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Research Article

GEOSPATIAL TECHNOLOGY BASED DETAILED MAPPING OF COASTAL GEOMORPHOLOGICAL FEATURES AND CERTAIN SIGNIFICANT OBSERVATIONS - PART OF PURI DISTRICT, ODISHA, INDIA

Kathiravan R[1], Palanivel K*[2], Ramesh Kumar K[3] and Sudhakar Ch[4]

[1,2]Centre for Remote Sensing, Bharathidasan University, Khajamalai Campus, Tiruchirappalli – 620 023, Tamil Nadu, India
[3,4]Atomic Minerals Directorate for Explorations and Research, Department of Atomic Energy Government of India, Hyderabad

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ABSTRACT

The Geospatial Technology, which includes a collection of computerized geospatial tools, such as Remote Sensing, Digital Image Processing, Digital Photogrammetry, Global Positioning System and Geographic Information System used to generate, manipulate and handle voluminous spatial and aspatial data easily and provide pragmatic information through spatial analyses. Apart from these regular tools of Geospatial Technology, the advanced tools like 3D visualization of the terrain in laboratory through high resolution Digital Elevation Model (DEM) developed out of CARTOSAT-1 Stereo data and its derivatives like vertical profiles, generation of stereo-anaglyph images of a particular area and Shaded Relief Maps (SRM), the detailed mapping of subtle coastal geomorphic landforms becomes very easy and cost- as well as time-effective. The present study is aimed to map the Geomorphological features found in the coastal part of Puri District, Odisha in a very large scale, i.e., on 1: 5,000 in GIS, using onscreen interpretation of False Colour Composites (FCC) of IRS LISS IV Satellite and high resolution CARTOSAT stereo data, FCC wrapped CARTOSAT DEM, SRM, Profiles and Digitally processed satellite images. Using these satellite data sets and advanced Geospatial tools, a spectrum of various Fluvial, Marine, Aeolian and intercalated Fluvio-marine geomorphic features such as, Palaeochannel, Flood Plain, Palaeo Beach Ridge and Swale Complex overprinted by Delta, River Island, Relict Beach Ridge, Planated Beach Ridge, Back Water, Swale, Palaeo Lagoon, Palaeo Lagoon overprinted by Delta, Mud Flat, Supra Tidal Flat, Inter Tidal Flat, Sub Tidal Flat, Spit, Sand Dune and Beach have been interpreted, mapped, field verified and finalized for the study area. Through this detailed Geomorphology map, certain important observations such as, evolution pattern of Geomorphic features, repeated erosional and depositional Geological processes that have sculptured the area for the present day resemblance and their significance in terms of active tectonism are made and discussed evidently in the present research paper.

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INTRODUCTION

Puri is one of the coastal alluvial districts of eastern Odisha located in the southwestern portion of Mahanadi river basin with four major distributary rivers such as, Daya, Devi, Kushabhadra and Bhargavi which have southerly, southeasterly and westerly courses with a well-developed irrigation canal system of networks. The climate of the district is subtropical with hot summer and pleasant winter. The summer season extends from March to middle of June followed by the rainy season from June to September.

The coast has unique environments where land, river, sea and atmospheric air interact, interplay continuously and develop certain unique landforms by erosion and deposition due to geological events like floods, cyclones, heavy winds, waves and littoral currents naturally and modified due to human developmental activities artificially. Indeed, the intercalation of these Earth system processes needs to be understood thoroughly for making a detailed Geomorphological map of a region. Moreover, as the study area covers coastal part, there are some limitations as far as accessibility due to the existence of Protected Forests and Wild Life habitats with water covered

Corresponding author:* **Palanivel K
Centre for Remote Sensing, Bharathidasan University, Khajamalai Campus, Tiruchirappalli – 620 023, Tamil Nadu, India

areas like swales, mudflats, salt flats and tidal flats. Further, these landforms are having very subtle differences in their topographic relief and without any critical distinction between the adjacent landforms. These special characteristics of coastal landforms made a feature-merging effect in the field similar to a continuous Lithofacies and thus very difficult for mapping through field surveys.

