

Monitoring Changes in Seafloor Morphology Using Multi-date Bathymetry data:

A Case Study of the Gulf of Mannar, Southeast Coast of India

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ABSTRACT

Bathymetry map of Gulf of Mannar area on 1:50, 000 scale was prepared using 1975 Naval Hydrographic Chart (NHO). This was collected from Marine Aids Center published by Admiralty. The prepared bathymetry map was digitized using ARC-INF GIS and a digital bathymetry map was prepared. In April 1999 bathymetry survey was conducted (within 10 m depth) using ecosounder (ODEM) along Mandapam and Tuticorin coastal area in the study region. The depth values are recorded at a particular location with reference to chart datum (1975). The recent depth contour map of 1999 has been compared with bathymetry map of 1975, it reflect that the seafloor level decreased along the coast and around the islands in Gulf Mannar. The average depth reduction of seafloor along the coast has been estimated as 0.51 m over a period of 25 years (1975-1999). The reduction of sea floor depth indicates that emerging of seafloor by tectonic activity.

1. INTRODUCTION

Any changes in sea floor may be the result of sea-level variation or to a change in the elevation of land surface. Changes in absolute water-surface levels are worldwide due to the interconnectivity of the oceans and are termed eustatic changes. Changes in the absolute level of the land are localized. They may be due to tectonic adjustments or due to adjustments caused by their distribution of weight on the land surface. As and when sedimentation or ice build-up occurs, such changes are known as isostatic. A rise in the sea level or down warping of land would involve the opposite movements of sea and land. Synonymous with positive and negative changes are the forms of sea-level transgression and regression, although in many cases these terms also refer to the horizontal movement of the shoreline associated with vertical changes of sea level. Indian shore has experienced submergence and emergence due to global as well as local oscillations of the sea level by multivariate tectonic, fluvial and marine geomorphic processes. The repeated emergence and submergency of coast have been instrumental in shaping the morphological expressions of the continental shelves in general and shoreline in particular (Jayaprakash et al. 2002). Thanikachalam and Ramachandran, 2002 proved that the coast is going on emerging by tectonic movement. There is a remarkable difference in the extent of continental shelf of the east coast of India when compared to west coast of India. The shelf on the west coast is broad with thin layer of sediment, while the eastern shelf is narrow with thick layer of sediment (Agarwal 1990). The main objective of the paper is to generate the bathymetry maps using multi date bathymetry data and identify the morphology of sea floor and its changes.

2. STUDY AREA

The study area (Figure 1), Gulf of Mannar, extending from Tuticorin to Rameswaram island in the SW-NE direction, lies between 78° 5' & 79°30' E longitudes and 8°47' & 9°15' N latitudes, to a length of about 140 km. There are 21 islands, situated at an average distance of about 8 km from the coast and running almost parallel to the coastline. This area is endowed with a combination of ecosystems including mangroves, seagrass, seaweeds and corals reefs. Different types of reef formations have also been observed in Gulf of Mannar viz. fringing reef, patch reef and coral pinnacles. The coast of Gulf of Mannar is mostly underling by Quaternary to Recent formation. The west of this coastal area is bound by heavy crystalline metamorphic rocks of Pre Cambrian and having breath of 10-100 km (Ramasamy 1997). Being a gradient coast it has developed well fabricated network of deltas, backwater, creeks, protruding deltas, estuaries, back swamps and coral reef etc.

