A BASIC MAP OF THE SEA AT THE SCALE OF 1/200 000

by Kiyoshi KAWAKAMI, D. Sc.
Chief Hydrographer of Japan

Introduction

In March and April 1969 the Japanese Hydrographic Department published as an initial step two sets of charts in the Basic Map of the Sea series. These sets are the charts 6328 — Bathymetric Chart for West of Akita, together with the complementary 6328M — Total Magnetic Intensity Chart, and 6328S — Submarine Structural Chart, covering the same area, and similarly the charts 6329, 6329M and 6329S for the Approaches to Mogami Tai in the Sea of Japan. The author wishes to offer some explanations about this new map series as well as a geomorphological and geophysical analysis of the bottom of the Sea of Japan on the basis of the published Maps.

Up to the present the Japanese Hydrographic Department has published nearly a score of different bathymetric charts, but none was based on a systematic survey and compilation conceived with the sole purpose of the making of a bathymetric chart. Since these bathymetric charts were merely prepared from bathymetric data obtained during surveys that differed not only as to methods, but also as to date, they contained when produced at larger scales many inconsistencies in the information charted, although this did not matter so much in the case of smaller scale charts.

It is to be particularly noted that the Japanese Hydrographic Department's surveys have been carried out primarily for the purpose of compiling classical nautical charts. Accordingly, in view of the fact that accurate portrayal of the deeper portions of the sea is of less significance with respect to the draught of vessels, these areas have been surveyed with sounding tracks more widely spaced, and no survey plan for closely representing the submarine topography on charts has as yet been worked out.

In the meantime, at the 9th International Hydrographic Conference in 1967, Canada proposed that in IHB Technical Resolution B 188 the wording adopted at the 6th Conference in 1952 "It is recommended that the number of soundings of great depths on nautical charts be strictly limited" be amended to read "It is recommended that the number of soundings on nautical charts in depths greater than 200 metres be limited only by the requirements of good cartography". In its explanatory note Canada pointed out that "nautical charts should portray as much bathymetric information as possible, consistent with good cartography, in order to assist the navigator to the greatest extent when he has the use of modern, deep-sea echo-sounders", and "every deep sounding may be useful to him in the evaluation of his position under adverse atmospherical radioelectric conditions".

The Member States of the IHB expressed their support and the proposal was adopted almost unanimously, but with the wording slightly modified to read "It is recommended that the number of soundings on nautical charts be limited only by the requirements of good cartography and modern navigation".

This fact indicates that during the short period of 15 years developments in sounding devices have made it possible to consider submarine topography as "an object useful in geo-navigation".

Furthermore, when considering future uses of atomic power, it can be envisaged that with the possible advent of merchant fleets designed to proceed underwater (thus avoiding rough surface seas) the precise portrayal of submarine topography on nautical charts would become a necessity.

On the other hand, more precise data on the topography and structure of the sea bottom is already required as a result of the recent progress in oceanography and geophysics. The development and improvement of instrumentation and techniques have made it possible to meet these requirements. Furthermore, in an age when the sea bottom is an object for exploitation, detailed maps of the submarine topography are being demanded. Taking as examples the exploitation of submarine fishing grounds, mining of submarine mineral resources, digging of submarine tunnels, or the laying of submarine cables, it becomes clear that all these works need full knowledge of submarine topographic and structural conditions.

In order to cope with this situation, the Japanese Hydrographic Department worked out a scheme to produce a detailed Basic Map of the Sea for waters around Japan, and the work was started in 1967. The first phase of the scheme is scheduled to be completed by 1975. The second phase will then be entered during which the coverage of the Map series will be extended to include off-lying regions. Figure 1 shows the first phase of the scheme.

