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REPRESENTATIONS OF SUBMARINE GEOLOGY AND GEOPHYSICS IN OCEANIC CARTOGRAPHY*

J.C.A. Commission on Oceanic Cartography**

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Abstract

The authors classified the maps on the sea bottom into three categories; submarine topography, geology and geophysics. In the present paper, the representations of geology and geophysics were studied and summerized as a second paper of intended reference paper series. The maps concerning submarine geology and geophysics are classified as follows.

Geology	: sediments	(sample station map, bottom sediment chart, mechanical analysis map, chemical analysis map, photograph and others)
	geology	(subbottom profile, isopack map, geological structure chart, submarine geological map and others)
	sea bottom mineral resources	
Geophysics:	geomagnetism	(total magnetic intensity chart, magnetic anomaly chart and others)
	gravity anomaly	(gravity anomaly chart and others)
	crustal heat flow	
	seismology	
	submarine volcanoes	

At first, characteristic representations of each item were discussed respectively and additional discussions on scales, projections, colors, symbols, abbreviations etc. were considered.

1. Introduction

As a part of intended reference paper series by I.C.A. Working Group on Oceanic Cartography, the J.C.A. Commission on Oceanic Cartography made a report by submitting the first paper on submarine topography in 1975 (MS). The present paper is the second one which summarizes and discusses cartographic representations of submarine geology and geophysics mainly used in Japan, concerning such parameters as sediments, geology, mineral resources, geomagnetism, gravity, crustal heat flow, seismicity, volcanoes, etc. It is supplemented by additional discussions on scales, projections, colors, symbols and abbreviations.

2. Sediments

Sea bottom sediments have been surveyed for navigational purpose, i.e.

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indication of bottom characters on nautical charts. The meaning of bottom character includes both rocky basement and bottom sediments. In hydrographic survey, identification of bottom character has been qualitatively done by naked eyes. However, in scientific investigations, it is quantitatively determined according to the results of mechanical analysis and composition of sediments.

(1) Qualitative identification and sample station map

In former days, sounding was usually done by lead sounding so that abbreviations of bottom characters are different in various countries (Table 1) and they have been changed by age (Sato 1960).

Table 1 Examples of abbreviation of bottom character in Japan

sand	S	calcareous	ca	shell	Sh
mud	M	quartz	Qz	oyster	Oy
ooze	Oz	coral	Co	sponge	Sp
clay	Cy	volcanic	V	sea weed	Wd
granule	Gr	lava	Lv	foraminifera	Fr
gravel	G	pumice	Pm	globigerina	Gl
shingle	Sn	tuff	T	fine	f
pebble	P	scoria	Sc	soft	so
rock	R	mangan	Mn	white	w

In today's sounding, the opportunities to obtain information on bottom characters have become very rare because sounding method has been changed from lead to echo sounding. Nevertheless, bottom sampling is nescessary for anchorages and station maps of bottom sampling are prepared by using such a style as shown in Fig. 1.

For the purpose of geological or sedimentological researches, sampling stations are sometimes shown on bathymetric charts (Fig. 2). Some detailed station maps

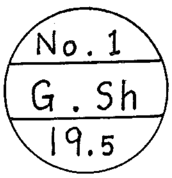

Figure 1
Representation form of bottom sampling station

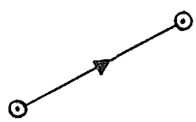

Figure 2
Bottom sampling station map shown on bathymetric chart (Hoshino 1958)

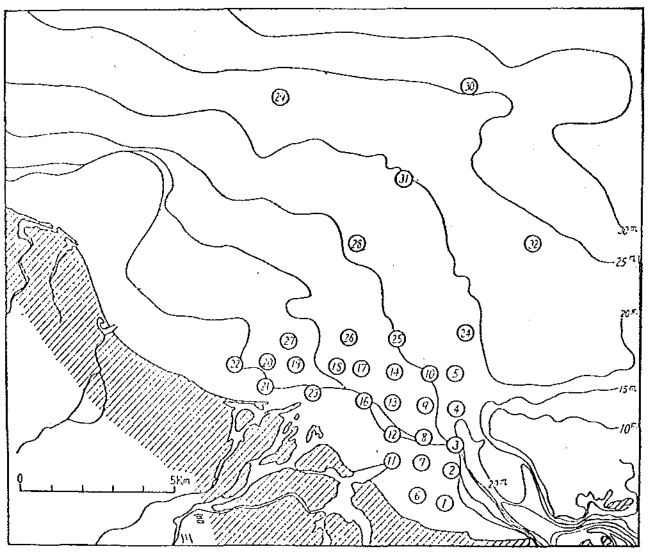

Figure 3 Dredge station map showing dredged distance

of dredge show lines of dredge by means of arrows from the position of bottom contact to that of hoisting dredge haul (Fig. 3).

(2) Bottom sediment chart

Bottom sediment chart (BS chart) is usually represented according to the results of qualitative identification of bottom character in the following styles: (1) map showing sampling stations with symbols of bottom characters, (b) areal representation with or without definite boundaries of distributions where bottom

Table 2 Example of symbol and color representation of bottom character

	Basic map of the sea (Coastal series)	J.G.S.I. 1/25,000	Basic map of the sea (Coastal series)	J.H.D. Nos. 7002-7006	J.H.D. Nos. 7051-7053
Rock			Pink	Brown	Brown
Gravel			Purple	Red hatch	Orange
Sand & Gravel				Red hatch on Yellow	
Coarse Sand				Red dots on Yellow	
Sand			Yellow	Yellow	Yellow
Fine Sand				Yellow hatch	
Sand & Mud				Green hatch on Yellow	Yellow Green
Silt					
Mud			Light Blue	Light Blue	Blue
Blue Mud					Green
Red Clay					Red
Shell					
Sea Weed					

characters are shown by symbols or colors (Fig. 4 & Tables 2).

The boundaries of bottom sediment distributions are always drawn according to interpolation or interpretation. Therefore, these boundary lines should be decided considering submarine topography, the distributions of vertical and horizontal relationship among sediments and between base rock and sediments. BS chart is sometimes drawn on a bathymetric chart.

The map of soft mud showing the thickness of soft mud layer floating above the sea bottom in isopack style, is a special type of BS chart.

(3) Results of mechanical analysis

The fundamental method of quantitative classification of sediments is based on grain size analysis, the purpose of which is clarification of grain size distribution. The results are shown by frequency curves or cumulative curves showing the relationship between grain size and distribution frequency.

In this case, grain size is usually shown by a scale which is a logarithmic scale of grain diameter. Namely,

$$d=\frac{1}{2\phi}$$

$$\phi=\log_2 d$$

where d is diameter of sediment grain in millimeter. Classification of gravel, sand and mud is shown in Table 3.

