Littoral Mapping from Digitized

Oblique Aerial Photograph

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ABSTRACT

The study deals with the analytical rectification of ditized oblique aerial photograph into the ortho-photo projection, which will be well applied to littoral mapping. The oblique aerial photograph has the advantages of wide coverage, selectability of ground control points, avoidability of sun glitter and so on, which would be useful to study the coastal environment.

The procedures involve the exterior orientation for metric and non-metric camera, grid insertion onto the oblique photograph, geometric resampling for ortho-photo projection and automated image output.

Examples are shown for panchromatic aerial photograph taken by metric camera, color aerial photograph taken by non-metric camera and color space photograph taken by reseaux 70mm camera borne in SKYLAB.

INTRODUCTION

Oblique photograph except very few taken by trimetrogon camera has not been used for mapping because of optical-mechanical constraints in mapping device. However, digital image processing technique overcomes these difficulties in optic.

Coastal mapping mainly deals with coast and adjacent offshore which can be assumed to be located in a plane. Therefore, two dimensional perspective projection can be applied between oblique photograph and the sea surface.

GEOMETRY OF OBLIQUE PHOTOGRAPH

Let the projection center of lense be $O(x_0, y_0, z_0)$, coordinates of an object be P(X, Y, Z), and their photographic coordinates by p(x, y) as shown in Fig. 1. Let the attitude of camera for oblique photograph have three rotation angles of roll ω, pitch ϕ and yaw κ. Then, coordinates of the object P(X, Y, Z) can be transformed to the camera coordinates as follows.

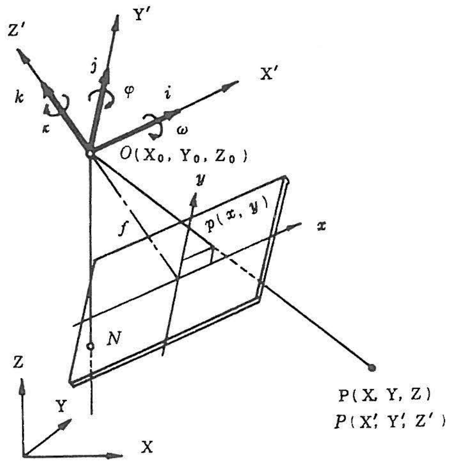


Fig. 1 Geometry of oblique photograph

$$\begin{pmatrix} X' \\ Y' \\ Z' \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\omega & -\sin\omega \\ 0 & \sin\omega & \cos\omega \end{pmatrix} \begin{pmatrix} \cos\varphi & 0 & \sin\varphi \\ 0 & 1 & 0 \\ -\sin\varphi & 0 & \cos\varphi \end{pmatrix} \begin{pmatrix} \cos\kappa & -\sin\kappa & 0 \\ \sin\kappa & \cos\kappa & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} X-X_0 \\ Y-Y_0 \\ Z-Z_0 \end{pmatrix} \tag{1}$$

The coordinates on the photograph, (x, y) are expressed as follows.

$$\begin{aligned} x &= -f\frac{X'}{Z'} = -f\frac{a_{11}(X-X_0)+a_{12}(Y-Y_0)+a_{13}(Z-Z_0)}{a_{31}(X-X_0)+a_{32}(Y-Y_0)+a_{33}(Z-Z_0)} \\ y &= -f\frac{Y'}{Z'} = -f\frac{a_{21}(X-X_0)+a_{22}(Y-Y_0)+a_{23}(Z-Z_0)}{a_{31}(X-X_0)+a_{32}(Y-Y_0)+a_{33}(Z-Z_0)} \end{aligned} \tag{2}$$

where

$$\begin{array}{lll} a_{11} = \cos\varphi\cos\kappa & a_{12} = -\cos\varphi\sin\kappa & a_{13} = \sin\varphi \\ a_{21} = \cos\omega\sin\kappa + \sin\omega\sin\varphi\cos\kappa & a_{22} = \cos\omega\cos\kappa - \sin\omega\sin\varphi\sin\kappa & a_{23} = \sin\omega\cos\varphi \\ a_{31} = \sin\omega\sin\kappa - \cos\omega\sin\varphi\cos\kappa & a_{23} = \sin\omega\cos\kappa + \cos\omega\sin\varphi\sin\kappa & a_{33} = \cos\omega\cos\varphi \end{array} \tag{3}$$

Equations (2) can be tansformed into the inverse equations as follows.

$$\begin{aligned} X &= (Z-Z_0)\frac{a_{11}x + a_{21}y - a_{31}f}{a_{13}x + a_{23}y - a_{33}f} + X_0 \\ Y &= (Z-Z_0)\frac{a_{12}x + a_{22}y - a_{32}f}{a_{13}x + a_{23}y - a_{33}f} + Y_0 \end{aligned} \tag{4}$$

Orientation parameters of projection center (X_0, Y_0, Z_0) and rotation angles (ω, ϕ, κ) can be determined by using both ground coordinates and photographic coordinates of control points which are input into the following non-linear equations.

