

**PETRONAS
PETROLIAM NASIONAL BERHAD
MALAYSIA**

**QUALITY CONTROL SERVICES FOR THE
ACQUISITION AND PROCESSING OF
SYNTHETIC APERTURE RADAR (SAR) DATA
OVER SABAH AND SARAWAK, EAST MALAYSIA**

FIFTH QC VISIT REPORT

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Appendix C to this report is a comparison by the Directorate of Photographic Interpretation of the quality of colour print material, i.e. the reproduction of microfilm data.

2. EVALUATION OF THE MAP DATA

The Survey of Malaysia maps for the two States, Sabah and Sarawak, vary in the dates and methods of construction. The maps date from the early 1950's to the 1980's. Two methods of map construction have been used. Some maps have been constructed by modern photogrammetric methods, while some of the earlier maps were made by direct photo triangulation, generally compiled onto a geoid, magnetic contour, in order to facilitate the construction of the maps. It is essential to understand the processes used and the problems that have arisen from the nature of the photography and the cover.

For example, it is evident on some of the maps that, in the heavily forested areas, the breaks due to the rising relief, where contours exist on the earlier maps they can be regarded as little more than lines and do not always properly reflect the terrain. In some cases the relief has been shown in a schematic. These examples do not apply to a small number of maps, but they do apply to many maps, both in Sabah and Sarawak.

Some of the maps can be regarded as becoming to a certain extent conforming to the accepted photogrammetric standards for such maps. Certain elements of the maps can be distributed through the Survey of Malaysia, which because of their importance, have been more fully investigated by the Directorate of Photographic Interpretation which has been mapped with the aid of the Survey of Malaysia, the photogrammetric expert. Furthermore, it is clear that some of the maps have been made with a high degree of accuracy, but it is not possible to verify this accuracy.

QUALITY CONTROL SERVICES FOR THE ACQUISITION AND PROCESSING OF SYNTHETIC APERTURE RADAR

FIFTH QC VISIT REPORT

1. INTRODUCTION

The fifth quality control visit was undertaken by the Consultants' representative Mr J.W.Trevett from the 17th February to the 21st February 1992 at the offices of Petronas in Kuala Lumpur.

The visit was scheduled to coincide with the delivery of at least fifty percent of the materials including those covering all the priority areas. The deliverables included mosaics at both the production scales, the corresponding strip imagery, negatives, and some of the CCT's.

Quality control checks were made comparing the mosaics against actual 1:50,000 survey map sheets. As these sheets had not been available in Calgary for earlier quality control this was the first occasion to perform such a check. However, a full set of map sheets was not available at the Petronas offices in Kuala Lumpur and types of errors found in some of the sheets that were checked suggest that a sheet by sheet check is necessary.

A representative sample of the strip imagery and the smaller scale mosaics was checked. The check of the strips included an assessment of the value for stereoscopic interpretation. It was considered that since the original mosaicing was common to both scales, it was preferable to concentrate on the larger scale mosaics where map comparison was possible rather than the smaller scale mosaics. It should be remembered that any error or scaler difference noted on the larger scale maps resulting in rejection of the data, will require a comparable rejection of the corresponding smaller scale mosaic(s).

No check has been made of the digital data, as Petronas do not currently have the facility to read tapes and the computer at Terra Controls was out of commission.

Appendix C to this report is a comment by the Consultants' photographic specialist on the use of colour print materials for the reproduction of monochrome data.

2. EVALUATION OF THE MAP DATA

The Survey of Malaysia maps for the two States, Sabah and Sarawak, vary in the dates and methods of construction. The maps date from the early 1960's to the 1980's. Two methods of map construction have been used. Some maps have been constructed by modern photogrammetric methods, whilst some of the earlier maps were made by direct photo interpretation possibly compiled onto a slotted template control. In order to evaluate the comparison with the radar data it is essential to understand the processes used and the problems that can occur that are related to the physiography and land cover.

For example, it is evident on some of the maps that, in the heavily forested areas, the interior data is not totally reliable; where contours exist on the earlier maps they can be regarded as little more than form lines and do not always properly reflect the terrain, in some cases the drainage pattern is, at best, schematic. These comments only apply to a small number of maps. Any major drainage is usually reliable, both in general form and location.

In general the maps can be regarded as belonging to a reliable series conforming to the accepted International Standards for such maps. Certain elements of the maps can be attributed with high accuracy. Particular features, which because of their importance, have been more precisely mapped. For example the coastline which has usually been mapped both from the land point of view and from the hydrographic aspect. Furthermore the coast shows such a distinctive interface that there is less possibility for error when interpreting from photogrammetry.