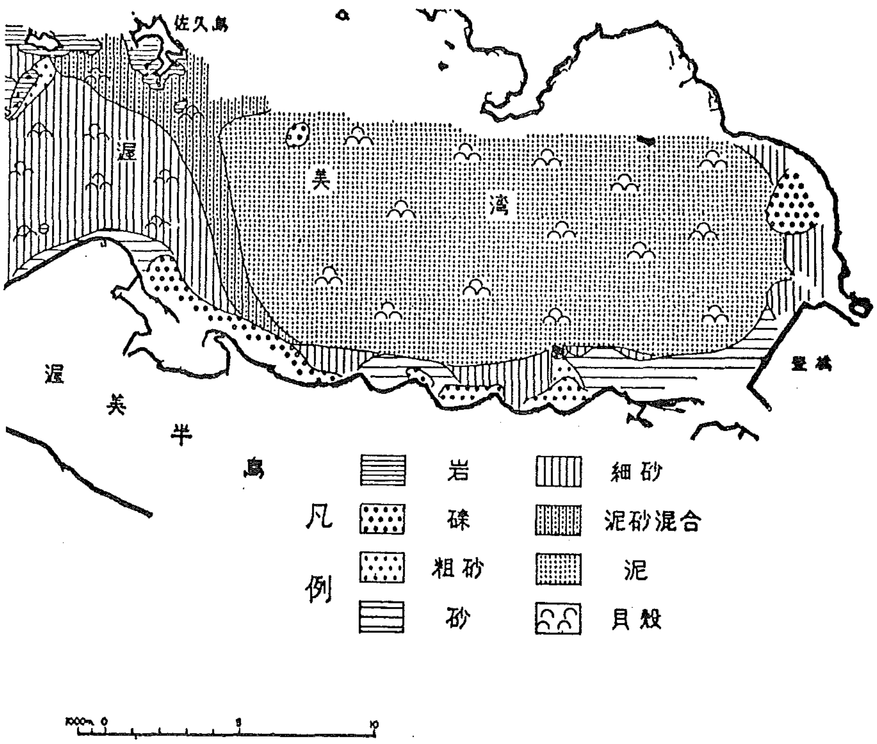

Figure 4 Bottom sediments chart shown by symbols (Japanese H.D. 1968)

Frequency curve is usually changed into cumulative curve and the shape of curve is quantitatively processed by the quartile-measure or ϕ-measure.

Areal distribution of sediments is usually represented by isopleths using median diameter, or coefficients of sorting, skewness or Kurtosis (Fig. 5).

In other cases, types of sediments are classified according to the combination of those coefficients. Fig. 6 is an example of the representation after sediment types.

When the number of sampling is scarce, the result is shown by histogram or

Table 3 Division of sediments and scale

ϕ		
−10		
9	boulder	
8		
7	cobble	
6		gravel
5	pebble	
4		
3		
2		
1	granule	
0	coarse sand	
1		
2	medium sand	sand
3	fine sand	
4		
5		
6	silt	
7		
8		mud
9	clay	
+10		

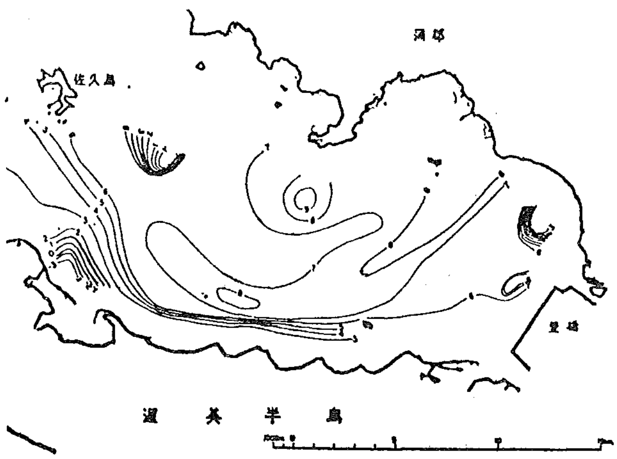

Figure 5 Isopleth map of median diameter (Japanese H.D. 1968)

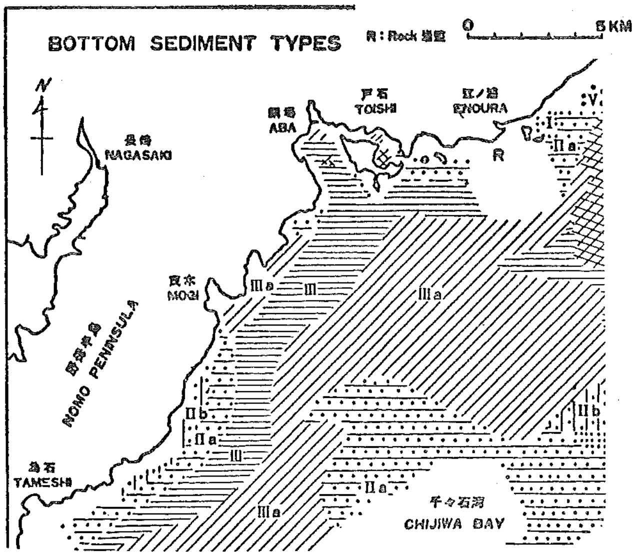

Figure 6 Bottom sediments chart shown by sediment types (Kamata et al 1973)

piegraph at sampling stations. On the other hand, isopleth or areal representation is used when sampling stations are many in number.

(4) Results of mineral composition analysis

The classification of bottom of sediments is based on grain size distribution in reference to such compositions as mineral, chemical or microfossil compositions, etc. The mineral composition analysis being made are ordinarily heavy or light mineral analysis for sand size grains and clay mineral analysis for clay size fraction, the results of which are shown by histogram or piegraph at sampling stations and rarely shown by isopleth (Fig. 7).

(5) Chemical analysis

The representations of chimical analysis results are also histogram and piegraph at sampling stations. As examples of inorganic chemical analysis, those of trace elements such as Mn, Co, Ni, Cr, etc. and radioactive elements such as U, and $CaCo_3$ contents are known.

Organic chemical analyses have been carried out from the view point of petroleum origin, sedimentary environment or pollution. Researches on the last item have been lately increased and following analyses are known A-Hg, PCB, ignission loss, COD, total sulfide, etc. The representations are usually shown by histogram or piegraph which are sometimes on bathymetric chart, but rarely shown by isopleth in nearshore area where there are a number of sampling stations (Fig. 8).

(6) Photograph

Although it is somewhat questionable whether photograph is a map or not, it gives us important information on the sea bottom condition. Namely, an aerophotograph taken over a shallow sea area makes it possible to delineate the rough outline of sunken reefs. An underwater photograph covers a very small area but it is useful

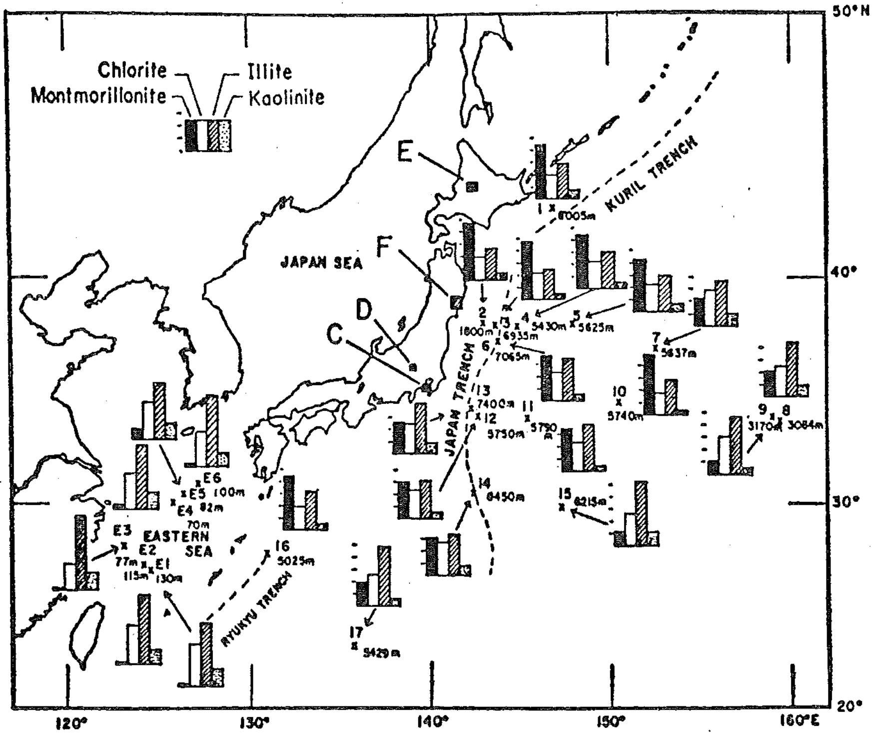

Figure 7 Mineral composition map shown by histogram (Oinuma & Kobayashi 1966)

