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Cyclonic Patterns of India and Its Importance in the Pleotsunami Investigations

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Abstract

Differentiating tsunami deposit from a storms deposit in the stratigraphy is a controversial topic. Similarities in the sedimentary structures and textures are the main reason for this controversy. Therefore, understanding cyclonic patterns and landfall associated with them in a particular geological setting is very useful to avoid controversy. This paper discusses cyclonic patterns and landfall associate with them in the context of pleotsunami investigations in India.

Keywords: Cyclones; Paleotsunami deposit; Subduction zone

Introduction

Mega earthquakes and associated transoceanic tsunamis are rare but it causes devastating effects once occur. Majority of this these events are commonly observed in the subduction zone tectonic settings. The recurrences of such events are ranging from the hundred to millennium scale, whereas seismic historic records are very short and incomplete. Hence scientific community used tsunami deposits to understand tsunami source, and its recurrence interval. But studies carried out in the moderns tsunami and storm deposits suggest much sedimentological similarities than differences [1-7]. Therefore, the cyclonic patterns, landfall associated with them in a particular ocean basin and sedimentary characteristics are very important aspects in paleotsunami research.

Nevertheless, some of the sedimentary characteristics associated with tsunami deposits are noteworthy. Most importantly the bidirectional structures and rip-up clast forms due to the 'shuttle' movement are a characteristic feature of tsunami deposit [8]. This is a typical physical characteristic associate with tsunami. In this process, the speed of water is same at top to bottom, even in very deep sea water without up-and-downelement. Whereas the speed of bottom boundary layer of the tsunami is zero. Hence very strong shearing occur in the seafloor, it results deformation and ripping up of materials in the sea floor and lifted up into the non-sheared layer (water column). Therefore, the weak and fragile sediment blocks and fossil remains will not break as they are lifted up into the non- shear layer. A soft-sediment rip-up clast about 1m in diameter in Holocene tsunami section in the southern Boso Peninsula in east Japan is an example for this [9].

Typically tsunami wave trains arrive one after another to the coasts, typically from 0 to 3 meters in 90 seconds and sustains up to 10 minutes [10]. The time when the tsunami strikes shallow coastal area velocity decreases (and its height increases), but the wavelength is large enough to inundate coastal plains. The shape of the tsunami wave also changes near to the coast and forms a single step. It may or may not break depending on the coastal configuration. Violent bottom erosion will occur when the wave breaks. Therefore, widespread erosional surfaces and scour-and-fill structures are left by a tsunami [10]. Each pulses of a single tsunami can deposit a series of sediment units (layers). However, those are not always preserved because of erosion by later pulses of the same tsunami event. The gigantic energy associated with earthquakes can trigger transoceanic tsunamis, which will travel large distances across the ocean, therefore the tsunami deposits are globally distributed [8].

Commonly, the run-up part of tsunami leaves thin deposit inland. The thickness and grain size of tsunami deposits are decreasing as these sediments are positioned more inland. The current ripple marks, heavy mineral laminations, and presence of benthic-planktonic foraminiferal assemblages and parallel lamination are also observed in the tsunami deposit [3,7,11].

The storm-induced wave generally sustains several seconds (up to 10–20 seconds) in small bays regions and on open coasts. Since the storm waveforms are slow the water level rises mainly due to atmospheric pressure, wind force [8]. The tide-inducedwater-level rise, <1 mm/s, is not sufficient to transport coarse sedimentary particles on the seafloor. Hence the effect of tsunami wave predominates at much greater effects than a wave induced by the violent storm. Frequent erosional activities of storm, the signatures of individual waves are hardly preserving [9].

