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VII

1. Introduction

The researches of natural environment condition of coastal sea area (landform, geology, vegetation, water current, water quality, etc.) are usually executed by sonic detection method, or direct observation and sampling. These methods have some weaknesses, which are as follows:

- 1) Specific instruments or techniques are required.
- 2) Only point or line data can be obtained with the exception of the side-scan sonar imagery.
- 3) Field observations require a lot of time.
- 4) It is often very difficult for the survey vessel to approach the shore.

One of the best ways to solve these problems is the research by means of air photographs and airborne sensor images. The author planned some researches with this method in the coastal sea area research projects by the Geographical Survey Institute (GSI). The present paper is based on the results of the researches (GSI, 1982, 1984, 1986, 1988; Kumaki and Haraguchi, 1984a, b; Kumaki et al., 1985, 1986).

2. Aerial photogrammetry of the shallow sea floor

When the sea floor is visible in air photographs, it must be possible to measure the elevation (depth) of the sea floor by aerial photogrammetry in the same way as the topographic survey. The correction of the light refraction at the water surface is necessary, however. W.O.J. Groenreld Meijer's correction method is known (Sato and Uchida, 1973). The correction formula is not simple, but it is easy to measure the depth by the use of an analytical plotter with the correction function.

Needless to say, the sea floor should be visible on the air photographs for the photogrammetry. Accordingly, it is impossible to measure the depth in case that there are fine waves on the sea surface, or the halation prevents the underwater vision. The photographing must not be done in such cases. The more transparent the sea water is, the lower the tide level is, and the lower the flight altitude is, the more clearly visible air photographs will be obtained. In general, the sea floor can be seen more clearly in true color photographs than in monochrome photographs. Photographs of panchromatic film are useless because they are taken through a yellow filter to cut a haze and the sea surface in the photographs becomes black. As the blue-green light is well transmitted in the water, air photographs which are sensitive to blue-green light might be better for the photogrammetry of the sea floor, but they are not necessary

advantageous because of the influence of the haze in the air.

One of the biggest difficulties of the sea floor photogrammetry is the orientation, as compared with land area photogrammetry. When land area is widely included in one-course photographs, control points on land are available. Otherwise, some particular methods, i.e. setting air-photo signals on the sea floor or buoys on the sea surface, as control points, have been used (Kitahara and Yamaguchi, 1977; Ota and Takatsu, 1987). These two methods, however, require the control point survey in the sea area and the precision is not so good.

The GSI made a bathymetric survey of a coastal sea area by the following photogrammetric method in 1984: Both the small-scale (1:25,000) true color air photographs widely including land area and the large-scale (1:5,000) true color air photographs of survey area are taken (Fig.1). Positions and depths of some points on the sea floor are measured photogrammetrically with the small-scale photographs, the orientation of which is made by the control points on land. Then the orientation of the large-scale photographs is made by the newly fixed sea-floor points as given control points, and the depth-contour lines are drawn.

