

1. Outline of the Study

1.1 Background of the Study

Mali is an inland country located in West Africa. The national land is about three times that of Japan and belongs to the Sahel region located south of the Sahara. Mali is a country whose front is exposed to the threat of desertification in recent years. The growth rate of population is high, 2.8 % per year and the population is expected to exceed 10 million in 2000. From these circumstances, the Republic of Mali has been making positive development efforts to attain the most important goals under the national development plan, attracting the private investments, as follows: (a) Self-supply of foods; (b) Prevention of desertification; (c) Satisfaction of the basic needs of the nation; (d) Improvement of employment; (e) Expansion of traffic networks. The Kita area that is located west of the capital city of Bamako has relatively high rainfall and is rich in forest resources. For this area, the comprehensive development plan is in progress to implement various socioeconomic development programs including agricultural development and industrial investments. Reserves of mineral resources such as gold, bauxite and iron ore have also been verified and the mining development is expected. Although these various development programs in the Kita area are in planning, the topographic map required for planning and formulating these programs is still insufficiently provided because only the 1/200,000-scale topographic map produced under the assistance by France is available at present. The newest topographic map including more detailed information on this Kita area has long been needed for planning such development programs. Thus, the Republic of Mali has made a request to the Government of Japan for cooperation in a 1/50,000-scale topographic mapping and, as a result, this Study has been realized.

1.2 Objectives of the Study

This Study had the objectives to create the 1/50,000-scale topographic map covering the area of 31,000 km² including Kita City in Mali and the mapping data for that map and to transfer the technology of topographic mapping to the counterparts in Geographic Institute of Mali (IGM) that is the implementing agency in Mali to implement this Study jointly during the period of 36 months from October 1998 to September 2001.

1.3 Outline of Study Area

(1) Geographic location

The study area ranges from latitude 12 to 14 degrees north and from longitude 9 to 11 degrees west, and corresponds to the southwest part of Mali. The greater part of the study area belongs to Kayes Province which is located in the southwest of Mali.

(2) Terrain and vegetation

The country of Mali is largely divided into the nomadic area in the desert and the agricultural area in the savanna. The study area belongs to the agricultural area in the savanna, and its greater part has a flat terrain. Table-like rock mountains are dotted in the north of the study area. The Bakoye River flows from east to west in the north area and the Bafing River runs from south to north in the west area. Relatively high forests continue around these rivers. The greater part of vegetation in the study area is characterized by the savanna consisting of extensive plains with sparsely grown trees and exposed rocks except the basins of the rivers. Spiral roads are extended around villages and the cultivated fields of cotton, peanuts, corn and millet are distributed along the roads.

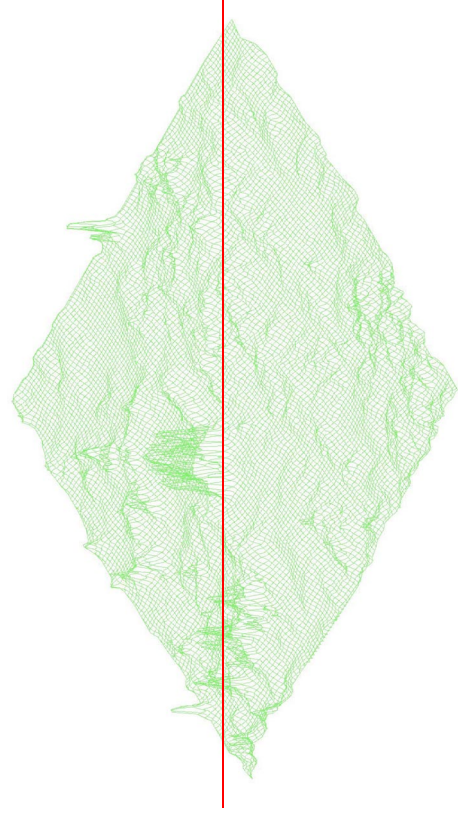


Fig. 1.3.1 Overview of study area (digital topographic model)

(3) Climate

The climate in Mali is clearly divided into the dry season (nearly November to May) and the rainy season (roughly June to October). The study area has a yearly rainfall of 1,000mm, therefore it belongs to the Savanna climate zone and forms an area with relatively many trees and natural conditions suited to agriculture.

