THE USE OF SIR-B AND LFC SPACE IMAGES FOR MAPPING

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ABSTRACT

Tests on the use of synthetic aperture SIR-B and LFC images for the identification of topographic features, and determination of ground coordinates have been carried out over residential rural and remote areas of Australia. The presentation will highlight the problems of point identification, and transformation to control on the SIR-B images and the geometric accuracy of point determination in the LFC images.

1. Introduction

The Shuttle mission launched by NASA in October 1984 carried on board the SIR-B Synthetic Aperture Radar experiment and the Large Format Camera (LFC), both of which have the potential for remote sensing and topographic mapping. Studies have been made on images derived from both systems. This paper will briefly discuss the characteristics of the imaging systems and summarize the results of experiments on the mapping potential of the data from the two systems.

2. SIR-B Synthetic Aperture Radar Experiment

2.1 Description of SIR-B

The SIR-B radar is the third of a series of experiments by JPL launched by NASA on the Shuttle. The L-Band radar on SIR-B has a wavelength of 23.5cm and unlike previous missions the look angle of the antenna was variable from 15-57°.

Because the image is derived from a process of integrating many returns from the same object but from different antenna locations, thereby synthesising a much larger antenna, the resolution of the data in the azimuth direction is independent of altitude of the spacecraft, and primarily dependent on the size of the antenna. Range resolution is dependent on the pulse time of the radar. Therefore, the ground resolution in the range direction will be a function of the look angle, and indeed higher for large look angles than for small look angles as shown in Figure 1.

The characteristics of radar images are in many cases quite different from those of photography. For example, since the radar measures range or distance from the spacecraft to an object, higher points will appear to be closer to the spacecraft than low points and therefore, closer to the spacecraft in the image than low points. This is the reverse situation to that which occurs on photography. In addition, surface characteristics influence the nature of the return signal and in many cases the image will have the opposite spectral characteristics to what may have been expected by a person familiar with photography e.g. short grassed areas will appear dark because there is very little backscatter of the radar signal, whereas the leaves of trees probably will appear bright. On photography, the reverse situation normally occurs.

Geometric characteristics of radar data have been thoroughly discussed in many papers by Leberl et al (1981). The SIR-B data received by University of New South Wales from JPL has already been processed by the digital correlator to produce the final image. Geometric quality is dependent on the completeness of the parameters introduced into the processor, such as the ephemeris data of the orbiter. Reports from JPL indicate that early images may be subject to a scale error of 3.2%. The investigations in this study have been able to determine the quality of the geometry of the processed data.

2.2 Investigations of Goemetry of SIR-B

The data provided by JPL over Australia included 3 multiple angle scenes or data takes (DT) with look angles of 48° (DT83.8), 36° (DT67.8) and 17° (DT51.8) over the coastal area near Sydney in Figure 2. Two study areas have been chosen from these scenes, one involving the coastal lake area also 70km north of Sydney, and the other a rural area about 120km south west of Sydney. Twelve metal corner reflectors were placed as ground control in the second of these two sites. Resolution in the azimuth direction for the 3 scenes is 25m and in the range direction it varies from 20m to 50m approximately for DT83.8 to DT51.8. Errors in range due to elevations are dependent on the look angle and the differences in terrain elevation.

Based on the spacecraft parameters, the radius of the earth and the look angle, displacements in range were computed across the image width of approximately 10-15km depending on the data take. These displacements were found to vary linearly with range and where of the order of 83m, 130m and 260m measured in ground units for each 100m in elevation above datum. It is therefore clear that corrections for displacements due to elevation are essential in any study of SIR-B image geometry.

Tests were carried out initially on the coastal region north of Sydney because of the wealth of control points available on the shoreline of the lakes and ocean as shown in Figure 3. A third order polynomial with the option to vary the number of parameters was available, also incorporating a correction to range for displacements due to elevations above datum.

