TECTONIC MAPPING IN NIAS ISLAND USING LANDSAT MSS IMAGERY

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ABSTRACT

Nias Island, is one of the best examples of an exposed subduction complex in active arc system. The aim of this study was to map the structural features of this tectonically complex area, using a combination of enhanced landsat MSS imagery and ground data.

A large amount of structural geological information including previously unmapped lineaments were revealed using a Sobel vertical filter and a standard false colour composite as a complement. The structural geology was found to be dominated by NW-SE and NE-SW orientated lineaments. These tectonic fabric features derived from enhanced image were integrated with the geological sketch map and Bouguer anomaly map. All of these processes were carried out within a geographical information system (GIS) framework.

I. INTRODUCTION

1.1. General

The global Coverage and synnoptic view provided by Landsat multi spectral scanner (MSS) imagery has enabled geologist to interpret regional features from the data. In this project, the geological structure of Nias Island were studied. Structural geology can be intepreted from land forms, out crop analysis and lineament analysis (Siegal and Gilespie, 1980). The present study deals with the lineament analyis. Lineaments were defined by O'leary et al (1976) as "mappable, simple or composite linear features of a surface whose part are aligned in a rectilinear or slightly curva linear relationship, and which differs distinctly from the pattern of adjacent features and presumably reflects a subsurface phenomenon".

The imagery used in the study was acquired by the United States Lansat 5 multy spectral scanner (MSS). The data was suplied from the Thailand Remote Sensing Centre's Satellite Receiving Station, in the form of a computer compatible tape (CCT). The format of the CCT was Telespazio Band Inter Leaved (BIL). Detail of imagery are given in Table 1.

The methodology of the study is as follows :

- Stage 1 : Involved a detailed study of the case study area, an area around Gunung Sitoli - Alasa for which ground information are available. The main purpose of this stage is to develop techniques that can be applicable for the whole of Nias Island.
- Stage 2 : standard image processing techniques from stage 1 were applied to the five full resolution subscene that covered almost all of Nias Island. Finally, after integrating all the data, an

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interpretation of the regional geological structure was produced.

I.2. Geological Setting

The islands west of Sumatra, at the western edge of the Sunda Arc System, constitute one of the best example of exposed subduction complexes in an active arc system (Figure 1). In this area, the slope from the trench up to the frontal arc can be subdivided into two morphotectonic regions, summarised in the schematic section in Figure 2. The upper slope is relatively smooth and sediments are little deformed. On the other hand, on the lower slope, the sediments are highly deformed. These slopes are separated by a ridge, a bench, ar a simple break in slope (Dickinson, 1974; Moore & Karig, 1980).

The trench slope break of the Sunda Arc is a broad ridge (outer arc ridge), continued from the Andaman Island in the west to the vicinity of Sumba in the east. However, it is only in the Andaman and Nicobar groups and in the region west of Sumatra that the ridge rises above sea level. Nias, the largest and most accessible in the island capping the ridge, exposed the trench slope break of the the Sunda Arc Trenh System and the seaward edge of the upper slope basin or forearc basin (Moore and Karig, 1980). Moore and Karig (1980) also identified two tectono-stratigraphic units which trend NW-SE, parallel to the trench (Figure 3). The units are shown in the Table 2.

II.3. Implication of Geological Setting to Remote Sensing

Morphology of the island which is mainly hilly area has steep sides and forms distinctive of the landscape. These steep sides often have less vegetation and form an isolated hill. The appearance of the hills contrast sharply with the other topographical features, and these can be detected on remotely sensed data as lineaments.

Lineaments reveal the geological structure, which are probably the boundary of tectonostratigraphic units or the eastern boundary of structural zones as a large homocline of bioclastic limesto[illegible] folds and faults. Most of these structural featur[illegible] orientated NW-SE, therefore the image processing [illegible]plied (edge enhancement) to the island will larg[illegible] focus on enhancing NW-SE trending lineaments.