However, some of the modern storm deposits are challenging the sedimentary characteristics of tsunami deposits and its general applications are as follows. Recent storm deposit from Mississippi and Alabama coastlines, USA shows a sharp erosional boundary between the pre-storm surge and storm surge sedimentary units. It also comprised of calcareous and agglutinated foraminifera [12,13]. Similarly, wash over deposit of Hurricane Ike at Galveston and San Luis Islands, Texas also shows the presence of intertidal and marshy foraminiferal assemblages [14]. Hurricane Ivan 2004 deposit, Florida gulf coast also reported horizontal basal erosional contact and horizontal to slightly landward-dipping stratification and rip-up clast [15]. The winter storm sediments at Atlantic City, New Jersey and reported a chipping of larger shells during the sediment transport [16]. The deposit of Hurricane Isabel in 2003, North Carolina shows a fining upward sequence [3].

In the Indian context, Sumatra-Andaman subduction zone in the east and Makran Subduction zone in the North West triggered mega earthquakes and transoceanic tsunamis (Figure 1). At the same time prevalence of storms in the region are also raising serious concerns. Therefore, the origin of storms and landfall associated with them are needed to consider before paleotsunami investigations in the region. Therefore, cyclonic porn areas and locations of landfall can be avoided before paleotsunami investigation.

2004 Sumatra-Andaman earthquake (Mw 9.3) and associated transoceanic tsunami is the modern example for the mega tsunami recorded along Sumatra—Andaman subduction zone. Historic records on such events are not available. However, very few studies are carried out to understand such paleo events in this tectonic setting and researches are under process. Paleotsunami studies from the northern part of the Sunda subduction zone suggest a recurrence of 300-400 years [16]. In this pioneering study authors depicted the tracks of few cyclones in the region to avoid the controversy between tsunami and storm deposit. In the other hand the northern part of this subduction zone suggests a highly variable recurrence of transoceanic tsunamis [17] However in this study cyclones and its patterns are not discussed. As far as the Makran subduction zone is concern 1945 Balochistan earthquake (Mw 8.1) on 28 November and associated tsunami is an example, however paleotsunami investigations are not carried out to understand the paleoevents. Similarly the cyclonic patterns in this area are not available in any literatures.

