# Deep sea exploration survey technology by JAMSTEC and results of sunken object search


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**1. Deep sea search technology in JAMSTEC**

Japan Agency for Marine-Earth Science and Technology (JAMSTEC) is the biggest national oceanographic institute in Japan where 1 drilling ship, 6 marine research vessles, a manned submersible ship, 5 ROV (Remotely Operated Vehicle) and 6 AUV ( Autonomous Underwater Vehicle) , etc. are possessed.。

Technical development for Japanese deep sea survey has started from JAMSTEC in 1973. JAMSTEC introduced U.S. technology in 1978, developed the first Deep Tow system Sonar **(Fig.1,Fig.2)**, TV camera **(Fig.1,Fig.3)** and acoustic positioning system, made an experiment by deep sea area beyond 6000m and got submersible survey technology. After that JAMSTEC has developed ROV "Dolphin 3K" and deep Submergence Vehicle "Shinkai 2000" and "Shinkai 6500" (Fig.5) and has got many research vessels with a multi-beam echo sounder and seismic survey system. More JAMSTEC used Deep Tow systems, much ROV and AUV for deep sea search, added to its experience and improved the deep sea investigation ability. I'm this thesis and JAMSTEC would describe several survey examples of a performed sunken ships and objects. An investigation of an sunken object of JAMSTEC has started with search of the Japan Maritime Self-Defense Force

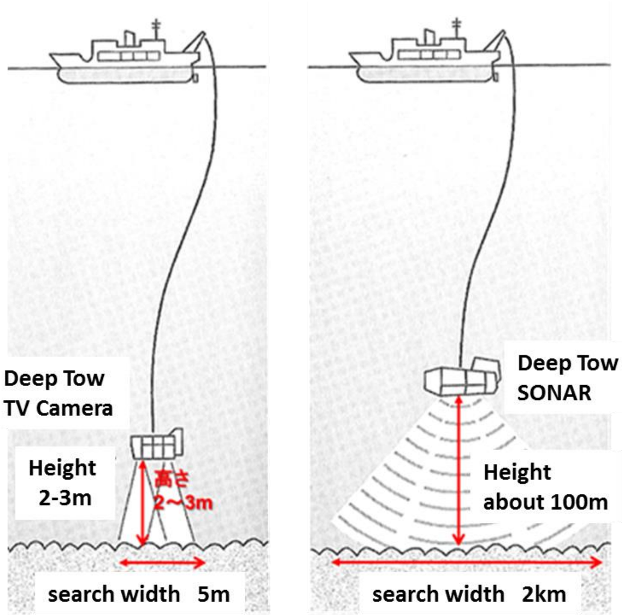



**Fig.1 Principle of a deep tow system**

**Fig.2 Deep Tow TV camera**

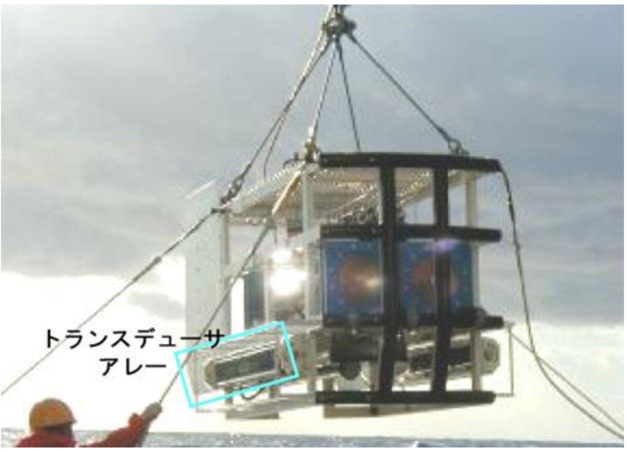



**Fig 3. Deep Tow SONAR System**

**Fig 4 Japan's first large ROV "Dolphin-3K"**

Fig .5 Submergence vehicle "Shinkai 6500"

helicopter which has fallen in 1995. We could find it at the bottom of the sea of offing water depth 740m in the Tokyo Bay by search using ROV "Dolphin 3k". **(Fig. 4).**

### 2. The Russian tanker "Nakhodka" survey which sank in the Sea of Japan (1997)

The Russian oil tanker "Nakhodka" was overwhelmed in an offing in Oki islands of Shimane on January 2, 1997, and


Fig .6 Outflow of heavy oil

pollution by outflow petroleum was social problem **(Fig.6).** JAMSTEC searched for the tanker which sank based on a request of a government. Sunken ship search was performed by a side scan sonar centering on area of sea in the neighborhood where oil is gushing from the bottom of the sea (about 2500 m of depth of the northeast about 140 km offing in Oki-island).**(Fig.7)** Survey work was begun by a support mother ship R/V "Natsushima" (1,553 tons) from January 23, 1998, and a hull was found by a Deep Tow side scan sonar on the 28th. An investigation by ROV "Dolphin 3K" has been begun after that. ROV found a sunken ship in a bottom on February 9. We confirmed the vessel name of Russian of a stern "Nakhodka" **(Fig.9)** by a television camera

