

# Large Slope Failure off Miyako and Yaeyama Islands, Southwest Ryukyus in Relation to the Yaeyama Earthquake Tsunami.

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## Abstract

A hazardous tsunami named "the 1771 Yaeyama Earthquake Tsunami" occurred in the 18th century on the landward slope of the Ryukyu Trench off the Miyako and Yaeyama Islands, westernmost part of the Ryukyu District. The tsunami is considered to be originated by a large-scale subsidence of one of the deep sea fans according to the result of seismic reflection surveys and a numerical simulation.

Swath bathymetric survey cruises in the southwesternmost part of the Ryukyu Trench area including the tsunami site were conducted by using SEABEAM (on board KAIYO) and HS-10 (on board YOKOSUKA) systems. These survey cruises revealed the following characteristics of the topographic features in the study area:

- a) A large-scale topographic depression off Yaeyama District, just the same position as assumed as the epicentre of the tsunamigenic earthquake.
- b) Lots of deep sea canyons are located on the north of the depression zone which large-scale underwater landslide might occur.
- c) The axial area of the trench is a flat plane the width of which is 30-40km in this place.
- d) An E-W trending half graben is located on the landward slope off Yaeyama Islands.

Two dives by SHINKAI6500 were conducted in the southwest Ryukyu area in 1992. The result by the dive near the summit of a seamount just south of the trench axis shows a collapse of the bottom at midst of the seamount slope, fine-medium size pebbles derived from sliding from the upper part of the seamount and exposure of basaltic rocks along the slope. The result by the dive on the landward slope of the trench (5900m in water depth) shows that the survey area is characterised dominantly by rough topography consisting of a series of steep slope and escarpment, coverage with suspended particles due to the present sliding and erosion of the surface layer and exposure of the internal sandy sediment in some sampling sites. This area is characterised by continuous landslide of

the surface of the basement rocks constructed by Shimajiri Formation.

Observation by JAMSTEC/Deeptow camera was carried out in 1996 on the Kuroshima Knoll, 30km south of the Yaeyama Islands and the source area of the tsunami. Relics of large collapse and landslide were observed along the southern slope near the summit of the knoll which might be the true origin of the tsunami.

The observed topographic features suggest an N-S or NE-SW tensional stress over the whole area of the southwestern Ryukyu Trench (both seaward and landward slopes). As soft sediment is always supplied from these islands through the underwater canyons, the accumulated sedimentary layer might collapse some time due to the gravitational instability derived from the tensional stress.

## 1. Introduction

Miyako and Yaeyama Islands are located in the southwesternmost part of the Ryukyu Islands, Southwest Japan (Fig.1). These islands are facing the East China Sea to the north and the Ryukyu (Nanseishoto) Trench and the Philippine Sea to the south. Hazardous geological phenomena such as large earthquakes, swarm earthquakes, tsunamis, hydrothermal and volcanic activities are reported in and around the islands. These phenomena are derived from the deformations of the surface and the shallow crust due to the subduction of the Philippine Sea Plate underneath the trench. The most remarkable hazard due to the plate convergence was the "1771 Yaeyama Earthquake Tsunami" or "the Great Meiwa Tsunami" which occurred on 24th April 1771 around 24.0°N, 124.3°E on the landward slope of the Ryukyu Trench. Maximum inundation height of the sea water was 85m and about 12,000 people were killed in these islands according to the description of the historical record named "Disaster Report of the Large Tsunami" which was presented just after the disaster from the prefectural government of Yaeyama to the Dynasty of

