Continental shelf survey of Japan

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Abstract

Japan conducted a very intensive, detailed, and high-quality geophysical/geological surveys, based on the "Basic Policy for the Continental Shelf Survey", participated by relevant government ministries, under the strong leadership of the Cabinet Secretariat. The outcome will not only be the basis of the Japanese submission for the extended continental shelf of UNCLOS, but also become the basis of the understanding of the evolution of the ocean bottom.

1. Outline of Japan

Japan is one of the island nations. It consists of four major islands and some 7,000 minor islands, scattered in its 4.5 million square kilometer Exclusive Economic Zone (EEZ), in which the deepest point reaches 9,780 meters. The country sits on 4 different major plates, i.e. the Eurasian Plate, the North American Plate, the Pacific Plate and the Philippine Sea Plate (Fig. 1).

In the Japanese EEZ, there are Kuril Trench, Japan Trench, Izu-Ogasawara Trench, Mariana Trench, Nansei-Shoto Trench, and Nankai Trough, which are all formed at the subducting boundaries of plates. At the triple junction of three plates, i.e. the North American Plate, the Philippines Sea Plate, and the Pacific Plate, located only some 200 km southeast of Tokyo, the capital of the country, dwelled by about a quarter of Japanese population, the depth is more than 9,000 meters.

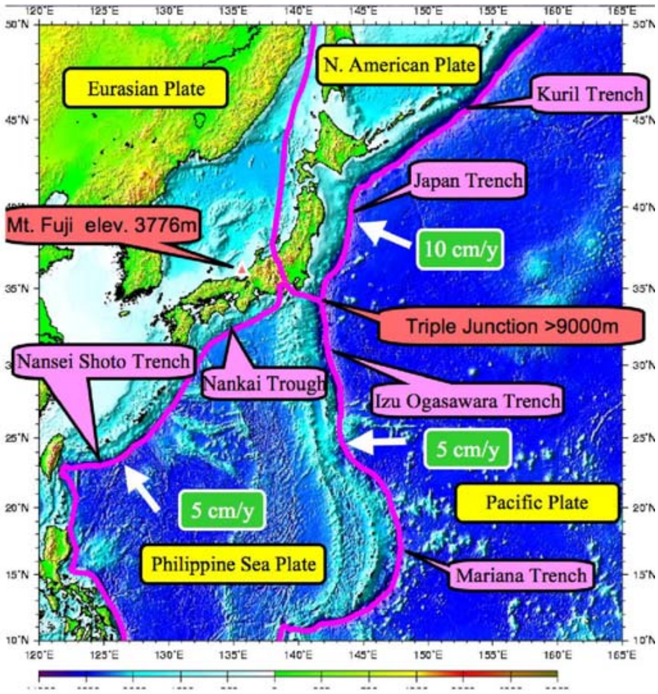

Fig. 1 Techtonic Setting around Japan

2. History of Bathymetric and Geophysical Surveys of Japan

Japan has a long history and experience, and deep know-how in bathymetric/geophysical surveys and charting, which has been led by the Japanese Hydrographic and Oceanographic Department (JHOD). The first scientific outcome was published as early as in 1925 as "Depths of the Adjacent Seas of Japan," compiled by Shinkichi Ogura, one of the real geniuses in JHOD history, who revised it in 1926 (Fig. 2). JHOD issued the revised edition as "Bathymetric Chart around Japan" in 1929 and 1936. GEBCO depicts the progress of the

Fig. 2 Bathymetric Chart of JHOD

understanding of the sea bottom off Japan as seen in its first edition to the fifth edition (Figures 3 to 6). In 1971, JHOD published a relief bathymetric chart of adjacent seas of Japan (Fig. 7). This is believed to be the first relief bathymetric chart in the world.