For this reason early meetings between Petronas and Intera stressed that in controlling the data it was essential that coincidence with the coast line should be achieved as far as possible, given the internal geometry of radar.

The majority of the maps have been constructed using the Borneo Rectified Skew Orthomorphic (RSO) projection and not the Universal Transverse Mercator (UTM) projection. The RSO is a Mercator type projection which has been skewed in order to provide the best error free base to the shape of the country to be mapped, in this case the skew is 90 degrees and is comparable to the Transverse Mercator but pre-dates it. The central meridian, would have been selected for the local convenience, unlike the UTM meridians which are predetermined using the whole globe. The grid has been added later, the Netherlands East Indies Grid on the earlier maps and the UTM grid on the later maps.

According to the tables available, the RSO is based upon an origin of North 4 degrees and East 115 degrees, whereas the UTM for the region (zone 49) is given by the Survey of Malaysia as North 0 degrees and East 111 degrees.

A detailed comparison of the two projections has not been made under this quality control, as such a study would require access to all the base tables for the two projections, and the time required was not thought to be justified.

All the maps used were paper copies and were therefore subject to the normal distortions that can occur with paper, this, however, did not affect the ability to make overall comparisons and any discrepancies recorded were clearly the result of a general misfit rather than due to distortion.

3. RELATIONSHIP TO THE MAP DATA

All mosaicing of the radar data has been carried out by computer with a visual display used for checking. The Global Positioning System (GPS) data obtained during acquisition flights, have been used for control. Cut-lines for the UTM corrected data were calculated by computer and automatically inserted into the mosaic sheets. As far as is understood no comparison with the large scale maps had been made.

When comparing a radar mosaic with map data it is important to be aware of the basic differences in the representation of the data. The radar image is an oblique view of the terrain to which a number of standard adjustments have been made in order to present a pseudo vertical view. In flat country the results are reasonably accurate, the geometric accuracy reduces as the steepness or severity of the landform increases, so that in the very mountainous areas large errors of comparative location with a map will occur.

A further distortion may be introduced by the radar platform, in this case an aircraft, although efforts are made to keep the platform stable variations in flying attitude will inevitably occur. Such variations are compensated for at the time of acquisition but these are mathematical generalisations and some attitude errors will remain.

The computer generated mosaics locate each strip of data in accordance with the GPS data. The operator ensures that all the obvious details of planimetry (roads, rivers etc.) join between adjacent images the computer then adjusts all detail in between the observed control to a best mean fit, this process is usually referred to as rubber sheeting. The radar mosaics, although, in general accurate cannot be regarded as perfect.

The maps, however, are regarded as the official survey of the country. Official authority on boundaries and location is expressed in terms of the map location and this will include any references to concession boundaries for exploration. Furthermore, it is reasonable to assume that any user will need to relate the interpreted data from the mosaics to the map and will accept the map as the true record. Comparison with the maps has been made with due regard for the differences in derivation but has also recognised the requirements of potential users.

The first sheets selected for comparison were 6/116/3,4,7 and 8, these sheets are centred on a small peninsula in Sabah. Coastline was present on each image to provide overall control. An attempt to fit the coastline for each mosaic showed that a precise fit was not possible. The variations that occurred could not be explained by coastal erosion or other changes, therefore, a best mean fit to detail was used. In subsequent sheets it was found that a reliable overall fit to detail was rarely possible and that the Best Mean Fit technique was the best way to make comparisons.

The Best Mean Fit showed a discrepancy with the map sheet corners which could not be explained by sheet distortion, detail on the mosaic was clearly spilling over the sheet edge to the adjacent sheet. The effect was repeated on all four sheets pointing to a possible error in the relative positions of the graticule cuts for the sheet corners. The sheet sizes, as computed, were checked against the map grid and after some adjustments a reliable comparison of size was achieved, this indicated a discrepancy in the actual location of the grid relative to the earth's surface.

Subsequent checking of all the sheets for which maps were available showed that a comparable shift in location had occurred on all sheets. The amount of shift varied from the insignificant to 15mm, subsequent plotting of the errors on the sheet location did not reveal any recognisable pattern, therefore the shift could not be said to be progressive. The average was shown to be North 3mm and East 7.25 mm in Sabah, and North 5.8mm and East 4.8mm in Sarawak. See Figures 1 & 2.

It is possible that some of the error is the result of the basic difference in the derivation of the two data sets, using the RSO and the UTM projections as explained earlier, but to verify this would require extensive calculation using the base tables, and a residual error would still remain. Any such error would be considered a true data misfit. Given that such a difference could be verified, in order to correct the error, all the mosaics would have to be replotted at considerable time and expense.