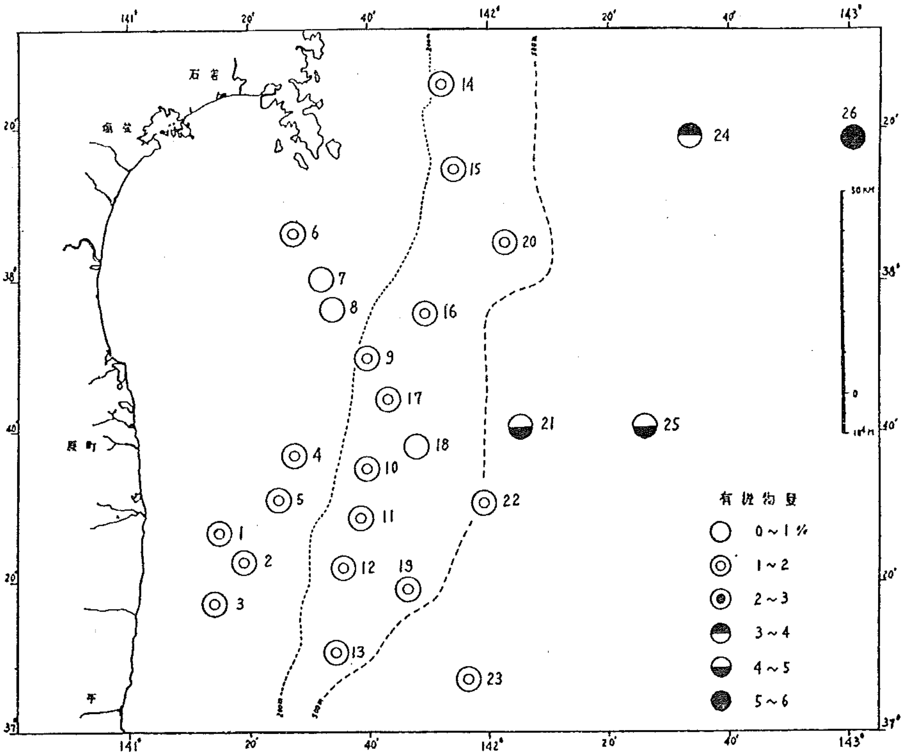

Figure 8 Map of inorganic chemical analysis shown by symbols (Iwabuchi 1962)

to make researches on sedimentary environment or to estimate the distribution of manganese nodules as mineral resources.

(7) Results of coring or drilling

Coring or drilling gives us good evidence for vertical variation of sediments such as lithology, microfossils (foraminifera, diatom, radioralia, nannoplankton, etc.), ratio of oxygen isotope, paleo-magnetism, etc. The age determination of cored sample layers are carried out by radiometric analysis, but all samples are not necessarily analysed by this method. The age determination are practically done by the identification of microfossils and paleo-magnetism.

The representation of vertical variation of cored samples is shown by columner section or profile compiled from columner sections. DSDP (Deep Sea Drilling Project) has taken many drilling cores from deep sea floor more than several thousand meters depth all over the world. The profiles compiled from these drilling results reveal horizontal variation of lithofacies across climatic zones (Fig. 9). The drilling results are also valuable evidences indicating age of sea floor generation in situ, and the map representing ages of ocean floor are also prepared (Fisher et al 1970).

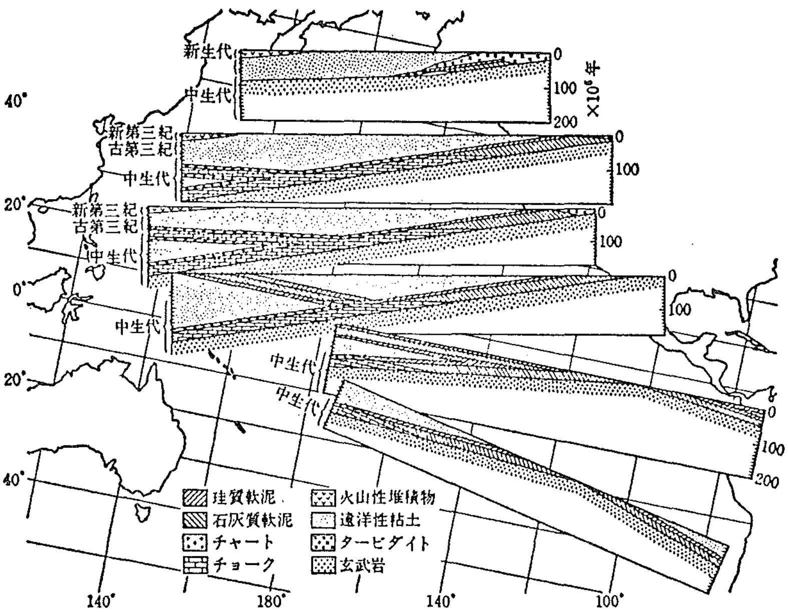

Figure 9 Horizontal variation of lithofacies on the profiles based on DSDP results (Okada & Kobayashi 1974)

3. Geology

Although submarine geological survey had long been carried out by sounding and dredge, continuous seismic profiling (CSP) survey changed its charactor. Namely, CSP records give us three dimensional structures beneath the sea bottom, which makes it possible to prepare submarine geological map.

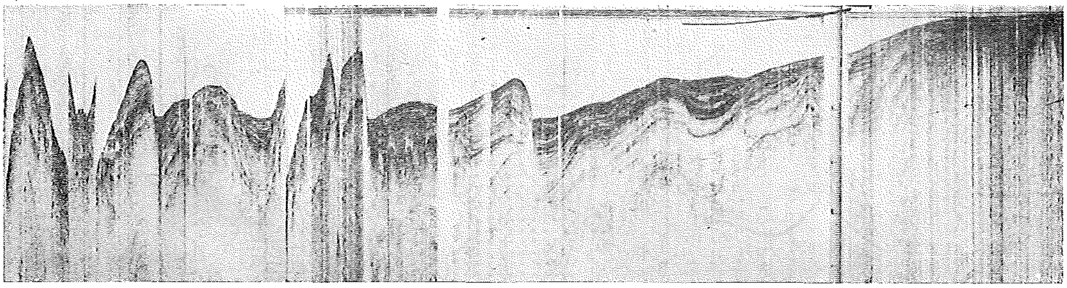

Figure 10 Photograph of continuous seismic profiling record (Sato 1972)

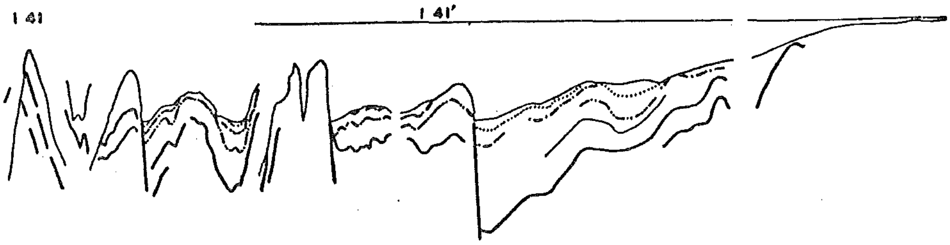

Figure 11 Interpreted subbottom profile (Sato 1972)

(1) Profile

Geological profiles beneath the sea bottom are shown by photograph of original CSP records, or interpreted profiles drawn by hand (Fig. 10 &11). Vertical exaggeration of the former profile is about thirty times to horizontal distance. On the other hand, in the latter profile the exaggeration is less than that of the former.

