EÖTVÖS LORÁND UNIVERSITY

FACULTY OF INFORMATICS

INSTITUTE OF CARTOGRAPHY AND GEOINFORMATICS

Comparison of topographic maps' legends (African colonial maps in 1940s)

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Thesis Title: Comparison of topographic maps' legend

Topic of the Thesis:
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The United states Geological survey (USGS) has compiled a set of topographical map symbols that represent features on spatial heterogeneous terrains. Legends constitute a set of symbols that represent physical features and human activities on the map. Point, line and area features on the map have different symbol categories. Legends symbols facilitate reading, interpretation and understanding of maps.
Map symbols are generated based on cartographic mapping principles in connection to cultural and natural aspects of the area they represent. They are generalized depending on the scale that is used for a specific topographic map. Generalization of map content based on scales has been applied and results reflected difference in variation of visual variables of map symbols. Various approaches have been proposed for evaluating cartographic styles such as those of Alexander, 2009.
Different countries have different rules on what is abstracted on the legend. We hereby propose a unified solution of handling legends. Automatic generation and implementation of symbols for large scale topographic map for large scale maps remains an issue to address. There is also a need to investigate the evolution of cartographic style and identifying the use of colonial style in current topographical maps. Comparison of different symbols styles was made for different themes involving 20 European countries at a scale of 1:50 000, leaving out other scales. There is a need to examine topographic maps with regards to the styling of the symbols for the large scales.

Budapest, 2020.11.26.

DECLARATION

I, undersigned NDUNGU LEWIS MJOMBA (NEPTUN CODE: JFG1RE), declare that the present master's thesis is my original intellectual product in full and that I have not submitted any part or the whole of this work to any other institution. Permissions related to the use of copyrighted sources in this work are attached.

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Budapest, 15th May 2021

(signature of the student)

Dedication

I would like to dedicate this thesis to my loving parents and siblings.

Acknowledgement

I want to acknowledge the advice given to me by my supervisor, Prof. László Zentai, the Director of Institute at ELTE Institute of Cartography and Geoinformatics. His guidance and constructive feedback at each stage of the thesis process significantly contributed to the timely completion of this work.

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I want to recognize the support of my family, friends, Budapest Powerhouse Cell (BPHC), and Riverside Church Budapest (RCB) during my studies in Hungary. I also extend my gratitude to Daniel Nyangweso for his encouragement during the research period. Lastly, let me thank and recognize my fellow course mates Natsnet Habtit Haile, Sara Urrea Mendoza, Guerrero Francisco Manuel, and Mohamed Dhia Turki for their assistance throughout this program.

Abstract

Studies conducted on map legend symbols have depicted a deficiency of reliable research in this area. This acknowledges that research on visual variation on symbols is of prime importance. Generally, map legends are considered as a visual tool that aids the communication of map information. Map (geoinformation) information is a valued resource in all sectors of the economy.

This study aimed (1) to establish map legends common features and their categorization, (2) to analyze the visual variables use in those categories, (3) to examine the qualitative and quantitative nature of the symbols. To achieve these objectives, five maps published in the 1940s, with a scale of 1:100,000, were selected. Tables and figures were used to examine the symbols.

This study showed that feature categorization varied from map to map though common features existed in some maps. Different shapes, fill, structure, and colour of symbols showed the qualitative nature of symbols. Size and thickness differences showed the quantitative nature of the symbols. Some symbols were also oriented differently from others, either longitudinally or transversely.

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ABBREVIATIONS

A.M.S.	Army Map Service
EGSA	Egyptian General Survey Authority
ERP	Engineer Reproduction Plant
G.S.G.S./ GSGS	General Staff Geographical Section
HTMC	Historical Topographic Maps Collection
IGEBU	Institut Geographique du Burundi
NGA	National Geospatial-Intelligence Agency
NIMA	National Imagery and Mapping Agency
NMA	National Mapping Agencies
NMO	National Mapping Organisations
OTC	Office de la Trographie et de la Cartographie
POI	Point of Interest
SCAR	Scientific Committee on Arctic Research
SCR	Service de Cartographie du Rwanda
USATC	U.S. Army Topographic Command
USGS	United States Geological Survey

PREFACE

This research is rooted from my passion for understanding how map symbols are used in displaying information on topographic maps. Are there any differences or similarities between features displayed in topographic map symbols of various countries? What are the visual differences or similarities of topographic map symbols of the same category of features? Are there any symbols for special features on topographic maps? These questions arose my curiosity in this topic. Examining various selected topographic maps may help address some of these questions by providing meaningful conclusion.

Curiosity for this research topic is a cumulative built up of various well-balanced courses that I have attended throughout the program. They have instilled a sense of importance for visualization and how valuable it is in simplifying complex, prolific information. Legends contain symbols which are part of visual communication, relaying important map information. Visual variation within symbols provides a basis for compelling reading of map information and symbols design.

CHAPTER 1: INTRODUCTION

1.1.Background

The United States Geological Survey (USGS) has assembled topographic map symbols that represent features on heterogeneous terrains (USGS, 2005). Legends constitute a set of symbols that represent physical features and human activities on the map. The point, line, and area features on the map have different symbol categories. Map symbols facilitate reading, interpretation, and understanding of maps.

Map symbols are generated based on cartographic mapping principles connected to cultural and natural aspects of the area they represent. They are generalized depending on the scale used for a specific topographic map (Sluter et al., 2018). The user abstracts are influenced by graphical characteristics, which aid in recognizing map symbols (Ory et al., 2015). Generalization of map content based on scales was applied, and results reflected a difference in variation of visual variables of map symbols (Nyangweso & Njoroge, 2013; Weibel & Dutton, 1999). The design of map symbols affects how to map readers recognize information displayed on the map based on their visual memory and visual perception (Ory et al., 2015).

Classification and comparison of topographic map symbol categories were carried out for 20 countries in Europe to identify their style similarities considering aspects such as colour, lettering, and visual hierarchy (Kent & Vujakovic, 2009). This study also proposed various approaches for evaluating cartographic styles. Mutually exclusive categorization of topographic map symbols of European maps into three broad themes such as land cover, general land use, and specific features was suggested, ensuring proper clustering and analyzing symbols (Kent & Vujakovic, 2009).

Research on the design and symbology of topographic maps remains a neglected area of research; therefore, little is known about the heritage of symbols and their association to society (Kent, 2009). This is a gap that only broad in-depth research can provide proven conclusions. Generally, topographic maps are a source of information on physical features on a socially constructed landscape whose cultural relation has yet to be investigated (Kent, 2009).

1.2.Problem statement

Different countries have different rules on what is abstracted on the legend. Cartographic symbol design has had less attention than the coding of information and referencing in recent cartographic works. Therefore, the need to investigate the variation of cartographic style between different maps exists.

Comparison of different legend styles was made for different themes involving 20 European countries at a scale of 1:50,000, leaving out other scales. Examining topographic maps with regards to the styling of the symbols across other scales may fill this gap. Hence a scale of 1:100,000 was chosen for this study. Moreover, assessing the changes in visual variables and types of symbol features for different topographic map scales is equally essential.

1.3.Objectives

1.3.1. Main objective

Comparison of symbol styles of various topographic maps to determine the classification of legend features and the qualitative and quantitative nature of the symbols used.

1.3.2. Specific objective

i. Review map legends to establish common features and their categories.
ii. Analyze various visual variables used in categorizing features in map legends.
iii. Examine the qualitative and quantitative nature of the symbols.

1.4.Scope

This study examined visual characteristics of topographic map symbols for the scale of 1:100,000. Variation of symbol types, nature, and category of the feature represented by the maps were considered in the analysis. The major analysis methods were desk studies, including tables and figures descriptions to achieve the set objectives.

Five sample maps chosen were from the map series of GSGS 4085, GSGS 4076, GSGS 4226, Z621, and GSGS 3980. The sample maps, extracted legends, and index sheets are shown in appendix A, B, and C, respectively. Legends were extracted from the sample

maps for symbols comparison. The maps used were for the present countries of Egypt, Libya, Tunisia, Rwanda, and Burundi, as shown in table 5.

1.5.Justification

This study aims to examine both man-made and natural features that are displayed as symbols on topographic maps. Furthermore, to investigate the visual differences between the symbols that are used. These are further expounded under main and specific objectives.

Factors influencing the choice of maps for analysis were (1) the year of publication, (2) the scale of the map, and (3) the resolution. The year of maps publication was between 1940 to 1943 (table 5), which coincides with the dates of World War II. The topographical map scale chosen was 1:100,000 because most countries have used this scale to produce topographic maps (at least this is one of the scales used). The resolution ensured quality image, allowing extraction of the map symbols. These factors depended heavily on the availability of the maps.

CHAPTER 2: LITERATURE REVIEW

2.0.Topographic maps

Topographic maps are characterized by displaying geographical features, using contours to show elevation of the land or depths of the sea (USGS, n.d.-b). This mix of information incorporated with man-made features makes topographic maps peculiar. Moreover, topographic map features can be points, linear and areal features (Xin et al., 2006). Government, industry, and land planning use topographic maps as planning tools while historical maps point out regions' physical and cultural features within a specific time (Fishburn & Allord, 2017; USGS, n.d.-a). This places topographic maps at the center of vast human activities.

Historical maps provide a basis for showing a change or a shift in both land use and how map information is represented. Historical Topographic Maps Collection (HTMC) collection documentation by the USGS included maps published between 1884 and 2006 (Allord et al., 2014). This points out that maps published before 2006 may be considered historical maps. Historical, scientific, and environmental research is aided by topographic maps and historical maps for a specific area and time (Fishburn et al., 2017).

Topographic map series developed by national mapping agency align with specific scales, similar map layout, and marginal information including legends. Choice of scale is directly linked to the maps intended use (USGS, 2002). National topographic system scale maps can range from 1:50,000 to 1:250,000. In other countries such as Hungary, larger scales of 1:25,000 or 1:10,000 are also used, while in Slovenia, topo maps of even 1:5,000 scale exist. National map series of 1:25,000, 1:50,000, 1:100,000, and 1:200,000 are the most widely used for civilian and military purposes (Gartner et al., 1997).

International Map of the World (IMW) (Böhme & Anson, 1993) had a standardized sheet line and numbering system into map series scale categories and subdivisions as shown in table 1 below. The 8th SCAR conference held in Paris in 1964 agreed on the range of scales used in displaying Antarctica, as shown in Table 1 below. Other world maps series include Soviet series whose scale is 1:2,500,000 (Portable Network Graphics, n.d.-b). This research is based on the Small-scale topographic map series, that is, 1:100,000.

Table 1 Classification of topographic map scale

National Mapping Agencies		**Antarctica**	
Map Series	**Scale**	**Map series**	**Scale**
Large scale topographic map series	1:10,000	Antarctica topographic mapping	1:25,000 1:50,000 1:100,000 1:200,000 or 1:250,000 1:500,000 1:1,000,000
Medium scale topographic map series	1:25,000 1:50,000		
Small scale topographic map series	1:100,000 1:200,000		
Geographical maps	1:500,000 1:1,000,000	Antarctica general mapping	1:3,000,000 1:5,000,000 1:10,000,000 1:20,000,000 1:40,000,000

2.1.Legends

Legends consist of a title, a panel, and described symbol features assisting map readers in understanding maps (Li & Qin, 2014). A legend is defined as a dictionary that conveys the symbols meaning (Schlichtmann, 1997). Map readers only comprehend a map's information with the help of a legend. Therefore, it is a medium that allows one to interpret the map's information.

Legends graphically summarize a map content, grouping features by their characteristics according to user needs (Clarke et al., 2010). They also portray the visual characteristics of features based on their quality and quantity. Furthermore, legends groups symbols according to meaning, structure map information, and define class intervals (Schlichtmann, 1997). Three legend layout designs have been identified (Gołębiowska, 2015). They include:

a) List legend – Symbols are in columns one after another, following a graphic or thematic order.
b) Grouped legend – Symbols are categorized as having descriptive headings.
c) Natural legend – Symbols displayed as a fictitious map area show spatial relationships between features.

Comparison of legends for 1:75,000, 1:84,000, and 1:100,000 maps showed different content classification of settlement, transport network, hydrography, and land use, despite

the closeness of scales (Panecki, 2015). This shows that changes in scale can change the features represented on the map. Topographic mapping design principles are recognized by graphical characteristics of touristic point of interest (POI), forests, representation of relief, toponymy, typography, main road networks, and individual buildings (Ory et al., 2015). Hand-drawing of some symbols and letters existed in earlier editions of map series but a rare occurrence nowadays (USGS, 2005).

Tables, star plot diagrams, histograms, figures, and pie charts were used to evaluate the range of symbols, the total number of symbols, and their means for the historical (vertical) topographic map series of the Ordinance Survey of Great Britain and Ireland (Kent, 2008). Tables and figures were also used to determine legend spacing and alignment design principles (Li & Qin, 2014). Figures were used to identify topographic map styles (Ory et al., 2013). Moreover, tables and figures provide a means for comparison to derive meaningful conclusions.

The USGS report of 2005 classifies topographic map symbols in broad categories, as shown in Table 2 below. This classification identified eighteen categories, themes, topics, or groupings of topographic map features, with about 200 symbols. Line symbols had the highest number, followed by area symbols, point symbols, and others (text/number).

Table 2 Category of topographic map symbols and their types

Category of topographic map features	**Number of Point symbols**	**Number of Line symbols**	**Number of Area symbols**	**Other (text/number)**	**Total**
Bathymetric features	1	1	1	0	3
Boundaries	0	12	1	0	13
Buildings and related features	12	0	8	0	20
Coastal features	1	3	4	0	8
Contours	0	14	0	0	14
Control Data and Monuments	15	0	0	0	15
Glaciers and permanent snowfields	0	0	4	0	4
Land Survey	1	19	0	2	22
Marine shorelines	0	3	0	0	3

Mines and caves	5	0	3	0	8
Projection and grids	4	5	0	0	9
Railroads and related features	3	11	0	0	14
Rivers, Lakes, and canals	2	12	12	0	26
Roads and related features	1	19	0	0	20
Submerged areas and bogs	1	0	6	0	7
Surface features	1	0	4	0	5
Transmission lines and pipelines	0	4	0	0	4
Vegetation	0	0	5	0	5
Total	47	103	48	2	200

Swiss national map conventional signs classification was based on three scales 1:25,000 (table 3), 1:50,000, and 1:100,000 (Federal Office of Topography swisstopo, 2018). Nine groupings of features were used, with a total of 139 symbols. Line symbols were the highest, followed by point symbols, area symbols, and others (text/number).

Table 3 Convectional signs for 1:25,000 Swiss maps

Category of topographic map features	**Number of Point symbols**	**Number of Line symbols**	**Number of Area symbols**	**Other (text/number)**	**Total**
Roads, tracks	0	20	2	0	22
Railways	0	15	0	0	15
Topography	0	5	5	0	10
Individual symbols	21	7	4	0	32
Trigonometric points, spot heights	5	1	0	0	6
Vegetation	1	2	6	0	9
Hydrography	9	13	8	2	32
Boundaries	0	5	0	0	5
Settlement	0	0	0	8	8
Total	36	68	25	10	139

2.2.Visual variables

Visualization assists us in understanding and interpreting various patterns, phenomena, and relations that form part of our daily lives (Cecconi & Weibel, 2003). Visualization of spatial data helps to comprehend the relationship presented. Map symbolism (map language) is the core of map semiotics, among other themes such as sign processes, contexts, marginal notes, and peripheral signification (Schlichtmann, 2009). The absence of prior symbol knowledge may hinder first-time readers of maps, especially for maps without legends.

Symbolism is a complex system whose research will enlighten the theory and practice of cartography (Schlichtmann, 1985). The fast-evolving world necessitates rapid research on symbols. Hence an emphasis on the need for proper map symbols research to improve symbol design and feature classification.

Topographic map symbols are refined continually to represent features with clarity, improve map legibility or appearance and reduce production cost (USGS, 2005). Symbol's refining depends on the cost, need, and relevance. According to the need, symbol development relates to the dynamic culture of the people and advancement in technology.

Maps display factors include layer order, annotation fonts, and symbol definition such as colour, line thickness, line symbology, and area fills (Fishburn & Carswell, 2017). This study focused on point line and area symbols. Visual (retinal) variables are classified into quantitative (size and value) and qualitative (texture, colour, orientation, and shape) (Griffin, 1987). Symbol similarity is determined by comparing three visual variables: size, shape, and colour (Qin & Li, 2017). Three grouping rules for effective legend design (Qin & Li, 2017) include:

a) Symbols grouped must have similar visual variables.
b) Larger spacing of groups of features compared to adjacent lines of features.
c) Groups of features can be enclosed with a boundary.

Though debated as not such an influential visual variable, Color has been suggested as a vital symbolization tool and used to distinguish qualitative data characteristics (Jégou,

2019). Colour depicts the aesthetic value, communicating qualitative differences and exhibiting legibility on a map (Jégou, 2019). Most topographic maps have a striking balance on colour, though using strong or mild colour depends on the national mapping agencies.

Certain features on maps are shown using universally accepted colour for example blue represents water. Colour coding on boundary lines, road networks, and railway stations has improved legibility (Federal Office of Topography swisstopo, 2018). This provides a clear difference, especially on the types of roads, railways, or boundaries.

According to the U.S. Geological Survey (USGS), the standard color for symbols is shown in table 4 below.

Table 4 Symbol feature and colour

Symbol features	**Colour**
Hydrographic features	Blue
Cultural features (Buildings, densely built up areas etc.)	Black, grey or red
Vegetation (Woodland, scrub, vineyards etc.)	Grey tint, green
Contours	Brown
Roads and trails, railroads, boundaries, and other cultural features	Black or red
Unchecked feature changes on maps from aerial photographs	Purple
Name of places and features	Colour corresponding to type of feature

Source: (USGS, 2001, 2005)

CHAPTER 3: METHODOLOGY

This thesis followed a step-by-step process in achieving the specific objectives. The steps involved include data collection, data manipulation and processing, analysis, and finally, conclusions.