Image coordinates were measured on a Dipix Image Analysis system in pixel and line coordinates (the pixel and line interval was 12.5m on the data supplied by JPL) while ground coordinates were measured on topographic maps at scales of 1:25,000 and 1:100,000, standard errors of the ground coordinates measured at the two scales were taken as 7m and 30m respectively.

TABLE 1

Results of Affine Transformation of Image to Ground Coordinates

Data Take	83.8	67.8	83.8	51. 8
Look Angle	48.0	37.2	48.0	17
Area	Coast	Coast	Rural	Rural
No. of Control	61	40	18	16
RMS of residuals at control based on 1:25,000 map derived control	3 pixels	3 pixels	-	-
RMS of residuals at control based on 1:100,000 map derived control	3 pixels	3 pixels	5 pixels	6 pixels

Tests to determine the most appropriate terms in the polynomial transformation were carried out on DT83.8 on the coastal area because of the good quality control available, the majority of which were at sea level and therefore unaffected by terrain effect. The tests revealed conclusively that all higher order terms than 1st order were insignificant in the transformations, with even the x, y term only marginally significant. Therefore, an affine transformation was adopted for the remainder of the transformations in Table 1. Dimensions of pixels on the DT83.8 were 12.65 and 12.82 respectively, reveal ing about 1.5% distortion in scale, somewhat less than predicted by JPL. This image was correlated early in the schedule of JPL and therefore apparently subject to errors in the ephemeris data. Pixel dimensions derived from DT67.8 were 12.52m in line and pixel and therefore not subject to scale distortion. This image was correlated much later than DT83.8 an presumably based on more precise ephemeris data.

The results of transformations shown on column 3 were based on far fewer ground control. Three corner reflector locations were available, while the remainder were topographic or cultural features. It was noted that the scale derived between two corner reflectors agreed well with that obtained in transformation 1 Table 1. Transformation 4 is based on control collected from the same area of transformation 3 but because of the much lower resolution , points were more difficult to locate and limited to topographic features. The results of this transformation however are only marginally worse than those of DT83.8 in the same area.

RMS residuals in column 1 Table 1 reveal that the geometric potential of the radar imagery is of the order of 3 pixels in line and pixel coordiantes , 4.2 pixels as a vector which is equivalent to about 50m in ground units. This accuracy appears to be a function of the availability of control points on the data. A large number of artificial control points such corner reflectors would be needed to determine the accuracy of the adjustment to higher precision. In column 2 the accuracy of 3 pixels demonstrates that there is no benefit to using higher accuracy control information. Accuracies of transformations in columns 3 and 4 are worse than the other two transformations because of the lack of good control information. Overall, an accuracy of feature extraction of 50m is appropriate for this data.

2.3 Correction of Image Data

Further computer program development is underway to enable the geometric correction of the data by resampling. This process involves the use of the affine transformation to relate image to ground and vice versa at a given height datum. A DEM then must be interogated to enable displacements to be introduced into calculated range values from the affine transformations which are at the datum level, thereby determining the equivalent coordinates in the image. Interpolation of image intensities for the computed range and azimuth image coordinates from the image data, will then provide the resampled image.

2.4 Interpretation of Features

The SIR-B is a forerunner to a number of future radar programs planned throughout the world. Primary applications of the radar data were for geology and not for topographic mapping. However, SIR-B should be investigated to determine its potentials for mapping and indeed, the experiemnt was approved by NASA. The interpretability of features is dependent of the variation in back scatter from specific features compared with their background. It is necessary to understand the back scatter characteristics of various types of ground features. Clearly, the higher the resolution of the data the better the interpretability of features. Therefore, data derived from the larger look angles are preferred. Generally, well established cultural features such as major roads, railways, power lines and interfaces between different types of vegetation are visible. However, visibility depends on the direction of the radar scan. When such features are within 20-30° of scan direction, the features may no be visible. Topographic features such as ridges and valleys are clearly defined, as are land/water interfaces, but such points are not well defined as the ground and hence are not good points for control. However, these are the predominant features which are visible and hence must be used, thereby limiting the accuracy of the transformation shown in Table 1 to the equivalentof 40-80m in ground units.