Table 1.3.1 Climate around Kita City

Average rainfall	1,028 mm (753 – 1,351 mm)
Rainy days	56 days
Average minimum temperature	21°C
Average maximum temperature	34°C

Source: Meteorological Observatory in Kita Area

(4) Accessibility

There were several roads to lead from Bamako to Kita City that is the center of the study area, but each road was narrow and unpaved. These roads were not well maintained so that it took about 6 hours to travel the distance of only 200 km by car. On the way, there were the places where a river had to be crossed, but there was no bridge and no passage was available in the rainy season. There was no bridge also over the Baoule River on the way to Diema town north of Kita City, where no passage was available in the rainy season. The road from the Kita city to Manantali was well maintained because the materials for construction of the Manantali dam located in the southwest area were transported to Kita by railway. However, this target area was not provided with a road network that was accessible in all the year. The accessible means of transportation was only the railway connecting between Bamako and Dakar, the capital city of the neighboring country, Senegal. This railway was operating daily, but it was discontinued for several weeks because the railroad bridge was damaged due to the heavy rain in the rainy season in 1999 during the study period.

Currently, the road between Bamako and Kita had been under construction with Germany's assistance in order to transport the cotton collected in the Kita city to Bamako, until it was put into service in 2001, the third year of the study to enable the 3-hour travel between Bamako and Kita. In future, this road will be paved and ensure easier access to Bamako.

There are over 1000 villages within the study area. The biggest city is the Kita city with a population of 30,000. This is an agricultural area with small villages scattered at intervals of 5 to 10 km and connected by a road network. The roads are passable in a 4-wheel drive vehicle in the dry season.

1.4 Considerations for Implementation of the Study

In this Study, the efficient, low-cost study method and scheme using the up-to-date technology was adopted aiming at producing the topographic maps with the high accuracy compared to the conventional mapping method and at low cost for the minimum time. The following working methods were adopted and conducted for this Study:

- (1) Leveling by digital levels
- (2) Ground control point survey using GPS
- (3) Elevation measurement by GPS survey
- (4) Map data acquisition using SPOT satellite images
- (5) Production of ortho-photos and automatic creation of contours using DTM
- (6) Digital plotting and compilation and production of printed manuscripts using a digital compilation system