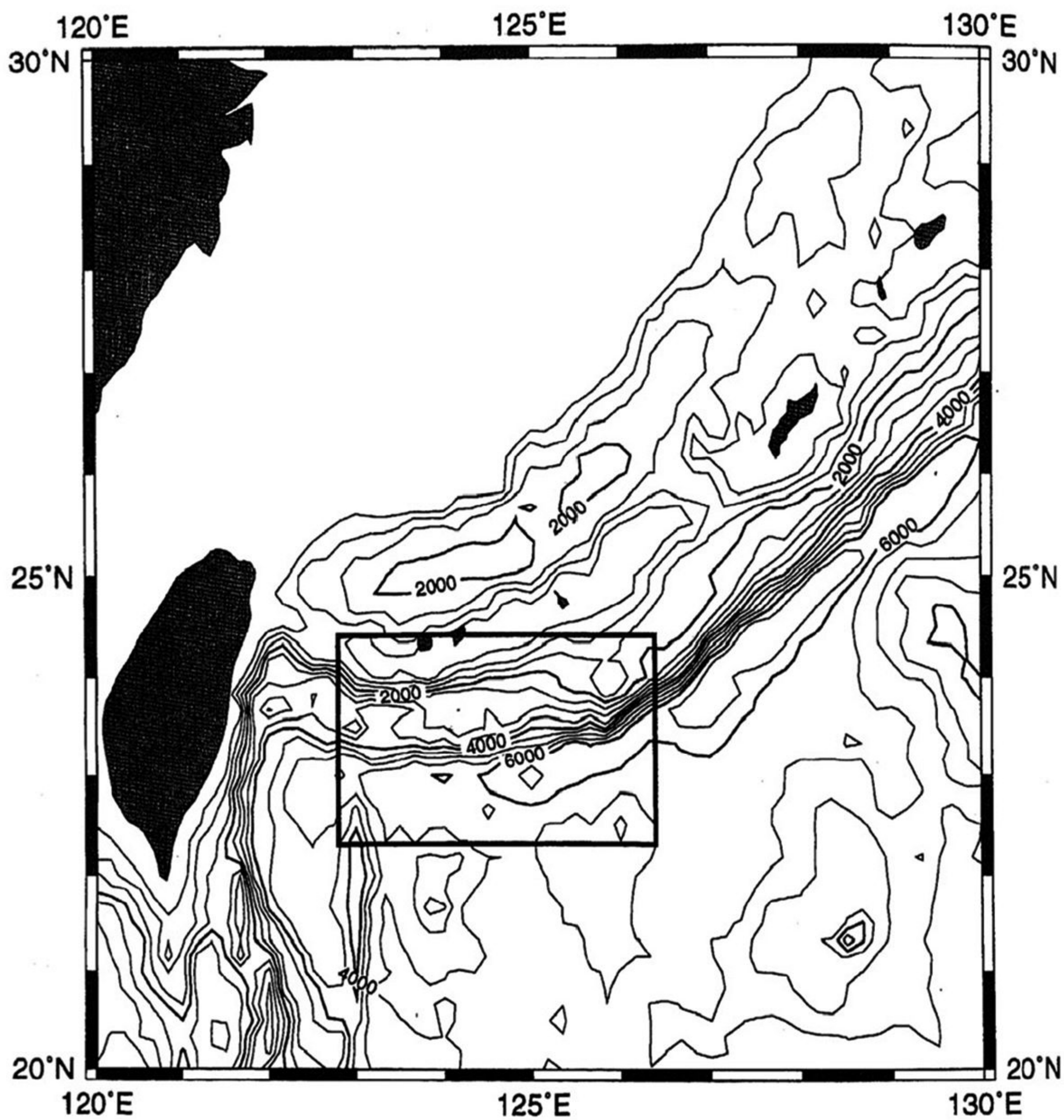


Fig.1: Study area in the southwestern Ryukyu.

Ryukyus. A lot of geological evidences still remain on land in these areas (Kato, 1983). The tsunami is considered to be originated by a large-scale subsidence of one of the deep sea fans according to the result of seismic reflection surveys (Kimura, 1985) and a numerical simulation (Hiyoshi, 1986), rather than by fault slip.