Further studies have been carried out on overlaying DT67.8 and DT83.8 together with a LANDSAT image of the same area on the Dipix System and considerable improvement in the interpretation of features was achieved. Since no corrections for effects of elevation on the radar data could be applied in this step of the work, th accuracy of the overlay procedure suffered, but generally there was a marked improvement in the detection of township street patterns and cultural features. The interpretability of features on overlaid radar images and Landsat is currently being studied with a view to investigating the most suitable combination for topographic mapping.

3. Large Format Camera Studies

The Large Format Camera is a specially built camera for installation in the shuttle. It has a format of 46cm x 23cm and a normal focal length of 306mm. Selected images were collected over the Earth in October 1984 with several paths over Australia. The area chosen for study in Australia is in the sand ridge desert area of Western Australia. The area has also been covered by high level mapping, superwide angle photography at a scale of 1:150,000 by the Division of National Mapping. Block adjustment was carried out using National Mapping's computer program to determine coordinates of pass points to a stated accuracy of approximately 2m. Seventy-eight of these pass points were transferred onto LFC image 1719 (which overalapped with image 1718 by 80%) by first photographically reducing the aerial photograph. The task proved particularly difficult in the sandy desert area and the conservationaly estimated accuracy of point transfer was 26m. Sixteen points were transferred to a higher accuracy than the remaining points and hence have been referred to as "good" points in the following.

Two models were formed from different sections of the photographs in an analytical plotter which is operated by Bendex US-1 software. Camera calibration data was provided by the US NOAA so that radial lens distortion was corrected but not targential distortion which is a maximum of about 1μm. Atmospheric refraction and earth curvature corrections were also involved in the software. Inner orientation was based on an affine transformation of 6 fiducial marks on each photograph. Fifty-four points existed on one overlap and of these 15 evenly distributed points were used as ground control. Of the remaining 25 points on the other model covering about half of the model area, 7 were used as control. Ground control coordinates were assigned a standard error of 1m and iamge coordinates 5μm in the computation of the orientation. Orientations based on a simultaneous solution of all camera parameters resulted in a standard error of residuals of 15-20μm at image scale. Coordinates were then measured of the remaining points and RMS residual errors determined. In addition, 16 other points were marked on the LFC photography and transferred onto the aerial photography. Coordinates of these points were then determined from orientation of the aerial photography and compared with those measured on the LFC photography. Results of the measurements are shown in Table 2.

TABLE 2

Summary of Measurements on LFC photography

	Model 1	Model 2
No. of control	15	7
No. of points observed	53	25
Residuals of control (m)	E 21 N 19 H 31	8 9 14
Residuals of remaining points (m)	E 20 N 17 H 27	16 16 28
Residuals of "good" points (m)	E 12 N 14 H 27	9 8 21
Points Transferred from LFC to Aerial Photography (m)	E 23 N 23 H 35	

In Table 2 the accuracy of point measurement on the 2 models is of the order of 15-20m on ground units or 20-30µm on the photograph. In elevations the accuracy is somewhat lower at 29m which is 0.12‰ spacecraft height, but this is due primarily to the poor base/height ratio of about 0.25. Expressed in terms of parallaxes this height accuracy is equivalent to as little as 13µm. The accuracies of the extra points observed on the LFC photography generally agree with the above results.

Given a planimetric coordinate accuracy of 15-20m the vector error would vary from 21-28µm which would satisfy the map accuracy standards of Australia 1:100,000. Height accuracy would be inadequate for the standard contour interval of 20m on the 1:100,000 maps but for map revision purposes height information is usually already available.

4. Conclusions

Tests on the two sets of data derived from the Shuttle indicate that for topographic mapping, for the studied area the LFC photography would provide planimetric information suitable for 1:100,000 map revision in Australia. The accuracy of 20-30µm on the image should be improved if better control information is available. The projected use of LFC photography for 1:50,000 map should therefore be possible (Doyle, 1982).

