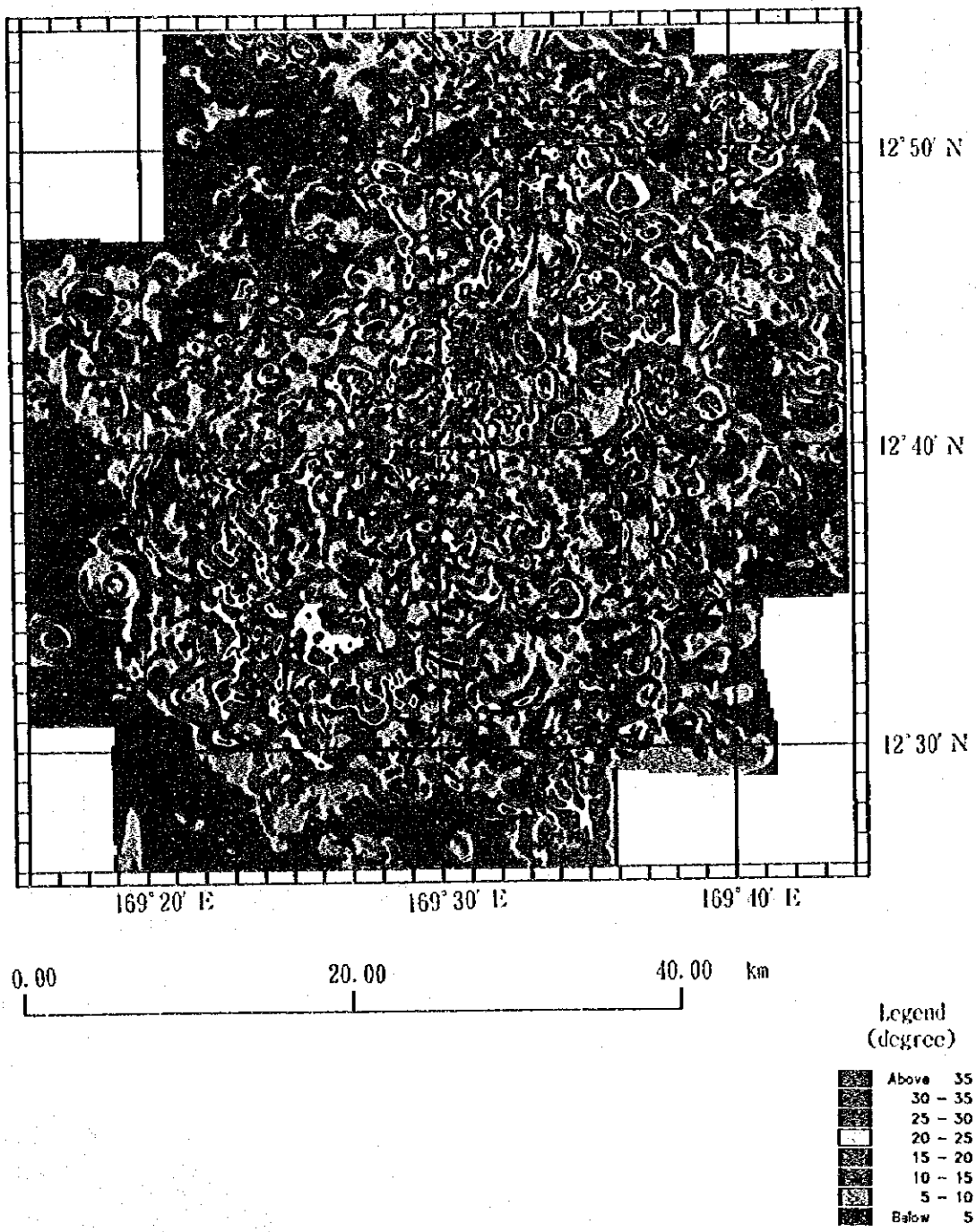

Fig. 3-1-3 (7) Topographic gradient map based on MBES of seamount MS07. Contour interval is 5 degrees.

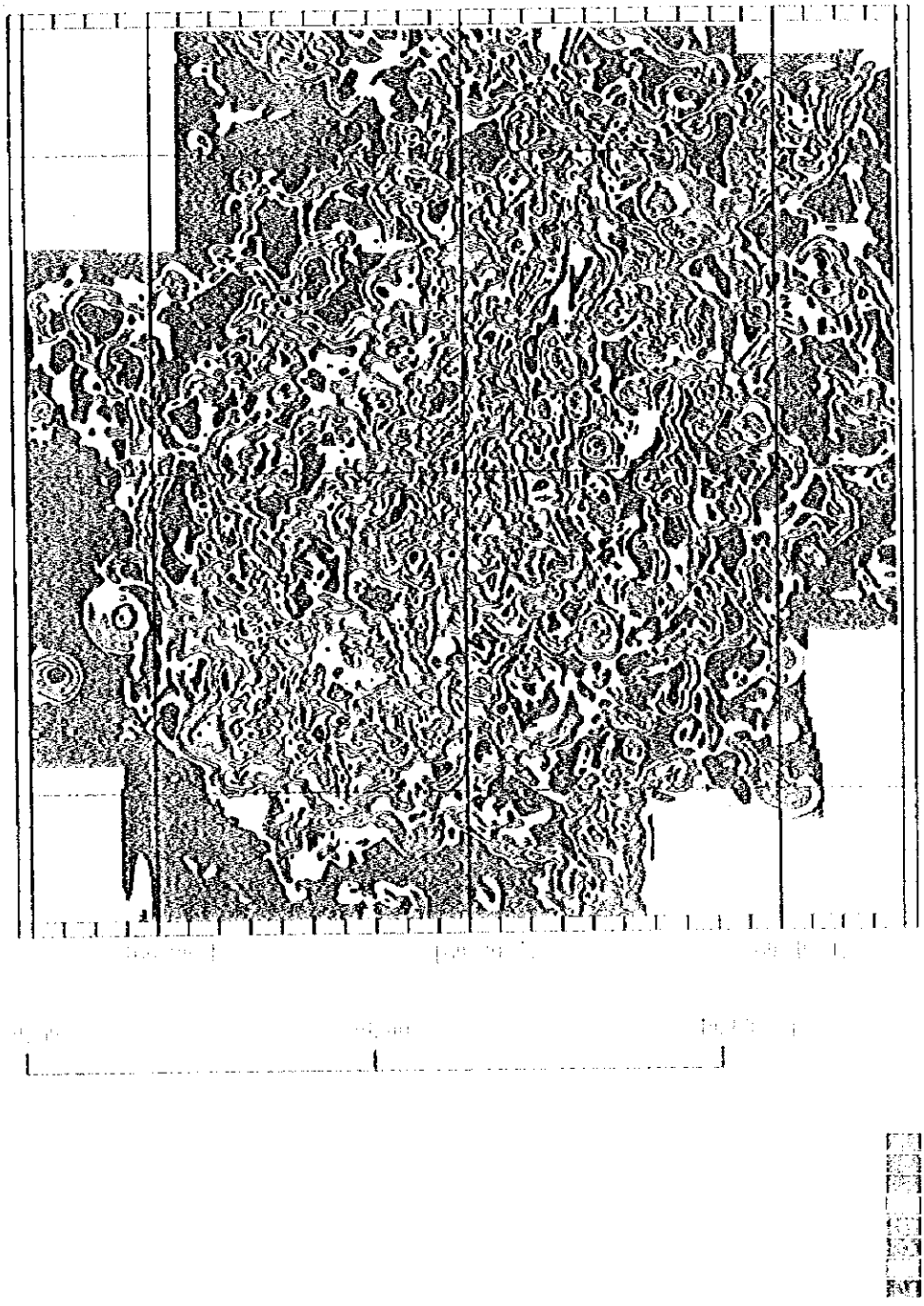

Fig 3.1-3(f) Topographic gradient map based on MBLS of seamount MS07. Contour interval is 5 degrees.