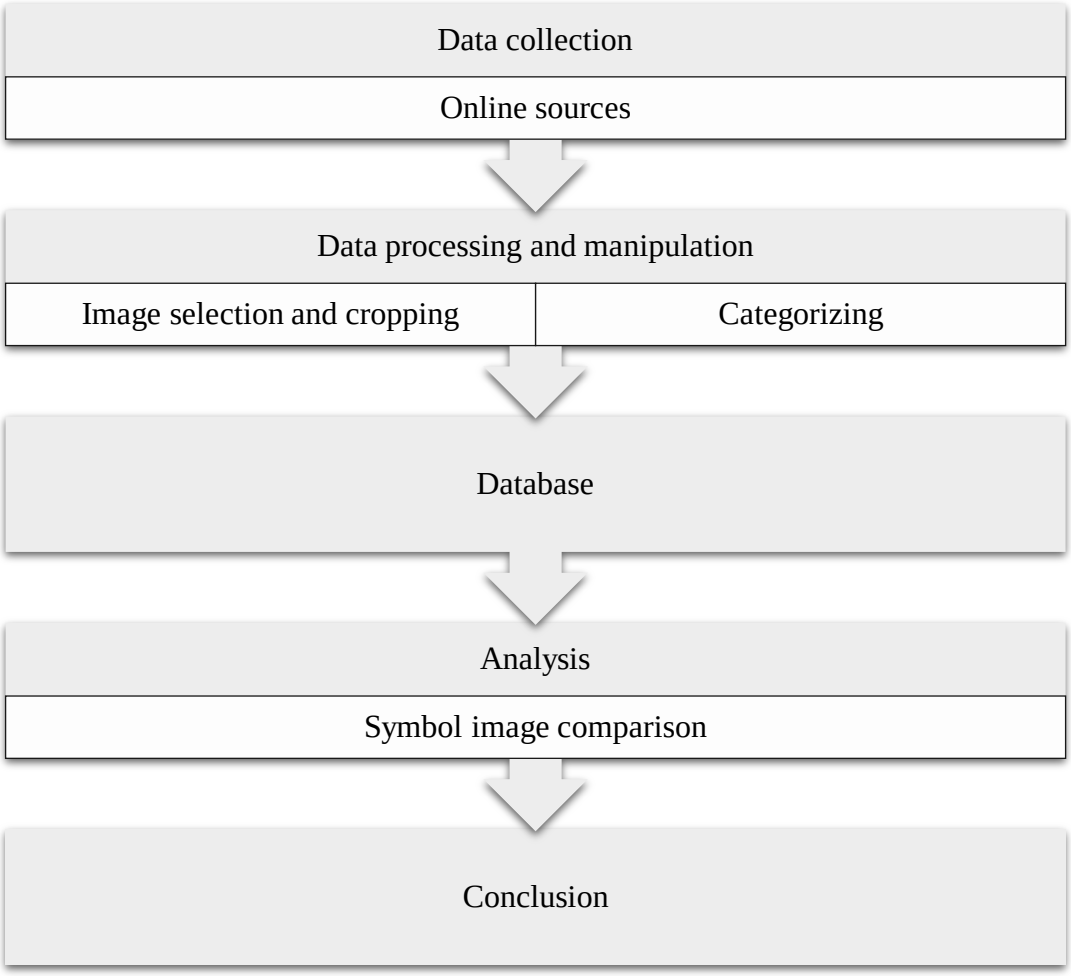


Figure 1 Research methodology flowchart

Data was collected through the internet in the form of topographic maps. The data was in raster format. During data manipulation and processing, cropped images of legend symbols were created for easy comparison. These images were stored in a database. Legend symbols were compared in terms of their types, classification, and visual aspects.

Tables and figures were used to illustrate the differences in the legend symbols. The expected outcomes in this study were to help answer the following questions:

i. What are the features of interest at those times?
ii. What are the visual variables used to classify features?
iii. What are the qualitative and quantitative nature of the symbols?

3.0.Data collection

Data was collected from various map series within Africa, having a scale of 1:100,000. A random sample map was drawn from each map series and used for analysis as shown in table 5. The data was sourced from the internet. These were maps published in the 1940s. The total sample maps are shown in appendix A, with their corresponding index sheets in appendix C.

Table 5 Sample map series (scale 1:100,000) for analysis

Map series	Publisher	Sample sheet name	Sheet number	Publication date	Present Country	Colonist country
G.S.G.S. 4085	A.M.S. (Army Map Service)	Benha	84/60	1940	Egypt	Britain
GSGS 4076	A.M.S.	Ed - Dèffa	71	1942	Libya	Italy/ Britain
G.S.G.S. 4226	A.M.S.	Zarzis	93	1942	Tunisia	France
Z621	A.M.S.	Ruanda-Urundi	Sheet 12 SA-35/R-11	1942	Rwanda, Burundi	Germany/ Britain
G.S.G.S. 3980	A.M.S.	Zuara	1372	1943	Libya	Italy/ Britain

3.1.Data manipulation and processing

Data collected went through a series of analysis stages with reference to the specific objectives that are set. The symbols on the legend were categorized into broad themes of man-made feature symbols and natural feature symbols to achieve the research objectives. Man-made features symbols were further sub-categorized into transport and communication, boundaries, social, cultural, and economic features, as shown in figure 2. Other relief features were sub-categorized into relief, vegetation, and hydrography. The feature symbols were compared to establish common features and their classification, analyze the symbols' visual variables and finally examine the symbols' qualitative and quantitative visual variables. Tables and figures were derived for proper analysis.

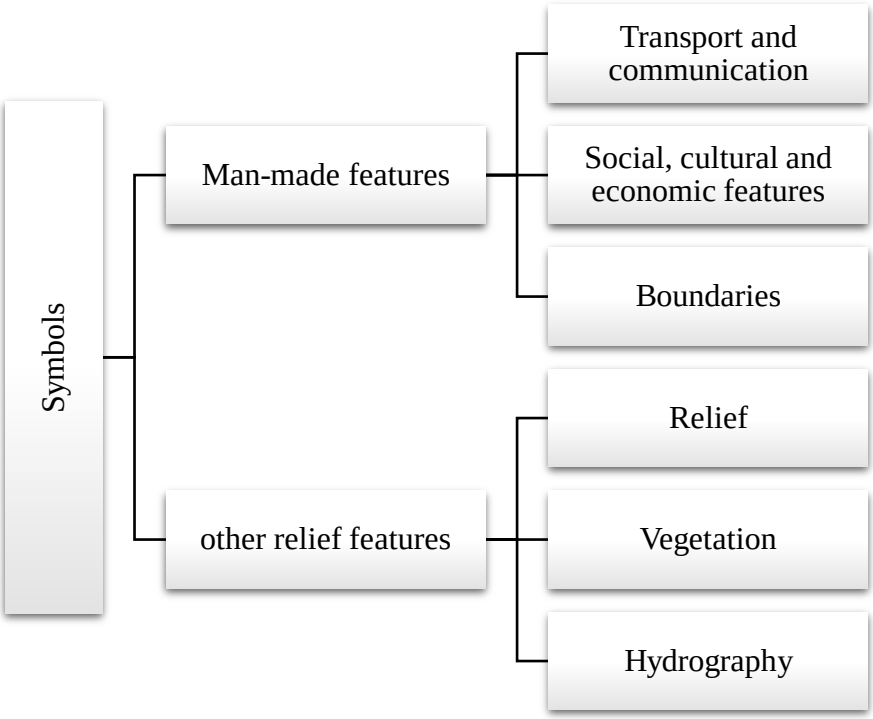


Figure 2 Feature symbols categorization

Feature symbols were further categorized for easier comparison of the symbols. Figure 3 shows man-made feature symbols sub-categorization. Figure 4 shows other relief feature symbol sub-categorization.

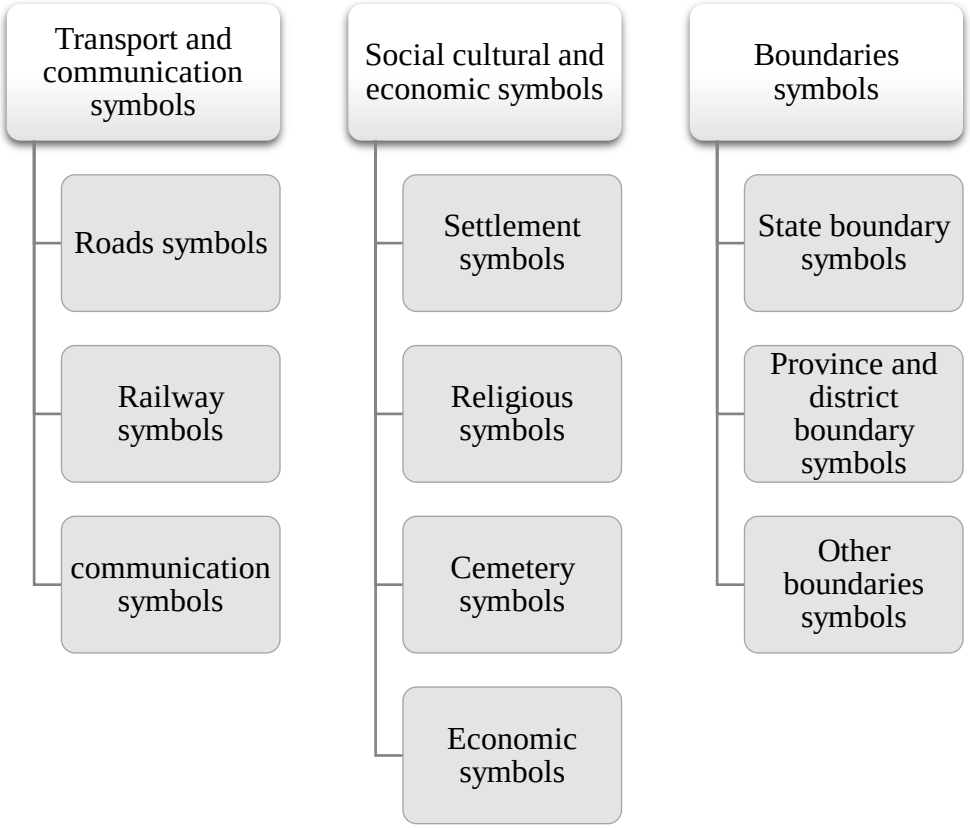


Figure 3 Man-made features symbols sub-categorization

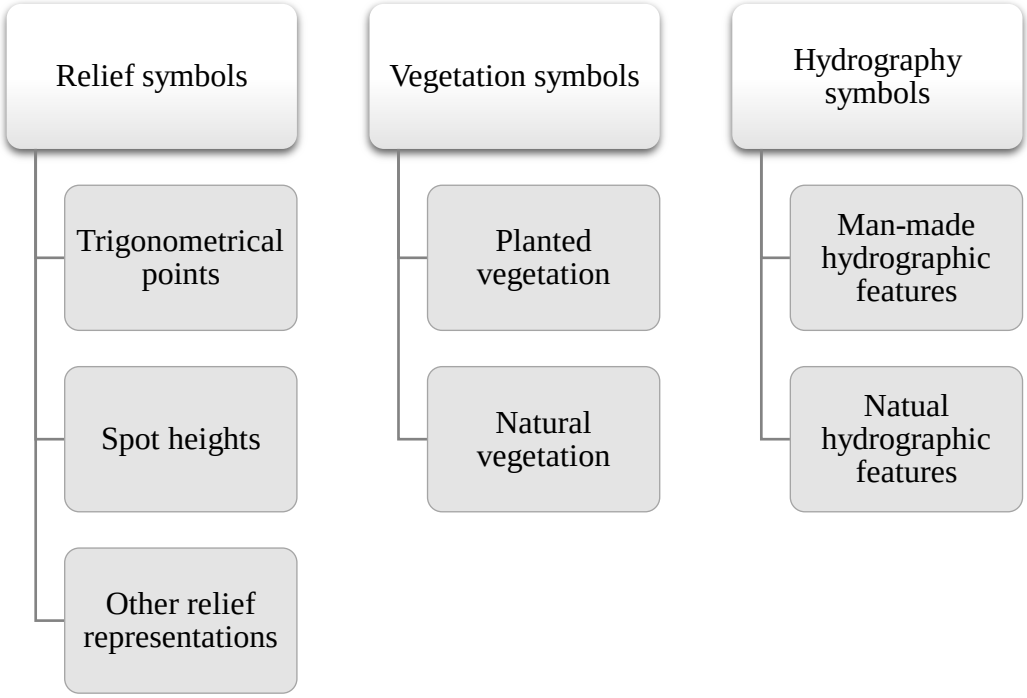


Figure 4 Other relief feature symbols sub-categorization

Visual variables that were considered include size, thickness, structure, colour, shape, fill, and orientation. The qualitative and quantitative aspects of the symbols connected to the visual variable are shown in Table 6 below. These visual characteristics are derived from map design (Vozenilek, 2014). Comparison of legends of different maps will determine the variations in visual variables.

Table 6 Symbols and visual variables characteristics

Object type	**Characteristics of visual variables**		
	Qualitative	**Quantitative**	**Orientation**
Point symbol	shape	Size (radius/size)	Direction
	fill		
	colour		
Line symbol	Structure (simple lines and complex lines)	Thickness (quantity/importance/ superordination)	Longitudinal orientation
	Colour		Transverse orientation
Area symbol	Colour	size	
	Fill		

3.2.Database

After assembling the data collected, it was stored in a database. Table 7 below shows the property description of the topographical maps used. This shows that the resolution of the maps used is sufficient to crop out the symbols needed for analysis.

Table 7 Property of sample maps

Sample sheet name	**Sheet number**	**Type of file**	**Dimensions (Pixel) W x H**	**HR**	**VR**	**Bit depth**	**Date accessed**
Benha	84/60	JPG File (.jpg)	5807 x 4302	300dpi	300dpi	24	3rd April 2021
Ed - Dèffa	71	JPG File (.jpg)	4124 x 3834	300dpi	300dpi	24	3rd April 2021
Zarzis	93	JPG File (.jpg)	5447 x 3759	300dpi	300dpi	24	6th April 2021
Ruanda-Urundi	Sheet 12 SA-35/R-11	JPG File (.jpg)	3303 x 3348	300dpi	300dpi	24	3rd April 2021
Zuara	1372	JPG File (.jpg)	4120 x 3800	300dpi	300dpi	24	5th April 2021

W – Width, **H**= Height, **HR**- Horizontal Resolution, **VR**- Vertical Resolution

3.3.Analysis

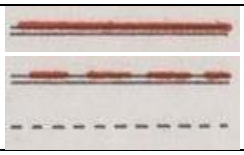
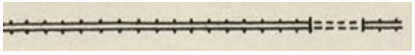
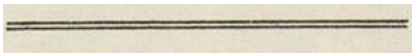
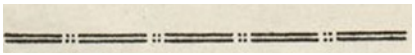
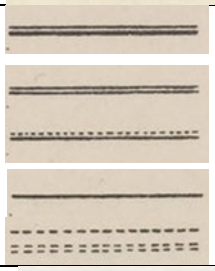
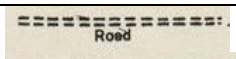
The analysis of the map series symbols was analyzed based on several categories. These categories were chosen because they were featured on the respective map series. The man-made feature symbols analyzed were road symbols, railway symbols, social-cultural and economic symbols, and boundary symbols. Other relief feature symbols analyzed were relief symbols, vegetation symbols, and hydrographic symbols.

3.3.1. Road symbols comparison

A comparison of roads for the chosen maps is discussed below. The complete symbol comparison table for roads is found in Appendix D1. Different representations of road types and classes discussed under roads for wheeled traffic, tracks, and paths. Generally, double black lines have been used to represent the main roads, while other roads are represented using a single line filled with black colour. Roads under construction are depicted by a discontinuous black line that may be a single line or a double line. The quality of the road is shown by differences in colour, the type of fill, type of line (continuous, dashed line) of the symbol. The thickness of the symbol and the fill pattern depicts the quantitative characteristic of the road.

1. Roads for wheeled traffic

Table 8 Roads for wheeled traffic

Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	 Roads Principal Roads suitable for wheeled Traffic Roads more than 4 meters wide
GSGS 4076 (Ed - Dèffa)	 Road under construction  Road for wheeled traffic wider than 6m  Road for wheeled traffic between 3m and 6m Road for wheeled traffic with natural foundation, partially made up  Motor track  Road bridges (masonry, iron, wood)
G.S.G.S. 4226 (Zarzis)	 Roads, main and metalled Roads, other and tracks of good surface Tracks with natural surface Mule and bridle paths Paths
Z621 (Ruanda -Urundi)	 Roads passable to wheeled vehicles
G.S.G.S. 3980 (Zuara)	 Road under construction  Road for wheeled traffic wider than 6m Road for wheeled traffic between 3m and 6m  Road for wheeled traffic with natural foundation, partially made up

Roads for wheeled traffic have different classification and symbols for different map series, as shown in table 8. GSGS 4085 roads principal symbol is a continuous double line having a continuous fill, roads suitable for wheeled Traffic symbol is a continuous double line having a dashed fill, roads more than 4 meters wide symbol is a single dashed line. GSGS 4076 road for wheeled traffic wider than 6m symbols is a continuous double line with outer marks. The road for wheeled traffic between 3m and 6m symbol is a

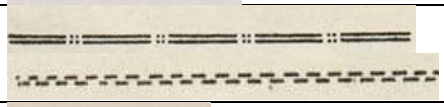
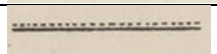
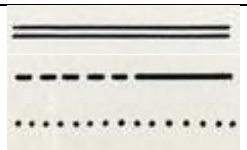
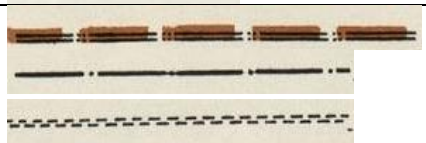
continuous double black line. The road for wheeled traffic with natural foundation, partially made up symbol is a double black line with a dashed line at the top and a continuous line at the bottom. GSGS 4226 Roads, main and metalled symbol is a double black continuous line.

Z621 roads passable to wheeled vehicles symbol is a double continuous black line. GSGS 3980 road for wheeled traffic wider than 6m symbol is a double continuous black line with outer marks, having a continuous colour fill. The road for wheeled traffic between 3m and 6m symbol is a double black line with a dashed fill. The road for wheeled traffic with a natural foundation partially made up symbol is a double line (dashed top line and a continuous bottom line) with a continuous fill.

