

SEMI-ORTHOPHOTOMAPS BY LANDSAT RBV CAMERA IMAGERY
AND HIGH ALTITUDE PHOTOGRAPHS

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ABSTRACT

This is an experimental study to investigate the possibility how the RBV camera imagery of Landsat or the other space photographs take place the role of orthophotomapping or contour line drawings. The authors carried out two examinations containing six examples and obtained following results.

Semi-orthophotomap by Landsat RBV camera imagery has a possibility to detect the environmental change like as new town formation at the scale of 1:50,000 through photographic processing. Topographic map compilation from RBV camera imagery remains in a trouble still now in spite of our efforts. However, in order to estimate the feasibility, contour map drawings from Skylab photographs were carried out. It is successful in the contour line drawings at the interval of 100 m from the Skylab 190A color photographs and also at the interval of 50 m from the Skylab 190B B&W photographs, while the areas are small.

1. INTRODUCTION

The authors have an interest to plan this semi-orthophotomap examination from two aspects. One is an utility of photomap in the sense of its interpretative availability as in the case of environmental change detection of the urbanized area. Another is purely due to the technical meanings, namely the practicality of semi-orthophotomap compilation from the Landsat RBV camera imagery because of its automatic data acquisition at every 18 days.

Where, a term of 'semi-orthophotomap' is temporally defined to a set of partially enlarged space photo with its corresponding superimposed topographical map. When enlarging a small part of high altitude photograph, planimetric geometry approaches that of orthoprojection. However, it never become the orthoprojection in the strict sense. In order to express above geometrical meaning, a prefix of 'semi' is attached to 'orthophotomap'.

First examination consists of four examples to compose each semi-orthophotomap at a scale of 1:200,000, 1:50,000, 1:25,000 and 1:10,000 from Skylab 190A color photograph, RBV camera imagery, Skylab 190B B&W photograph and Jet plane one respectively. Second examination consists of two examples to make topographical maps at a scale of 1:200,000 and of 1:50,000 from Skylab photographs.

2. SEMI-ORTHOPHOTOMAPS

2.1 GEOMETRY OF SEMI-ORTHOPHOTOMAP

Planimetric accuracy of semi-orthophotomap depends mainly upon the ratio of horizontal distance of the point by orbital altitude. Denoting the horizontal distance from the nadir point, an orbital altitude and a relative elevation of observation point by D , H and dH , the horizontal displacement of the image on the map can be expressed as

$$dD = M \times \frac{D}{H} \times dH \dots\dots\dots(1)$$

Supposing the mapping scale by M , and the map development accuracy by A which is substitutive for dD , the allowance of relative elevation leads to

$$dH = A \times \frac{1}{M} \times \frac{H}{D} \dots\dots\dots(2)$$

Every maximum ratio of D/M is approximately same as the tangent of half of the picture angle, $\tan(\theta/2)$, in a vertical photograph as shown in Figure 1. Geometrical parameters for four imageries under the study are listed in Table 1.

Extending the map accuracy of semi-orthophotomap to 2.0 mm, while this value corresponds to 10 times of the Japanese standards of map accuracy, the allowance of relative elevation becomes 2200 m, 1000 m, 450 m and 26 meters for each case of Example 1 to 4 respectively.

