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A new method of terrace analysis to determine precise altitudes of former shoreline

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The study area is situated in Japan Sea side margin of the Shakotan Peninsula, Hokkaido, Japan, where MIS5e Terrace is preserved along the cost. Numbers of tight drilling have done to establish new method for terrace analysis. Buried wave cut terrace and sea cliff (when the MIS5e Terrace was formed) are reconstructed by distribution of the terrace deposits and these bottom of unconformity planes. The precise site and altitude of former shoreline was also obtained. Altitudes of the former shoreline from the 7 sections are almost the same 22 to 27m in height. Previous data of the height of shoreline are obtained from the topographic MIS5e Terrace surface. The altitudes have variation from 30m to 60m. It suggests that the traditional method for the MIS5e terrace analysis had some errors in the study area.

Keywords: MIS5e, marine terrace, terrace deposits, tight drilling, shoreline

Introduction

Outcrops of marine terrace deposits which are effective to analyze former shoreline are limited. So far, recent topography of scarp-foot line of terrace is regarded as former shoreline. But the line was commonly disturbed by younger cover deposits. Precise determination of the former shoreline could be obtained from geological analysis of marine terrace deposits and unconformity plane between marine terrace deposits and basement. The area of western side of the Shakotan Peninsula is selected for research (Fig. 1). Numbers of tight drilling have done to establish new method for terrace analysis (Fig. 2).

7 sections across the MIS5e Terrace were selected (Fig. 3). 4 to 8 tight drilling in individual sections, total numbers of 32 (total length 456m) drillings have done. Buried wave cut terrace and sea cliff are reconstructed by distribution and geometry of the terrace deposits and the precise site of former shoreline was obtained (Fig. 2).

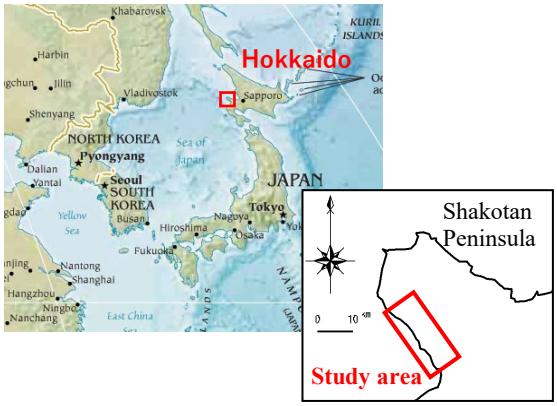

Fig1.Study area

General topography and geology

The Shakotan Peninsula is located in the southwestern part of Hokkaido and extending to the NW-SE direction. The landform of the peninsula is characterized by rocky coast. Basement is mainly composed of Neogene andesitic volcanic and sedimentary rocks which are covered by early to middle Pleistocene sandy successions (Saito, 1968). The Neogene successions are composed of the middle Miocene Hurubira Formation, the late Miocene Kamoenai Formation and the Pliocene Yobetsu Formation (Yamagishi & Ishi., 1979).

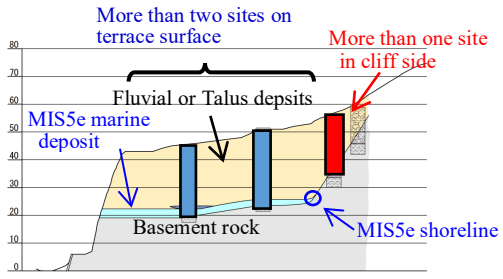

Fig2. Bore hole site setting
(Technological Summary)

