Marine Geology 372 (2016) 66–78

Contents lists available at ScienceDirect

Marine Geology

journal homepage: www.elsevier.com/locate/margo

Geologic records of Holocene typhoon strikes on the Gulf of Thailand coast

Harry Williams [a,*], Montri Choowong [b], Sumet Phantuwongraj [b], Peerasit Surakietchai [b], Thanakrit Thongkhao [b], Stapana Kongsen [b], Eric Simon [a]

[a] University of North Texas, United States
[b] Chulalongkorn University, Thailand

ARTICLE INFO

Article history:
Received 25 August 2015
Received in revised form 14 December 2015
Accepted 23 December 2015
Available online 24 December 2015

Keywords:
Tropical cyclone
Paleotempestology
Washover
Storm surge
Gulf of Thailand

ABSTRACT

Washover sedimentation resulting from modern typhoon strikes on the Gulf of Thailand coast forms anomalous sand layers in low-energy coastal environments including marshes, ponds and swales. The primary diagnostic for recognizing prehistoric typhoon-deposited sand layers in the geologic record are sharp upper and lower contacts between coarser-grained transported sand layers and finer-grained in-situ sediments. In this first paleotempestology study in Thailand, cores from two low-energy settings on the Gulf of Thailand coast – a coastal marsh near Cha-am and beach ridge plain swales near Kui Buri – reveal geologic evidence of up to 19 typhoon strikes within the last 8000 years. The sand layers have sharp upper and lower contacts with enclosing finer sediments. Some sand layers also contain other evidence of a sudden powerful landward-directed surge of ocean water, including gravel-sized clasts, offshore foraminifera, abundant shell fragments, plant debris and mud rip-up clasts. Sand layers record eleven typhoon strikes at Cha-am, ranging in age from AD 1952 to 7575 cal. yr. BP, and eight typhoon strikes at Kui Buri, ranging in age from 4075 to 7740 cal. yr. BP. Bayesian age–depth models, derived from eight AMS radiocarbon dates, suggest that the frequency of typhoon strikes was 2–5 times greater from 3900 to 7800 cal. yr. BP compared to 0–3900 cal. yr. BP. Possible explanations for this variability in the typhoon record are that typhoons were more frequent and/or more intense in Southeast Asia in the mid-Holocene because of climatic changes associated with the Mid-Holocene Warm Period or that the record reflects site sensitivity changes resulting from a mid-Holocene sea-level highstand. The preliminary finding of a possible link between warmer conditions and a greater frequency of intense typhoon strikes could have important societal implications, given possible consequences of ongoing global warming.

1. Introduction

The devastating impact of 2013's Typhoon Haiyan in the Philippines highlighted the need for improved understanding of tropical cyclone risk and impacts for vulnerable coastlines throughout Southeast Asia. A major factor in making Haiyan the Philippines' deadliest typhoon, with 6300 fatalities, was its unusually large storm surge, estimated at 5–7 m near landfall in the Gulf of Leyte (NDRRMC, 2014; Paciente, 2014). There are reports that many local residents may have ignored government warnings and calls for evacuation because they were not aware of the potential danger of a large storm surge, having never experienced a comparable event in their own lifetimes (Mullen, 2013; Paciente, 2014).

Many countries in the region lack long-term records of tropical cyclone strikes which could be used to more reliably estimate landfall recurrence intervals and tropical cyclone risk, and to ascertain if tropical cyclone activity displays centennial to millennium-scale variability, possibly related to climate changes (Elsner and Liu, 2003; Fan and Liu, 2008). This kind of information is valuable because it can be used to better inform public policy, guiding formulation, maintenance and execution of appropriate preparedness plans (Nott, 2007). Linking typhoon activity to climate changes improves prediction of future typhoon activity in response to ongoing global warming. In Thailand, reliable meteorological records of typhoon strikes cover only about the last 70 years — too limited a time span to provide insights into centennial to millennial-scale tropical cyclone variability (Joint Typhoon Warning Center, 2014). In response to these shortcomings in historical data, the new science of paleotempestology (study of ancient storms) has emerged as a way to obtain much longer prehistorical records from chemical, biologic and geologic proxies of tropical cyclone strikes (Donnelly and Woodruff, 2007; Emery, 1969; Lane et al., 2011; Liu and Fearn, 1993, 2000a, 2000b; Yu et al., 2009).