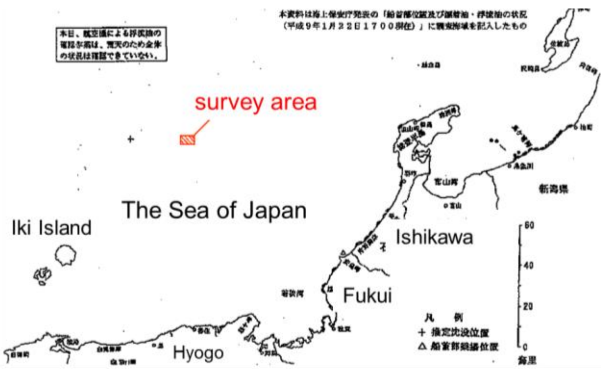



Fig .7 Map of survey area

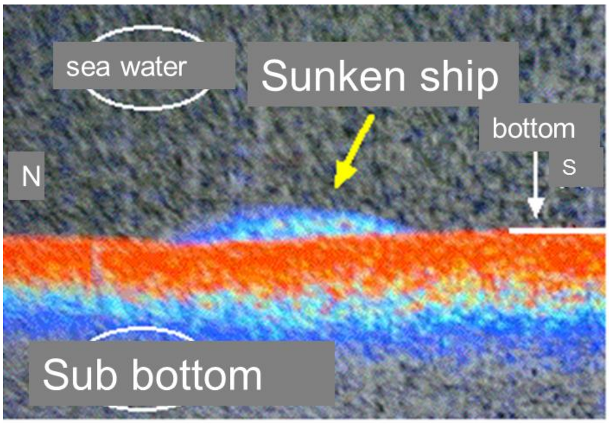



Fig .8 Result of Sunken ship survey by a sonar

Fig .9 Confirmation of a vessel name "Nakhodka" by ROV

Fig .10 The heavy oil which leaks from a crack of a hull and extracted more samples of oil. A hull fractured vertically in the stern direction from a bow as a result of the investigation by a television camera of ROV. Oil was leaking from the bow side fracture part neighborhood of the deck.**(Fig.10)**

### 3. Survey of the evacuated pupil ship which sank "Tsushimamaru" in the World War II (1997)

In December 1997, JAMSTEC conducted a search for the "Tsushimamaru" **(Fig.11)**, a ship tragically sunk during World War II in the course of its mission to evacuate a number of pupils. During this search, the comprehensive use of a multi-beam echo-sounder, a side-scan sonar and a narrow-beam sub-bottom profiler, made impossible in a short period of time to

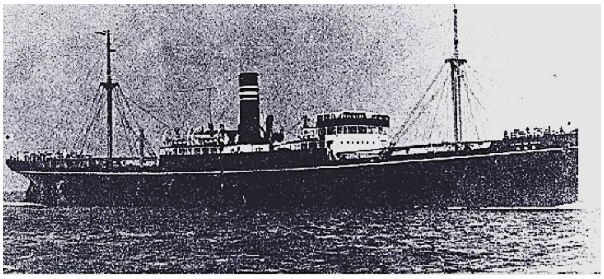


**Fig.11 Evacuated pupil ship "Tsushimamaru" in WW II**

successfully discover the Tsushima-Maru (at the depth of approximately 900 m). I am reporting on the search method employed and results obtained.

During the final phase of World War 2nd the Tsushima Maru, a Japanese evacuation ship left Naha (an Okinawa Island) for Nagasaki, Japan, with 1,747 civilians onboard-primarily consisting of elementary school pupils and their teachers. This evacuation plan was carried out in order to move civilians away from Okinawa, where a ground battle was impending, to a safer place. The "Tsushimamaru", however, received a torpedo attack from an U.S. submarine and eventually sunk in the northwest off Akuseki-shima Island (the Tokara Gunto islamds archipelago) on the night of August 22, 1944. As many as 1,508 lives (including those of 738 innocent pupils) were lost. On the 25th anniversary of the return of Okinawa to Japan (November 1997) the director general of the Okinawa Developing Agency requested the director general of the Science and Technology Agency to conduct a search for the "Tsushimamaru" in the estimated area where it was sunk、where it was sunk. In order to accommodate that request, it was determined that JAMSTEC would carry out the search.

**(1) Preliminary Research**

When searching for a sunken ship, in general, if the position is known it is effectivc as the flrst stage to start with to the visual observation (using a TV camera from an unmanned survey vehicle or a manned research submersible). In the case of the Tsushimamaru, however, there was little information available on the exact location (53 years had passed since the disaster). Presumably, there would be little chance to find the ship using a TV camera that provides a narrow view at that point in time. Accordingly, we held a meeting and prepared in flow chart foe the search based on our experience and knowledge. The most important thing (in this flow chart) was how exact the position where the "Tsushimamaru" was sunk could be located. To accomplish our goal, we started collecting the necessary information for preliminary research.

First, in order to find out the location of the sunken ship, specialist at the ship Japan Defense Agency examined the last communication from the "Tsushimamaru" along with some