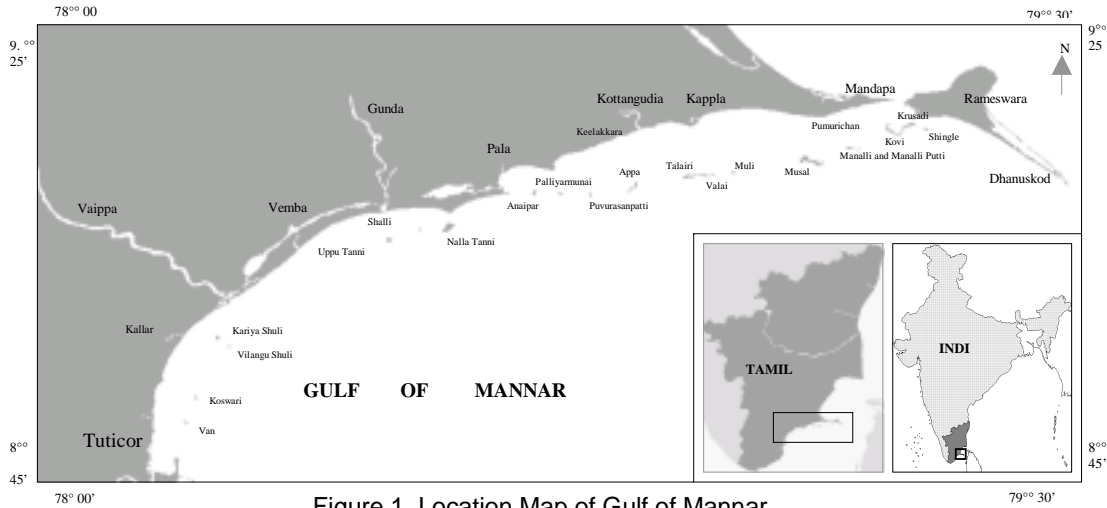


Figure 1. Location Map of Gulf of Mannar

3. MATERIALS AND METHODS

Naval Hydrographic Chart (1975), Survey of India Topographic Sheet (SOI), Ecosounder (ODEM) and Global Position System (GPS) were used in this study. Bathymetry map of study area on 1: 50,000 scale was prepared manually using 1975 Naval Hydrographic Chart. The prepared bathymetry map was digitized into ARC-INFO and a digital elevation model was prepared using ERDAS imagine software. During April 1999 bathymetry survey was conducted using eco-sounder (ODEM) and Global Position System (which is used to locate the sample points) along Mandapam and Tuticorin coastal area (within 10 m depth) in the Gulf of Mannar. The depth values are recorded at a particular location with reference to chart datum (1975). The measured depths were tide corrected with respect to time and then converted with respect to chart datum. Measured tide table from the Tuticorin port was used for final data conversion to chart datum.

4. RESULT AND DISCUSSION

4.1 Continental Shelf Morphology

In Gulf of Mannar, the slope and width of the continental shelf is approximately the same as the average for the eastern coast of India (Ahmad 1972). The total width of the shelf is around 30 km having a slope of about 21'. The slope near the shore is about 4'. Shelf morphology (Figure 2 and 3) of the study area has been described in detail by dividing the study area into four segments viz (1) Tuticorin to Vaippar River, (2) Vaippar River to Gundar River, (3) Gundar River to Palar River and (4) Palar River to Dhanushkodi shelf regions.