II. GEOLOGICAL IMAGE PROCESSING

II.1. General

The main aims of image processing in [illegible] study are to enhance the image for geological [illegible]pretation, especially to highlight lineaments, the[illegible] enabling the geological structure to be mapped. T[illegible] processing was carried out at both the centre [illegible] remote sensing of Imperial College and Univers[illegible] College London University of London, using Inte[illegible]tional Imaging System (I2S) model 70 and 75 - T[illegible] VICAR software and 750 program.

II.2. Spectral Enhancement

The study area is almost completelly cove[illegible] by vegetation, and spectral studies of vegetation [illegible] could be potentially correlated with the underlying [illegible]ology were carried out, these are :

- Contrast enhancement
- Colour composite
- Band subtraction and addition
- Band ratioing and multiplication
- Principal component analysis

Experimentation showed that lithological [illegible]ferences could not be detected by spectral studies [illegible] vegetation (geobotany) using MSS data, due to [illegible] limitation of its spectral and spatial resolution. How[illegible]ever, a standard false colour composite (FCC), ban[illegible] 5 and 4 were displayed as red, green and blue (R[illegible]) respectively is useful in determining general struc[illegible] information (photographs 1). The colour compos[illegible] principal component 3, 2 and 1 (RGB) is also help[illegible] due to its capability to highlight rivers or drainage pa[illegible]tern.

II.3. Edge Enhancement

Edge is intensity differences between pixels and can be defined as sudden changes in gradient. A measure of the first derivative at the point p (x,y) is the measure of the first derivative at the point. Therefore, a steep slope is equivalent to an edge. A Large number of filters designed to calculate approximation to variations in the derivatives exist. In this study, it was performed using a linear filters, ie convolution.

Data convolution are commonly used in remote sensing for the edge enhancement of digital imagery. Most of the computer algorithms are used in matrix operations to define how much an individual pixels differs from its neighbours. Using this method, an edge or lineament is a line of pixels differences from the majority of each of their respective neighbours.

Filters may be non directional for more general sharpening effects, or directional if a structural trend is anticipated. In this study, a number of filters were initially tested on band 7 and the best result was found from Sobel vertical filter (Photograph 2). The Sobel filters are an effective edge enhancers to indicate the magnitude or strength on an edge, without paying any attention to its direction. The matrix are 3 x 3 elements with the following value :

– 1 0 1
– 2 0 1
– 1 0 1

This will be used as a standard technique to apply for five subscenes of Nias.

III. DATA INTEGRATION AND INTERPRETATION

III.1. Interpretation of the Case Study Area

Lineaments could be traced interactivelly and the result indicate that the dominant trend is NW-SE. This directions has been identified previously as either tecto nostratigraphic unit boundaries between the Nias Beds and the Oyo Complex, a homocline of Middle Miocene limestone, a reef terrace edge or folds and faults.

A NW-SE trend was also depicted from the imagery. This trend was previously unreported and could be intepreted as an antithetic strike slip fault (see Harding, 1974) as some of the lieaments cut by this faults can be seen to be dis placed.

III.2. Image-to-map-Registration

Remotely sensed data image generated by a multy spectral scanner are stored in raster format. To integrate this with thematic information, the data need to be corre lated and registered with known ground information. The method of image rectification used is affine transformation. Four ground control points, which are evenly distributed were used.

The first step of the work was to generate the coast line from five subscenes and ground control points were also written. The data were then transformed and fitted together. The second step, the coastline taken from the digitised map was overlaid onto the mosaic subscenes to verify the accuracy of the registration. Finally, the comand macros were constructed to integrate the digitised gravity and geological sketch map files with the lineaments files. Output on hard copies were also produced (Figures 4 and 5).