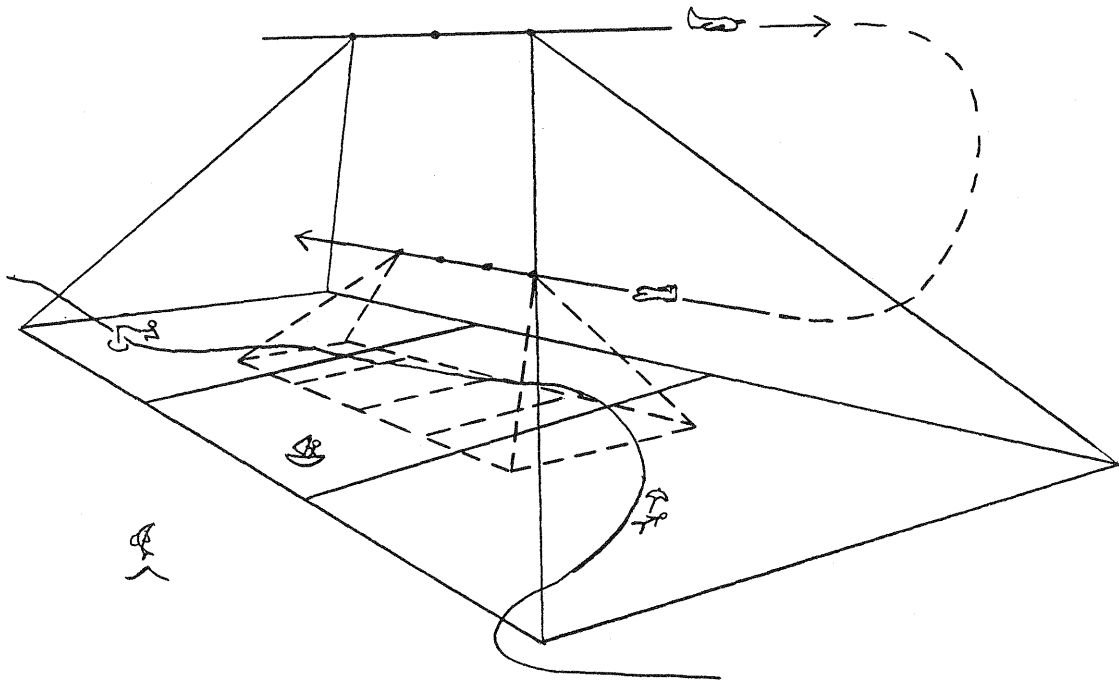


Fig.1 Photographing for the sea floor photogrammetry by GSI

One of the advantages of this method is that the on-the-sea work is not necessary, but it is adoptable only in the area where some clear points exist on the sea floor.

The sea floor of the survey area was rocky with a lot of low relief. The water transparency was around 15 meters. The result of the survey is shown in Fig.2. The upper of Fig.2 was compiled from the depth-contour map made by the above-mentioned method; the middle was plotted photogrammetrically from the small-scale (1:25,000) photographs; the lower shows a depth-contour map by echo-sounding, the sounding line interval of which was 500 meters.

The upper obviously represents the detailed relief of the sea floor. The maximum plottable depth was 10 meters. The depth-contour lines of the middle are smoother than those of the upper, but the rough forms are very similar. On the contrary, though the indentation degrees of the contour lines are not so different, the contour forms in the middle and in the lower are distinctively different, especially in between sounding lines. Besides, part of 0-3 meter depth contours were not plotted in the lower map because of the difficulty for the survey vessel to approach the shore.

As a result, it can be stated that the photogrammetry is useful for plotting accurate depth contours in coastal shallow sea area. It is very suitable for the survey of very shallow and rugged sea floor such as a coral reef. In flat and monotonous sandy or muddy sea floor, however, the difficulty of stereoscopy reduces the efficiency of this method.

3. Air photograph interpretation of the shallow sea floor

When the sea floor is visible in air photographs, it must be also possible to investigate the sea floor features by the air-photograph interpretation. The subjects of the interpretation are geomorphology, geology, vegetation, artificial bodies such as gathering objects for fish, etc.

As to geomorphology, it is known that some mega-ripples on the sea floor are observable in a 1:10,000 air photograph (Verstappen, 1983). The air-photo interpretation is especially effective to know the distribution of the wave-cut benches, the coral reef forms, etc. Even if the stereoscopy is difficult in sandy or muddy sea floor, the color (the depth of blue) shows the micro-relief situation. Researches on the sea-floor micro-landforms may make it possible to know the water action upon sea floor.

In Japan, many scientists research into the late Quaternary crustal deformations using raised shoreline data. It is necessary to study the present sea floor geomorphology for the recognition of the raised shorelines. The air-photo interpretation is one of the most effective methods in this field.