SIR-B data to date results in an accuracy of transformation to ground coordinate systems of approximately 50m. The location of features presents some difficulty but should be improved by overlaying more than one data take with other types of remotely sensed data.

5. References

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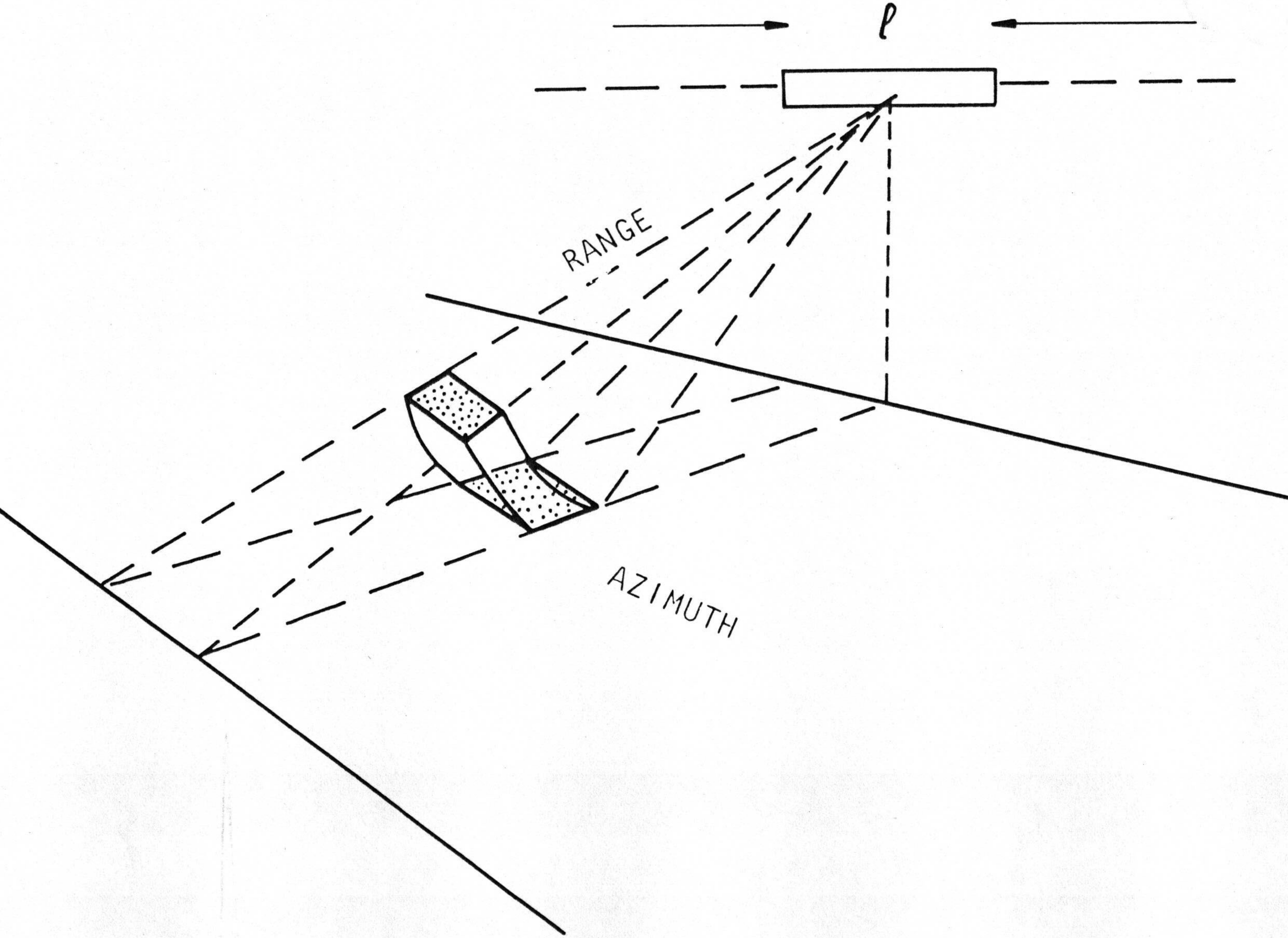

