Sedimentary evolution of the Sagara coastal area in Japan and its potential to preserve extreme wave deposits

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1. Introduction

Japans Pacific coast towards the Nankai Trough experienced a Holocene sea level highstand. The vertical displacement of the shoreline dominated the sedimentary evolution of coastal areas. These are the same coastal areas, which are now targeted by geoscientists, because recent events have highlighted the importance of coastal sedimentary records in assessing tsunami risk. After the unexpectedly large impact on the coastal regions of northern Japan during the 2011 Tōhoku earthquake and tsunami, the Central Disaster Management Council of the Japanese Cabinet Office specifically included the necessity to pay more attention to evidence from geological records to seismic risk assessment guidelines. This was introduced as a direct response to the disastrous Fukushima-Daiichi reactor melt-downs and the successful prevention of a similar disaster at the Onagawa nuclear power plant, where the Coastal Engineering Committee was aware of historical and geological evidence of the CE 869 Jōgan tsunami and advised to build accordingly. On the coast along the Nankai Trough similar insight before the next great tsunami could prevent death and infrastructural damage.

2. Setting

The Nankai-Suruga subduction zone is the destructive plate boundary between the overriding Eurasian Plate and the subducting Philippine Sea Plate. The relative motion of 40-55 mm yr^{-1} on average causes extreme earthquakes to occur on the Nankai megathrust. The lowlands of Sagara are located on the coast of the easternmost section of the Nankai-Suruga subduction zone, the so-called Tōkai region. Historical and geological evidence exist for megathrust earthquakes from at least six earthquakes in 684 CE (Tenmu or Hakuho), 1096 (Eichō), 1361 (Shōhei), 1498 (Meiō), 1707 (Hōei) and 1854 (Ansei), which ruptured beneath the study area (Ando, 1975; Garrett et al., 2016). Our aim is to reveal the coastal sedimentary evolution of the Sagara coastal and, if possible, identify traces of overwash events in the sedimentary record and possibly expand the tsunami record in the region.

3. Methods

We collected cores of the Sagara floodplain in two field campaigns in 2016 and 2017. All cores were split, sedimentologically described, analyzed with a multi sensor core logger using a gamma ray attenuation density sensor, a magnetic susceptibility point sensor and a spectrophotometer. Most cores were additionally scanned with a medical X-ray computer tomography scanner. The results of these analyses were used to identify 17 different lithofacies, which comprise several facies associations from various environments ranging from continental to paralic. Age control is achieved through radiocarbon dating of calcareous fragments and plant remains.

4. Results

Five up to11 m long cores show that mud is dominant in the early- to mid-Holocene. Four core-transects of 3 m long cores show that fluvial processes dominate at the base and evolved towards mostly mixed and mud-dominated floodplain sub-environments. This fits the general coastal history of the region. The area of the Sagara lowlands was submerged by the Jomon Transgression, which lead to a sea level highstand in the early- to mid-Holcocene. During this time the accommodation space left by the transgression was filled with first estuarine sediments, which then transitioned into a tide-dominated deltaic complex evidenced by firstly muds, and then flaser beds and other fluvial sediments. At present, long-shore coastal currents and riverine input are the two dominant sediment supplies in the greater sedimentary system.

Preliminarily, we identified only two potential extreme wave deposits, however, their occurrence is limited to a small area in the record. Precise age control is not yet available for the two extreme wave deposits. However, the deposits will be most likely from the last 1200 years BP. The low abundance of extreme wave deposits contrasts expectations, as historical documents give evidence for numerous large tsunamis in the area. Human activity, dynamic fluvial processes and shoreline displacement are probably the limiting factors to the preservation potential of sandy sheets deposited by extreme wave events, which appears to be a common problem along the entire Nankai coast. Further investigations may reveal how much each process contributes to the problem.

In the general sedimentary record, XRF-scanning data show low abundance of sulphur (S) in the upper part, which we interpret as low marine influence. The sulphur count across suspected extreme wave beds remains low, too, which may indicate that these layers despite their sedimentary characteristics are not of marine origin or, if they are of marine origin, that they have lost their sulphur chemical signature that would be expected from marine water.

Scatter electron microscopy on the sand of the potential extreme wave deposits shows a complete lack of biogenic skeletal remains, like diatoms, foraminifera or ostracods. The grains are mostly quartz and are angular with fresh surfaces and edges. Again, this could be due to a non-marine origin of the sandy deposits or it could be that the ~700 m between the core sites and the present-day coastline are enough to remobilize enough material from the onshore area that the clear marine signature is lost along the way. There are examples that would contradict this interpretation (e.g. Kelsey et al., 2005), however, others have found the same marine signature depletion after significant onshore transport (Kempf et al., 2015).

Despite being common among extreme wave deposits, none of the mentioned characteristics can be exclusively linked to extreme wave deposits. The sharp lower contact that suggests an erosive surface and the gradually upward increasing bioturbated mixture of sand and mud are indicating rapid transport and deposition with the typical post-depositional processes that lead to altered and bioturbated sandy sheets, as it is described for many extreme wave deposits elsewhere.

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