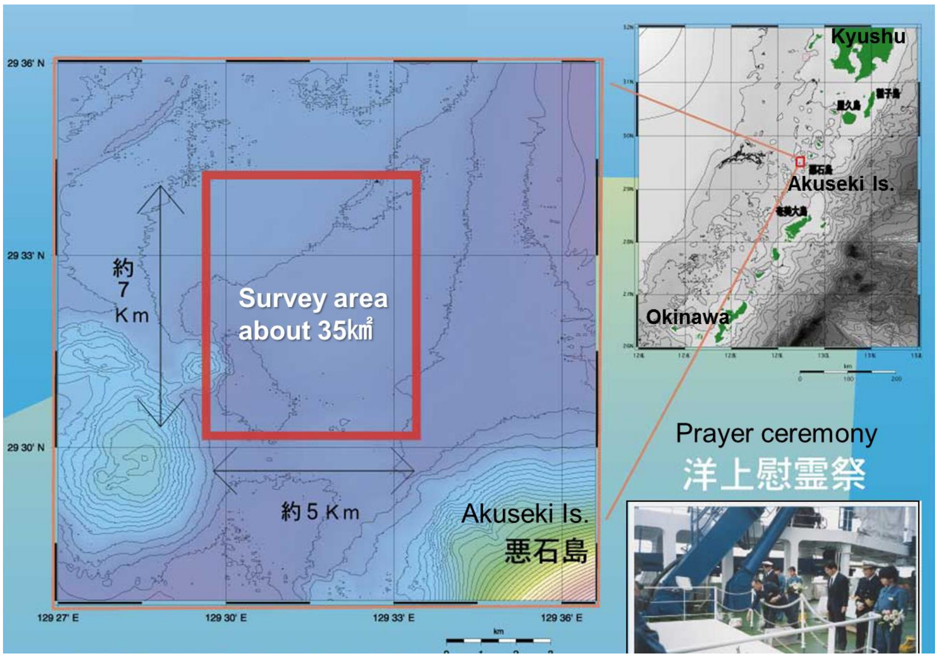



**Fig.12 The search area of sea decided by a preliminary investigation**

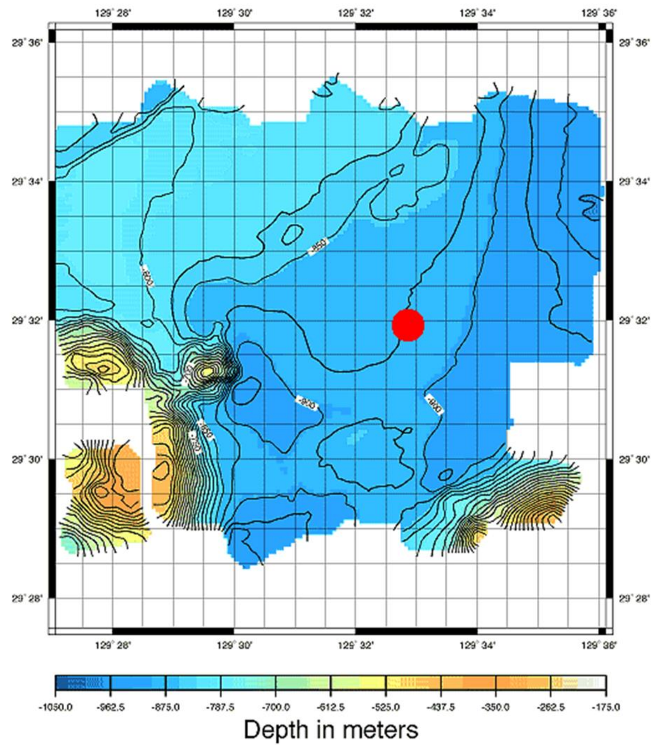



**Fig.13 Map of the survey area**

official documents of the U.S. forces that the Japanese Health and Welfare Ministry had investigated. As a result, the ship was estimated to be situated in the area centering on latitude 29 degrees, 32.9 minutes north, and longitude 129 degrees, 3l.l minutes east **(Fig.12).** Further inconsideration of calculation errors and influences by the current, we set a 12kilometer square search area **(Fig.13).** In addition, we obtained a design drawing of the ship in the same model as "Tsushimamaru" from the shipyard record sand found that the ship had a displacement of 6,756 tons and was 136meters long. It featured a straight bow form and a unique figure having three heights called "Mishima" (three island) type.

**(2) Sonar System Survey**

The search activities commenced on December 3, 1997 . To start. the determined survey area was investigated with the multi-beam bathymetric survey sonar with an integrated sub-bottom profiler (Sea Beam model 2l12.004) installed on the deep water R/V Kairei. The Sea Beam echo sounder provided 2 x 2 degree fine beams, in combination with a number of l2-kHz transmit beams and narrow receive beams, which enabled acquisition of multiple sounding data at one time **(Fig.14)**. It can cover a range that is in excess of 3.4 times the depth in the shallow and middle deep water survey mode. In the survey area, the depth was between 600-800 meters. We designed

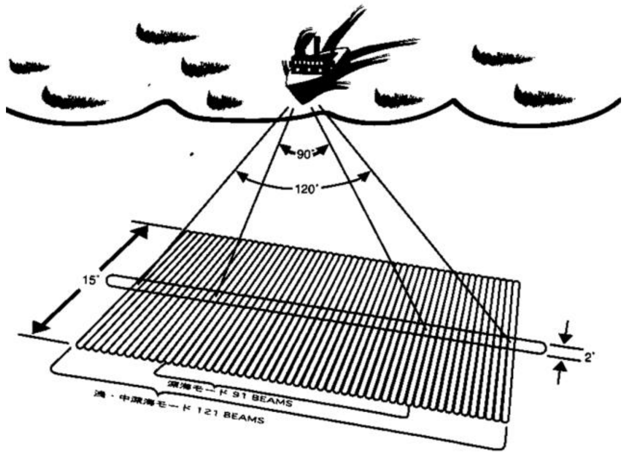



**Fig.14 The acoustic beam construction of the multibeam echo sounder**

survey lines every 2 kilometers in consideration of overlaps.

The primary benefit of the Sea Beam 2l12.004 to this integrated approach was its capacity to co-locate sub-sediment data with the surface depth and backscatter reflectivity data provided by the system's multi-beam sub-system. This model provided a function that can plot the contour of the seafloor and measure the reflection intensity of the sea floor at the same time. Therefore, it was estimated that if a large object, like a sunken ship, having a great acoustic reflection intensity was positioned on a muddy seafloor the possibility of locating it would be high.