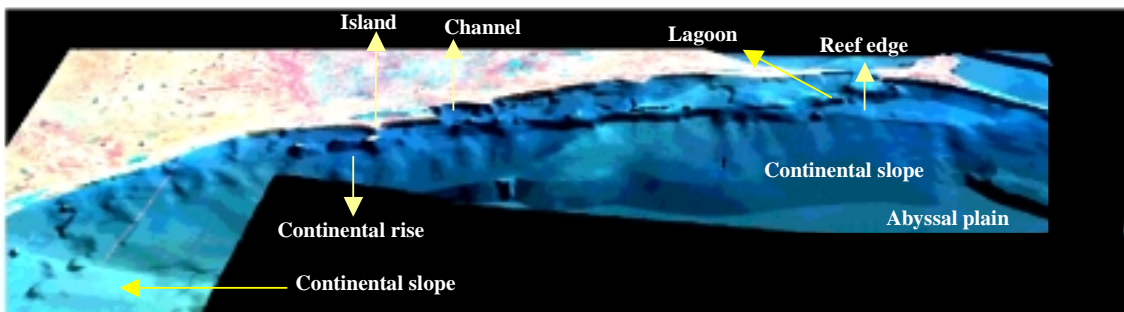


Figure 2. Three dimensional model for Gulf of Mannar sea floor

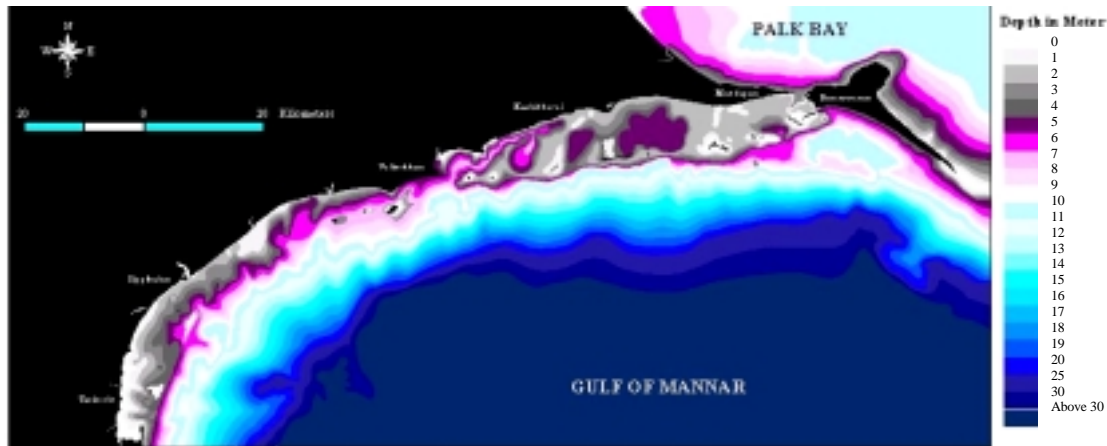


Figure 3. Bathymetry Map of Gulf of Mannar (1975)

In the shore between Tuticorin to Vaippar River, the sea floor is sloping gently down to 5m depth while in Sippikkulam coast where the sea floor is very steep down to 2m depth and it extending up to 0.129 km from the coast. In between 4 and 5m depths, some elevated rises and islands are noticed. At a distance of 4.30 km ($78^{\circ} 12'16''E-8 49'N$) from Tuticorin coast, a 3.9m elevated rise was observed. Just northeast of this rise a 6m elevated island ($78^{\circ} 12'28''E-8 49'35''N$) called Van Island, which is situated 5 km away from Tuticorin coast. Around this island the sea floor is sloping very gently down to 2m depth in southeast, east, northeast and north directions. Where as west, southwest, and northwestern parts of the island, the sea floor slope is very steep. On the northeastern, eastern and southern sides of the island, the sea floor is covered by fringing coral reef, extending down to 2 m depth with an average distance of 1.50 km from the coast of the island. Between the depths of 3m and 4m, there is another island called Koswari Island, which is located at $78^{\circ}13'22''E-8^{\circ}52'2''N$, with a distance of 6.09 km from Taruvaikkulam coast. In between 5 and 10m depths, the sea floor slopes moderately. From the depth of 10m to 20 m, the sea floor slopes gently, having a distance of 16.65km between them. At a depth of 20m, the seafloor falls suddenly with a very steep slope (continental slope) extending till 30m depth. The width of this slope has been calculated as 7.27 km. The total width of continental shelf in Tuticorin region has been calculated as 26.75 km. In the coast from Veppaloadi to Sippikkulam, between 4m and 6m depths, elevated islands namely Kariya Shuli and Vilangu Shuli Islands are situated at a distance of 4.77 km and 6.56 km from Sippikkulam coast respectively. The sea floor is found to be sloping gently towards north, east and south from the shore of Vilangu Shuli Island, whereas west of the the sea floor tends to slope very steeply. An extensive well-developed fringing reef has been identified around Vilangu Shuli and Karia Shuli Islands extending to 3 meters depth.

In the shore between Vaippar and Muttiapuram, the sea floor is at a depth of 3 m., which extends to an average distance of 3.51 km from the shore. In the area near the mouth of Vembar the sea floor topography is plain with a depth of 2 m. Between 2 m and 20 m the sea floor slopes very gently and extends to a distance of 19.75 km. A sudden steep slope is encountered at 20m depth, this area is the starting point of the continental slope and it extends to the depth of 30m. The width of the slope has been calculated as 5.45 km and the width of the continental shelf has been calculated as 19.75 km. In the area from Terkku Narippeyur to Gundar River, the shelf is found at a depth of 3m, extending to 0.36 km south and southeast of Narippeyur coast and 0.88 km south of Gundar River mouth. Between the depths of 7 and 8 km, the sea floor is very broad and the slope is very gentle. An elevated island is found exposed above sea level viz., Uppu Tanni Island situated at 6.72 km from Gundar River mouth. The sea floor is plain up to 1m depth in all directions around the island except in the north and northeastern directions where the slope is very steep.