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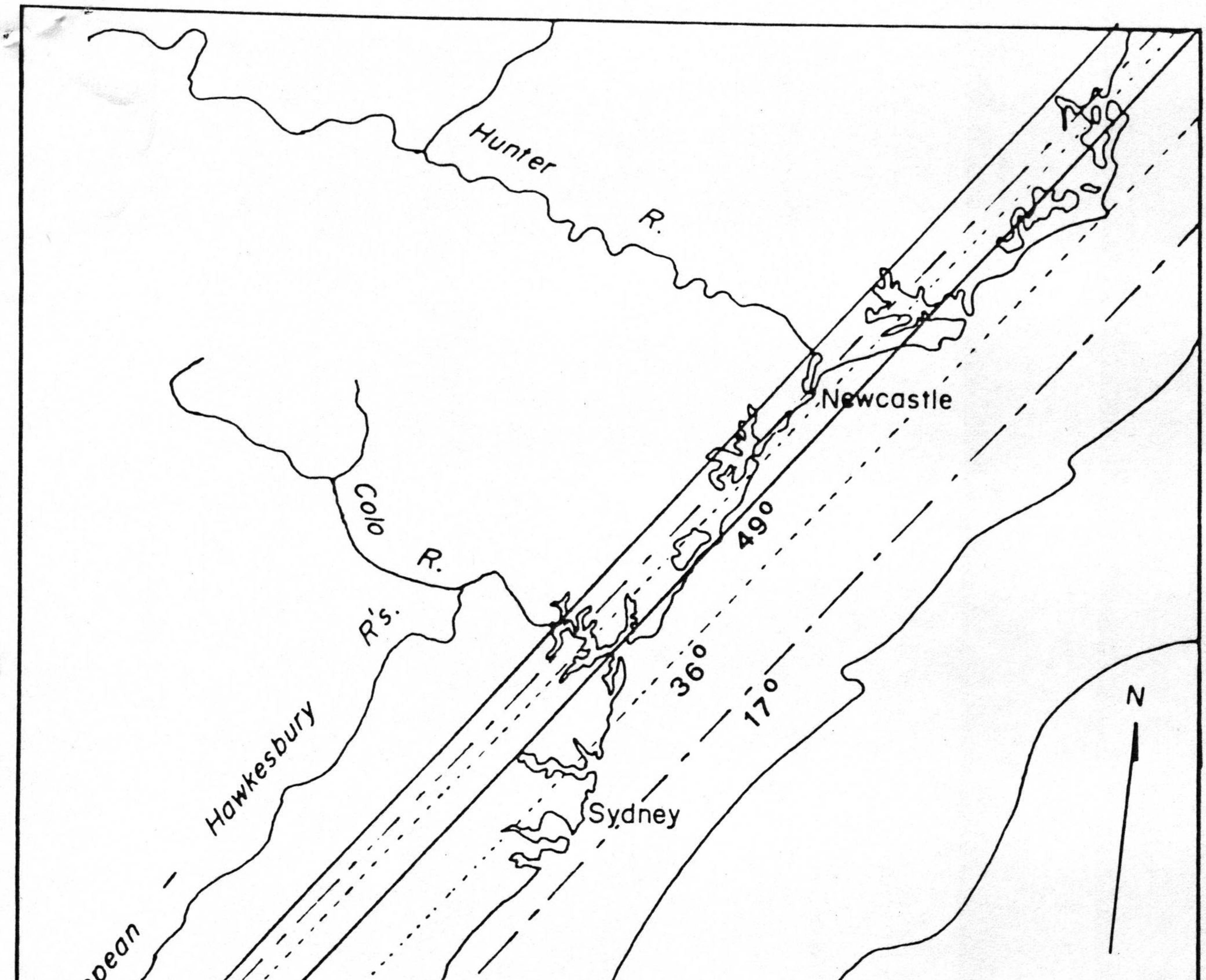
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