In addition, this unique ability to simultaneously collect data sets means that a more detailed analysis and classification of sediment types, geophysical activity, and geomorphic trending is accomplished in near real-time. The distribution of the

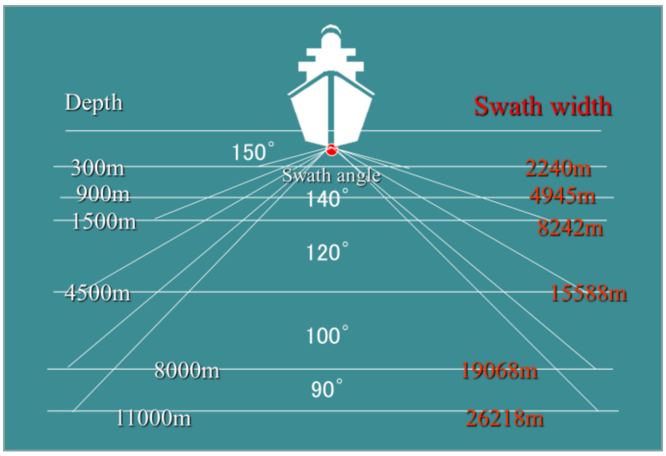



**Fig.15 Relation between the depth of SEABEAM 2112 and the swath on R/V "Kairei"**

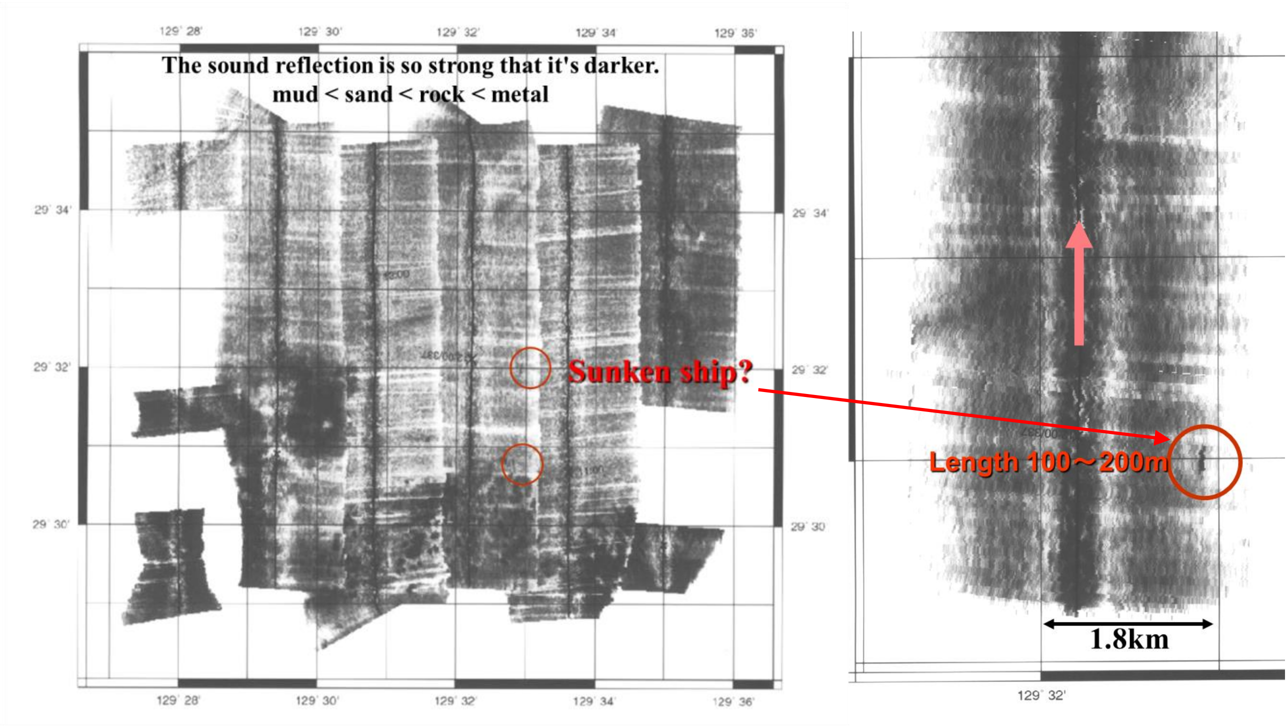



Fig. 16 Bottom reflection intensity by the multi-beam echo sounder

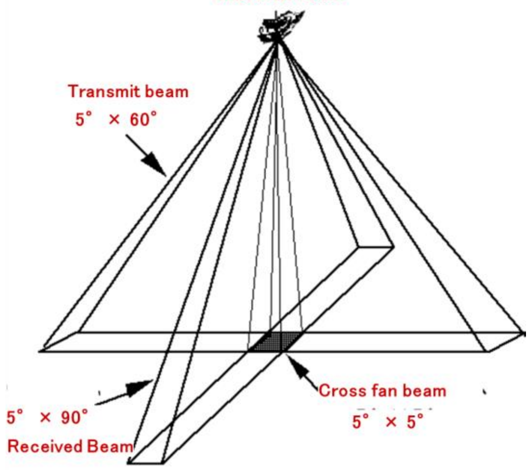



Fig.17 The sound beam construction of Cross-fan beam Sub bottom profiler

reflection intensity in the entire survey area and the portions closer to black indicate larger reflection intensity. It was observed that the reflection intensity varies greatly reflecting a noticeable change in the configuration of the seafloor on the south side-since that area is immediately extended from Akuseki-shima Island.