III.3. Interpretation for Nias Island

As in the case study area, the NW-SE and NE-SW directions are the major orientation of the lineaments. In the NW-SE trend, the homocline of the limestone horizone are very prominent as a group of subparallel lineaments. The repetition of these horizones which are reported by Moore and karig (1980) are evidence of both east and west dipping reverse faults. In the north westend of the island, these horizones were formed a rounded nose of anticlinal structure and displaced by NE-SW orientated lineaments. This area coincides with the Bouguer anomaly high.

A second trend, NE-SW is widely distributed throughout Nias. Field data (bedding attitudes) from the SW part of the island suggest some of these lineaments are anthitetic strike slip faults. N-S trends were also founds, especially in the N-NW area (Lahewa) as a series of parallel ridges, shown from field data to be composed of limestone.

IV. CONCLUSIONS AND DISCUSSIONS

Data used in this study is from landsat MSS in which the bands are highly correlated and apparently shows no distributions in the spectral signatures. Although digital image processing allows a great flexibility in data manipulation, in heavily vegetated terrain like this study area, a large number of image enhancement and information extraction techniques were not provide adequate spectral information that could be used to discriminate the underlying lithology.

The 79 metres of spatial resolution of this data has limitation in detecting small structure features. However, in areas like Nias Island, where few studies have been done. A large amount of structural data as previously discussed has been revealed thus still providing new information.

The result of this study found that the Sobel vertical filter can be an effective detector for the lineaments trending NW-SE and NE-SW. Ideally the digital gradient are orthogonal to the optimum edge enhancement. However, as far as this study is concerned, the lineaments orientated at oblique angle to the gradient direction are well detected.

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Table 1
Imagery detail of Landsat scene and tape

Path number		: 129	
Row number		: 59-60	
Data acquired		: 29-06-1985	
Scene centre	- Latitude : 1.26 N		
	- Longitude		: 97,90 E
Number of sample	: 3780		
Number of lines	: 2286		
MSS bands	4	: 0.5 - 0.6 um	
	5	: 0.6 - 0.7 um	
	6	: 0.7 - 0.8 um	
	7	: 0.8 - 1.1 um	
Correction applied	:	- sensor offset	
			- Communication error
			- fixed geometry
			- earth rotation
			- line length
			- radiometric

Table 2
Stratigraphic column of Nias Island (after Kallagher, 1987)

AGE				NIAS (Moore *et al.*, 1979; Moore & Karig, 1980)
QUATERNARY				Uplifted Quaternary coral reefs
TERTIARY	NEOGENE	PLEIST	UPPER	
			LOWER	
		PLIOCENE	UPPER	
			LOWER	
		MIOCENE	UPPER	NIAS BEDS: coarsening upwards & thickening upwards sequence of interbedded marls, calcareous siltstn, sstn, conglom. & tuff indicating a vertical progression from basin plain facies, through outer fan to mid fan facies. Less diagenesis & metamorphism than the Oyo Complex.
			MIDDLE	
			LOWER	These deformed Neogene strata are interpreted as uplifted trench slope basin deposits.
	PALAEOGENE	OLIGOCENE	UPPER	
			MIDDLE	OYO COMPLEX: strongly sheared, chaotic melange containing angular tectonic inclusions immersed in a sheared matrix. Inclusions are: -Sed: (80%), congloms (15%): clasts suggest derivation from mainland Sumatra, shale (15%), sstn (70%) -Volc: (20%), mafic & ultramafic plutonic rocks & pillow lavas
			LOWER	
		EOCENE	UPPER	
			MIDDLE	Interpreted as a tectonically disrupted thin sequence of oceanic crust & mantle, oceanic plate strata & trench deposits
			LOWER	
	PALAEOCENE			
PRE TERTIARY				