Fig.3 shows an example of the air-photo interpretation of the sea floor materials. It was confirmed by sampling and a diver's

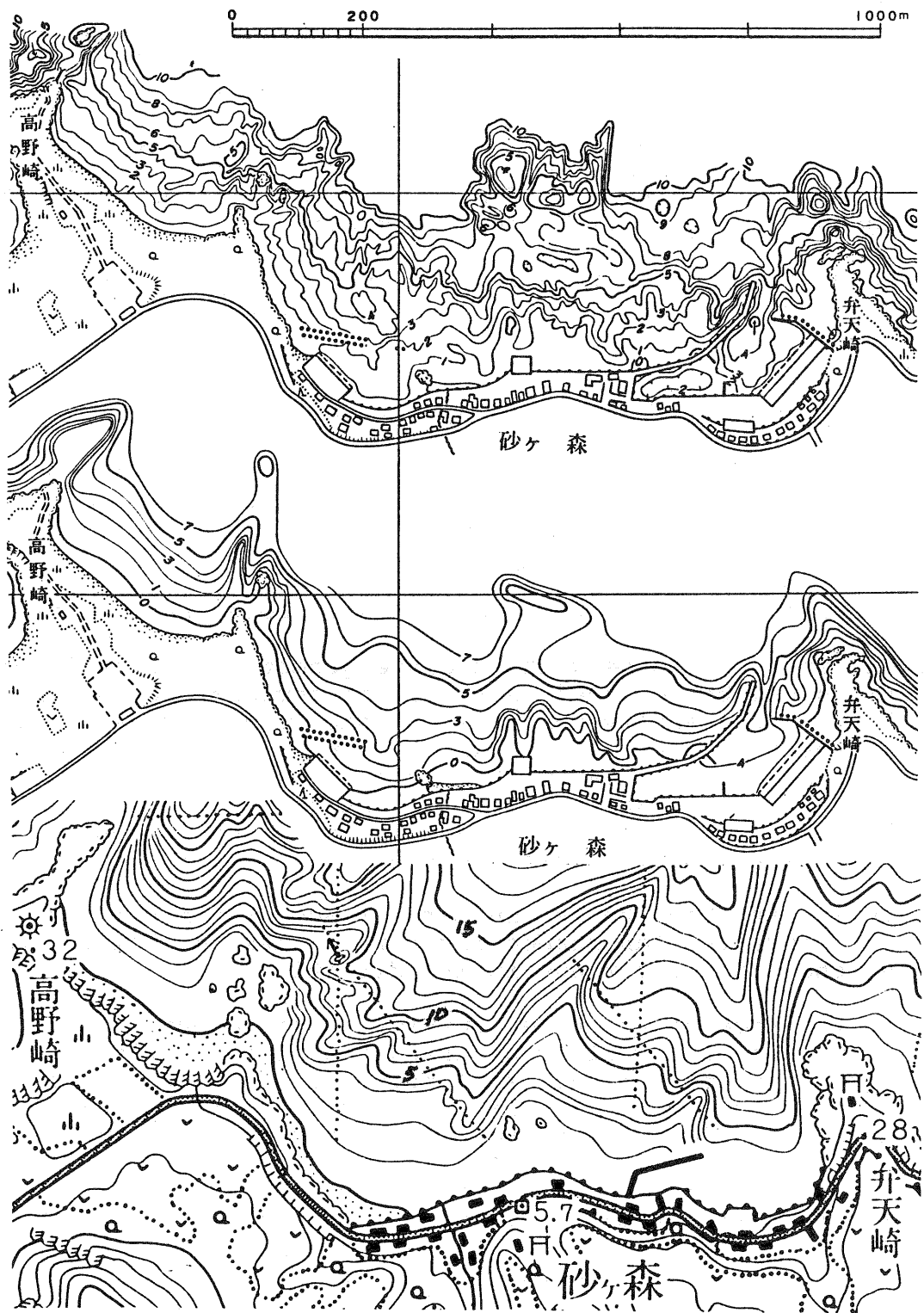


Fig.2 Three kinds of depth-contour map
Dotted lines in the lower map are sounding lines.

observation. In this case, not only the rock/sand distribution but also the situation of thin sand or gravel layers on small depressions of rocks can be interpreted. Generally speaking, the photo image of rock surface shows a rough texture and stripes due to the geologic structure. Some of the stripes are deformed by faults and folds. Stripes which are observable without stereoscopic view show that there is a micro-cuesta on the rock surface and sand is deposited in the depression part. The image of sand area is bright and smooth.