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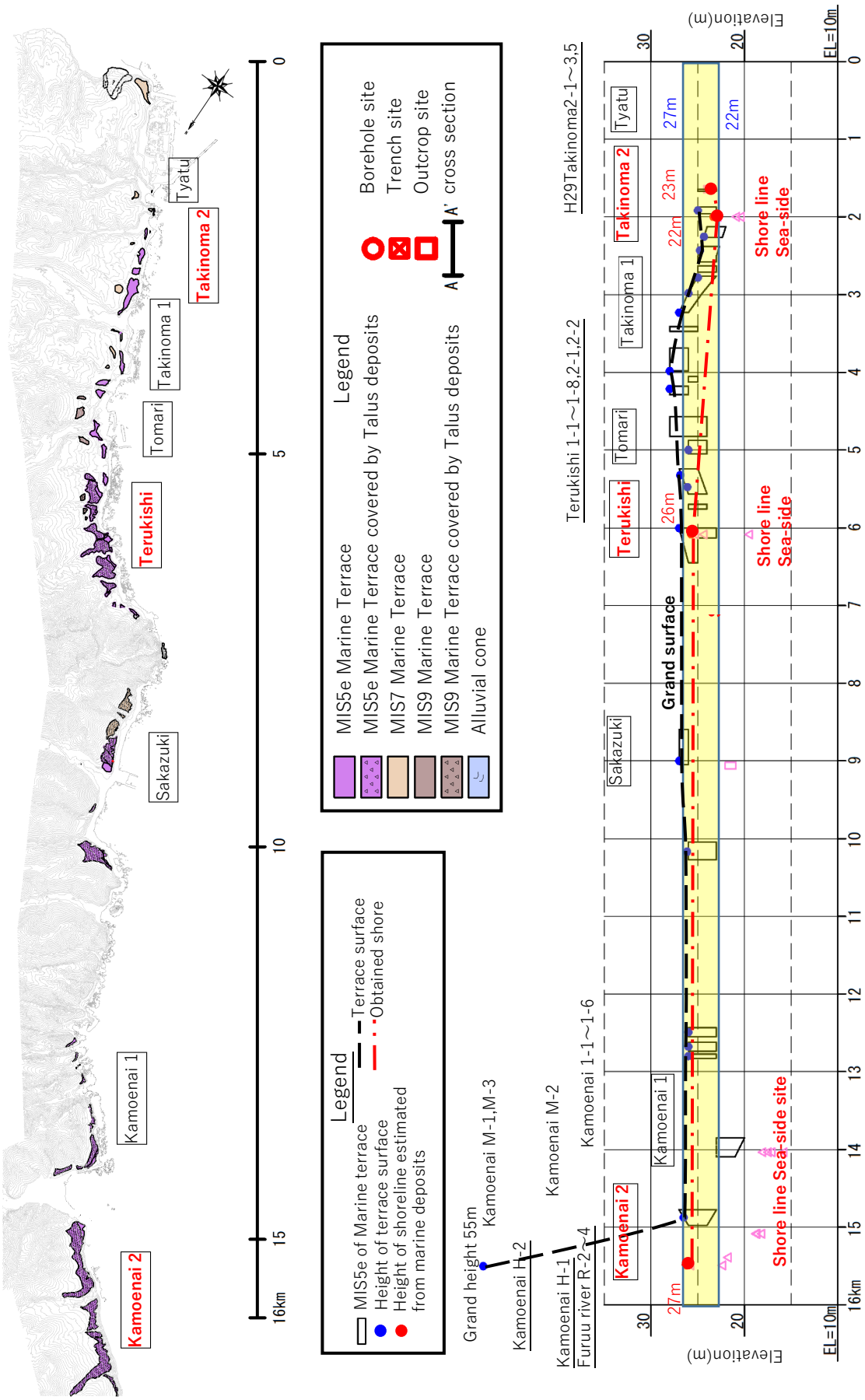

Fig3. Distribution of MIS5e marine terrace

The Hurubira and Kamoenai Formations are mainly composed of andesitic volcanic rocks and associated with mudstones. The Yobetsu Formation is mainly composed of mudstones and andesitic volcanic sandstones. Layers of andesitic tuff breccia are intercalated. The Pleistocene successions comprise the Noduka Formation (Yamagishi & Ishi., 1979) and the Iwanai Formation (Hirokawa & Maruyama, 1955). The Noduka Formation is mainly composed of sands and associated with andesitic pyroclastic rocks. The Iwanai Formation is mainly composed of sands and gravels.

The marine terraces are distributed along the coast. The MIS5e Marine Terrace (formed in Marine Isotope Stage 5e : 124k to 119k years ago(Koike & Machida, 2001)) develops relatively well and the height of the topographic surface is 30 to 60m. Generally the height of the surface is lower in coast side and higher in mountain side. Older Marine Terraces of MIS 7 (50 to 65m in height) and MIS 9 (65 to 80m in height) remain and are distributed in limited area (Fig. 3).

The MIS5e Terrace is composed of basement rocks, marine terrace deposits and talus deposits from lower to upper (Fig. 2 and 4). The marine terrace deposits mainly comprise well sorted coarse-grained sand and granule (Fig. 5). The marine deposits have 1 to 4m in thickness. Well sorted clasts and rounded granules and pebbles suggests that the sediments were deposited in beach environments. The talus deposits are composed of units of palaeosol and breccia. The terrace marine deposits are covered by the palaeosol unit. In the unit, Toya tephra (erupted about 115 ka (Machida & Arai, 2011)) is intercalated. The MIS5e terrace is identified by the tephrochronology (using analysis of chemical composition and index of volcanic glass). The talus deposits (5 to 30m in thickness) are mainly composed of poorly sorted breccia which were formed by periglacial process.

Method to obtain paleo-shoreline when the MIS5e Terrace was formed

Tight drilling has done on the MIS5e Terrace. The drilling sites were on a line from seaside to mountainside. Precise site of paleo-shoreline is reconstructed from the geological cross section along beach profile (Fig. 2, 7, 9, 11). More than 2 drilling were done in the wave cut terrace side. More than 1 drilling was done in the ~~sea~~ cliff side. Upper limit of marine terrace deposits and surface of paleo sea cliff are obtained from geological analysis. Paleo-shoreline is estimated at the point A in Fig. 2. Three sections of Takinoma 2, Terukishi and Kamoenai 2 areas are selected to describe in this paper.