Although such kind of phenomena which occurred in the past and may occur at any time in the near future in this area are quite hazardous and are to be studied for the purpose of disaster prevention, quite few systematic geological and geophysical survey works were conducted so far in this area. Therefore, JAMSTEC and University of the Ryukyus started a new collaboration programme on geological and geophysical studies in this area in 1990 by use of the research facilities of JAMSTEC.

In this article the authors would like to report the results of the recent topographic survey and visual observation by Shinkai6500 diving and JAMSTEC-Deeptow survey in the study area. Then the mechanism of the large-scale tsunami in relation to the regional geotectonics will be discussed through the analysis of these new data.

## 2. Topographic survey

As the first step of the series of the survey mission, multibeam bathymetric survey in the southwesternmost part of the Ryukyu Trench area was carried out through the research cruises by the JAMSTEC fleets "Kaiyo" and "Yokosuka." Since the area north of 24°N in the Ryukyu region had already been surveyed by the Hydrographic Department of Japan (Oshima et al., 1988), these JAMSTEC cruises were planned in order to complete a precise topographic map mainly south of 24°N off Miyako and Yaeyama area. Total five cruises were devoted for this purpose. They are:

- 1) DK90-8 Cruise Leg1 by R/V Kaiyo, November 1990
- 2) DK91-2 Cruise Leg3 by R/V Kaiyo, April 1991
- 3) Kariyushi Cruise (cruise ID = DY92-1) by R/V Yokosuka, January 1992
- 4) Tsunamiko Cruise (cruise ID = DK92-3) by R/V Kaiyo, April 1992
- 5) Y92-2 Cruise by R/V Yokosuka, nighttime geophysical survey during the diving cruise by Shinkai6500, June 1992

Thus, the area north of 22°20'N, south of 24°20'N, east of 122°50'E and west of 126°20'E including the westernmost part of

the Ryukyu Trench and tsunami source area (around 24.0°N, 124.3°E) was covered by swath bathymetry (Matsumoto and Kimura, 1993, Fig.2). The survey area is classified into five different topographic domains which are arranged zonally. Those are:

Zone 1: North of 24°00'N, which is characterised by the distribution of well developed submarine canyons along the southern coasts of Yaeyama Islands.

Zone 2: 23°40'N ~ 24°00'N, which is characterised by deep sea fans and their large-scale subsidence edged by steep scarp near 23°55'N-24°00'N, 124°10'E - 124°20'E. The observed relative height of the depression is about 200-300m.

Zone 3: South of 23°40'N on the landward slope of the trench, which is characterised by quite complicated topography such as several escarpments and ridges and troughs of which trend is not clearly recognized. An E-W trending half graben is also located.

Zone 4: Trench axis area with depth about 6500-6600m, which is characterised by a broad plain. Maximum width of the axial plain is about 40km.

Zone 5: Seaward slope of the trench, which is characterised by horsts and grabens, as well as in the sea area south of Okinawa Islands. The strike direction of the horsts and grabens is NW-SE off Okinawa Islands, and slightly changes to WNW-ESE towards the west.

## 3. Result of the Shinkai6500 diving - precise topography and surface structure of the diving sites

The final leg of Y92-2 Cruise by Shinkai6500/Yokosuka (June 14-20, 1992) was devoted to the diving in the southwestern Ryukyu Trench area off Yaeyama Islands. The following two dives (Dive#124 and Dive#125) were conducted in this area.

### Dive#124 - Seaward slope

There are four seamounts placed on the trench axial plain area and on the seaward slope of the trench between 123-30'E and 125-15'E. The dive was aimed at the precise surveying near the summit of "Shiraho Seamount," the largest one in the area. The summit of the seamount is located at 22-50'N 124-27'E, 10nm south of the plain bottom surface of the trench area. The diameter is about 10nm in NNE-SSE direction and about 8nm in WNW-ESE direction. The relative height is about 1800m. The southern part of the seamount seems to be split by a E-W