Further, it also indicates the existence of protruding rocks. Thus, we feared that if the "Tsushimamaru" had been sunken on the south side of the area, it would be less likely to be found. In the course of the survey, however, we observed that one spot stood out on a relatively flat area on the north side at which the backscatter reflection intensity was remarkably larger than the surrounding seafloor. The result of the more detailed survey, around the remarkable spot, confirmed that an oblong object in 100 to 200 meters length lied on these a floor **(Fig.16).** Further, an investigation was conducted using the integrated sub-bottom profiled which accompanies the SEABEAM system, for surveying the strata under the seafloor (beam width: 5 x 5 degrees, 4-7 kHz chirp signals) **(Fig.17)**. The system utilizes a 12-kHz projector array to collect bathymetric data and a dedicated projector array operating at 4 kHz to obtain sub-sediment data, forming a single along-track beam. The system's wide-aperture hydrophone array received the sub-bottom returns and provided an across track beam. This single hydrophone array is shared-ping cycles are synchronized such that the sub-bottom and bathymetric data sets are interleaved-but still co-located, one with the other.

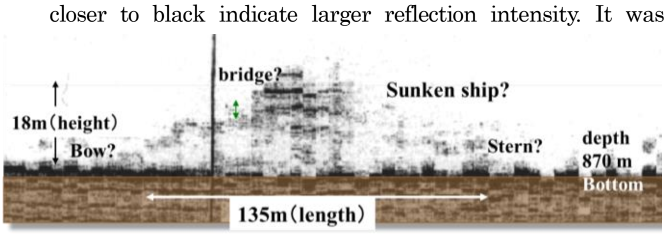
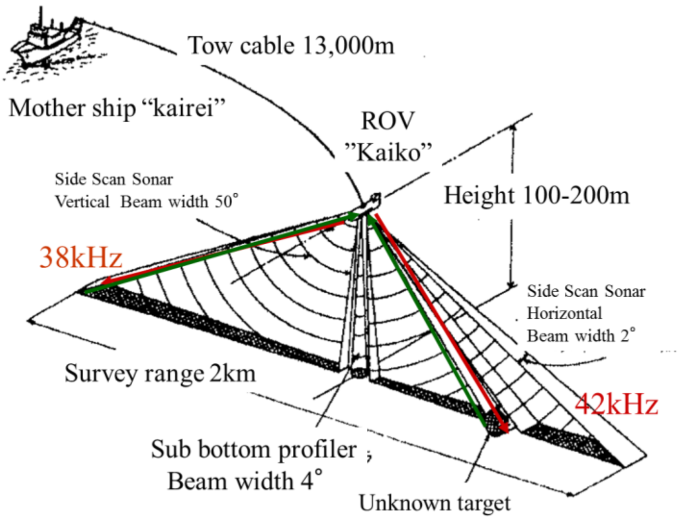



Fig.18 Image of a sunken ship by Cross-fan beam Sub bottom profiler




The survey result, showed an observation of the strata

**Fig.19 Sonar system of ROV "KAIKO"**

approximately 18 meters below the seafloor (where the speed of sound is 1500 m/s) **(Fig18)**. It was speculated that the surface of the seafloor nearby would be a mud substance and that sound waves would pass through well. It was quite obvious that the remarkable spot (indicated by an oblong circle) differs from the rest of the seafloor and was highly possible that the object was a ship. The location was discovered to be situated 2 kilometers off the estimated sinking site in the direction of the east-southeast (at a depth of approximately 870 meters).

### (3) Side-Scan Sonar Survey

During the next stage, we performed a precise survey around the marked position using the side-scan sonar mounted on the Kaiko (an unmanned survey vehicle). This side-scan sonar can be towed by the Kairei, its mother ship, up to the depth of 11,000 meters (maximum). It provides an approximately 42 kHz frequency, with a slight difference between the port side and the starboard side, and its beam width is approximately 2 degrees. This side-scan sonar enables scanning of more than a 1,000 meter area on one side. **(Fig19)**

In the survey, the side-scan sonar was towed along a survey line about 350 meters off the remarkable spot at 90 to 100 meters above the sea bottom. A raw acoustic image data was acquired and there was a great reflection intensity observed. This was considered to be a ship. Also a shadow appeared, part of which reflected sound waves (prevented by the ship), it was observed that this object had a certain height.

**Fig.20** shows that the results of the image process (in which the shadow part was enhanced), and the aspect ratio was compensated in relation to the depth of the tow vehicle and the length of the shadow, it was estimated that the height of the object was approximately 15 meters. According to the towing speed, the length was between 130-140 meters and the result of towing on the other side indicated that the object was at a tilt in the direction of the west. In addition, based on the side view of the Tsushima-Maru, we studied the shape of the image and confirmed the unique figure (called "Mishima" type) and straight bow form. Thus, we had reached a conclusion by December 5, 1997, that this object must be the "Tsushimamsru" with its bow headed for the north.

Given a good search result obtained by the acoustic instruments, it was immediately determined to dispatch the R/V "Natsushima", the mother ship of an unmanned survey