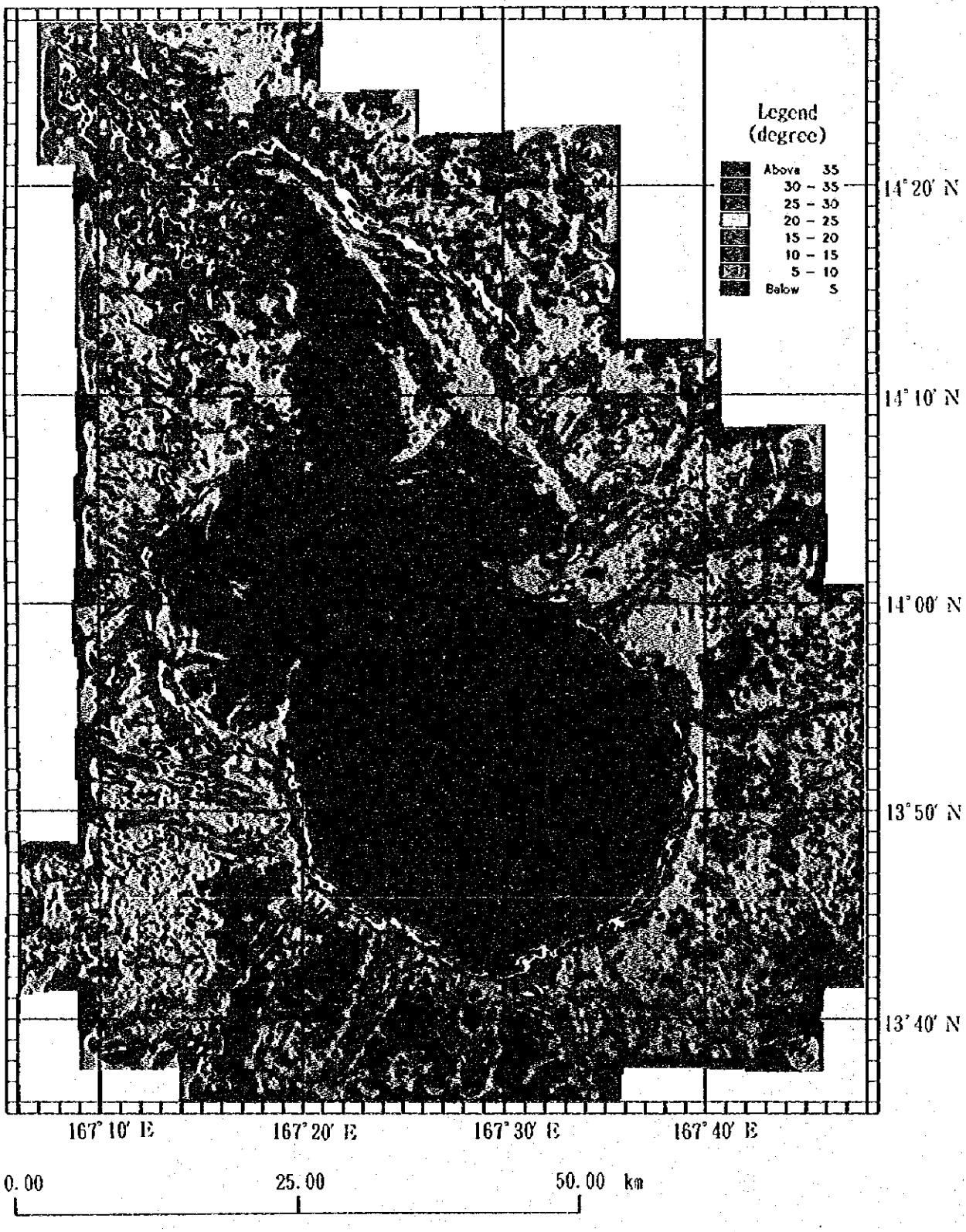

Fig. 3-1-3 (8) Topographic gradient map based on MBES of seamount MS08. Contour interval is 5 degrees.

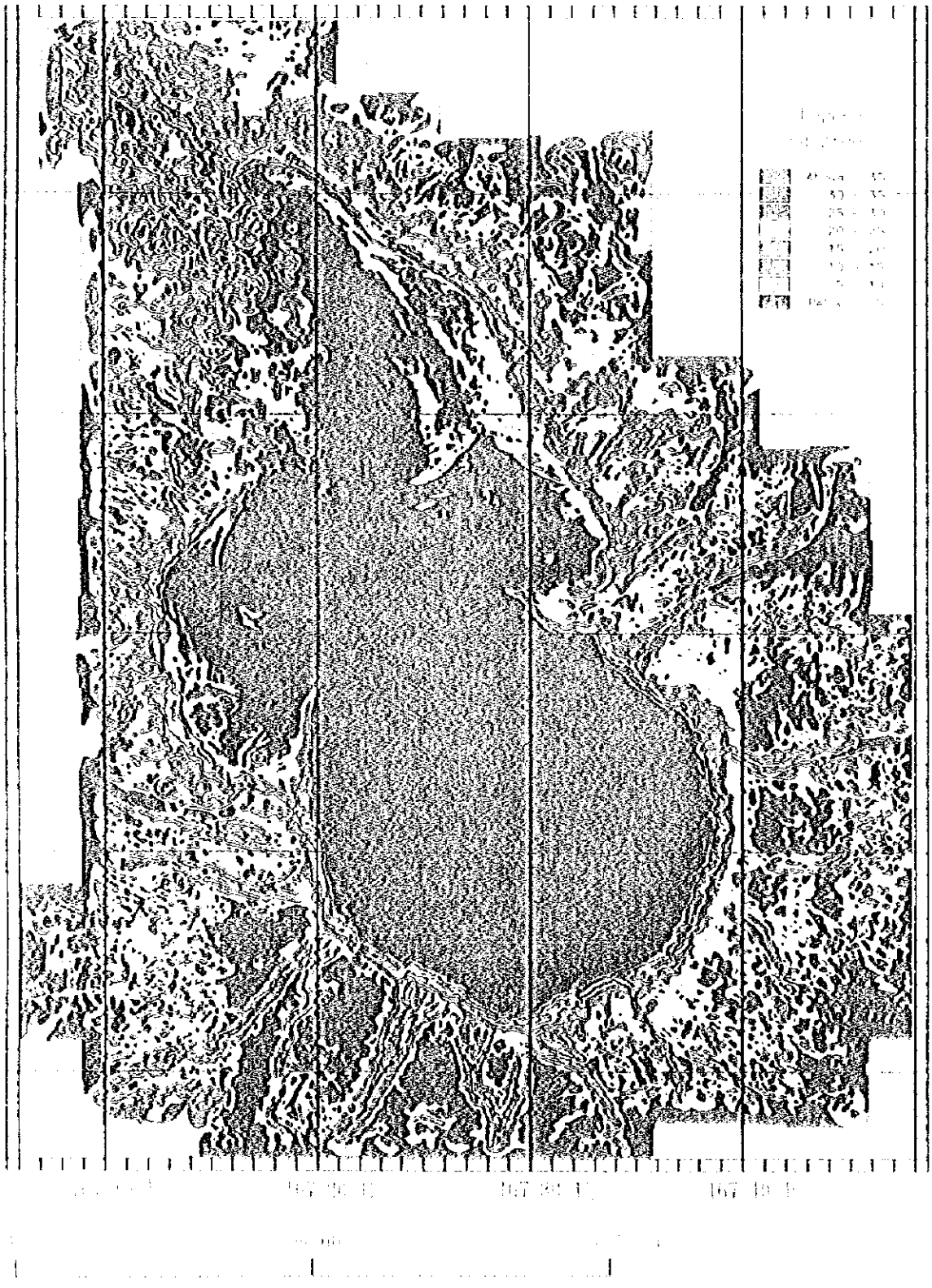

Fig. 3.1.3(8) Topographic gradient map based on MBES of seamount MS08 Contour interval is 5 degrees.

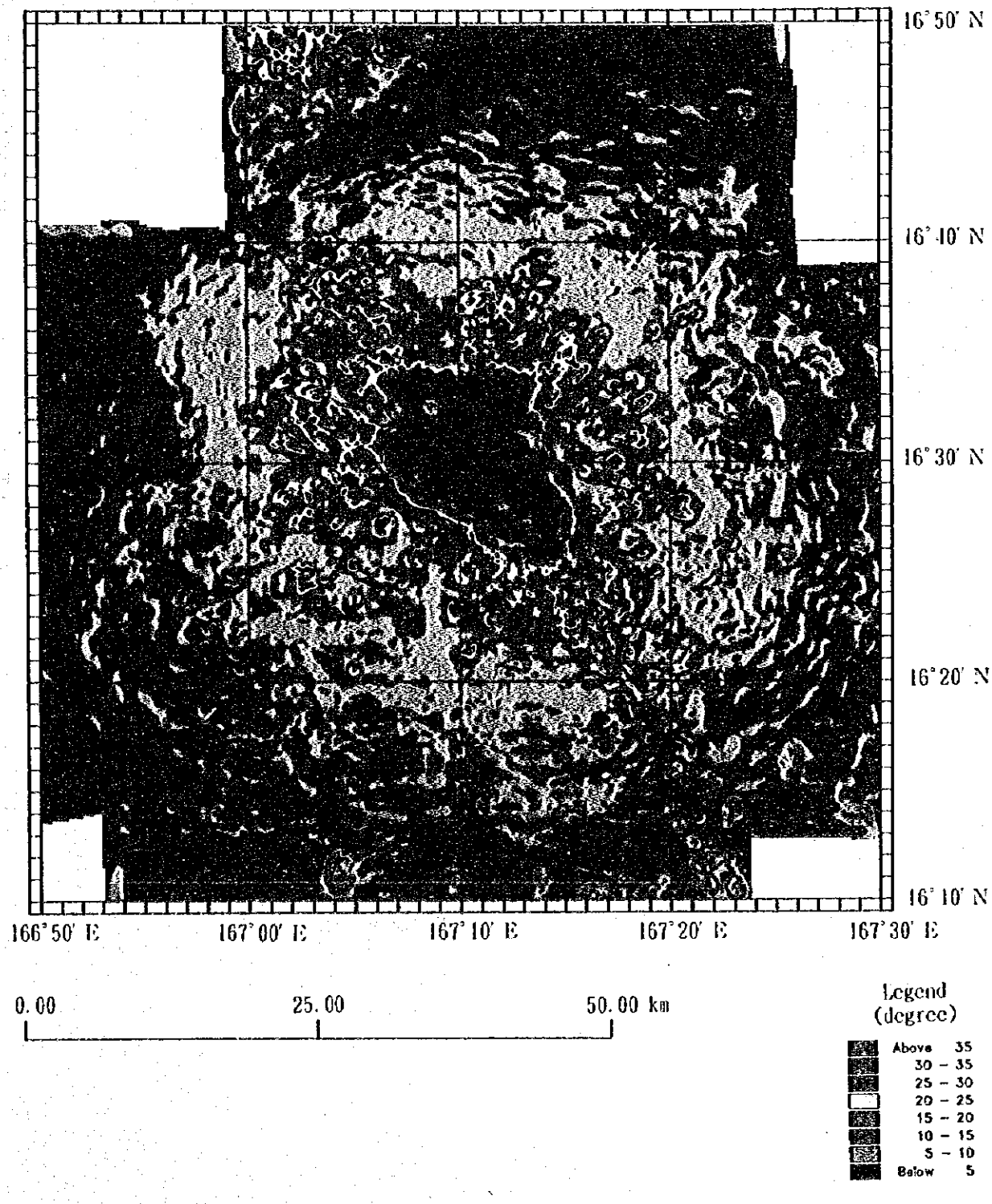

Fig. 3-1-3 (9) Topographic gradient map based on MBES of seamount MS09. Contour interval is 5 degrees.