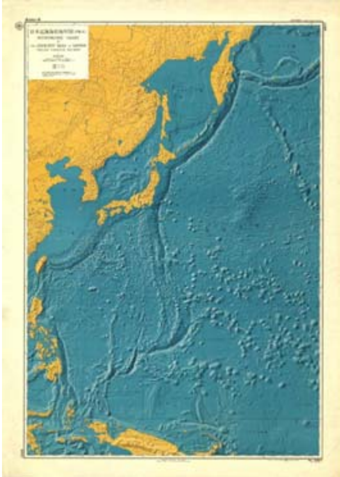

Fig. 7 Relief Bathymetric Chart

Fig. 3 GEBCO Ed.1

Fig. 4 GEBCO Ed.2

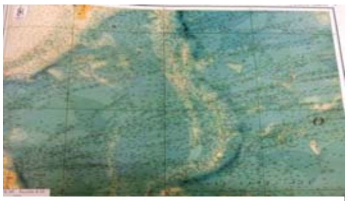

Fig. 5 GEBCO Ed.3

Fig. 6 GEBCO Ed.5

JHOD started its continental shelf surveys for the compilation of the “Basic Map of the Continental Shelf” series, at a scale of 1:200,000, in 1968. The survey included single beam bathymetry, surface gravimetry, geomagnetism, and single channel seismic surveys, at the track interval of 2NM, with bottom samplings. JHOD also started other series of geophysical surveys. One of those is the survey for the “Basic Map of the Coastal Sea” series at a scale of 1:50,000 (Fig. 8.), which included single beam bathymetry and single channel seismic surveys. New series of the Basic Map of the Continental Shelf is also published at a scale of 1:500,000 (Fig. 8.) Compiled bathymetric charts published by JHOD without having dedicated survey programs include those at the scale of 1:1,000,000 (Fig. 10) and 1:3,000,000 (Fig. 11), other than GEBCO plotting sheets of 1:1,000,000, which are also published.

Fig. 8 Suruga-Bay 1:50k

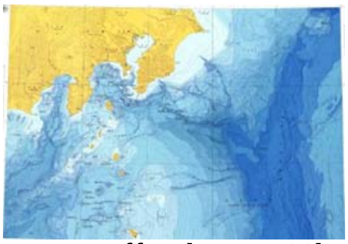

Fig. 9 Off Tokyo 1:500k

In 1984, JHOD dispatched S/V TAKUYO for its first WESTPAC cruise, in which she conducted a performance test of the Sea Beam system by measuring the deepest point of the world at Challenger Deep of Mariana Trench, which was the world first multibeam survey at Challenger Deep. With sound velocity corrected by combination of in situ CTD record down to 6,000 meters and statistical temperature/salinity data below the depth, the deepest point was identified to be 10,924 meters with 10-meter uncertainty. The value was adopted by GEBCO, which modified the then world deepest depth of 11,034 meters reported by Vityaz, to 10,920 meters.

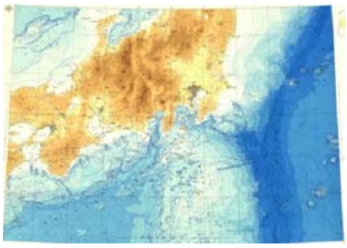

Fig. 10 SE Japan 1:1M

3. UNCLOS Related Surveys

In order to match the new paradigm projected by UNCLOS, there were several scientific challenges for Japan. One of the challenges was the geodetic system. Japan adopted Tokyo Datum, which based on Bessel ellipsoid with its base point determined by celestial observation in Tokyo. As described above, there are deep trenches not too far from Tokyo, combined with complicated geology beneath Tokyo attracted the plumb line other than the center of the earth. Because of this plumb line deviation at Tokyo Observatory, the reference

