EXTENDED ABSTRACT

PALEO-TSUNAMI EVIDENCE IN SRI LANKA AND SOUTH INDIA

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Abstract
Coastal sedimentary archives can record both immediate and long-term environmental changes. The objective of this ongoing research is concise the available data to reconstruct paleo-tsunami occurrences along Sri Lanka's and South India's coastlines. Tsunami deposits have been preserved in sheltered areas up to 1000 m from the coast. Besides, tsunami sediments can be deposited in higher elevations (>5 m) compared to storm sediments. Although tsunami sediments ranged from fine-grained mud to coarse-grained gravel, the most significant feature is sand layers in a muddy coastal environment. These sand layers are typically featured with marine fossils (foraminifera, radiolarians, and diatoms), fining upward and landward sequences. Consequently, radiocarbon age and optically stimulated luminescence age accompanying historical data provide geological evidence of at least four paleo-tsunami events during the past 3000 years along the coast of Sri Lanka and South India in 2004 AD, ca. 1000 years BP, ca. 1500 years BP, and ca. 2700 years BP (200 BC) as also recorded in *Mahāvaṃsa* in the period of King *Kelenitissa*.

Keywords: Paleo-tsunami, Sri Lanka, South India, storm deposit, sheltered area

1. Introduction

Unlike other geohazards, tsunamis can cause huge destruction along with the coastal areas. The coast of Sri Lanka and India were hit by the December 26, 2004 Indian Ocean tsunami waves created from the earthquake that occurred in the Sumatra-Andaman subduction zone (Dahanayake and Kulasena, 2008). This caused a noticeable impact on coastal lives, infrastructures, and geomorphology. In this case, well-established past historical records are required for the understanding of such events. Besides, the issue of whether this sort of event/hazard ever reached coastal areas has gone unanswered. Therefore, the study of paleo-tsunami records can be used to predict the recurrence of similar events in the future and to conduct a vulnerability assessment. Long-term geologic records give opportunities to evaluate these tsunami hazards more completely. The coastal sedimentary archives provide opportunities for reconstructions of the paleoenvironment, based on sedimentological observations. However, few studies have been focused on the reconstruction of the Holocene paleoclimate in the Indian Ocean (e.g., Andrade et al., 2014; Klostermann et al., 2014; Ratnayake et al., 2017). Therefore, it is important to develop a database for understanding the past natural hazards, and planning future scenarios. In this literature review, we reported paleo-tsunami data of the Indian Ocean as a part of the ongoing research project.

2. Identification of tsunami deposits from storm surges

Since the tsunami deposits are addressed by various types of sediments (e.g., similar to storm deposits or altered by post-depositional actions), the recognisable proof of paleo-tsunami deposits is troublesome. The inland movements of tsunami and storm surges are constrained by several factors such as geomorphology, surface roughness, and vegetation. However, the overland flow and landward limits of tsunami deposits are comparatively high compared to storm surges. Tsunami waves have more noteworthy energy to transport coastal sediments further inland. According to the literature, storms and tsunami deposits are generally preserved up to 200 m and 1000 m from the coast, respectively (Goff et al., 2004). In addition, tsunami sediments can be deposited in higher elevations (>5 m) compared to storm sediments (< 4 m above mean sea-level). The identification of tsunami deposits and storm surges remains a challenge due to many similarities in sedimentological observations (Morton et al., 2007). Nevertheless, the presence of marine microfossils and macrofauna, horizontally broad and frequently structureless bedded sand sheets with landward thinning, and normal or inverse grading are the most common characteristics of tsunami deposits which conventionally created through suspended load transportation (Dawson and Smith, 2000; Andrade et al., 2014). In comparison, considerable planar laminae and climbing ripples (shows highest bed thickness close to shore and thinning landward abruptly) are the fundamental characteristic of storm deposits which are conventionally created through bedload transport (Morton et al., 2007).

3. Preservation potential of tsunami sediments

Depositional environments are also important for preserving tsunami sediments and for distinguishing noticeable contacts with the pre-existing surface. For instance, the deposition of tsunami sands over the sandy beaches shows poor contrast, while tsunami sands in mud/silt dominant marshy wetlands show a clear contrast. Sandy paleo-tsunami deposits around the world are relatively easy to recognize because they are inter bedded with fine-grained, muddy sediments (lagoons, peat marshes), representing a sharp difference in depositional energy (Monecke et al., 2008). The island of Sri Lanka is of particular interest for reconstructions of paleoclimatic (sea-level changes) and geological (paleo-tsunami) records. Sri Lanka is located at the southern tip of the Indian subcontinent and about 800 km north of the equator, as well as a far-field location comparable to the Sumatra-Andaman subduction zone. Consequently, the preservation potential of mega-tsunami (like the 26th December 2004 tsunami) events is at a high level of consideration. Similarly, the southern coast of India, especially the coast of Tamil Nadu, is framed by narrow beaches except for the river delta. Much of India's southeastern coastal plain is composed of fine to medium sand. Therefore, inland lakes and streams have a greater chance of preserving paleo-tsunami records than storm surges due to their inland penetration.

