International Research: **Back Arc Basins**

Deep-tow sonar "WADATSUMI" survey in the Okinawa Trough

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Introduction

The Okinawa Trough, located between Japan and Taiwan, is an incipient backarc basin formed by the extension within continental lithosphere behind the Ryukyu trench-arc system (Fig. 1). The continuous formation of new oceanic crust has not occurred yet, however, the crustal thinning and rifting is ongoing and many normal faults have developed. The early rifting phase was dated late Miocene, however, the date of the beginning of the extension and the characteristics of the early phase are still being debated (*e.g.* Kimura, 1996, Park 1998). The second rifting phase started about 2 Ma, indicated by the normal or listric faults trending 065° and the associated tilted faults blocks in the northern and middle Okinawa Trough. The faulting and the subsidence in the second phase have formed the present wide depression of the Okinawa Trough. The most recent phase of the extension is characterized by 085° normal faults. The faults are mainly located in the south-

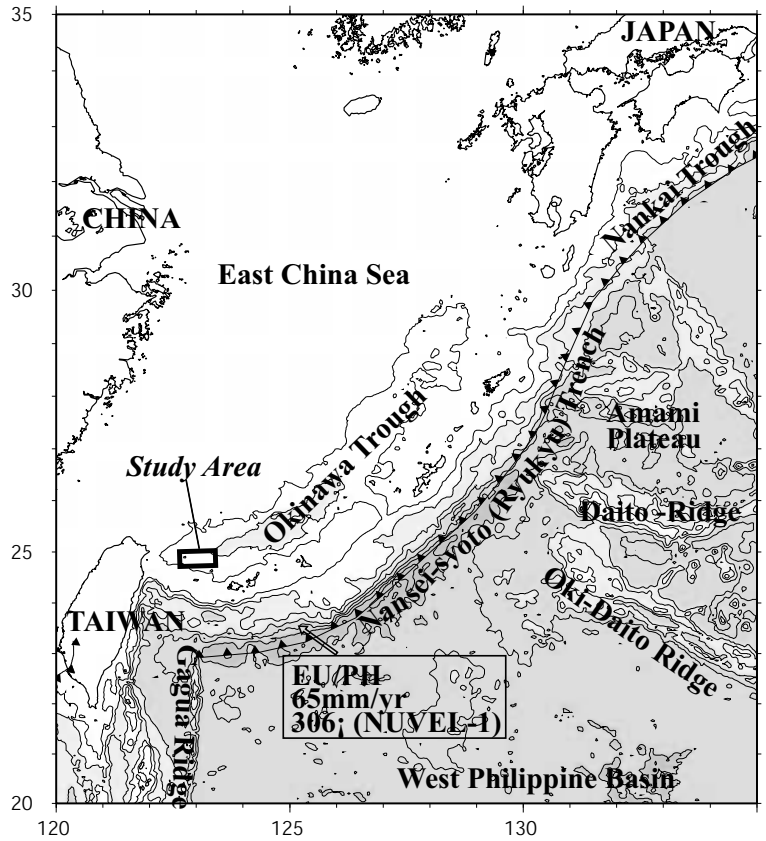

Figure 1. Location of the survey site, southwestern tip of the Okinawa Trough, backarc rifting zone behind the Ryukyu arc-trench system.

western Okinawa Trough and the distribution of faults is restricted within an east-west trending 13-km wide band (Sibuet *et al*., 1998). Volcanic rocks from the central grabens in the middle and southwestern Okinawa Trough show that magmas emplaced in the area are bimodal in composition, with basalt and rhyolite as the dominant modes (*e.g.* Shinjo et al, 1999) and their ages are younger than 1 Ma (*e.g*. Ishikawa *et al*., 1991).

