LANDSAT PHOTOMAP OF SPLAJ - photogrammetric and cartographic evaluation

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1. GENERAL INFORMATION

Socialist People's Libyan Arab Jamahiriya / SPLAJ / is one of the first countries in the world,which edited the First National Landsat Photomap series at scale 1:250,000 based on Landsat satellite images. The complete set of Landsat Photomaps consists of 127 map sheets / $1,5^{o}$ x 1^{o} / covering the total territory of SPLAJ, it is 1 775 500 sq.kms.

The Landsat Photomaps were prepared in the years 1978-80 for the Secretariat of Municipalities under the supervision of Surveying Department / SDL / by :

- Pacific Aero Survey Co.Ltd. - Tokyo, Japan,
- ESRI International - Redlands California, U.S.A.,
- Earth Satellite Corporation - Washington,D.C., U.S.A.

In Surveying Department the photogrammetric and cartographic evaluation of Landsat Photomaps was performed and brief results are presented in this paper.

2. TECHNICAL PROCEDURE OF LANDSAT PHOTOMAP PRODUCTION / Fig.1 /

2.1. Selection of Landsat scenes

For Landsat Photomaps of SPLAJ 100 Landsat scenes were selected. Presumed image selection criteria were as follows:

Date - most up to date Landsat scenes registered over SPLAJ territory by Landsat-2 since 1975,

Season - prefered winter scenes /October - February/ due to the less incidence of sandstorms,

Cloud cover - cloud free or minimized cloud cover,

Image quality - high image quality / good to excellent /.

Above mentioned criteria for image selection were applied, but were limited by available CCT tapes.For many of selected scenes fulfiling the presumed quality, the CCT tapes could not be generated by NASA, because the High Density Tapes-HDDT's were deteriorated. Thus other best alternative scenes were selected.

2.2. CCT tapes

For digital processing,the Landsat CCT tapes from EROS / U.S.A/ / 92 scenes / and Fucino station in Italy / 8 scenes / were used.All Landsat scenes, except one, were registered by Landsat 2 MSS system. One scene was registered by Landsat 1 MSS system.

2.3. GEOPIC image processing

All Landsat scenes used for Landsat Photomaps were digitally processed by Earth Satellite Corporation / EarthSat / using GEOPIC software. GEOPIC images are produced from Landsat computer compatible tapes / CCT's / using proprietary algorithms for geometric and radiometric corrections, edge enhancement,grey scale adjustment and scanline suppression.

Standard GEOPIC processing include algorithms to improve scene contrast and thereby increase the interpretable information contained in each of the final colour prints. In GEOPIC processing the reflectance values,which on image histogram occupy limited

range of the available grey levels , were stretched to benefit from the full dynamic range of grey levels / densities / that may be accomodated by Optronics film recorder.
Prior to processing, EarthSat developed a "national Landsat histogram for Libya", based on sample histogram from 30 percent of well distributed scenes. The result of this procedure was not acceptable due to the serious loss of information and subteli - ties within an individual scene. Thus the digital processing on an individual scene by scene basis was performed with the empha size on maximum information contents.

2.4. GEOPIC band separation

The corrected and enhanced digital data for each MSS spectral band / 4, 5 and 7 / were individually recorded on black-and-whi te photographic film using Optronics P-1500 Photowrite System. The film positives were recorded at scale 1:1,14 million.

2.5. Additive multiple exposure

From the three spectral band positive images, registered by Optronics P-1500 Photowrite System, the colour composite negative images by additive filtration were produced.

- MSS band 4 / green / was exposed through blue filtration act ing on the yellow dye layer / blue sensitive/in colour film ,
- MSS band 5 / red / was exposed through green filtration, acting on the magenta dye layer / green sensitive /,
- MSS band 7 / near IR / was exposed through red filtration,act ing on the cyan dye layer / red sensitive /.

On the colour negative,the image is composed from complementary colours , which are opposite to the primary red,green and blue, which will occur on positive colour images exposed through such negative.