For a proper comprehension of submarine topography it is necessary to grasp correctly not only the configuration of the bottom but also its constituent materials and its structure. Moreover, taking into account the degree of accuracy of position fixing for survey ships there must be room for some doubt when discussing the correlations between the different kinds of charted information if the indispensable bathymetric surveys and geophysical observations (such as geomagnetic surveys, geological surveys, gravity measurements and heat-flow measurements) have each been conducted separately. In addition if the spacing of track lines is several tens of miles or even several hundred miles, there would be much risk — even

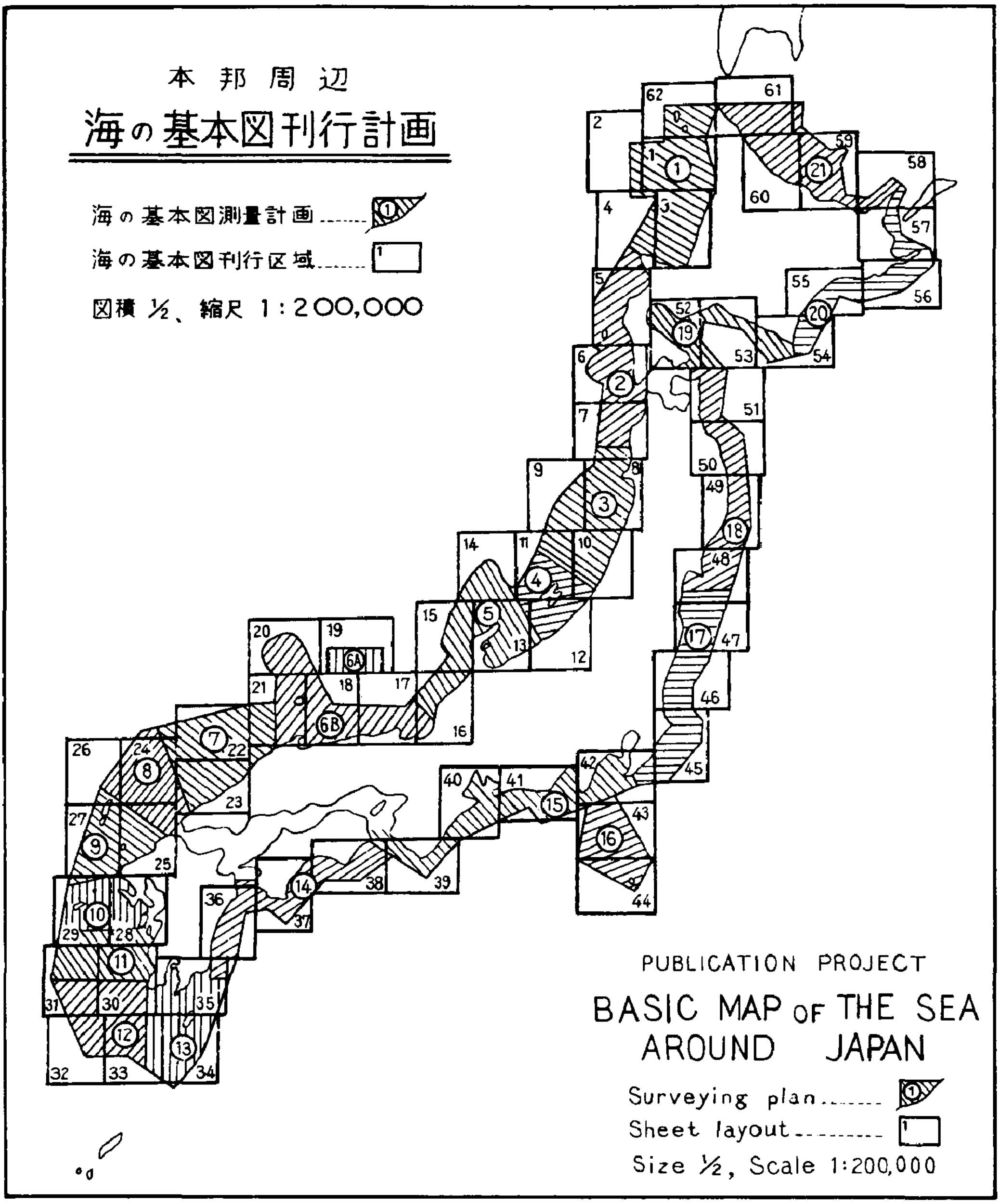


FIG. 1

though there might have been no errors in the soundings themselves — in giving generalized information on bathymetry over the whole area concerned, giving the impression that this had been exhaustively surveyed.

In order to solve these problems, it will be necessary to carry out a bathymetric survey in the area in question with sufficiently closely spaced tracks, and to undertake simultaneously the other necessary surveys and measurements.