In the Okinawa Trough, the southwestern part of the trough is most active and contains many interesting features, such as, numerous volcanoes crossing the rift zone (cross backarc volcanic trail: Sibuet *et al*., 1998), high heat flow, and active hydrothermal activities (Matsumoto *et al*., 2001). A French-Taiwanese co-operation cruise in 1996 has provided a seafloor bathymetry map and the seismic profiles of the region. During the R/V Hakuho-maru KH02-1 cruise in June 2002, we conducted detailed geological, geophysical and geochemical experiments in this area based on the previous studies. The main purposes of the cruise were 1) to investigate the process and evolution of continental rifting based on high-resolution sonar imaging, 2) to characterize the hydrothermal activity in relation to rifting, 3) to understand the genesis of volcanism in the backarc continental rift zone, and 4) to examine the thermal structure in the hydrothermal region. The main survey item was the high-resolution seafloor imaging by the deep-tow sidescan sonar "WADATSUMI" and the name of the research cruise was assigned as "HOTWATER (Hakuho-maru Okinawa Trough WadaTsumi ExpeRiment) " cruise. The cruise was planned and conducted under the international cooperation among Japan, Taiwan and France.

Instrumentation

The HOTWATER cruise started from Naha on June 10 and ended at Tokyo on June 24, 2002. The instruments used during the cruise included:

1) Deep-tow side-scan sonar system "WADATSUMI" (100kHz) with self-recording MAPRs (Miniature Autonomous Plume Recorder / provided by E. Baker in NOAA)
2) Hull-mounted SeaBeam2120 (20kHz) multibeam echo sounder and 3.5 kHz sub-bottom profiler
3) Dredge sampler
4) CTD Carousel Multi-Sampling system with a DO sensor and light transmissometer
5) Probe-type heat flow meter (4.5m)
6) Piston core (15m)

The deep-tow vector sidescan sonar "WADATSUMI" (Fig. 2) is the 100 kHz system, which provides not only high-resolution backscattering images but also phase bathymetry. The system also includes a 3-6 kHz chirp sonar to investigate sub-bottom structure. The swath width was 1 km and the towing altitude ranged from 100 to 350 m. The pixel size of the collected images is 50 cm. The towfish positioning was done by ISBL (inverted short baseline) system, in which the signal transmitted from the ship is received at the towfish and the all information is sent to the onboard control unit using a co-axial cable. Four MAPRs were equipped on the deep-tow system to detect the hydrothermal activities using its thermometer and nephelometer. Three MAPRs were attached to the towing cable with spacing 1, 50 and 100 m above the depressor and another one was suspended 50 m below the depressor (Fig. 2). In addition total 5 CTD hydrocasts, 6 dredges, and 2 piston cores were done in the area. Eight heat flow measurements were conducted near the hydrothermal vent reported in the previous submersible dives.

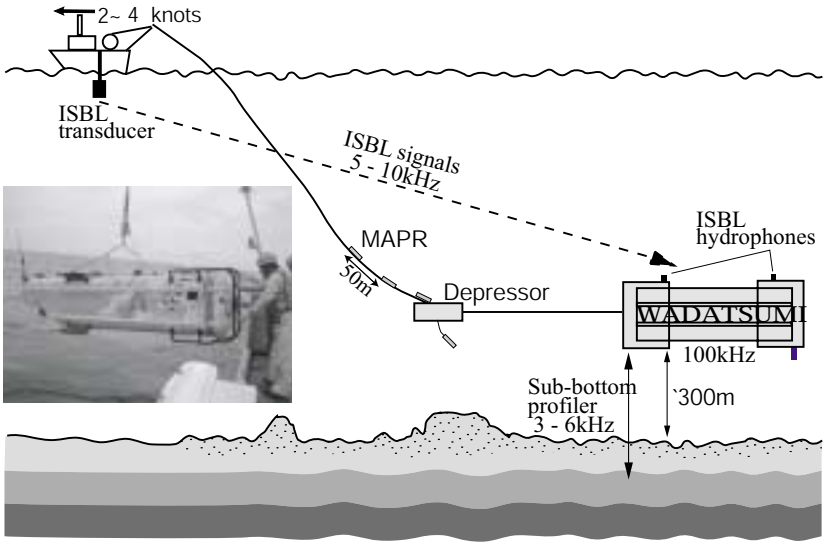

Figure 2. Schematic diagram showing the WADATSUMI deep-tow sonar and attached MAPRs. Insert – WADATSUMI deployment