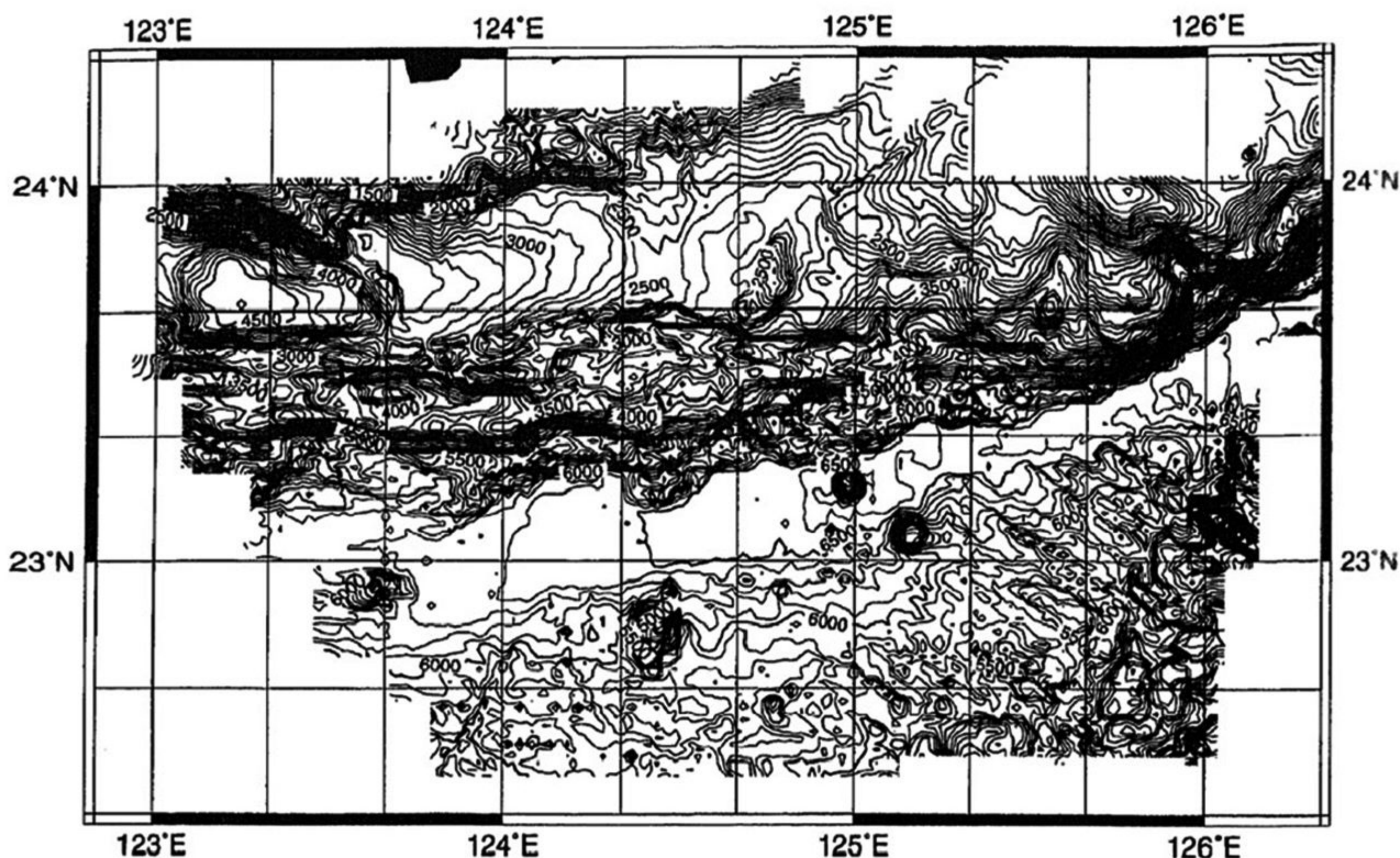


Fig.2: Precise topographic map in the study area off Yaeyama Islands.