On the basis of these considerations it was decided that the Basic Map of the Sea should consist of four different topical maps : (1) a bathymetric chart showing the bathymetric information obtained with a precision depth recorder (PDR) in the form of isobaths; (2) a submarine structural chart showing the positions of faults, anticlines, and synclines, as well as the configuration of the basement, obtained from the records of an air-gun type seismic profiler; (3) a total magnetic intensity chart showing the total magnetic intensity by means of isodynamic lines at 50-gamma intervals, using the results of a survey with a ship-towed proton magnetometer; and (4) a gravity anomaly chart on which is expressed in equal difference curves the difference between the local standard and the observed gravity values, the Tokyo Surface Ship Gravity Meter being employed for these measurements. Each of the charts is to be at the scale of 1/200 000, 63 × 46 cm in dimensions, and thus half the size of an ordinary nautical chart.

As to the projection, the Lambert conformal conic projection has been adopted so that the true sizes and configurations can be represented, and to allow for accurate butt-jointing with adjacent maps of the series as well as with land maps which are at this same scale.

The scale of 1/200 000 was decided upon on the basis of the accuracy attainable in ship's position fixing. At the present time, the most accurate position fixing methods utilizable throughout the whole region are the three-point fix method, where suitable landmarks are available, and, where there are no landmarks, the Loran A method. Regarding the accuracy of Loran A, measurements made with chains 2S3 (Matsumae-Niigata) and 2S4 (Niigata-Miho) were both of the order of ± 4 microseconds in the Akita offshore area, and this led us to the conclusion that the 1/200 000 scale was the largest practical scale because it had to be considered that errors of up to 2 000 metres in position fixes might occur.

As to the spacing of sounding lines, it was considered that it might be too risky to give a bathymetric assessment of the area using data obtained from widely separated sounding lines. On the contrary, however, too narrow spacing would be meaningless, taking into account the relative accuracy of position fixing. Consequently the sounding line interval was fixed at two miles on the continental shelf and four miles in the areas beyond.

A study of the dimensions of geological structures represented on the 1/200 000 land maps revealed that even the smallest is larger than 4 kilometres. It could therefore be concluded that a two-mile spacing at sea would be appropriate from the viewpoint of comparisons with land forms. The direction of sounding lines was selected so that as far as possible they would cross at right angles the expected direction of the topographic and structural features.

The disposition of various instruments used for the survey is illustrated in figure 2.

There was a distance of 225 m between the echo-sounder and the proton magnetometer's sensor unit, this being the longest separation between instruments. This distance is 1.1 mm on a 1/200 000 chart. Thus even employing these two instruments with this separation, one can regard their measurements having been made effectively from one and the same point.

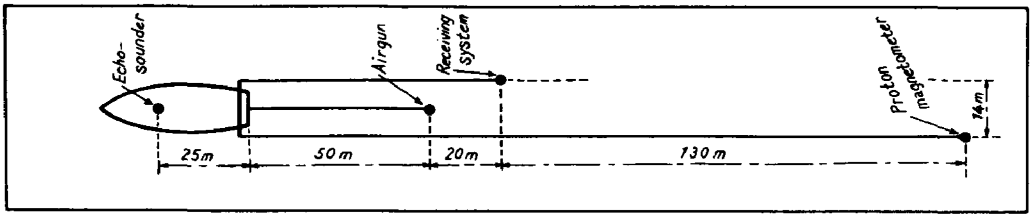


FIG. 2

TABLE 1

Particulars of echo-sounders

Item \ Type	Shallow water type	Mid to deep water type (PDR)
Max. sounding range	100 kHz : 500 m , 18 kHz : 2000 m	12000 m
Accuracy	(shallow) ± (0.1 + depth × 1/1000) m (deep) ± (0.5 + depth × 1/1000) m	± 1 × 10^{-6} (= accuracy of frequency of synchronized electric source)
Recording system	Linear recording	Linear recording
Recording range	(s) 40 m , (d) 200 m	0- 1000 m , 0-6000 m , 0-12000 m
Paper speed	(s) 400 mm/min , (d) 8 mm/min	12 mm/min , 2 m/min , 1 m/min
Paper	Electric spark marking. Width 300 mm ; length 20 m	Electric spark marking. Width 486 mm ; length 100 m