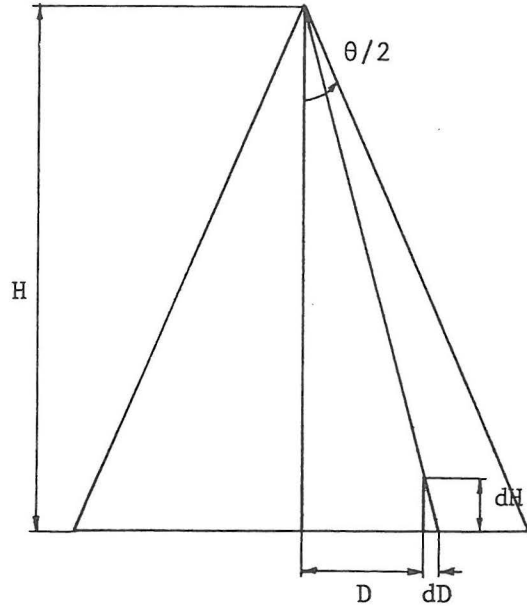


Fig.1 Geometry of image displacement

Table 1. Parameters of Four Example

| Example No. | Carrier/Camera | Altitude | Image angle $\tan(\theta/2)$ | Focal length | Image size | Estimated ground resolution |
|-------------|----------------|----------|---------------------------------|--------------|------------|-----------------------------|
| 1 | Skylab/S190A | 435 km | 0.18 | 152 mm | 57 mm | 40-46 m ²⁾ |
| 2 | Landsat/RBV | 917 km | 0.10 | 236 mm | 23 mm | 19 m ²⁾ |
| 3 | Skylab/S190B | 435 km | 0.11 | 457 mm | 114 mm | 17 m ²⁾ |
| 4 | Jet plane/RC10 | 12 km | 0.76 | 152 mm | 230 mm | 1.5 m |

| Example No. | Delivered film positive products | | | | |
|-------------|----------------------------------|------------|---------------------|------------|-------------|
| | Type | Generation | Enlargement | Image size | scale |
| 1 | Color | 3 | 4.0 X | 229 mm | 1:725,000 |
| 2 | B/W | 2 | 2.4 X ¹⁾ | 56 mm | 1:1,600,000 |
| 3 | B/W | 3 | 1.97 X | 225 mm | 1:482,000 |
| 4 | B/W | 1 | 1.0 X | 230 mm | 1:79,000 |

| Example No. | Final paper products | | | | Horizontal displacement | |
|-------------|----------------------|-------------|------------------|------------------------|-------------------------|----------|
| | Genera- tion | Enlargement | Mapping scale | Measured resolution | Estimated | Measured |
| 1 | 5 | 3.6 X | 1:200,000 | 50 m | 0.9 mm | 1 mm |
| 2 | 4 | 32.0 X | 1:50,000 | 40 m | 0.2 mm | 0 mm |
| 3 | 5 | 19.3 X | 1:25,000 | 25 m | 0.4 mm | 0 mm |
| 4 | 2 | 2.9 X | 1:10,000 | 1.5 m | 6.6 mm | 6 mm |

1) By digital processing
2) At low contrast

2.2 EXAMPLE 1: 1:200,000 SEMI-ORTHOPHOTOMAP FROM SKYLAB S190A PHOTO

Among the coverage of S190A photographs in Japan taken during the three manned Skylab missions, only a photograph taking Kyushu area is available for this examination. Using a third generation color transparency of it enlarged at a scale of about 4 times, the intermediate negative film was made. Next, it was set up in a rectifier, SEG-V, equipped with a special lamp, Color Head 184 of Durst in Italy, in order to obtain an optimum registration accuracy of the semi-orthophotomap.

Enlargement and tilt angles of the photograph are manually determined as 3.51 times, 1.2 grads in the flight direction and 2.0 grads in the lateral one, through comparison of a 1:200,000 geographical map of Nobeoka with its corresponding image on the projection table. Registration accuracy of the products is estimated as 0.9 mm by substituting 1:200,000, 0.18 and 1000 m, namely the mountain elevation of this region, for M, D/H and dH respectively in Eq.(1). On the contrary, the largest measured displacement was found at a side of the map, which size is 46 cm × 37 cm.

The fact that the accuracy of registration due to the terrain feature is comparable with that due to the photographic process, means a geometrical practicality of semi-orthophotomap in this case. The effect of Earth's curvature is estimated about 0.15 mm in maximum because a side length of a 1:200,000 geographical map in the latitude of 20° is about 92 km in Japan map standards. Following equation can convert a side length to its corresponding elevation differences, ΔH.

$$\Delta H = S^2/8R \dots\dots\dots(3)$$

where, S is a side length of map and R is Earth's radius.

The fifth generation, namely the generation of final products, causes big deterioration of color quality, while the measured resolution does not decrease. Among three primitive colors, the green tone loses.