Preliminary results

The WADATSUMI sonar system attached with MAPRs was towed within the central rift valley of the western Okinawa Trough from 122°35'E to 123°16'E (Fig. 3). Total 300 miles backscatter image and phase bathymetry data were obtained. During the 5-day survey, we mapped the major regions of the Yonaguni Graben (westernmost segment of the Okinawa Trough rift axis). Within the graben, a set of rift-parallel lines covers about 70~80% of the axial valley width including the steep northern rift wall. Another set of lines oblique to the rift axis was planned to cover the volcanic/hydrothermal area and to investigate the sub-surface structure using the

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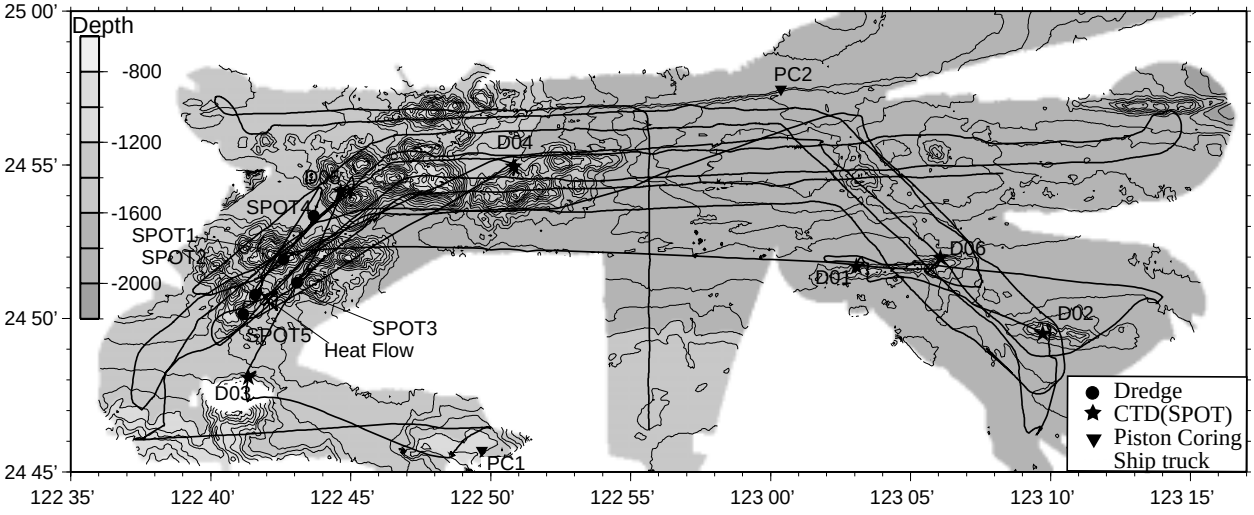

Figure 3. Ship's track and locations of stationary operations during the HOTWATER cruise on the bathymetry map.

chirp sonar attached to the WADATSUMI. The towfish position was determined using the ISBL system, however, the quality of the positioning varied among lines mainly due to miss communication between the transducer and the towfish.