Bathymetric chart

Soundings were carried out with shallow water type and mid to deep water type echo-sounders whose characteristics are shown in table 1. Corrections for the speed of sound in sea water were made to the closest metre for soundings of less than 1 000 metres, and to the closest 10 metres for deeper soundings. Regarding the data for calculation of these corrections, use was made of the data obtained during oceanographic observations conducted at an earlier date in the same area and at the same season of the year. Tidal corrections were not made because the isobaths were to be drawn for depths of 20 metres and more. When preparing the bathymetric chart the isobaths to represent the bottom topography were drawn at depth intervals of every 20 metres down to a depth of 200 metres, and every 100 metres for the deeper areas. For the delineation of isobaths bottom topography profiles were first drawn along every track and, using these as basis, isobath outlines were determined and confirmed by analyzing the continuation of valley lines to summit lines and the transition points of slopes. Then, in order to position the isobaths, points were selected on echograms at the depth intervals chosen for representation mentioned above. Then reading the time for each of these points, they were plotted on a chart by interpolation with reference to the time of sounding fixes. This method was employed for the first time since it was considered to be more accurate than the conventional method formerly used in oceanic surveys, where soundings were read with reference to the time interval and the isobaths were then drawn by interpolation of the charted distance between sounding positions.

Of the data which had been previously acquired, only those data whose positions were fixed by means of three point fixes or by Loran A were adopted as basic data. Data positioned by astronomical observation or by dead reckoning were not utilized. When there was any uncertainty in interpreting the topography the seismic profiler records were used for reference.

Submarine structural chart

A seismic profiler of the air-gun type was employed for the survey of the geological structure.

TABLE 2

Particulars of air-gun type seismic profiler

Surveying range	About 1 sec below the bottom of the sea
Recording system	Linear recording
Recording range	0-1 sec, 0-3 sec, 0-6 sec
Paper speed	15.70 m/hour at 0-3 sec
Filter band frequency	37.5-19.200 Hz. Selective in 19 phases
Signal delay set time	0-10 sec. Selective at 1-second intervals

The air-gun unit was towed about 70 metres astern of the survey vessel. The airgun's frequency of sound was low, falling between less than 100 and up to several hundred Hz.

When reading the records, the following basic considerations were taken into account.

(1) The record of any surface always appears on the recording paper as two parallel lines, the upper giving the true information. This is because the towed air-gun runs at a depth of about 3.5 metres below the surface, so that the sound it emits takes two routes to reach the receiver, one being directly reflected from the bottom whilst the other first reaches the surface, travels thence to the bottom and finally to the receiver. There is a resulting interval of 0.01 second between the two parallel lines.

(2) The reason why a number of signal marks appear below the emitted sound line is that the air-gun blast is not a single one but is accompanied by the so-called "bubble effect". When setting T.V.G., the marks with a delay of 0.05 second are particularly prominent, and from this it can be reckoned that the second blast will occur 0.05 second after the first. This phenomenon always appears in cases of sound reflected from the bottom, but it is of no help in the study of geological structures.
(3) Of the number of parallel lines recorded, the uppermost one can be considered to give the true information, indicating the trend of the layers. The others may, or may not, give true information because if multiple layers exist many reflections between these layers may be recorded, and thus it becomes impossible to distinguish the true information from the secondary or the tertiary reflections.

In order to make an analysis of the submarine structure from the records of a seismic profiler, a continuous profile was drawn along each track and comparison was made with the corresponding echogram. The discontinuity between rocky basement and sediments was considered as being a fault, and its strike was identified. Anticlines and synclines of folds were also observed on the records.

The most conspicuous interfaces appearing on the seismic profiler record were where the bottom was composed of layers of sediment. Considering the portion below the bottom as a basement, its relief was read on the record and was then represented in contours. In addition to this faults, anticlines, and synclines read from the record were superimposed on the chart, and in this manner the chart of the submarine structure was prepared.

In this work the values are merely those related to speed of sound. Since the speed of sound propagation in sediments has not been fully ascertained, it is impossible to be certain of the absolute value of the depth of the sediments. Assuming, however, that this speed may not be so different from speed through sea water, a rough estimate of depth can be obtained by multiplying the travel time value by 750 (metres).

Total magnetic intensity chart

Total magnetic intensity was measured by using a ship-towed proton magnetometer. In order to reduce the effect of the ship's magnetic field, the sensor unit for the proton magnetometer was towed approximately 200 metres astern.