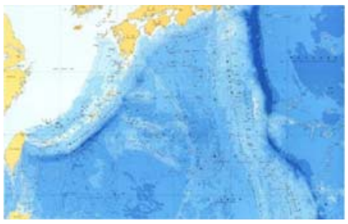

Fig. 11 SW Japan 1:3M

point was observed to be 13 arc seconds south and east respectively from which it should have been. Wrong referential ellipsoid and the deviated reference point led the deviation of Tokyo Datum from WGS 84 in Japanese EEZ to some 300 to 600 meters. Furthermore, coordinates of most of the isolated islands were based on the in situ celestial observations, and because of the nature of most of these islands, which stood thousand of meters from the sea floor, above mentioned plumb line deviation was an inevitable component of the measurements. In some cases the positions were deviated by a mile from it should have been. Deviation of horizontal datum of a nautical chart from that of a positioning device such as a GPS receiver was an immediate threat to the safety of navigation, and of course a major problem in delineation and delimitation of the outer limit or boundary of nation's maritime jurisdiction. JHOD started the satellite laser ranging at Shimosato Station in 1982 in order to precisely determine its location in terms of ITRF framework. For about 100 isolated islands, JHOD conducted geodetic surveys using NNSS and GPS, combined with satellite laser ranging for key islands, using a proprietary portable precise satellite laser ranging device since 1986.

Based on these survey results along with the VLBI outcome obtained by Geographical Survey Institute of Japan, Japan altered its national geodetic datum from Tokyo Datum to WGS84, by amending the Survey Law and the Hydrographic Law, in 2002. All the Japanese nautical charts of some 900 hundreds were replaced by WGS84 chart series in a couple of years and completed by the enforcement of the amendment.

Another challenge includes the survey of normal baselines for territorial waters. As prescribed in the Article 5 of the UNCLOS, the normal baseline for measuring the breadth of the territorial sea, the exclusive economic zone, etc. is the low-water line along the coast as marked on large-scale charts officially recognized by the coastal State. Nautical charts are subjective maps, and published for the purpose of navigation. Depending on the ship traffic and terrain condition, a "largest-scale chart" available for a particular area may be at the scale of 1:1,000,000, in which one millimeter on the chart has a value of one kilometer or 0.55 nautical miles in the real world. As the hydrographic survey requirements reflect the chart to be published, data spacing of the hydrographic data for the smaller scale charts is normally proportional to the scale of the chart for the area. One of the purposes of the Basic Maps of the Coast was to obtain reliable, precise, and uniform quality information on the low water line at the scale of 1:50,000, nation wide. The first stage of refreshing and modernizing the low water line was completed in late 1990s, after a quarter-of-a-century-long project. As newer technologies such as better positioning, acoustic swath echo sounding and bathymetric lidar technologies allow to obtain much more detailed and more precise location of low water lines in quicker manner, the refreshment of baseline information is still an ongoing project for Japan.

Delineation of the outer edge of the legal continental shelf beyond 200 NM from the territorial sea baseline (hereafter "extended continental shelf") was another UNCLOS challenge to Japan. As described above, JHOD had a long history and in depth expertise in bathymetric and geophysical surveys and charting. Based on its experience in surveys and its scientific knowledge for the adjacent seas of Japan, JHOD was granted to build a new survey vessel in 1981 for the purpose of the delineation of the extended continental shelf and also for other scientific and practical purposes such as plate tectonics study, study of earthquake mechanism, and the safety of navigation. A 2600-ton survey ship was launched in 1983, and named TAKUYO, which meant "pioneering the ocean."

She was the first survey ship in Japan which was equipped with a multibeam echo sounder. She was also equipped with the multichannel seismic survey system, the heat flow gauge, the integrated positioning system, the onboard rubidium clock for ρ-ρ positioning, to name a few. The ship was also equipped with two of the survey crafts which made her possible to pursue shallower area surveys including offshore shoals, and coast and ports/harbours at remote islands. In order to supply fresh vegetables during 40-day cruise of UNCLOS surveys, she was equipped with bean sprout farm, as well.