(2) Isopack map and basement contour map

The basement configuration beneath Alluvium on land had been represented as a contour map by using boring data. CSP survey easily distinguishes the basal boundary of alluvial soft sediments in shallow sea bottom, accordingly basement relieves are also used to be shown by contour lines. These maps are very useful for undersea engineering.

In the case of deep sea CSP survey, isopack maps are used for the sake of petroleum exploration and basement contour maps for the research of geological structure. Both representations have the same meaning. They can be converted each other by the intervention of a bathymetric chart.

(3) Geological structure

Geological structure is the deformation or dislocation of surface rocks by the force originated from the earth's interior. The large structure includes even orogenic zone, geosyncline, etc. On the other hand, the small structure includes folding, fault and so on. Accordingly, the maps of geological structure are variable according to their purposes.

As a submarine geological structure map for large structure, the geomorphological map of the Pacific Ocean published by the USSR is a very good example; it shows anticline and syncline zones in orogenic zones or each geological age, seaward continuations of orogenic zones, oceanic plates, island arc rises, block rises,

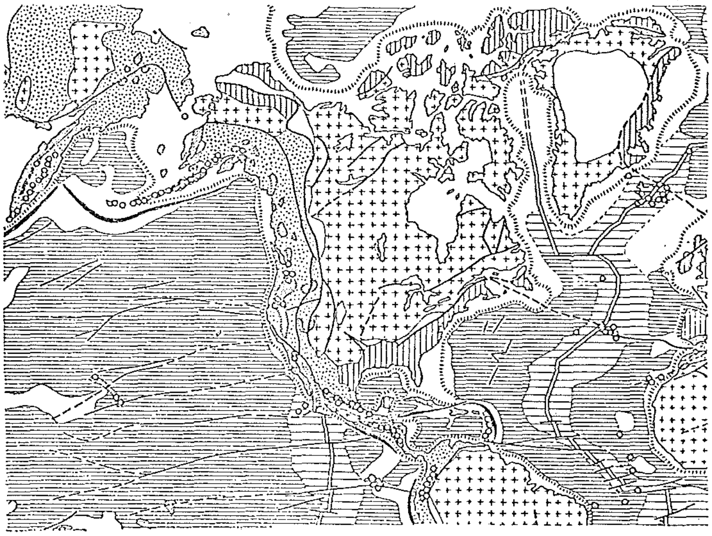

Figure 12 Map of large geological structurs (Katsui 1973)

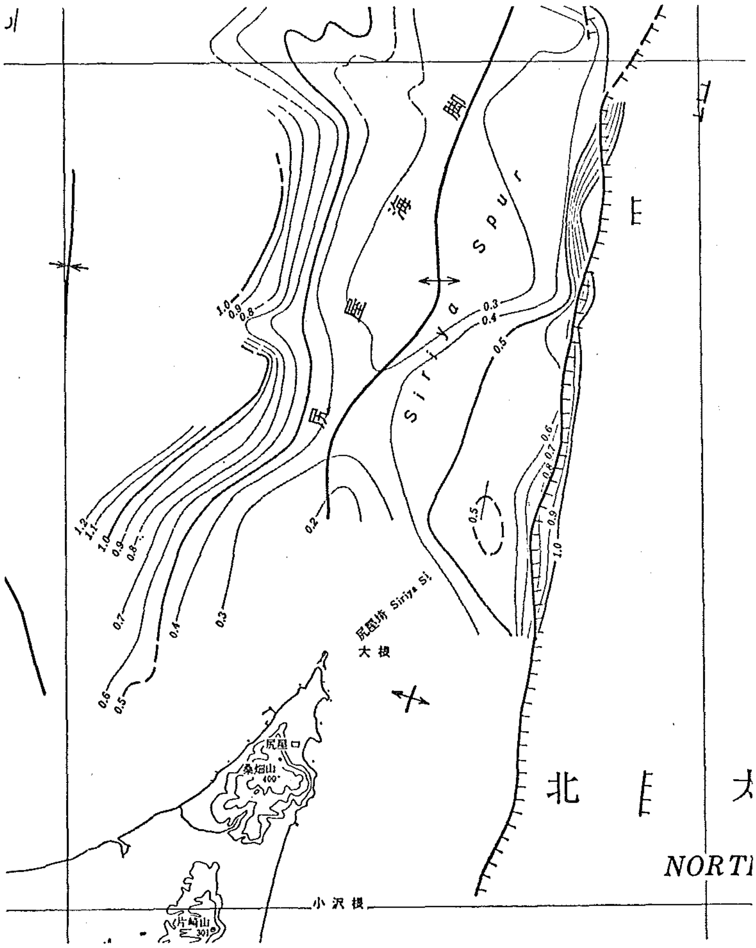

Figure 13 Submarine geological structure map (Japanese H.D. No. 1672S)

mid-oceanic ridges, fracture zones, marginal swells, distribution of igneous rocks, trenches and various information including ages of sea bottom rocks, symmetrical axis of geomagnetic lineations, results of refraction survey, sea floor ages from DSDP, etc.

Fig. 12 is another example showing large geological structures in a black color.

As a submarine geological structure map for small structure, there is the Basic Map of the Sea of J.H.D. which represents the distribution of folding axes and faults on the contour map of acoustical basement relieves (Fig. 13).

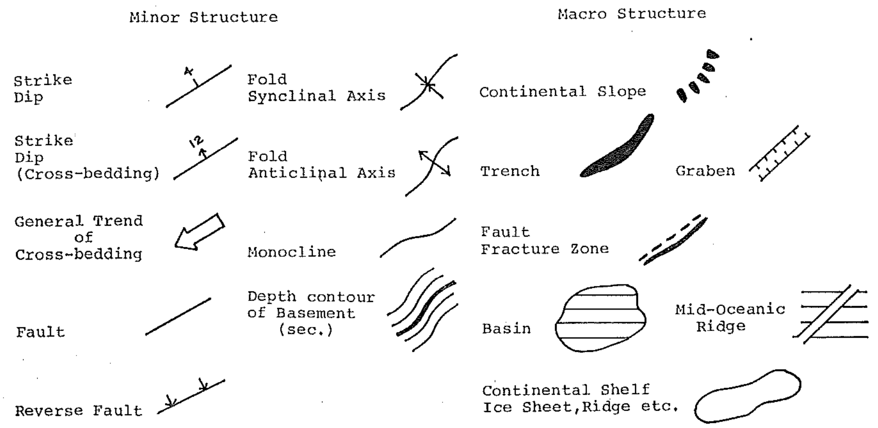

Figure 14 Various symbols in submarine geological maps

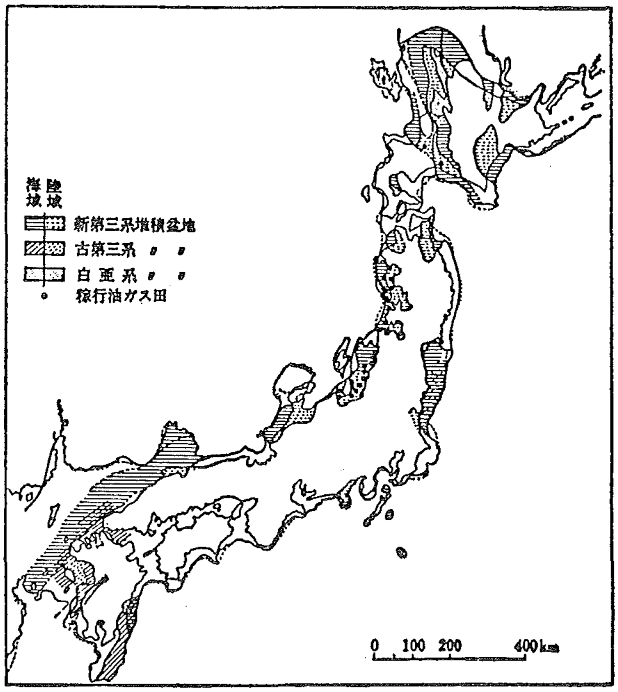

Figure 15 Distribution of sedimentary basins around Japan (Sato 1969)

(4) Submarine geological map

There are some difficulties in defining the difference between a geological map and a geological structure map. However, the authors consider that the former usually includes the latter. The geological map represents the distributions of exposed sedimentary, igneous and metamorphosed rocks, and geological structures. It should be drawn to that geological history can be read.