Geology of MIS5e Terrace and reconstruction of paleo-shoreline

Takinoma 2 area

The MIS5e marine deposits crop out in the terrace cliff and road side (Fig. 4). The section line runs the outcrops to landward (Fig. 6a, b). The marine terrace deposits (1 to 4m in thickness) overlay Miocene andesitic tuff breccia (Kamoenai Formation) with unconformity contact (Fig. 4). Talus deposits overlay the marine terrace deposits and have 2 to 5m in thickness. The marine terrace deposits are observed from “Takinoma 2 outcrop 1 & 2”, “Takinoma-1 drill core” and “Takinoma 2-3 drill core” (Fig. 7), and composed of rounded pebble to coarse-grained sand. Well sorted nature of sediments suggest that the deposits might be effected by continuous wave action. A beach environment on wave cut terrace was inferred. Palaeosol layer with Toya tephra (115Ka) overlay the marine deposits (Fig. 7). Surface of paleo sea cliff which corresponds the unconformity plane between talus deposits and basement rocks is inferred from “Takinoma 2-5 drill core” and “Takinoma 2-4 drill core”. The shoreline of maximum MIS5e transgression might be estimated as the highest level of the marine deposits. Altitude of reconstructed shoreline of the MIS5e transgression at this area is about 22m in height.

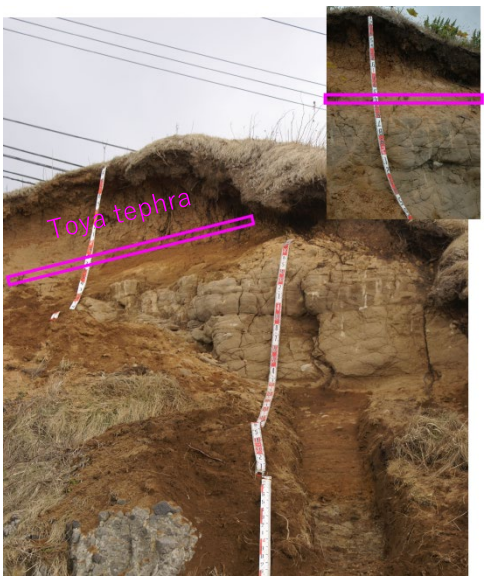

Fig. 4 Takinoma 2 outcrop 1

Fig. 5 well sorted nature of the terrace deposits in thin section (4mm in width)