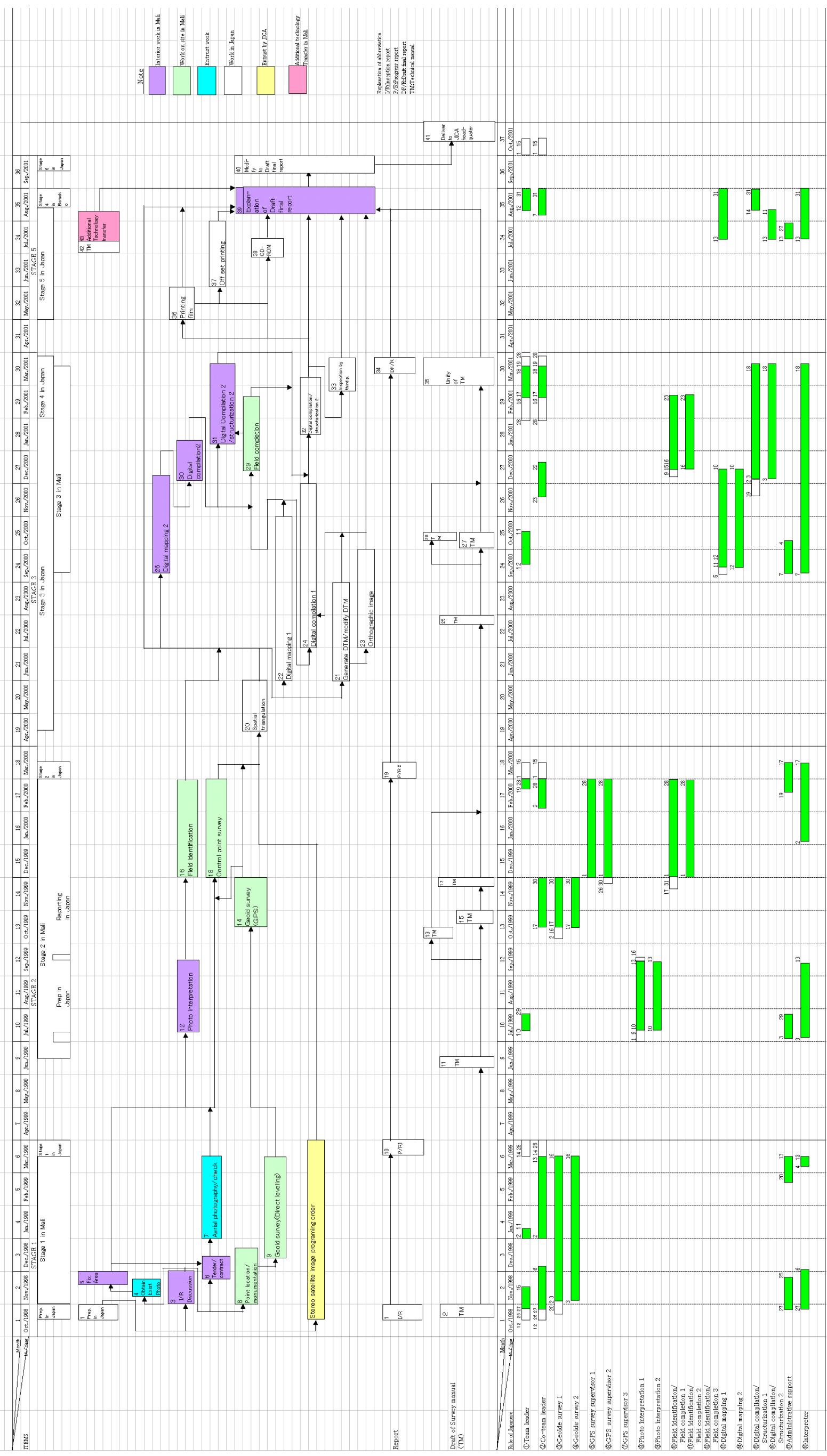
1.5 Specifications of the Study

Table 1.5.1 Specifications of the study

Type of Work		
Leveling	Third order leveling	S: Leveled distance Discrepancy between back-and-forth leveling 10mm S Error of circuit closure 15mm S
GPS survey	First order ground control point survey	Use of 2-frequency receiver and translocation method
Symbols	Symbol specifications	Employment of digital symbolization was decided through the discussion with Mali. See attached material

1-6-1 Table of yearly work schedule

FLOWCHART AND JAPANESE COUNTERPART ASSIGNMENT



Note
 Interior work in MIA
 Work on site in MIA
 Entrust work
 Work in Japan
 Entrust by JICA
 Additional technology transfer in MIA