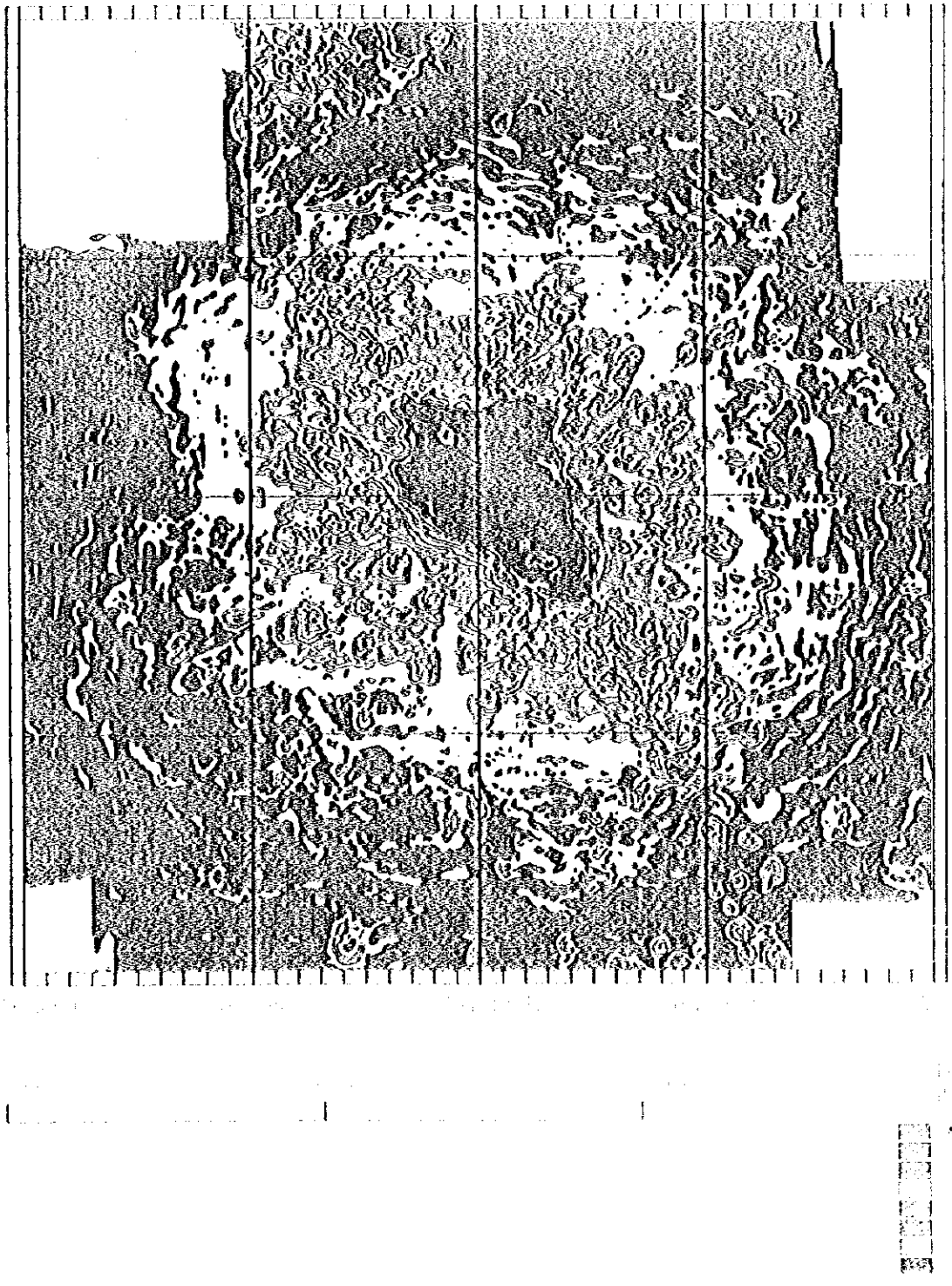

Fig 3.1.3(9) Topographic gradient map based on EM12S of seamount MS09. Contour interval is 5 degrees.

55 km east–west and 50 km north–south.

The top is oriented northeast–southwestward and its area is 406 km ^{2}. Largely, the top has a step morphology, lower to the west of 163 ° 05'E line. There are several topographic highs of about 2 km in diameter in the western part. the eastern part is the shallowest with dome structure around a peak. Average gradient of 6.9 ° is the steepest top of the table seamounts in the survey area. This top is not flat and has somewhat complex morphology.

The slope is relatively steep in the upper to middle parts of this seamount with average of 20 ° for the upper and 19 ° for the middle part. The average of the lower slope is 9 °. Three major ridges extend in the northeast, northwest, and southwest directions.

c. MS03

This is a table seamount with the largest flat top in the survey area. The shallowest part is 1,740 m deep and 3,500 m in relative height. During the present survey, topographic cruise did not cover the foot of this seamount, and thus the size of this seamount is not clear, but it is at least 80 km east–west and 70 km north–south.

The top is oriented in the NE–SW direction and has a gentle dome morphology with an average gradient of 2.8 °. The area of the top is the largest of those in the survey area at 2,247 km ^{2}. There are terrace structures on two ridges extending northeast–southwest on this top. Relatively large depression of 10 km X 5 km occur near 13 ° 43'N., 163 ° 40'E.

The average gradient of the upper slope is 9.9 °, the middle slope 9.4 ° and is relatively gentle. On the northeastern side of the upper part of slope, the slopes more than 20 ° are shown widely. The southwestern slope is gentler than that on the northeastern side.

d. MS04

This is a truncated cone–shaped table seamount. The shallowest part is 980 m deep, relative height 3,500 m, and extends 60 km east–west and 60 km north–south.

The top is oblong with N–S extending long axis, and its area is 252 km ^{2}. The average gradient of the flat and relatively smooth top is 2.8 °.

The average of the upper slope is 17 °, of the middle slope 14 °, and that of the lower part of the slope 9 °. Thus the whole slope is gentler than other seamounts of the survey area. Many small changes of relief occur along the slope together with many pinnacles of around 1 km in diameter and 200 m high.

e. MS05

This is a peaked seamount and the shallowest part is 950 m deep, relative height 3,800 m, and extends 50 km east–west and 50 km north–south. This is the shallowest seamount surveyed.

The top is oriented in the N–S direction.

The average gradient of the upper slope is 20 ° , middle slope 21 ° , and the lower slope 9 ° . The gradient is almost constant from the upper to the middle part of the slope. Many pinnacles of around 2 km in diameter and 500 m in height occur in the lower slope.

f. MS06

This is a truncated cone–shaped table seamount and the shallowest part is 1,580 m deep, relative height 3,600 m, and it extends 40 km east–west and 50 km north–south.

The top has oblong shape with the southeastern part broken off. It has NE–SW extending long axis and its area is 149 km ^{2} . The average gradient of the top is 4.8 ° and has gentle dome morphology.

The upper slope is steep at average of 25 ° , middle slope 19 ° , and the lower slope 11 ° . Ridges occur on the northeastern and southwestern slopes and extend into deeper zones.

g. MS07

This is a peaked seamount and the shallowest part is 1,750 m deep, relative height 3,100 m, and it extends 50 km east–west and 50 km north–south.

The top is oriented in the NE–SW direction.

The average gradient of the upper slope is 16 ° , middle part 16 ° , and the lower part 9 ° . It has almost constant slope from the top to the middle part. Unlike the MS06 to the north, the slope of this seamount has many small topographic relief, and a large number of small pinnacles and terraces under 2 km in diameter and 500 m in height are distributed on the slope. This is clearly observed on the topographic gradient map.

h. MS08

This is a table seamount and the shallowest part is 1,350 m deep, relative height 3,600 m, and it extends 130 km E–W and 100 km N–S. This is the largest seamount in the survey area.

The top is divided into the northern and southern parts by 14 ° 06'N line, and has two peaks. The southern part is 200 m higher than the northern part. The southern part is elongated NW–SE direction and the northern part in the NNW–SSE direction, both are oblong with total area of 1,074 km ^{2} . The top is flat with 1.5 ° gradient and has almost no relief.

The average gradient of this seamount is gentle with 7.3 ° for the upper part and 7.9 ° for the middle part, but in detail, there are many steep parts exceeding 20 ° in the upper southern side. Also valleys descending steeply from the top are developed radially in zones where the reef edges form smooth arcs. On the other hand on the northern side, gentle slope under 10 ° occur widely in the upper part which is considered to be the continuation of the top, and many steep parts

exceeding 20° occur in the northeastern slope. Also a large ridge extends in the northwestern direction and its southwestern slope has many small relieves.

i. MS09

This is a truncated cone-shaped table seamount and the shallowest part is 1,140 m deep, relative height 3,900 m and it extends 70 km east-west and 70 km north-south.

The top is diamond-shaped and elongated in the NE-SW direction, and occupies an area of 145 km^2. The top is slightly sloped at 2.8° and is generally flat and there are four or five small depressions of 1 km x 2 km aligned in the NE-SW direction.

The upper part of the slope is somewhat steep at 21°, the middle part 17°, and the lower part 7°. Many pinnacles of around 2 km in diameter occur on the middle to the lower slope. Ridges extending NE-SW are particularly developed.

(3) Summary of bathymetric survey

The characteristics of the nine seamounts surveyed are summarized as follows.

- Table seamounts: MS01, MS02, MS03, MS04, MS06, MS08, MS09
  Peaked seamounts: MS05, MS07
- Largest seamount: MS08 (130 km E-W X 100 km N-S)
  Smallest seamount: MS06 (40 km E-W X 50 km N-S)
- Seamount with shallowest top: MS06 (950 m deep)
  Seamount with deepest top: MS07 (1,750 m deep)
- Seamount with largest flat top: MS03 (2,247 km^2 top)
- Seamount with largest relative height: MS02 (5,500 m)
  Seamount with smallest relative height: MS07 (3,100 m)
- Seamount with largest slope area: MS08 (over 4,692 km^2)
  Seamount with smallest slope area: MS06 (1,850 km^2)
- Topographic characteristics relative to the latitudinal and longitudinal directions and Pacific plate movement at the time of the formation of the seamounts were not recognized.
- There is no clear topographic differences between those belonging to the Ralik Seamount Chain (MS01-MS03) and those of Ratak Chain (MS04-MS09).

3-2 MBES Acoustic Reflection Images

(1) Acoustic reflection intensity distribution

Images of the reflection acoustic intensity from the seafloor by MBES were prepared. The reflection acoustic intensity is significantly influenced by the incident angle of the sonic waves to the seafloor. And the relation between the incident angle and the acoustic intensity of the back-scattered waves is not clearly known. Thus for correction of the observed values, statistical method was used, namely average acoustic intensities for incident angles 0 ~ 90 ° were obtained and the difference between the observed and the average acoustic intensity for each incident angle was used for the correction. The observed acoustic intensity data were corrected for output level, TVG, distance attenuation and other relevant factors. And then, acoustic intensities for all incident angles between 0 and 90 ° were obtained by statistical method.