2.6. Photographic enlargements

From the GEOPIC colour composite negatives at scale 1:1,140,000, the photographic enlargements at scale 1:500,000 were produced. For scaling the existing cartographic materials / North and West part of SPLAJ/ were applied. The enlargement factor was not constant,because the composite negative scale is subtle varying due to the spacecraft altitude changes. The enlargements for individual scenes were adjusted to receive the same scale of enlargements on the basis of image comparison of adjacent images. In the process of photographic enlargement also subtle adjustment in colour balance was made principally on the basis of maximum scene information contents, and secondary of aesthetic matching of adjacent scenes.

2.7. GEOPIC mosaicing

Landsat mosaic of SPLAJ territory was laid at scale 1:500,000. For mosaicing the conventional image detail matchning process was used together with adjustment in positioning of images to cartographic control. It should be noted, that at this time only in North and West part of SPLAJ the cartographic control was existing.
The mosaicing was performed in three separate sections / each one covering ca 30 - 40 % of SPLAJ territory / starting from the northwest corner and processing to East and South.Hence,the mosaic for the total territory of SPLAJ was not laid at the same time.

The mosaic cut lines were normally made between prominent ground features or in areas of minimum image-to-image contrast within the overlap areas of adjacent scenes. Where possible the cut lines were positioned to eliminate areas of poor contrast, clouds and seasonal differences.

2.8. Photomap sheet division

As each one section of SPLAJ original mosaic at scale 1:500,000 was completed, the sheet corners were determined using the geographic grid overlay. The geographic grid overlay - 1,5° longitude x 1° latitude - was constructed from geographic tables. Also available cartographic materials were used for correlation of horizontal control with sheet intersections. After determination of photomap sheet corners, the photomap sheets were cut from the original mosaic section.

2.9. Photographic reduction

Each one of photomap sheet, cut from the original mosaic, was copied onto 8" x 10" colour negative film at scale ca 1:750,000 .

2.10. Landsat Photomap prints

Photomap colour negatives were then scaled to 1:250,000 and projected onto photographic print paper, which was pre-punched and pre-exposed with frame, geographic coordinates, titles and legends cartographically prepared on contact map frames.

Each photomap sheet contains the approximate geographic tick marks at 15 minute intervals. Map sheets are designed by both sheet number and sheet name. On the bottom margin the following information are given: credit statement, photomap location index, bare scale, photomap index showing sheet numbers of each adjacent sheet, index of Landsat images used in the respective photomap sheet.

The Landsat Photomaps were printed both as colour copies and as black-and-white copies. Also Cronaflex film copies were printed for each one photomap sheet.

For users interpretation purposes the Landsat Photomap Colour Guide was elaborated and printed.

3. Evaluation of photogrammetric and carographic quality / Fig.2 /

3.1. Method of quality evaluation

For proper evaluation of photomap quality the complex method of verification was applied. The applied methodallowed to verify both the quality of each one photomap sheet and the quality of complete set of photomaps covering SPLAJ territory.

The complex method of verification contains the following steps

- verification of image-to-image fitting,
- verification of photomap sheet-to-sheet fitting,
- verification of photomap and negative dimensions,
- comparison of photomap to negative ratio,
- verification of Landsat Photomap scale,
- verification of photomap geographic coordinates,
- evaluation of Landsat Photomap photographic quality,
- "combine analysis" of photomap quality.

3.2. Verification of image-to-image fitting

Verification of image-to-image fitting was performed for all photomap sheets. On this stage of verification the mismatching errors between Landsat images were determined.

Each cutting line between adjacent images was checked and the direction and value of detected displacement were measured. On the basis of photomap image examination, not all mismatching errors can be detected, thus for checking also full scene Landsat images both 1:1 million and 1:250,000 were used. Without these full scene images the overlapping errors between images can not be detected and measured. For detecting of mismatching errors the distance between pair of points both on adjacent scenes on photomap and on full Landsat scene image was measured. The differences in length, after scale corrections, give the value of mismatching errors.
The mismatching errors together with direction of displacement were indicated on so called "sheet verification diagram" on which all cutting lines were drawn.
On the basis of image-to-image verification the following perceptions can be derived:

- generally mismatching errors are rather small 0,25 - 1,00 mm / 0,1 - 0,4 km /, but in several cases they are very large up to 24 mm / 6 km /,
- mostly the mismatching errors are caused by overlapping of adjacent images and hence some details are eliminated from photomap image,
- in several cases the mismatching errors are resulting from separation of adjacent images, which is very easy to detect on photomap, because the same details are appearing on both the sides of cutting line / maximum value of such mismatching errors up to 24 mm /,
- the mismatching errors are smaller between adjacent images from the same orbit path and when these images were registered during the same day,
- the errors in image-to-image fitting are caused mostly by inaccurate image matching during original mosaic assembling,
- only in few cases the mismatching errors indicate the scale change between the adjacent images.

3.3. Verification of photomap sheet-to-sheet fitting

All edges between the adjacent sheets were compared and checked and the results indicated on "sheet verification diagrams". Generally the image-to-image fitting between sheets is better than between images within the photomap sheets. The reason is that photomap sectioning was done from the mosaic subregion section, so the only error between sheets can occur due to the different scale factor during the reproduction procedure / mosaic original at scale 1:500,000 - colour negative at scale 1:750,000 and photomap print at scale 1:250,000 /.
In few cases really such scale change between photomaps was recognized / 1:250,000 - nominal - and 1:255,000 /.
For verification of sheet-to-sheet fitting also Landsat full scene images were used. By comparison of full scene images with images on adjacent sheets, in many cases gaps in imagery were recognized. The range of such gaps varied between 1 up to 32 mm / 0,4 - 8 km /. The small gaps within the range from 1 to 4 mm were caused mainly by inaccurate masking of the colour negatives. These gaps can also be detected from the differences in negative dimensions / see point 3.4 /.
The largest gaps are occuring on the boundary between sections

of original mosaic at scale 1:500,000. In the south part of country there is lack of terrain belt of 8 kms width. The missing belt is occuring along a few pairs of sheets.
Verification of photomap sheet-to-sheet fitting indicated also large discrepancies in photomap image corners between adjacent sheets. If two adjacent photomap sheets are matched with each other according to Landsat images, the photomap image corners are not placed in the same position but are shifted each other. These errors were caused during sheet division of original section mosaic and it is difficult to understand while such shifting of corners was introduced. Probably this was done for better image fitting, of one part of sheets, with geographic coordinates. Such shifting of sheets is occuring in the south-east part of the country along 8 pairs of sheets. Generally on 74% of sheets these discrepancies are within 2-3 mm, but between rest of the sheets are larger up to 32 mm.
For verification of sheet-to-sheet fitting very useful were the scan lines, occuring in many cases, on adjacent sheets. These lines can be used for detecting of scale changes between sheets as well as for detection and determination of image gaps between sheets even without using of additional full scene images.

3.4. Verification of photomap and negative dimensions

The preliminary checking of sheet dimensions indicated large variations in sheet sizes, thus the dimensions of all photomap image sizes were measured. The results were indicated on two map diagrams: sheet dimensions and sheet size differences. The differences of sheet size dimensions were computed as differences between practical and nominal dimensions. It should be noted that practical dimensions of sheet size, according to geographic tick marks, were not changed in comparison with nominal dimensions. This indicated high stability of paper prints.
The analysis of sheet size differences indicated that:

- the differences in sheet dimensions are rather small in the areas where cartographic materials were used as horizontal control for mosaicing and scaling,
- the differences in cartographically remote areas are larger - up to 33 mm,
- the differences in longitude dimensions are larger / from - 33 mm to + 3 mm / than the differneces in latitude / from - 11mm to + 9 mm /. On the same latitude / e.g. $\varphi = 24^{\circ}$ / the differences in the sheet length are varying from -32,5 mm up to + 0,2 mm, while for the same longitude / e.g. $\lambda = 21^{\circ}$ / the differences are from -11 mm up to + 8,8 mm.
- on the 75% of sheets, the practical dimensions are smaller than nominal,
- in few cases dimensions of adjacent photomap sheet edges are not equal / up to 10 mm / what indicates the displacement in sheet division or scale changes between photomap sheets.