Photo 1
False colour composite of band 7, 5, and 4 (RGB) of the case study area

Photo 2
Sobel Vertical enhanced band 7 image of the case study area

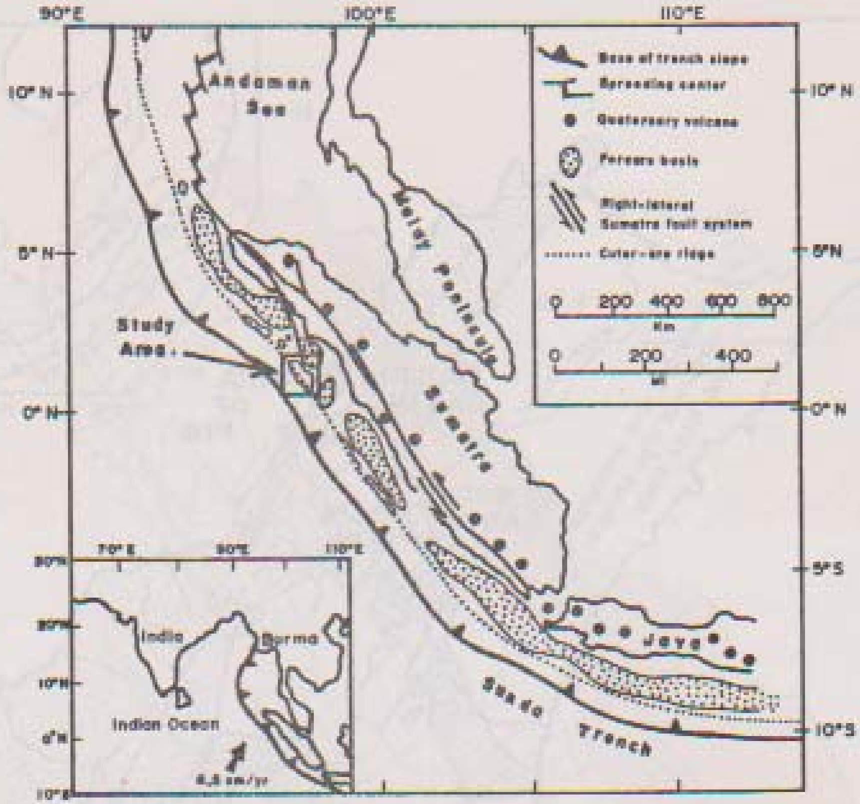

Figure 1
Tectonic map of the western Sunda Arc (beaudry and Moore, 1985)

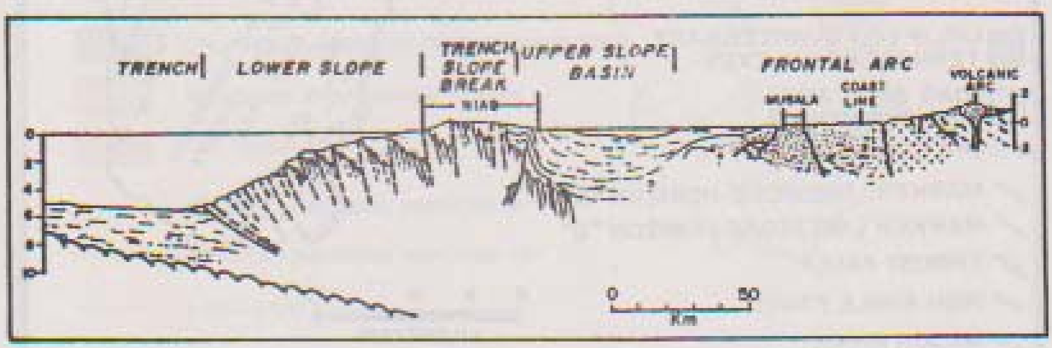

Figure 2
Hypothetical shallow structure across the Sunda Arc in the Nias area (after Moore & Karig, 1980)