Measurements were made, usually at one minute intervals, but where extraordinary values were being obtained the interval was shortened to 10 seconds. Corrections were made to the observed values by comparison with diurnal variations for the same period observed at the Kanozan Geodetic Observatory.

As the measurement accuracy of the proton magnetometer was $\pm$ 10 gammas, the results obtained were represented by isodynamic lines at 50-gamma intervals.

Gravity anomaly chart

Since gravity measurements started after the other surveys, and because data processing is taking a good deal of time, the gravity anomaly chart has not yet been published.

The Tokyo Surface Ship Gravity Meter developed at the University of Tokyo was employed for these measurements.

The chart will show the free-air gravity anomaly obtained by subtracting the standard gravity values from the observed values, the necessary corrections having been made to the latter.

Basic Map of the Sea and analysis of charted information

The Basic Map's strongest characteristic is that it shows the results of simultaneous bathymetric and geophysical surveys carried out on closely spaced soundings lines in order to represent information on the survey area as accurately as possible, thus making possible a comprehensive portrayal of the locality. The Map offers sufficient accuracy in its presentation of information to enable analysis of any correlation between topography, submarine structure, geomagnetism and gravity.

The present author participated in the preparation of the Westward of Akita and the Approaches to Magami Tai maps, and later had occasion to publish a paper on geomorphological and geophysical studies of the bottom in this region.

In that paper he raised the following pertinent points :

(1) Elevations of the basement can be seen along the edge of the continental shelf, and the formation of the continental shelf itself was due to sediments accumulating between the mainland and the elevations along the edge of the basement. A number of folds can be seen on the continental shelf, and some of these are considered to be related to folds found on land.

(2) Two troughs — one located between the continental shelf and Okujiri Ridge, and the other between the Okujiri and the Sado ridges — are separated by elevations of the basement, the former into two and the latter into three basins. Comparing these basins it becomes clear that the further south a basin is situated the shallower is its depth of water. In each basin the layer of sediments is thicker towards the continental shelf side, or in the southern part. In the trough between the Okujiri and the Sado ridges the basement is irregular despite the flatness of the trough bottom, this being considered as having been formed by sediments accumulating over the irregular basement.

(3) Each ridge is formed of blocks cut by faults in which can be seen a number of bendings.

(4) The basins are not connected by submarine valleys, these being situated around the rim of each basin, disappearing when they enter lower basins.

(5) The submarine valleys have been formed by turbidity mud currents which have occurred intermittently in the region.

(6) Magnetic anomalies have been observed along the faults. In many cases, the basement being comparatively shallow, the faults are large in scale. These anomalies are considered to have resulted from igneous rocks that extruded along the faults, forming magnetic anomaly areas around them.

(7) No magnetic anomalies accompanying folds are seen, except in two cases where the folds are considered to be accompanied by faults.

(8) There were some cases where no magnetic anomalies were observed along faults. This phenomenon was considered to be caused by the fact that the faults are rather small in size or because the sediment layer is thin.

* * *

Viewed from the standpoint of making an analysis of the Basic Map of the Sea for purposes of ocean exploration, it is the author's firm belief that this map will provide a great deal of valuable information at the planning stage of such an exploration programme.

Acknowledgements

The author wishes to express his gratitude to the staff of the Japanese Hydrographic Department at present working on the preparation of the Basic Map of the Sea. His thanks are also due to Mr. Yasuhiro OYAMADA for his cooperation in the preparation of the present paper.

The following three illustrations show the same part of the charts 6328, 6328M, 6328S, reduced in the same ratio.

日本

秋田西方

NIPPON

THE WEST OF AKITA

第6328号 海底地形図 1/200,000

ランベルト正角円錐図法（標準緯線39°10′, 40°00′）
Lambert Conformal Conic Projection
(Standard Parallels 39°10′ and 40°00′)