Double dashed lines are used for roads under construction for GSGS 3980 and GSGS 4076. The other map series legends have no symbol for roads under construction. GSGS 4076 also showed road bridges (masonry, iron, wood) symbol, which did not feature other maps. Generally, road symbols count decrease from GSGS 3970, GSGS 4070, GSGS 4085, GSGS 4226, and lastly, Z621.

2. Tracks

Table 9 Tracks

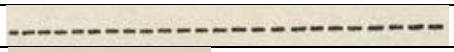
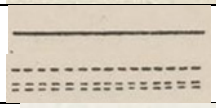
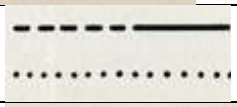
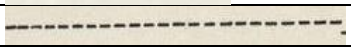
Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	 Main desert communication tracks Camel Tracks
GSGS 4076 (Ed - Dèffa)	 Motor track Country track
G.S.G.S. 4226 (Zarzis)	 Tracks with natural surface
Z621 (Ruanda-Urundi)	 Roads passable to wheeled vehicles Important native paths Native paths
G.S.G.S. 3980 (Zuara)	 Motor track Track unfit for wheeled traffic Country track

Tracks are named as camel tracks in GSGS 4085 and county tracks in GSGS 4076, as shown in table 9. The camel tracks are single dashed lines, while the country tracks are

double dashed lines. GSGS 4226 legend contains roads, other, and tracks of good surface indicated by a continuous double line. GSGS 4226 also has tracks with a natural surface whose symbol is a double line combining a continuous bottom line and a top dashed line. GSGS 3980 motor track symbol is a double dashed line having a dashed colour fill. GSGS 4085 has a main desert communication tracks symbol which is a dashed red line.

3. Paths

Table 10 Paths

Map series	**Symbol representation and description**
G.S.G.S. 4085 (Benha)	None
GSGS 4076 (Ed - Dèffa)	 Foot path
G.S.G.S. 4226 (Zarzis)	 Mule and bridle paths Paths
Z621 (Ruanda-Urundi)	 Important native paths Native paths
G.S.G.S. 3980 (Zuara)	 Footpath

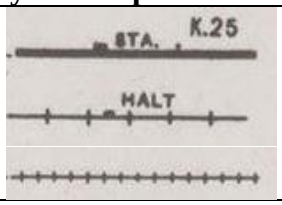
Paths are named differently in each map series, as shown in table 10. GSGS 4076 contains a foot path symbol which is a dashed line. GSGS 4226 has a single continuous line for mule and bridle paths, while paths have two symbols (single dashed line and double dashed line). Z621 has a single dashed and continuous line for important native paths and a single dotted line for native paths. GSGS 3980 footpath symbol is a single dashed line. GSGS 4085 did not have any symbol for paths.

3.3.2. Railway symbols comparison

Comparison of railway symbols was analyzed under two categories: standard gauge railway and other railways, Ordinary and narrow-gauge railway, and finally railway bridges. Appendix D2 shows the full railway symbol table.

1. Standard gauge railway and other railways

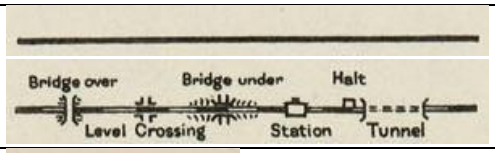
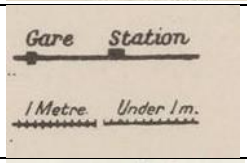
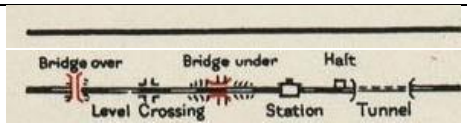
Table 11 Standard gauge railway and other railways

Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	 Standard gauge railway Light railway Trolley lines and decauvilles
GSGS 4076 (Ed - Dèffa)	None
G.S.G.S. 4226 (Zarzis)	None
Z621 (Ruanda-Urundi)	None
G.S.G.S. 3980 (Zuara)	None

GSGS 4085 is the only map series with a standard gauge railway, a light railway, and trolley lines and decauvilles as shown in table 11. Two double black lines symbolize the standard gauge railway with a rectangle station block. The light railway symbol is a continuous single black line with tiny black lines crossing it at right angles and a halt. The trolley lines and decauvilles symbol are similar to the light railway symbol, but the only difference is that it has a smaller width and does not have a halt. The other map series here do not have the same types of the railway.

2. Ordinary and narrow-gauge railway

Table 12 Ordinary and narrow-gauge railway

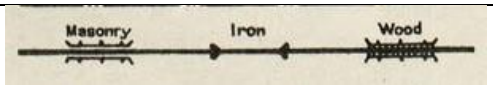
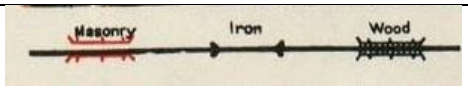
Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	None
GSGS 4076 (Ed - Dèffa)	 Railway, ordinary gauge Railway, narrow gauge
G.S.G.S. 4226 (Zarzis)	 Railways, normal gauge Railways, narrow gauge
Z621 (Ruanda-Urundi)	 Railroad with stations
G.S.G.S. 3980 (Zuara)	 Railway, ordinary gauge Railway, narrow gauge

The GSGS 4076 and GSGS 3980 are the only maps here with an ordinary gauge railway, as shown in table 12. The symbol is a continuous thick black line. The symbols are similar in colour and size. Z621 legend has a railroad with a station symbol, a continuous double black line with a dashed black fill.

The narrow gauge railway is found in the map legends of GSGS 4070, GSGS 4226, and GSGS 3980 (table 12). GSGS 4070 and GSGS 3980 narrow gauge railway symbols have a similar colour, similar continuous line thickness, and similar attached symbols, including a bridge over, level crossing, bridge under, station, halt, and tunnel. The only difference between the two symbols is that the GSGS 3980 has red line marks on the bridge over and bridge under symbols, while in GSGS 4070, they are in black.

3. Railway bridges

Table 13 Railway bridges

Map series	**Symbol representation and description**
G.S.G.S. 4085 (Benha)	None
GSGS 4076 (Ed - Dèffa)	 Railway bridges
G.S.G.S. 4226 (Zarzis)	None
Z621 (Ruanda-Urundi)	None
G.S.G.S. 3980 (Zuara)	 Railway bridge

GSGS 4076 and GSGS 3980 have separate railway bridge symbols, as shown in table 13. The bridge symbols are three, masonry, iron, and wood bridge symbols. Both railway bridge symbols are similar in appearance, except that the GSGS 3980 symbol for the masonry bridge is red. GSGGS 4085 and GSGS 4226 map series do not have a separate railway bridge.

4. Other transport symbols

Table 14 Other transport symbols

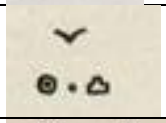
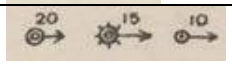
Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	 Lighthouses Buoys Light-Buoys
GSGS 4076 (Ed - Dèffa)	 Aerodrome or landing ground Lighthouse; light; monument
G.S.G.S. 4226 (Zarzis)	 Lighthouse
Z621 (Ruanda-Urundi)	None
G.S.G.S. 3980 (Zuara)	 Aerodrome or landing ground Lighthouse; light; monument

Table 14 shows other transport symbols. Lighthouses act as a navigation guide for sailors and are depicted in the GSGS 4085, GSGS 4076, and GSGS 3980 map legends. GSGS 4085 lighthouse symbol resembles a hut. GSGS 4076 lighthouse symbol is a back circle with a dot at the center. GSGS 4226 has three lighthouse symbols, characterized by a circular shape with a pointing arrow and a number. GSGS 3980 lighthouse symbol is red, but the shape is not precise. Aerodrome or landing ground symbol is similar in shape and colour, in the GSGS 4076 and GSGS 3980 map series legends.

3.3.3. Communication symbols

Table 15 Communication symbols

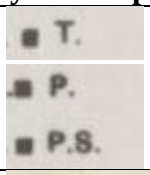
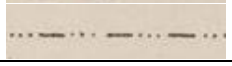
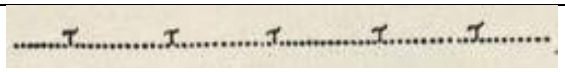
Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	 Teleg. Offices Post Offices Post stations
GSGS 4076 (Ed - Dèffa)	 Permanent telegraph or telephone lines  Radio station
G.S.G.S. 4226 (Zarzis)	 Post and Telegraph Office  Telegraph line
Z621 (Ruanda-Urundi)	None
G.S.G.S. 3980 (Zuara)	 Permanent telegraph or telephone lines  Radio station

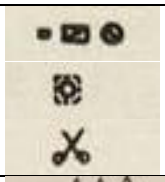
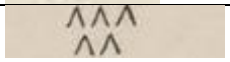
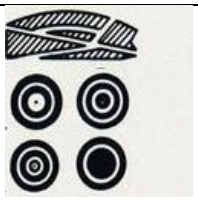
Table 15 shows the variation of communication symbols for the selected map series. GSGS 4085 legend has a separate symbol for telegram offices, post offices, and post stations. GSGS 4070 and GSGS 3980 have similar symbols, as shown in Table 15 above. GSGS 4226 has three symbols for post and telegraph office: black letters enclosed with a circle. GSGS 4226 also has a telegraph line symbol. Z621 legend does not have these symbols.

3.3.4. Social, cultural, and economic symbols comparison

These symbols are further categorized into the settlement, religious, cemetery, and economic symbol, and are discussed below. The entire table for comparison is in appendix D3.

1. Settlement symbols

Table 16 Settlement symbols

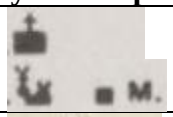
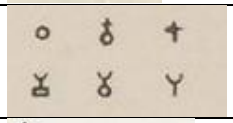
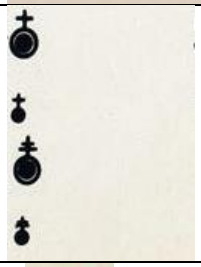
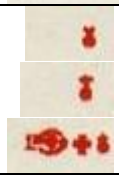
Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	None
GSGS 4076 (Ed - Dèffa)	 House masonry, wooden, Hut Cave dwelling Battlefield
G.S.G.S. 4226 (Zarzis)	 Permanent encampments
Z621 (Ruanda-Urundi)	 Capital of mandated territory Chief town of district Important native town usually chief town of a territorial subdivision Native town of secondary importance Individual houses, (native huts) Camp, possibly a native town Large farm or native settlement
G.S.G.S. 3980 (Zuara)	 Houses masonry, wooden, Hut Occasional camping ground Cave dwelling

GSGS 4085 legend does not have any settlement symbol, as shown in table 16. GSGS 4076 and GSGS 3980 cave dwelling symbols and house masonry symbols have a different colours. GSGS 4076 battlefield symbol shape resembles a pair of scissors. GSGS 4226 permanent encampments symbol and GSGS 3980 occasional camping ground symbol have the same arrowhead shape though the shapes are five and three, respectively.

Z621 camp symbol and large farm symbol have a rectangle shape, but their size and the fill differ. Z621's native town symbol is smaller in size compared to the important native town symbol. The chief town symbol and the important native town symbol have a similar circular shape and size, but the fill pattern differs, hence the qualitative difference.

2. Religious symbols

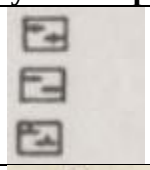
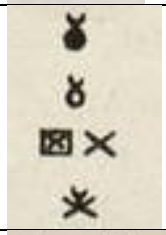
Table 17 Religious symbols

Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	 Churches Mosques
GSGS 4076 (Ed - Dèffa)	 Mosque Synagogue Churches or chapels
G.S.G.S. 4226 (Zarzis)	 Church Mosque
Z621 (Ruanda-Urundi)	 Catholic mission Small catholic mission Protestant mission Small Protestant mission
G.S.G.S. 3980 (Zuara)	 Mosque Synagogue Churches or chapels

Religious symbols differ, as shown in Table 17 above. Generally, all the symbols are in black except for GSGS 3980 symbols. All church symbols have a cross sign. The mosque symbol have a crescent shape attached. GSGS 4226 has three symbols for church and mosque. GSGS 4076 and GSGS 3980 have the same types of symbols, but they differ in colour. Z621 symbols have differences in size between the symbols. GSGS 4076 and GSGS 3980 church symbol is oriented transversely.

3. Cemetery symbols

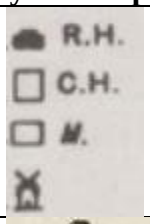
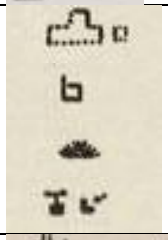
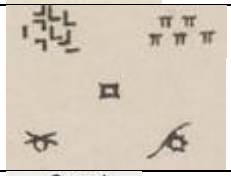
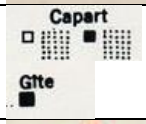
Table 18 Cemetery symbols

Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	 Cemeteries: Christian Cemeteries: Mohammedan Cemeteries: Jewish
GSGS 4076 (Ed - Dèffa)	 Sheik's tomb with building Sheik's tomb without building Cemetery: Christian, Jewish Cemetery: Moslem
G.S.G.S. 4226 (Zarzis)	 Cemetery
Z621 (Ruanda-Urundi)	None
G.S.G.S. 3980 (Zuara)	 Sheik's tomb with building Sheik's tomb without building Cemetery; Christian, Jewesh Cemetery, Moslem

GSGS 4076 and GSGS 3980 have the same type of symbols, but the later sheik's tomb symbol is red (table 18). GSGS 4085 cemeteries symbols are enclosed in a box, as they have an area fill while the others have no area fill. GSGS 4226 has three cemetery symbols combined with different shapes to depict the church and moslem cemetery.

4. Economic symbols

Table 19 Economic symbols

Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	 Rest Houses Cotton Halagas Markets Windmills
GSGS 4076 (Ed - Dèffa)	 Important antiquities: ruins Ruins of ancient castle Grain store Electric power station; factory
G.S.G.S. 4226 (Zarzis)	 Ruins Fort Windmill, watermill
Z621 (Ruanda-Urundi)	 Farm or plantation with name of owner, or farm name Lodging
G.S.G.S. 3980 (Zuara)	 Important antiquities; ruins Ruins of ancient castle Grain store Electric power station; factory

Economic symbols differ from one map series to another as shown in table 19. The symbols were placed under this category because of their economic importance. For example, ruins, antiquities, fort, and logging can be sources of revenue from tourism. Cotton halagas and grain stores can be used to store grain which can later be sold.

GSGS 4076 and GSGS 3980 symbols are similar in shape, but they differ in colour. GSGS 4226 has two ruins symbols, the same as GSGS 4076 and GSGS 3980 legends. GSGS 4085 and GSGS 4226 windmills symbols are of the same colour by they are different shapes. GSGS 4226 is the only legend here with a watermill symbol.

3.3.5. Boundary symbols comparison

Boundary symbols were categorized into state boundary, province and district boundary, and other boundaries. These are discussed below. Appendix D4 shows the full boundary symbol table.

1. State boundary

Table 20 shows the boundary symbol comparison. State boundaries are found in the GSGS 4076, GSGS 4226, and GSGS 3980 map series. The GSGS 4076 and GSGS 3980 boundary symbol are similar in appearance and colour. The symbol is a continuous black line with crossed black marks. The GSGS 4226 state boundary symbol is a dashed black line interchanging with black crosses.

Table 20 State boundary

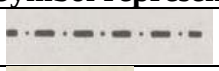
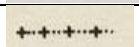
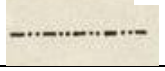
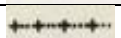
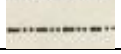
Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	None
GSGS 4076 (Ed - Dèffa)	State boundary
G.S.G.S. 4226 (Zarzis)	State boundary
Z621 (Ruanda-Urundi)	None
G.S.G.S. 3980 (Zuara)	State boundary

2. Province and district boundary

Province and district boundaries are shown in GSGS 4076 and GSGS 3980 (table 21). These provincial and district boundaries are similar in colour and appearance. The province boundary symbol is a black dotted line with a cross sign line. The district boundary symbol is a dashed black line having dots.

The GSGS 4085 contains a province boundary symbol with a dashed line interchanging with single dots (table 21). Z621 district boundary symbol is a black dashed line interchanging with dots.

Table 21 Province and district boundary

Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	 Mundiriya (province) boundaries
GSGS 4076 (Ed - Dèffa)	 Province boundary  District boundary
G.S.G.S. 4226 (Zarzis)	None
Z621 (Ruanda-Urundi)	 District boundary
G.S.G.S. 3980 (Zuara)	 Province boundary  District boundary

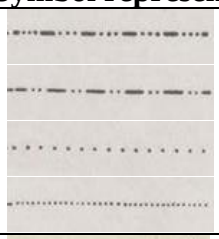
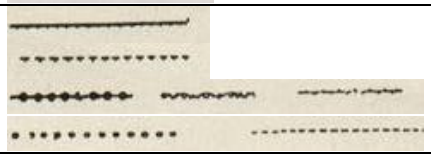
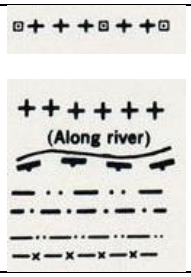
3. Other boundaries

These are boundaries, shown in table 22, that are not found across all the map series. GSGS 4085 house tax boundaries symbol and Z621 boundary of mandated territory symbol have a similar pattern: a single dashed line with two dots. Z621 map series uses two symbols to represent boundary of minor civil division and boundary of national park.

Z621 boundary of mandated territory with numbered stations symbol and boundary of mandated territory symbol have a cross sign line, with the former containing small square sign. GSGS 4085 village boundary symbol and cultivation symbol is a dotted black line, with a difference in the space between the dots and the size of the dots. GSGS 4076 limit of wood symbol and cultivation symbol have a dotted black line with differences in the dots' size.

GSGS 4076 walls with mortar symbol and walls without mortar symbols are different. Walls with mortar symbols are a continuous black line, while walls without a mortar symbol are a dashed black line. GSGS 4076 palisade, hedge, and wire fence symbols are differentiated in terms of the symbol's size and pattern though they have the same colour.