The shore between Gundar and Palar River, the sea floor is found at a depth of 3m, and this deep extends to 1.19 km from the coast. At the south of Mel Mendal coast the sea floor slopes very steeply to 7 m depth and extends to 1.44 km from the coast. Between the depths of 10 and 20 m the sea floor slopes moderately with a width of 7.52 km. At an average depth of 20 to 30 m, there is a continental slope with 16.56km width. In between 7 and 8 m depths, the sea floor is broad and has a very gentle

slope. In this region particularly at latitude of 9°6'5"N and longitude of 78°32'10"E, an island, namely Shalli Island, having 9 m elevation from sea floor is encountered. On the northern and southern sides of this island, the sea floor slopes very steep, while on the eastern and western sides, the slope is gentle. Towards east from Shalli Island another island namely Nalla Tanni Island is encountered (78°34'29"E-9°6'11"N). Around this island the sea floor slopes very gently, particularly in the northeast, east and southeastern sides of the island, which extends to a depth of 4 m from the shore of the island. Whereas northern and southwestern sides of this island, the seafloor have a very steep slope, extending to a depth of 4 m at a distance of 0.36 m from the coast of the island.

The region between Palar River mouth and Dhanushkodi shelf, the topography has some irregularities. In the area opposite to Palar River mouth, there is a gentle depressed channel, having an approximate length of 4.41 km towards south. The coast between Palar River mouth and Kalachimundal, the sea floor is found at a depth of 1 m and it extends to a distance of 0.28 km from the shore. Between these areas the sea floor gradient is very steep to a depth of 7m. The width of this area is 1.60 km. After reaching 7 m depth the sea floor rises upto 3 m depth, this depressed channel runs to a distance of 21.27 km towards northeast and south, and lies between 78°40'4"E-9°9'15"N and 78°47'37"E-9°13'8"N. The average width of this channel has been measured as 0.75 km. After reaching 3 m depth the sea floor has a sudden fall to 10 m depth. In between the two depressions, a flat-topped continental rise has been observed. The average width of the continental rise is 1.58 km and is located 5.7 km from the shore. On this rise, there are two elevated islands rising 4m from the sea floor and are located between 78°41'28"E-9°9'3"N and 78°43'32"E-9°9'4"N. These islands are called as Anaipar and Pilliyarmunai Islands. Around these islands the sea floor slopes very gently and extensively developed fringing corals are found within 2 m depth. Between 4 and 5m depth, at a lat-long of 78°45'8"E-9°9'12"N, an island namely, Puvarasanpatti Island, having an elevation of 4.50m from the sea floor is encountered. At a depth between 10m and 20 the sea floor slopes gently. The width of this continental shelf is 18.17 m. In the area between Keelakkarai and Pudumadam, the seafloor is almost plain and has a depth of 3 to 4m. This plain extends to a distance of 9.72 km from coast. In this plain some low elevated rise and Islands are observed. Located at a lat-long of 78°49'10"E-9°9'31"N an island namely Appa Island, having an elevation of 5m from sea floor has been noticed. Around this island the sea floor slopes gently to 2m depth. It extends to an average distance of 1.50 km. At 78°51'25"E-9°14'2"N and 78°52'31"E-9°14'32", two continental rise have been observed having an elevation of 1m from the sea floor. In between 4 and 5m depths, there are some low elevated islands (5.50m from sea floor) namely Talairi, Valai and Muli Islands. They are located at an average distance of 8.45 km from Kaplar River mouth. In this region the sea floor gradient is very steep extending from 5m depth to 10m depth and then it slopes gently upto 30 m depth.