Note
 Work in MIA
 Work in Japan

1.7 Work Types and Volumes

Table 1.7.1 List of study contents

Item	Sub-item	Description	Remarks
1. Point selection and Monumentation		36 points	
2. Leveling		360km	
3. Aerial photography	Scale of photography	1:50,000	Black/white
	New photographed area	10,600km ²	Based on photo inspection
	New photographs	334 sheets	
	New photography strips	22 strips	
4. Photo processing	Existing contact prints	596 sheets	Incl. photo inspection
	Existing photography strips	44 strips	
	Two times enlarged photos	596 sheets	
	Four times enlarged photos	82 sheets	
5. Reproduction of satellite image	Stereo scenes	20 scenes *2	
	1:100,000 image output	20 sheets	
6. GPS observation	On leveling route	80 points	
	Surrounding areas	24 points	
7. Photo interpretation	Aerial photos	596 sheets	
	Satellite images	19 sheets	
	Quality control sheet	1 set	
8. Ground control point survey	Horizontal plane	54 points	
	Elevation	272 points	
9. Field identification		31,000km ²	
10. Spatial triangulation	Spatial triangulation	19 scenes	1 scene: outside the target area
	Quality control sheet	1 set	
11. Generation of DTM	DTM intervals	100 m	
12. Satellite ortho-image production	Ortho-image production	48 sheets	
13. Digital plotting 1/2	Digital plotting 1	46 sheets	Japan
	Digital plotting 2	2 sheets	Mali
	Creation of contours	48 sheets	Japan
	Production of base maps for data acquisition	48 sheets	2 sheets in Mali
	Digital mapping data files	48 files	2 files in Mali
	Quality control sheet	1 set	
14. Digital compilation 1/2	Digital compilation 1	46 sheets	Japan (29,500km ²)
	Digital compilation 2	2 sheets	Mali (1,500km ²)
	Scale	1:50,000	
	Total area	31,000km ²	
	Contour lines	Main: 20m Index: 100m	Averaging and tree height correction
	Quality control sheet	1 set	
15. Field completion	Total area	31,000km ²	

Item	Sub-item	Description	Remarks
16. Supplementary compilation and structuralization 1/2	Supplementary compilation and structuralization 1	46 sheets	Japan
	Supplementary compilation and structuralization 2	2 sheets	Mali
	Adjoining compilation	48 sheets	2 sheets in Mali
	Topographic map (structuralized) data files	1 set	2 files in Mali
	Quality control sheet	1 set	
17. Inspection by third party	Visual inspection	46 sheets	Japan
	Logical inspection	48 sheets	Japan
18. Production of printing films	EPS files	48 sheets * 4 files	Japan
	Mapping data files	1 set	2 files in Mali
19. Printing	Offset printing	503 sheets/map	Japan
	Quality control sheet	1 set	
20. Topographic map (structuralized) data file	CD-R	53 sets	Japan
	Quality control sheet	1 set	Japan
21. Reports and others	Inception Report	1 set	Japan
	Progress Report 1	1 set	Japan
	Progress Report 2	1 set	Japan
	Draft Final Report	1 set	Japan
	Overall Manual	1 set	Japan
	Final Report	1 set	Japan
	Symbols and marginal information	1 set	Japan

1.8 Plans and Implementation

1.8.1 Plans and Implementation of the Study

The 1st to 4th year studies were completed as shown in Table 1.8.1 Comparison table of planned and implemented works.

Table 1.8.1 Comparison table of planned and implemented works

Item	Planned	Implemented	Remarks
1. Point selection and monumentation	36 points	36 points	
2. Leveling	360km	360km	
3. Aerial photography			
Photograph scale	1:50,000	1:50,000	Black/white
New photographed area	5,500km ²	10,600km ²	On photo inspection
New photographs	224 sheets / 2 copies	334 sheets / 2 copies	1 copy: Japan 1 copy: Mali
New photography strips	13 strips	22 strips	
4. Photo processing and reproduction			
Existing contact prints	592 sheets	596 sheets	Incl. photos for inspection (Mali)
Existing aerial photography strips	44 strips	44 strips	
Two times enlarged photo	592 sheets	596 sheets	296 sheets: Mali
Four times enlarged photo	80 sheets	82 sheets	For description of control point
5. Satellite image copying		20 scenes * 2	
Satellite images	20 scenes * 2	20 scenes * 2	Digital data
1:100,000 image output	20 sheets	20 sheets	Mali
6. GPS observation			
On leveling route	70 points	80 points	
Surrounding area	7 points	24 points	
7. Photo interpretation			
Aerial photos	592 sheets	596 sheets	
Satellite images	20 sheets	20 sheets	Mali
Quality control sheet	1 set	1 set	
8. Ground control point survey			
Horizontal plane	50 points	54 points	
Elevation	250 points	272 points	
9. Field identification			
Field identification	31,000km ²	31,000km ²	Field identification of photos in Japan
10. Spatial triangulation			
Spatial triangulation	19 scenes	19 scenes	1 scene: outside the target area
Quality control sheet	1 set	1 set	
11. Generation of DTM			
DTM intervals	200m	100m	