昭和42年日本海上保安庁水路部の測量
陸部は国土地理院の資料による

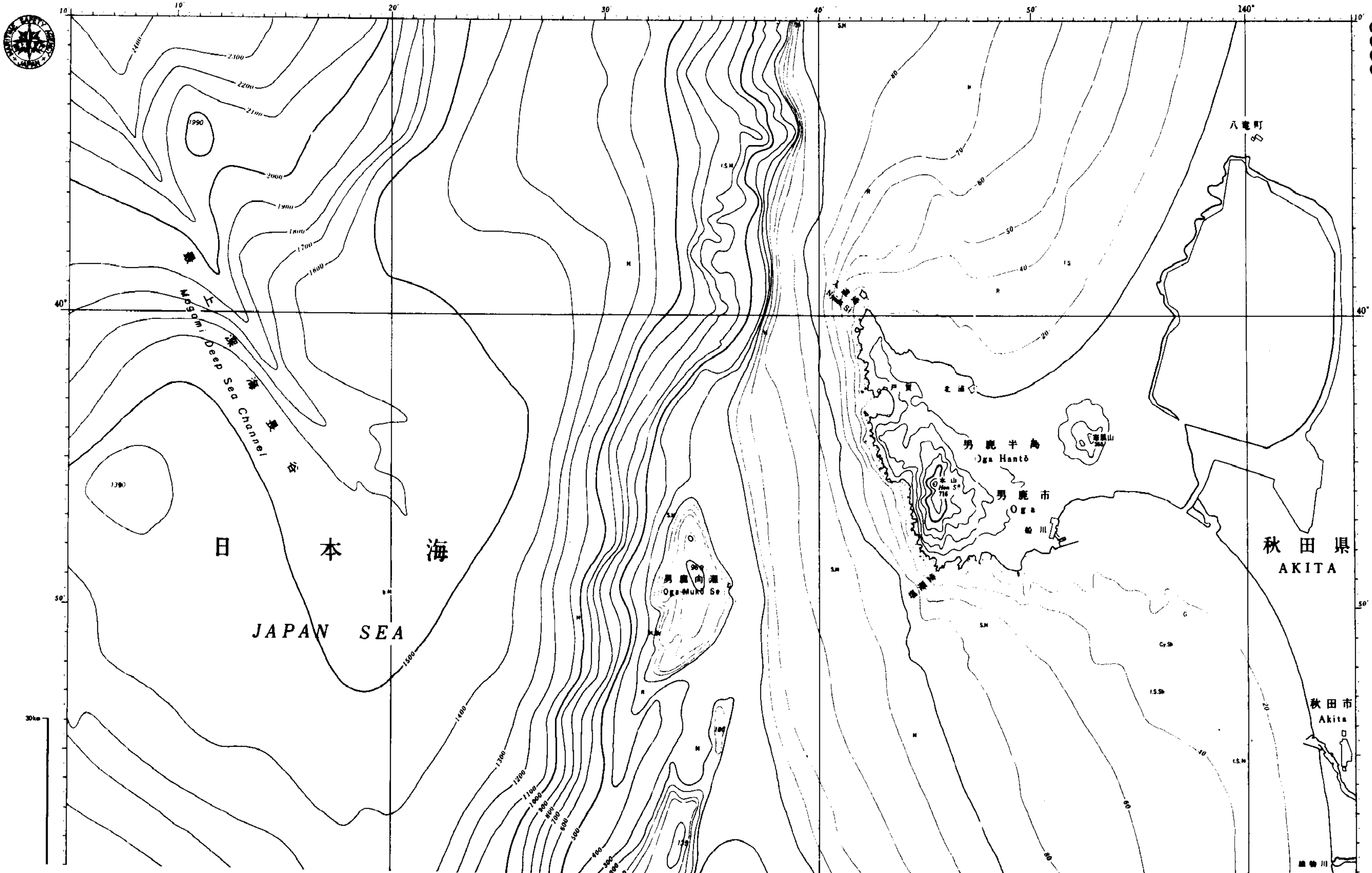
水深…メートル
高程…メートル

Survey of the Hydrographic Division, M.S.A., Japan, 1967.