Acoustic reflection images for the seamounts surveyed are laid out in Figures 3-2-1 (1) ~ (9). In these images, the parts with high intensity are expressed in black, and the low parts in white. Generally, the dark parts reflect exposed bedrock, while the pale parts unconsolidated sediments.

a. MS01

Dark zones of the image correspond to the edge of the top at the marginal parts of the top which show the highest reflection acoustic intensity., There are dark parts along the steps indicating exposed rocks on the terrace of the southwestern part of the top. In the northeastern part, dark belts appear along the slope exceeding 5 °, indicating exposed rocks. Dark zones are also distributed in the depressions in the southern and northwestern parts of the top. Most of the top has pale tone showing low acoustic intensity and indicating the predominance of unconsolidated sediments.

In the slopes, dark zones appear from the periphery of the top to the upper slope, and also along the five major ridges extending radially, indicating exposed rocks in these parts. Pale zones are distributed widely between the ridges in the gentler slopes showing the increasing unconsolidated sediments in these parts.

b. MS02

Dark images corresponding to edges of the top appear from the periphery of the top to the upper slope. The topographic highs with 2 km in diameter in the western part of the top are expressed in dark color indicating exposed rocks. Also in the southwestern part of the top, dark color appears in zones exceeding 5 ° slope. In the eastern part of the top, dark color is distributed in the domes structure including the shallowest part of this seamount. High acoustic reflection intensity continues

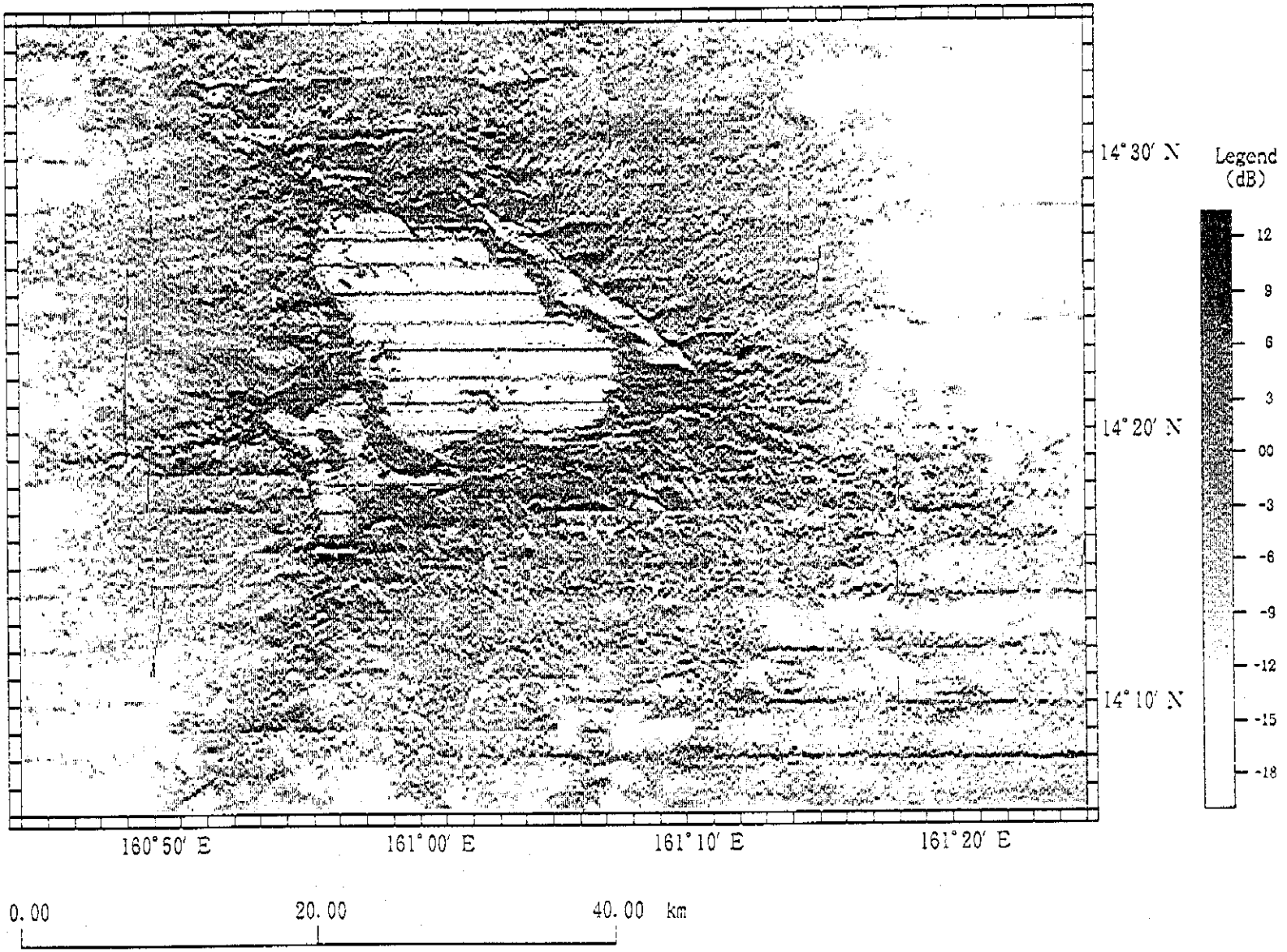

Fig. 3-2-1 (1) Acoustic reflection image based on MBES of seamount MS01. Darkly shaded areas indicate high sound amplitudes and light areas indicate low sound amplitudes.

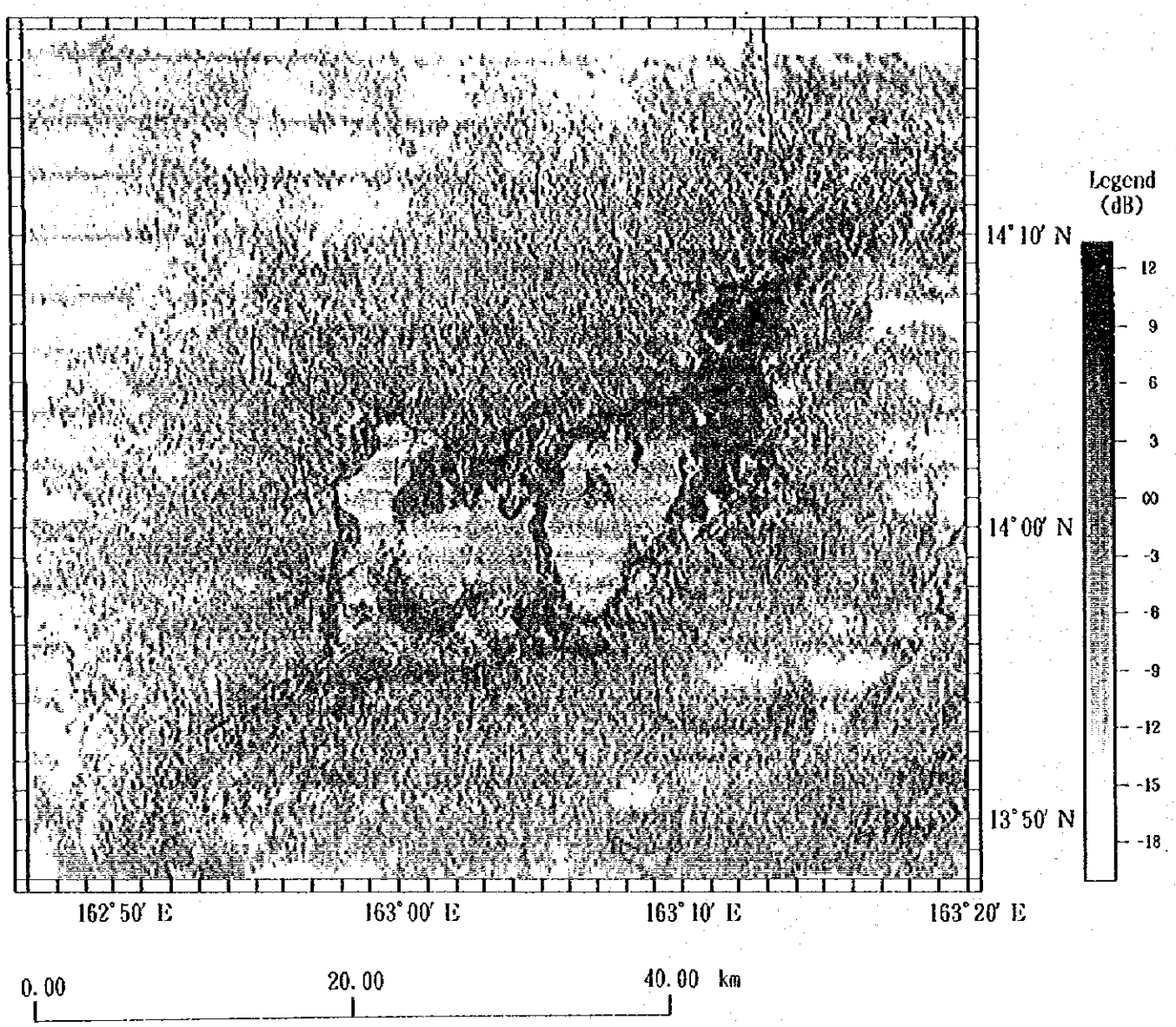

Fig. 3-2-1 (2) Acoustic reflection image based on MBES of seamount MS02. Darkly shaded areas indicate high sound amplitudes and light areas indicate low sound amplitudes.