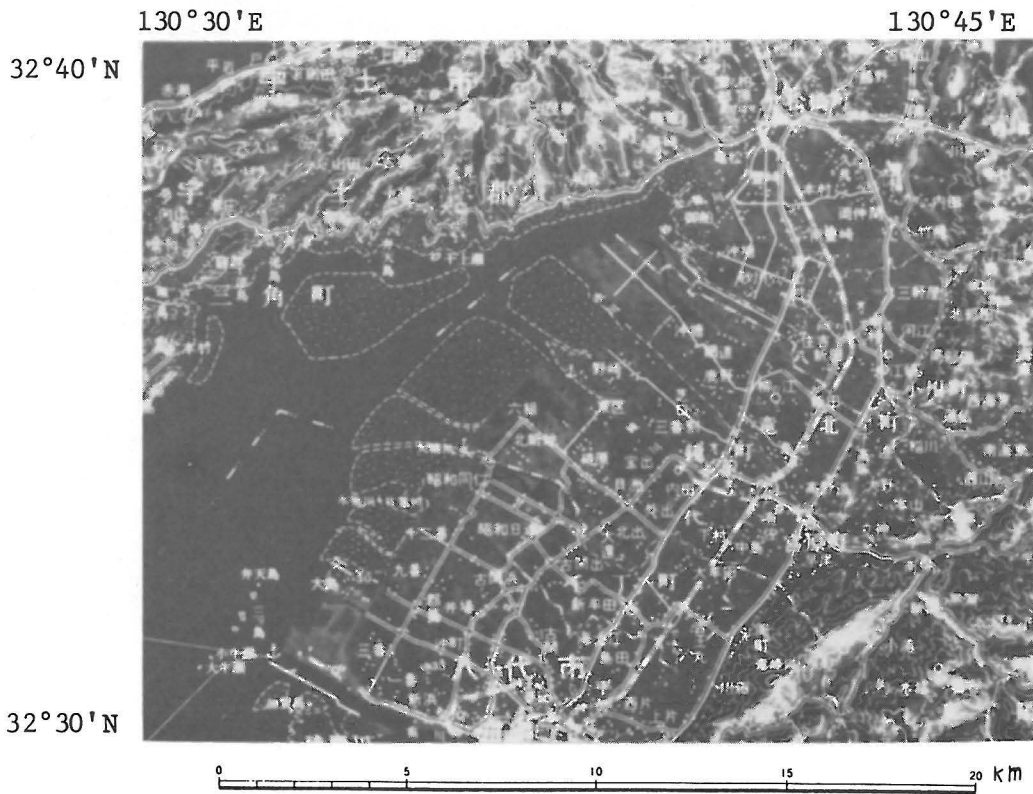


Plate 1. Part of a 1:200,000 semi-orthophotomap of Nobeoka

2.3 EXAMPLE 2: 1:50,000 SEMI-ORTHOPHOTOMAP FROM LANDSAT RBV

Using a 57 mm positive transparency of RBV camera imagery, the registration for a 1:50,000 semi-orthophotomap was carried out through 32 × enlargement with no tilt, via an intermediate negative enlarged film.

Though maximum displacement can be estimated as 0.2 mm under the worst condition of elevation differences, 650 m, there appears little displacement along four sides. Image quality is at a grade in which a ship and its trail can be recognized, however, the measured resolution decreases under a half of the original.

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Plate 2. Semi-orthophotomap of the central Kobe from Landsat RBV
Corner 1: 34°44'00"N, 135°00'30"E 2: 34°44'00"N, 135°15'50"E
coordinates 3: 34°39'10"N, 135°00'30"E 4: 34°39'10"N, 135°15'50"E

2.4 EXAMPLE 3: 1:25,000 SEMI-ORTHOPHOTOMAP FROM SKYLAB S190B

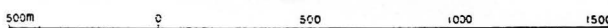
Using a 225 mm positive transparency of Skylab S190B photograph, the registration was carried out with no tilt via an intermediate negative film. Against an estimated horizontal displacement, 0.4 mm, there appears little one in four sides of the map, as well as Example 2. A value, about 25 m, is found as a measured resolution on the product from isolation capability on Port Island, as shown at bottom right part of Plate 3.