SOUNDINGS IN METRES
Heights in Metres

索引図 Index Chart

6327
6329 6328
6330



秋田西方

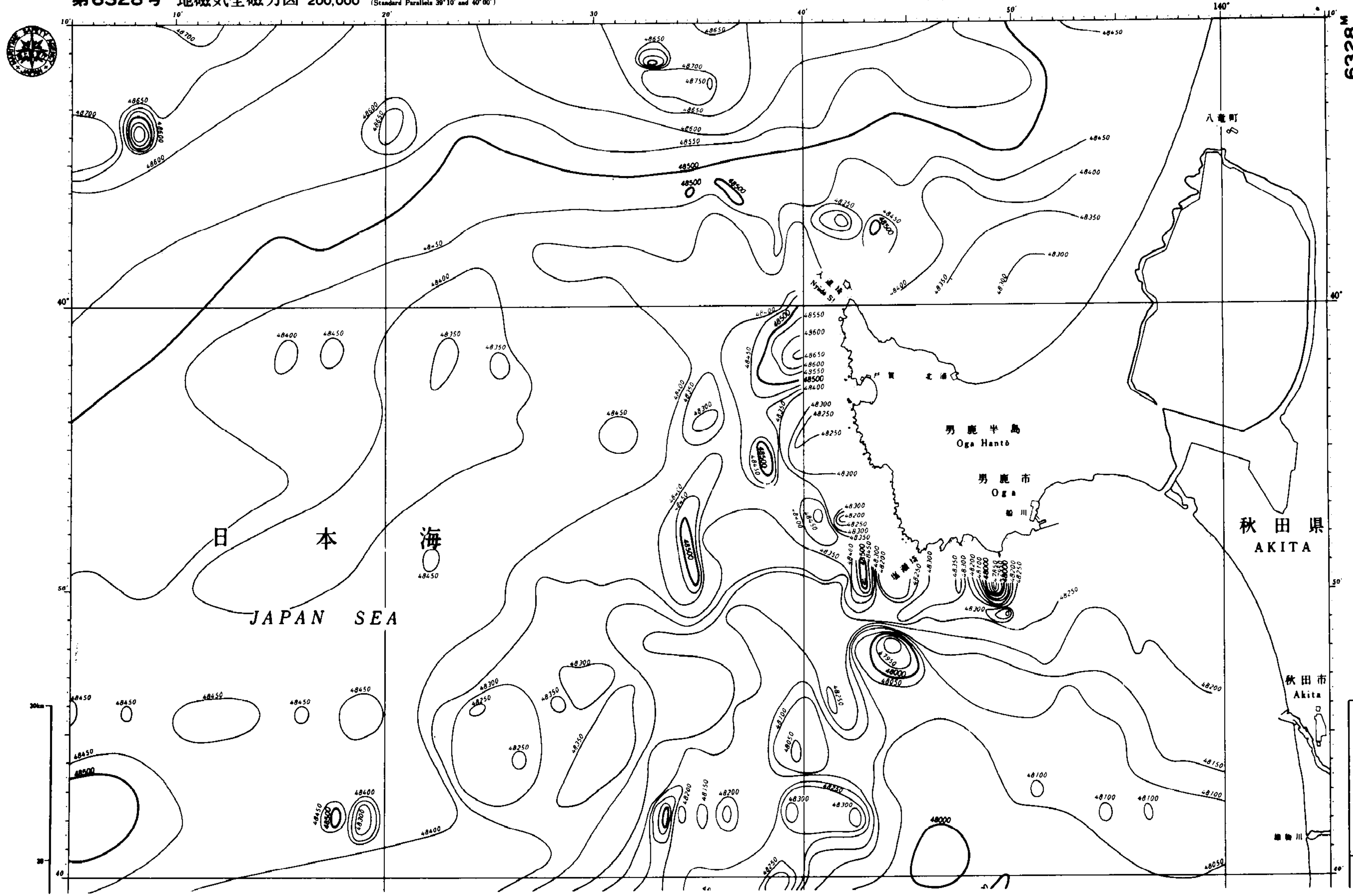
NIPPON

THE WEST OF AKITA

第6328号[M] 地磁気全磁力図 1/200,000

ランベルト正角円錐図法（標準緯線39°10′, 40°00′）
Lambert Conformal Conic Projection
(Standard Parallels 39°10′ and 40°00′)

昭和42年日本海上保安庁水路部の測量
等磁力線間隔……50γ
Survey of the Hydrographic Division, M.S.A., Japan, 1967.
Curves of Equal Magnetic Intensity express every 50γ.



日本

秋田西方

NIPPON

THE WEST OF AKITA

第6328号[S] 海底地質構造図 1/200,000

ランベルト正角円錐図法（標準緯線39°10′, 40°00′）
Lambert Conformal Conic Projection
(Standard Parallels 39°10′ and 40°00′)

昭和42年日本海上保安庁水路部の測量
Survey of the Hydrographic Division, M.S.A., Japan, 1967.

索引図 Index Chart