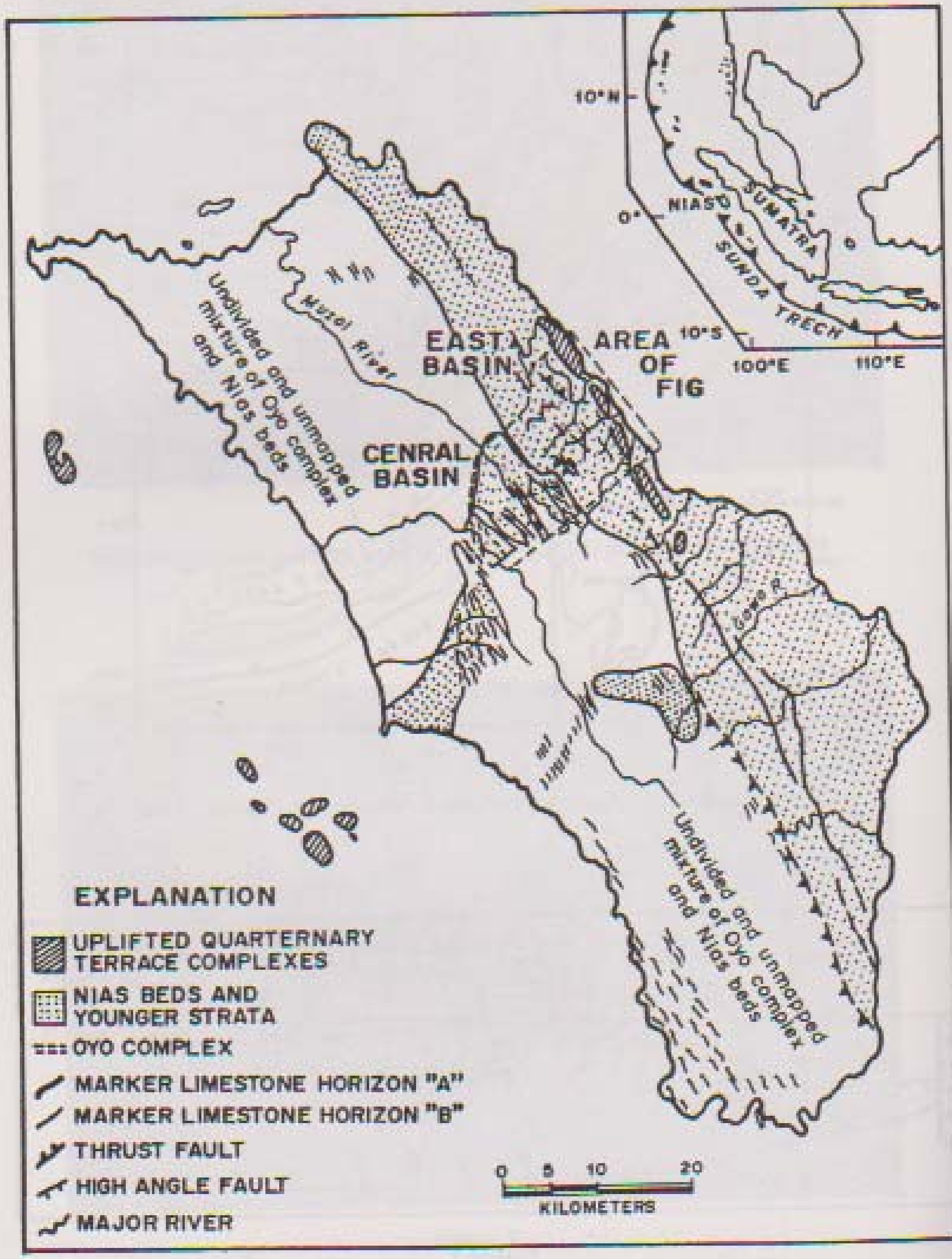

Figure 3
Geological sketch map of Nias Island (after Moore & others, 1980)