The recommended solution is to ignore the graticule values as shown on the mosaics and to remove them from all future copies and the negatives held by Petronas. The sheet referencing system should remain as it will be necessary in order to provide a general locational reference. A note, should be enclosed on the mosaic, to explain the difference in fit. It is recommended that a general cautionary note about the mosaic is enclosed to avoid any misconceptions by users. The text of a suggested note has been included as Appendix A to this report.

It could be argued that the calculations used by Intera in association with the use of the GPS gives a more accurate result. However, the point at issue is to avoid any confusion by potential users who may not be aware of the problems of using different map projections.

Leaving aside the errors due to the projections, the general relationship of the mosaics to the maps is within acceptable tolerances. Where good accurate base maps exist the mosaics should not be used as a map base, but data should be compiled onto the map.

Comparison of the radar strips with the maps at 1:50,000 shows a much better local relationship. This supports the comment that the local errors in fit are due mainly to mosaicing imprecision.

Experienced interpreters will interpret the strips rather than the mosaics, this will be necessary if the stereoscopic potential is to be used, compilation should be directly onto an overlay to the map base. In this case the mosaics are only used to provide a general overview of the structures and to identify trends.

In some cases the misfit to the map could be related to definite errors in mosaicing. The following section considers the mosaic/map comparison on a sheet by sheet basis. Errors are

noted in detail and the sheets recommended for rejection. In case a serious error in the plotting of the sheet cut-line was found and this sheet is also recommended for rejection.

The discovery of mosaicing errors gives great cause for concern since the first sheets that were quality controlled in Calgary (without the aid of maps) and those sheets for which maps were not available on this QC visit may well contain similar errors. It is recommended that final acceptance of all sheets should not be made until each sheet has been checked against the corresponding map. This will be part of the task of the last QC visit.

4. DETAILED MAP/MOSAIC COMPARISONS

2/113/1 (map 1975)

There is very little internal detail to compare, but a relation of hill features showed this image to be acceptable. But, note comments to sheet 2/113/2

2/113/2 (map 1975)

There is very little reliable data and much evidence to suggest that the drainage as mapped is suspect or fictitious. One river, the Sungei Binio, appears to be reliable since the overall direction and shape in detail resembles the feature on the mosaic.

Fitting to this river gives an overall fit that is comparable to that on other nearby sheets but the strip corresponding to H25 appears to be shifted to the West on the mosaic by 6-7mm, this represents 250 metres on the ground. Since this is not an area of extreme relief and given the experience with the remaining sheets, this is probably a mosaic error and the sheet should be rejected, checked and the strip remosaiced. All other sheets that could be affected by changes in the mosaicing must be rejected and redone.

2/113/4 (map 1974)

Best mean fit to detail is good also the contours give a good reflection of the land form as shown on the mosaic. But note comments to sheet 2/113/2

3/113/4 (map 1973, photography 1959-63)

There is insufficient detail to make a reliable assessment, the Miri/Bintulu road runs through the centre of the map but although this can be fitted, the map style of the road suggests that this is a later addition to the map and may not be reliable.

3/113/6 (map 1968, photography 1962-63, one area nil)

This sheet is rejected as it has a 30mm overlap with 3/116/7 and 3/113/3 with the same values given to the sheet edge. This raises some doubts on the way in which computer sheet cuts are generated.

3/113/7 (map 1979, photography 1962-63)

Checking the overall fit was limited to one river and a logging track. The sheet is considered acceptable.

3/113/8 (map 1973, photography 1961-63)

Some very localised detail fit in one area was possible, but no other significant detail to fit to, however, the sheet is considered acceptable.

At North 114degrees 42min. and East 113degrees 53min there is either a bad mosaic join or a scratch on the negative this should be checked and if damaged a new negative made or the area remosaiced to improve the join.

3/113/11 (map 1973, photography 1962-63)

There was insufficient detail for a full comparison.

3/113/12 (map 1968, photography 1963)

Both the fit and comparison were acceptable.

3/113/14 (map 1975)

Both the fit and comparison were acceptable.

3/113/15 (map 1975)

Best mean fit is acceptable.

4/113/16 (map 1963, photography 1958-61)

The coastline is in agreement, there is very little internal detail.

4/117/9 (map 1979)

A fit to the map sheet using the best mean fit shows an error in the borders. The expression of relief as shown on the map is clearly inadequate when compared to the mosaic, the contours can only be regarded as form lines on this map. In general the boarder with Indonesia is adequately covered.