Fig.4 shows a result of a vegetation density interpretation. This was also confirmed by a diver's observation. The darker the image of rock surface is, the higher the vegetation density may be.

4. Air photograph interpretation of the sea surface

It is possible to obtain some data on wave direction and water current direction from the air photographs. For example, small swirls on sea surface often indicate the appearance places and directions of strong water current.

5. Water current and quality research by airborne sensor imagery

A thermal infrared image with adequate geometric and radiometric corrections can be regarded as a surface temperature map. A coastal sea area usually consists of some water masses of different temperature, e.g. river water flowing from the river mouth into sea, inland bay water, offshore water, etc., and the water mass boundary pattern suggests the current direction. When the quality of each water mass is known, it is possible to presume the water quality distribution.

Fig.5 is an airborne thermal infrared image of a river mouth area. It shows the fan-shaped river water mass of low temperature and the coastal current in N-S direction.

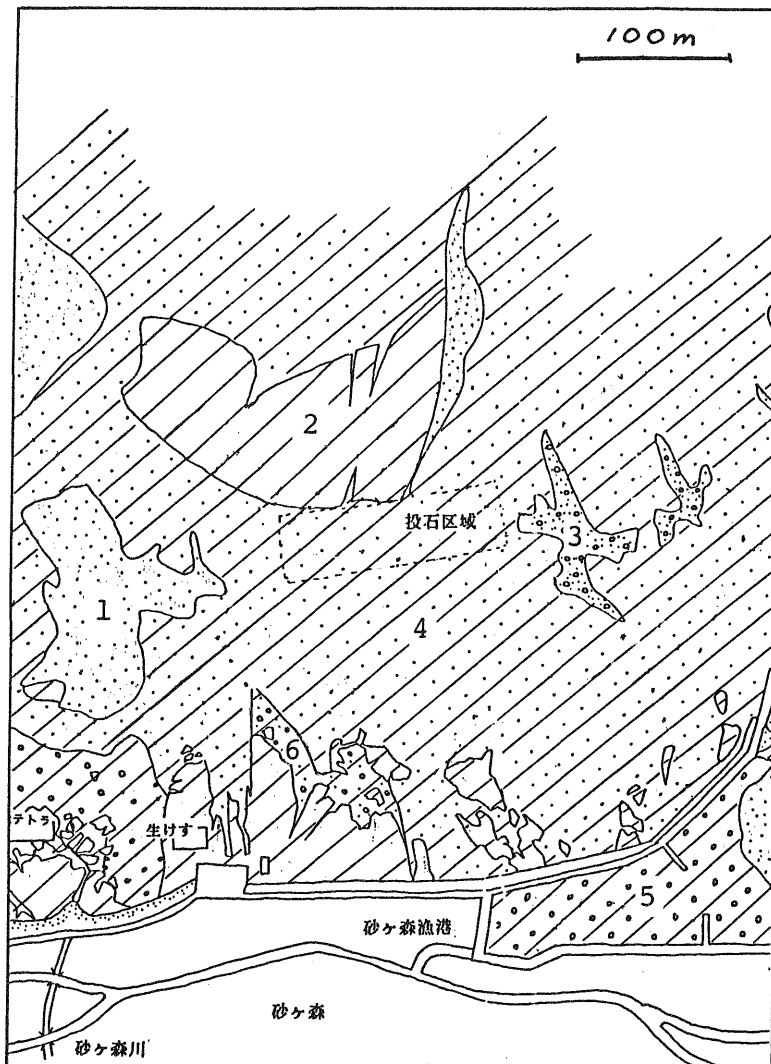
When the variance of the water quality is big enough, it is possible to know the quality distribution from the visible wavelength image and the ground (sea) truth data. In the case of a bay, yellow band (0.55 - 0.60 μ m) data of a multispectral scanner correlated most highly with the water transparency. The relationship is as follows:

$$\log Tr = -0.071Y + 4.42 \quad r = -0.68, \quad n = 100$$

where Tr=transparency(m), Y=digital number of yellow band data. As a result, a transparency distribution map (Fig.6) was made. The thermal infrared image obtained at the same time (Fig.7) suggests that there was a counterclockwise current along the shore and that the current in the central part of the bay where the transparency was low was stagnant.