Table 22 Other boundaries

Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	 Governorate boundaries House Tax boundaries Village boundaries Cultivation limits
GSGS 4076 (Ed - Dèffa)	 Walls with mortar Walls without mortar Palisade, hedge, wire fence Limit of wood, cultivation
G.S.G.S. 4226 (Zarzis)	None
Z621 (Ruanda-Urundi)	 Boundary of mandated territory with numbered stations Boundary of mandated territory Boundary of mandated territory Boundary of minor civil divisions Boundary of national park
G.S.G.S. 3980 (Zuara)	None

3.3.6. Relief symbols comparison

Relief symbols have been divided into trigonometrical point, spot height, and others for easier comparison. The whole relief symbol table is shown in appendix D5.

1. Trigonometrical points

Table 23 below shows the trigonometrical points for the various map series. GSGS 4085 does not have this symbol. GSGS 4085 and GSGS 3980 trigonometrical point symbol is a triangle with a dot at the center and numbering on the side. GSGS 4226 and Z621 have the same symbol for the primary triangulation point. Z621 secondary triangulation point symbol is different, having a circular shape.

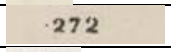
Table 23 Trigonometrical points

Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	None
GSGS 4076 (Ed - Dèffa)	 Trigonometrical point
G.S.G.S. 4226 (Zarzis)	 Trigonometrical point
Z621 (Ruanda-Urundi)	 Primary triangulation point (named) with elevation in meters  Secondary triangulation point with elevation in meters
G.S.G.S. 3980 (Zuara)	 Trigonometrical point

2. Spot heights

GSGS 4076 and GSGS 3980 spot height symbols are identical, with the same single black dot and the same number (table 24). GSGS 4085 spot height symbol is a single black dot and a number beside it. GSGS 4226 height in meters symbol is a small black dot and a number beside it. Z621 spot elevation in meters uses two symbols, a black circle with a black fill and a black circle with a dot at the center.

Table 24 spot heights

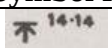
Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	 Spot Heights
GSGS 4076 (Ed - Dèffa)	 Spot height
G.S.G.S. 4226 (Zarzis)	 Height in meters
Z621 (Ruanda-Urundi)	 Spot elevation in meters
G.S.G.S. 3980 (Zuara)	 Spot Height

3. Other relief representations

GSGS 4076 and GSGS 3980 depth of water and of well symbol are similar, a black circle and a fraction (table 25). Z621 depth in meters, in a lake symbol, is a circle with a center dot and a smaller circle with a black fill. GSGS 4085 benchmarks with altitude symbol is an arrow with a mark at the top and a number beside it.

GSGS 4226 has drawings for two symbols, Depression with vegetation and sand dunes. The lava flows symbol in the Z621 legend is also a drawing. Moreover, Z621 has a text symbol to indicate the name of the mountain.

Table 25 other relief representations

Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	 Benchmarks with Altitude
GSGS 4076 (Ed - Dèffa)	 Depth of water and of well
G.S.G.S. 4226 (Zarzis)	 Depression, usually with vegetation  Sand Dunes
Z621 (Ruanda-Urundi)	 Depth in meters, in a lake  Followed by name of mountain, indicates volcano  Lava flows
G.S.G.S. 3980 (Zuara)	 Depth of Water and of well.

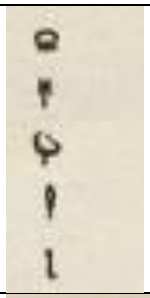
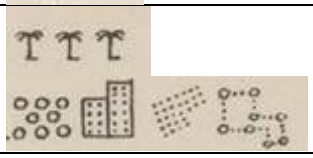
3.3.7. Vegetation symbols comparison

Comparison of vegetation symbols is broadly categorized into planted vegetation and natural vegetation. The full table of comparison is in appendix D6.

2. Planted vegetation

GSGS 4085 and GSGS Z621 map series have no planted vegetation symbols, as shown in table 26. GSGS 4076 symbols are in black, while and GSGS 3980 symbols are in green colour, though they have the same symbol types. GSGS 4226 palms symbol resembles an actual palm tree. GSGS 4226 has four different symbols to represent cultivation.

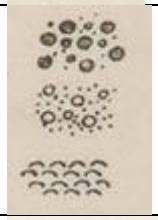
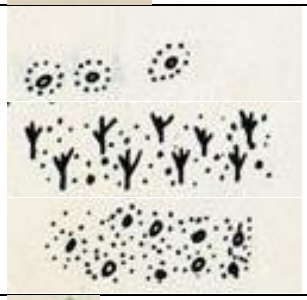
Table 26 Planted vegetation

Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	None
GSGS 4076 (Ed - Dèffa)	 Plantations Palms Olives Citrus Vines
G.S.G.S. 4226 (Zarzis)	 Psalms Cultivation
Z621 (Ruanda-Urundi)	None
G.S.G.S. 3980 (Zuara)	 Plantations Psalms Olives Citrus Vines

2. Natural vegetation

GSGS 4076 symbols are in black, while GSGS 3980 symbols are in green, though the symbols appear similar in shape (table 27). GSGS 4226 wood, scrub, and cactus symbols have different shapes and appearances. Z621 dense forest symbols fill is denser while the scattered forest symbol fill is less dense. GSGS 4085 does not have natural vegetation symbols.

Table 27 Natural vegetation

Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	None
GSGS 4076 (Ed - Dèffa)	 Eucalyptus Acacia Thorny bush on dunes
G.S.G.S. 4226 (Zarzis)	 Wood Scrub Cactus
Z621 (Ruanda-Urundi)	 Forest clumps scattered through the savanna Types of dense forest cover Dense forest growths
G.S.G.S. 3980 (Zuara)	 Eucalyptus Acacia Thorny bush on dunes

3.3.8. Hydrographic symbols comparison

Hydrographic symbols are broadly categorized into man-made hydrographic features and natural hydrographic features symbols. Appendix D7 shows the entire hydrographic symbols table.

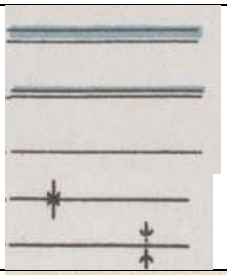
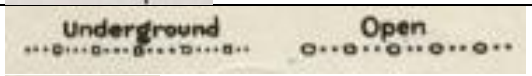
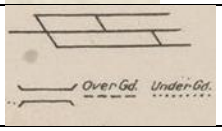
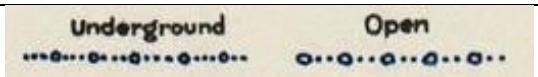
2. Man-made hydrographic features symbols

GSGS 4076 and GSGS 3980 aqueduct and cistern symbols are similar, though they differ in colour as shown in table 28 below. GSGS 4226 has an aqueduct and water conduit symbol though it differs from the one in GSGS 4076 and GSGS 3980 maps. GSGS 4226 canal irrigation symbol is a continuous black single and multiple lines.

GSGS 4085 canal symbols line structure varies according to the width of the canal. The 20 meters canal has a blue colour fill. The 5 to 20 meters canal does not have a fill. The

2.5 to 5 meter canal is a continuous single black line. Two pipes' symbols have different line structures depending on whether they are run over or under canals.

Table 28 Man-made hydrographic features symbols

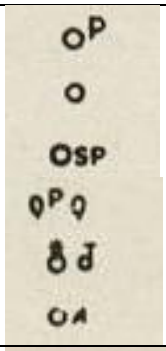
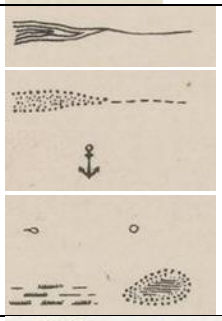
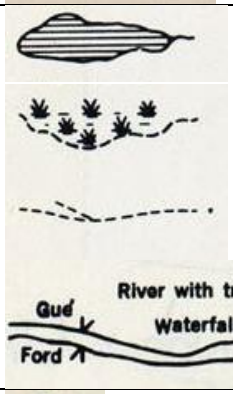
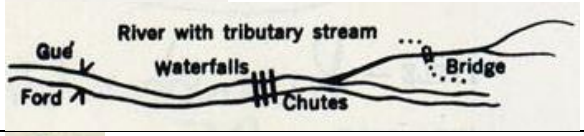
Map series	**Symbol representation and description**
G.S.G.S. 4085 (Benha)	 Canals and drains over 20 meters wide Canals and drains from 5 to 20 meters Canals and drains from 2.5 to 5 meters Pipes or aqueducts over canals Pipes or syphons under canals
GSGS 4076 (Ed - Dèffa)	 Aqueduct  Cistern
G.S.G.S. 4226 (Zarzis)	 Canal, irrigation Aqueduct. Water conduit
Z621 (Ruanda-Urundi)	None
G.S.G.S. 3980 (Zuara)	 Aqueduct  Cistern

2. Natural hydrographic features symbols

GSGS 4076 and GSGS 3980 have similar symbols, but the symbol's colour differs, as shown in Table 29 below. GSGS 4085 has a banks symbol, while Z621 has a lake symbol. The spring symbol in GSGS 4226 has a transverse orientation, while the GSGS 4076 and GSGS 3980 have a longitudinal orientation. Z621 has a lake, swamp, and unsurveyed stream symbol.

GSGS 4226 perennial river symbol is continuous, while the non-perennial is shown by dense dots and dashed lines. GSGS 4076 perennial well and spring symbol have a later 'p', the brackish has 'SP' beside it, while the non-perennial does not. GSGS 4076 and GSGS 3980 dry well symbol has a capital letter 'A.' GSGS 4226 has a marsh and salt lagoons symbol.

Table 29 Natural hydrographic features symbols

Map series	**Symbol representation and description**
G.S.G.S. 4085 (Benha)	 Banks
GSGS 4076 (Ed - Dèffa)	 Well, perennial Well, non perennial Well, perennial but brackish Springs, perennial, and non-perennial Well with windpump, waterwheel Well, dry
G.S.G.S. 4226 (Zarzis)	 River, perennial River, non-perennial Head of navigation Spring, well Marsh, Salt lagoons
Z621 (Ruanda -Urundi)	 Lake Swamp Unsurveyed stream  River with tributary stream
G.S.G.S. 3980 (Zuara)	 Well, perennial Well, non perennial Well, perennial but brackish Springs, perennial, and non-perennial Well with windpump, waterwheel Well, dry

CHAPTER 4: RESULTS AND DISCUSSION

4.0. Countries and their colonial rule

The maps series used for this study were published in the 1940s, as shown in table 5. GSGS 4085 was the map series covering Egypt and was published in 1940. GSGS 4076 and GSGS 3980 was covering Libya and were published in 1942 and 1943, respectively. GSGS 4226 was covering Tunisia and was published in 1942. Z621 sample was covering Ruanda-Urundi, and it was published in 1942.

4.1.1. Egypt, Libya, and Tunisia

Egypt, Libya, and Tunisia were previously former colonies, as shown in figure 6 (The National Archives, n.d.). The publication of the maps (1940s) used in this study took place when Egypt was an independent state, while Libya and Tunisia were under Italian and French rule, respectively. Libya and Tunisia later gained their independence in 1951 and 1956, respectively.

Cyrenaica is the name for GSGS 4076 series, while Tripoli is the name for GSGS 3980. This map series covered the present country of Libya. Libya was split into Cyrenaica and Tripolitania in 1927, under Italian rule, up to its independence in 1951, explaining the series names. Figure 5 shows the changes in Egypt, Libya, and Tunisia National Mapping Organisations (NMO) (Böhme & Anson, 1993).

Egypt:

- 1919 :Survey of Egypt
- 1971 : Egyptian General Survey Authority (EGSA)

Libya:

- 1940-Instituto Geografico Militare in Florence
- After 1969 revolution: Survey department

Tunisia:

- Before 1955: French Institut Géograhique National
- 1955- Office de la Trographie et de la Cartographie (OTC)

Figure 5 National Mapping Organisations (NMO)

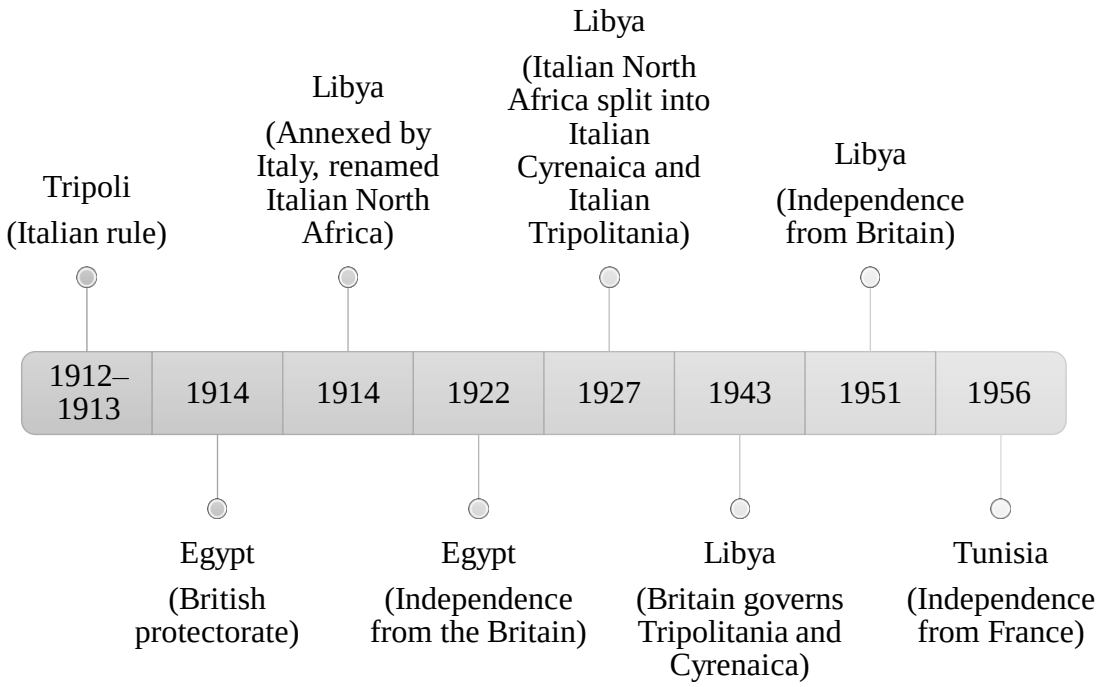


Figure 6 Egypt, Libya, and Tunisia geopolitical changes

4.1.2. Rwanda and Burundi

Rwanda and Burundi have gone through several geopolitical changes as shown in figure 7 below (The National Archives, n.d.). The sample sheet for the Z621 map series was published when both Rwanda and Burundi were under Belgium's control. The title of the series is Ruanda-Urundi, derived from the change of name in 1919 when Rwanda was under Belgium's control. In 1962 Ruanda-Urundi change its name to Rwanda after gaining its independence from Belgium. Burundi also gained its independence in the same year.

Rwanda and Burundi production of topographic maps was under several organisations as shown below (Böhme & Anson, 1993):

- 1936: Survey under Belgian authorities (covered both Rwanda and Burundi)
- After 1985: Service de Cartographie du Rwanda (SCR) was established.
- 1962: Institut Geographique du Burundi (IGEBU) was established.

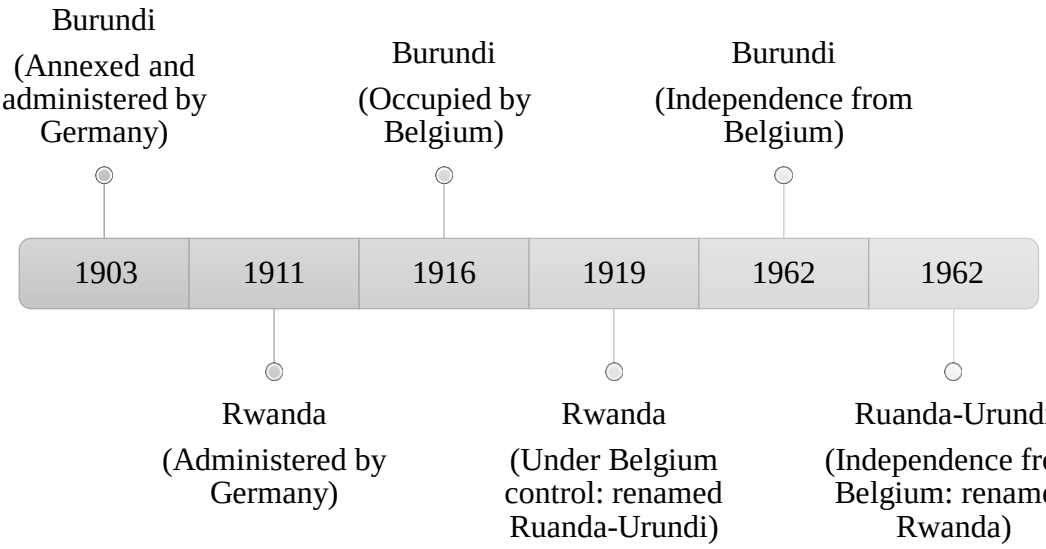


Figure 7 Rwanda and Burundi geopolitical changes

4.2.Symbol's comparison

This section derives general outcomes of the analysis that are discussed in the previous chapter.

4.2.1. Classification of common features

Throughout the analysis, some common features have are established. The common transportation features represented by symbols across all the maps examined include, road for wheeled traffic and railways. Five road feature symbols are shown for GSGS 4085 and GSGS 4226. Eight road feature symbols are shown by GSGS 4076 and GSGS 3980 map series, while Z621 has three.

GSGS 4085, GSGS 4076, and GSGS 3980 had three railway feature symbols. Two and one railway symbols were identified for GSGS 4226 and Z621 series, respectively. The naming and visual characteristics of the symbols vary.

The cemetery was a common feature found in all the map series, except Z621. The cemeteries were all classified into Christian, Jewish, and Moslem/Mohammedan. Churches and mosques were also typical across all the map series. The synagogue symbol

was found in GSGS 4226 and GSGS 3980 series, while the Protestant symbol is seen in the Z621 map.

Ruin feature was common in GSGS 4076, GSGS 4226 and GSGS 3980 maps. Windmill feature is found in GSGS 4085 and GSGS 4226 maps. Fort feature is only found in GSGS 4226 map. Province boundary is found on all map's legends, except GSGS 4226. Trigonometrical point feature was represented on all maps except GSGS 4085. Spot heights feature was found on all the maps.