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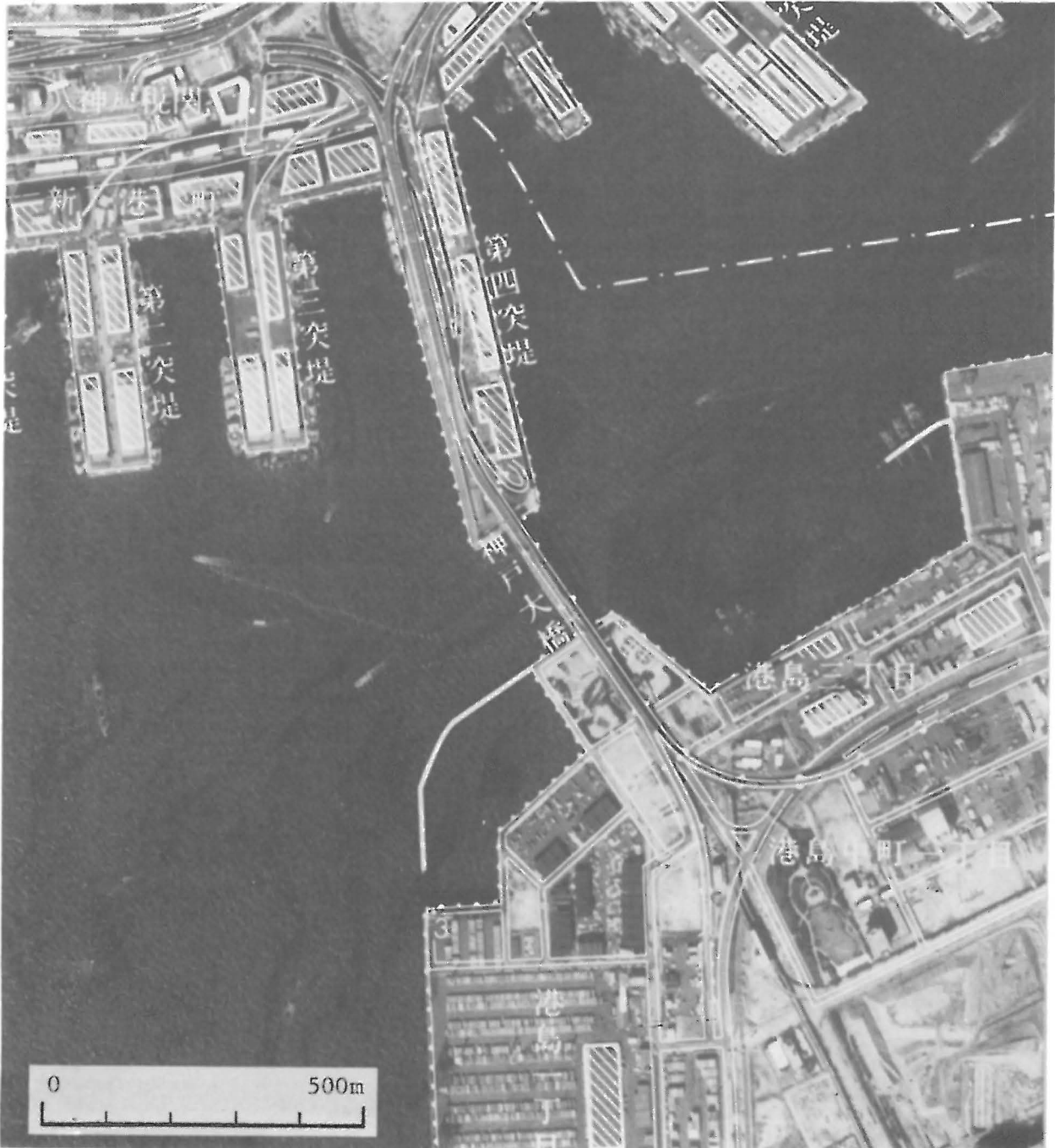
Plate 3. Semi-orthophotomap of the central Kobe from Skylab S190B
 Corner 1: 34°42'00"N, 135°10'30"E 2: 34°42'00"N, 135°13'10"E
 coordinates 3: 34°39'30"N, 135°10'30"E 4: 34°39'30"N, 135°13'10"E

2.5 EXAMPLE 4: 1:10,000 SEMI-ORTHOPHOTOMAP FROM JET PLANE'S RC-10

This product was made as same way as in Example 2 and 3. Fortunately, there is no tilt and the enlargement is the smallest as about 7.9 times. Therefore, since the semi-orthophotograph is projected directly from the first generation negative film, the image quality is best among the four examples. Displacement is estimated about 6.6 mm under an elevation difference, 256 m of mountain height. The residual remains actually about 6 mm in a side of map quadrangle of about 46 cm × 46 cm. As for the ground resolution of product, there is no problem.