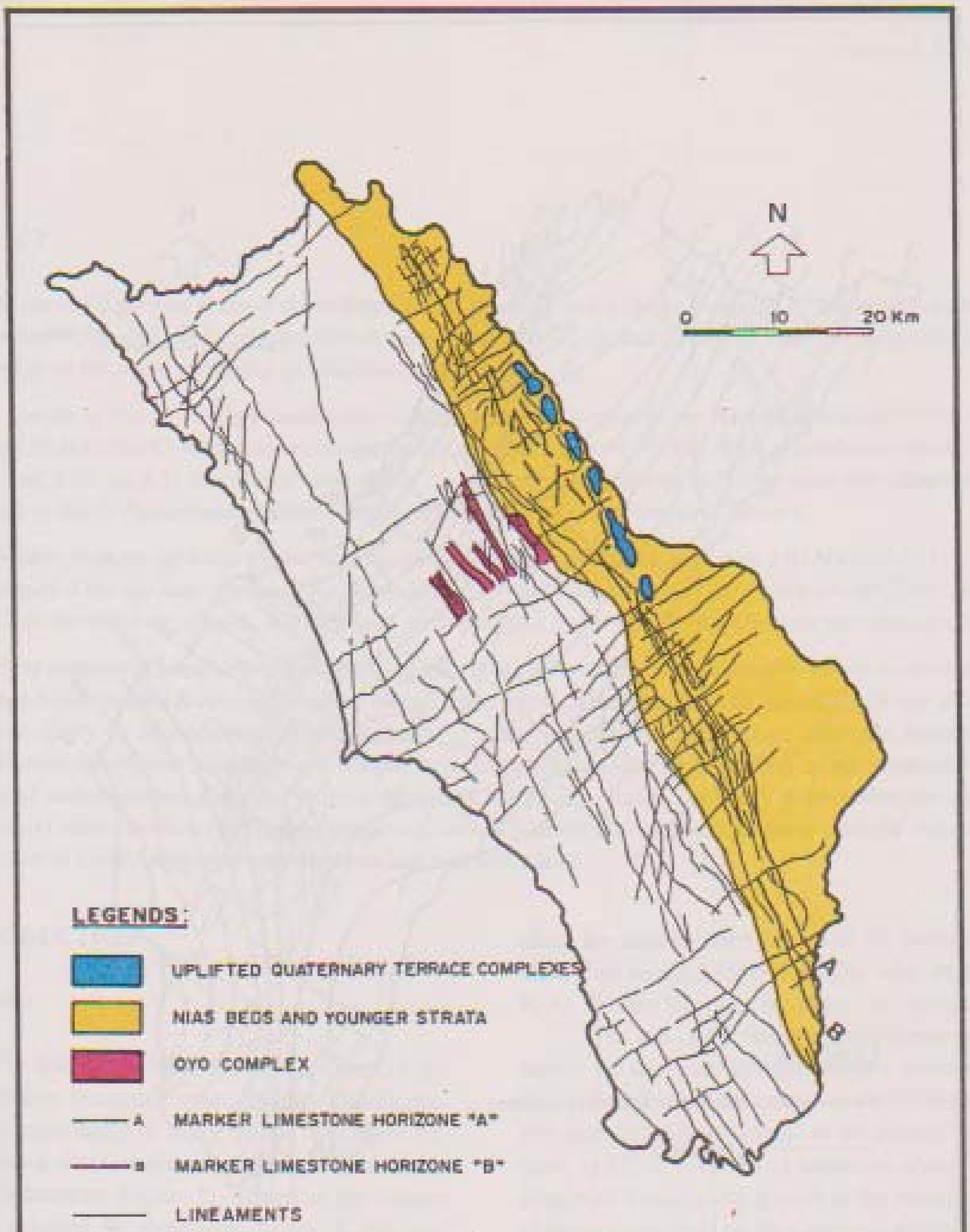

Figure 4
Tectonic fabric map with geological sketch map of Nias Island