The dimensions of all colour masked negatives were measured and presented on "negative dimensions map diagram". The analysis of measured sheet dimensions indicated that the dimensions of sheets from the same row are not equal. The differences in the dimensions of adjacent sheets have shown some mistakes in negative masking, causing gaps in Landsat imagery on photomap. Such places were then checked on photomaps and compared with full image

3.5. Comparison of photomap to negative ratio

On the basis of photomap and negative dimensions, the enlargement ratio for all edges of sheets was determined and presented on "enlargement ratio map diagram". This diagram allowd to recognize the limits of each subregion of original mosaic, due to the significant changes of enlarement ratio. For the north-west subregion the enlargement ratio for all sheets has the same value / 2.99 ± 0.005 / while for the other subregions it is not equal and is varying between 3.03 and 3.08 ; for the middle and north -east part and for the south-east subregion this value is between 3.00 and 3.03.

3.6. Verification of Landsat Photomap scale

The scale of Landsat Photomap was verified on the basis of existing cartographic materials. In the areas where for mosaicing and scaling the cartographic materials were applied the scale of photomaps is within the range 1:249,000 - 1:251,000. These values are concerning measurements performed within single Landsat image on photomap not influenced by mismatching errors.
In regions without cartographic materials, only the relative scale changes between photomaps could be determined. As it was mentioned before, such scale changes are occuring in few cases. The largest detected scale change is between 1:250,000 / as nominal / and 1:259,000. Such scale changes were caused by inaccurate scaling of Landsat images before mosaicing any by changing of enlargement ratio between negative and photomap sheet.
For evaluation of Landsat Photomap scale an other method, based on comparison of nominal and practical dimensions of photomaps was also applied. Of course such method,due to the errors in sheet division, can not be applied for separate sheets, but can be used for larger blocks of photomaps, when the errors of sheet division can be neglected. According to this method the average scale for all photomaps sheets of SPLAJ is 1:252,000, but there are significant differences in scale depending of photomap location.The scale of north-west subregion is varying from 1:249,000 to 1:253,000. The scale of photomaps of the middle and east part of the country is changing gradually from the north to the south within the range from 1:249,000 to 1:256,000. Above mentined figures are concerning the measurements of longitude dimensions. The scale changes in latidude dimensions are smaller and are varying between 1:249,700 and 1:252,500.

3.7. Verification of photomap geographic coordinates

On each photomap sheet the geographic grid is presented in the form of tick marks at 15 minute intervals. As it was stated,on marginal description of photomap, the geographic coordinates may be used for reference purposes only. Due to the large differences in sheet sizes,this geographic grid has only approximate value and sheets can not be matched by these coordinates.
Nevertheless the verification of geographic grid was performed. This verification indicated that the differences in geographic coordinates between adjacent sheets are up to 5 minutes /ca 8 kms /.
The absolute differences of geographic coordinates were determined by the comparison of geographic coordinates of the terrain details on photomaps and on existing cartographic materials.The determined differences were presented on map diagram giving the

spatial distribution of geographic coordinates errors. The analysis of differences indicates good coincidence of geographic coordinates in areas where cartographic materials were used for photomap production /$\Delta\varphi = \Delta\lambda = 0{,}5'$/. In the cartographically remote areas these differences are bigger / up to 6'/.

3.8. Evaluation of Landsat Photomap photographic quality

The image quality of selected Landsat scenes was not such as it was assumed in requirements. Several of selected scenes were with slight to moderate cloud cover and on several other scenes the scanning errors were appearing.

According to NASA information 71 scenes were cloud free, on 21 scenes the cloud cover was below 10%, on 3 scenes was below 20% on other 3 below 30%, on 1 scene below 40% and on 1 scene below 50%. Above mentioned figures are concerning nominal values of cloud cover occuring on full scene image. During mosaicing procedure, wherever possible, the cloud cover areas were eliminated by selecting parts of adjacent scenes without clouds. Nevertheless, on ca 18,000sq kms the image is covered by clouds or by clouds shadows. The clouds and clouds shadows are appearing on 23 photomap sheets. The results of cloud cover verification were presented both on sheet verification diagrams and on map digram for entire territory of SPLAJ.