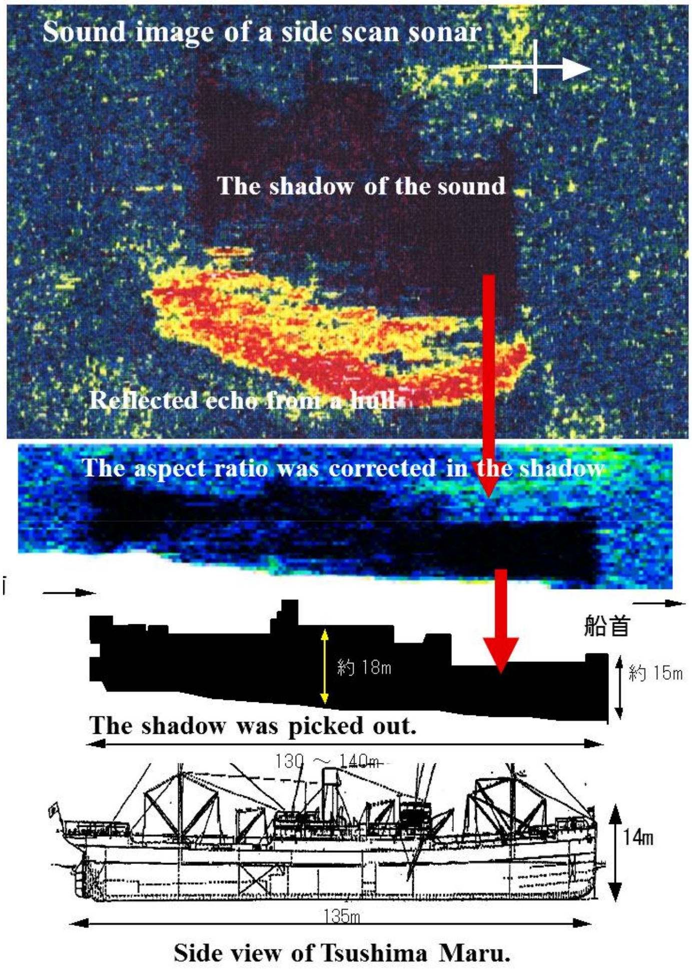



**Fig.20 Analysis result of the side scan sonar image**


**Fig.21 "Tsushimamaru" vessel name confirmation by ROV**

vehicle of the "Dolphin 3K" for visual observation, and an investigation of the ship body started on December 12.The location of the ship was already marked and through the use of the front-looking sonar the ship body was immediately found. The high-sensitive TV camera of the Dolphin3K approached the ship and succeeded in displaying the name of "Tsushima Maru" in old Chinese characters on the ship **(Fig21).** It was then identified that this ship was the "Tsushimamaru", which sank in 1944. Thus, we successfully accomplished the search work. Our experience in this search taught us the importance of a comprehensive and effective use of several kinds of sonars in achieving a successful and efficient search for an object on the sea bottom for which the exact location is not given such as an old sunken ship.

## 4. Fuselage search of H2 rocket which has fallen by trouble (1999)

### (1) Background of survey

The National Space Development Agency of Japan (NASDA present :JAXA) made launch of H2 rocket No.8 in November, 1999 **(Fig.22).** A main engine broke down just after the launch, so a rocket has been dropped by NASDA on a sea. NASDA has decided to collect a rocket for cause of breakdown explication. And JAMSTEC requested difficult search at a deep sea from NASDA. But we assumed that the work was very difficult. A reason is because an investigation area is very vast about 1,000 ㎢ **(Fig.23),** and the depth is very deep about 4,000 m and moreover the rocket which has fallen becomes dispersive. Multi beam echo sounder "SEABEAM 2112" of deep sea research ship R/V "Kairei" equipment investigated topography of the seabed in detail in search of the first time of November 19 - December 2 ,1999. The resolution of the "SEABEAM" by water depth 4,000m is 140m. Therefore we judged that it was difficult to find a rocket engine with several m of size from a research vessel on the sea. Therefore we have decided that all fall estimated area of sea is examined thoroughly by a deep tow side scan sonar **(Fig.24).**