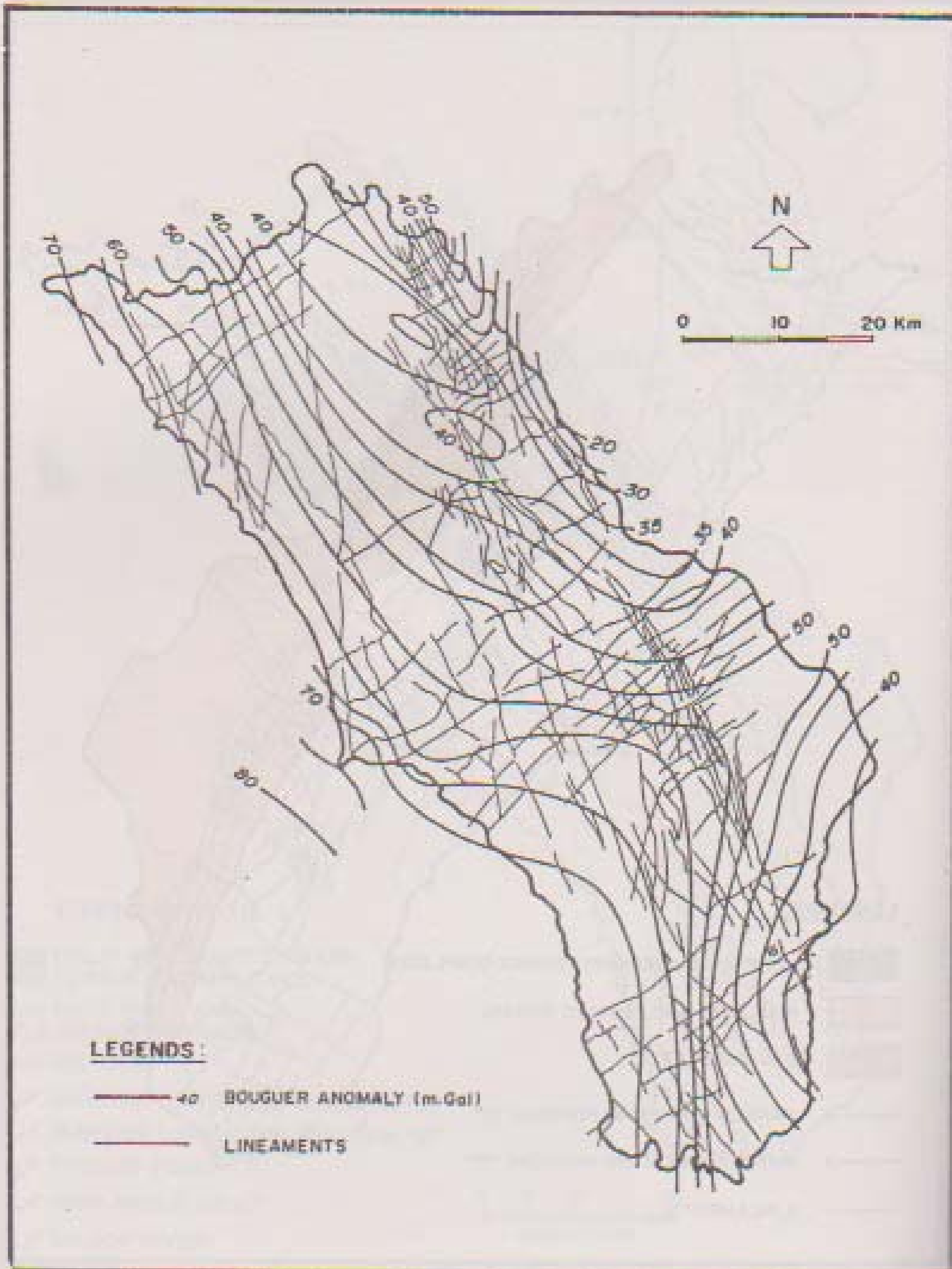

Figure 5
Tectonic fabric map with gravity map, Nias Island