In the coast between Pudumadam and Thoniturai, the sea floor is almost plain having a depth of 2 to 3m. This plain extends 6.95 km from the coast. Near Senniappa Dargah and Thoniturai this plain is encountered at 2m depth and it extends to an average distance of 2.17 km from the coast of Senniappa Dargah and 0.50 km from Thoniturai coast. Along this plain some low elevated continental rise (79°5'19"E-9°12'14"N) and chain of islands have been observed. From Senniappa Dargah to 6.65 km towards south, an island namely Musal Island having an elevation of 3.5m from sea floor is encountered. Around this island fringing corals have developed very extensively to a depth of 2 m, they extend 1.45 km towards north, 1.75 km towards northwest, 1.69 km towards west and 1.42 km towards south from the coast of the island. Around this island the sea floor slopes gently upto a depth of 2m. On the seaward side of this island, the sea floor slope is very steep to 10m depth and to an average distance of 2m. About 6.18km away from Marakkayarpatinam, there are two islands namely Manalli and Manalliputti Islands (79°7'26"E-9°12'23"N and 79°8'16"E-9°12'23"N). Around these islands, the sea floor is encountered at 1m depth and the topography of the sea floor around this island has a moderate gradient. On the seaward side of this island, the sea floor slope is very steep, between 3m and 6m depths. The width of this slope is 0.73 km. At a depth of 6 to 7m a plain having a width of 3.52 km is encountered. The sea floor slopes gently between 7 and 30 m depths. In the area between Thoniturai and Pamban canal, the sea floor is encountered at a depth of 1m and extends to an average distance of 1.07 km from the coast of Thoniturai and Velupilliyarkovil. In this area the sea floor slopes very gently upto 2 m depth. In between 2 and 3 m depths, there is a vast plain sea floor extending 3.80 km from north to south and 23.3 km from east to west. Along this plain there are low elevated chain of islands (79°10'28"E-9°14'28"N and 79°14'16"E-9°13'28") namely Pumurichan, Kovi, Kursadi and Shingle islands. Around these islands the sea floor is encountered at a depth of 0.5m and extends to an average distance of 0.49 km towards north, 1 km towards south, 0.19 km towards east and 0.27 km towards west. In the north of these islands the sea floor slope is steep (till a

depth of 1 m) whereas it is very gentle in the south (till a depth of 3m). In between 3 m and 10m the sea floor slope is steep having a width of 1.83 km. From 10 to 30 m the sea floor slopes moderately. In the area between Dhanuskodi and Kundugal the sea floor is at a depth of 6 m and slopes moderately up to 30 m depth. The width of the continental shelf in this area has been measured approximately as 26.25 km.

4.2 Sea Floor Changes

The sea floor depth contours with reference to chart datum (1975) measured at Tuticorin and Mandapam coasts during April 1999 are shown in the Figures 3. The variations of sea floor elevations to chart datum in the study area, measured along 10 transects that are perpendicular to shoreline with an interval of 250m are presented in the Figures 4a to 4d.

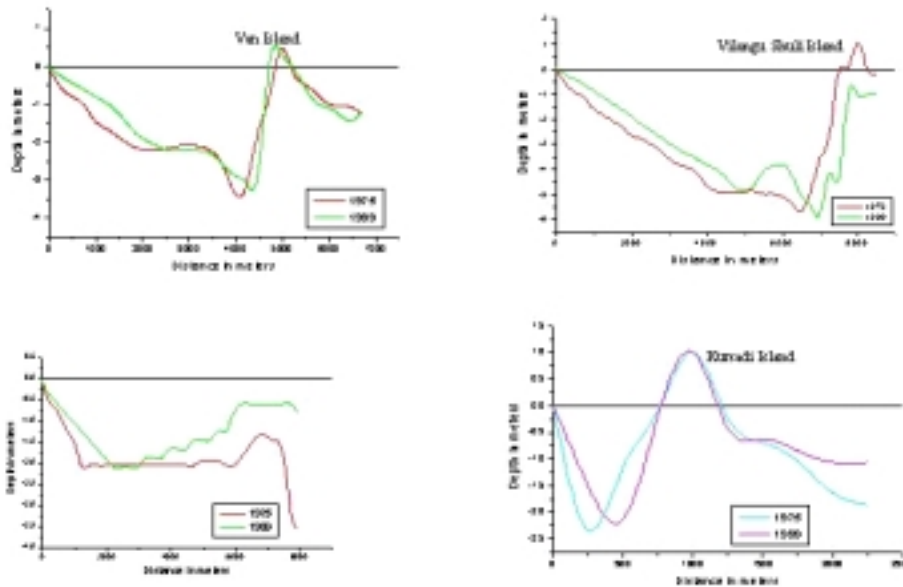


Figure 4. a) Sea floor changes at Tuticorin and Van Island
 b) Sea floor changes at Veppaloadi and Vilangu Shuli Island
 c) Sea floor changes at Marakkayarpattinam Coast
 d) Sea floor changes at Gundugul and Kursadi Island