As a part of the outcome of its initial test cruise, a detailed bathymetric map of Daiichi Kashima Seamount, which was split in two at the Japan Trench on subducting beneath Honshu Island with 1300 meters of vertical displacement, was produced, and the location and the depth of the deepest point of Japan trench was identified, based on a full swath multibean survey. These results clearly demonstrated the apparent advantage of multi-narrow-beam echo sounding in bathymetric surveys especially at steep slopes and rugged terrain. In these topography records obtained by a conventional echo sounder was covered by fake bottoms, or hyperbolic echoes, and could not show the real shape or depth. The area had been surveyed by another JHOD survey vessel four years before the TAKUYO's survey using a 12 kHz conventional echo sounder for the purpose of producing one of the Basic Map of the Continental Shelf, and it was identified that the previously known Daiichi Kashima Seamount had been split into two, making itself the direct testimony of plate motion and plate subduction. However the survey result could only show that the seamount was split into two but not clearly show the vivid shape of the splitting fault. The Challenger Deep campaign mentioned above took place in early 1984, several months after the cruise of the Daiichi Kashima Seamount.

4. The First Stage of the Japanese Continental Shelf Survey for the Purpose of Art. 76 of UNCLOS

In 1983, when JHOD started the continental shelf surveys for the purpose of the UNCLOS article 76, there was no annotation, or even a sign or indication or smelling of the requirement or necessary specification for the UNCLOS survey. Based on the success of the 1:200,000 bathymetric, geophysical and geological survey series, JHOD decided to apply the same scheme for the UNCLOS survey with some improvements. The next question was the scale. At that moment, no one had any idea as to when the Convention would come into force by the ratification or accession of the 60th country as prescribed in the article 308 of the Convention, and when Japan would ratify the Convention. JHOD assumed that Japan would have 16 years, or in 6 years the Convention would come into force and additional 10 years would be given according to the article 4 of the Annex II to the Convention. Based on this given time, the survey plan was designed. The area of potential extension of the continental shelf was sought, and the total track length achievable in 16 years devided the area. This calculation gave 5 NM separation of track line spacing. From the experience of the 1:200,000 chart series, the chart scale for UNCLOS was selected to be 1:500,000 based on the 5 NM track interval survey. As for the scale, taking account of the extent of the potential extended continental shelves and the sea bottom features to be described, the scale of 1:500,000 was thought to be appropriate as well.

Track line separation of 5NMs was welcomed by geophysicists in charge of analysis of the surface gravity and geomagnetism. As for the bathymetry however, with 5NM at the typical depth of Philippine Sea and Pacific Plate of 4000 to 6000 meters, the ensonified area could only reach 30 to 40 percent of a given survey block, by the first generation of SeaBeam System with 16 beams and 42 degrees of swath angle. Multibeam echo sounder data was of course a much improvement even a 1/3 coverage of comb shaped strips compared to the profile data provided by a conventional echo sounder because even it was only one third of the area, it did provide multibeam strips, which indicated the athwartships tendency of topography, and of course it did no include any hyperbolic effect thanks to finer beam angles. However, because of the very complex sea bottom topography around Japan, scientists in charge of bathymetry were required hard work to draw contour lines between the multibeam strips or where multibeam bathymetry was not available. Along with the technical improvement of commercially available multibeam echo sounders, JHOD replaced the SeaBeam system with SeaBeam 2000, which largely contributed to the improvement of the ratio of ensonified area, and then moved to SeaBeam 2100. In year 2001 it was decided to design survey plans to obtain 100 ensonification in a survey block, and some of the survey blocks with poor to medium ensonification were to be resurveyed. An example is shown in Fig. 12 to 14. The initial survey outcome (Fig. 12 (a)) and its supporting foot prints, (Fig. 12 (b)), the redone survey outcome (Fig. 14 (a)) and its supporting foot prints (Fig. 14 (b)), and the depth difference of Fig.12 (a) - Fig. 14 (a) are shown. In some cases the depth difference exceeded 2000 meters by skipping the ensonification of the summit of a huge seamount.