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Plate 4. Semi-orthophotomap of the central Kobe from Jet plane's RC-10
 Corner 1: 34°40'33"N, 135°11'53"E 2: 34°40'33"N, 135°12'56"E
 coordinates 3: 34°40'00"N, 135°11'53"E 4: 34°40'00"N, 135°12'56"E

2.6 BALANCE BETWEEN MAP AND IMAGE

There is found an important conclusion of semi-orthophotomap through the above four examples. It is the information balance between a photographic image and the superimposed map, in the other words, a problem of density balance between both informations. A merit of orthophotomap is considered as a weaving effect coming from two information sources.

The photographic image informs the real substance on the Earth's surface, while the symbols or contour lines drawn on the map inform a different category of informations as ground elevation or the name of the place. In Example 1, map information prevails against photographs, and as a result, decreases the value of photomap. In Example 2, it is relatively in good condition of the both information balance because of thinness of lines. Therefore, photographic processing technique has a big role to give a high grade-products, as well as the geometrical accuracy.

3. MAPPING FROM SPACE IMAGERIES

It is necessary to prepare the topographical map for the production of semi-orthophotomaps. In this second examination, the authors investigate a possibility to make a topographical map from space imageries. Since the mapping from RBV camera imageries, while this is the first and final destination, cannot succeed due to some reasons, the examples by using Skylab S190A and B photographs are approached.

3.1 EXAMPLE 5: MAPPING AT 1:200,000 SCALE FROM SKYLAB S190A PHOTOGRAPH

Chosing a pair of Skylab S190A color photographs of Kyushu area, mapping of Sakurajima was carried out at 1:200,000 scale at 100 meter interval, by an analytical plotter Planicomp C-100. There are two merits in the C-100, i.e., any focal length can be set freely and the effect of Earth's curvature is automatically compensated. These capabilities enable us to set the delivered film in the carrier without any photographic process.

Focal length of the film was determined as 611.41 mm based upon the enlargement of the film, 4.022 times, determined by deviding the mean length of 8 sides of 2 frames, 230.08 mm, by the nominal frame side length 2.25 inches.

As a result of relative orientation, residual parallaxes are obtained as 8 microns in the mean value, and -16 microns at the maximum by using 21 parallax points. Residual coordinate errors in the absolute orientation Table 2. Orientation parameters of S190A imageries for the C-100

| MODEL SATELLITE 3/1 (桜島) OPERATOR HASEGAWA DATE 1980 3. 2. 18. 27 | | | | |
|---|----------------|------------------------|---------------|------------|
| ----- | | | | |
| MODEL SCALE 1:1000000 TABLE SCALE 1: 200000 PHOTO SCALE 1: 722969 | | | | |
| ----- | | | | |
| ORIENTATION DATA LEFT PHOTO RIGHT PHOTO | | | | MODEL |
| ----- | | | | |
| F | 611.410 | 611.410 | FLIGHT HEIGHT | 440826 |
| OMEGA | .065 | .308 | ABOVE GROUND | |
| PHI | -2.418 | -1.071 | | |
| KAPPA | 1.053 | 1.009 | AZIMUT | 44.884 |
| RX | -38.780 | 38.780 | MODEL (XG0 | -62050.81 |
| RY | -.652 | .652 | CENTER (YG0 | -145725.00 |
| RZ | .037 | -.037 | POSITION(ZG0 | 441061.50 |
| ----- | | | | |
| MODEL BASE: B = | 77.571 (GRTHO) | EARTH CURV. CORR.: R = | 6370000 | |

leads to 56 m, 42 m, and 36 m in the mean values for each x, y, and z coordinates, and also 61 m, -60 m, and -67 m at the maximum, by using 4 planimetry and 6 elevation control points.

In accordance with this orientation, the photoscale comes to 1:722,969 and the flight altitude comes to 440,826 m, while its nominal one is 435 km.