Item	Planned	Implemented	Remarks
12. Satellite ortho-image production			
Ortho-image creation	48 sheets	48 sheets	Mali
13. Digital plotting 1/2			
Digital plotting 1	46 sheets	46 sheets	Japan
Digital plotting 2	2 sheets	2 sheets	Mali
Contour line creation	48 sheets	48 sheets	Japan
Creation of base maps for data acquisition	48 sheets	48 sheets	2 sheets: Mali
Digital mapping data files	48 files	48 files	2 files: Mali
Quality control sheet	1 set	1 set	
14. Digital compilation 1/2			
Digital compilation 1	46 sheets	46 sheets	Japan (29,500km ²)
Digital compilation 2	2 sheets	2 sheets	Mali (1,500km ²)
Scale	1:50,000	1:50,000	
Total area	31,000km ²	31,000k m ²	
Contour lines	Main: 20m Index: 100m	Main: 20m Index: 100m	Averaging and tree height correction
Quality control sheet	1 set	1 set	
15. Field completion			
Total area	31,000km ²	31,000k m ²	Original (Japan) Copy (Mali)
16. Supplementary compilation and structuralization 1/2			
Supplementary compilation and structuralization 1	46 sheets	46 sheets	Japan
Supplementary compilation and structuralization 2	2 sheets	2 sheets	Mali
Adjoining compilation	48 sheets	48 sheets	2 sheets: Mali
Topographic (structuralized) data files	1 set	1 set	2 files: Mali
Quality control sheet	1 set	1 set	
17. Inspection by third party			
Visual inspection	46 sheets	46 sheets	
Logical inspection	48 sheets * 4 files	48 files	
18. Production of printing films			
EPS files	48 sheets * 4 files	48 files * 4 files	
Topographic data files	1 set	1 set	2 files: Mali
19. Printing			
Offset printing	503 sheets/map	503 sheets/map	3 copies: JICA
Quality control sheet	1 set	1 set	
20. Topographic (structuralized) data file			
CD-R	53 sets	53 sets	3 sets: JICA
Quality control sheet	1 set	1 set	

Item	Planned	Implemented	Remarks
21. Reports and others			
Inception Report	1 set	1 set	
Progress Report 1	1 set	1 set	
Progress Report 2	1 set	1 set	
Draft Final Report	1 set	1 set	
Overall Manual	1 set	1 set	
Final Report	1 set	1 set	
Symbols and marginal information	1 set	1 set	

1.8.2 Study Period

Data acquisition and compilation using the procured equipment could not be performed in the third year due to delay in the arrival of the equipment in Mali. These processes were therefore performed as an addition in the fourth year.

1.8.3 Technical Meetings

This Study was implemented over a long period of 4 years. Therefore, the technical meetings were held at the beginning and at the end of the study work in each fiscal year. Furthermore, the plan of operation, work manuals (drafts) and technology transfer plans were prepared at the beginning of the study work in each fiscal year, which were discussed and confirmed at the technical meeting on the work for each fiscal year before the study work was conducted. The items discussed and confirmed at the technical meeting in each year will be described below.