$$F(X_0, Y_0, Z_0, \omega, \varphi, \kappa) = -\frac{a_{11}(X-X_0) + a_{12}(Y-Y_0) + a_{13}(Z-Z_0)}{a_{31}(X-X_0) + a_{32}(Y-Y_0) + a_{33}(Z-Z_0)} - \frac{x^*}{f} = 0 \qquad (5)$$

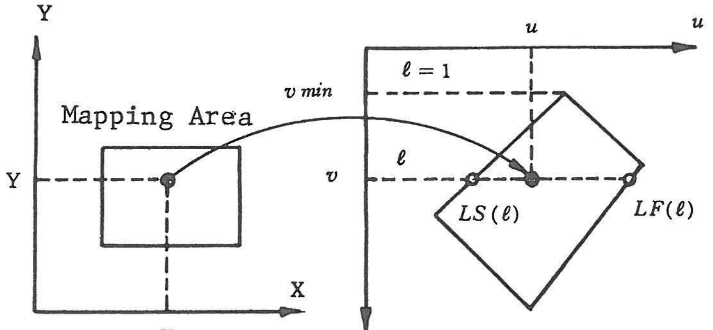
$$G(X_0, Y_0, Z_0, \omega, \varphi, \kappa) = -\frac{a_{21}(X-X_0) + a_{22}(Y-Y_0) + a_{23}(Z-Z_0)}{a_{31}(X-X_0) + a_{32}(Y-Y_0) + a_{33}(Z-Z_0)} - \frac{y^*}{f} = 0 \qquad (6)$$

To determine the six parameters, least square method is applied to the linearized equation with Tailor's extensions around approximate values.

DIGITAL RECTIFICATION OF OBLIQUE PHOTOGRAPH

Digital rectification and ortho-photo mapping are executed in the following steps.

1. Digitize the oblique photo with pixel size of 0.1 millimeters.
2. Select an area of ortho-photo map.
3. Input the size of pixel of the ortho-photo map.
4. Calculate the area on the image plane corresponding to the area of map by Equations (2) and transfer the image data into computer memory.
5. Generate a regurarly spaced pixel on the map, transform to the photographic coordinates and interpolate the corresponding image data, as shown in Fig. 2.
6. Produce ortho-photo map by converting digitial data to film pixel by pixel.



a. Mapping Area b. Image Plane

Fig. 2 Resampling and Interpolation

APPLICATIONS

a. Oblique Photographs taken by Metric Camera

Two oblique photographs of coastal zone in northern Japan were taken by metric camera Zeiss RMK A, f=153.12mm, on the 12th, December, 1977, as shown in Fig. 3. Fig. 4 shows one of the oblique photographs with control points and with grid lines of one killometer which were described by using calculated photographic coordinates by Equation (2).

Six orientation parameters were determined by computer as follows.

$$X_0 = +187{,}859.528 \text{ m} \qquad \omega = -46^\circ\ 57'\ 00''$$
$$Y_0 = +106{,}799.206 \text{ m} \qquad \phi = -\ 3^\circ\ 31'\ 23''$$
$$Z_0 = +\ 1{,}663.183 \text{ m} \qquad \kappa = 25^\circ\ 11'\ 00''$$

Root mean square of residuals was about 20 micrometers with respect to both x and y on the image plane for nine control points.

Fig. 5 shows the ortho-photo map which was automatically generated pixel by pixel for the area of 4 km by 3 km with 2000 pixels by 1500 pixels respectively. Effluents from river and coast are well identified in the ortho-photo map.

b. Oblique Photograph Taken by Non-metric Camera

A color aerial oblique photograph in Okinawa, south Japan was taken by non-metric 35mm camera Olympus OM-1, f=50mm, in 1978 as shown in Fig. 6.

Six orientation parameters were determined by computer as follows.

$$X_0 = 55{,}734.39 \text{ m} \qquad \omega = 68^\circ\ 30'\ 10''$$
$$Y_0 = 48{,}024.29 \text{ m} \qquad \phi = 0^\circ\ 29'\ 07''$$
$$Z_0 = 658.28 \text{ m} \qquad \kappa = 4^\circ\ 37'\ 54''$$

Root mean square of residual was 64 micrometers on film.

Fig. 7 shows the area for ortho-photo in the map.

Fig. 8 shows the computer generated ortho-photo for three primal colors, that is, red, green and blue, corresponding the area shown in Fig. 7.

c. Oblique Space Photograph Taken by Reseaux Camera

A color space oblique photograph in Kyushu Island in Japan was taken by 70mm reseaux camera, Hasselblad MK-70, f=100.00mm borne in SKYLAB on the 1st, January, 1974, as shown in Fig. 9.