How precise we can draw contour

lines from binocular vision of the S190A stereo-photographs? In accordance with our experience, the vertical discrepancy at control points when using the C-100 comes to about 1/10,000 of flight altitude numerically, however, it changes for the worse about 2 or 3 times when drawing contour lines. In this case, the mean residual, 36 m, corresponds to the ratio of about 1/12,000 and the 100 meter interval to 1/4000. A plotted sheet of Sakurajima with no edition is shown as a practice in Figure 2. The contour lines from 0 m to 1000 m express the mountain and those from 1000 m to 1800 m express the cloud height erupted from the volcano. Since crossing of contour lines appears scarcely, the contour line drawing can be expected at the interval of 100 m.

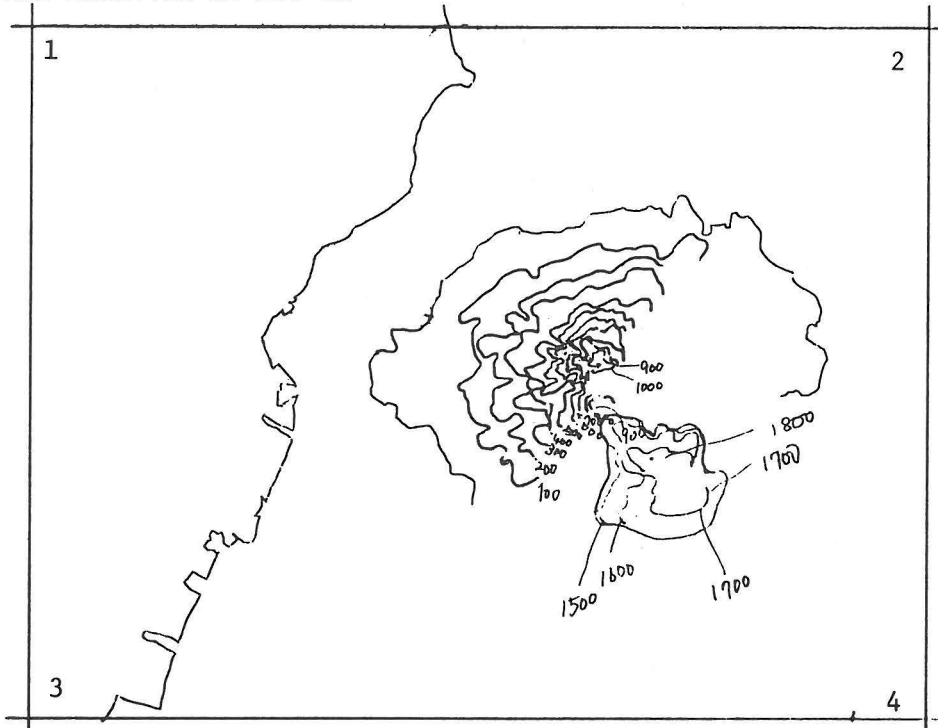


Fig.2 Mapping of Sakurajima at 1:200,000 with contours at 100 m from Skylab S190A



Corner coordinates:
 1: 31°40'N
 130°30'E
 2: 31°40'N
 130°45'E
 3: 31°30'N
 130°30'E
 4: 31°30'N
 130°45'E