(1) First Year

Plan of operation

Ground control point installation: Technology transfer plan; Survey manual

Aerial photography

Geoid survey (leveling): Technology transfer plan; Survey manual

Photo interpretation: Technology transfer plan; Survey manual

Symbols and application rules for map symbols

(2) Second Year

Progress Report 1

Plan of operation

Geoid survey (GPS survey)

Ground control point survey: Technology transfer plan; Survey manual

Field identification: Technology transfer plan; Survey manual

(3) Third Year

Progress Report 2

Plan of operation

Digital plotting: Technology transfer plan; Survey manual

Digital compilation: Technology transfer plan in structuralization; Survey manual

Field completion: Technology transfer plan; Survey manual

(4) Fourth Year

Additional technology transfer

Draft Final Report

Combined binding of survey manuals

Submission of Final Report

1.8.4 Cooperation with and Training of Counterparts

The Study Team consisted of Japanese engineers and counterparts of Geographic Institute of Mali (IGM) and the counterparts were trained for the technology of field identification work under the supervision of Japanese engineers while they conducted the work together with Japanese engineers. The counterparts that participated in the technical discussions and work of this Study were as follows:

1. Mr. Issa COULIBALY	Directeur de l'IGM
2. Mr. Diakalia OUATTARA	Directeur Ajoint
3. Mr. Aliou COULIBALY	Chef Division Infrastructure de Base
4. Mr. Silamakan TRAORE	Ingenieur Photogrammetre
5. Mr. Chaka FORE	Technicien des Constructions civiles
6. Mr. Modibo CAMARA	Ingenieur Topographe
7. Mr. Bakary COULIBALY	Ingenieur Topographe
8. Mr. Soboua TRAORE	Technicien des Constructions civiles
9. Mr. Yala SIDIBE	Technicien des Constructions civiles
10. Mr. Cheickna KOUMARE	Technicien des Constructions civiles
11. Mr. Mamadou CAMARA	Ingenieur Photogrammètre
12. Mr. Alassane BA	Docteur Ingenieur Cartographe
13. Mr. Modibo DIAKITE	Technicien des Constructions Civiles
14. Mr. Bakari DIARRA	Technicien Superieur Photogrammètre
15. Mr. Amadou DIALLO	Technicien Superieur Photogrammètre
16. Mr. Bourama KONTA	Technicien Superieur Photogrammètre

1.8.5 Individual Training of Counterparts

The counterparts received the on-the-job training during the study period in Mali and the counterparts as listed below visited Japan to participate in the individual training and the long-term training in Japan.

The trainees received the training for the works conducted in Japan. In addition, they visited the Geographical Survey Institute, Japan Association of Surveyors, Japan Map Center and other related organizations to understand the Japanese system related to surveys and receive the explanation of the services provided and the equipment used by those organizations.

The counterparts collected and brought back many materials related to the actual conditions of survey in Japan that were not obtainable in Mali. The results of these training and visits were reported to other counterparts at the reporting meeting so that all the counterparts could jointly possess all the acquired information.

Table 1.8.2 Training of counterparts in Japan

Name	Training Period	Item of Training
Modibo CAMARA	13/9/1999 ~ 9/10/1999	Survey Situation in Japan
Amadou DIALLO	17/7/2000 ~ 14/9/2000	Plotting, Aerial Triangulation and Data Applications
Silamakan TRAORE	31/7/1999 ~ 2/7/2000	Group training
Aliou Coulibaly	15/6/2001 ~ 14/7/2001	Printing, confirmation of final printing

Three counterparts that participated in the training in Japan shared the central roles in the works of this Study and fulfilled the effective functions in the technology transfer through interpretation of technical terms. The effects of training in Japan were proven to be large.