Ruanda-Urundi map did not have any symbol for planted vegetation, while it had three feature symbols for natural vegetation. The features represented by the natural vegetation symbols were only similar for GSGS 4076 and GSGS 3980 maps. Man made and natura hydrographic features are similar for GSGS 4079 and GSGS 3980 maps.

4.2.2. Visual variables and nature of symbols

Point symbols such as light houses, buoys, aerodrome, and landing ground. These symbols are differentiated in terms of their shape. These symbols were black except for the lighthouse, light, monument symbol for GSGS 3980 map. Some point symbols also used letters for example the GSGS 4226 and GSGS 4085 post and telegraph office symbol. Point symbol fills are also used to differentiate sheiks tombs in GSGS 4076 and GSGS 3980 maps. This shows the qualitative differences among the symbols.

The quantitative difference of point symbols is seen in Z621 catholic and protestant symbols. Some point symbols were transversely oriented, for example, the church or chapel symbol in GSGS 4076 and GSGS 4226 map, and the GSGS 4226 lighthouse symbol. Most point symbols were longitudinally oriented, such as GSGS 4085 lighthouse.

Line symbols dominated road and railway symbols though they were supplemented by point symbols. Variation of qualitative, quantitative nature of the line symbols was evident across the map series. A simple dashed line represented lower rank road features such as camel tracks, native paths, and footpaths. Higher ranked roads used complex lines such as roads for wheeled traffic and road principal. Simple marked lines are used to represent Light railway and trolley lines. Double lines are used to represent narrow,

ordinary, and standard gauge railways. The supplementing point symbols were mainly on the upper side of the line symbols.

Hydrographic features symbols also displayed variation in line thickness. For example, GSGS 4085 canal width was captured in the symbols. Canals from 5 to 20 meters wide had a line symbol whose width increased proportionally. A single line was used for 2.5 to 5 meters canal.

GSGS 4085 Christian, Mohammedan, and Jewish cemetery symbols had different fills. This cemetery classification is based on religion. GSGS 4226 perennial and the non-perennial river had different fills, continuous lines, and dots, respectively. These were to differentiate the nature of the rivers visually. Z621 forest symbols give a quantitative difference between dense and scattered forest cover.

4.3.Army Map Service

The Army Map Service (AMS) was established in 1942 by merging two organizations (CSUN University Library, n.d.). These organizations were the Engineer Reproduction Plant (ERP) and the Library and Cartographic Section of the War Department General. Its formation during World War II placed it at the center of mapping for military purposes. The AMS name has changed over the years, as shown below (CSUN University Library, n.d.; Portable Network Graphics, n.d.-a):

- 1941-1968: Army Map Service (AMS)
- 1968-1972: U.S. Army Topographic Command (USATC)
- 1996-2003: National Imagery and Mapping Agency (NIMA)
- 2003-Present: National Geospatial-Intelligence Agency (NGA)

CHAPTER 5: CONCLUSION AND RECCOMENDATION

5.0.Conclusions

Map legends symbols reveal to a given level the situation of the region that they represent. Interpretations on the culture and level of development can be drawn from the symbols and their description on the map at their publication.

Based on the symbols shown on the different map series, it can be suggested that Libya (GSGS 4076 and GSGS 3980) had made extensive development on road construction, with several road types. Egypt (GSGS 4085) was second, then Tunisia (GSGS 4226), and lastly Rwanda and Burundi (Z621).

GSGS 4076 and GSGS 3980 were different map series, but for the same present country of Libya; hence, the number of features depicted on the symbols were the same, but there were minor differences in the symbols' colour. This shows that the different areas that they represent were similar in terms of culture and development. The natural features on the same maps were also similar.

Z621 map did not have a cemetery symbol, while GSGS 4085 did not have any settlement symbol. Both map series also lacks the state boundary symbol. This shows there may not be uniformity of features represented across maps of the same scale.

In summary, the set objectives were achieved, as establishing common features and their classification. The analysis, results, and discussion included the qualitative and quantitative nature of the symbols for the maps analyzed.

5.1.Recommendations

This research has shed light on the need for research in legends, their use and how they depict our environment. I would therefore recommend the following:

i. This study can provide a basis for comparison to current topographical maps produced in the same countries.
ii. Research on legend design across different regions or National Mapping Agencies (NMA).

iii. Suggestion on further research on maps layer order representation in different times.

iv. A study to examine colonial index maps to determine areas they cover.

Notes:

Glossary

Terms used in this text which have are borrowed from other languages include:

Decauvilles- this is a light railway constructed in Egypt.

Halagas – The British used ‘halaga’ to refer to one section of a town (Seri-Hersch, 2011). Towns were divided into six sections, each having a president, a secretary, and two ‘murshids’(guides). It is a Sudanese Arabic term ‘*halaqa*’ meaning ‘circle’ or ‘ring’. In this study it is used in the cotton halagas symbol.

Markaz – It means a district; it was used in Egypt. Here the name is used in the district boundary symbols.

Mundiriyah – It means a province; it was used in Egypt. In this study, it is used in the province boundary symbols.

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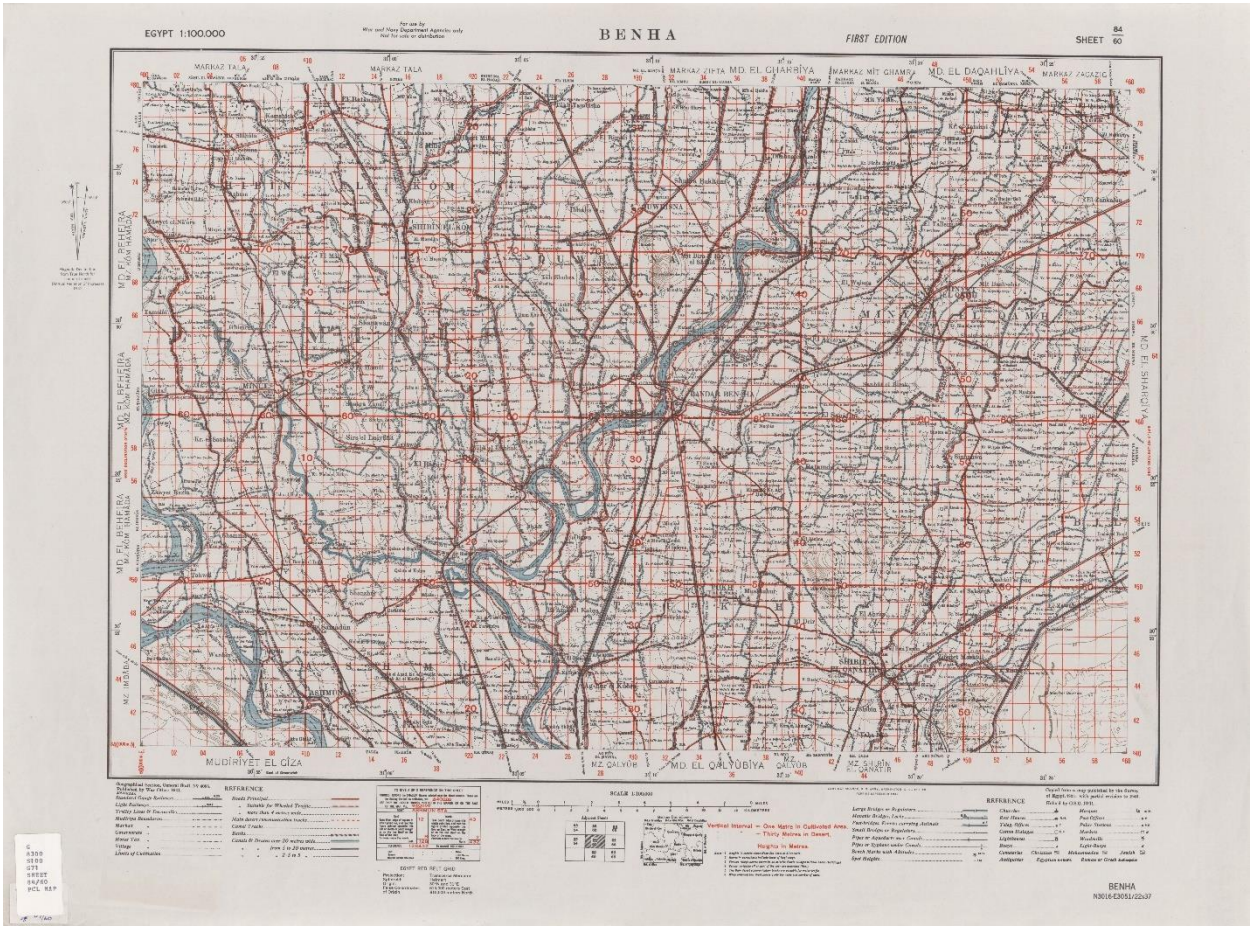
APPENDICES