Six orientation parameters were determined by computer as follows.

$$X_0 = 132^\circ\ 14'\ 06'' \qquad \omega = -33^\circ\ 30'\ 26''$$
$$Y_0 = 29^\circ\ 23'\ 06'' \qquad \phi = -24^\circ\ 17'\ 12''$$
$$Z_0 = 437.460 \text{ km} \qquad \kappa = 8^\circ\ 07'\ 59''$$

Root mean square of residual was 27 micrometers of film.

Ortho-photo projection was based on the Mercator Map Projection. Fig. 10 shows the map of Kyushu Island based on the Mercator System. Fig. 11 shows a geographically corrected space photograph.

Smoke from the famous volcano "Sakurajima" can be exactly located in the map.

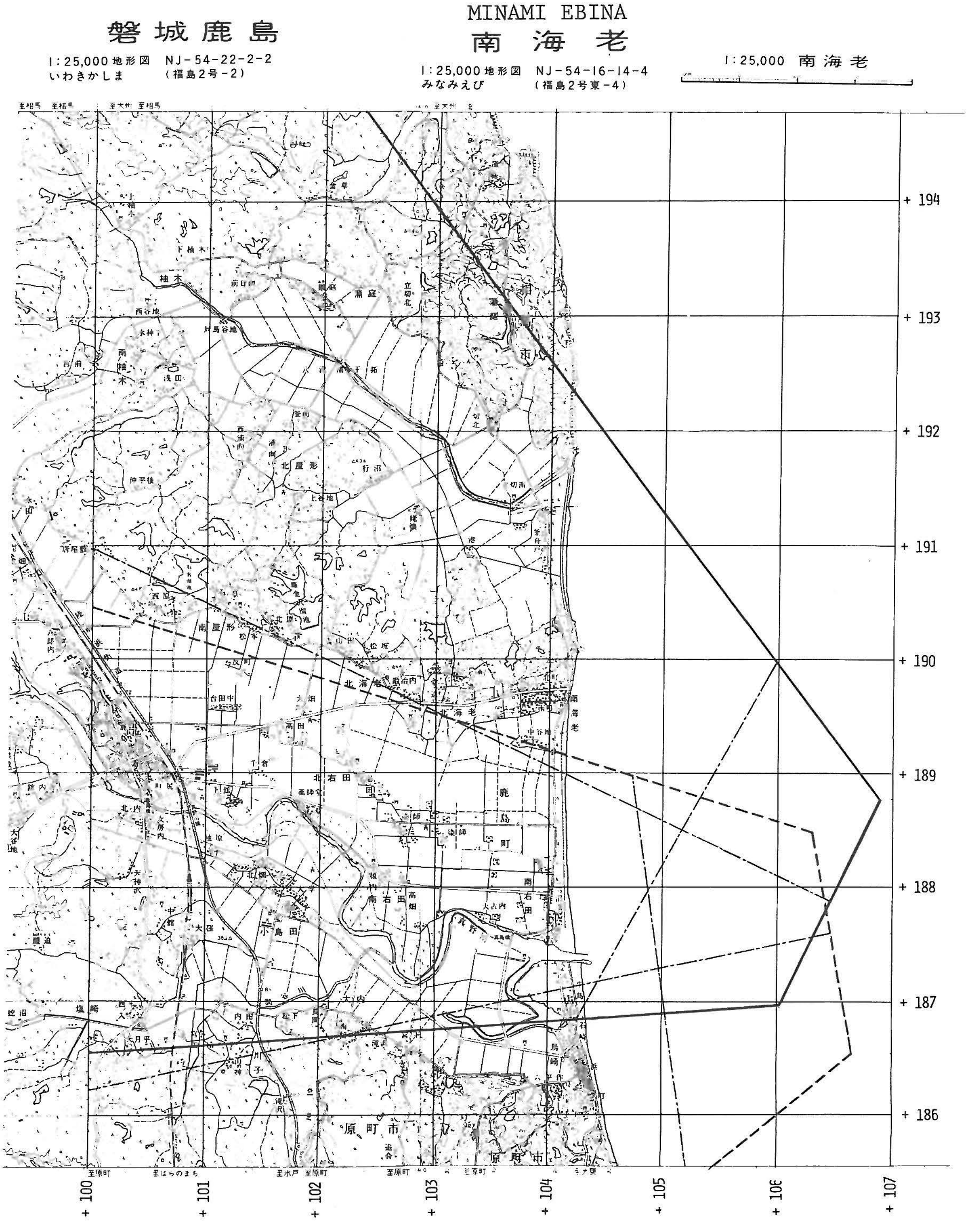


Fig. 3 Test Site

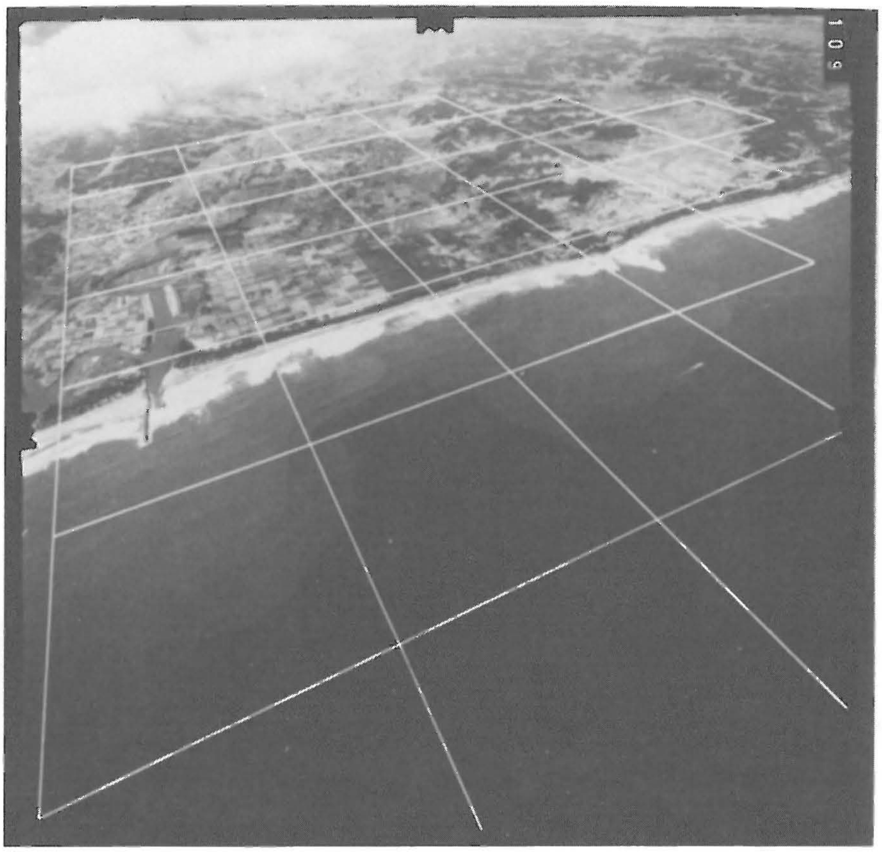


Fig. 4 Oblique Photograph with Grid Lines

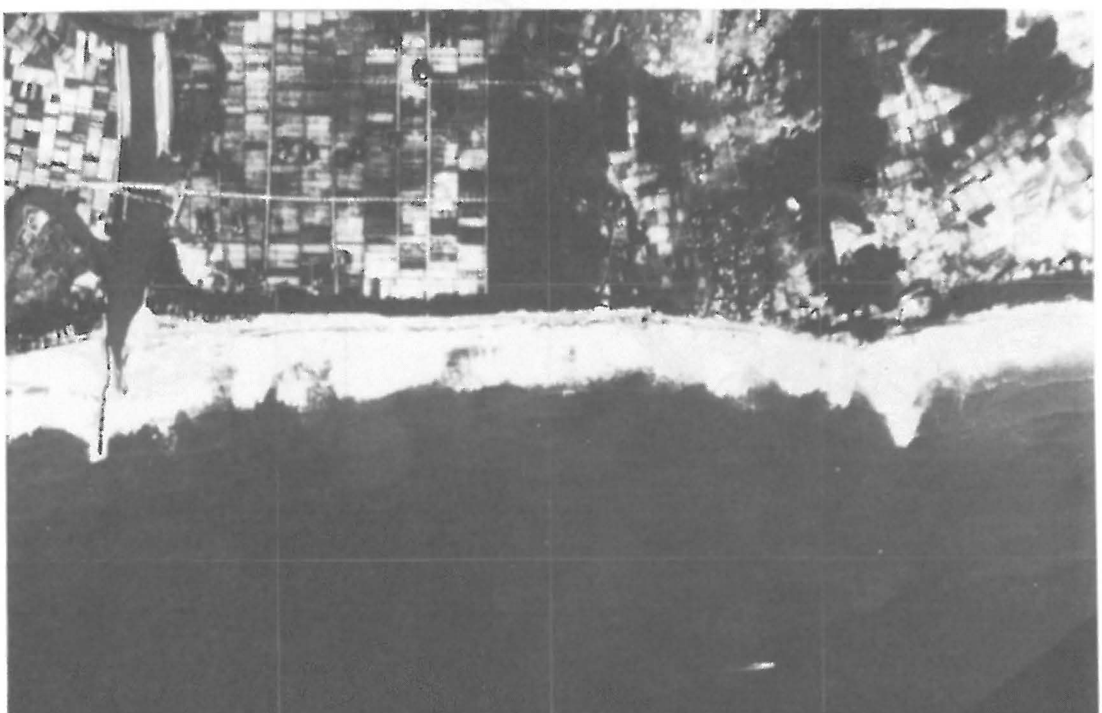