The technical quality of selected scenes was also a little lower than it was presumed. 44 scenes have the MSS quality fair in all three channels. 25 scenes have the mixed quality fair and good and 31 scenes have the quality qood in all three channels. The lower quality of scenes is appearing in the form of noise presented by scan lines or dropouts on the image. In few cases these noise effects are degradating image quality and are causing some problems in image interpretation. The scenes with MSS noise effects were presented on image quality map diagram.

The differences in season of Landsat scene registration are greatly influencing the image quality of photomaps. Requirements concerning the season of imagery were only partly fulfiled.Most of selected scenes were registered in season between October and March / 77 scenes/. 95 scenes were registered in the years 1975-1976, but also 1 scene was from 1973, 3 scenes were from 1977 and 1 scene from 1978. The differences of season are causing contrast changes of photomap image and changes in colour balancing Colour matching was often degraded due to the extreme variations in season, year and terrain characteristics.

Generally the quality of photomap image is good and the photomaps are containing very subtle terrain features informations which were enhanced by GEOPIC processing. Few photomaps have rather poor contrast and topographical details are not readable . These sheets are concerning mainly sand sea areas.

Comparison of photomap contents with existing topographic maps indicates that in many cases the Landsat Photomaps are presenting more terrain information than the topographic line maps.Such topographic elements like roads, tracks, wadies are prominently visible.The colour photomaps are very useful for detecting vegetation and bare soils as well as bare rocks.Very important information can be detected in sand areas which up to now were not covered by topographic maps.Various shades of yellow,light brown and white charaterize sand seas and sand dunes and different parent materials.

3.9. "Combine analysis " of photomap quality

The "combine analysis" of photomap quality was performed on the basis of results from particular verifications.For combine analysis the different verification diagrams were used and the comparison of different results has been done. Comparison of different errors, which in some cases are complementary, indicated the areas for more detailed checking / e.g. comparison of sheet and negative dimensions with sheet to sheet matching, comparison of sheet dislocation with geographic coordinates differences etc./.

Performed "combine analysis" indicated that the quality of Landsat Photomap is not uniform, and was degraded mostly on the stage of assembling the original mosaic. The main source of errors was the division of original mosaic into sections,The considerable improvement of photogrammetric quality can be obtained by assembling the original mosaic for the entire territory of SPLAJ even on smaller scale. The assembling could be done in two stages: preliminary and final one. On the basis of preliminary mosaic assembly, the analysis of errors should be performed and the proper corrections could be introduced during the second stage of mosaicing. By adopting such procedure, many errors which are occuring in the evaluated edition, could be eliminated and the quality improved notably.

Detailed results of performed verification and evaluation of Landsat Photomap at scale 1:250,000 are presented in technical report prepared by Surveying Department and in this paper only brief outline of applied method is presented. The final results of performed verification were used for elaboration of clarification for photomap users.In the clarification, among others , the areas with lower photogrammetric and cartographic quality are also indicated.