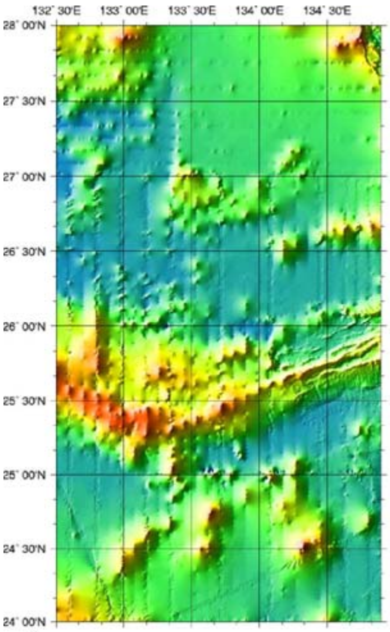

Fig. 12 (a)
bathymetric chart of 1985

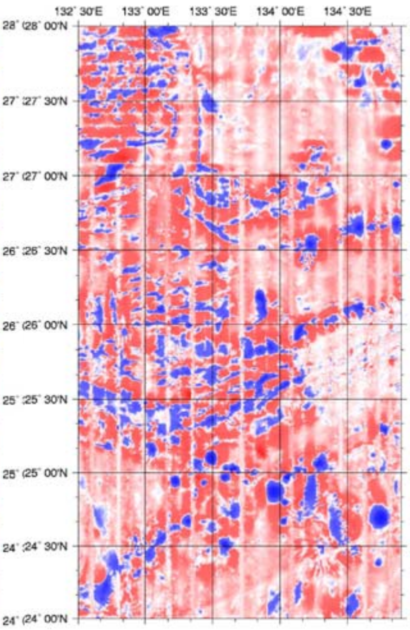

Fig. 13 depth difference
between Figs. 12 and 14 (a)

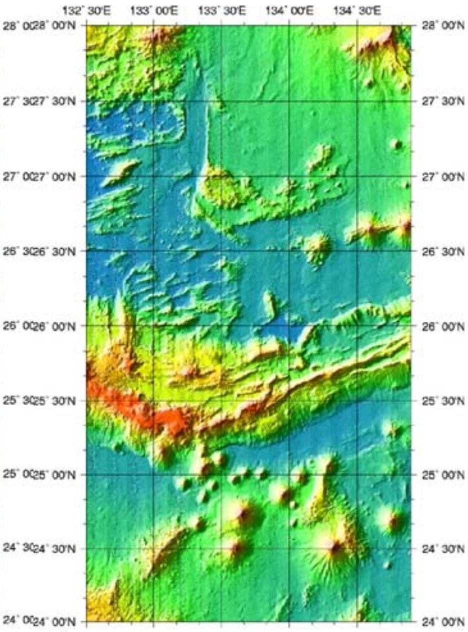

Fig. 14 (a)
bathymetric chart of 2002

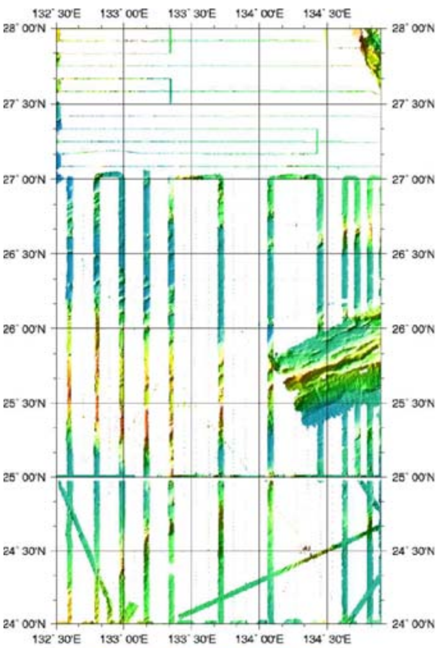

Fig. 12 (B) ensonified area
for the chart Fig. 12 (A)