Fig. 5 Computer Generated Ortho-photo Map

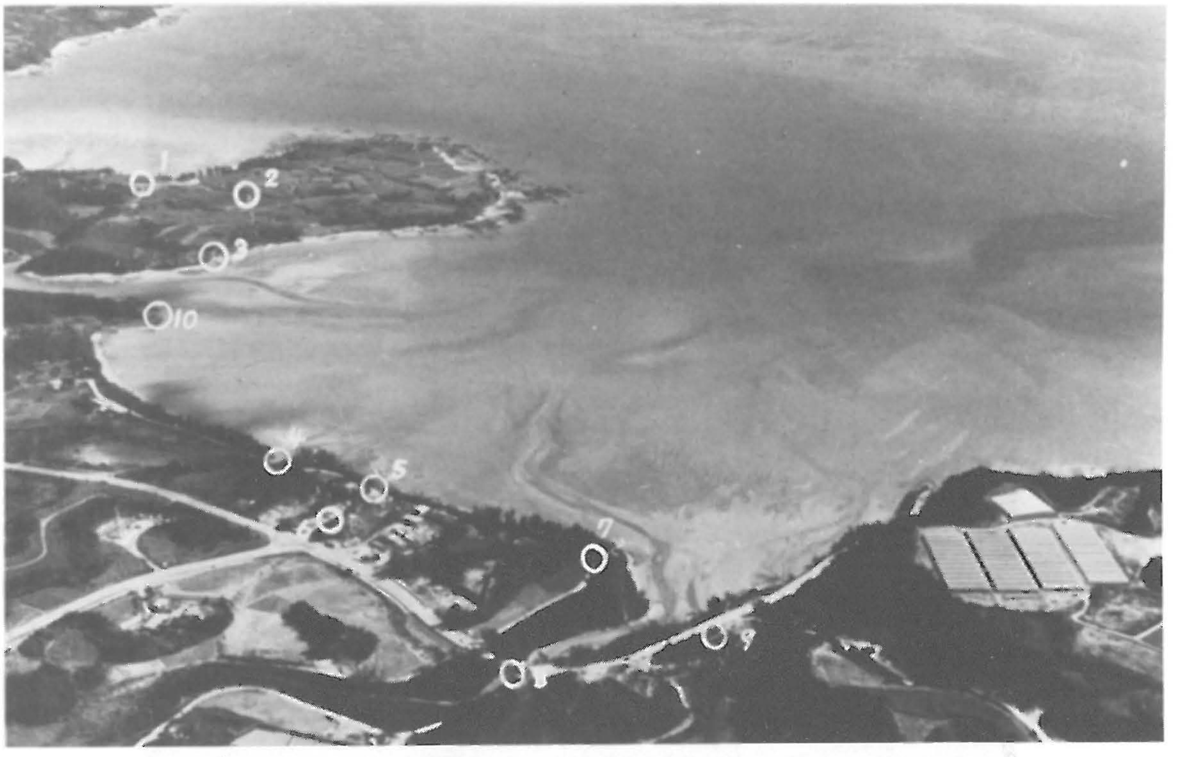


Fig. 6 Oblique Aerial Photograph with Control Points

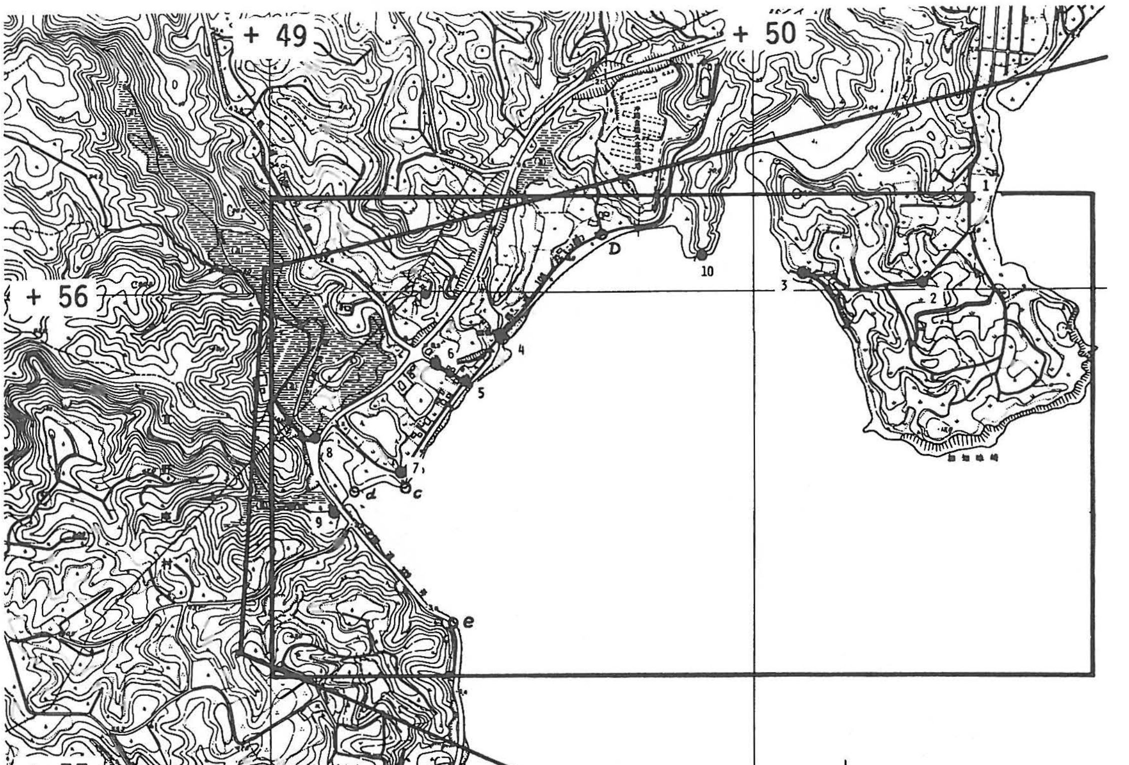
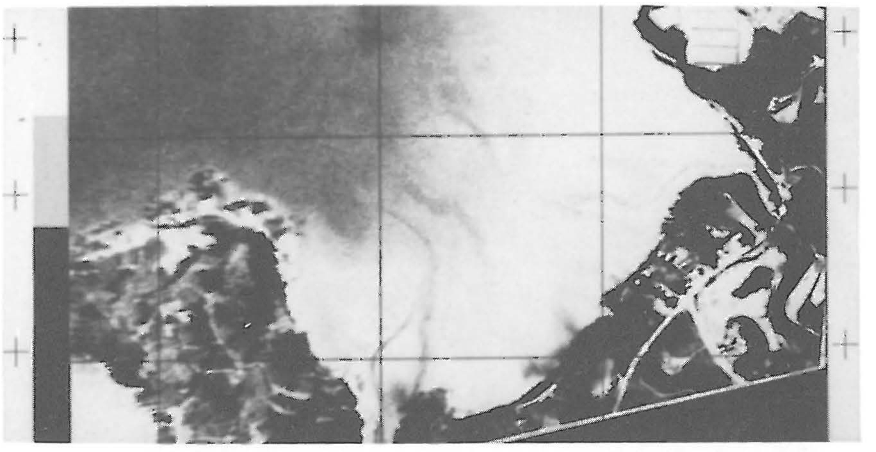
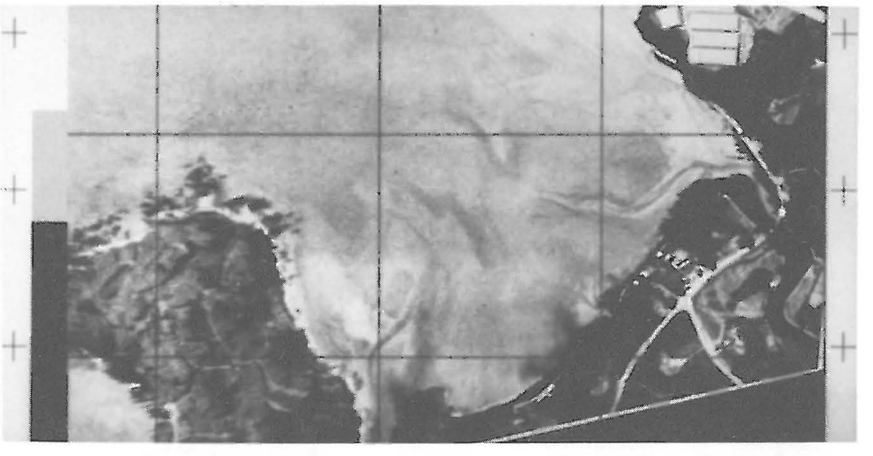


