MASTERARBEIT

Titel der Masterarbeit

„Topographic Maps from Open Data"

Making High Quality Topographic Maps
in a Scale of 1:50.000 from Open Data

Verfasser

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Table of Contents

Index of Figures

Index of Tables

Abstract

The emergence of open data, that can be used to make maps, present new possibilities for the field of cartography. The aim of the thesis is to prove that topographic maps can be made from open data. The approach taken is twofold; on the one hand, literature is reviewed covering the topics of map making, open data and topographic cartography; on the other hand, a practical example is conducted. Maperitive, a map renderer, is used to produce topographic maps in a scale of 1:50.000. For this purpose, the style of the Austrian topographic map series is reproduced and then applied to OpenStreetMap data, as well as to elevation data from Viewfinder Panoramas and SRTM. The resulting maps are compared to print maps of the Austrian national topographic map series 1:50.000. The conclusion is that it is possible to make topographic maps from open data, but with a number of exceptions regarding the map quality.

Kurzfassung

Das Aufkommen von offenen Daten, die für die Kartenherstellung benutzt werden können, stellt neue Möglichkeiten für die Kartographie dar. Das Ziel dieser Arbeit ist es zu beweisen, dass topographische Karten aus offenen Daten hergestellt werden können. Dafür wird einerseits Literatur zu den Themen Kartenherstellung, offene Daten und topographische Kartographie untersucht und andererseits ein praktisches Beispiel ausgearbeitet. Um topographische Karten im Maßstab 1:50.000 herzustellen, wird eine Kartenrendering-Software namens Maperitive benutzt. Im Beispiel wird der Kartenstil der österreichischen topographischen Karte reproduziert und auf OpenStreetMap, Viewfinder Panoramas und SRTM Daten angewandt. Anschließend werden die Ergebnisse mit Druckkarten des österreichisch topographischem Kartenwerks 1:50.000 verglichen. Das Fazit dieser Arbeit ist, dass die Herstellung topographischer Karten aus offenen Daten möglich ist, wenn auch nicht die Qualität der Vergleichskarten erreicht wird.

Disclaimer

OpenStreetMap is *open data*, licensed under the Open Data Commons Open Database License (ODbL).

ASTER GDEM is a product of METI and NASA.

EU-DEM data and layers - Produced using Copernicus data and information funded by the European Union.

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1   Introduction

1.1   Motivation

One of the most recent developments in cartography has been the democratization of maps, map making and geo-information. There are a number of reasons for this. One reason is the development of the internet and the web. They have enabled maps to be transmitted very easily to anybody who has access to the internet. Another important factor was the development of maps designed for the web, as well as web mapping applications to view the maps. The most common example is Google Maps, which has become ubiquitous on the web and for many people has become a synonym for map. Yet another reason has been the development of devices, which can connect to the internet from multiple locations and can consume digital media, such as smart phones, tablet computers, laptops. Besides digital maps, analog maps are now more attainable than ever, due to online shopping possibilities and well developed delivery logistics. This means that no matter what medium a person prefers, maps are more affordable and accessible than ever before.

The democratization of maps and the adoption of new technologies have impacted cartography and maps in a number of ways. First of all maps themselves have changed, from being primarily static representation of the Earth to dynamic representations. This has changed how users interact with maps, as well as their expectations of maps and map usability. Users now expect to be able to pan and zoom the map, and even to change the layers or data that are being visualized. For cartographers, this means that the definition of a map, and its purpose, have become blurred. Cartographic techniques, principles and knowhow have always adapted to new technologies and tools. One problem with the democratization of map making is, that nowadays many of the people making maps are not trained cartographers. Instead map makers today might be graphic designers, hobby cartographers, or anybody else. This has lead to very creative maps and map-like products, but it has also led to large differences in the quality of maps and mapping applications. This is important because maps have power and can be used for misinformation. In this sense cartographers have a duty, as experts in the area, to set and then uphold standards in map making and to teach others their know-how and best practices. In order to give knowledge, cartographers must first get acquainted with the tools and data used to make maps.