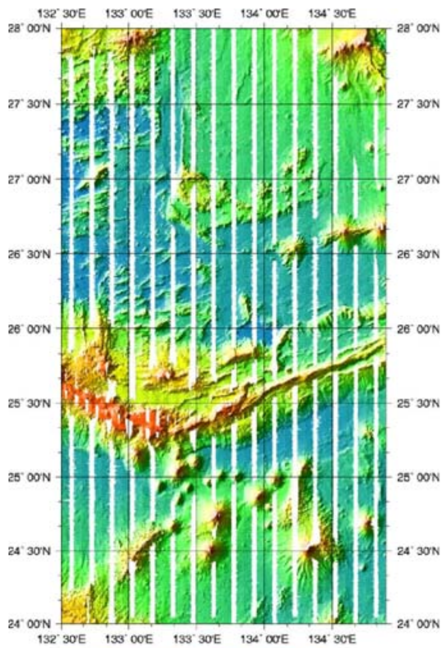

Fig. 14 (B) ensonified area
for the chart Fig. 14 (A)

5. The Second Stage of the Japanese Continental Shelf Survey for the Purpose of Art. 76 of UNCLOS

There were two major problems in the continental shelf survey conducted by JHOD, when its survey came close to the completion of its original program. The first problem was that the survey was an isolated program of JHOD and was not necessarily recognized by the entire government. JHOD did not have any idea how to proceed to make submission after it completed the survey, such as how to proceed to get the approval of Cabinet. The other problem was the Scientific and Technical Guidelines of the CLCS (STG) issued in 1999. The issuance of the STG itself was not a problem at all, rather it was welcomed as it gave JHOD a more definite idea of the necessary survey specifications. However the necessity to identify the ocean continent boundary or continental-oceanic transitional (COT) zone as described in 6.3 of the STG was identified as a major challenge. Because of the geological setting and the evolution of the sea bottom around Japan, identification of COT was felt inevitable. As one can easily imagine, identification of COT requires time, money, tool, and expertise. JHOD, as an office to provide information for the safety of navigation, had a decent experience in seismic refraction/reflection surveys for the purpose of monitoring active sea bottom volcanism and locating active faults, its manpower, ship time and the budget would not allow JHOD to complete the mission by 2009. A simple calculation indicated that it would need 100 years to complete the necessary refraction surveys under the same budgetary condition.

A break through was brought when JHOD hosted GEBCO meetings in 2001. After the meetings, JHOD provided a press release on GEBCO meetings with the fact that the numerous newly named seamounts are found during the continental shelf surveys. Some of the newspaper companies were interested and not only the GEBCO articles came out but UNCLOS survey project was introduced in a couple of major newspapers. The really good luck was one of the newspapers was the very newspaper the Minister responsible for JHOD was subscribing. And another luck was that she was a powerful politician. She requested to brief what was happening. She immediately reported to the Chief Cabinet Secretary and he decided to establish the Interministerial Committee for the Continental Shelf (ICSS), to bring the matter to the Cabinet level.

The second wave, again, was triggered by a newspaper article, introducing the dreamable value of the sea bottom minerals expected on the extended continental shelf. This time the Secretary General of the governing party requested to brief what it was. He immediately took an action that the matter be listened to by the Prime Minister. Right after this, in the National Diet there was a question to the Prime Minister how he would handle the continental shelf issue. He replied crystal clearly that he was for it. His this answer changed the budgetary situation, and it was decided to allocate scores of billion yen was to be allocated to the extended continental shelf program. He also ordered to establish the Coordinating Office for Continental Shelf Surveys (COCCS) in the Cabinet Secretariat. In December 2008, COCSS, the first ocean related office in Japanese Cabinet Secretariat was established, and some 52 billion yen (500 million USD) survey plan was granted.