**Fig.22 Lift-off of H2 rocket**

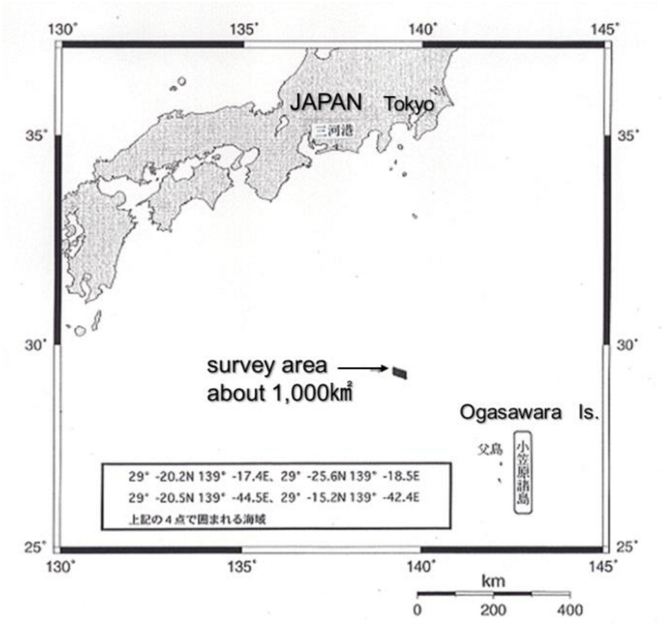



**Fig.23 Search area map of the fallen rocket (wide**

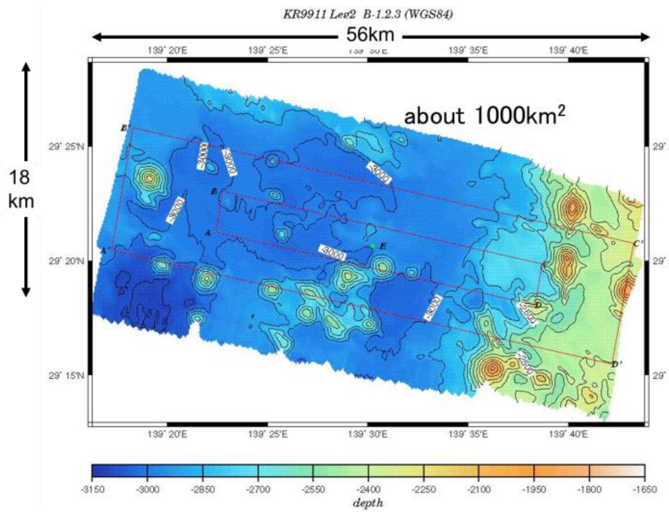



**Fig.24 Search area map of the follen rocket (details)**

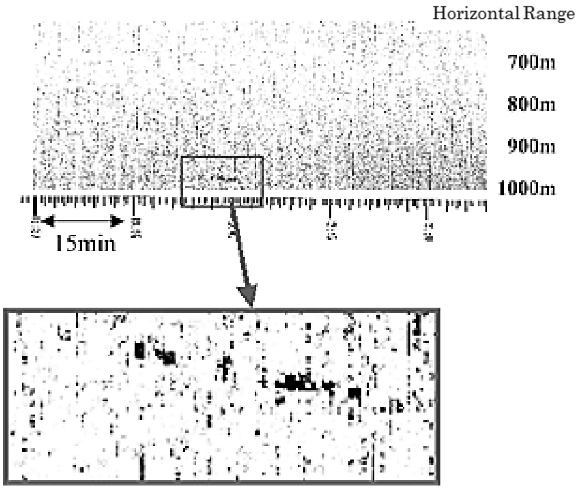



Fig.25 Discovery of a rocket engine by a side scan sonar (black dots)

**(2) Survey works**

We towed the height of the deep tow sonar (about 3 km of investigation width) into 100-200m with 1-2 knots of speed from the bottom of the sea while keeping it. About 2 weeks later, we found the medium reflection which was surrounded with a square of the sonar record shown on a **Fig.25** (black dots). After that a deep tow television system found many rocket parts including a certain hydraulic line of an engine part by water depth 3000m from these sound reflection. NASDA recalculated the fall location of the main engine based on these survey result. We expanded the investigation reach by the deep tow sonar and the deep tow television camera based on a re-calculation result. And at last, a deep tow television system found a main engine **(fFig.26)** at area of sea in about 380 km of northwest in Ogasawara-Island (water depth 2,917m) on December 24, 1999. After that the engine collected by ROV from the bottom **(Fig.27)** in the sea was analyzed by engineers of NASDA with a detailed investigation, and a cause of the accident was specified.

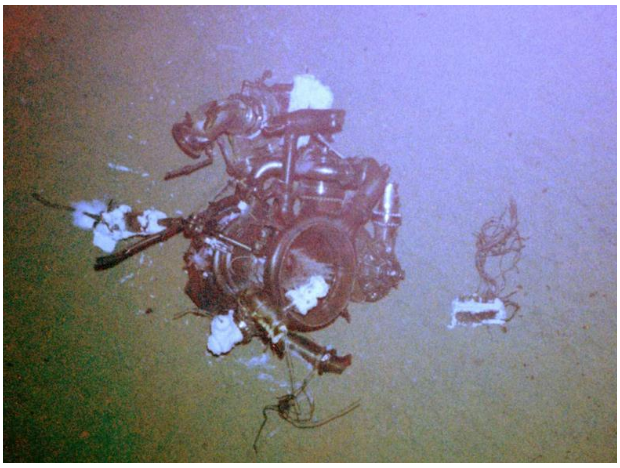


Fig.26 Discovery of a main engine by a deep tow television camera

Fig.27 The main engine drawn by ROV up on the board

**5. Other survey**

JAMSTEC introduced 2 of latest ROV for heavy work like **Fig. 28** which can dive to water depth 4,500m "Hyper-dolphin" in 2000, so the deep sea search ability became stronger.

Fig.28 The new ROV "Hyper-dolphin" for heavy work which can be evaded to 4500m

Investigation request of a lost article of a sunken ship also

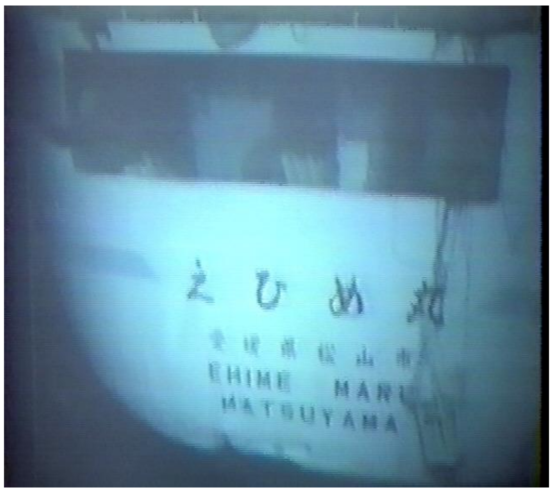


Fig.29 "Ehimemaru" of the sunken ship found at the sea bottom

Fig.30　Collection work of a memento by ROV

led to JAMSTEC after that. In 2001,"Ehime Maru" fishing training ship of Ehime fisheries high school which sank in (water depth 400-1,800m) by a collision with a U.S. Navy new clear submarine at the offing of Hawaii was investigated again(**Fig.29**). And

Fig.31　Sunken fishing boat "Seitokumaru"

a lot of mementos for which it was left by this investigation were collected (**Fig.30**), and these were delivered to the family of the deceased.

