the acid spikes in the Greenland ice cores, our results have two important implications: (i) they leave the controversy about the age of the Minoan eruption unresolved, and (ii) they suggest that the acid spike cannot be attributed to the Santorini Minoan eruption, and therefore the environmental perturbation(s) caused by this eruption were most probably not as widespread or as significant as previously envisaged (Eastwood et al., 2002).

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Last Glacial Sea-Levels Reconstructed by Buried Fluvial Terraces and Tephrochronology in a Pacific Coast Plain, Japan

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Introduction

Japanese paleoenvironmental sciences that include tephrochronological studies make a significant contribution to studies of sea-level change during the Last Glacial period. The study here highlights the contribution that Late Pleistocene tephrochronological studies make to a synthesis of findings about past sea-level fluctuations in the Lower Sagami Plain.

Millennial-to-centennial scale climatic fluctuations in the Last Glacial period can be detected in ice-cores (Stuiver and Grootes, 2000) and there is evidence that these are paralleled by changes in sea-level. As a result, much is still to be discovered about eustatic global sea-level changes and corresponding changes in ice volume during parts of the last Glacial period (van Andel, 2002). In coastal areas, however, it is often hard to obtain evidence of sea-levels during the Pleistocene period, as suitable material for study may be submerged or buried under younger deposits.

The small, steep coastal Lower Sagami river plain lacks a distinct continental shelf, therefore changes in sea-level can cause a flight of terraces to form. Tephra layers in deposits from the Lower Sagami Plain provide the means to correlate the formation of the terraces. The area is well-suited to studies that incorporate tephrochronology of Fuji and Hakone Volcanoes for the Last Glacial Cycle.

Fig. 1: Sagami River and its terraces. Minahara (MIS 2) and Tanahara (MIS 3) terraces (back) are steeper than the present river bed (front). Terraces are covered with volcanic ash soil.

Study Site and Methodology

The Lower Sagami Plain has well-developed marine and fluvial terraces and the mouth of the Sagami River (drainage area = 1,680 km^2) faces the ocean trough at a point where there is no distinct continental shelf. The Sagami River has been repeatedly sensitive to past sea-level changes. More than fifteen subaerial terraces from the Last Glacial Cycle can be identified in the lower Sagami Plain, including the Koza (K), Sagamihara (S), Nakatsuhara (N), Tanahara (T) and Minahara (M) terraces. Collectively, these form the Sagamino Upland, from the mouth of the river to about 30 km upstream. The average gradient of the present Sagami River is 2.4x10^{-3} in this section, although most of the upper terraces are steeper (Fig. 1).

The Fuji and Hakone Volcanoes are the major sources of tephra in the terraces. The dates of the major marker tephras have been obtained by fission-track, thermoluminescence, electron spin resonance, K-Ar and 14C. Additionally, the widespread AT (circa 25 ka) and Aso-4 (circa 90 ka) tephras also provide age controls. In the plain, deposition is roughly continuous and the average accumulation rate of volcanic ash soil during the last 100 ka is 0.22 m/kyr (22 m/100 ka). A multi-proxy approach that included tephrostratigraphy, pollen stratigraphy, and correlation with regional stratigraphy was used to determine the chronology of the terraces and their deposits, demonstrating that they correspond to MIS 5e (K terrace), 5c-5a (S terraces), 3 (N and T terraces) and 2 (M terraces), respectively.

The buried terraces in the plain were located by using bore-hole logs. They are recognizable as gravel layers with overlying volcanic ash soil several meters thick beneath Holocene deposits. These buried terraces have steeper profiles than those of the present river plain. Some bore-hole logs describe marker tephras in the volcanic ash soil layer, and in a further core sample, the presence of AT tephra was confirmed by microscopic examination. The occurrence of this tephra layer provided a time horizon for further aspects of the study.

After confirmation of the morphological continuity and tephra sequences, buried terraces and deposits were examined. Buried terraces in the plain correspond to MIS 5a (S), 3 (N) and 2 (M), respectively. The more broadly-extended buried N terrace has thick valley-fill deposits. The base of the buried valley corresponds to MIS 4 (Fig. 2).