Coastal zones in India are high productivity in nature because of their ecosystems, natural parks and breeding centers. Thus, these places attract people for their development and recreational activities. Hence there are many cities located along coasts are disturbing the natural and cyclic Geological processes. Further, these coasts are economically important due to the existence of renewable and non-renewable natural resources. Coastal zones are dynamic and prone for interactions between the oceanic, fluvial systems, wind and denudational processes which are leading to erosion, deposition cum accretion and inundation due to monsoon floods, sea level rise, storm surge, shifting of shoreline caused by natural or anthropogenic activities (Pethick and Crooks, 2000).

In the present study, the latest advancements in mapping techniques and the tools in Geospatial technology such as high resolution Digital Elevation Models developed using CARTOSAT Stereo data, FCC wrapped CARTOSAT DEM, Vertical Profiles, Anaglyphs and digitally processed satellite images have been used effectively to prepare a very large scale / cadastral scale (on 1:5,000) Geomorphic map of subtle fluvial, fluvio-marine, marine and aeolian landforms of coastal part of Puri district.

Study Area

Odisha is one of the prosperous states of India owing to its fertile land and rich in mineral resources. The study area lies in the coastal tract of Puri district extends from northeastern part of Chilika Lake up to Puricity (19° 30' to 20° 00' N and 85° 25' to 85° 50' E). The study area has a 34 km long coast. The major towns / cities located in the study area are: Gopinathpur, Brahmagiri, Giral and Puri. The part of famous Chilika Lagoon is covering the southwestern portion of the study area. Asian Highway / National Highway-5 and other road networks are linking the major cities and towns in this area (Fig. 1).

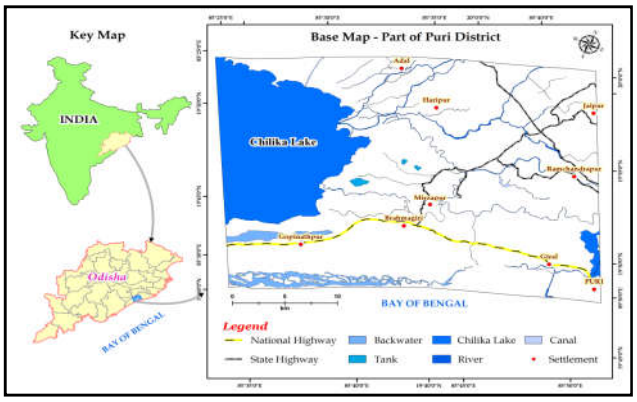

Figure 1 Base Map

Mapping Methods of Geomorphic Units

Mapping of Geomorphology on 1:5,000 scale for the coastal tract of Gopinathpur to Puri District involved the interpretation of the following various types of satellite and topographical datasets:

- IRS P6 LISS IV FCC Satellite data of 5.8m resolution,
- Ortho image generated from the CARTOSAT-1 satellite data of 2.5m resolution,
- Digitally Processed Satellite images(Fig. 2),
- 3D Topographical map derived from SRTM & ASTER DEM and fine resolution CARTOSAT-1 DEM (Fig. 3) and
- 3D Stereo Anaglyphs, Vertical Profiles and Shaded Relief Maps derived from high resolution DEM generated using CARTOSAT-1 stereo data.

After the validation of the mapped landforms by conducting geological field surveys, the detailed Geomorphology map has been finalized after correcting and updating it in GIS environment.