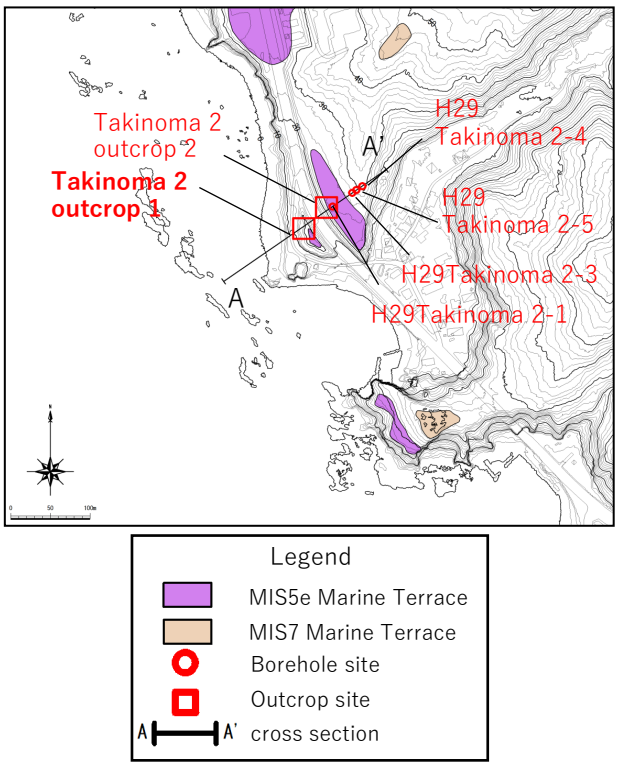

Fig. 6a Borehole sites of Takinoma 2 area

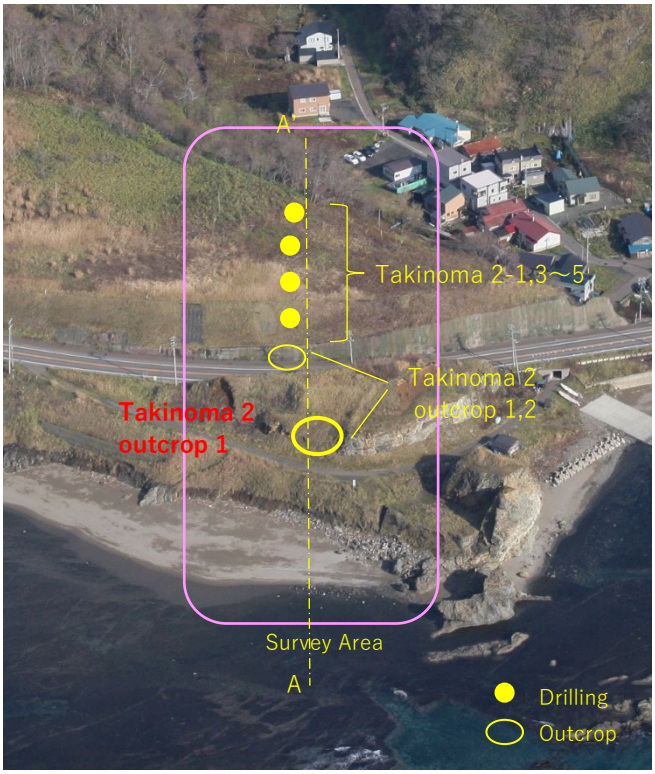

Fig. 6b Aerial view of Takinoma 2 area

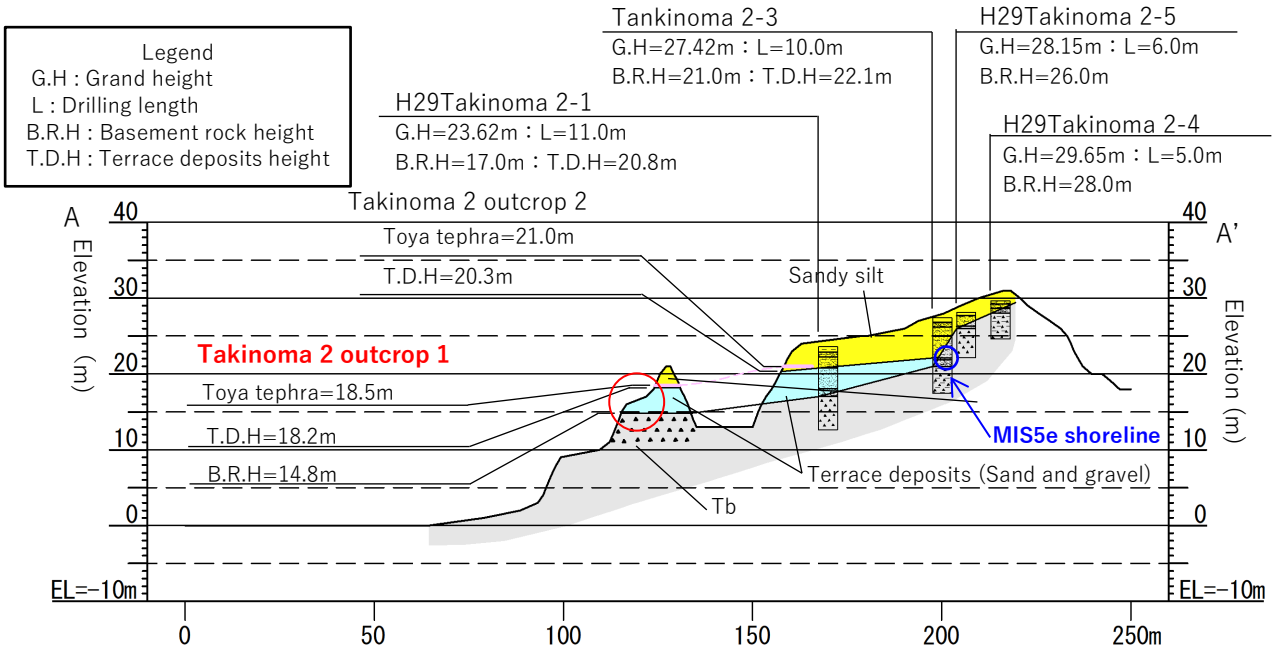

Fig. 7. Takinoma 2 A-section in Fig.6

Terukishi area

8 drill cores are obtained by geological boring survey in this area (Fig. 8a and b). The cores "Terukishi-1 to 6" are from wave cut terrace side. The cores "Terukishi-7 and 8" are from paleo sea cliff side. Reconstructed wave cut terrace is flat and gently dipping to the sea side (Fig. 9). The basement rocks are composed of andesitic hyaloclastite and tuff breccia of the Kamoenai Formation. The marine terrace deposits (1 to 4m in thickness) have wedge-shaped layer in cross-section (Fig. 9). The talus deposits cover the marine deposits with more than 10m in thickness. The Toya tephra is observed at the lower most part of the talus deposits from the core of "Terukishi-3, 4 and 5". Altitude of reconstructed shoreline of the MIS5e transgression is about 26m in height at this area.