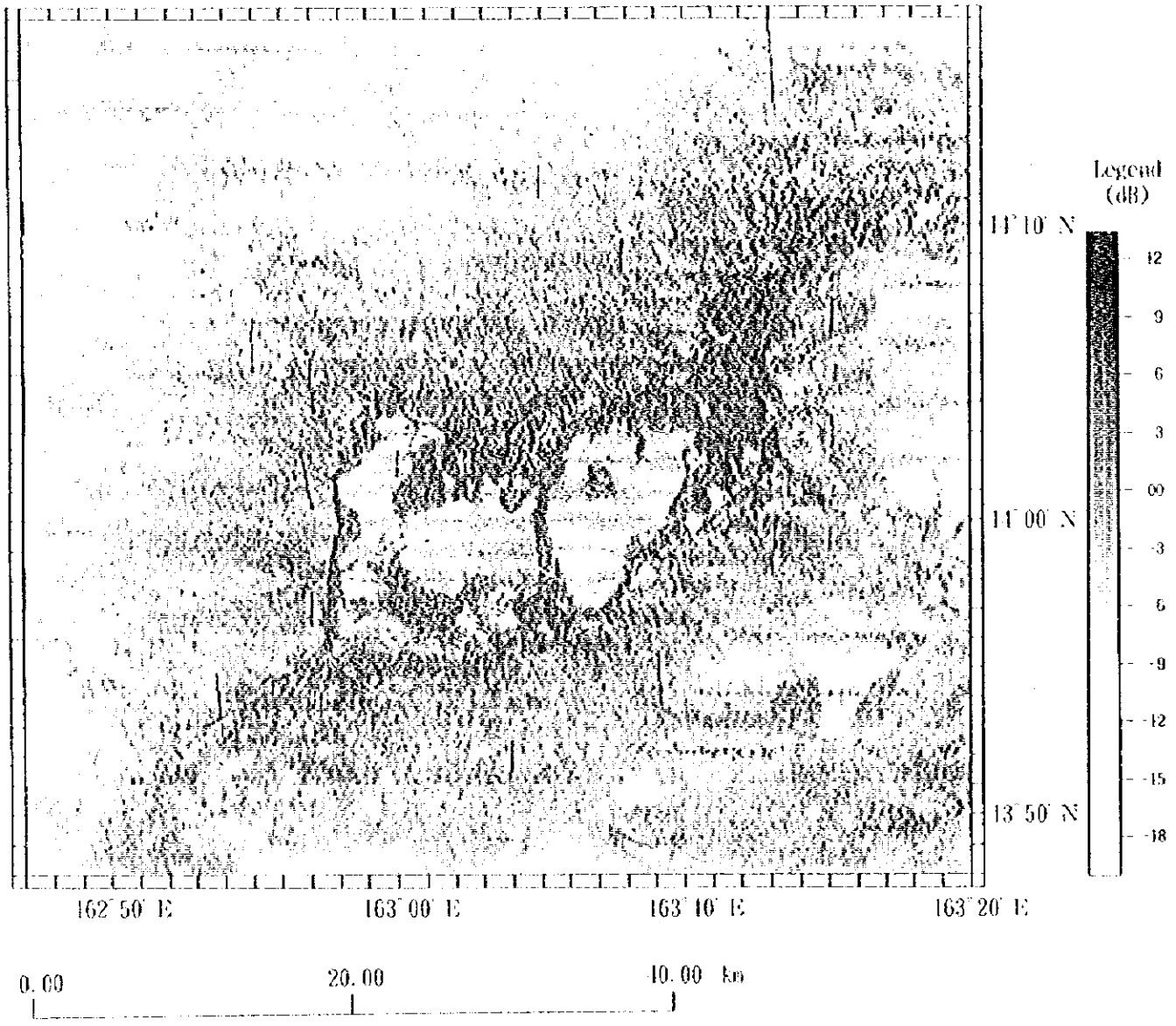

Fig. 3-2-1(2) Acoustic reflection image based on MBES of seamount MS02. Darkly shaded areas indicate high sound amplitudes and light areas indicate low sound amplitudes.

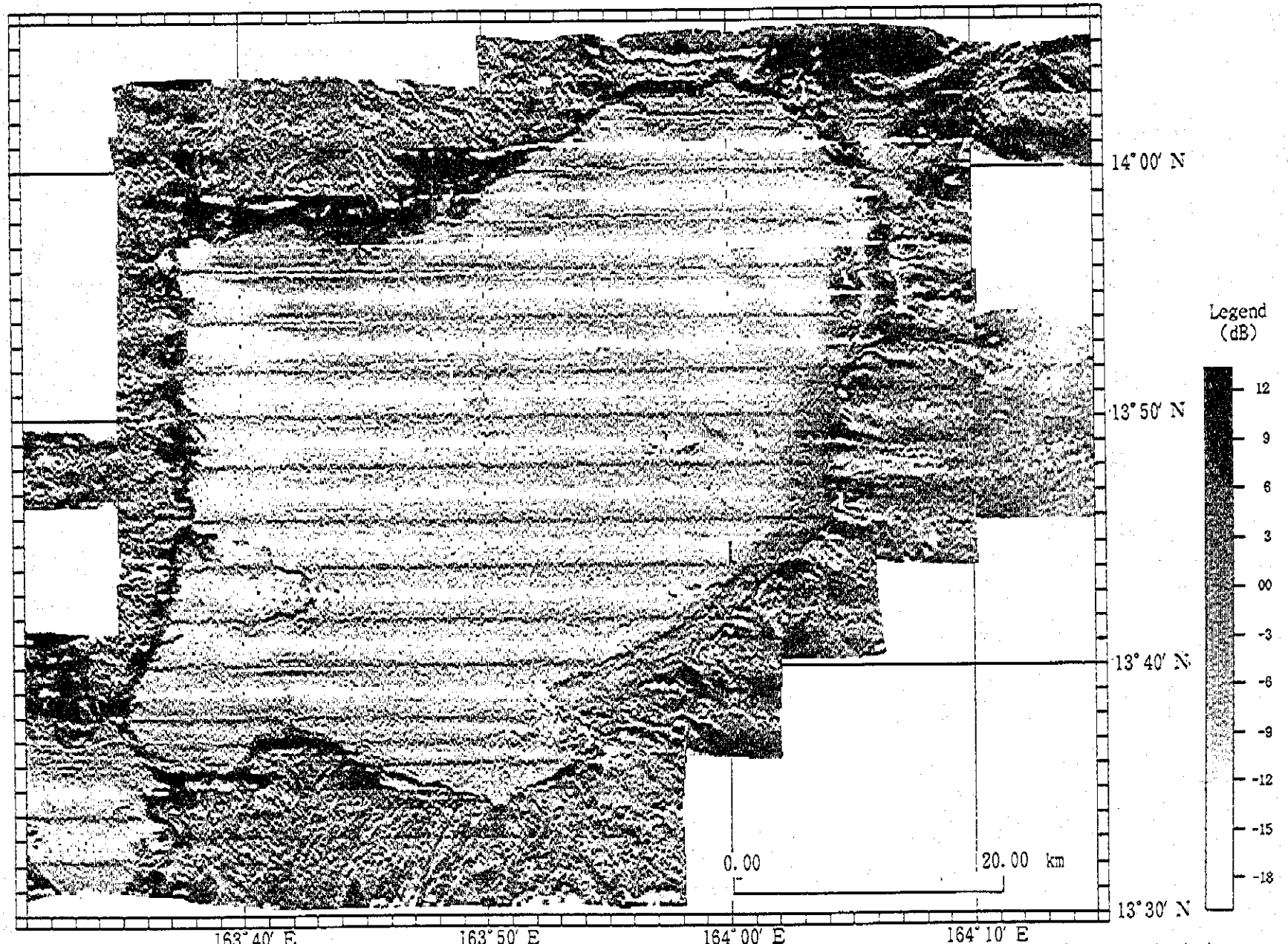

Fig. 3-2-1 (3) Acoustic reflection image based on MBES of seamount MS03. Darkly shaded areas indicate high sound amplitudes and light areas indicate low sound amplitudes.

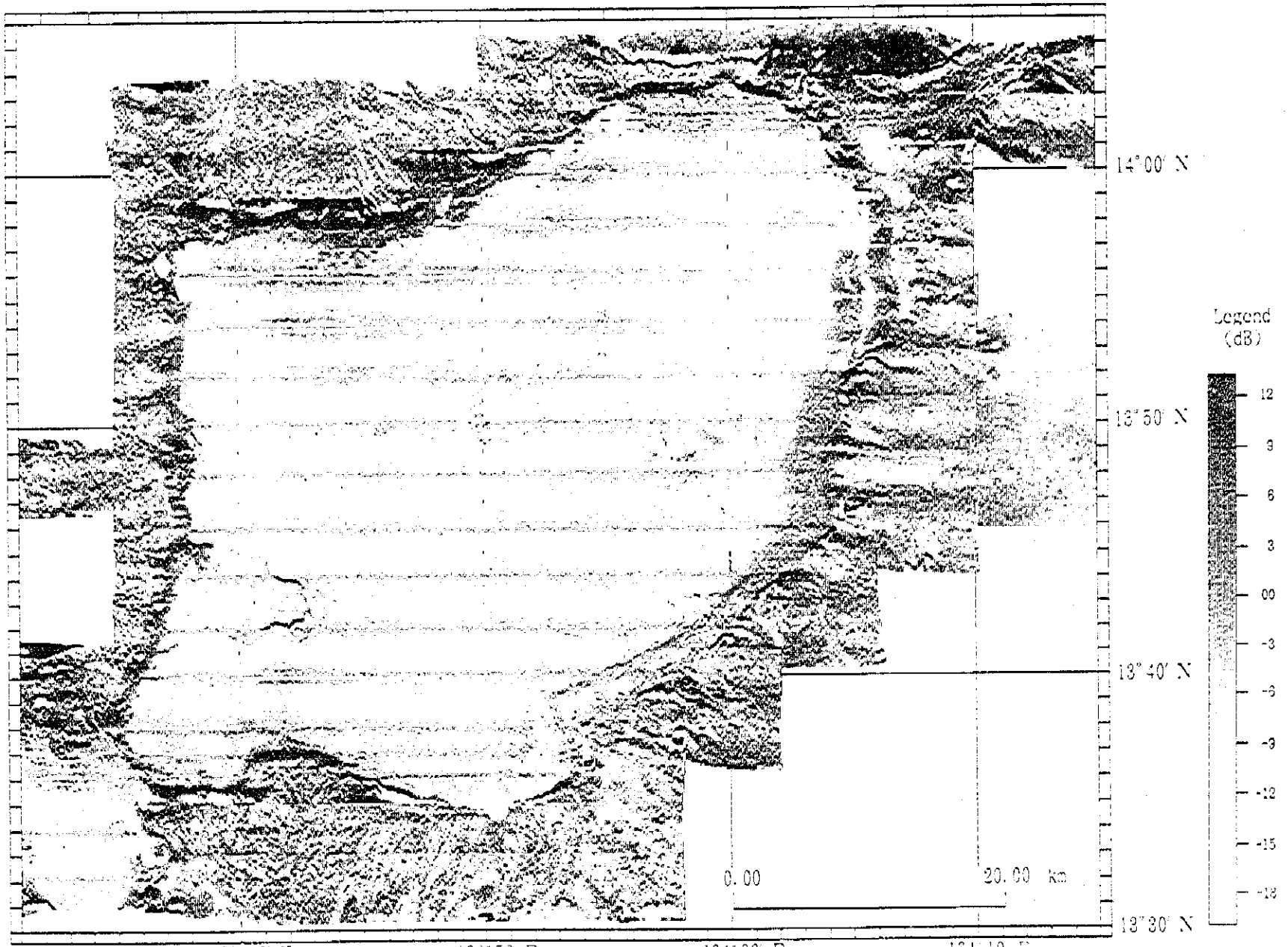

Fig. 3-2-1 (3) Acoustic reflection image based on MBES of seamount MS03. Darkly shaded areas indicate high sound amplitudes and light areas indicate low sound amplitudes.