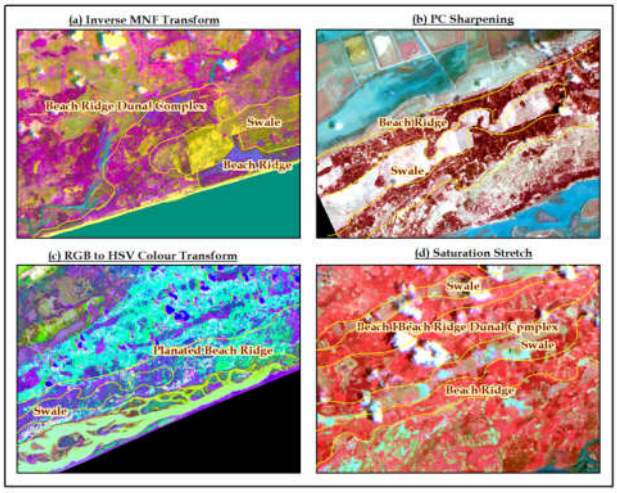

Figure 2 Digitally Processed Satellite Image

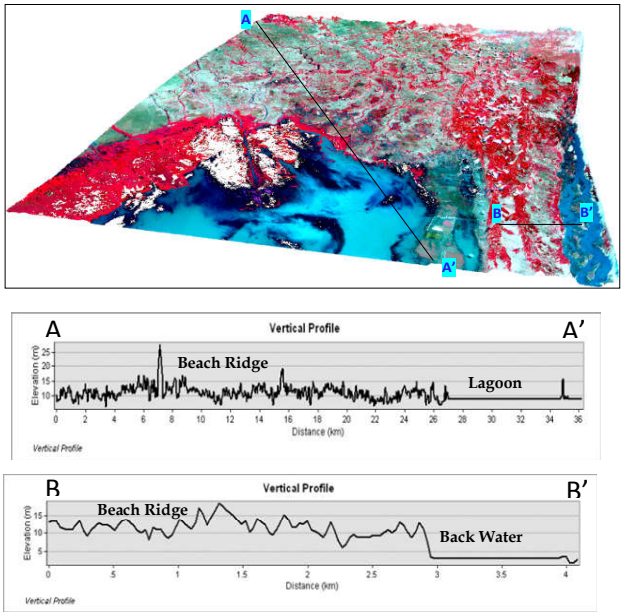

Figure 3 (a) FCC wrapped 3D visualized CARTOSAT DEM; (b) Vertical profiles (i) & (ii) showing coastal geomorphic landforms

Detailed Geomorphology Map

Major part of the study area is a gently sloping plain. The present study area has been majorly developed over the

Quaternary layered sand and clay deposits and contains various erosional and depositional landforms of Fluvial, Fluvio-marine, Marine and Aeolian regimes.

Each and every landform has their own physical and topographical characters covered by specific Land use and Land Cover patterns developed under distinct environment (Bhattacharya *et al* 1979, Mishra *et al* 2008). Hence, these landforms have distinct morphological expressions in the satellite image. With this idea, an attempt has been made to prepare a detailed geomorphologic map on 1:5,000 scale for the present study area using the raw, digitally enhanced, stereo and 3D visualized, FCC wrapped satellite data like IRS LISS IV acquired during the year 2012 and CARTOSAT-1 acquired during the year 2013. Photo recognition elements like tone, texture, shape, size, shadow, site, association and pattern of the features and the Geotechnical elements have been utilized in delineating the different landforms present in the study area. The geomorphic features interpreted and mapped in the study area are:

1. Deltaic Plain
2. Palaeochannel
3. Floodplain
4. Channel Island / River Island
5. Beach
6. Beach Ridge
7. Beach Ridge &Dunal Complex
8. Relict Beach Ridge
9. Planated Beach Ridge
10. Palaeo Beach Ridge & Swale Complex overprinted by Delta
11. Lagoon
12. Palaeo Lagoon
13. Palaeo Lagoon over printed by Delta
14. Mud Flat
15. Supra Tidal Flat
16. Inter Tidal Flat
17. Sub Tidal Flat
18. BackWater
19. Swale and
20. Sand Dune.

Finally, a short term field survey has been conducted to check the existence and areal extents of geomorphic features in the study area (Fig. 5).

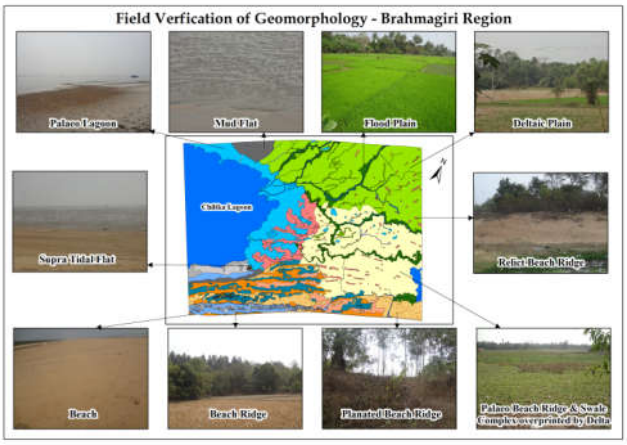

Figure 4 Photographs of Geomorphic landforms taken during Field survey

After the field survey, the map has been updated wherever needed and finalized. The detailed morphologic description and the occurrences of these landforms in the study area are mentioned in the following paragraphs.