In 2008, Japanese Aegis destroyer of "ATAGO" Japan Self-Defense Forces and "Seitokumaru" fishing boat collided and two people died, and a fishing boat sank

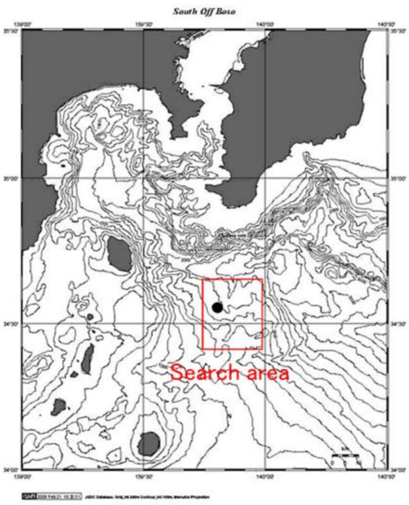



Fig.32　Survey area of a sunken fishing boat "Seitokumaru"

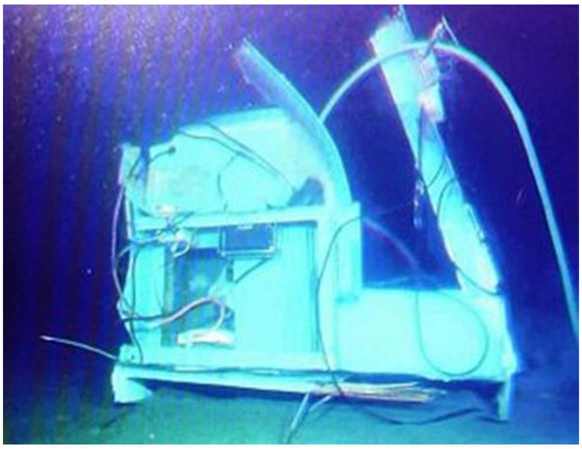


Fig.33　The part of the wheelhouse of "Maru of Seitoku" was found at the bottom. at the bottom

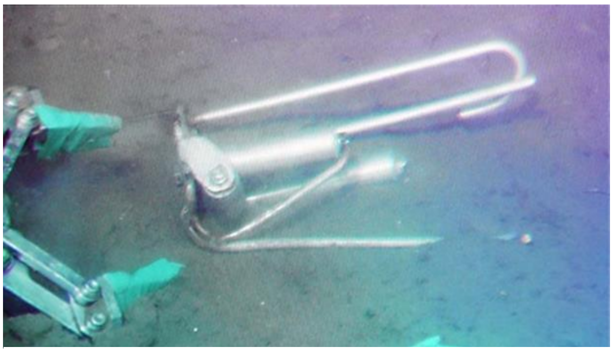


Fig.34　Collection of a part by "Hyperdolphin"

in water depth 1,800m (**Fig.31**). We searched for a sunken ship by area on **Fig.32** immediately by the reliance of Japan Self-Defense Forces, found the part of the ship hull in a wheelhouse (**Fig.33**) like figure 38 and collected many parts (**Fig.34**)

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## 5. Wide area survey in the 3.11 earthquake focal region

JAMSTEVC is investigating an abyssal floor in various areas for more than 30 years.

In 2011-2012, many research vessels, much ROV and submergence vehicle were used for an urgent investigation in a earthquake focal region of Tohoku-district Pacific offing earthquake on March 11, 2011 with many researchers. A large

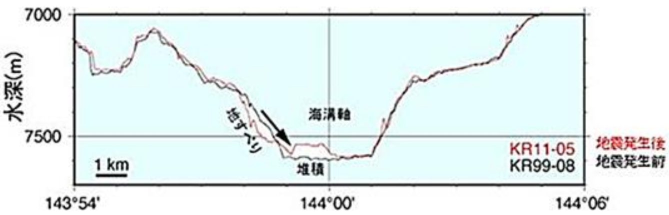


Fig.35　Topography of the seabed fluctuation comparison before (red line) and after (black line) an earthquake

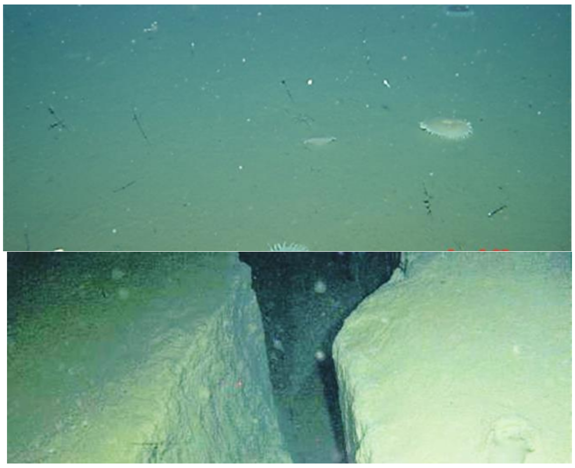

**Fig.36 The same bottom picture comparison taken in ROV Earthquake before (the top for 2006 years) after (the bottom for 2011 years) before and after an earthquake**

number of seafloor study went to us at a focal region in the past. Much in-depth submarine topographic map was made based on quite many depth sounding results, and enormous bottom picture and movie were also recorded. Therefore we could do a comparative study before and after a world's first earthquake by much data. After a topographical map before and after an earthquake was compared, the whole was also moving to 50m in east-southeast in the bottom around the focal region. The huge bottom landslides had occurred around the trench axis like **Fig.35**. Comparison of the bottom picture taken a picture of (**top of Fig .36** ) and a picture in 2011 (**bottom of Fig.36** ) showed that bottom circumstances have completely changed with a lot of new faults in 2011. For JAMSTEC also to check a developmental change at present, it's being investigated continually in detail at a focal region.

## 6. Future's development

I think the discovery technique by the research vessel, the deep tow, ROV and the manned submersible ship is established mostly already. But the latest machinery and materials of a deep sea exploration should be utilized most suitably like the investigation example introduced this time for an efficient investigation more quickly. It's important to utilize experience of the various search cases performed in the past. We'd like to correspond to future's resource-searching in EEZ and deep sea accident as quickly as possible. So I'm thinking main technology of search will be shifted to unmanned probing machine AUV with the artificial intelligence which doesn't use a mother ship like **Fig. 37** and grinds self-navigation from now on. We're developing new AUV with the various functions and are advancing the technical research which uses a lot of AUV at the same time for it

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**Fig.37 Concept of a wide area bottom investigation by much ROV**