trending fault. The water depth of the start and end points was 4462m and 4163m, respectively. A collapse of the bottom the diameter of which is about 10m was observed at midst of the seamount slope. Sparsely distributed fine-medium size pebbles were observed on the slope covered with mud, which might be rolling stones derived from sliding from the upper part of the seamount. Outcrops covered with thin sediment were also observed on the steep slope near the summit. Collected samples were basaltic rocks, which shows that the seamount consists of igneous rocks and was constructed by a volcanic activity on the Philippine Sea Plate. These findings suggest that the seamount suffered from deformation recently, maybe when it reached the trench area by the motion of the Philippine Sea Plate.

#### Dive#125 - Landward slope

Diving site for the precise observation on the landward side of the trench was selected at 23°15'N 124°15'E and nearby, 5900m in

water depth. The site is on a small spur which is sticking out to the south from the landward slope of the trench and is facing the plain bottom surface of the trench area. The spur is bordered by canyons along which the relics of southward underwater landslides are recognised according to the topographic map. The diving survey revealed that the whole survey area is characterised dominantly by rough topography consisting of steep slopes and escarpments. The actual topographic roughness scale is much shorter than is expected from the topographic map which is obtained by HS-10 multibeam echo sounder the precision of the beam width of which is about 250m in the case of this water depth. The site was covered with suspended particles during the diving, which might be due to the present sliding of the surface materials and erosion on the surface layer. Basement rocks, presumably consisting of sedimentary layer of Shimajiri Formation, are exposed here and there due to the linear sliding of the surface

sediment on the slope.

#### 4. Precise survey by JAMSTEC-Deeptow system at Kuroshima Knoll

Seafloor observation using JAMSTEC-Deeptow camera system on board the R/V Kaiyo was carried out in October - November 1996. The survey area was limited to the Kuroshima Knoll located 30km south of the Yaeyama Islands. The southern foot of the knoll coincides with the estimated source area of the Yaeyama Earthquake Tsunami. Seven transects in total were made in the precise survey area. The results show the large collapse along the southern slope of the knoll, especially the water depth shallower than 1700m. Thick sediment with the dead *Calypotgena* community was found at the southern foot of the knoll where water depth exceeds 2400m, suggesting an existence of a hidden fault. As a whole, the observed collapse on the southern slope of the Kuroshima Knoll could be a source of the 1771 Tsunami. However, since a large hazard occurred along the southern shore of Miyako Islands on the occasion of the tsunami, the source area is not limited to the present area and some other areas near the southern coast of Miyako Islands and Tarama Island had also collapsed at the same time, which suggests that a wide (200km or more horizontal scale) earthquake fault slip occurred at that time.

#### 5. Discussion

The topographic features in the present study area are: 40km-wide, E-W trending flat plane of the axial area of the trench, E-W trending half graben placed on the landward slope, gradual change of the trend of the horst and graben towards the west. These topographic features suggest a N-S or NE-SW tensional stress over the whole study area. Considering also that the western part of the East China Sea north off Miyako and Yaeyama Islands is characterised by a broad basin and

the water depth more than 2000m in contrast with the northeastern part, the whole southwestern Ryukyu area is characterised by the features derived from such kind of tensional stress.

Since no record of tremor corresponding to the tsunami was reported, a large-scale underwater landslide or collapse of sediment derived from the assumed regional tensional stress should be the origin of the tsunami. In the coastal area off Miyako and Yaeyama Islands, a number of underwater canyons are located and most of them are connecting these islands and the Tananao Basin the northernmost part of which coincides with the large-scale depression and the estimated origin point of the generation of the tsunami. As soft sediment is always supplied from these islands through the underwater canyons, the accumulated sedimentary layer might collapse some time due to the gravitational instability. Then an underwater landslide might occur along a slope on the island shelf if the sediment accumulates and the gradient of the seafloor exceeds the repose angle. This is evidenced by a repeated turbidite layer observed in the core samples off the islands (Ono et al., 1989).

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