Deltaic Plain

Deltaic Plains are the flat to gently sloping plain covering large areal extent consisting of thick sandy sediments with fan shape formed at the old stage of river up to the coastwith an apex in the inland. About 45% of the study area located in the northeastern part is covered with Deltaic Plain and its intercalated landforms. In the central part, the Palaeo Lagoon overprinted by Delta is fringing the Chilika Lake and the Palaeo Beach Ridge and Swale Complex over printed by Delta is mapped along the northeastern inland coastal area covering 15 km width extending from Giral up to Ramchandrapur in the NE.

Palaeochannel

Palaeochannels are ribbon like moisture tract of linear to curvilinear or meandering areas covered by agricultural lands that are arranged in the shape of the palaeo river tract and are developed parallel or semi-parallel to the existing rivers by the side of them. These palaeochannels are demarcated by the visual interpretation methods as well as by image processing techniques. Palaeochannels are seen in the north and center part of the study area.

Floodplain

The nearly leveled plain that borders a river / stream and is subjected to inundation seasonally during monsoon floods unless protected artificially is known as floodplain. It is a constructional landform built by the river / stream sediments deposited. Unparalleled floodplains are developed in the northeastern half of the study area.

Channel Island or River Island

River island can be as small as a rock outcrop above the surface, or as large as an island covering more than a few hundreds of square kilometers. The channel island or river islands are found in the Northern part of the study area along Kushabhadra river channel.

Beach

Loose sand deposits fringing parallel to the shore line as a long linear strip is beach and occupies the coastal transition zone between land and water. All along the coast of the study area, the beach landform has been mapped. The width of the beach is varying from 9m up to 320m. The wide beach is located in the area 2.5 km south of Bedhasundar near Brahmagiri.

Beach Ridge

Beach ridges are the long, linear and stabilized sand bodies occurring inland, fringing the coast by the beach. The existence of beach ridges is attributed to the ancient shore lines (Wolfert 1995). These beach ridges were formed by marine regression processes either due to the emergence of the land or lowering of sea level or the combination of both. These features are occurring as discontinuous linear patches parallel to the coastal tract from Brahmagiri to Puri.

Beach Ridge & Dunal Complex

Long and linear unconsolidated sand deposit as sand dunes over and near the early formed Beach Ridges parallel to the shoreline presently reformed by wind action (Rao1989). These features are located mainly in the southwestern part of the study area.

Relict Beach Ridge

Small, discontinuous, indurated, red coloured / oxidized sandy landforms (Tripathy *et al*, 1996) that are located inland at a comparatively elevated level than the surrounding plains and are parallel or sub-parallel to the elongation of the present day Beaches, mostly covered by coconut or mixed plantation with a few habitations or a small village over them. These Relict Beach Ridges are enveloped by fertile Deltaic Plains that are being used as crop lands. These landforms become islands during cyclonic storms due to heavy floods submerging the surrounding deltaic plains and get disconnected from the other area. In the study area, the Relict Beach Ridges are located sporadically in the NE parts.

Planated Beach Ridge

Wide Beach Ridges consisting of unconsolidated or semi indurated linear mound like sand bodies which are being leveled artificially for developmental activities and stabilized them by afforestation with casuarina, cashew, and other trees. Small habitations are seen over them wherever possible. Most of the coastal part of this study area has been blanketed with such leveled or Planated Beach Ridges as patches and they are located up to 3 km inland from the Beach. The width of these Planated Beach Ridges increases constantly towards Northeast.

Palaeo Beach Ridge & Swale Complex Over Printed By Delta

The formation of superimposed or intercalated new set of fluvial landform, i.e., Delta, over a pre-existing set of marine landform, i.e., Palaeo Beach Ridge and Swale Complex, developed because of marine regression due to tectonic upliftment or lowering of sea level. The existence of this intercalated landform has been confirmed with the help of subsurface samples collected through deep drilled bore holes and field surveys. It was presumed a massive marine transgression during Mio-Pliocene followed by a major regression during Early Upper Pleistocene. This was followed by a secondary or minor marine transgression during Late Upper Pleistocene and a regression during Early Holocene (Mahalik *et al*, 1996). Hence, this intercalated landform was formed during these Early Upper Pleistocene and Early Holocene periods. This landform has also been confirmed during field survey as there are pinnacle like Relict Beach Ridges outcropped as islands at a slightly higher elevation than the surrounding lower level Deltaic Plains. These features are found mainly in the southeastern part of the study area located at a distance of 5 km north of Puri.