A submarine geological map is prepared from acoustical profiles and shows distribution of sediment layers, basement rocks and geological structures. In particular, the most important character is the representation of geological history. Fig. 14 shows various symbols ordinarily used on submarine geological maps.

4. Sea bottom mineral resources

Maps showing submarine resources related to the sea bottom are divisible into two categories; one is for the mineral resources in sediments and another is for those in layers. For the latter case, although oil and gas are under exploration or exploitation, no detailed maps have been published except those smaller scale ones showing the distribution of sedimentary basins (Fig. 15), because detailed data are kept secret by exploiting companies.

As for the former, resources to be shown are placer iron, placer cassiterite, diamond, quartzose sand and manganese nodule. No detailed maps are known to be prepared for those resources except the last one, although there are some maps on smaller scales only showing the distribution of production of those resources by using various symbols.

Manganese nodules are expected to be an important mineral resource in the near future and the following maps are prepared; maps showing distribution of

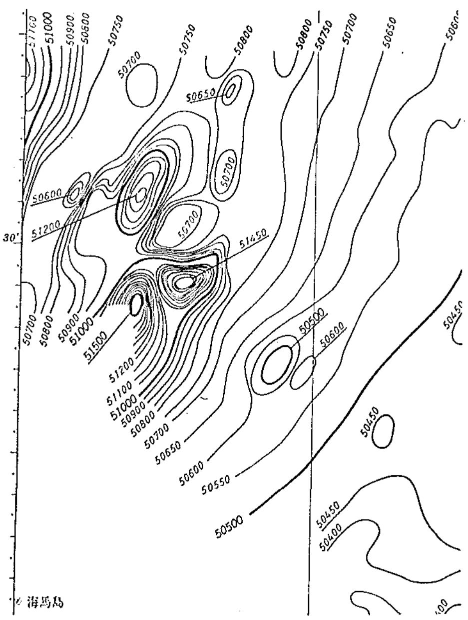

Figure 16 Total intensity map of geomagnetism (Japanese H.D. No. 6381M)

nodules, each content of chemical components, and trace components such as Ni, Co, Cr, Cu, etc.

5. Geomagnetism

For the purpose of navigation, geomagnetism at sea has been represented on nautical or miscellaneous charts. Geomagnetism is a kind of vector and it can be shown by declination, inclination and horizontal component, each of which is represented by isopleth. Geomagnetism is gradually changing and its annual change is also shown by isopleth.

(1) Total intensity chart

Three elements of geomagnetism above-mentioned are measured by a magnetometer of flux-gate type at sea. However, the advent of a proton magnetometer has made it easy to measure total intensity of geomagnetism on moving vessels or aircraft. Measured data are corrected for annual variation and are converted to the value on a specific date, usually 1st January. The isopleths are drawn for the corrected data (Fig. 16).

(2) Magnetic anomaly chart

The total intensity of geomagnetism is gradually changing and the correction of annual variation is necessary for the comparison of surveys carried out in different years. For this reason, representation of magnetic intensity as not total intensity but anomaly with respect to some reference field is desirable. For the purpose of

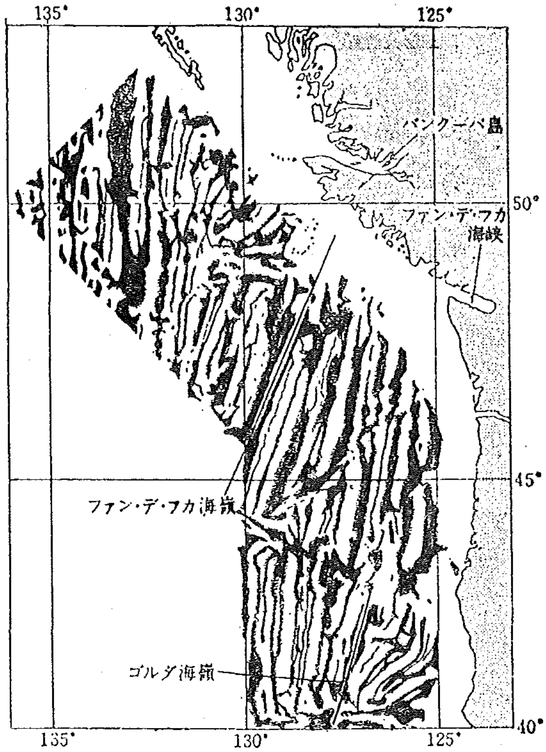

Figure 17 Liniation of geomagnetic anomalies (Mason & Raff 1961)

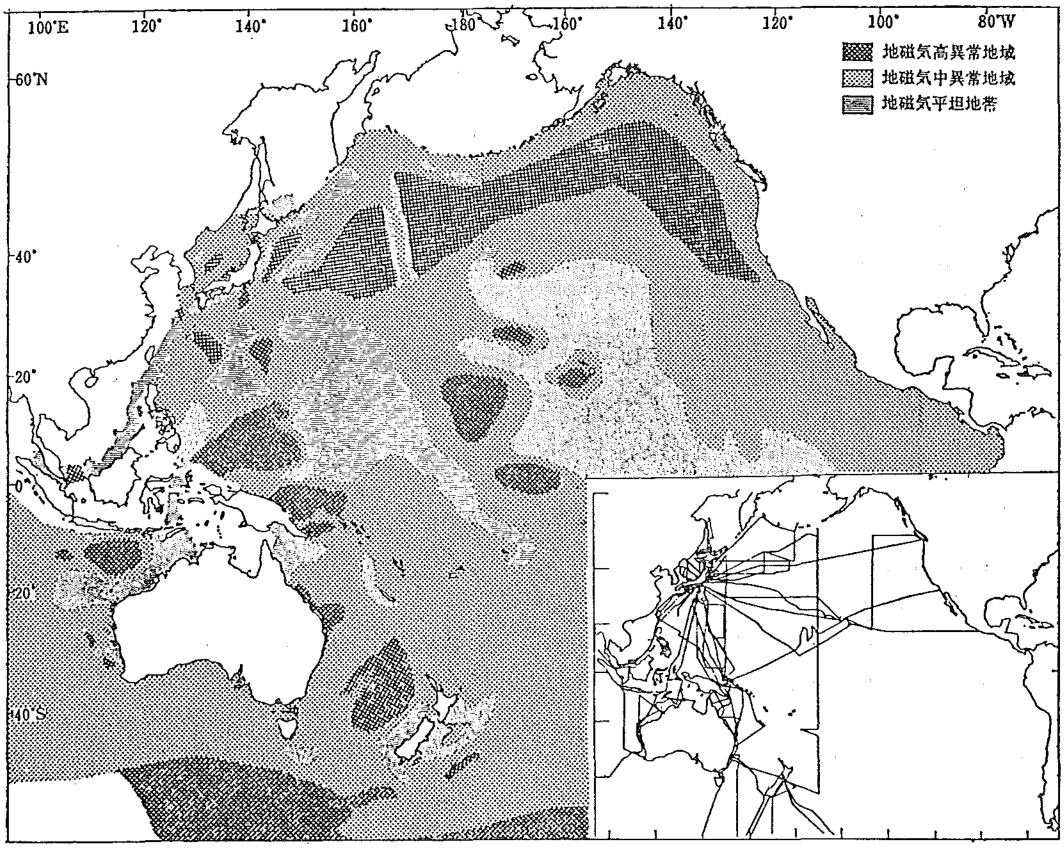

Figure 18 Map of geomagnetic anomalies shown by symbol (Kobayashi 1972)

studying geological structures, the anomaly chart is more convenient.