4/117/10 (map 1978)

Using the best mean fit the Indonesian border would be regarded as covered. The contours again are not a true representation of the terrain.

4/117/14 (map 1979)

The general coincidence good. The Indonesian border is not shown but is adequately covered.

5/115/8 (map 1977, photography 1959)

Using the best mean fit no errors in detail were found.

5/115/11 (map 1974, photography 1958)

The area covered by the map is essentially a flat, well cultivated area with distinctive main drainage, roads and a railway. It can therefore be regarded as an area of minimum relief distortion and as a result, suitable for direct comparison between the map and the radar mosaic.

A tracing of the main features of the map was made and this was fitted over the mosaic. A direct fit to corners was not possible so the best mean fit was used.

In general the fit to the detail was acceptable, differences tended to arise in the expression of detail along the water course; the mosaic indicated that the rivers were more convoluted than is shown on the map. In one case the mapped river was clearly in error.

This map was also significant since it was made, using photography flown in 1958, by manual compilation. The fact that so few differences occurred would confirm the overall reliability of the map series.

5/115/14 (map date 1963)

Two small coastal areas are shown on the sheet, the best mean fit provides a good comparison but corner errors occur.

The coast is mainly delta and mangrove, since the map was made in 1963 some changes are to be expected, however, there is no evidence of any significant change.

5/117/3 (map 1979)

Best mean fit was obtained by using a number of minor roads and the drainage, as a result the conclusion can be drawn that one major road is clearly wrongly plotted on the map.

5/117/4 (map 1978)

Best mean fit is acceptable, with some variations in the coastline, but the interior road comparison is acceptable.

5/117/7 (map 1975)

Best mean fit shows an acceptable relationship and the error in sheet cuts is consistent with surrounding sheets.

5/117/8 (map 1977)

Best mean fit shows an acceptable overall relationship between identifiable detail. There is some inconsistency with a major road alignment but there is evidence to indicate that the map itself may not be reliable.

5/117/9 (map 1974)

The overall best mean fit is reasonable given the type of terrain.

5/117/10 (map 1976)

There is insufficient detail for a reliable overall fit. Using the single main river indicates that a close approximation to fit is possible.

5/117/13 (map 1978)

There is very little detail on the sheet except for some drainage, the area is rugged with a substantial hill feature.

Best mean fit to drainage is basically good with some evidence that the mosaic represents the drainage better than the map. This is not surprising since the air photos would be difficult to interpret in this area. This is due to the fact that on an air photo, in an area of dense forest, the alignment of the rivers can only be inferred, whereas using radar, at a wavelength suitable for the detection of water bodies, the partial penetration of the forest canopy and expression of relief the drainage can be more reliably inferred.

5/118/5 (map 1981)

The bottom section of this map shows a distinctive estate road pattern which showed a good general fit to the mosaic. To the north there was a distinctive coastline which was also in agreement. However with these two areas in coincidence there appeared to be a shift in the central portion of the mosaic, but insufficient detail was observed to explain the difference.

Subsequent checking of the next sheet, see below, confirmed the displacement as a mosaicing error and the sheet should be rejected.

5/118/6 (map 1974)

A general best mean fit to detail at the top and bottom of the sheet showed a good relationship, with an error in the borders. There is however a serious misfit in the drainage in the central area. The error did not agree with the concept of either an error in mapping or changes in the drainage. Although the area is swampy there is no other evidence of severe changes in the river course and a lateral displacement of the sheet showed that the drainage could be made to fit.

Closer examination of the image showed that the band of error can be identified as being confined to one strip of the mosaic, the edges of the strip being clearly visible as a distinct change in both tone and contrast. It would appear that this strip had been badly mosaiced although all the drainage had been made to join up across the mosaic edges.

To test the theory the 1:50,000 strips were laid out and matched to each other, no apparent scale differences were noticed and a good match resulted. A tracing of the map detail was placed over the laydown and no error in general fit occurred comparable to that seen on the mosaic.

This sheet must be remosaiced as must any adjoining sheets that are affected, the re-mosaicing should be performed at both scales, thus this sheet is rejected. It is suggested that the tracing overlay of the map detail showing the extent of the error is sent to Intera, not only will this demonstrate the extent of the shift, it can also be used to ensure the revised sheet is correct.

Sheets 6/116/3,4,7 and 8

These four sheets are mentioned earlier in the report, and were examined in relative detail because there was a coastline on each of the four sheets in the block.

A master overlay was traced onto transparent film from the 1:50,000 map sheets using the coastline, major drainage and roads. The location of spot heights on major hill tops were also recorded in order to form some idea of the possible height displacement that occurs.