1.8.6 Role of JICA Study Team and Period of Dispatch

The role of the JICA Study Team and the period of dispatch to Mali are as follows:

JICA Study Team	Assignment	Working in Bamako	Fiscal Year
Junichi KOSEKI	Team leader	27/10/1998-15/11/1998	First year
		02/01/1999-11/01/1999	First year
		13/07/1999-27/07/1999	Second year
		20/02/2000-28/02/2000	Second year
		16/09/2000-09/10/2000	Third year
		18/02/2001-16/03/2001	Third year
		13/08/2001-28/08/2001	Fourth year
Nobuo SHIMIZU	Sub-team leader, Management of sub-contract	27/10/1998-06/12/1998	First year
		02/01/1999-13/03/1999	First year
		18/10/1999-28/11/1999	Second year
		24/11/2000-20/12/2000	Third year
		18/02/2001-16/03/2001	Third year
Hajime GOTO	Control point survey supervisor 1	03/11/1998-16/03/1999	First year
		18/10/1999-26/02/2000	Second year
Hitoshi KOAMI	Control point survey Supervisor 2	03/11/1998-16/03/1999	First year
		18/10/1999-26/02/2000	Second year
Toshiyuki FUJIOKA	GPS supervisor 3	18/10/1999-26/02/2000	Second year
Hiromi Ogawa	Photo interpretation supervisor 1	13/07/1999-11/09/1999	Second year
		02/12/1999-26/02/2000	Second year
		18/12/2000-21/02/2001	Third year
Kenji NAMIKI	Photo interpretation supervisor 2	13/07/1999-11/09/1999	Second year
		02/12/1999-26/02/2000	Second year
Kenji SUZUKI	Field identification supervisor 3	02/12/1999-26/02/2000	Second year
Tetsuzo YAMAMOTO	Field completion Supervisor 2	18/12/2000-21/02/2001	Third year
Tsuneo TERADA	Digital plotting supervisor 1	16/09/2000-08/12/2000	Third year
		14/07/2001-29/08/2001	Fourth year
Chugo ODAKA	Digital plotting supervisor 2	16/09/2000-08/12/2000	Third year
Toru WATANABE	Compilation/structuralization Supervisor 1	03/12/2000-16/03/2000	Third year
		15/08/2001-29/08/2001	Fourth year
Yoshiteru MATSUSHITA	Compilation/structuralization Supervisor 2	03/12/2000-16/03/2000	Third year
		16/07/2001-09/08/2001	Fourth year

Ichiro NONAKA	Coordination	27/10/1998-25/11/1998	First year
		06/07/1999-27/07/1999	Second year
		08/09/2000-02/10/2000	Third year
		16/07/2001-27/07/2001	Fourth year
Manabu KAWAGUCHI	Coordination	20/02/1999-13/03/1999	First year
Norio YOKOKAWA	Interpreter	27/10/1998-06/12/1998	First year
		02/01/1999-13/03/1999	First year
		06/07/1999-27/07/1999	Second year
		08/09/2000-16/03/2001	Third year
		14/07/2001-29/08/2001	Fourth year

1.8.7 Significance of the Results Obtained in the Study

(1) Standardization of survey results

The Government of Mali has planned to establish the ground control point network in the nationwide standardized coordinate system. The control point survey that was made with high accuracy under the cooperation by the US Defense Mapping Agency (DMA) was the 12th parallel survey. The control point network was based on traversing points 58 made by this survey. In this Study, the control points were also surveyed relative to these control points obtained in that survey. Therefore, the control points established in this Study can also be used as part of the national standardized control point network.

(2) Use of topographic maps

This Study completed a total of 48 sheets of 1/50,000-scale topographic maps covering the Kita, Sirakoro and Bafing-Makana areas that are covered by the 1/200,000 topographic maps. (See Fig. 2 “Sheet Index Map”.) These topographic maps may be used for planning and formulating the future agricultural, industrial and mining development programs.