Total intensity measured is a compound force including regional anomaly of magnetic field and local anomaly caused by geological structures. The former is so regional that it is assumed as a flat plain in the order of in length 10^5m. To determine this plain, measured data at the mesh of several square kilometers are processed by the least squares method. However, the average magnetic field obtained by this method cannot be applied in other areas. Therefore, the comparison of anomalies between two distant areas is difficult.

The best reference field may be IGRF (International Geomagnetic Reference Field) which was adopted in 1968 based on global data then available. This gives the standard for the distribution of total intensity and its secular variation.

As the representation of magnetic anomalies, following examples are known; profiles along track lines, isopleth and symbolizing or coloring (Fig. 17). If either of plus or minus area of anomalies is blackened, stripe pattern of anomalies clearly appears along both sides of mid-oceanic ridges (Fig. 18).

6. Gravity anomaly

Measurement of gravity at sea had been done by a gravity pendulum in a

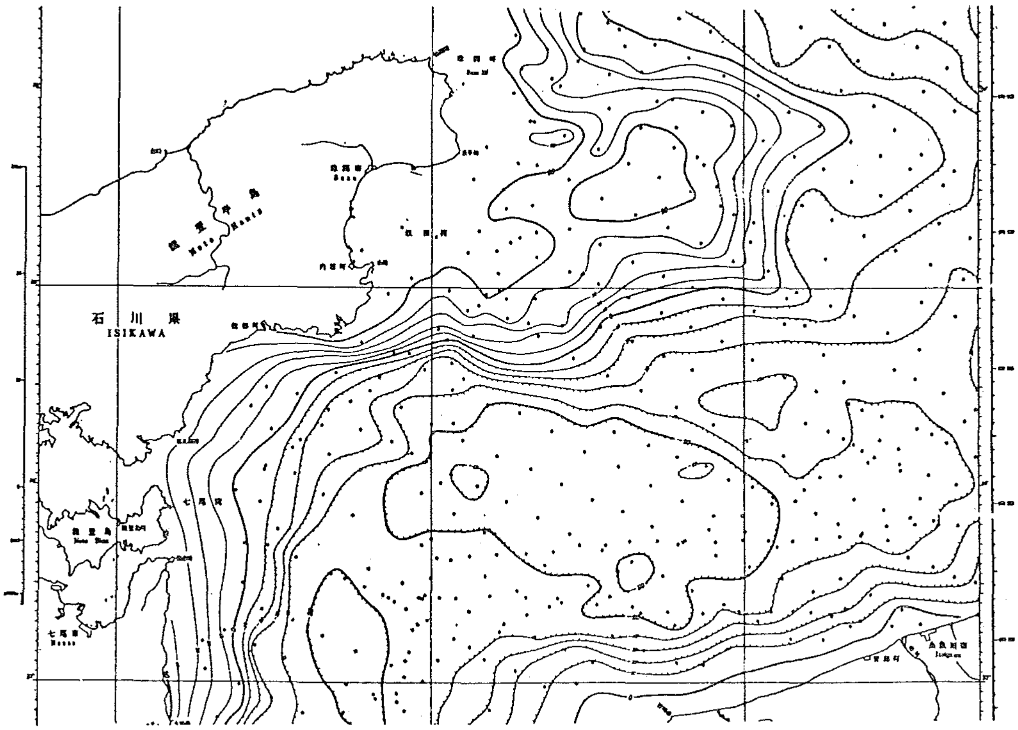

Figure 19 Map of Free-air anomalies (Japanese H.D. No. 6381G)

submarine, and negative gravity anomalies along trenches were discovered, which was described in many text books. A submarsible seagravimeter on the shallow sea bottom has been developed for the exploration of oil field. It is controllable from a vessel through a cable. The results of the measurement by using this seagravimeter have not been published as they are kept secret by the oil companies concerned.

Recently, various types of sea surface gravitymeter have been in use and a number of anomaly maps from large to small scales are published (Fig. 19).

To measure gravity value, the effect of height is corrected on land and the difference between the corrected value and the standard gravity is defined as free-air anomaly. On the other hand, a vessel is running at the sea surface, so that free-air correction is not necessary to the measured value. Namely, the difference between the measured gravity and the standard gravity is free-air anomaly itself.

Bouguer's correction on land is made for the effect of mass between the measured station and the geoid surface. The Bouguer's anomaly has two meanings; (a) gravity anomaly on geoid surface where there is no mass above the surface, and (b) parameter for mass distribution below the geoid surface. From the former viewpoint, free-air anomaly at the sea surface has the same character as that of Bouguer's anomaly on land. There is an example representing both anomalies on one map. However, from the latter viewpoint, it is desirable that gravity anomalies at the sea surface should be the parameter for mass distribution below the sea bottom. The Bouguer's correction in sea gravity is calculated by substituting sea water depth for

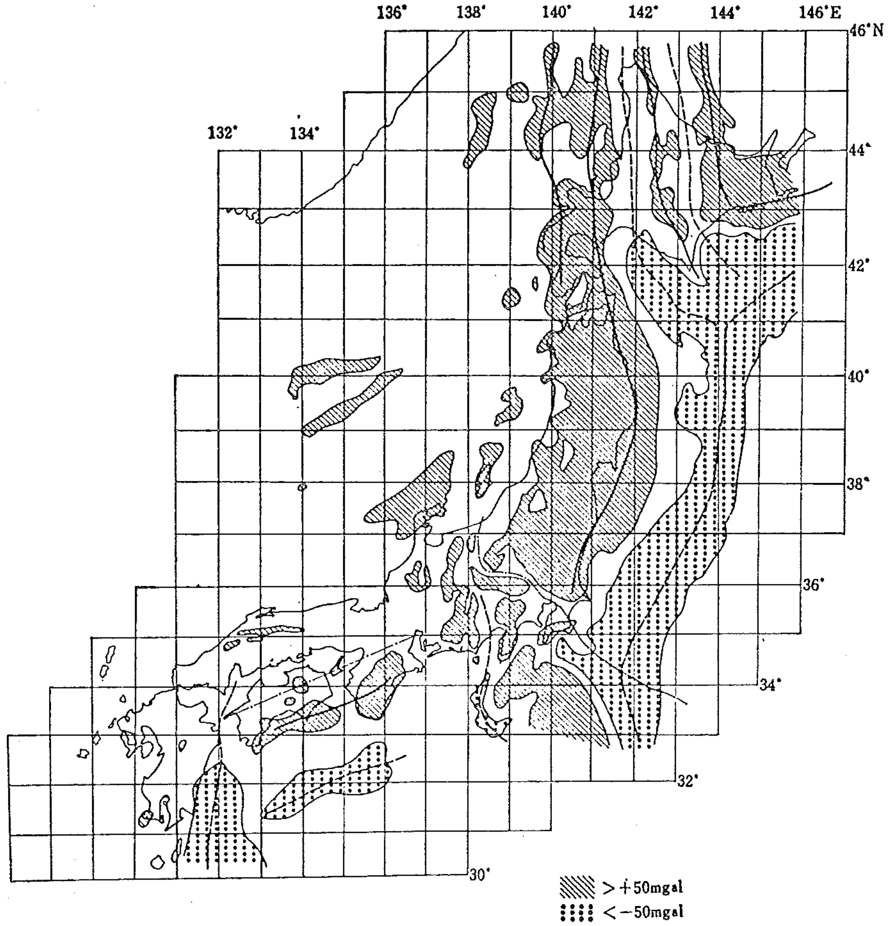

Figure 20 Free-air anomalies chart around Japan (Tomoda 1972b)

crustal materials with average density of 2.67 gr/cm³.