In the first instance each mosaic sheet was located against the corner marks for the map. Although there was relative coincidence on the corners indicating correct calculation of size, it was not possible to fit the detail by this method. It was possible to obtain a best mean fit to the overall detail and this indicated a good correlation between the mosaics and a general shift of the sheet corners relative to the maps.

The edge detail on the mosaics was clearly seen to spill over the edges of the map sheets and could be identified on the adjacent map sheet. This indicates that the cut line positions were in error.

A direct overall fit to detail was not possible and indeed in subsequent sheet comparisons at no time was a reliable overall fit achieved, a best mean fit to detail showed that certain local differences occurred. Some of the local differences could be attributed to either coastal changes or uncertainty of the exact sea/land interface.

There was clear evidence of differences of road alignment in some areas and it was reasonably certain that these were definite changes. It was also interesting to note that on the best mean fit, there was a good relationship between the spot heights and the estimated top of a mountain on the mosaic, which indicates that the processing had minimised the height distortions.

On sheet 6/116/7 a portion of coast line in the bottom left hand corner has not been included in the mosaic. On the map this is shown as a minor extension to the map and does not warrant a separate sheet. It is clear that the use of the schematic sheet layout and computer generated cut lines has resulted in this area being missed. The sheet should, therefore, be rejected and a corrected version made.

6/116/11 (map date 1978)

Best mean fit shows that the sheet corners are not in coincidence, excepting this there is an acceptable overall fit. Some evidence exists that errors occur in the rivers as mapped mainly through being overgeneralised.

6/117/7 (map date 1980)

Fit to sheet edges marginally in error, local fit to detail is more precise.

Note: In common with other coastal sheets, the map records considerable off shore sand bank detail, this detail cannot be seen on the radar, however, the radar often shows coral reefs that are not shown on the maps. This is due to the backscatter changes observed in the shallower water over the reefs.

5. MOSAIC CHECK ONLY

No maps were available for the following sheets and they have only been examined for general quality, it is considered essential that the maps are made available for the next visit and that the sheets are checked against the maps before final acceptance.

4/118/2

This sheet consists mainly of coast and islands. It is of interest since some of the coast and a number of the islands have very steep mountains which cast deep shadows. The shadows merge with the sea and both appear black due to low or absent signal return. It is, therefore, impossible to determine the sea land interface. A cursory comparison with the map would infer that the island shapes were wrong; this mosaic should be viewed, therefore, keeping in mind the imaging system by which it was produced.

All of the following sheets were of acceptable image quality for the mosaics, in some cases variations in tone between mosaic strips can be seen. If interpretation is not carried out on the strips but directly on the mosaic these changes could be mistaken for a change in the vegetation and lead to severe interpretation errors; extra care is therefore needed in interpreting the mosaics.

0/110/3; 0/110/4; 1/109/12; 1/110/7; 1/110/8; 2/113/3; 2/113/5; 2/113/6; 2/113/7; 2/113/8; 3/113/3; 4/113/12; 4/116/4; 4/116/7; 4/116/8; 4/117/1; 4/117/3; 4/117/4; 4/117/7; 4/117/8; 4/118/3; 4/118/4; 4/118/5; 4/118/8;

Figures 1 and 2 summarise the Quality Control carried out on the individual mosaic sheets to date. The shading indicates the status of the sheets. Accepted signifies an acceptance of the sheets as they stand. Conditional acceptance indicates that the mosaics have been accepted provisionally, pending comparisons with map data. Rejected signifies that the sheets have been rejected and must be redone.

6. CONCLUSIONS

There is clearly a difference in the derivation and consequently the positioning of the two grids, that of the map and that of the mosaic. It is probable that this is the outcome of using two base projections, the RSO and the UTM. At this stage it is not feasible to redo the correction work and so it is recommended that the notations on the mosaic sheet cut-lines are removed to avoid confusion. It is also recommended to put a cautionary note on each sheet, even though experience suggests that few people ever read such notes.

A note outlining the displacement and possible differences observed between the map and mosaic sheets should nonetheless be issued to every potential user of the data. The text of such a note is as given as Appendix A.

There is much evidence to show that although in the more remote areas, the detail in the maps may not always be complete, the overall reliability and accuracy of the maps is such that they should remain as the Official Survey of the area. The mosaics cannot be considered a substitute for the maps and for reliable mapping. Interpreted data should be transferred from the strips to the maps.