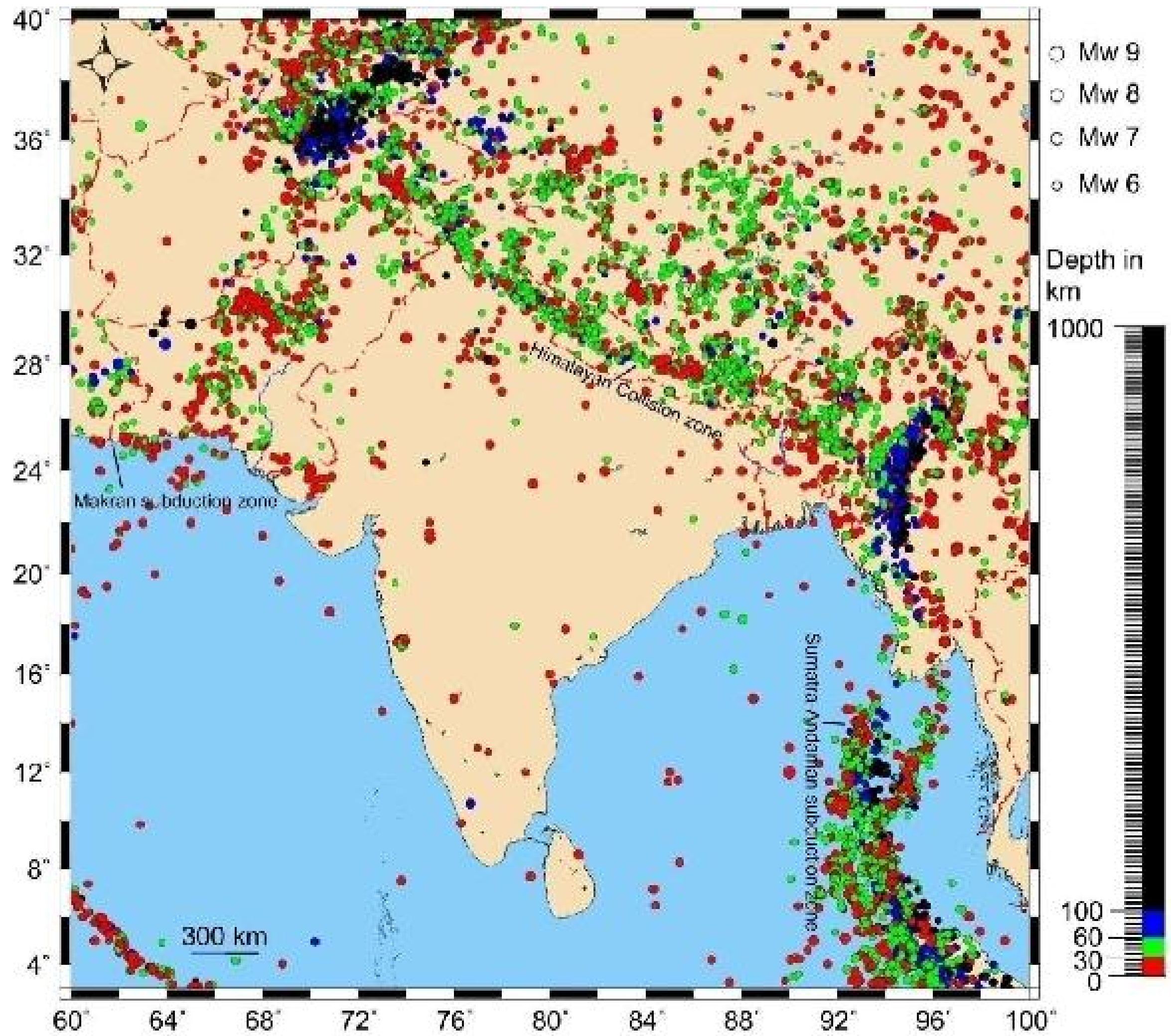

Figure 1: Occurrence of the earthquake in Indian tectonic settings since 1505. Earthquake magnitude and depth data procured from IMD and NEIC (USGS).

Therefore in this study author try to summarized the details of cyclonic patterns and landfall associate with them in India for the future paleotsunami research.

Tectonic setting

In the Indian domain, ongoing collision between the Indian plate and the Eurasian plate resulted in the formation of the Himalayas in the north, Sumatra-Andaman Subduction Zone in the southwest and Makran subduction zone in the northwest respectively (Figure 1). Out of which earthquakes and associates transoceanic tsunamis are reported from subduction zones. The 2004 Sumatra-Andaman earthquake (Mw 9.3), 1945 Balochistan earthquake (Mw 8.1) and associated transoceanic tsunamis are the modern historic examples.

Methodology

In order to study the storms and its patterns in the Indian subcontinent the cyclone best track data of India Meteorological Department (IMD) since 1990 were used. The data comprised of date wise speed and geographical coordinates of cyclones, depressions on Bay of Bengal, Indian Ocean and Arabian Sea basins. These coordinates were plotted on a map by using Generic Mapping Tool (GMT) (Figure 2).