APPENDIX A: Sample maps

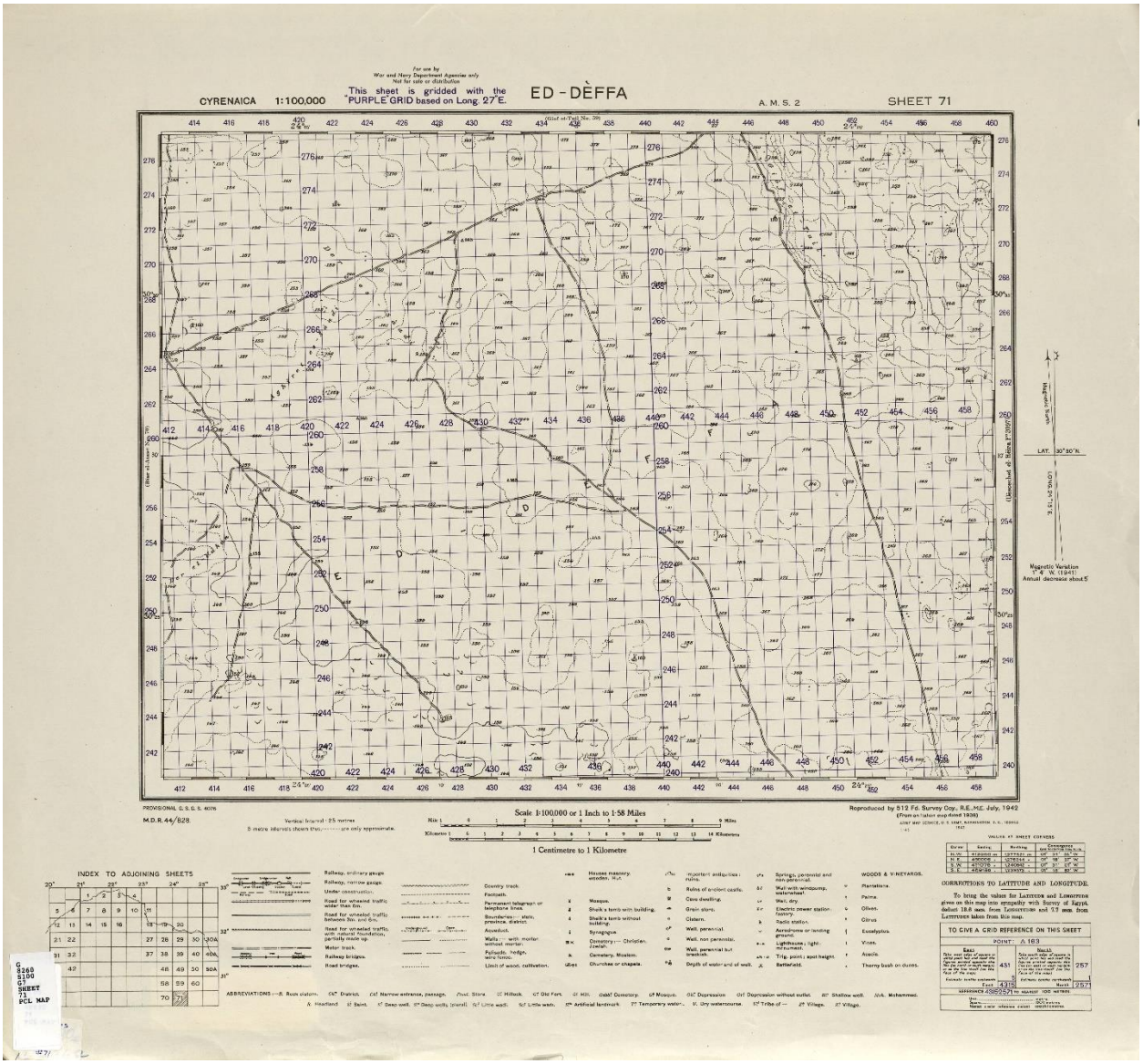
Appendix A1: Benha map



Source: http://legacy.lib.utexas.edu/maps/ams/egypt/

Index map: Appendix C1

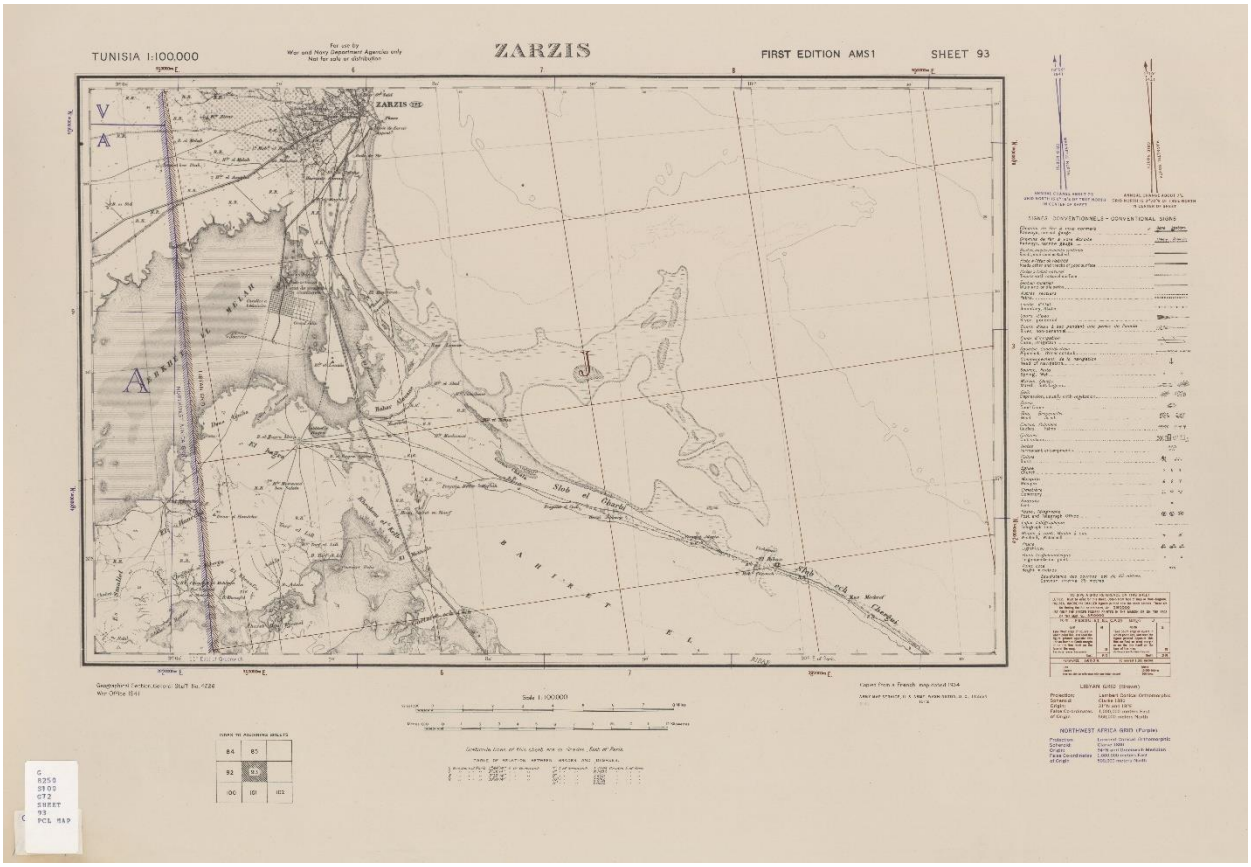
Appendix A2: Ed – Dèffa map



Source: http://legacy.lib.utexas.edu/maps/ams/cyrenaica/

Index map: Appendix C2

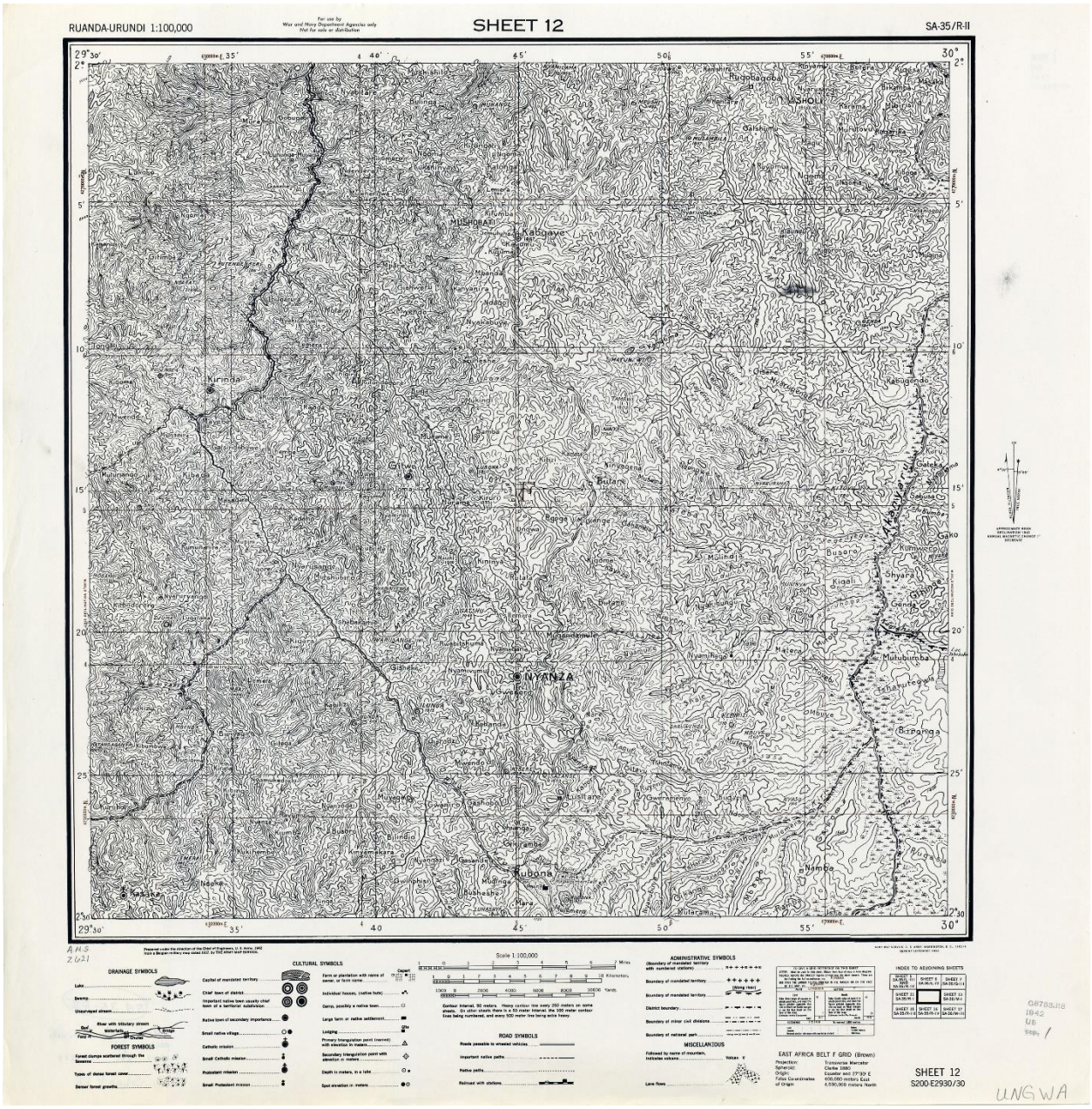
Appendix A3: Zarzis map



Source: http://legacy.lib.utexas.edu/maps/ams/tunisia/

Index map: Appendix C3

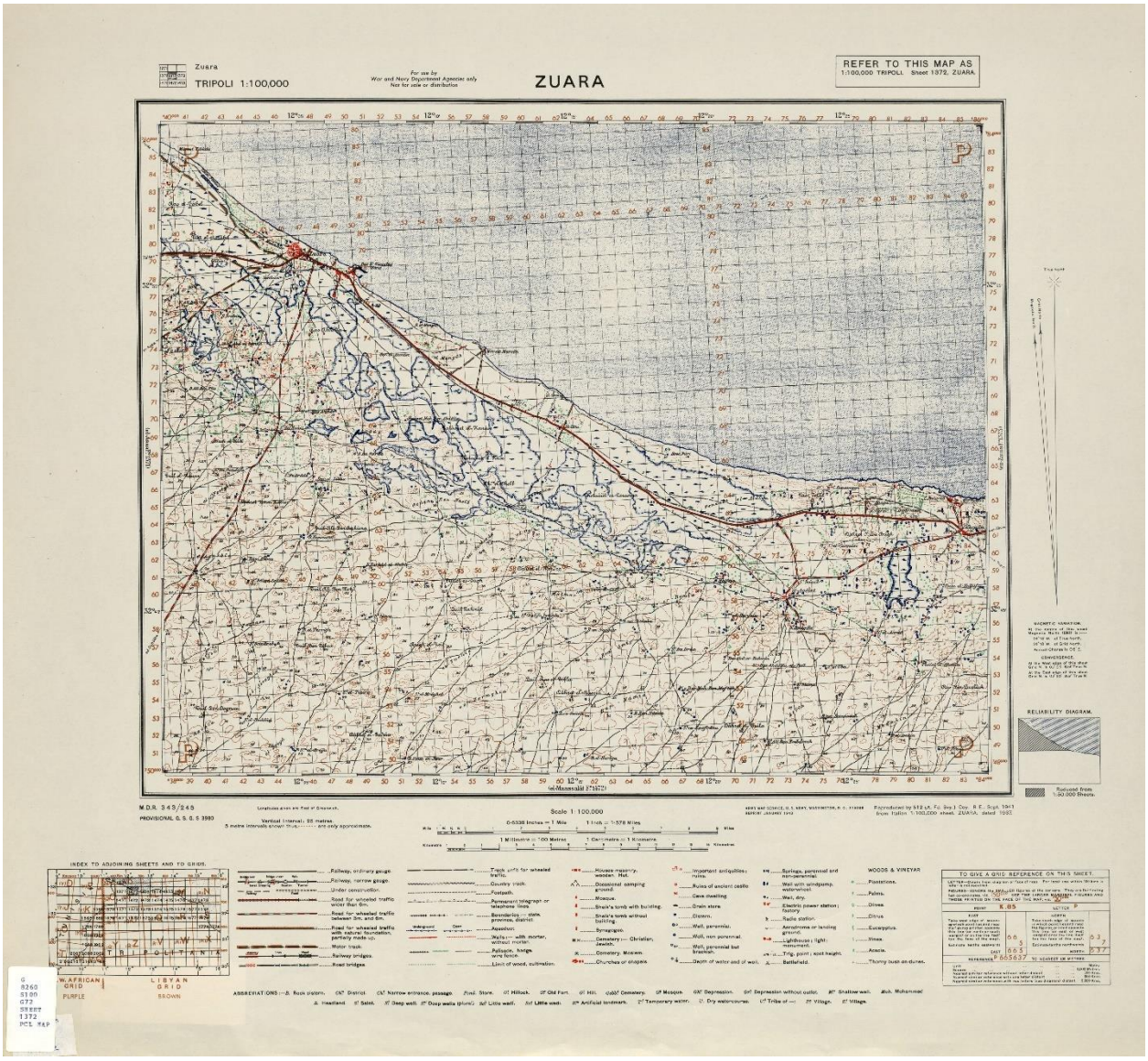
Appendix A4: Ruanda-Urundi map



Source: http://legacy.lib.utexas.edu/maps/ams/ruanda-urundi/

Index map: Appendix C4

Appendix A5: Zuara map



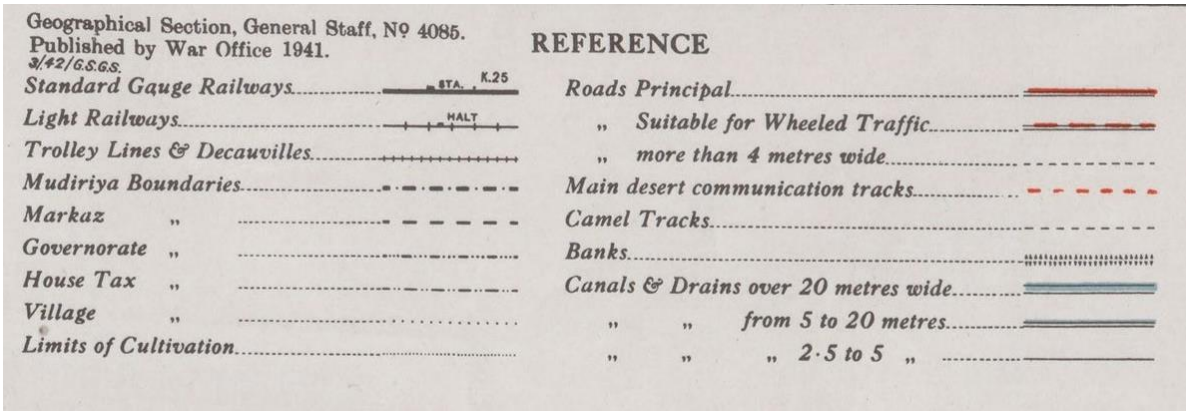
Source: http://legacy.lib.utexas.edu/maps/ams/tripoli/

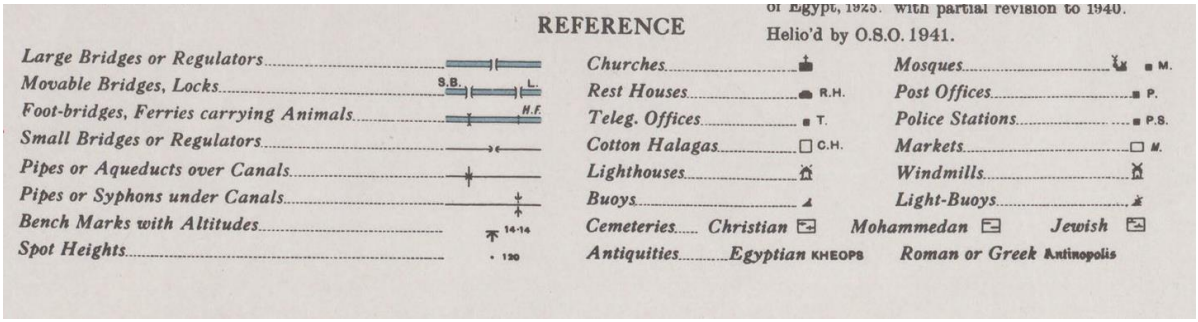
Index map: Appendix C2

The map legends for the maps portrayed in appendix A1, A2, A3, A4, and A5 are not visible. However, the legends used for comparison were extracted separately by zooming in and cropping the image. The legends are indicated in appendix B1, B2, B3, B4, and B5.

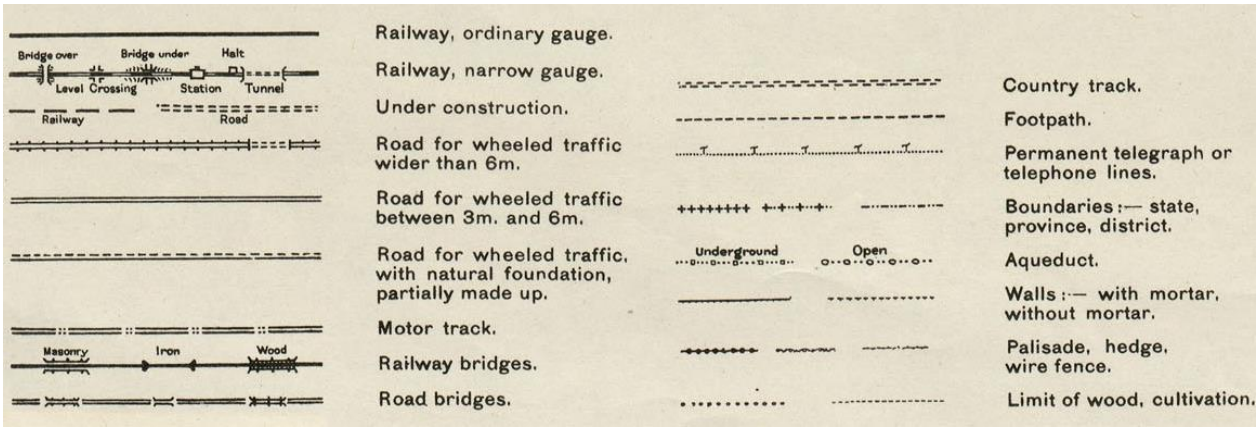
APPENDIX B: Legends extracted from sample maps