4. Final remarks

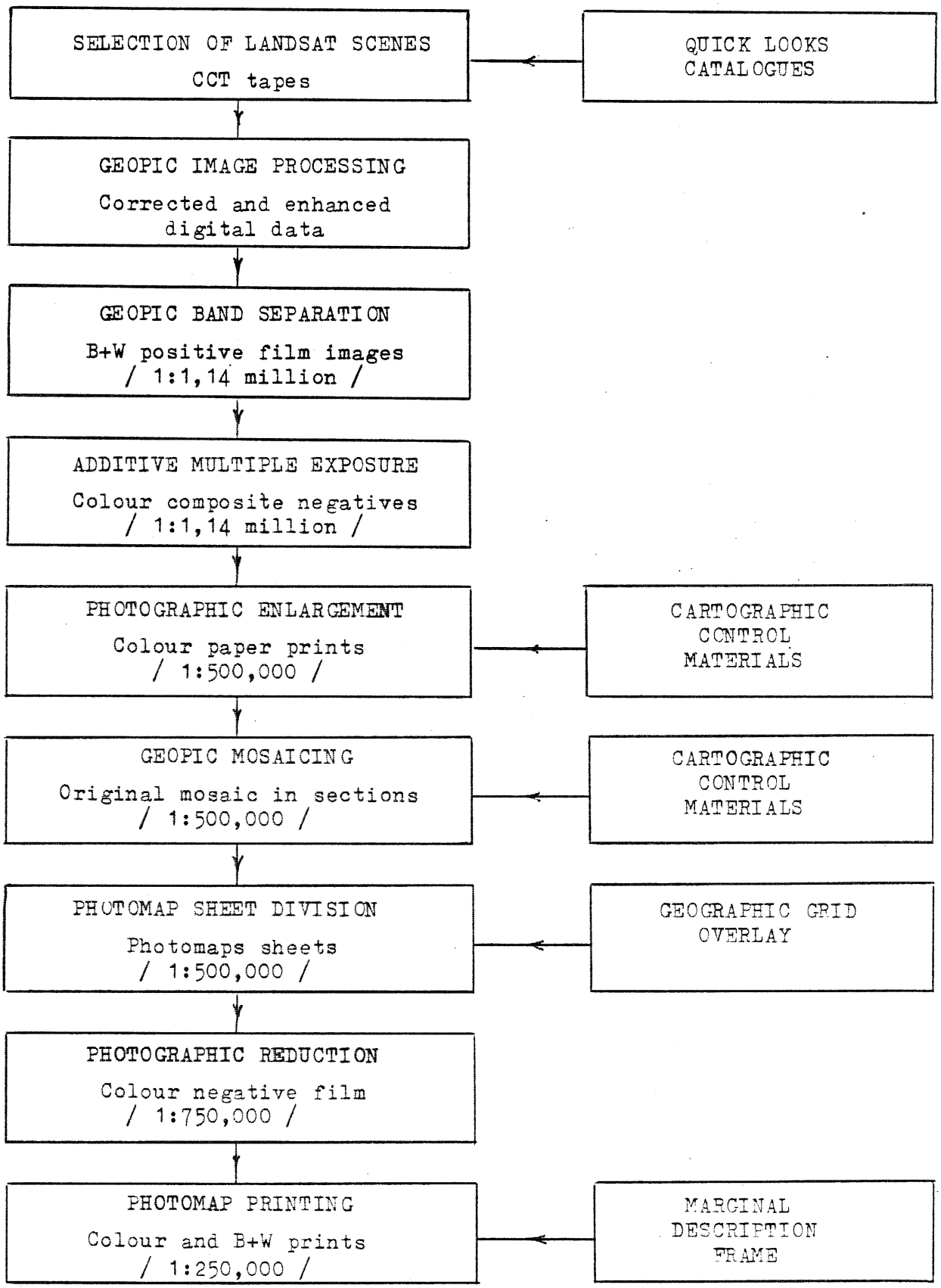
The Landsat Photomaps at scale 1:250,000 are the first homogenieous up-to-date cartographic basemap covering the entire territory of SPLAJ and are very useful for many practical applications, particulary in the areas where basemaps of similar scale are presently unavailable. The Landsat Photomaps provided a broad geographical overview of SPLAJ's physical resources and diverse environments for regional mapping, geographical and geological studies,development and exploration planning and for multiple resource applications.

The performed evaluation of Landsat Photomaps in Surveying Department indicated not uniform quality of photompas, which can be partly classified as semicontrolled and partly as uncontrolled.Several sheets have degraded accuracy and lower image quality while other sheets are presenting high photogrammetric and cartographic value.

Taking under consideration that the evaluated photomaps were prepared on the basis of Landsat images registered in the years 1975 - 1976 and in the meantime many changes occured in terrain, it is recommended that the new Photomap Series based on the new Landsat -4 images should be compiled. The photogrammetric and cartographic quality should be improved by digital mosaicing procedure or by more careful manual mosaicing with application of all existing cartographic materials.

LANDSAT PHOTOMAP PRODUCTION SCHEME

/ Fig. 1 /



LANDSAT PHOTOMAP QUALITY EVALUATION SCHEME

/ Fig.2 /