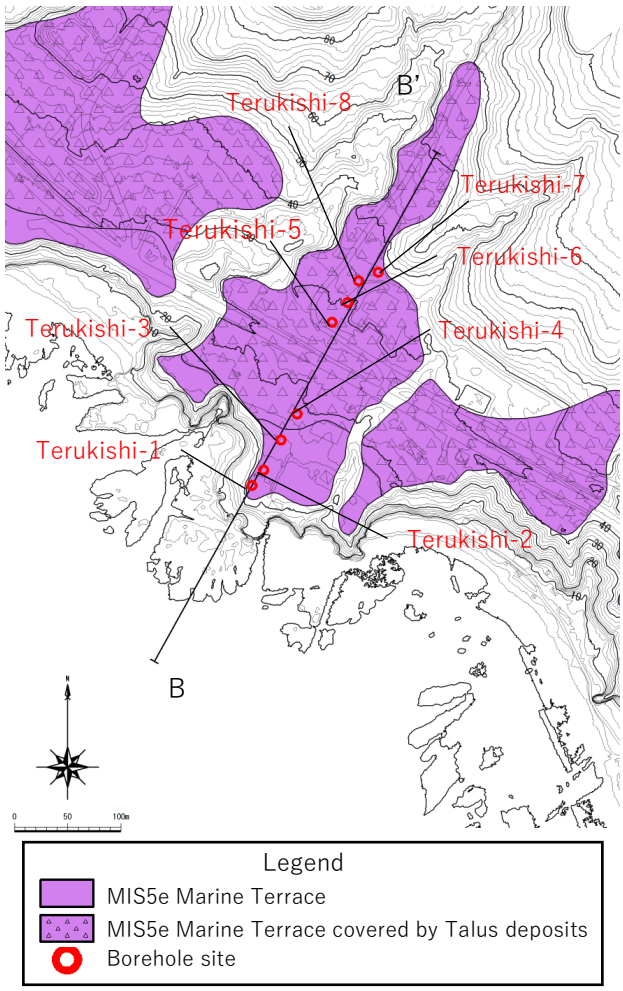

Fig. 8a Borehole sites in Terukishi area

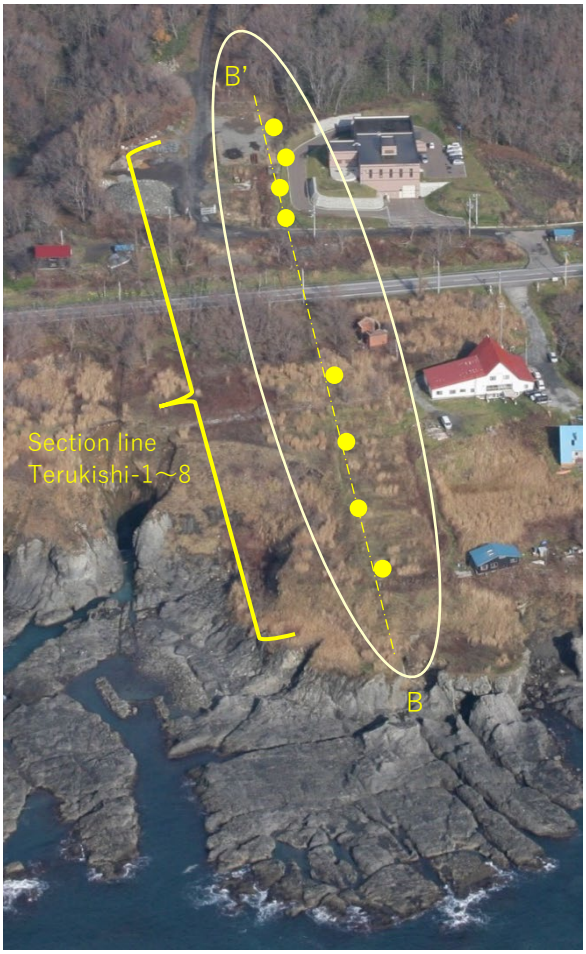

Fig. 8b Aerial view of Terukishi area

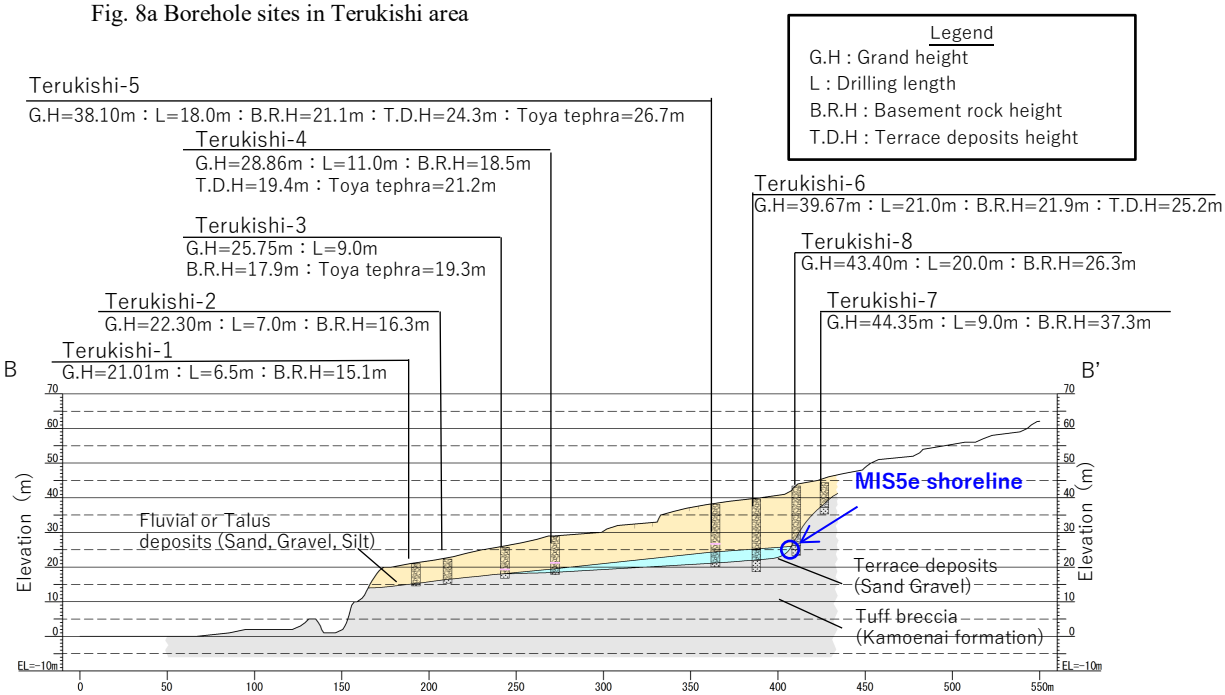

Fig. 9. Terukishi B-section in Fig.8

Kamoenai 2 area

Two outcrops and 8 drill cores were observed (Fig. 10a and b). Geological cross sections along C, D and E line were constructed in Fig. 11. The basement rocks are composed of the Kamoenai Formation (andesitic tuff breccia) and the Yobetu Formation (mudstone, sandstone and conglomerate). The marine deposits distribute from 18 to 25m in height and gently dipping to seaward (Fig. 11b and c). The marine deposits layer is horizontal in C section which is subparallel to the coast line (Fig. 11a). The samples of Toya tephra which are intercalated in the cover of the marine deposits are collected from the D and E sections. Aso4 tephra (90ka (Machida & Arai, 2011)) covers Toya tephra (115ka) was discovered from M-2 core in D-section. It represents that there was no talus deposition during the period from MIS5e to 5c. After the fall of Aso4 tephra, thick talus deposits were accumulated and covered the original MIS5 terrace surface. Reconstructed shoreline of MIS5e transgression is about 27m high in this area (Fig. 11c).

Discussion and conclusion