Lagoon

A shallow stretch of brackish water body located along the coast, partly or completely separated from sea or lake by an offshore reef, barrier island, sandbank or spit and located near the planated beach ridge is called as Lagoon. Sand, silt or clay-sized sediments transported and deposited by wind, currents, tides and storm wash with relatively low-energy, brackish to saline and shallow waters are the Geological characters of a lagoon. Northeastern part of the famous Chilika lake forms lagoon in this area.

Palaeo Lagoon

The slightly wet or dried out inland side portion of flat muddy landform fringing the present day lagoon is Palaeolagoon (Mohanty *et al*, 1988). In outer part of this area, sometimes, salt tolerant crops have been practiced by the local people. These features are located in the central part of the study area centered by the habitations like Khetandi, Jagadal and Kusubenti.

Palaeo Lagoon overprinted by Delta

In areas of Palaeo lagoon, where the river enters towards the present day lagoon, the loose unconsolidated sand and clay materials brought by the rivers have been deposited in the form of finger like extended landforms from the Delta. In the present study area, this intercalated landform is mapped in the west of Brahmagiri.

Mud Flat

Mud flats are the vast inland plain bordering the coast or a lagoon, leveled by the tidal / lagoon waters, contains mud and may have salt evaporates. The Mud flats are related to the phenomenon of regression of the sea or tectonic uplift of the land. These features are found mainly in the northwestern part of the study area bordering between the Chilika Lagoon and Palaeo lagoon.

Supra Tidal Flat

The supra tidal flat is the low lying strip of land gets submerged by the sea water during high tides and usually covered with salt water vegetation like mangroves characterized by gentle relief and with fine grained deposits. These features are mapped mainly in the southern part of the study area.

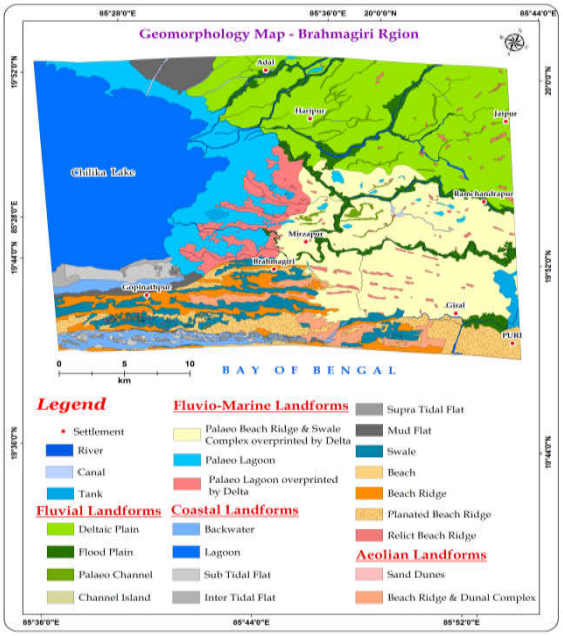

Figure 5 Geomorphology Map

Inter Tidal Flat

The strip of land located where sea water enters gently during every high tide and is exposed at low tides. They occur between salt marsh communities and supra tidal flats landward and subtidal areas seaward. The Intertidal Flats are seen in the southern part of the study area near Satapada.

Sub Tidal Flat

Elevation wise, this strip of plain land is located below the low-tide mark, close to shore and thus always submerged by tidal waters. These zones provide habitat to a large diversity of marine fauna in contrast to the other zones. In the study area, Sub Tidal Flats are located in the southern part.

Backwater

Backwater is located in estuary part of a river in which there is little or no wave or current. It refers either to a branch of a main river, which lies alongside it and then rejoins it, or to a body of water in a main river, backed up by the tide or by an obstruction such as a dam. These features are located mainly in the southern part of the study area.