It is unfortunate that not all the mosaics could be compared with the maps, especially for the coastal regions, as had been recommended earlier. The problems in obtaining maps are understood but it should have been possible to have access to maps in Malaysia either through the Survey or Petronas, and to make tracings of the salient features for comparison.

Similarly, it should have been possible to trace the international boundaries and either to digitise them and introduce them into the mosaic to form a digital mask, or to use them for a mask to be introduced at the photographic stage.

Much data already exists on the map base and as users will inevitably make comparisons, it is strongly suggested that a complete check against maps both for the new data and for the data for which maps had not previously been available is carried out.

A one day seminar is proposed to take place during the final visit. The seminar will give an introduction to radar from the interpreters point of view and will explain the findings of the QC. An outline of the suggested programme is given as an Appendix B.

Appendix C contains a specialist comment on the use of colour print materials for the reproduction of monochrome data.



FIGURE 1 MOSAIC DISPLACEMENT OF SABAH QC OF SABAH SHEETS

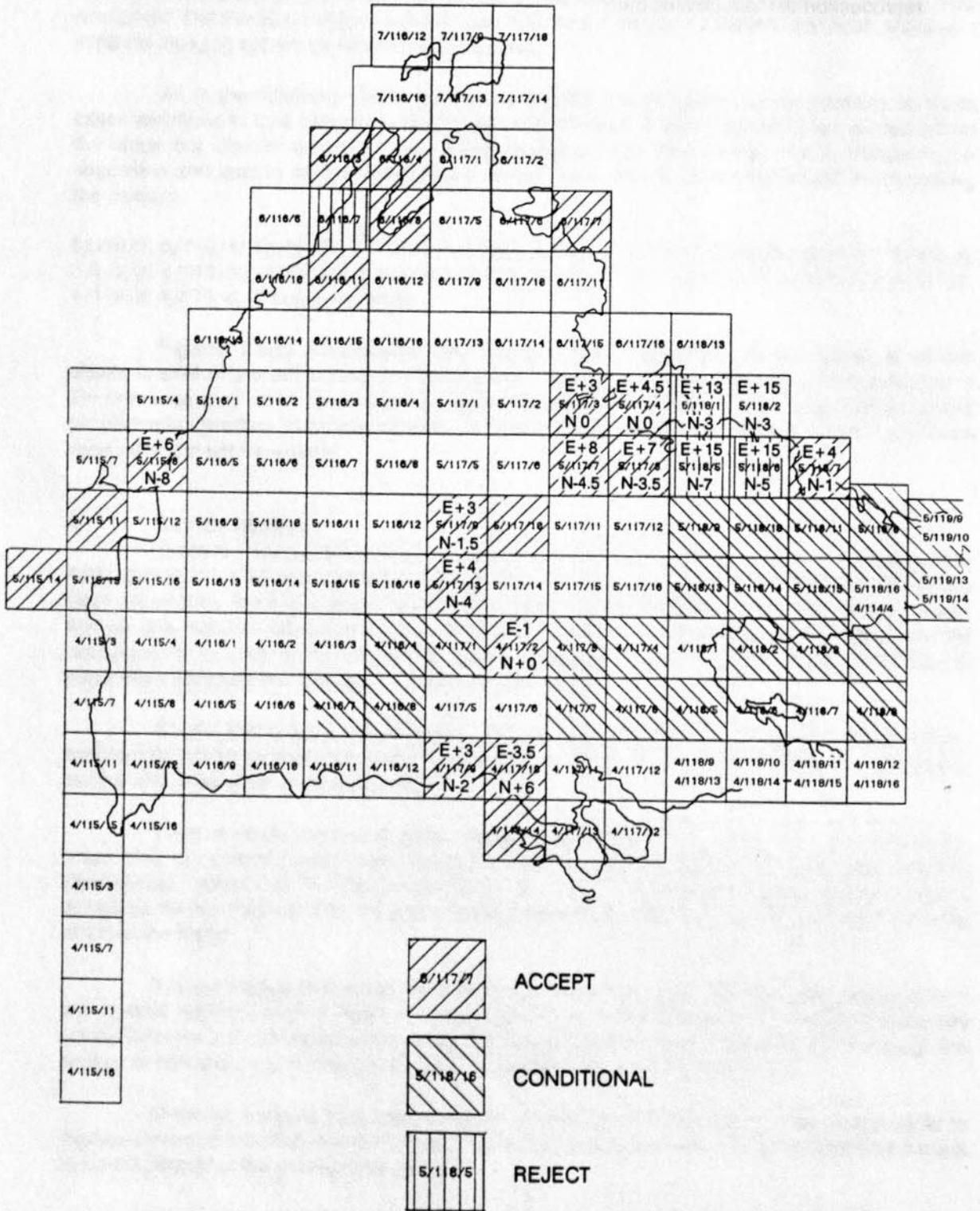
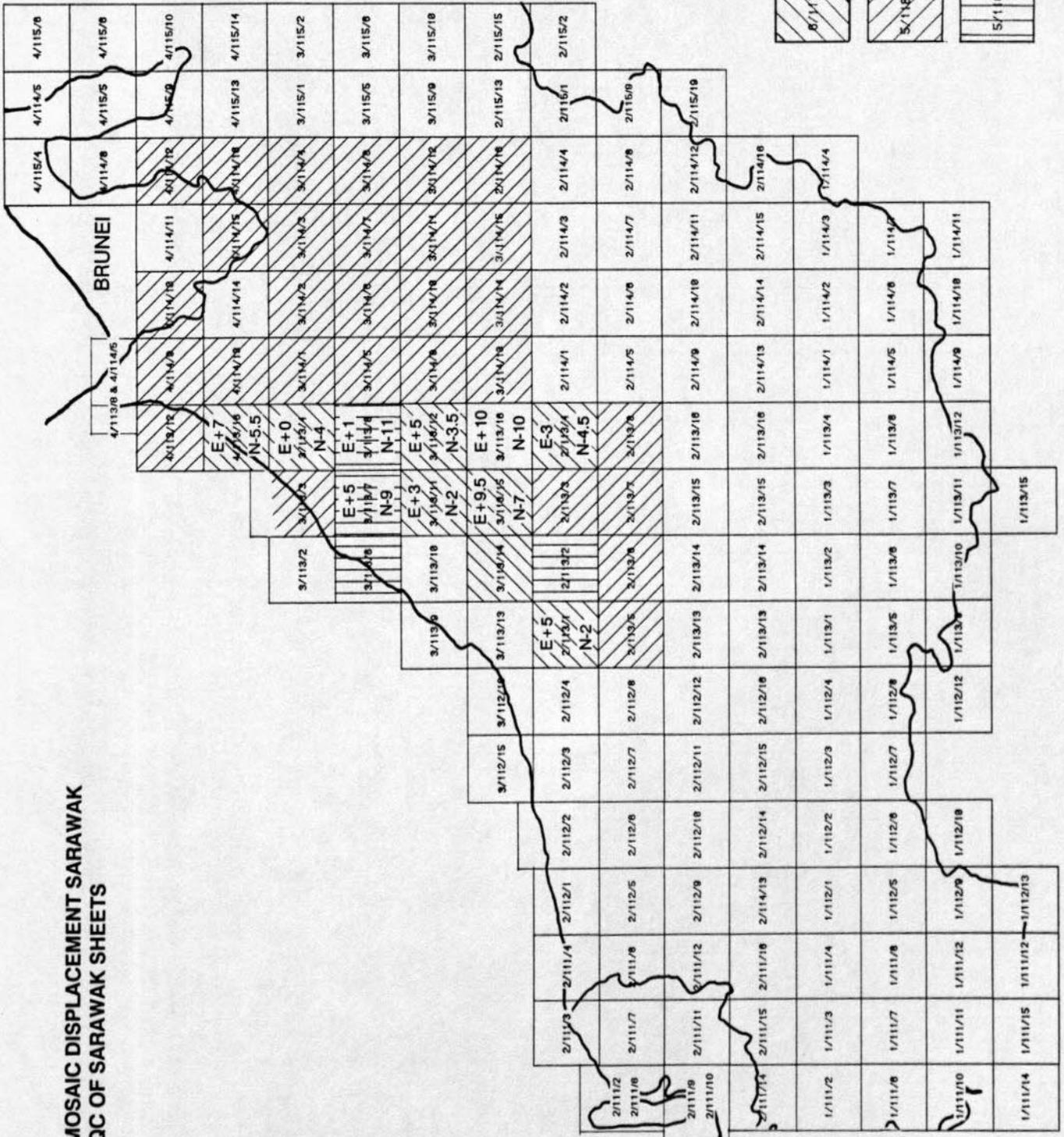


FIGURE 2

MOSAIC DISPLACEMENT SARAWAK
QC OF SARAWAK SHEETS



ACCEPT
CONDITIONAL
REJECT

APPENDIX A

PROPOSED CAUTIONARY NOTE

It is suggested that the following cautionary note should be included with any data sent to external users.

This mosaic has been constructed from side looking airborne radar imagery using control data obtained from a satellite Global Positioning System. The GPS information was recorded on the aircraft during acquisition. The mosaics have not been controlled to the 1:50,000 Survey of Malaysia map sheets, although, the layout for these sheets has been followed.