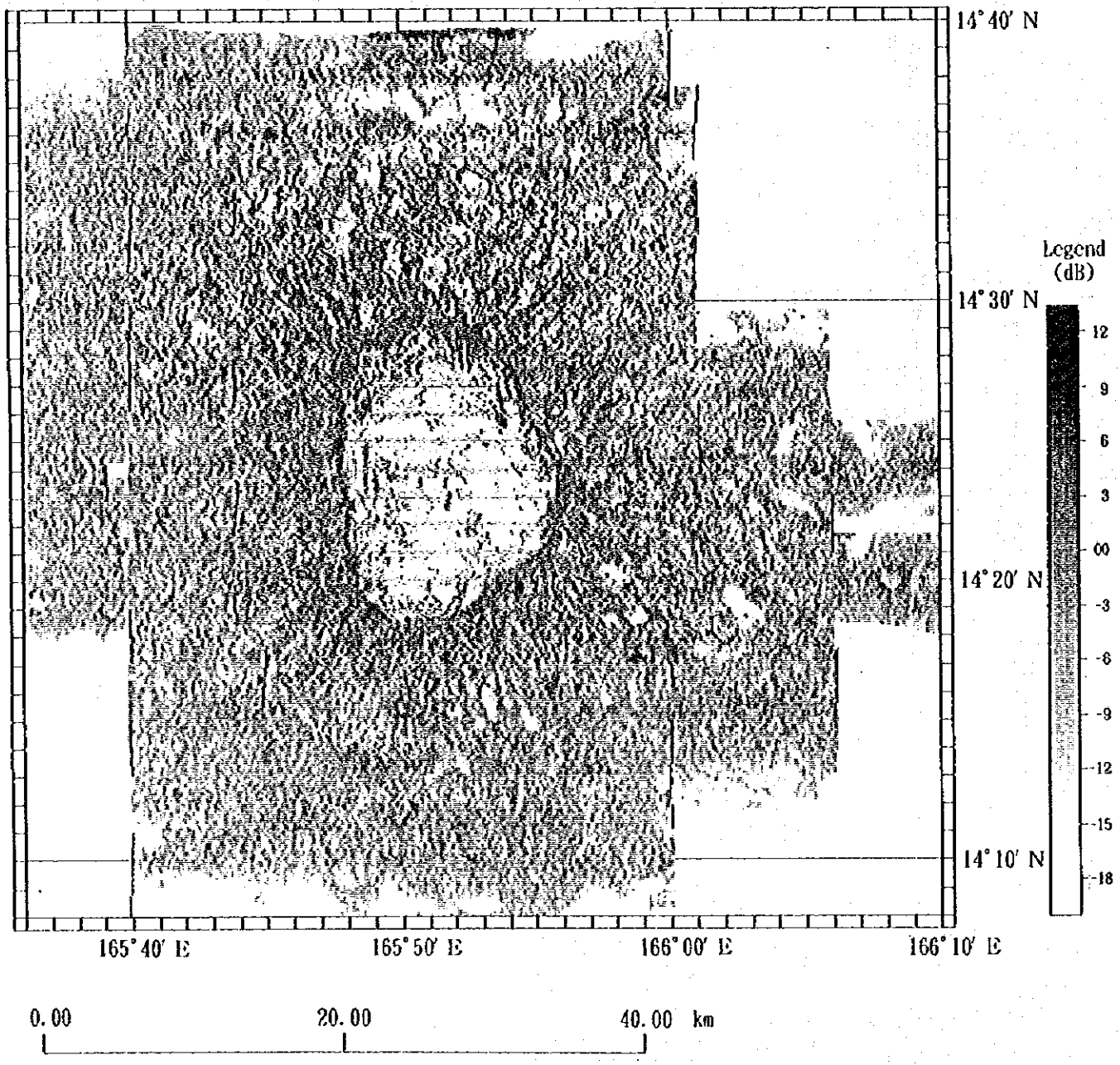

Fig. 3-2-1 (4) Acoustic reflection image based on MBES of seamount MS04. Darkly shaded areas indicate high sound amplitudes and light areas indicate low sound amplitudes.

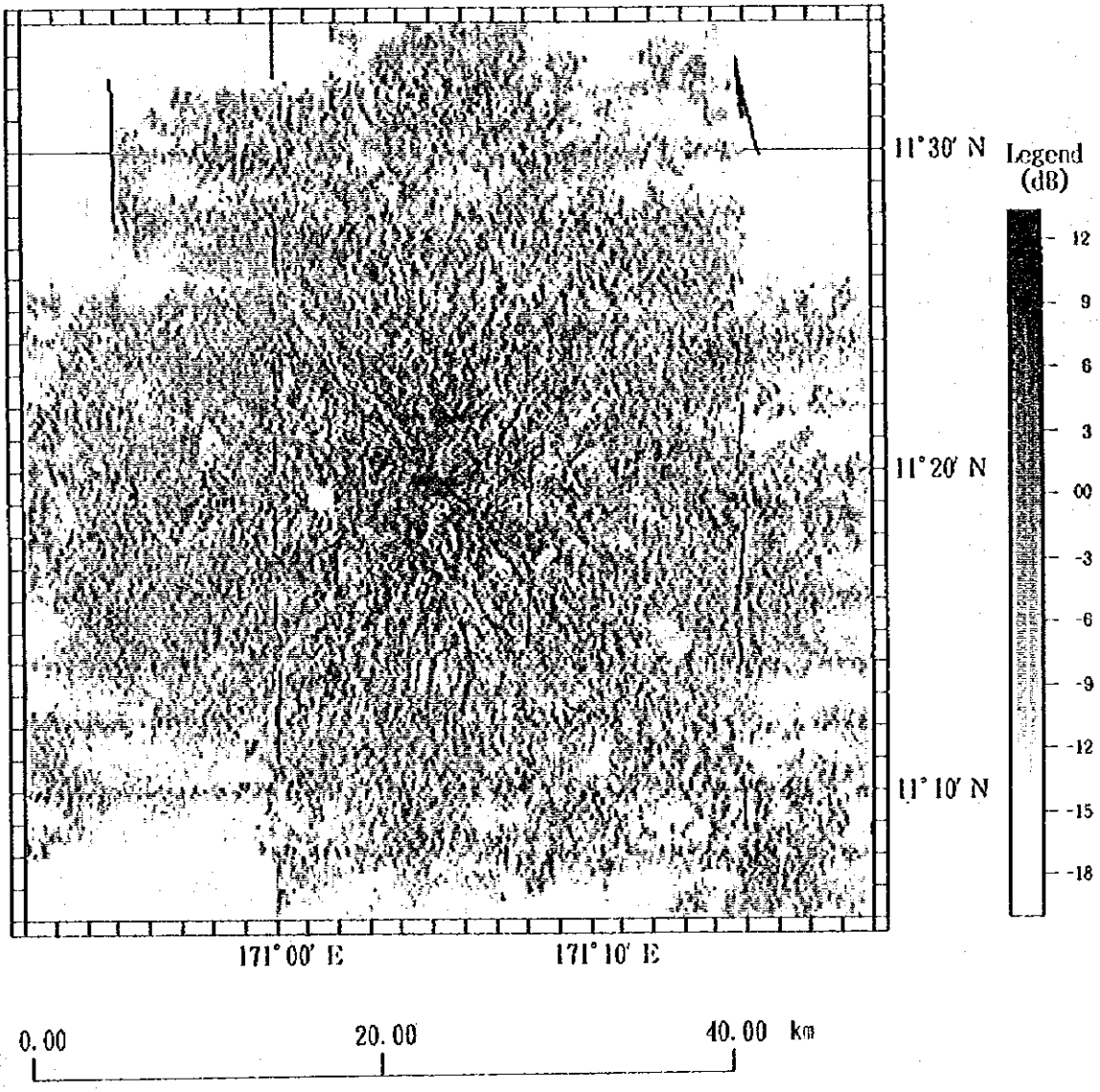

Fig. 3-2-1 (5) Acoustic reflection image based on MBES of seamount MS05. Darkly shaded areas indicate high sound amplitudes and light areas indicate low sound amplitudes.