Swales

Swales are the narrow linear depressions found in between the adjacent beach ridges. They are varying in length between several hundreds of meters to several thousands of meters (Meijerink1982). The width of Swales in the study area is ranging from 30m to 1,050m. These are mapped by their varying shades of grey and black due to the varying thickness of water column during high or low tides and currents in different seasons. In this present study area, the swales are mapped as swarms parallel to the coast from Sanapada to Bandalo.

Sand Dunes

Sand Dunes are formed under the action of wind on the secondary or tertiary sand deposits dumped by the rivers, panned, resized and deposited along the coast as Beach and Beach Ridge (Naik Prabir Kumar and Ravindra Nath Hota 2014). These features are typically found as patches along the areas like Harichandi temple in the south and southeastern part of the study area.

Significance of Geomorphic Landforms

Though, a general concavity is seen along the coast of the study area, a slight convexity is also observed in the south of Gopinathpur. Further, the sequential arrangements of certain geomorphic landforms are observed from north to south in this study area. In the north, the Deltaic Plains are developed at the surface by the Nuna River (Mishra *et al*, 2008). These are followed by Palaeo Beach Ridge and Swale Complex overprinted by Delta studded with Relict Beach Ridges in the middle and in the middle eastern part. Further, these intercalated landforms are followed by another Fluvio-marine intercalated feature namely Palaeo Lagoon overprinted by Delta in the slightly south from the middle part. Then, they are followed by Palaeo Lagoon and finally the present day Lagoon is located in the south of the study area. This progressive alignment of geomorphic features suggests that the area has a gently sloping topography from northeast to southwest. Further, the development of intercalated landforms has suggested that the area may be undergoing ongoing tectonic subsidence towards south. This is further evidenced by the alignment of Palaeochannels in the east of every distributary rivers of Mahanadi and interpreted that these distributary rivers are migrating from east to west.

The mouth of this Chilika lagoon is located in the southern most coastal part which is not seen in this present study area. The Beach Ridge & Dunal Complex / Planated Beach Ridges are tapering towards southwest. On the contrary, majority of the interlocked swales maintaining their overall width have also suggested that the aforesaid ongoing tectonic submergence activities might be crippling the study area. A small local convexity of the beach developed at the south end part to a length ranging from 5 to 10 km, may be due to the littoral currents and the strong northeasterly winds. The profiles prepared using LISS IV FCC wrapped CARTOSAT-1A DEM shows that the terrain seems to have southwesterly slope. The Beach Ridge and Swale Complex overprinted by Delta and Relict Beach Ridges that are representing the repeated erosional and depositional activities of the southwesterly migrating distributaries such as Kushabadra, Daya, and Bhargavi in the recent Geological past due to the tectonic activities. Thus, the overall Geomorphic landform setup gives raise to scintillating information about the ongoing tectonic activities that are prevailing in the study area.

DISCUSSION

The fluvial landforms are highly fertile and forming good groundwater aquifers below and thus they have been utilized as irrigable lands throughout the study area. In the areas where intercalated fluvial and coastal landform exists, wherever salinity increases, then the aquaculture forms are developed and salt tolerant crops are found. The low lying deltaic plains are frequently inundated by cyclonic floods due to which the crop lands are affected. On the contrary, the groundwater aquifers are maintaining their hydrostatic pressure of because good natural recharge through these deltaic plains and safeguarding the potable groundwater aquifers from saltwater intrusion in this area. Further study on groundwater quality, subsurface lithology, lineaments and faults, seismicity and buried structures will reveal the ongoing tectonic activities and importance of these landforms.

CONCLUSION

The present study depicts that the remote sensing satellite imageries supported with the advanced Geospatial tools like Digital Image Processing of raw satellite data to enhance the terrain and feature visibility, 3D visualization and profiling in GIS are highly potential favouring a very detailed interpretation and mapping of four types of geomorphological landforms developed in the study area such as fluvial, marine (erosional and depositional) fluvio-marine and aeolian processes. Further, from this detailed Geomorphology map, evidences have been delineated indicating the ongoing tectonic activity in the present study area. The detailed Geomorphology map and the derivative information for the present study area may serve as basis for various further detailed researches, urban planning, tourism development, and coastal zone management decisions for the coastal part of Puri district, Odisha.

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