5. Conclusion

The air photographs for the sea floor research have to be taken under the limited conditions. The research is possible only in shallow area. Air photographs and remote sensor imageries show



- 1: Sand
- 2: Rock
- 3: Sand and gravel
- 4: Rock with thin sand layer
- 5: Rock with thin gravel layer
- 6: Rock with thin sand and gravel layer

Fig. 3 Distribution of sea floor materials by 1:3,000 air photograph interpretation

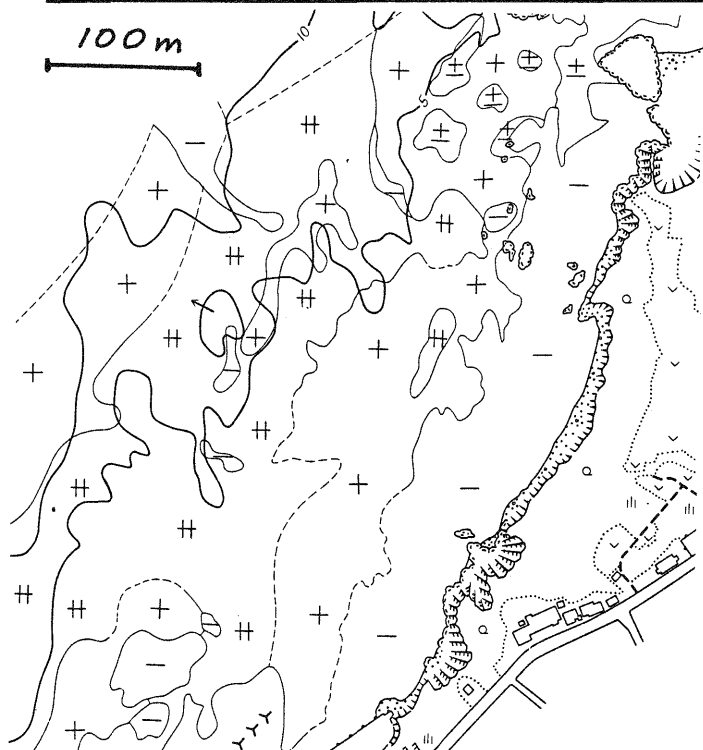
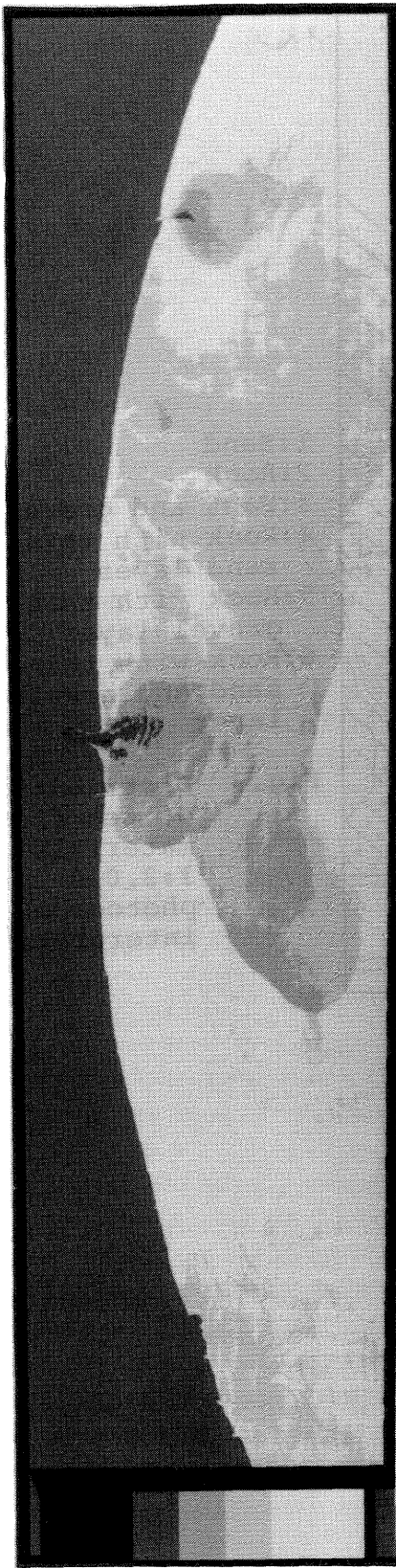