Recent depth contour map (1999) has been compared with bathymetry map of 1975; it reflects that the sea floor level decreased along the coastal and around the islands in the study area. It may be due to emerging of land due to tectonism. Many authors have reported that the coast of Gulf of Mannar is on an emerging phase due to tectonic movement (Foot, 1888; Ahmad, 1972; Stoodart and Pillai, 1972; Loveson and Rajamanicam, 1988; Ramasamy, 1989). Ramasamy, (1996), has build up a post collision tectonic model for the southern part of Indian and in which he has observed a series of geoenvironmental problems being caused due to such ongoing tectonic movement. In very few places particularly at river mouths and in island areas, the sea floor level has increased, which may be due to erosion caused by anthropogenic activities. The removal of corals in Tuticorin group of island by coral mining the depth has increased to about 1m (Thanikackalam and Ramachandran 2002).

The average depth reduction of seafloor along the coast of the study area has been estimated as 0.51m over a period of 24 years. Assuming that the rate of change of depth of sea floor is uniform over a year, the rate of decrease of depth is estimated as 0.021m/year along the coast and 0.023 m/year around the island.

The seafloor depth contours with reference to chart datum measured at Tuticorin coast during April 1999 along 10 transects perpendicular to the shoreline are shown in the Figures 4a and 4b. The

average reduction in the depth has been calculated as 0.31m over a period of 24 years (1975-1999), it may be due to deposition of sediment and emerging of land (by tectonics). The depth of sea floor has reduced along 8 transects and increased along 7 transects around the Vilangu Shuli and Van Islands. This reduction of depth may be caused by deposition of sediment due to ocean currents, whereas the increasing of sea floor depth may be due to erosion caused by anthropogenic activities (Coral mining). Evidences show that the entire Shuli Island was eroded and lies below the sea level. The average amount of reduction and increase of sea floor depth around the Vilangu Shuli Island were calculated as 0.08 m and 0.35 m over a period of 24 years. Around Van Island the decreasing and increasing trend of sea floor depth have been calculated as 0.88 and 0.62 m over a period of 24 years. The sea floor has rise with reference to chart datum along 8 transects off the coast of Mandapam area may be due to emerging of land and sediment deposition. This part the of study area is very dynamic and during the southeast monsoon period a long shore current transports large amount of sediment from Palk Bay to Gulf of Mannar through Pamban Channel and deposit the sediment. In addition during the low tide period the tidal current move towards south and deposit some amount of sediment in this part. New spit formation near Kundugal is the evidence for deposition of sediment (Thanikachalam and Ramachandran, 2002). The average rising of sea floor along Mandapam coast is found to be 0.68m over a period of 24 years (1975-1999). Around the Mandapam group of islands, the raise of sea floor was noticed at the seaward side of the island. It may be due to sedimentation caused by wave induced current. At the seaward side of Kursadi, Kovi, Pumurichan, Musal, Manalli and Manalli Putti Islands the reef edge was found at an average distance of 1 km away from the shores of the island towards sea. The reef acts as a wave breaker and when the high velocity waves hit against the reef edge, it reduces the velocity of waves and the wave induced current moves towards north, distributing the littoral sediments on these coral reefs. By such repeated action, the area between islands and reef edge gets shallow. The average rising of sea floor at seaward side of Pumurichan, Kovi and Kursadi Islands was calculated as 0.23 km for the past 24 years and the rate of rising of sea floor is 0.009 m/year. Towards the seaward side of Musal, Manalli and Manalli Putti Islands the sea floor depth has decreased by 0.36m over a period of 24 years. The rate of rising of sea floor in this area is estimated as 0.015m/year. The sandbar formation between Manalli and Manalli Putti Islands, occurrence of spits along the coast and rising reefs in Mandapam and Keelakkara groups of islands are the evidences for rising of the sea floor.

5. CONCLUSION

Geographic Information System and ERDAS imagine soft wares are very much useful for bathymetry mapping. Various shelf morphological features like channels, continental raise and islands, and their slopes and extents are identified. The present study suggests that in the study area sea floor has been gradually rising due to tectonic upliftment.

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BIO-DATA



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