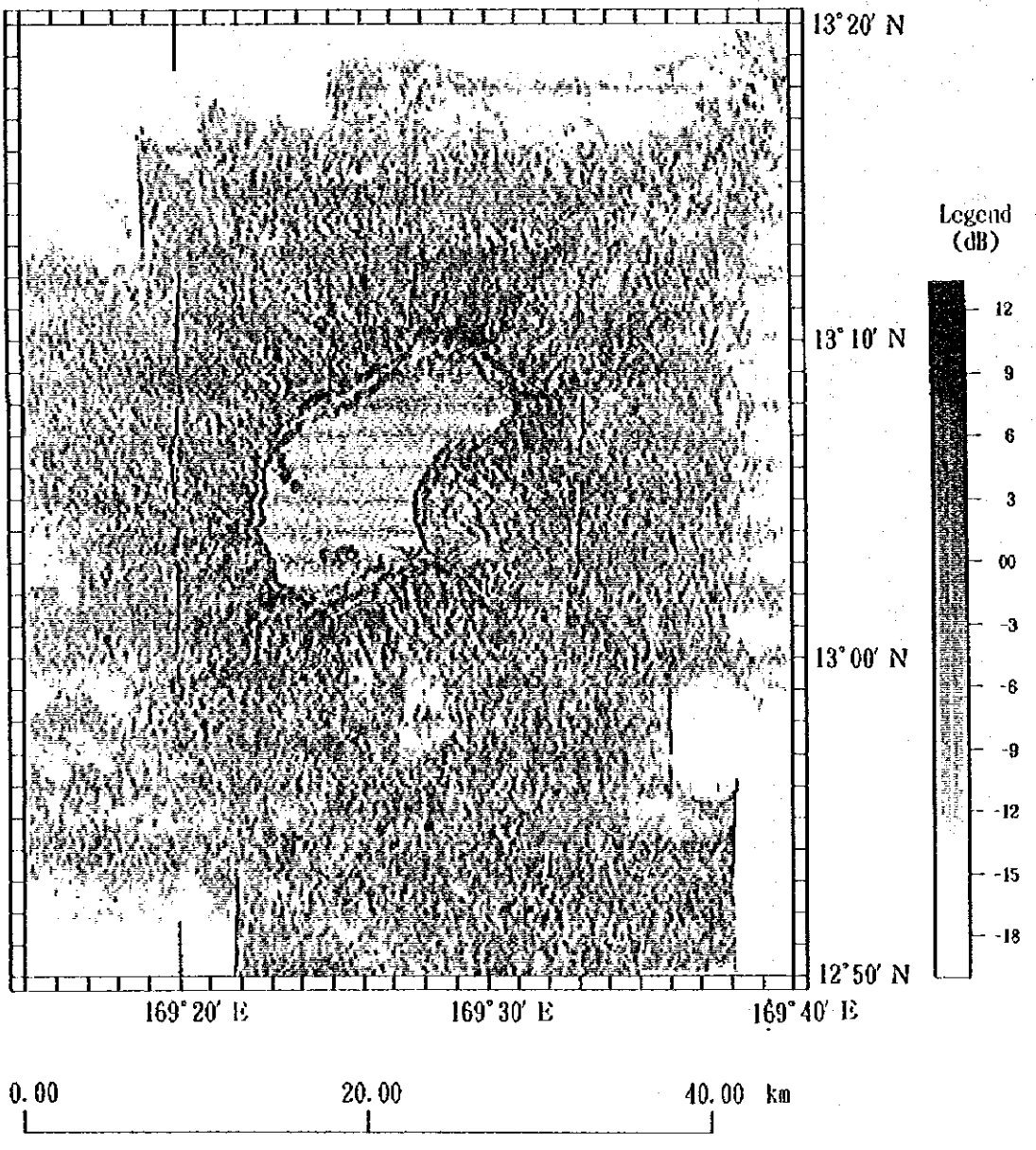

Fig. 3-2-1 (6) Acoustic reflection image based on MBES of seamount MS06. Darkly shaded areas indicate high sound amplitudes and light areas indicate low sound amplitudes.

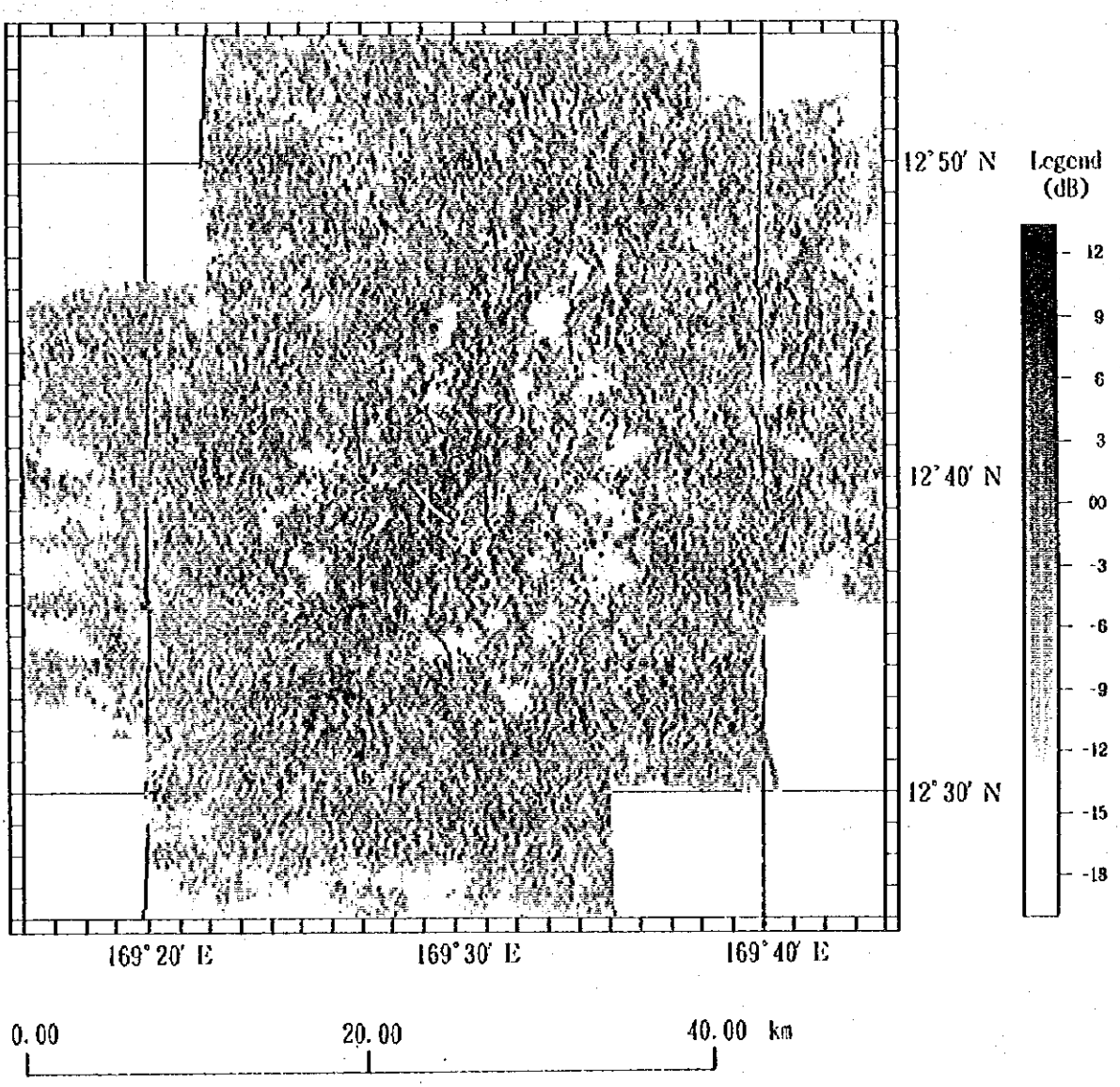

Fig. 3-2-1(7) Acoustic reflection image based on MBES of seamount MS07. Darkly shaded areas indicate high sound amplitudes and light areas indicate low sound amplitudes.

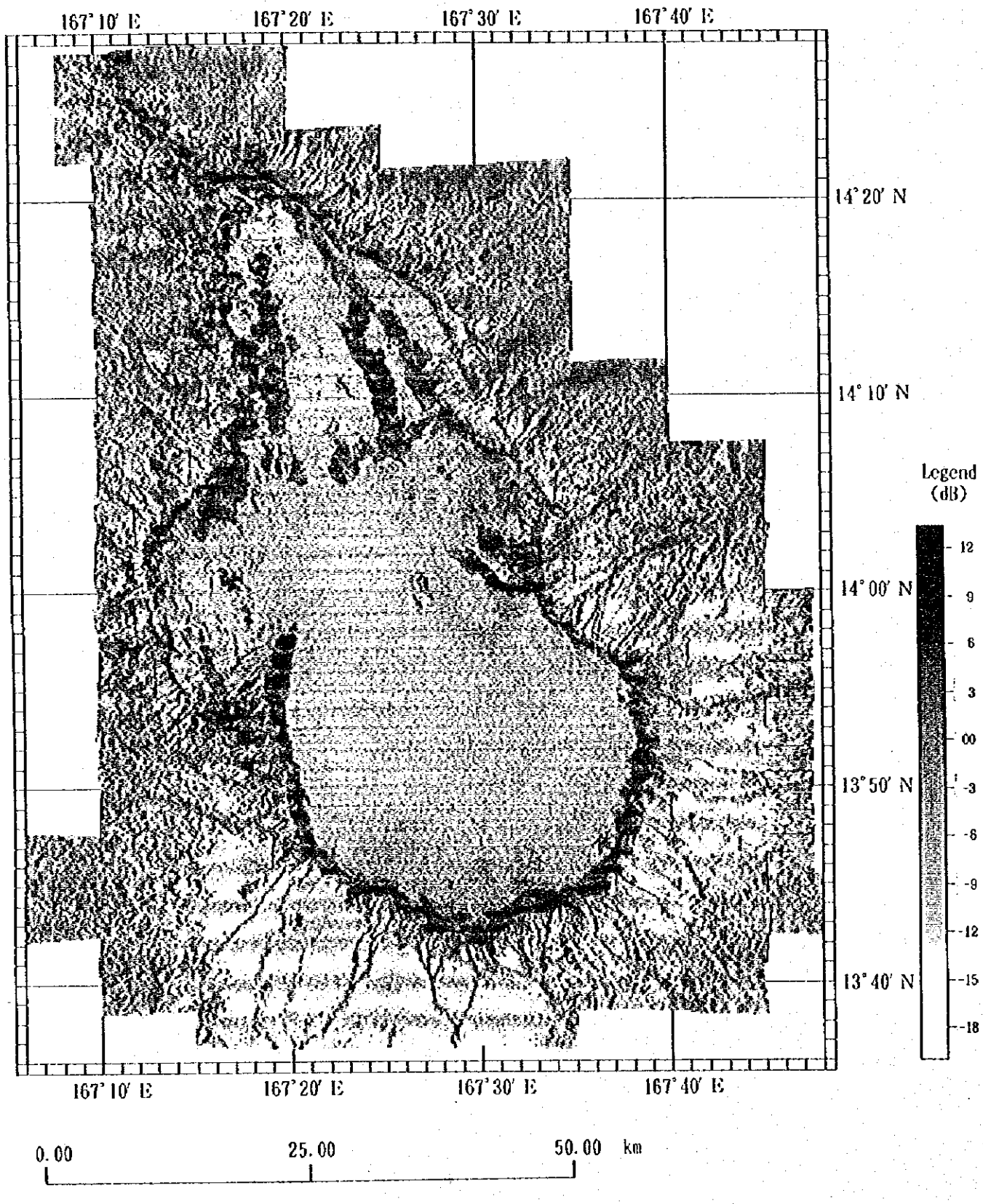

Fig. 3-2-1 (8) Acoustic reflection image based on MBES of seamount MS08. Darkly shaded areas indicate high sound amplitudes and light areas indicate low sound amplitudes.