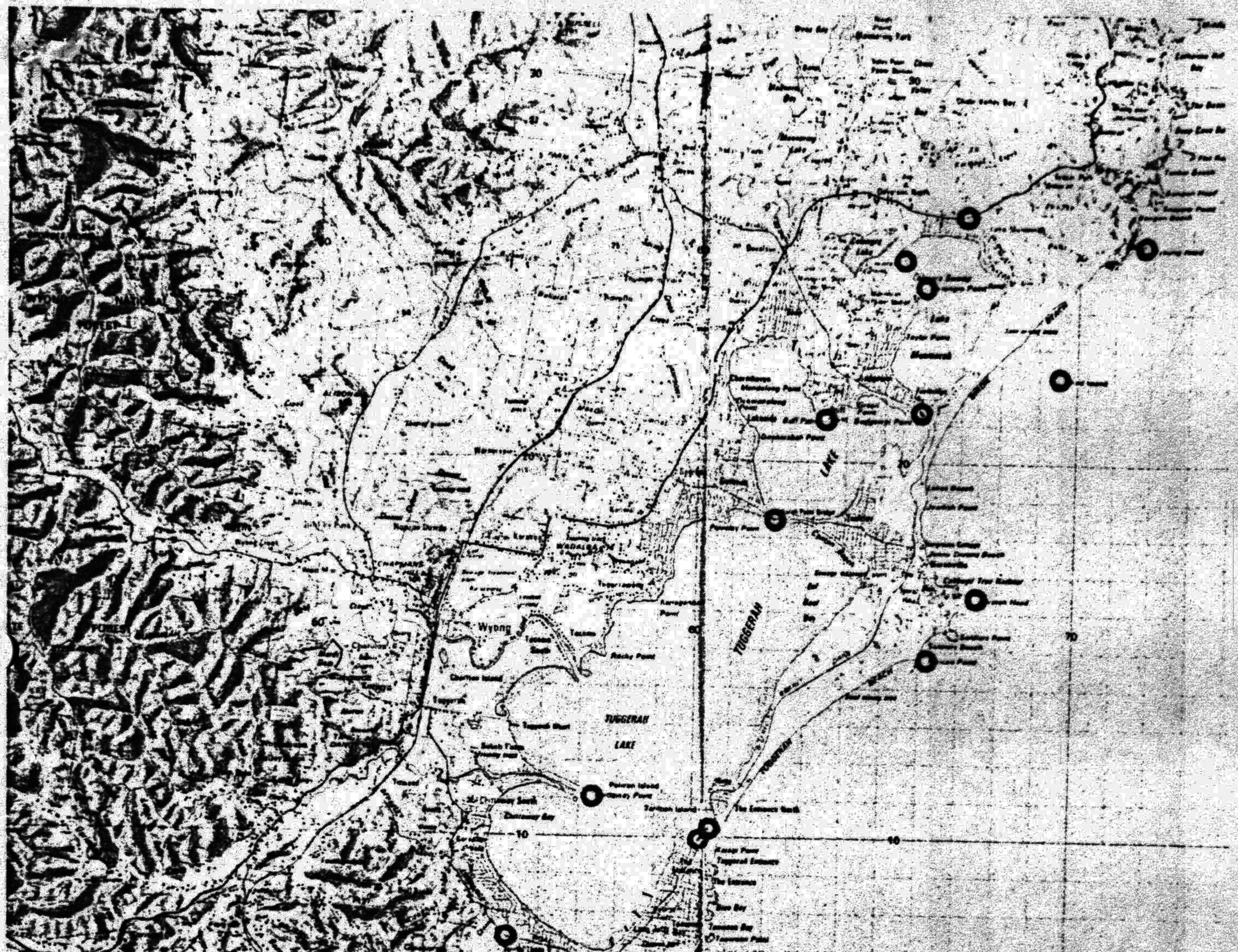

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