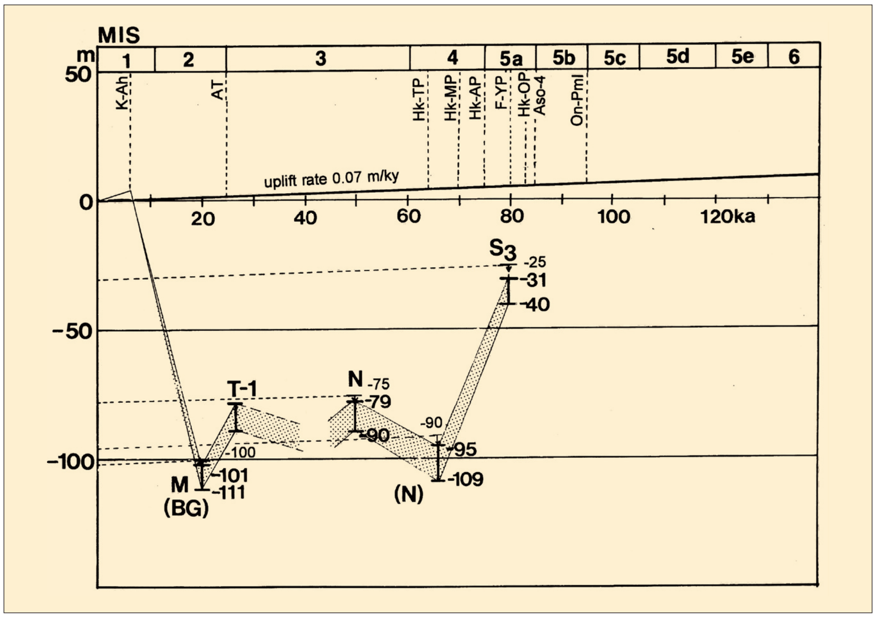

Fig. 3: Sea-level changes during the Last Glacial Cycle reconstructed from buried terraces. Vertical dashed lines show marker tephras. Shadowed area shows estimated sea-levels.

Sea-Level Reconstruction

The edge of the continental shelf occurs about 2 km offshore from the present Sagami river mouth, therefore projected terrace height (depth) at its edge represents the sea-level at that time, after tectonic deformation is subtracted. The tectonic component (average uplift rate) is estimated, from deformation of the marine K (MIS 5e) terrace, to be 0.07 m/ky near the present river mouth. Assuming this deformation rate to be constant throughout the period of terrace formation, sea-levels were estimated for the culmination of several stages during the Last Glacial Cycle: -31 to -40 m in MIS 5a; -95 to -109 m in MIS 4; -78 to -89 m in MIS 3; and -102 to -112 m in MIS 2 (Fig. 3).

Sea-level changes show in the changes in the shape of the plain. During MIS 4 and 2, a deep and narrow valley incised the plain. During MIS 3, this deep valley was filled, and a relatively wide plain of compound fans developed, suggesting that a relatively low sea-level remained throughout MIS 3.

Significance of the Findings

Tephrochronology refined the precision of the chronological framework for the study. With secure time frames at hand, comparing studies of river plain systems during low sea-level stands with studies that employ coral terraces (Chappell, 2002) as well as investigations of fluctuations in ice mass balance will enhance understanding of sea-level fluctuation at times of change in marine systems during the Last Glacial period. In addition, the investigation makes a contribution to studies that investigate early human occupation in Japan.

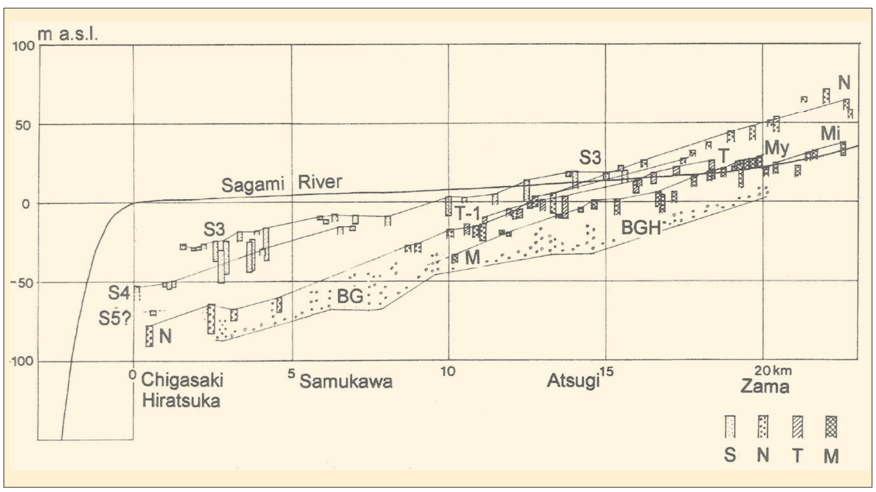

Fig.2: Longitudinal profiles of buried terraces along the Sagami River. S, N, T, M represent the gravel layer of each terrace. BG and BGH are basal gravel of younger deposits.

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