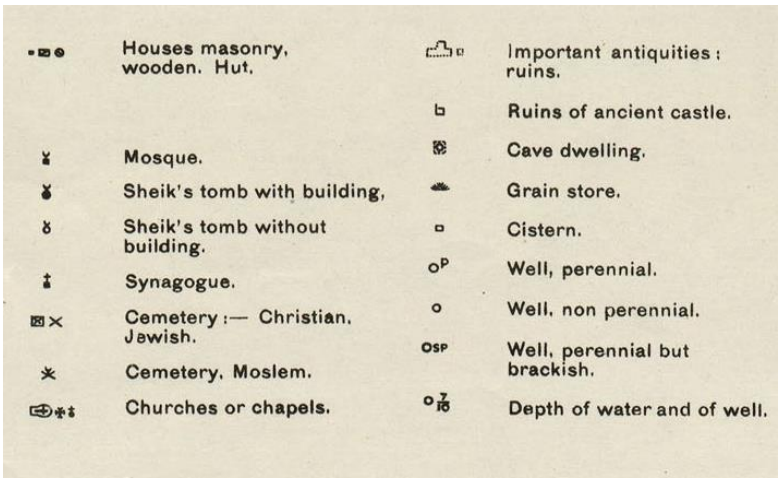
Appendix B1: Benha legend

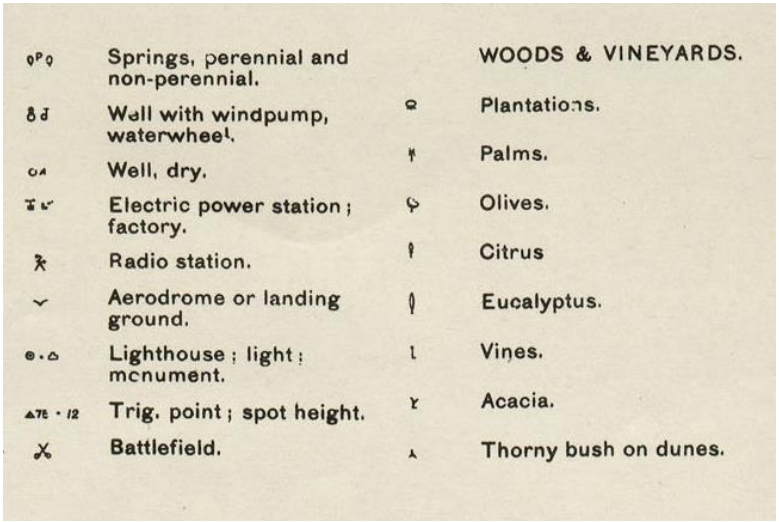




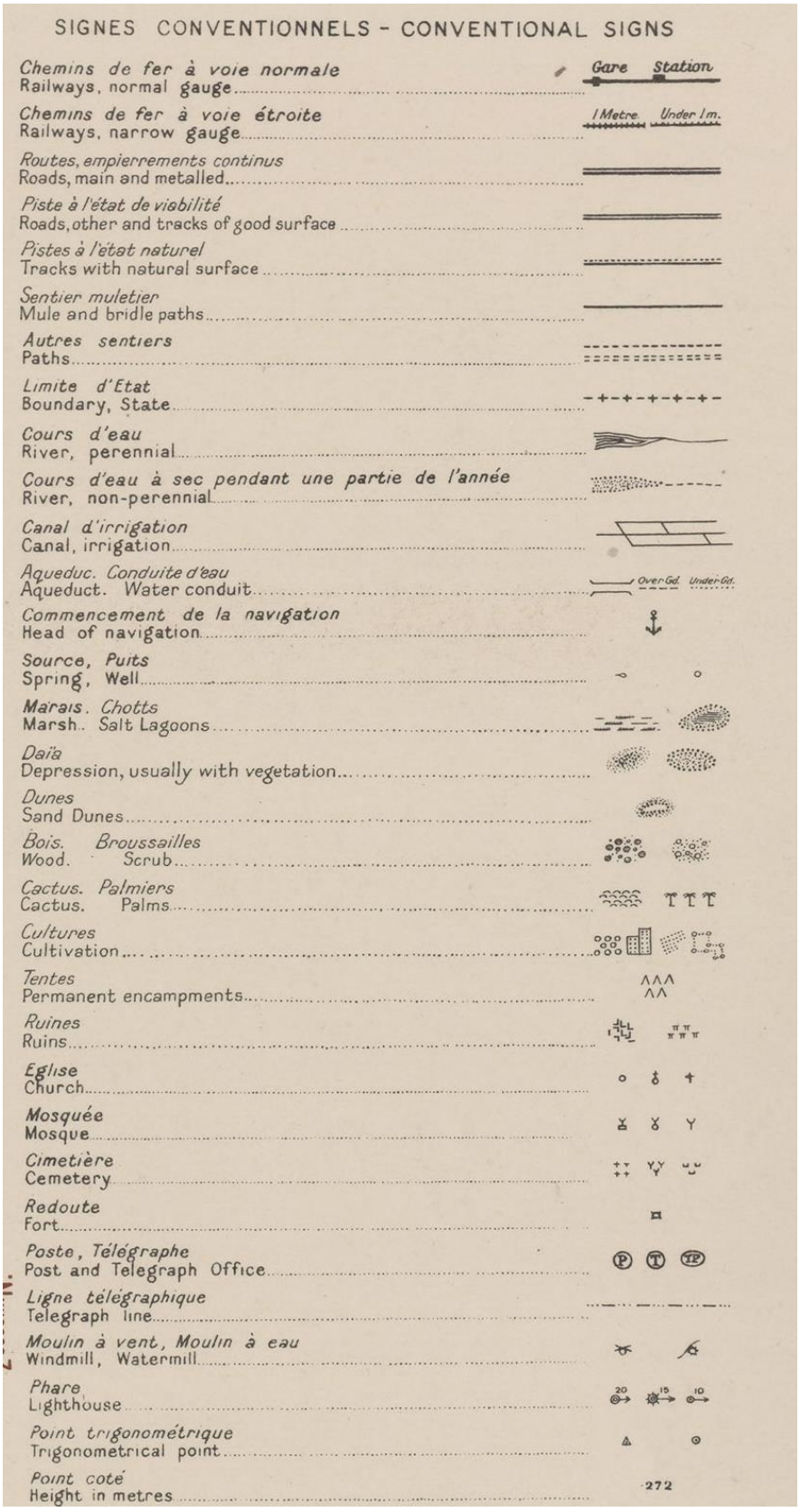
Appendix B2: Ed – Dèffa legend



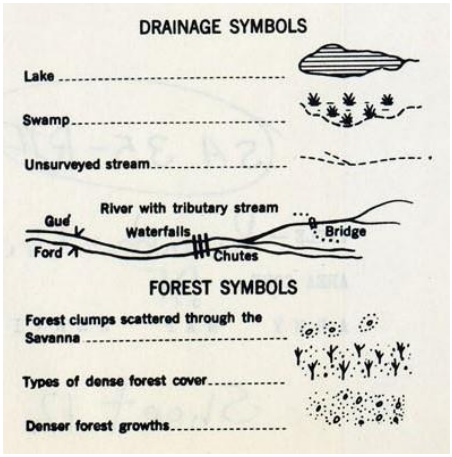


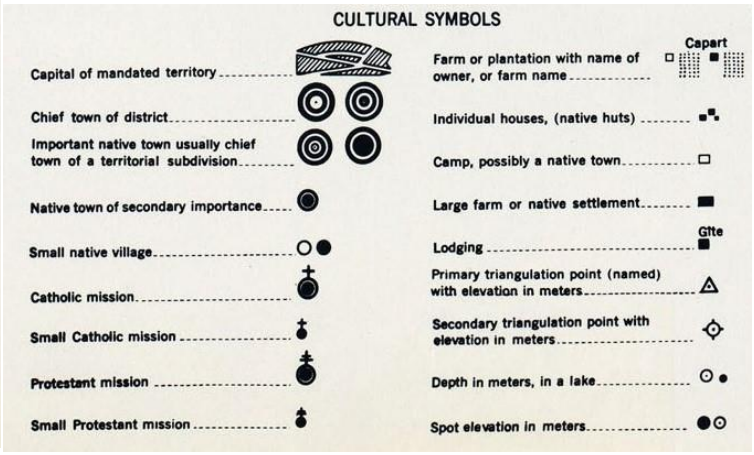


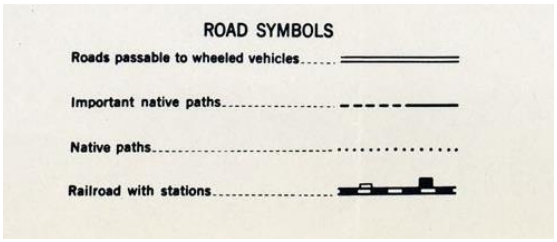
Appendix B3: Zarzis legend

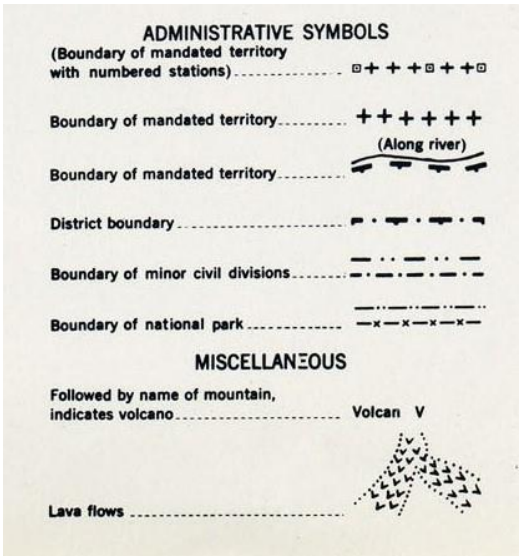


Appendix B4: Ruanda-Urundi legend

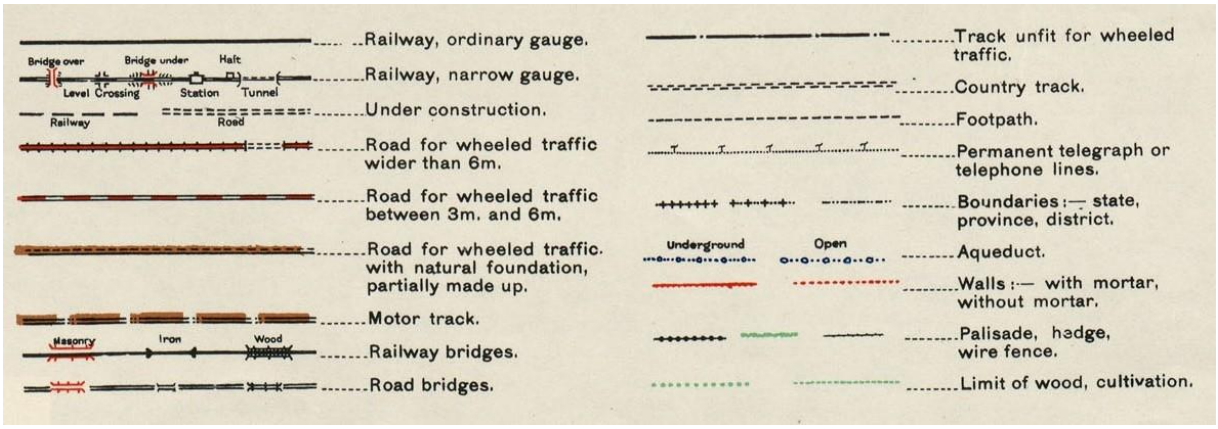


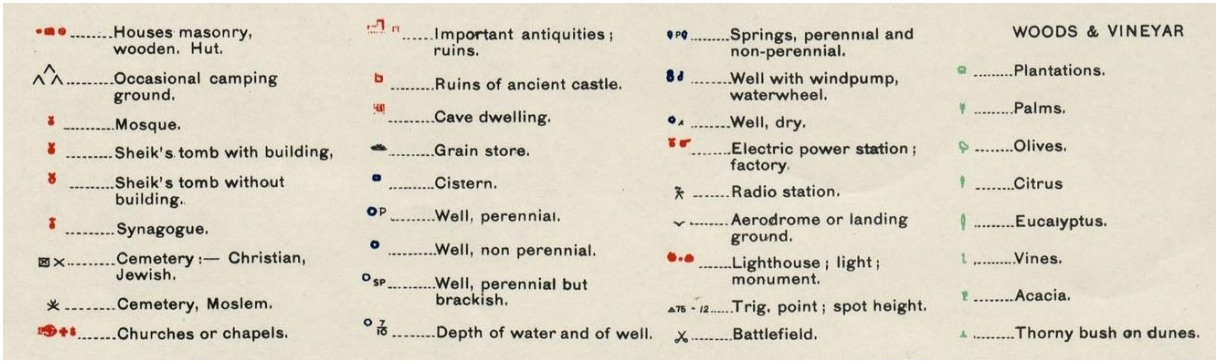






Appendix B5: Zuara legend

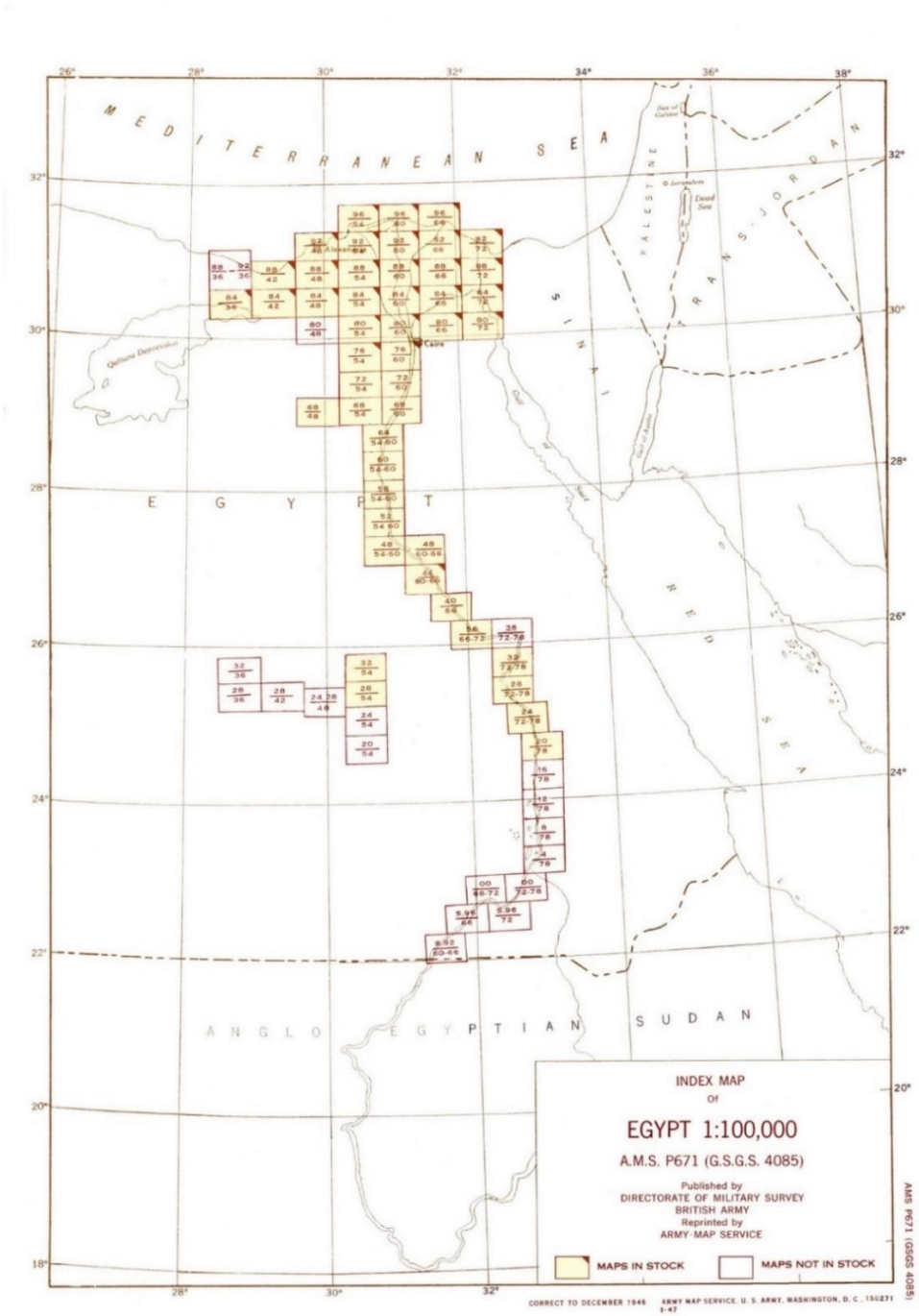




APPENDIX C: Index Sheet for the map series

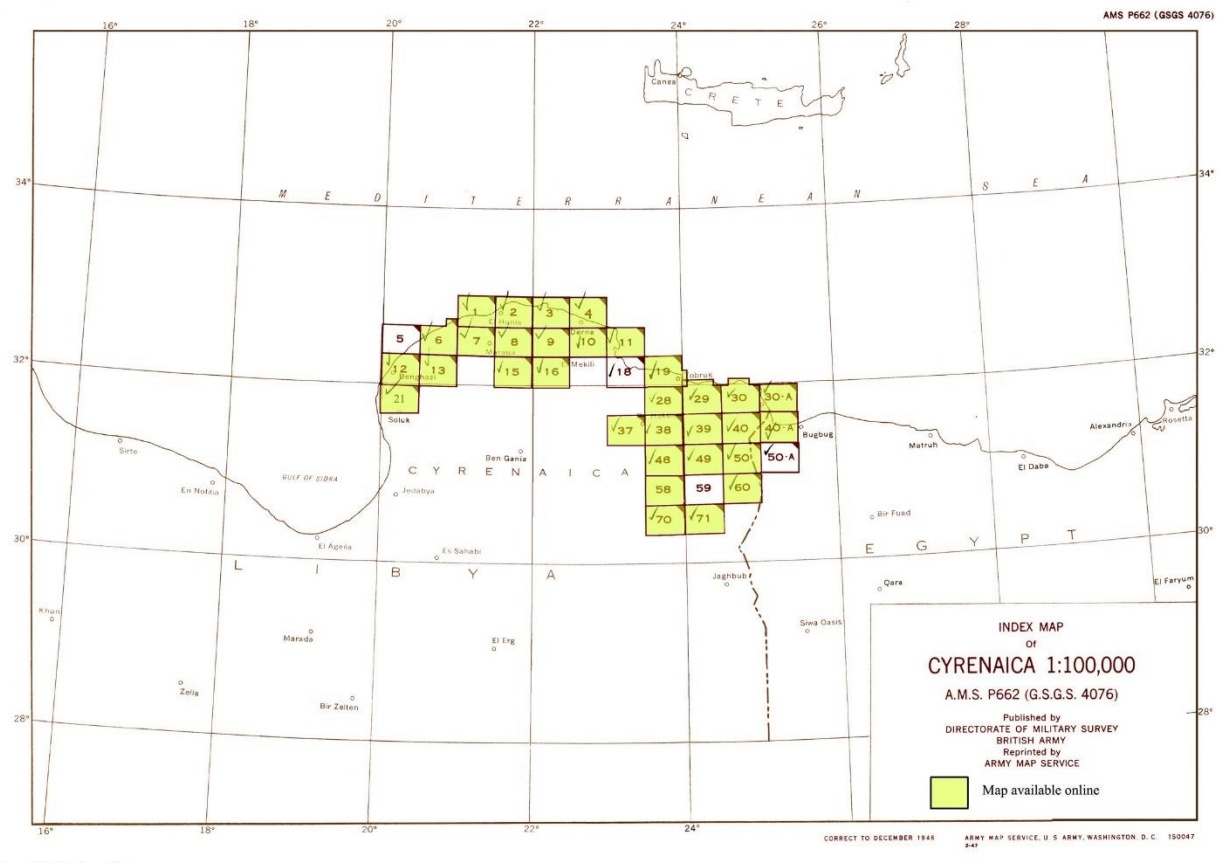
The sample maps shown in appendix C1, C2, C3, C4, and C5 are from 1:100,000 scale series. They correspond to the sample maps shown in appendix A1, A2, A3, A4, and A5.

Appendix C1: GSGS 4085 (Benha map)



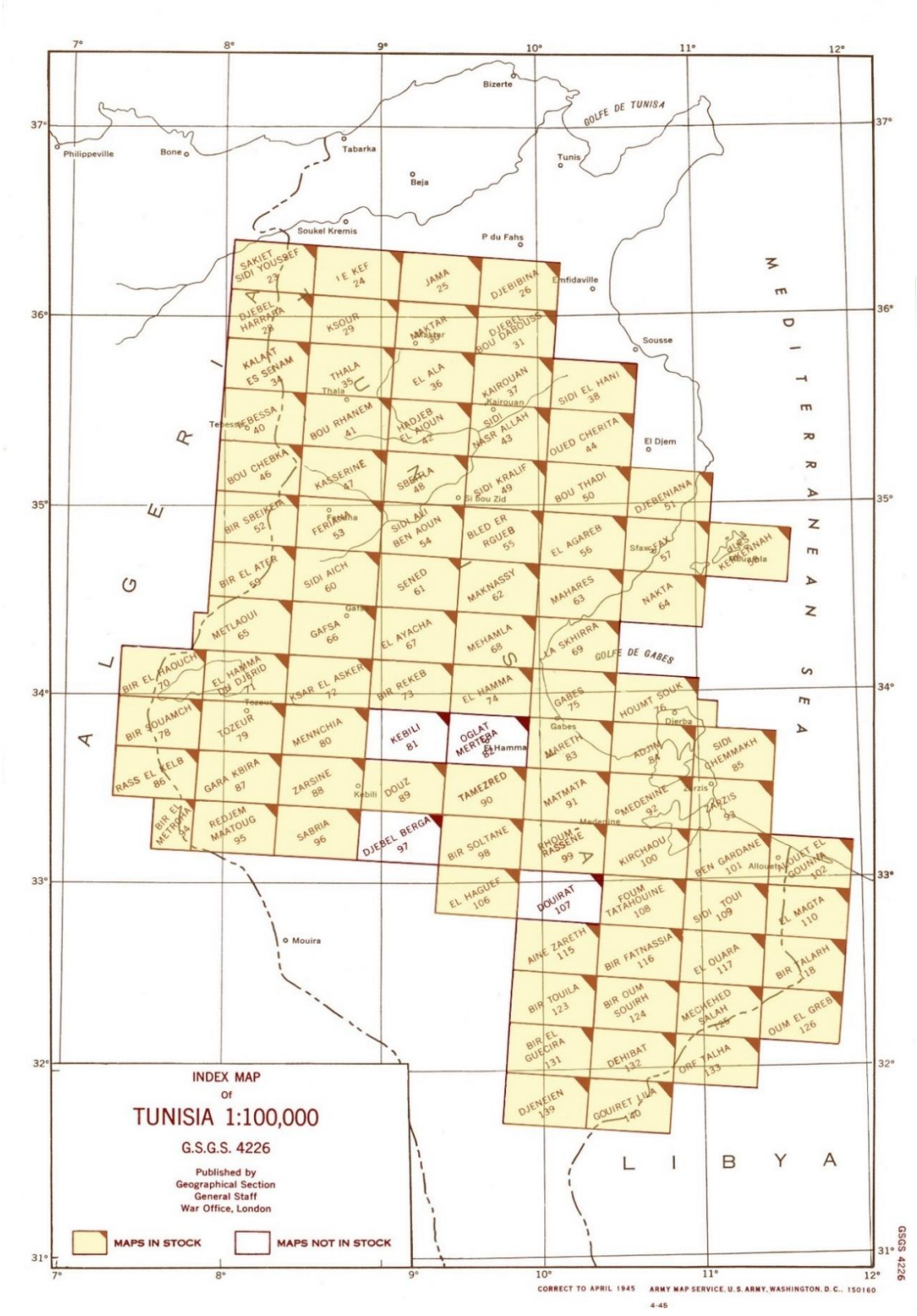
Source: http://legacy.lib.utexas.edu/maps/ams/egypt/index_map.jpg

Appendix C2: GSGS 4076 (Ed – Dèffa map)



