historic and geophysical data, is attempted here. Such a study will be a first attempt at melding such a vast and diversified data. Thus this study will bridge the gap left by other studies making use of process-response model, models based on sea-level fluctuations and models based on historic data incorporating statistical analysis as well as Monte Carlo simulations (cf. Budetta et al., 2000; Collins and Sitar, 2008; Ashton et al., 2011). This study is carried out in a coastal village called Varkala in the state of Kerala, South India.

The state of Kerala, a linear stretch of land sandwiched between the Western Ghats and the Arabian Sea, exhibits a variety of physiographic features ranging from tall mountains such as Anaimudi (2695 m) to the water-logged lands below mean sea level at Kuttanad. The coastal geomorphology of this state is usually manifested as dunes, beaches, cliffs, marshes and backwaters. Of these coastal landforms, the most conspicuous components are the coastal cliffs. Varkala, a coastal town fringing the Arabian Sea in the state of Kerala, exposes three such cliffs *viz.* Edava cliff, North cliff and South cliff (from north to south) with a maximum elevation of ~40 m and running for 5.5 km.

A study on coastal landslides and coastal recession modelling is of utmost importance in this part of the world because such a cliff edging the sea and extending for several kilometers is rare in a region experiencing tropical climate. Moreover, these cliffs form a part of the recently declared national geopark, which is also an aspiring geopark in the Global Geopark Network (GGN). These cliffs and the adjacent beaches sustain a thriving tourism industry, with

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property prices in the very-high bracket (Rajan, 2011). The present study is concentrated on the North cliff which is the most important tourist destination.

Varkala is situated about 55 km northwest of Thiruvananthapuram – the capital of Kerala (Fig. 1). It falls within the Survey of India (SOI) topographic sheet 58D/10 (1:50,000 scale). The picturesqueness of the place attracts a large number of domestic and international tourists round the year. The charm of this place is the presence of beautiful wave-cut cliffs and confined beaches. Tourism activities are mainly concentrated in and around the North cliff, which runs for a length of 1.6 km between Papanasham (a ritual place for performing ablutions for ancestors) (8°43′59.34″N, 76°42′19.91″E) and Black Beach (8°44′35.75″N, 76°41′54.21″E) and hence the present study is only concentrated on this cliff.

The main aim of the study is to create a composite fall-slippage model on the basis of various geologic and climatic parameters. A detailed geological mapping (including cliff face mapping, preparation of lithostratigraphic sections and geologic profiles), determining the geotechnical parameters of the difficult lithounits, analysis of rainfall, tidal and wave data, shoreline changes over a

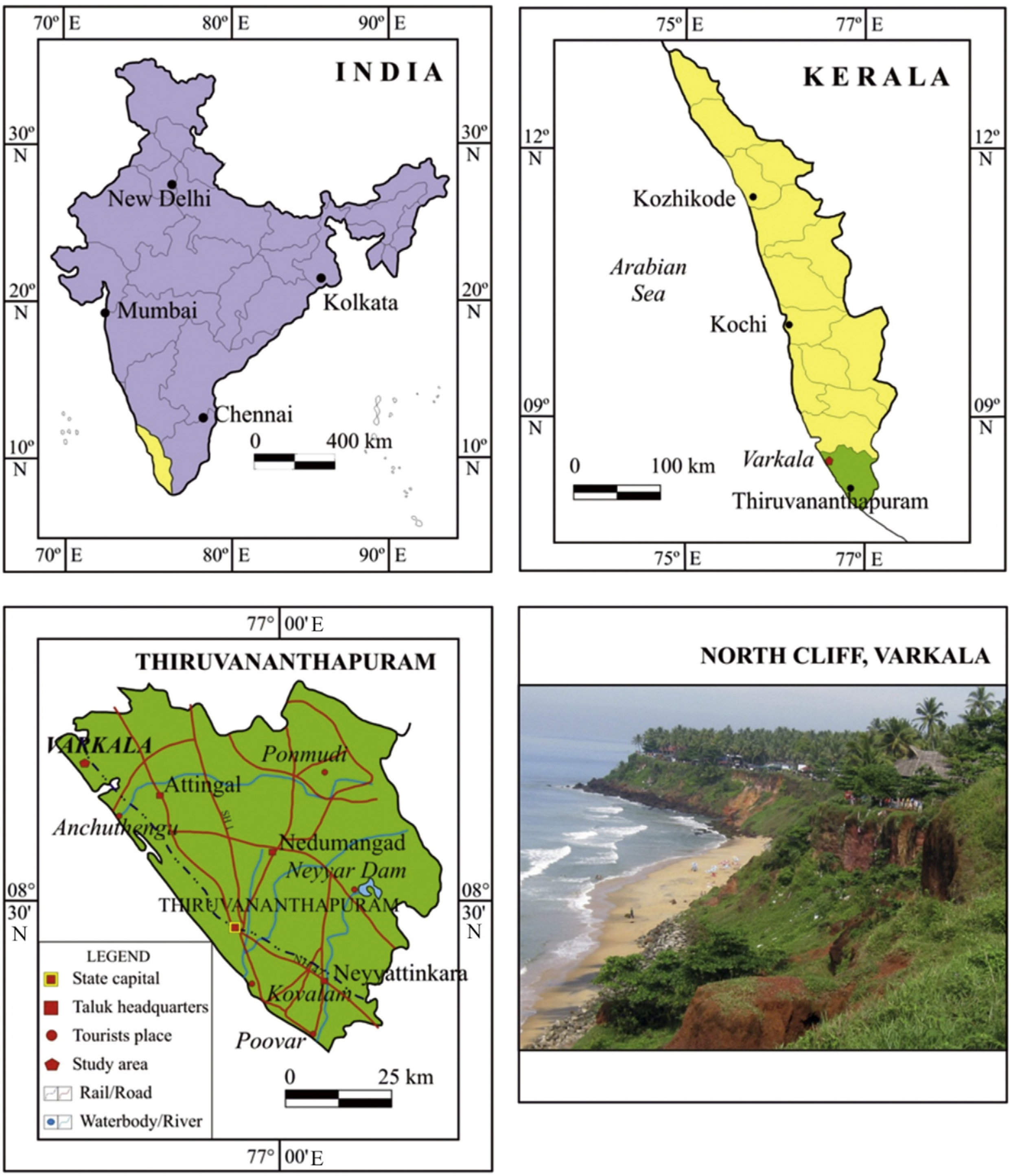

Figure 1. Location map of the study area with respect to India, Kerala State and Thiruvananthapuram District. The photograph is a view of the North cliff.