Terrace analysis has been studied using by topographic map. Geological drilling survey in the study area suggests that the original MIS5e terrace surface was covered by 10 to 30m talus deposits. In the Kamoenai 2 area, Koike and Machida (2001) (depend on the height of the terrace surfaces) subdivided the Middle Terrace into 2 terraces, terrace in E-section (50m) and in D-section (30m) which were formed in different events. However the MIS5e marine deposits continued and distribute horizontally beneath the 2 terrace. It indicates that the surface of 2 terraces is formed by later sedimentary activity of talus deposits and not indicate the surface of the MIS5e terrace. These results suggest that the traditional geomorphological analysis has some errors in the study area to define height of the terrace. Koike and Machida (2001) estimated that the altitudes of MIS5e shoreline in Shakotan Peninsula decrease from north (60m) to south (30m) used by geomorphological analysis. The shoreline of maximum MIS5e transgression is estimated as the highest level of the marine deposits from the geological cross section. The obtained altitudes of the former shoreline from the 7 sections are 22 to 27m in height throughout in 16km long along the Peninsula. Our research proved that the MIS5e surface is not inclined in the study area and the previous study was misinterpreted by the cover of talus deposits.

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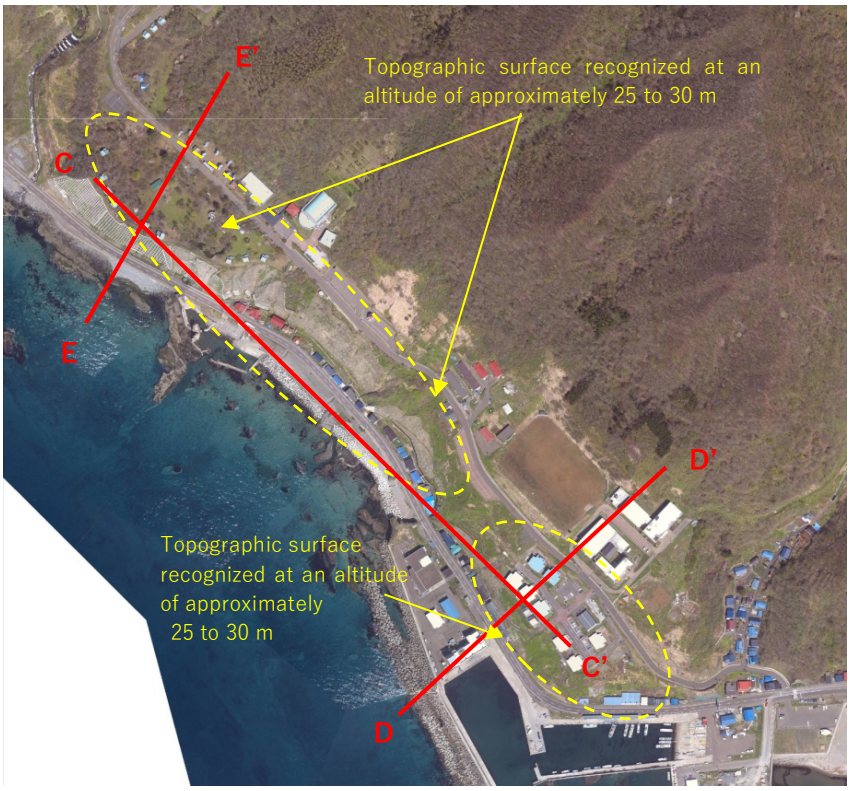