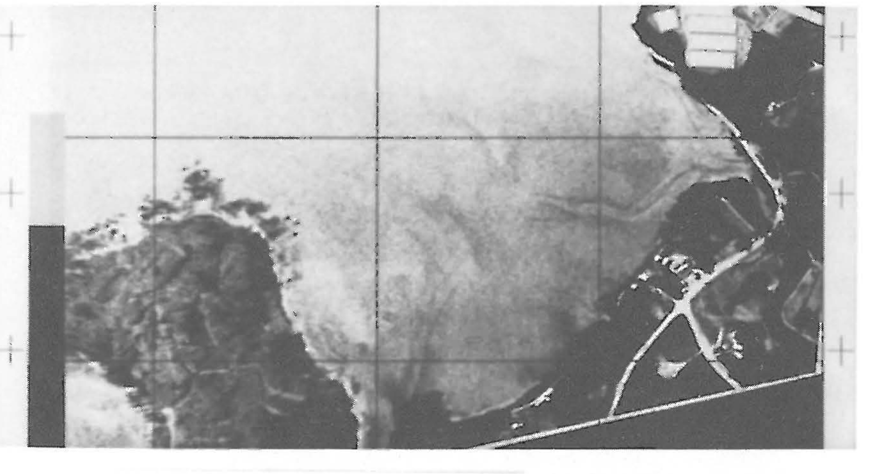
Fig. 7 Coverage and Mapping Area



(a) Red Band



(b) Green Band



(c) Blue Band

Fig.8 Computer Generated Ortho Photos

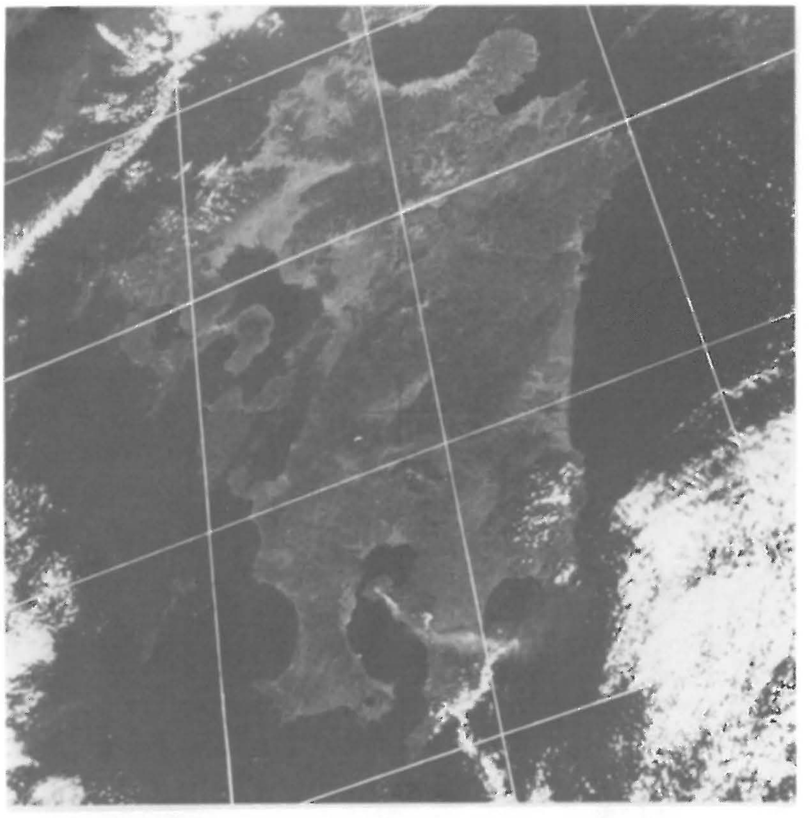


Fig. 9(a) SKYLAB Space Photograph with Grid

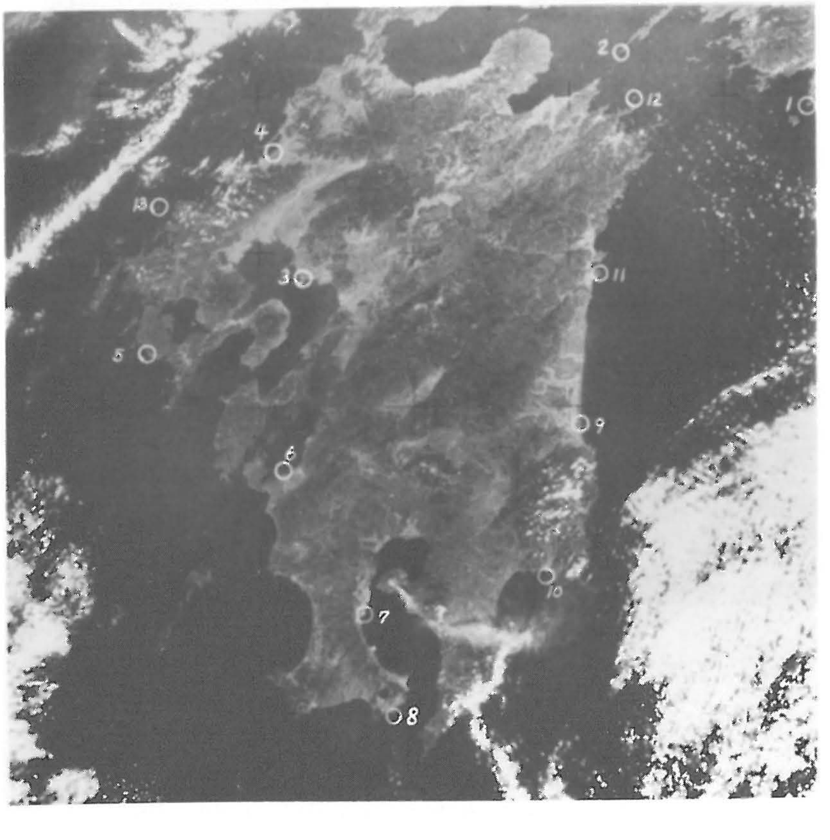