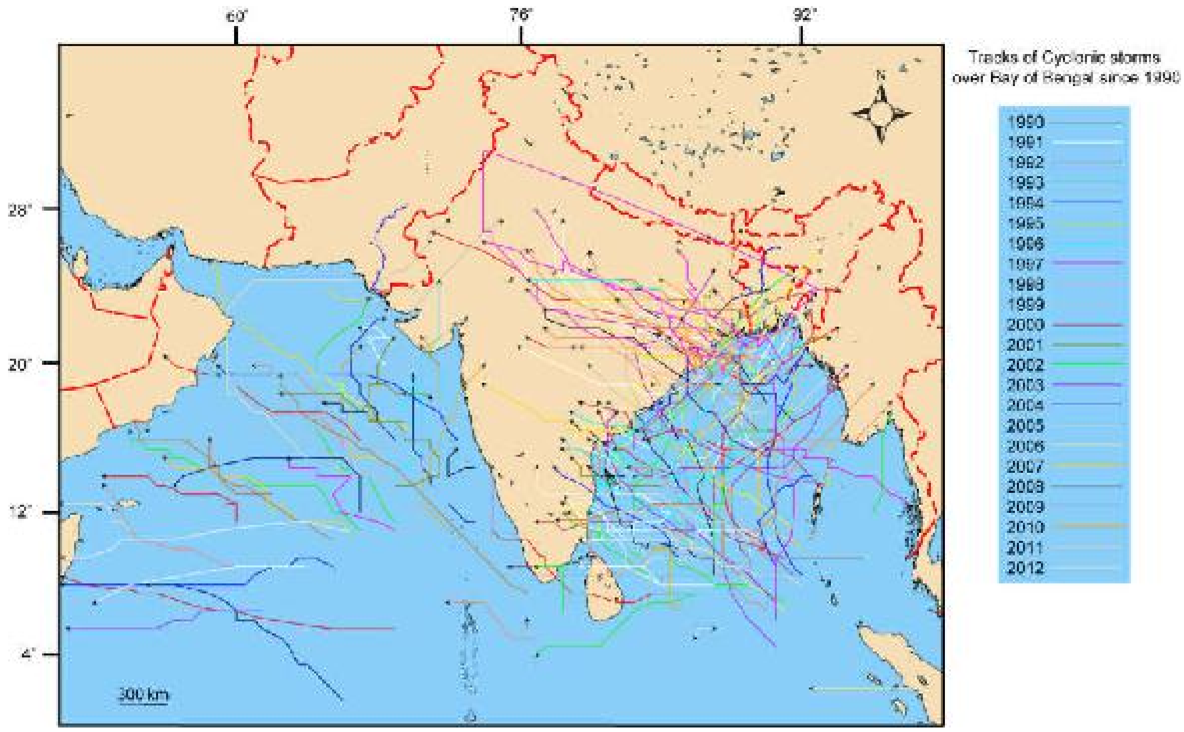

Figure 2: Cyclonic trend map of India, since 1990.

By using this map located the origin and land fall of the cyclones and inferred its general trend.

In the Indian history a systematic studies was done by Henry Piddington, president of the marine court, Calcutta in the mid of 19th century (Sarma, 1997). He collected the cyclonic data from the meteorological logs of vessels and deciphers the trends of cyclones. He published this study in the "Journal of the Asiatic Society of Bengal" in 1839 to 1858 and published a book in 1864 entitled "The sailor's hand book for the laws of storm" (Piddington, 2010). Since the geographical coordinates of cyclonic tracks before 1990 are not available in the IMD catalogue, in this study author used Piddington's handbook of storms to justify the results.

Results and conclusion

Based on the cyclonic trend map and data this study inferred high frequency of cyclones in the months of October, November and December. Majority of these cyclones are observed in the Bay of Bengal basin. Most of them are originated near to the Andaman Islands and intensify above Bay of Bengal while moving towards the western coastlines of India. Therefore, landfalls associated with them are reported from the eastern coastlines of India, Sri Lanka and coastlines of Bangladesh (Figure 2). Piddington's handbook of storms and available literature are also justifying this trend [11,18,19]. Therefore the Andaman and Nicobar Islands are the most suitable location to study the paleotsunami deposit related to Sumatra-Andaman subduction zone. As far as the cyclones in the Arabian Sea basin is concern comparatively less number of cyclones were observed. Most of them are originates above the Arabian Sea and moving westward to the coastlines of Oman and Gujarat, India. Therefore, the coastline of Persian Gulf and western coastlines of India is not severely affected by these storms. Therefore, coastlines of Persian Gulf are suitable to study the tsunami deposits related to Makran subduction zone. Similarly northern Kerala coastlines, Karnataka and Maharashtra coastlines of India are also the potential spots to study tsunami deposits associated with Makran Subduction zone.

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