Paleotempestology studies have focused primarily on identifying and dating washover sand layers in coastal marshes located immediately landward of sandy barriers (Donnelly, 2005; Donnelly and Webb,

* Corresponding author.
E-mail address: HarryF.Williams@unt.edu (H. Williams).

http://dx.doi.org/10.1016/j.margeo.2015.12.014

2004; Donnelly et al., 2001a, 2001b, 2004; McCloskey and Keller, 2009; Scileppi and Donnelly, 2007; Williams, 2011, 2013). This geologic proxy approach is based on the premise that a tropical cyclone storm surge overtops the barrier and wind-driven waves transport dune, beach, intertidal and sub-tidal sand onto a muddy, organic-rich marsh to form an anomalous sand layer (Williams, 2011). Over time, during which normal marsh aggradation occurs, multiple tropical cyclones are recorded by multiple sand layers separated by muddy, organic-rich marsh sediments (Williams, 2011, 2013). Tropical cyclone storm surge deposits present in the subsurface are typically distinguished by a coarser texture and lower organic content than enclosing marsh sediments, by sharp upper and lower contacts, by marine microfossils and by a wedge-shaped profile that thins and fines landward. Identified storm surge deposits can be readily dated by radiocarbon dating because the buried marsh under the deposit usually contains abundant organic material.

The east coast of Thailand, bordering the Gulf of Thailand, is subject to large damaging typhoon strikes. Most typhoons affecting Thailand originate in the northwestern Pacific Ocean and move in a westerly or northwesterly direction. Many strike the Philippines or China, but some travel west into the South China Sea, making landfall in Vietnam or Thailand. Notable typhoons or tropical storms (powerful cyclonic storms with wind speeds below the threshold for typhoon status) to make landfall on the east coast of Thailand in recent decades include: Tropical Storm Harriet (1962) causing 769 fatalities in southern Thailand; Typhoon Gay (1989), a Category 3 typhoon at landfall, which caused over 800 fatalities in Thailand; and Tropical Storm Linda (1997) causing 164 fatalities in Thailand (Fig. 1).

There has been relatively little research on storm surge sedimentation in Thailand. Phantuwongraj et al. (2008), examining shallow coastal sediments near Talat Chaiya, Tha Chana and Laem Talumpuk, describe sand sheets, in otherwise muddy environments, tentatively attributed to Tropical Storm Harriet, Typhoon Gay and Tropical Storm Linda. The sand sheets, found in non-active tidal channels and swales behind beach ridges, vary from four to sixty cm in thickness, generally fine and thin inland and extend up to 90 m from shore. The key distinguishing criteria are sharp top and basal contacts with enclosing muds. Phantuwongraj et al. (2013) describe washover deposits near Ban Takrop, Laem Talumpuk and Khao Mai Ruak resulting from small-scale, monsoon-driven storm surges occurring along the southern peninsular coast of the Gulf of Thailand in 2007, 2008, 2009, 2010 and 2011. The washover deposits formed washover terraces, perched fans and sheetwash lineations. The deposits vary from fifteen to eighty cm in thickness, extend up to 100 m inland and have sharp basal contacts. Phantuwongraj et al. (2010) found sand sheets, tentatively attributed to prehistoric typhoons or tropical storms, in paleo-lagoon deposits, 1.2 km inland near Phanang Tak in Chumphon Province (Fig. 1). The sand sheets are typically 2–3 cm thick, but range up to 35 cm in thickness and have sharp contacts with enclosing muds.

This paper reports on a study to identify and date geological evidence of prehistoric typhoon strikes preserved in coastal marshes on the Gulf of Thailand coast. Currently, there are no published long-term records of typhoon strikes on the Gulf of Thailand, even though this coastline is subject to intense tropical cyclone strikes, including 1989's Typhoon Gay (Fig. 1). Typhoon Gay originated in the Gulf of Thailand in November 1989 and intensified rapidly, resulting in 11-m-high swells and 275 offshore fatalities from capsized vessels. The storm caused high winds and swells along much of the Gulf of Thailand coast. Winds increased to 185 km/h at landfall, elevating the typhoon to Category 3 status. There was widespread destruction close to landfall in Chumphon Province, where around 450 deaths were directly attributed to the storm. Fatalities totaled more than 800, making Typhoon Gay one of the deadliest tropical cyclones in Thailand's history.