Fig. 9(b) SKYLABE Space Photograph with Control Point

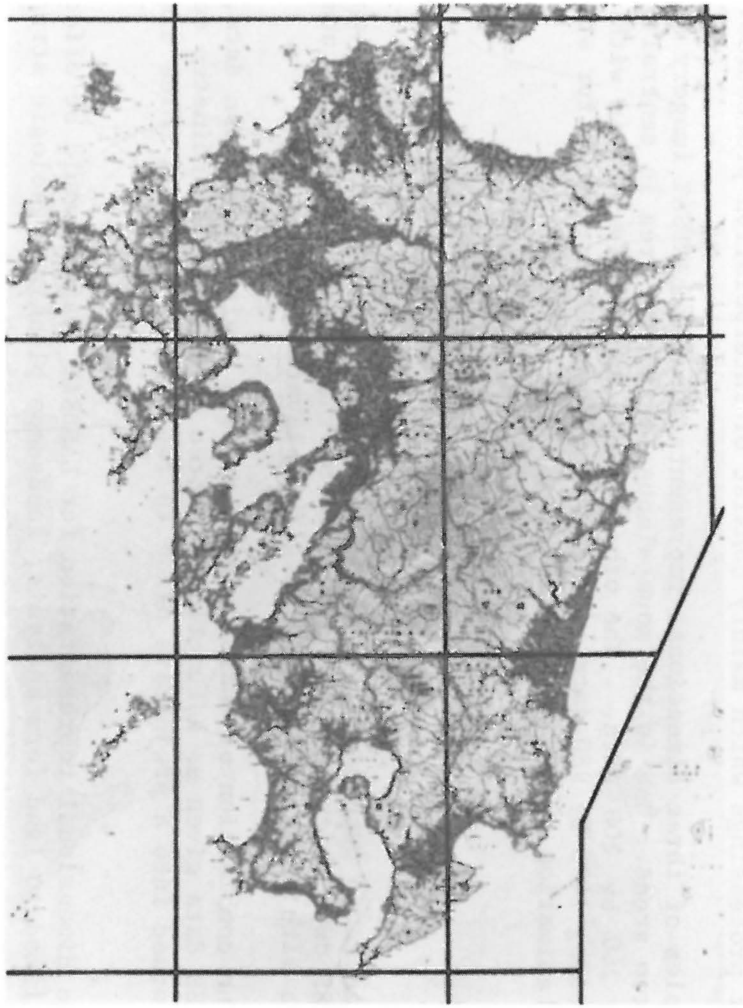


Fig. 10 Map of Kyushu Island (Mercator Projection)

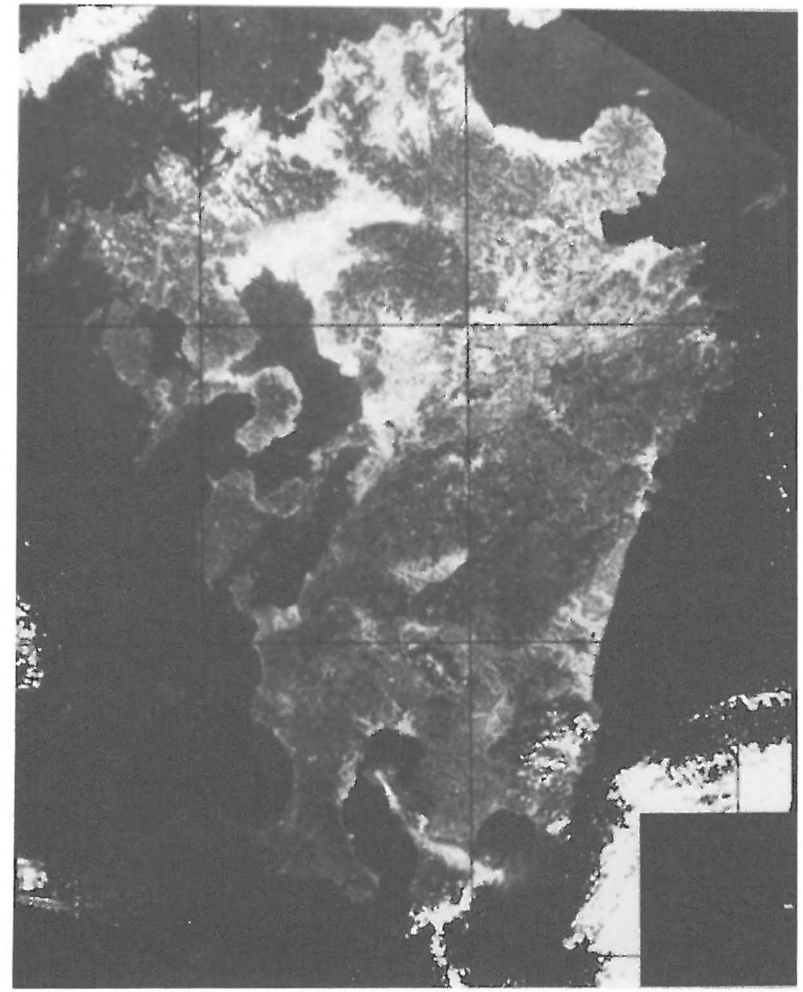


Fig. 11 Geographically Corrected Space Photograph (Mercator System)