For both anomalies at sea, the basic representation is isopleth with 10 to 20 mgal intervals together with the location of measured stations.

On smaller scale maps with random tracks, average value is calculated in an appropriate mesh such as 10′×10′, from which an isopleth map is drawn.

The accuracy of sea gravity measurement ranges about 10 mgal. If data are processed within this accuracy, the relief of graviy anomalies will become so a gentle surface that automatic contouring may be possible.

Besides the isopleth, a gravity anomaly map is represented by layered coloring or symbols (Fig. 20). Special representation was developed by Tomoda (1972a) in which the strength of layered colors is proportional to the reflective indices of light, and it is possible to take a monocolor photograph or to make spectrum analysis on this map.

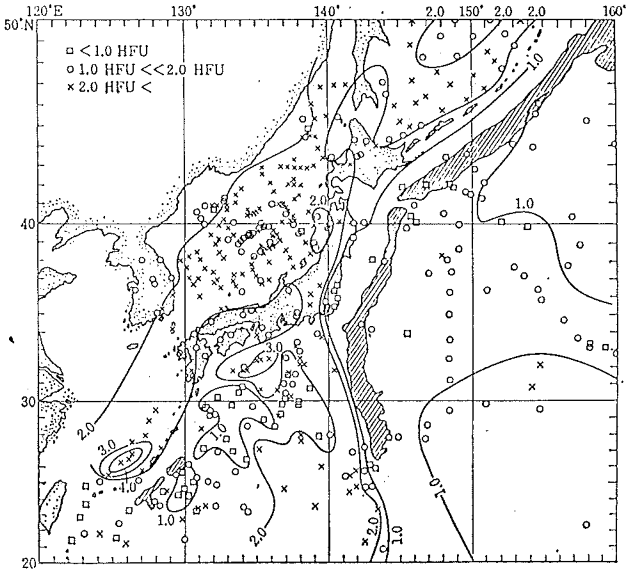

Figure 21 Map of crustal heat flow around Japan (Uyeda & Sugimura 1970)

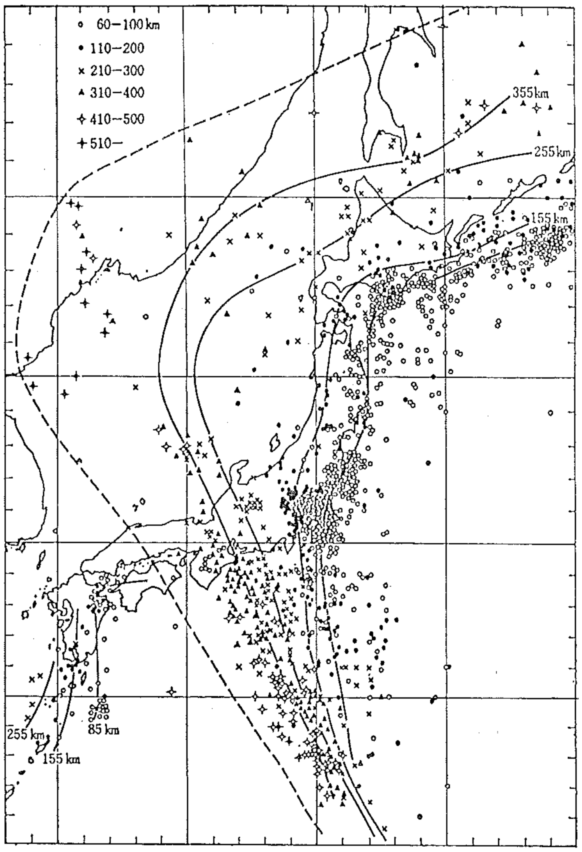

Figure 22 Distribution epicenters around Japan (Uyeda & Sugimura 1970)

7. Crustal heat flow

The crustal heat flow is the heat flow from the interior to the surface of the earth through its crust. Direct effects of thermal phenomena on the earth's surface are volcanoes, hot springs and so on. Indirect effects of them are earthquakes or tectonic movements. The physico-chemical phenomena in the earth's interior are controlled by thermal conditions and the energy caused from this physico-chemical changing is converted to heat. Thus, the measurements of crustal heat flow on the earth's surface are very important to know the structure in the earth's interior.

The heat flow measurement at the sea bottom started in 1948, which is the measurement of thermal gradient in sea bottom sediments and heat' conductivity of the sediments. The crustal heat flow is obtained as the product of both values. Thus, the measurement is done on board a vessel stationed.

The results of heat flow measurements are usually shown by different symbols for various values at measured stations, over which isopleths are drawn (Fig. 21). For regional representation, averages in appropriate squares are calculated and contoured as is done in some gravity anomaly maps.

8. Seismology

Earthquakes are mostly observed at stations on land but rarely on the sea bottom. The seismological observations clarify the distribution, magnitude and character of earthquakes, and these are available for the research on mechanism of earthquakes. The results of observations are shown in such representations as the distribution of epicenters and their depths, magnitude, frequency, area of after shocks, time sequence of occurrence, direction of fault plane or displacement, etc.

(a) Distribution

The simple plotting of epicenters on a smaller scale map reveals earthquake zones. Plotting them in different symbols according to their depths on a larger scale map and contouring on it reveal three dimensional inclination of the seismic plane beneath the island arc and trench system (Fig. 22). It is also represented on vertical section perpendicular to the arc and trench for earthquake occurrences.

The accordance of submarine topography with epicenters is clearly shown along the median rift and transversing fracture zones on the crest of mid oceanic ridge.

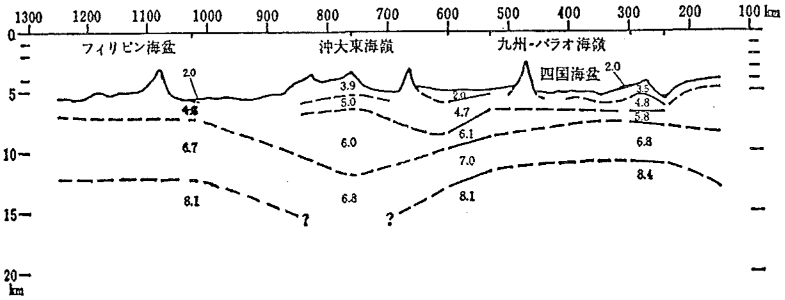

Figure 23 Profile of crustal structure in northern part of the Philippine Sea (Murauchi et al 1968)

(b) After-shock distribution

The distribution of after-shock epicenters for an earthquake with large magnitude reveals a relation between the extent of after-shocks and magnitude. The large earthquake off Nemuro was predicted according to the lack of after-shocks extending along the continental margin of island arc.

(c) Others

The distribution of initial motions is important to the analysis of earthquake mechanism. Concerning the submarine earthquakes, focal mechanism maps have been prepared on the basis of the nodal planes determined by the distribution of initial motion (Stauder 1968).

(2) Seismic refraction survey

As for reflection survey, a description was already given in Chapter **3**. Refraction survey is carried out by using explosives or on the occasion of nuclear explosion, and it clarifies deep structures of the crust or mantle of the earth. The profiles of crust have been published last 10 year by Research Group of Explosion Seismologists in Japan (Fig. 23). Lately, the states of crust and lithosphere to the depth of several thousand kilometers have been made clear by the observation covering a long distance using high sensitive undersea seismographs. Moreover, the researches on dispersion of surface waves from earthquakes have shown the thickness of crust in and around Japanese Islands.