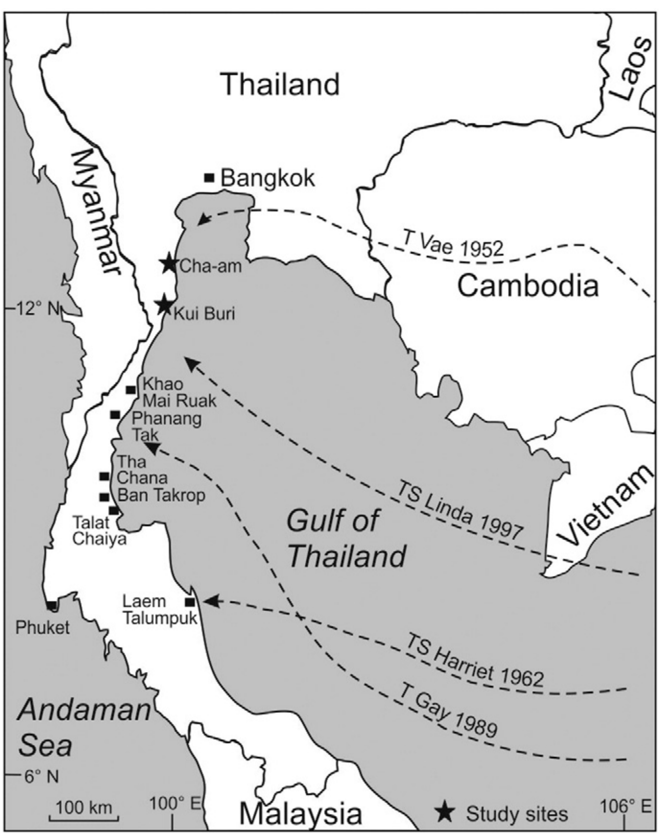

Fig. 1. Location map showing study areas at Cha-am and Kui Buri, sites of documented washover sedimentation and tracks of recent notable tropical cyclones in the Gulf of Thailand (TS: Tropical storm, T: Typhoon).

2. Study area

Reconnaissance coring, using a gouge corer to probe to ~2 m depth, was conducted at a number of potential sites on the Gulf of Thailand coast. Two sites were selected for this study where gouge coring revealed multiple sand layers at depth with sharp contacts with enclosing predominantly fine-grained sediments: a coastal marsh near Cha-am (site designation HW1) and two beach ridge plain swales near Kui Buri (site designation SRY) (Fig. 1). The coastal marsh occupies about 0.5 km^2 of undeveloped land 4 km south of the city of Cha-am. The marsh surface is between 2 and 2.5 m above mean sea level (a.m.s.l.), slopes gently seaward and is drained by a branching tidal creek network which flows into the Gulf of Thailand through a breach in a sandy barrier beach. Trees and shrubs line the creek network and low-lying herbaceous plants cover parts of the marsh surface between creek channels. The rest of the marsh surface is unvegetated sand to muddy sand, is slightly lower than vegetated areas and prone to shallow flooding during rain (Fig. 2 a, b, c). The beach ridge plain swales are part of a large beach ridge plain near Kui Buri (Fig. 1). The first swale is about 150 m inland, 50 m wide and is landward of a small beach ridge with a crest about 1.6 m a.m.s.l. The floor of the swale is about 0.6 m a.m.s.l. The second swale is 550 m inland, 40 m wide and has a floor about 0.8 m a.m.s.l. The beach ridge immediately seaward of the swale rises to about 2.4 m a.m.s.l. (Fig. 2 d, e, f). Both swales are floored by fine-grained sediment, were sparsely vegetated when visited and are largely cut off from tidal influence by numerous road beds, which form barriers to tidal inflow. Sediments in the swales seemed relatively undisturbed by human activities, although they are presumably used for growing crops during part of the year. Both swales are also presumably subject to flooding during periods of rain.

A number of studies have documented evidence of a mid-Holocene highstand on the Thai–Malay Peninsula resulting from the Post-Glacial