(3) Use of geoid maps

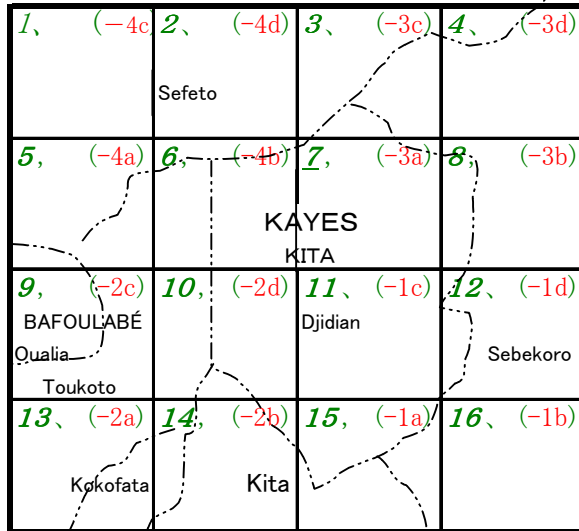
As the conversion parameters from the WGS84 into the CLARKE1880 and the geoid maps (see Fig. 3 “Geoid Map”.) were produced, the positions and orthometric elevations on the CLARKE 1880 reference ellipsoid that is governed in Mali can easily be obtained by making the GPS survey in the study area of Kita, Sirakoro and Bafing-Makana covered by the 1/200,000 topographic maps.

The program that enables the results of this Study to be easily used was also developed.

Index Map

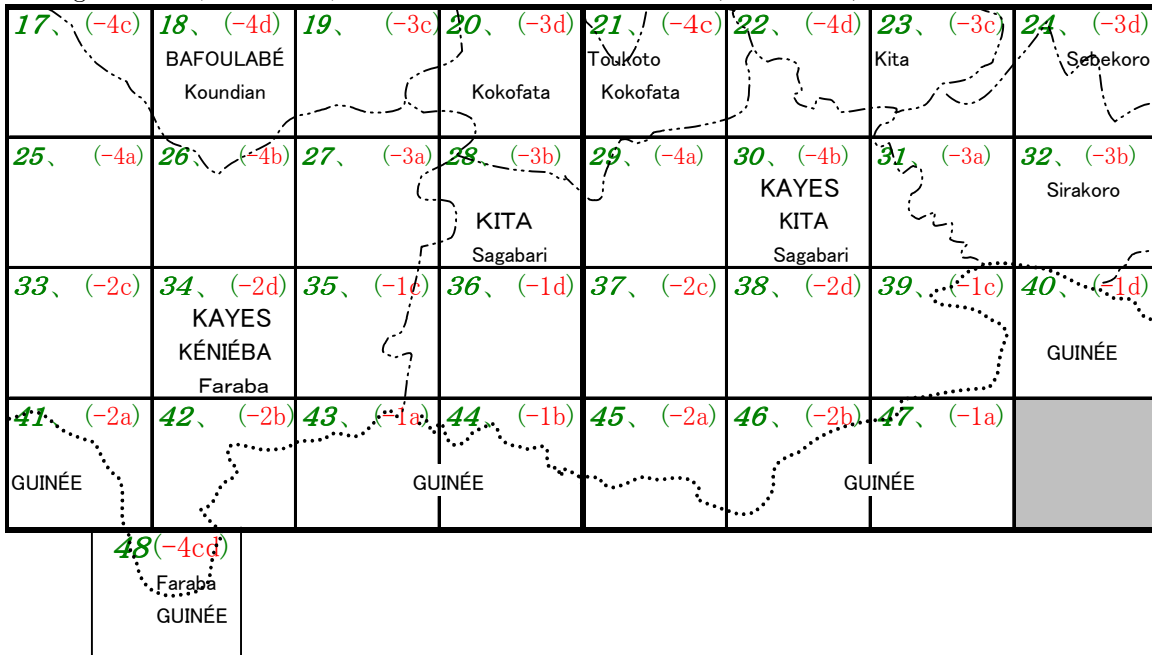
Carte d'index

KITA (ND-29-IX)



Bafing-Makana(ND-29- II)

Sirakoro (ND-29-III)



Dinguiraye (NC-29-XX)

Fig. 1.8.1 Map sheet design (Kita, Sirakoro and Bafing-Makana)