Fig. 10b Aerial view of Kamoenai 2 area

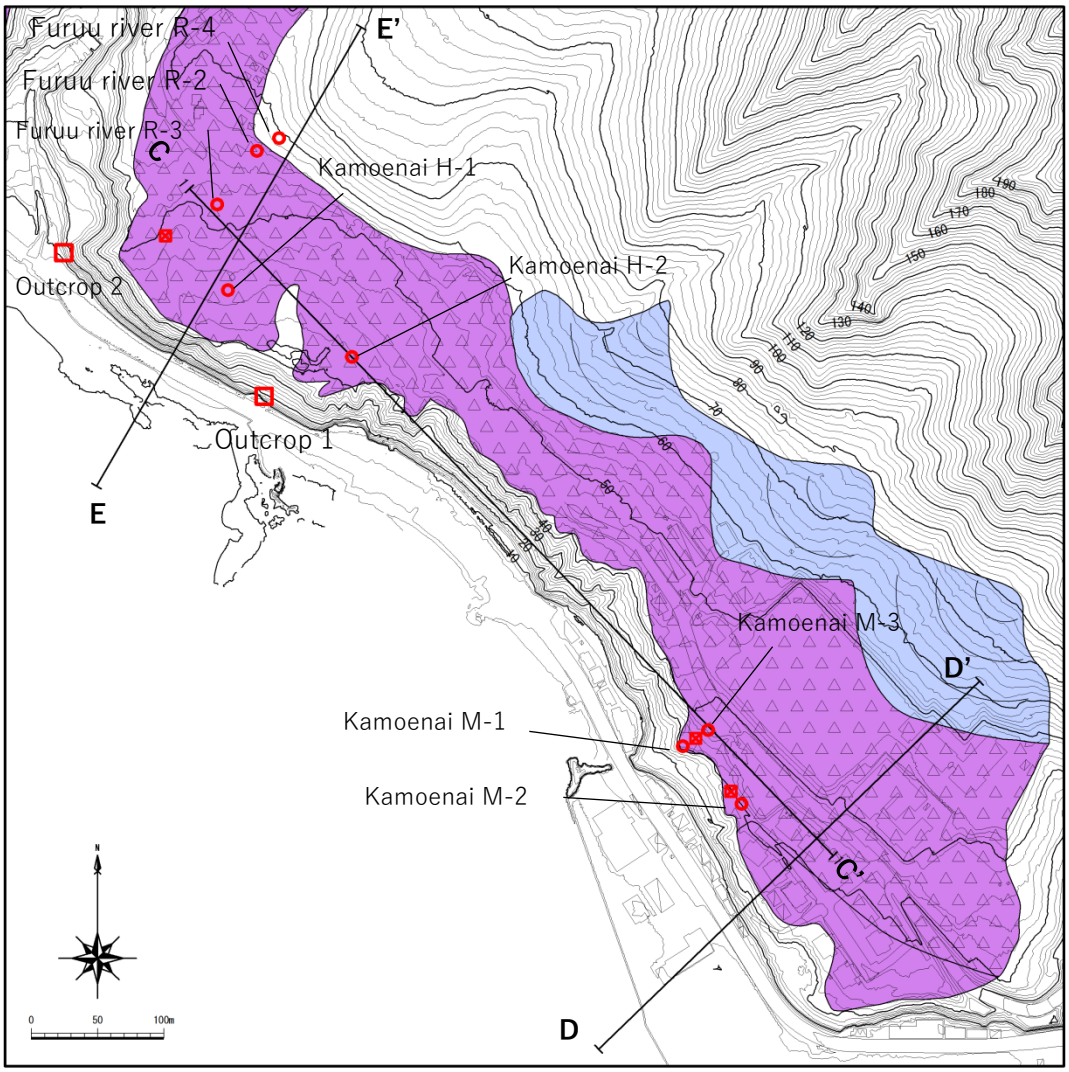
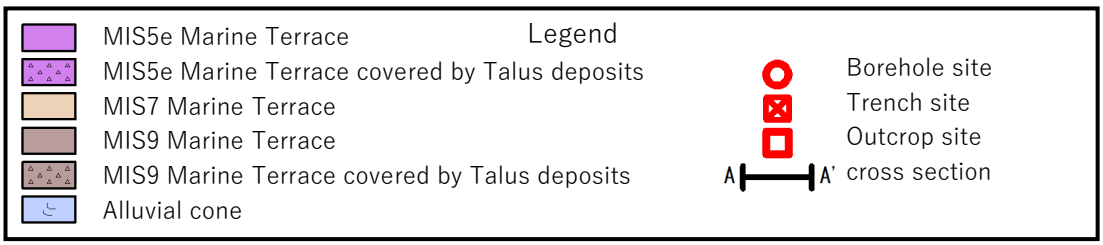