From the political side the Legislators Union for the Promotion of Continental Shelf Surveys, which was participated by major portion of the governing party was established as well, and from the industrial side the Nippon Keidanren (Japan Business Federation) (JBF) promised to unify the industry to provide necessary support for the continental shelf survey, responding the request from the Cabinet Secretariat. Nippon Foundation, an independent non-profit, non-governmental organization generously offered any supports which the government might or could not provide, through its subsidiary body, the Ocean Policy Research Foundation.

Once the Cabinet, the ruling party, the mass media, the industry, and NPO/NGO support a program of any kind, it becomes really strong.

The Evaluation and Advisory Board (EAB) was established in the Cabinet Secretariat, participated by professors and scientists in the field of the ocean law, marine geology and geophysics. EAB proposed a detailed survey specifications, which was accepted by the ICSS as the Basic Policy for the Continental Shelf Survey (BPCSS), which resulted in funding of 52 billion yen in five years.

Under the BPCSS, bathymetric, gravimetric and geomagnetic surveys were to be conducted by JHOD, refraction and reflection seismic surveys by JHOD and Japan Agency for Marine-Earth Science and Technology (JAMSTEC), and bottom sampling using boring and dredging technique by Japan Oil, Gas and Metals National Corporation (JOGMEC). However it was obvious that the ship time of JHOD and JAMSTEC would not allow the seismic portion of the BPCSS requirements be fulfilled in time for the then dead line of May 2009. With the cooperation of JBF, a special purpose company was established participated by major marine construction companies and survey companies. The company obtained a seismic vessel with a 8000 ci tuned air gun array and 6000-meter streamer cables. For the refraction survey JHOD tendered ocean bottom seismometers and Tokyo Sokushin was granted by newly designed OBSs. Some 800 OBSs were procured. The OBS was found to be really dependable, by almost 99 percent was retrieved out of some 6000 deployments and the lost OBS were mostly deployed at most hostile condition of near or below 6000 meter.

Under the ICSS, eight ministries cooperatively worked together for surveys and compilation of submission documents, controlled and coordinated by the Cabinet Secretariat. 610 thousand nautical miles of track line geophysical survey, 290 thousand nautical miles of reflection survey, out of which 22 thousand nautical miles of multichannel seismic survey, and 20 thousand nautical miles of refraction survey using about 900 OBSs with 6,573 deployments, and 470 core samplings using Benthic Multi-core System (BMS) to dril 2313 meters in total, were successfully completed by the end of June 2008. Total ship time amounts to 7845 days with 321,456 person engaged on board.

In the course of comprehensive continental shelf survey, scientific findings have been made, such as the development history of Philippine Sea Plate, ultra-mafic rocks dredged at the mega-mullion structure in the Philippine Sea, development system of continental crust out of subduction plate, crustal structure of seamounts, to name a few.

Significant survey tracks of refraction/reflection seismic surveys and bottom samples allowed to shed light on the evolution of the island arc system. Subduction of oceanic plates with water will eventually produce continental crust, the mechanism of which is named Subduction Factory. Mega mullion was found in the Philippine Sea, where mantle substances were dredged. The mega mullion is a similar structure as those found around the Mid Atlantic Ridge but much larger in scale.

5. Conclusion and recommendations

Article 76 of UNCLOS has posed a difficult question, especially topographically and geologically mixed up areas such as adjacent seas of Japan. Some good lucks, deep and the understanding of the matter and its importance by politicians and other sectors have made Japan possible to execute some 500 million USD program for the surveys for the extended continental shelves. Of course the outcome will be crystallized to perfection as the submission but the data is and will benefit the scientific community, whose outcome may benefit the resource community as well.

As the dead line has virtually taken away, many countries, said to be some 60 more, which have potential to extend its continental shelves. It is apparent that coordinated effort of entire country is inevitable. In order to make this happen, political understanding is a must, which may be obtained through articles and broadcastings of mass media. Easy to understand and crystal clear message from survey experts can only make this happen. Good luck to everybody who are on the way.