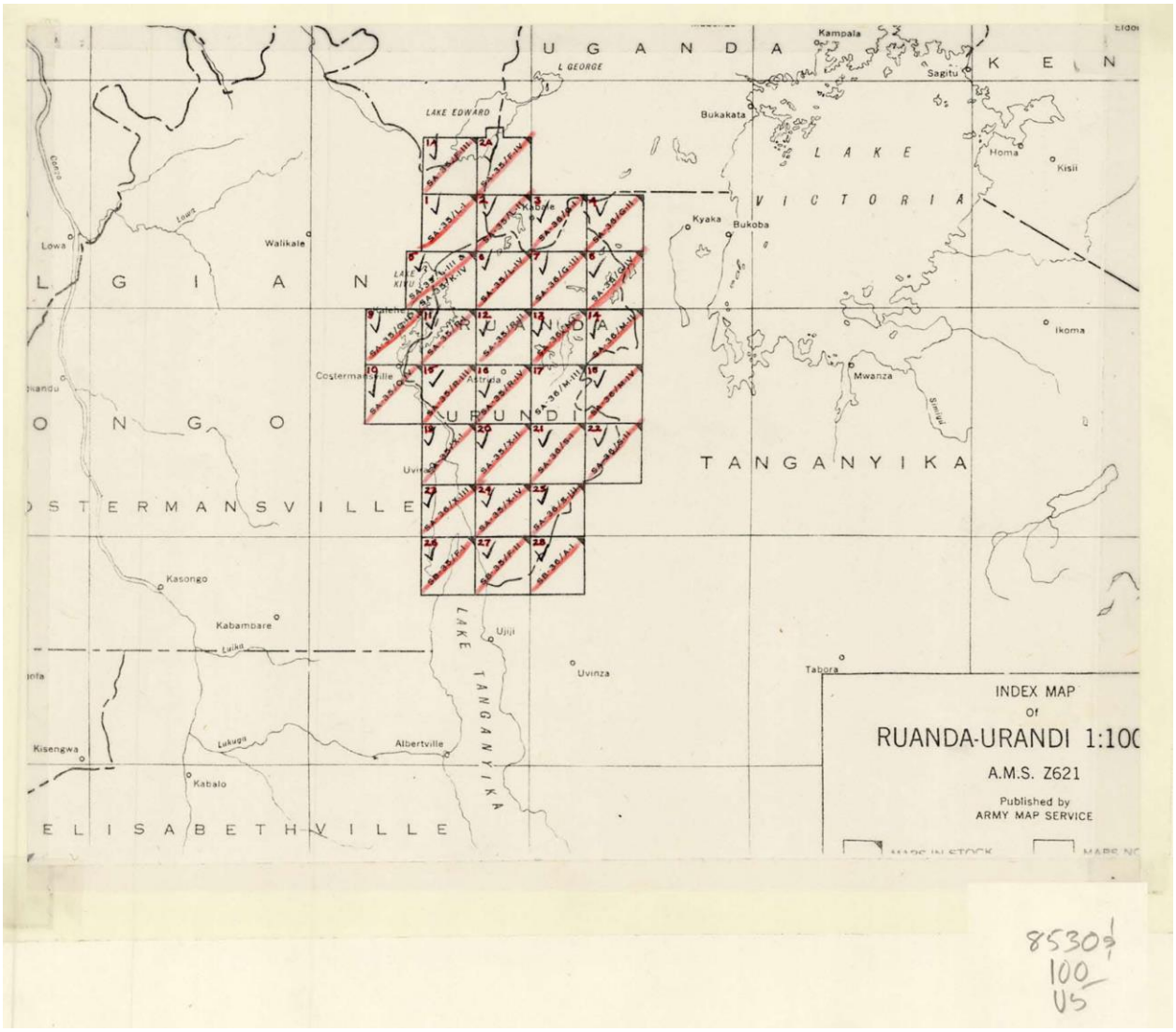
Source: http://legacy.lib.utexas.edu/maps/ams/cyrenaica/cyrenaica_index.jpg

Appendix C3: G.S.G.S. 4226 (Zarzis map)



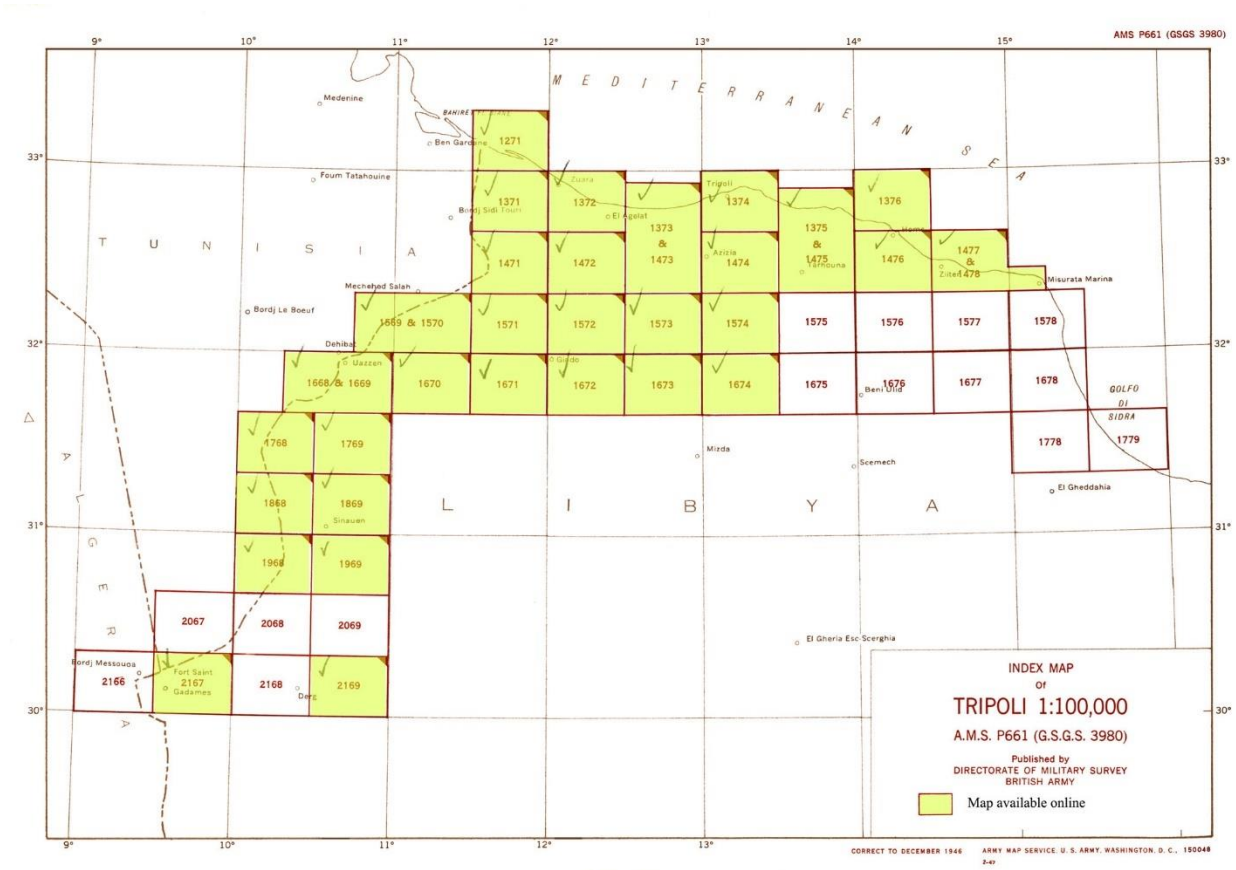
Source: http://legacy.lib.utexas.edu/maps/ams/tunisia/index_map.jpg

Appendix C4: Z621 (Ruanda-Urundi map)



Source: https://mil.library.ucsb.edu/mapindexes/topo-index-scans/8530s_100_u5_index.pdf

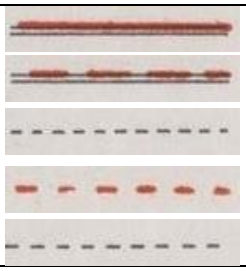
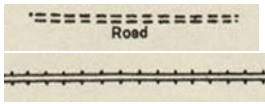
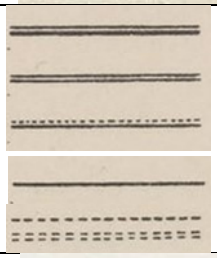
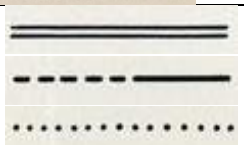
Appendix C5: G.S.G.S. 3980 (Zuara map)

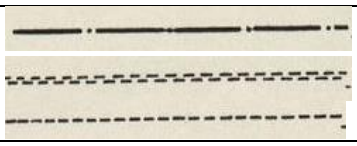


Source: http://legacy.lib.utexas.edu/maps/ams/tripoli/tripoli_index.jpg

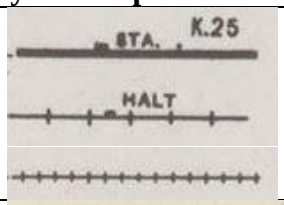
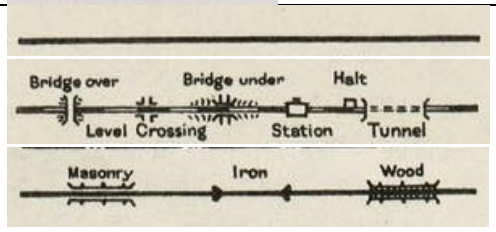
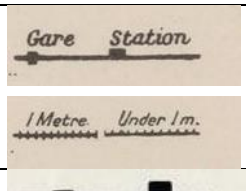
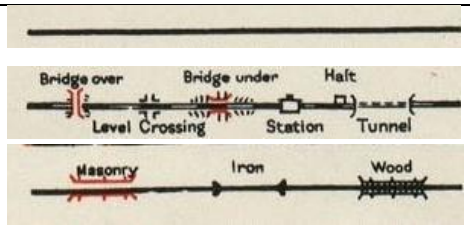
APPENDIX D: Full symbol comparison tables

Appendix D1: Road symbols

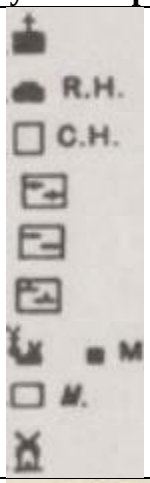
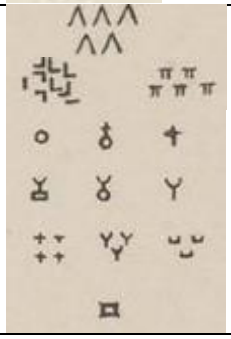
Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	 Roads Principal Roads suitable for wheeled Traffic Roads more than 4 meters wide Main desert communication tracks Camel Tracks
GSGS 4076 (Ed - Dèffa)	 Road under construction Road for wheeled traffic wider than 6m Road for wheeled traffic between 3m and 6m Road for wheeled traffic with natural foundation, partially made up Motor track Road bridges (masonry, iron, wood) Country track Foot path
G.S.G.S. 4226 (Zarzis)	 Roads, main and metalled Roads, other and tracks of good surface Tracks with natural surface Mule and bridle paths Paths
Z621 (Ruanda -Urundi)	 Roads passable to wheeled vehicles Important native paths Native paths
G.S.G.S. 3980 (Zuara)	 Road under construction Road for wheeled traffic wider than 6m Road for wheeled traffic between 3m and 6m Road for wheeled traffic with natural foundation, partially made up Motor track

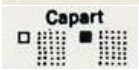
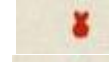
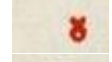
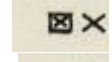
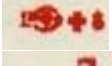
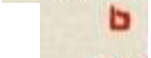
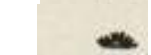
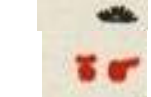
		Track unfit for wheeled traffic Country track Footpath

Appendix D2: Railway symbols

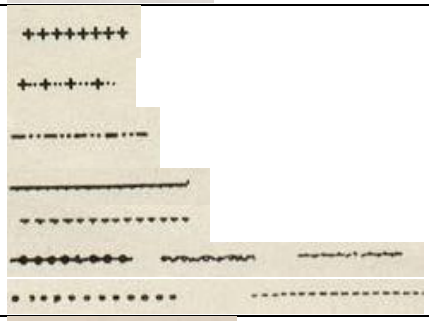
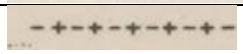
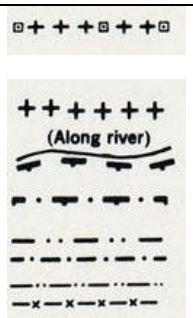
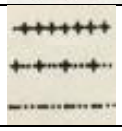
Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	 Standard gauge railway Light railway Trolley lines and decauvilles
GSGS 4076 (Ed - Dèffa)	 Railway, ordinary gauge Railway, narrow gauge Railway bridges
G.S.G.S. 4226 (Zarzis)	 Railways, normal gauge Railways, narrow gauge
Z621 (Ruanda-Urundi)	 Railroad with stations
G.S.G.S. 3980 (Zuara)	 Railway, ordinary gauge Railway, narrow gauge Railway bridge

Appendix D3: Social, cultural, and economic symbols

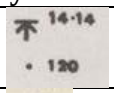
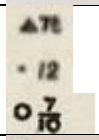
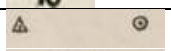
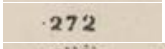
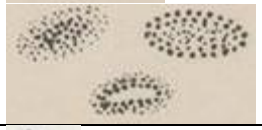
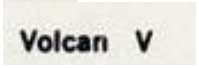
Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	 Churches Rest Houses Cotton Halagas Cemeteries: Christian Cemeteries: Mohammedan Cemeteries: Jewish Mosques Markets Wind mills
GSGS 4076 (Ed - Dèffa)	 House masonry, wooden, Hut Mosque Sheik's tomb with building Sheik's tomb without building synagogue Cemetery: Christian, Jewish Cemetery: Moslem Churches or chapels Important antiquities: ruins Ruins of ancient castle Cave dwelling Grain store Electric power station; factory Battlefield
G.S.G.S. 4226 (Zarzis)	 Permanent encampments Ruins Church Mosque Cemetery Fort

	 Windmill, watermill
Z621 (Ruanda-Urundi)	 Capital of mandated territory  Chief town of district  Important native town usually chief town of a territorial subdivision  Native town of secondary importance  Small native village  Catholic mission  Small catholic mission  Protestant mission  Small Protestant mission  Farm or plantation with name of owner, or farm name  Individual houses, (native huts)  Camp, possibly a native town  Large farm or native settlement  Lodging
G.S.G.S. 3980 (Zuara)	 Houses masonry, wooden, Hut  Occasional camping ground  Mosque  Sheik's tomb with building  Sheik's tomb without building  Cemetery; Christian, Jewesh  Cemetery, Moslem  Churches or chapels  Important antiquities; ruins  Ruins of ancient castle  Cave dwelling  Grain store  Electric power station; factory

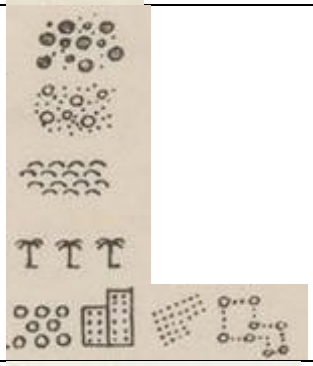
Appendix D4: Boundary symbols

Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	 Mundiriya (province) boundaries Markaz boundaries Governorate boundaries House Tax boundaries Village boundaries Cultivation limits
GSGS 4076 (Ed - Dèffa)	 State boundary Province boundary District boundary Walls with mortar Walls without mortar Palisade, hedge, wire fence Limit of wood, cultivation
G.S.G.S. 4226 (Zarzis)	 State boundary
Z621 (Ruanda-Urundi)	 Boundary of mandated territory with numbered stations Boundary of mandated territory Boundary of mandated territory District boundary Boundary of minor civil divisions Boundary of national park
G.S.G.S. 3980 (Zuara)	 State boundary Province boundary District boundary

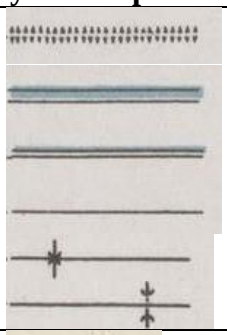
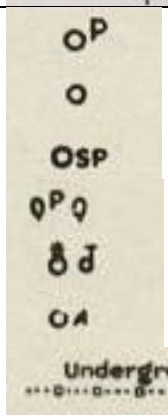
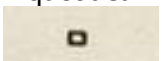
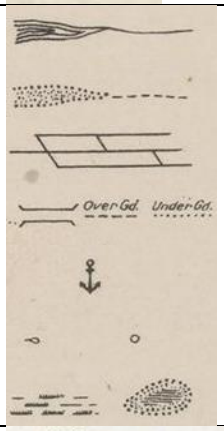
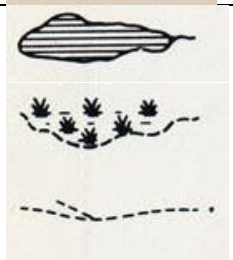
Appendix D5: Relief symbols

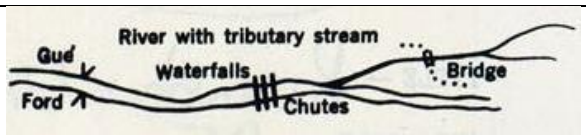
Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	 Bench Marks with Altitude Spot Heights
GSGS 4076 (Ed - Dèffa)	 Trigonometrical point Spot height Depth of water and of well
G.S.G.S. 4226 (Zarzis)	 Trigonometrical point  Height in meters  Depression, usually with vegetation Sand Dunes
Z621 (Ruanda-Urundi)	 Primary triangulation point (named) with elevation in meters  Secondary triangulation point with elevation in meters  Depth in meters, in a lake  Spot elevation in meters  Followed by name of mountain, indicates volcano  Lava flows
G.S.G.S. 3980 (Zuara)	 Depth of Water and of well.  Trigonometrical point  Spot Height

Appendix D6: Vegetation symbols

Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	None
GSGS 4076 (Ed - Dèffa)	 Plantations Palms Olives Citrus Eucalyptus Vines Acacia Thorny bush on dunes
G.S.G.S. 4226 (Zarzis)	 Wood Scrub Cacrus Psalms Cultivation
Z621 (Ruanda-Urundi)	 Forest clumps scattered through the savanna Types of dense forest cover Dense forest growths
G.S.G.S. 3980 (Zuara)	 Plantations Psalms Olives Citrus Eucalyptus Vines Acacia Thorny bush on dunes

Appendix D7: Hydrographic symbols

Map series	Symbol representation and description
G.S.G.S. 4085 (Benha)	 Banks Canals and drains over 20 meters wide Canals and drains from 5 to 20 meters Canals and drains from 2.5 to 5 meters Pipes or aqueducts over canals Pipes or syphons under canals
GSGS 4076 (Ed - Dèffa)	 Well, perennial Well, non perennial Well, perennial but brackish Springs, perennial, and non-perennial Well with windpump, waterwheel Well, dry  Aqueduct  Cistern
G.S.G.S. 4226 (Zarzis)	 River, perennial River, non-perennial Canal, irrigation Aqueduct. Water conduit Head of navigation Spring, well Marsh, Salt lagoons
Z621 (Ruanda-Urundi)	 Lake Swamp Unsurveyed stream

	 River with tributary stream
G.S.G.S. 3980 (Zuara)	 Springs, perennial, and non-perennial  Well, perennial  Well, non perennial  Well, perennial but brackish  Springs, perennial, and non-perennial  Well with windpump, waterwheel  Well, dry  Aqueduct  Cistern