Fig. 10a Borehole sites of Kamoenai 2 area



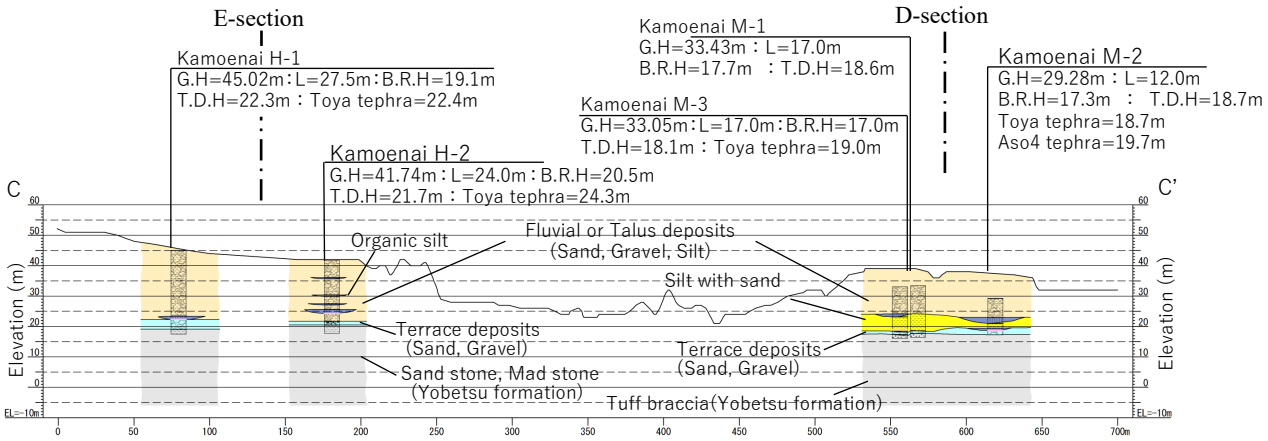


Fig. 11a C-section in Fig.10

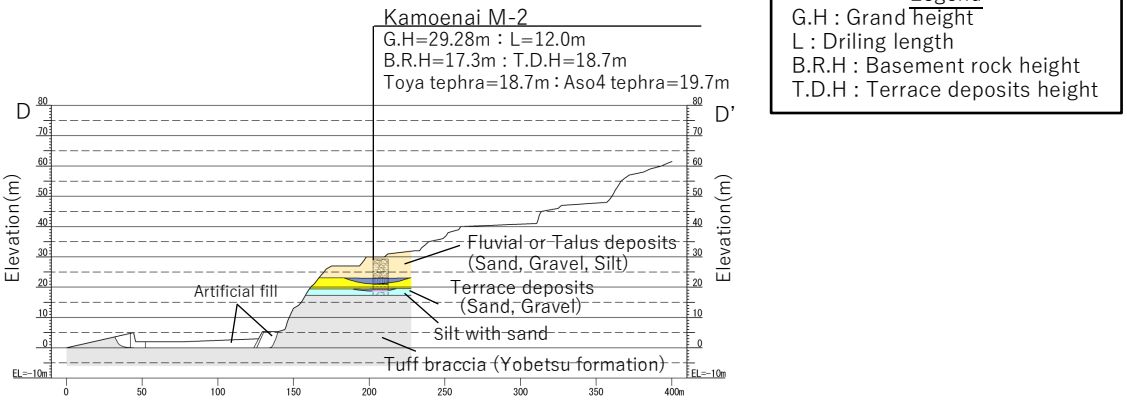


Fig. 11b D-section in Fig.10

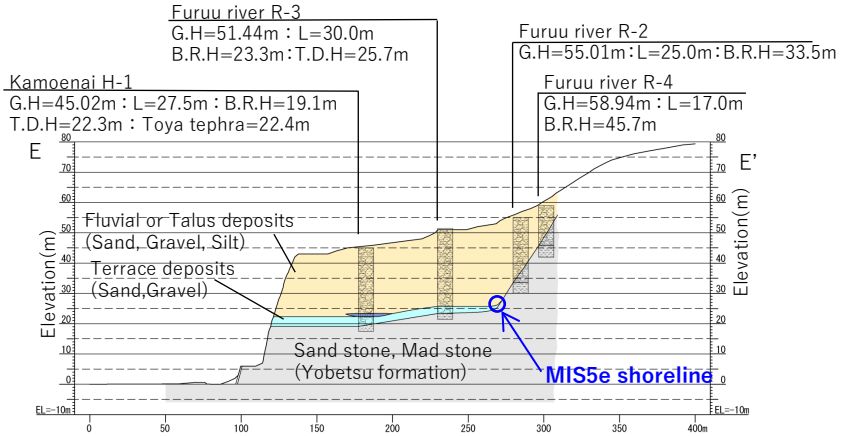


Fig. 11c E-section in Fig.10

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