Fig. 4 Vegetation density by 1:3,000 air-photo interpretation



N
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5km

Fig.5 Airborne thermal infrared image of a river mouth area

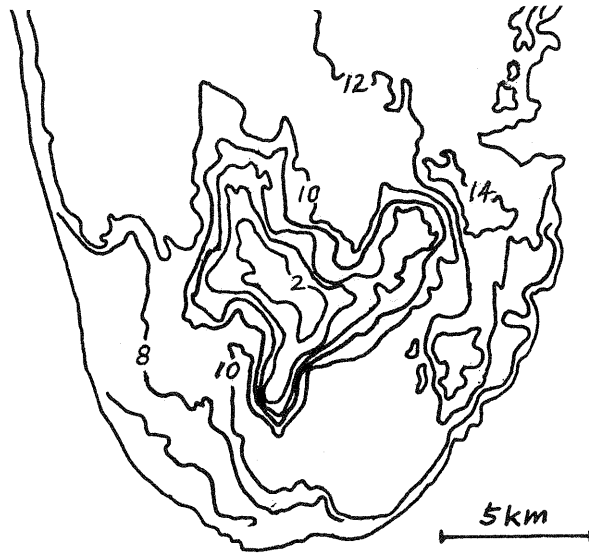


Fig.6 Transparency (m) distribution of a bay by MSS data

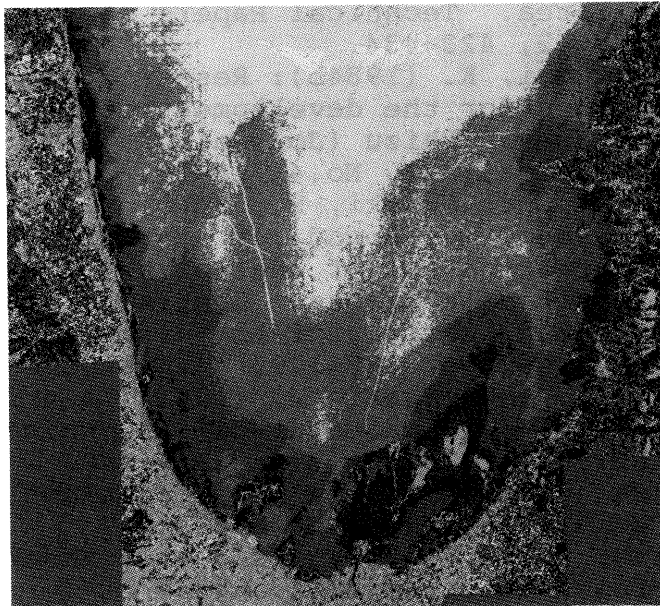


Fig.7 Thermal infrared image of a bay by airborne MSS

the water surface environment, and it is impossible to know the underwater environment from them. However, these methods have a lot of advantages, such as the uniformity, the rapidity, the safety, etc. True color air photographs at a scale of 1:8,000 - 1:12,000 are available in any part of Japan. Therefore, the methods from the air are very effective for the coastal sea area research.

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