Fig.3 Geographical map of above same area at 1:200,000

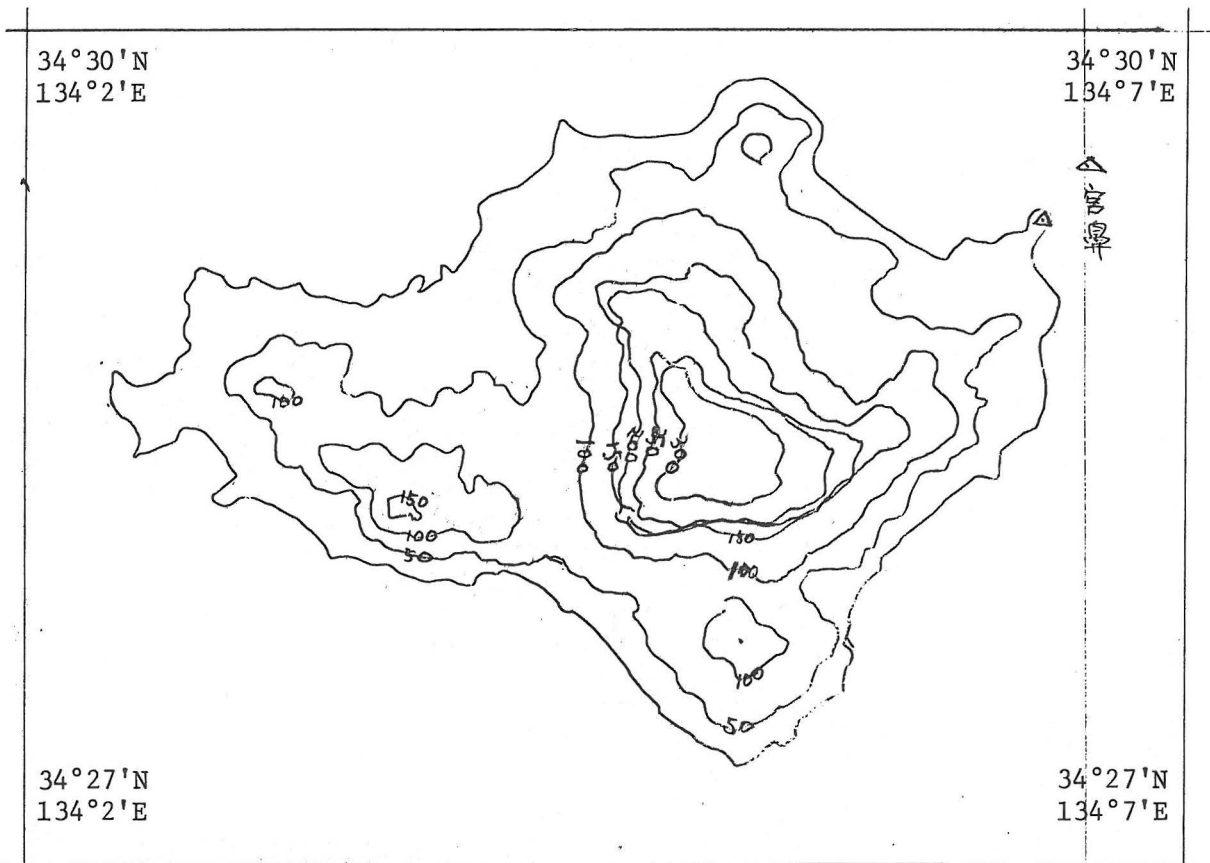


Fig.4 Mapping of Toyoshima at 1:50,000 with contours at 50 m from Skylab S190B

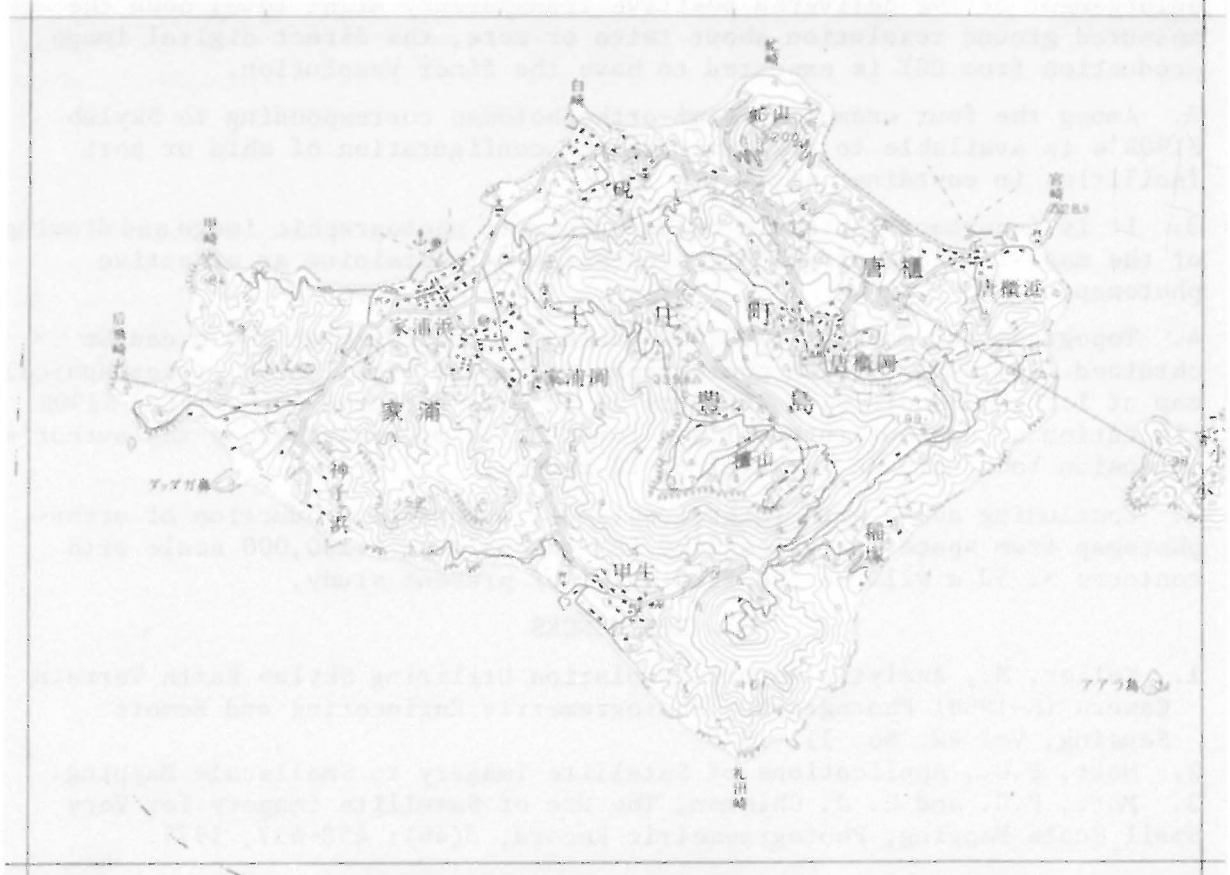


Fig.5 Topographical map of above same area at 1:50,000

3.2 EXAMPLE 6: MAPPING AT 1:50,000 SCALE FROM SKYLAB S-190B PHOTOGRAPH

Selecting an island, Toyoshima in the Inland Sea of Japan, as test site, mapping at 1:50,000 scale from the Skylab photographs was examined. The enlargement of film of our use is about 1.97 time and the focal length was determined as 900.3 mm. Residual parallaxes in the relative orientation, comes to 17 microns in the mean value, and 30 microns at the maximum by using 18 control points.

The vertical residual coordinate errors in the absolute orientation becomes 12 meters in the mean, and 19 meters at the maximum by 5 elevation control points. The photoscale, the model base, and the flight height lead to 1:474,141, 45,997 km, and 426,041 meters respectively.

A plotted sheet of Toyoshima with no edition is shown as in Figure 4. Crossing of contour lines slightly appears at the elevation between 150 m and 300 m. The terrain, where contour lines are confused, is steep and the place corresponds to a cliffy area.

Inclination of the place is estimated about 40° or more and the distance of adjacent contour lines comes to about 1.3 mm or less. If taking it the other way round, contour line drawing of the terrain, where the slope is less than 40°, can be possible at the interval of 50 m. Contour line confusion occurs when the planimetric interval of adjacent contours coming less than 2 or 3 mm in our ordinary plotting. The above contour line confusion is allowable in this respect. There is little problem about planimetric accuracy in the shore line.

4. CONCLUDING REMARKS

1. Semi-orthophotomap by Landsat RBV camera imagery attains at 1:50,000 scale with little horizontal displacement as less than 2.0 mm, even if there exist an elevation difference of 1000 meters in the scene. Though 32 × enlargement of the delivered positive transparency might level down the measured ground resolution about twice or more, the direct digital image production from CCT is expected to have the finer resolution.
2. Among the four examples, semi-orthophotomap corresponding to Skylab S190B's is available to discriminate the configuration of ship or port facilities in container size.
3. It is important to take a balance between photographic image and drawings of the map, in the photographic processing for obtaining an effective photomap.
4. Topographical map at 1:200,000 scale with contours at 100 m can be obtained from Skylab S190A photographs for small area. Also, topographical map at 1:50,000 scale with contours at 50 m is expected from Skylab S190B. Limitation of contour interval was found at 50 m, nevertheless the author's intension to attain an interval of 20 meters.
5. Concluding above with references(1-3), automatic production of orthophotomap from space imageries like RBV camera's at 1:100,000 scale with contours at 50 m will be the first goal of present study.

REFERENCES

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