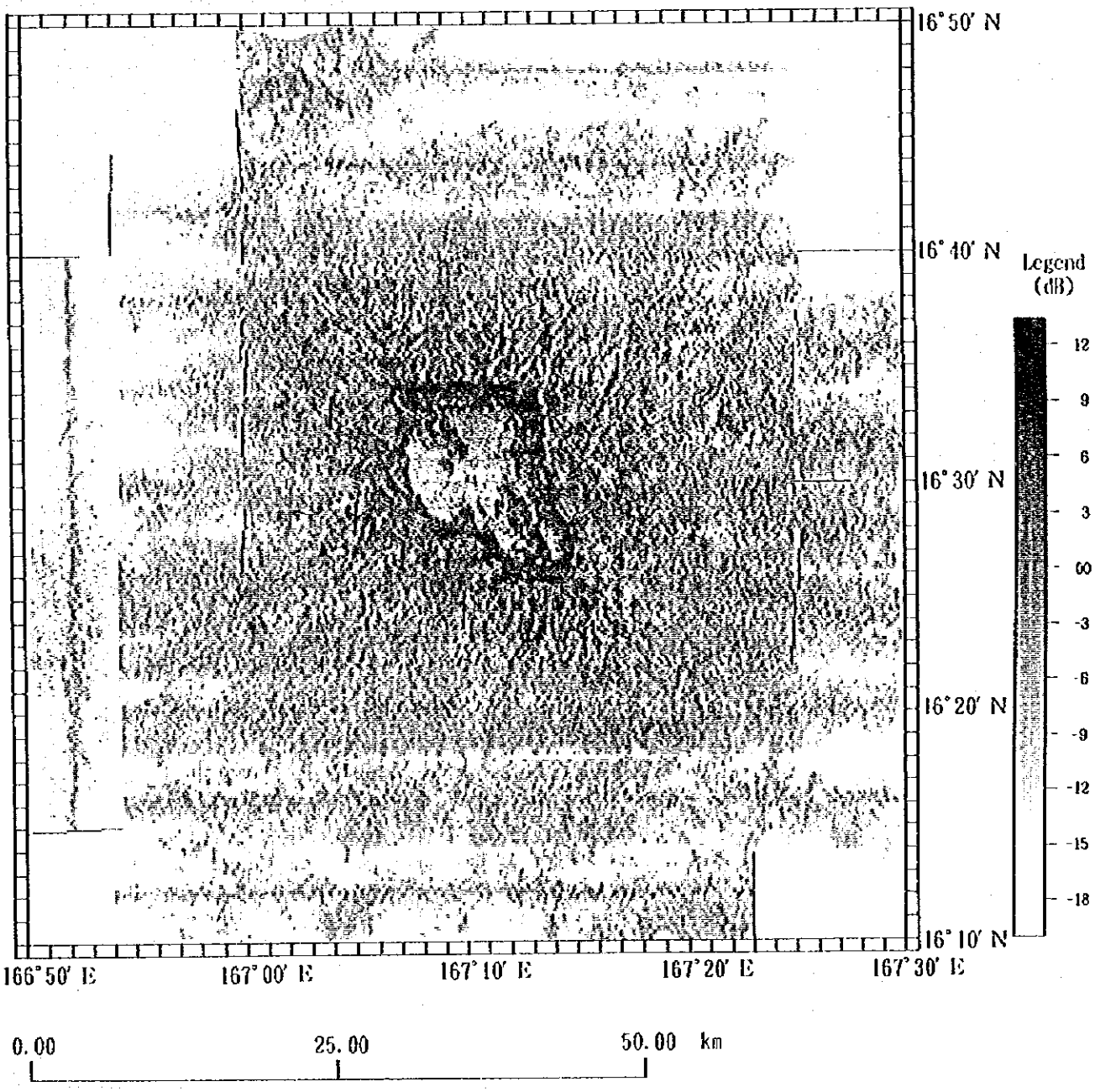

Fig. 3-2-1 (9) Acoustic reflection image based on MBES of seamount MS09. Darkly shaded areas indicate high sound amplitudes and light areas indicate low sound amplitudes.

to the edge of the top in the northeastern part of the dome structure, indicating wide areas of rock exposure. Major part of the top is expressed in pale color, showing the predominance of unconsolidated sediments.

In the slopes, dark color appears from the periphery of the top to the upper slope, and along the major rides extending northeastward, northwestward, and southwestward indicating the exposed rocks. In other parts of the slope, pale color increases as the slope becomes low angle, indicating the increase of unconsolidated sediments.

c. MS03

Most of the top is in pale color indicating low acoustic intensity with predominance of unconsolidated sediments. Dark color appears at the terrace structure in the northeastern part of the top indicating exposed rocks. Relatively high reflection acoustic intensity occurs at the depressions in the southwestern part of the top. Dark color is distributed from the edge of the top to the upper slope in zones with the highest reflection acoustic intensity. Relatively dark color is distributed in a 2 km wide belt at the southwestern periphery of the top indicating the exposure of rocks in this part.

Dark color is widely distributed on to the steep slope of the northern and southeastern upper slope.

d. MS04

The top is largely covered by pale color indicating the predominance of unconsolidated sediments. In the northern part, however, dark color appears widely showing the predominance of exposed rocks in this zone. It is inferred that the variation of the dark to pale tone in parts of the top indicates the variation of the coverage of unconsolidated sediments. Dark color corresponding to edges are distributed in the marginal parts of the top indicating the highest acoustic intensity, and these suggest the occurrence of exposed rocks.

Along the slope there is a strong tendency for the tone to pale downward indicating the dominance of unconsolidated sediments in the lower slope. Also fine variations of the tone is observed on the slope corresponding to the small topographic relieves.

e. MS05

The color of the image tends to change from dark to pale from the top to the upper, middle and lower slope. It is seen that rocks are exposed on the top to the middle slope. Many pinnacles in the lower slope are shown on the image as fine variation of the dark and pale tones. The spots of white on the western side and other parts of the lower slope correspond to the small terrace structures with unconsolidated sediments.

f. MS06

The top mostly shows pale color on the image indicating the dominance of unconsolidated sediments. In the central part of the top, small rock exposures are distributed similar to the small topographic highs in the southwestern part. The highest reflection acoustic intensity appears where the edges occur from the margin of the top toward the upper slope. The marginal parts of the top generally show high reflection acoustic intensity and in them steep slopes especially show higher reflection acoustic intensity, in other words distribution of the tone reflects the incline of the slope in general.

g. MS07

A NE–SW trending oblong high acoustic intensity zone appears on the image from the top to the upper slope. This coincides with the trend of this seamount. As compared with MS05 which has similar dimensions and type, the tone of MS07 is pale and has lower reflection acoustic intensity. The color distribution of the slope corresponds to the many pinnacles on this seamount. Also the remarkable white spots of the lower slope correspond to the unconsolidated sediments on the small terraces.

h. MS08

The wide distribution of the white indicates the occurrence of unconsolidated sediments over the top. The highest acoustic intensity shown by the dark tone occurs in zones corresponding to the edges from the top to the upper slope and the southern part shows the highest acoustic intensity.

Pale color appears widely on the slope in contact with the smooth arc of the edge of the top on the southern side indicating the dominance of the unconsolidated sediments. The valleys extending radially from this edge are shown by the dark tones of the image.

Dark belts appear along the topographic contours on the northern upper slope and it shows the dominance of exposed rocks. These dark belts are strongly correlated to the slope steeper than 5 ° and have stronger reflection acoustic intensity than those corresponding to the reef edges.

i. MS09

Dark color appears along the edges from the top to the upper slope, this has the highest acoustic intensity. High reflection acoustic intensity zones occur extensively in 2 km wide belts particularly in the northern ~ northeastern ~ eastern parts of the top inside the edge. Dark color also appears widely in the southwestern part of the top indicating the dominance of exposed rocks. Regarding the depressions aligned in the NE–SW direction, the reflection acoustic intensity is high at the boundary with the flat part, but it is low in the central part of the depressions.

Generally, the color grades from dark to pale from the upper slope downward and the acoustic intensity tends to decrease, it shows that unconsolidated sediments increase as the slope becomes gentle.

(2) Summary of MBES acoustic reflection images

It is inferred from the results of FDC observation and sampling that the exposed rocks of the images correspond to manganese crust exposures and that the unconsolidated sediments correspond to the bottom material consisting mainly of foraminifera sand. Now, the shade of the image changes with the amount of the foraminifera sand. Namely, it is believed that the tone darkens as the ratio of exposed manganese crust increases in the area in question. Therefore, it is inferred that the dark parts of the acoustic image indicate exposed manganese crust while the white parts indicate the occurrence of foraminifera sand.

From the above, the MBES acoustic reflection images clarified the following facts.

As a whole, in all seamounts, the manganese crusts are extensively exposed, along the edges of the top, the ridges of the slopes, and the steep valleys.

Regarding individual seamounts, MS09 has a small top, but the exposed manganese crust occupies a relatively large portion. On the other hand, MS03 has the largest top area, but most of it is covered by foraminifera sand. On MS07, manganese crust is exposed in oblong area extending in the NE–SW direction around the top.

Thus it is seen in this survey that the MBES acoustic reflection images are very useful in investigating the extent of the manganese crust exposures on seamounts regionally and efficiently.