The WADATSUMI images revealed the detailed volcanic and tectonic structure of the area (Fig. 4). In the western part the seafloor is dominated by volcanic constructions, including hummocks, sheet flows, and blocky lava terrains. Small volcanic cones with crater pits are aligned in E-W direction, which may build an elongated volcanic ridge within the graben. On the other hand, the eastern part of the survey area is a sedimentary, deep (~1900m) depression, where the numerous normal faults are observed. The combination of elongated sedimentary pond and E-W trending narrow horsts characterize the area. The sub-bottom profiler on the WADATSUMI clearly reveals the structure of these horsts. E-W step faults are also recognized near the rift wall and the slope failure and debris flow mound modify the original tectonic landform in some locations. One of the most important targets of the sonar analysis is the relationship between the volcanism and tectonic deformation. Further processing of the sonar imagery as well as the phase bathymetry will provide new information for understanding the magmatic/tectonic process of the backarc rift zone.

The MAPRs were deployed with WADATSUMI in six survey lines. The nephelometric anomalies suggest that the hydrothermal activity is restricted in the western part of the survey area. The locations of these anomalies correspond to the ryolitic volcanism in the western volcanic area and occur close to the known hydrothermal active site (SPOT site). Based on the MAPR results, five CTD hydrocasts were focused on the western volcanic area. Station SPOT-5 (Fig.3) showed the highest light transmission anomaly up to ~5% within 300 m above the seafloor. The pH profile also showed negative pH anomalies at almost the same depths, indicating the effect of acidic hydrothermal fluids.

Heat flow measurements were done at 8 sites along two crossing lines near the known hydrothermal vent area. The preliminary analysis shows high heat gradient suggesting very high heat flow in the area. Precise heat flow values will be calculated by using thermal conductivity directly measured from the piston core samples.

Six dredge hauls were conducted during the cruise, three in the eastern E-W elongated minor ridges and others in the cross backarc volcanic trail. Volcanic rocks were recovered from two sites. Pumiceous rhyolite samples were obtained at D-05 and some samples have mafic inclusion. Aphyric basalt samples with glass rind were dredged at D06 (Fig. 3).

Besides the tectonics and hydrothermarism, the study area is also a good site for understanding the Kuroshio warm current, which has played an important role to constrain the paleo-environment of the region. Two piston core samples were recovered during the cruise to confirm the migration of the Kuroshio Current axis during last 20 Ka.

The collected dataset contributes to our knowledge on the interaction of the magmatism, tectonics and hydrothermal activity in the backarc rifting zone. The detailed analyses of various measurements are in progress, and we hope to integrate the analyzed results in the near future.

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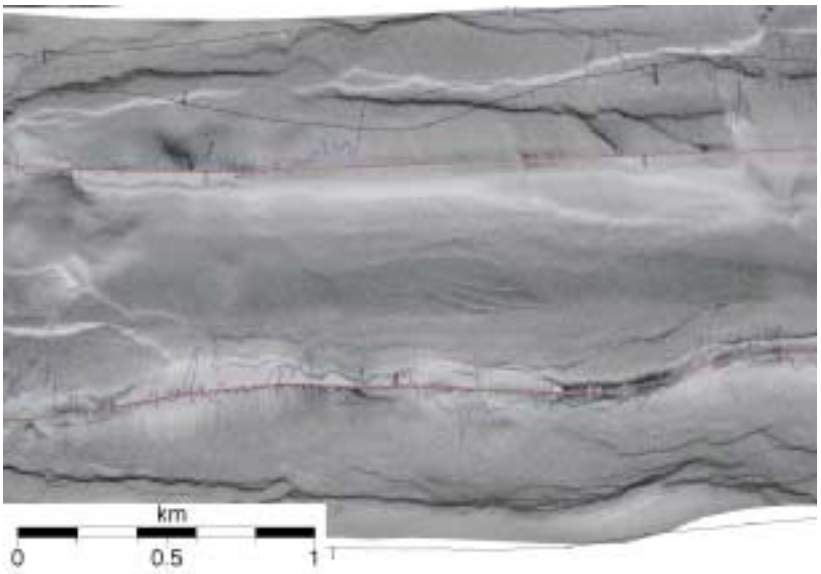

Figure 4. Example of mosaic image of the fault-dominant area within the central rift axis.