4. Paleo-tsunami chronology

Tsunami deposits are diverse due to several factors, such as coastal topography, nearshore bathymetry, tsunami intensity, and their sediment source (Jankaew et al., 2008). By considering all these factors and anecdotes, two tsunami events in ca. 1000 years and 1500 years BP (other than the 2004 AD tsunami event) have been well recorded in southeast India and Sri Lanka during the past 2000 years (See Table 1 and reference therein). Another paleo-tsunami deposit was also recorded in ca. 3700 years BP in Sri Lanka and India (See Table 1 and reference therein). The tsunami event (ca. 1000 years BP) can be correlated with recorded paleo-tsunami chronology in Thailand (Jankaew et al., 2008; Brill et al., 2012), Sumatra (Monecke et al., 2008), Andaman (Malik et al., 2015). Similarly, the tsunami event (ca. 1500 years BP) can be correlated with the recorded paleo-tsunami chronology in Andaman (Malik et al., 2015), and Maldives (Klostermann et al., 2014). As a result, at least three previous tsunami occurrences have been documented in the Indian Ocean along the coasts of Sri Lanka and South India in the last 2000 years. Furthermore, another paleo-tsunami with an estimated age of 2700 years BP was discovered. The great chronicle evidence of Sri Lanka, named as *Mahāvaṃsa*, states the historical tsunami occurred in the period of King *Kelenitissa* in 200 BC (Geiger, 1934; Jackson et al., 2014). This tsunami event (ca. 2700 years BP) can correspond to recorded paleo-tsunami chronology in Thailand (Rhodes et al., 2011), South Andaman (Johnson et al., 2016), Maldives (Klostermann et al., 2014), and Sri Lanka (Jackson et al., 2014).

Table 1. Selected tsunami chronology during the past 3000 years along the coastline of Sri Lanka and southern coastline of India.

Location	Age or depth of tsunami sediments	Sediment characteristics	References
Kaveripattinam Tamil Nadu, India	Around 1000 years BP	Sediments consist of hummocky cross-stratification, convolute lamination with heavy minerals, and rip-up clasts. In addition, an erosional contact with the underlying mud bed, and a landward thinning geometry can be identified.	Rajendran et al. (2011)
Mamallapuram, India	1000 years ago	Fining upward, contains clasts from the underlying layer, laminations	Rajendran et al. (2006)
	1500 years ago		
Alleppey, Southern coast of Kerala, India	1343 C.E.	Historical evidence	Rajendran (2019)
Peraliya, Southern coast of Sri Lanka	30 cm below the present ground surface	Brownish silty fine sand	Dahanayake and Kulasena (2008)
	75 cm below		
Dickwella, Hambantota, Southern coast of Sri Lanka	3500 - 7500 years BP	Upward fining feature	Goto et al. (2009)
Guhagarh, West coast of India.		Sporadic boulders, wedge-shaped heavy minerals contain sand layers. Deposit is capped by pedogenic surface.	Sangode and Meshram (2013)
Southwestern coast of India	1000 years BP 3700 years BP		Nair et al. (2010)
East coast of Tamil Nadu, India	Three shreds of evidence of tsunami event including the recent tsunami that occurred on 26th of December 2004		Muthukrishnan and Sivasamandy (2012)
Southern Coast of Sri Lanka	2700 cal. years BP	Fining up sequences	Jackson et al. (2014)
	4200 cal. years BP		
	4500 cal years BP		
	5000 cal years BP		
	6200 cal years BP		
	6400 cal. years BP		
	6600 cal. years BP		

5. Conclusion

The coastline of Sri Lanka and the southern coast of India contain favourable environments to record paleo-tsunami deposits. Sedimentological records would provide supporting evidence of mega-tsunamis in the Indian Ocean that affected the Indian and Sri Lankan coastlines. At least four previous tsunami occurrences have been documented on Sri Lanka's and India's southern coasts in the last 3000 years. The historical evidence is admixed with the tsunami chronology with the provided ages of 2004 AD, 1000 years BP, and 1500 years BP, in addition to the historical well-known tsunami event that occurred in the period of King *Kelenitissa* in 200 BC (ca. 2700 years BP), according to the great chronicle evidence of Sri Lanka, named as *Mahāvaṃsa*.

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