Differences between the map and the mosaic sheets will be observed and their causes divide into two categories:

- a). *a variation in the projections used to construct the map and the mosaic results in a lack of coincidence between cut lines or sheet edges.*
- b). *the rectified but uncontrolled oblique radar view will result in displacement of data especially in the hilly areas.*

It is recommended that where detailed interpretation is carried out it should be completed on the original image strips and compiled onto the map base not the mosaic. The mosaic should only be used for a general overview and to map major structures and trends.

Petronas cannot be responsible for any locational or positional errors that may result from making graticule measurements from the mosaics.

APPENDIX B

SEMINAR OUTLINE

MORNING

1. Basics of Radar for Interpreters.

This will provide a basic introduction to the principles of imaging radars. It is not intended to cover in depth the physics of SAR, but to highlight those factors which are essential knowledge for all users.

2. Case Studies of Applications.

A number of practical case studies taken from actual projects and research will be demonstrated and discussed.

3. Satellite Radars and the Future.

Descriptions of Seasat, Shuttle radars, ERS-1, JERS-1 and RADARSAT with examples of results where possible, and an outline of future plans including regional plans for receiving the data.

AFTERNOON

4. The Petronas/Intera Data

An overview of the survey and the quality control study and results.

5. Using the Data

This lecture will include the use of stereoscopic data and the practical interpretation and mapping for geological applications. Merging and comparison with other data sets will also be covered.

The seminar will be structured towards all users of the data and will assume a knowledge of interpretation from air photographs and from optical satellite imagery but no detailed experience of using radar.

By including past and future developments, especially in satellite coverage and by relating to other optical satellite data, it is hoped to demonstrate the long term potential of SAR.

The seminar would be suitable for attendance by all levels of staff within Petronas as well as by other government departments or for users from the mineral exploration community.

APPENDIX C

USE, AND LIMITATIONS ON IMAGE QUALITY OF RADAR IMAGES REPRODUCED ON COLOUR PAPER

The reproduction of Black and White (B&W) negatives on colour photographic paper can be achieved with reasonable success, provided it is accepted that a different standard of quality will result.

The differences in quality can be expected to affect four aspects of reproduction:-

- a) overall image colour
- b) appearance of the grey scale
- c) resolution and sharpness
- d) long term keeping, archival behaviour.

Colour papers are manufactured to be compatible with negative materials having different sensitometric characteristics to B&W films. The resultant tone and colour reproduction obtained by having a combination of colour and B&W materials is dependent on the match that can be achieved between image contrast in the B&W negatives and the exposure range, or latitude, of a particular colour paper. Any departure from what represents an ideal match between the two types of material will show as an overall bias in the appearance of the image towards some given colour. This bias can be minimised, but not altogether removed to leave an image with a neutral grey scale, by the use of colour correction filters during photo-reproduction. In addition to the overall bias in image colour there is a change in colour that is dependent on the grey level involved. Typically this can show as lighter shades of grey in the image having a magenta appearance, and the darker grey levels having a green or blue bias. The particular combination of change in image colour will vary according to the materials and photoprocessing that are used.

The resolution and sharpness of a radar image printed on colour paper can result in improved contrast for larger point targets when compared with B&W paper, but this feature of a colour paper is gained at the expense of contrast with smaller point targets. As the size of point targets in an image become progressively smaller, the limit of detectability is reached more quickly for images reproduced on colour paper than they would be if reproduced on a B&W material. In association with the causes that affect the resolution and sharpness is a change that occurs in image colour especially if this is accompanied by periodicity in the pattern of point targets. All these effects on resolution, sharpness and image colour are caused by the way an image is formed and spread in the reproduction on a colour paper.

B&W papers can be expected to last many years without obvious deterioration in the appearance of an image, provided that careful attention has been given to long term storage during photo-processing. The image reproduced on colour paper is formed by coloured dyes, unlike the extremely fine-structured silver image of a B&W paper. The dyes produced in the image formation of a colour paper are not as stable as the image obtained on a B&W paper. In particular they are affected by light, temperature and humidity, with the rate of deterioration in a dye-formed image increasing as the values for each of the three ambient conditions increases.

While all these aspects appear to argue against the use of a colour paper in reproduction, they can be regarded as a comparison against a stringent standard for materials that are not available in the size and packaging needed by the production of large sheets of radar imagery. Apart from the question of any need for long term storage, the inferior qualities of a colour paper are not likely to cause serious problems for the user who is in a position to understand the inherent limitations of the materials.