9. Submarine volcanoes

As for the representaion of volcanoes, the following factors are important;

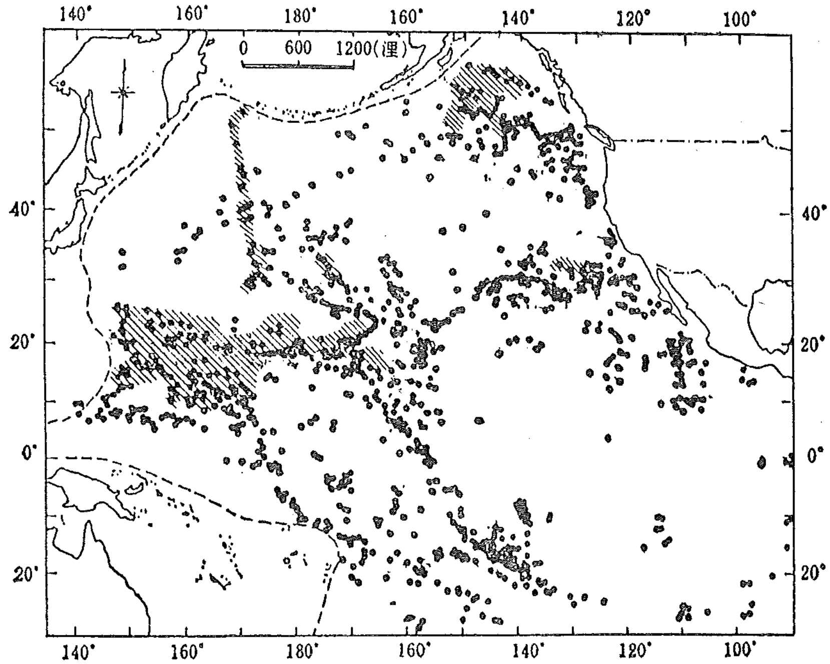

Figure 24 Distribution of seamounts and guyots (Menard 1959)

the position, age or history, extent of activity, character of eruptives, etc. In this chapter submarine volcanoes with present topographic features are included irrespective of their being active or inactive.

The distribution maps of active volcanoes in the world indicate that volcanoes are concentrated to island arcs. It has been revealed that the volcanoes are also located along median rift zones on mid oceanic ridges and on mantle plumes. The mode of volcanic activity in these deep sea volcanoes is assumed to be greatly different from land volcanoes. Former volcanology was constructed only from land volcanoes. The future volcanology should be considered from volcanoes over the world including these submarine volcanoes. In this sense, distribution maps of submarine volcanoes are interesting (Nakamura 1974).

Numerous seamounts on the ocean floor are probably extinct volcanoes because rock dredged from them are invariably volcanic and their topographic features are similar to volcanoes. Guyots are also truncated and submerged volcanoes. Seamounts and guyots are distributed mostly in groups (Fig. 24).

The order of generation in seamount chains is rarely made known because the age determinations of dredged rocks for radioactive elements are scarecely done. Seamounts along the Emperor Seamounts and Hawaiian Ridge are rare examples in which their ages were determined. The Seamounts become younger from north to south or southeast, which is considered an evidence of mantle plume hypothesis and lateral movement of the Pacific Plate (Jackson et al 1972).

The magnitude of volcanic activity is usually detected from eruptive materials. Although volcanic activity in deep sea bottom may be much different from that on land, the size of seamounts may represent the magnitude of activity. Fig. 25 shows the similarity of form and also size of seamounts.

The extent of volcanic ash layer is also an indication of volcanic activity. The tephra with vast distribution more than thousand kilometers in length on land is assumed to continue to the ocean floor, but they have not been correlated each other in spite of the existence of many ash layers in core samples from the ocean floor.

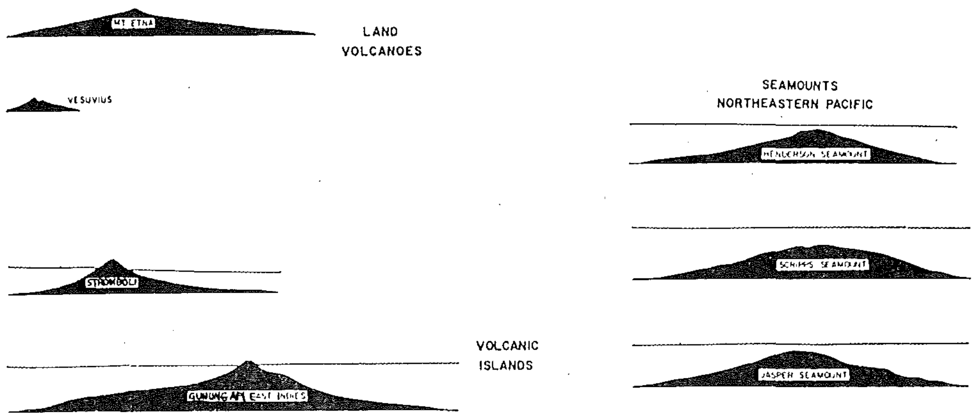

Figure 25 Topographic profiles of land volcano, volcanic island and seamounts (Menard 1964)

The characters of volcanoes are not so well known that no map representation is found. Submarine volcanic rocks are petrologically assumed to be slightly different one another according to their geographic locations. For example, the volcanic rocks in mid oceanic ridge are called as abyssal tholeiite which is different from basalts seamounts. But there are also differences of K_2O and Na_2O contents even in abyssal tholeiites according to places, which are considered to be related to the spreading rate of mid oceanic ridges (Miyashiro 1976).

10. Considerations on each element of representation

Samples of representation of submarine geology and geophysics studied in the present paper are mostly those illustrations appeared in scientific articles, while separate sheets or atlas are very scarce. As separate sheet, there are Basic Map of the Sea (J.H.D.), Natural Resource Chart (Canada), Conshelf Series (US NOS) and Geomorphological Map of the Pacific (USSR), etc.

As for the atlas, Geological and Geophysical Atlas of Indian Ocean (USSR & IOC) is the only example. Considerations are given to these illustrations and maps concerning each element of the representation.

(Scale) The scales of separate maps on submarine geology and sediments range from 1/10,000 to 1/50,000 in coastal area and from 1/200,000 to 1/500,000 in continental margin. Maps on geomagnetism and gravity range from about 1/200,000 in continental margin to less than 1/10 mil. in oceanic area. Generally, a separate map on submarine geology or geophysics is rarely published and existing maps are mostly appeared in scientific articles. The latter are various in scales.

(Projection) The projections of geological or geophysical maps are rather due to other projections than Mercator. For continental margin, Transverse Mercator (USA, Canada & Australia), Lambert's Conformal Conic (Japanese H.D.) and Mercator (NZ) Projections are adopted. For coastal area, Conformal Conic or UTM Projections are known.

As regards the illustrations in scientific articles, smaller scale maps are prepared by various projections as follows; Mercator, Lambert's Azimuthal Equal-area, External Perspective, Homolosine and Hammer's Projections.

(Color) Colors are used in separate maps. In bottom sediment charts, generally brownish colors are applied to rocks, yellowish colors to sandy sediments and bluish colors to muddy sediments. In geological maps, use of colors is not fixed for lithology, but dark colors are generally used to lower layers. As for geophysical maps, there are following examples of layered coloring; red to yellowish brown in geomagnetism map and purple to white or red to blue in gravity anomaly maps.

(Symbol) There are many symbols and abbreviations in submarine geological and geophysical maps as shown in Fig. 15, Table 1 and 2. However, no standardization of symbols and abbreviations have been made except those applied to nautical charts.

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