Today, cartographic tools are usually some kind of software run on computers. Cartographic tools come in a wide range of complexities, from all-in-one GIS to small applications to import data into a database. Many of the tools available have been developed as open source projects. Some others have been developed as proprietary software by universities and government institutions and have retroactively been released to the public. Many of the tools are now at a very mature point of development and

compete with commercial mapping solutions. The most recent developments in this area has been the integration of separate tools into technology stacks, as well as the development of standards and formats for data exchange and compatibility between the different tools. This all means that there are free-to-use tools covering the whole map making process.

There are a number of data sources available for making maps. The data itself comes from a number of places. A large part is from user generated data such as geotagged photographs or comments. Sometimes such data is collected without the knowledge of the user via smart phone applications. For cartographic purposes the largest and most mature project is OpenStreetMap, which strives to be a map of the world created by user generated data. Another important source of open data is open government data. This is data that for some reason or another is made freely available to the public by some government institution. In some countries Open Government Data (OGD) has a long history and in some others not, but it is becoming common for citizens to demand that their governments make data available. Usually this is on the grounds that, the data was created with resources paid for by tax money and should therefore be given back to the citizens who have paid taxes for it.

This brings us to the focus of the thesis. It strives to explore this democratization of maps and mapping. Furthermore, to examine how open data and open tools can be used by cartographers, both professional and layman, to make maps. More specifically, it focuses on topographic maps. It could have dealt with any other type, but topographic maps stand out for a number of reasons. They show the physical surface of the earth including natural and man-made objects. Topographic maps are characterized by excellent geometric accuracy, high detail and a high density of information. This means that the quality of topographic maps, both of the data used to create them, as well as the cartographic design is generally of high quality. And thus pose a high standard with which to measure maps made from open data and open tools.

With this motivation and context in mind we come to the guiding questions.

1.2 Guiding Questions

The main question being asked is:

– Is it possible to make high quality topographic maps from open data using open source or free-to-use tools?

In order to understand the question, it must be broken down into secondary questions:

– How are maps made?

– What is a topographic map?

- What are the basics of topographic design and how are they applied in a digital map production process?

- What does "open" mean?

- What is open data?

- What are open source tools?

- What open data is there?

- What tools can be used for cartographic purposes?

- How can the quality of a map be assessed, valued and interpreted?

1.3   Aim of the Thesis

The aim of the thesis is to investigate and try to answer the guiding questions. The questions will be addressed in a theoretical, as well as a practical manner.

The theoretic part consists of investigating, reviewing and summarizing relevant literature on the topics of cartographic theory, topographic maps and design, and the open movement. On the one hand this should answer some of the questions posed directly, on the other hand it should create a framework for practical examples.

The practical part of the thesis consists of an exemplary procedure with the goal of creating a topographic map in a scale of 1:50.000 using open data and open tools. In order to assess the quality of the data and tools used to create it, the map is compared to maps from the Austrian national map series 1:50.000. In order to compare the maps more accurately, the style of the Austrian map series is imitated as faithfully as possible. With this goal in mind the style of the Austrian maps is first analyzed from the point of view of cartographic design. For this purpose the map style is broken down into its constituent elements according to point, line and area symbols, as well as terrain representation and lettering.

2   Theoretical Framework

The purpose of the following chapter is to create a framework for the thesis by defining cartographic terms and positioning the thesis within the canon of cartographic theory. Nowadays, due to a number of reasons such as the adoption of new technologies or the shift in the needs and expectations of map users, the definitions of 'cartography' and 'map' have become blurred. According to a survey, carried out amongst experts in the field of cartography, there seems to be no agreement upon a definition as to the meaning of the terms 'cartography' and 'map', although most experts define cartography and maps along a number of common keywords [see KRA-14].

In *A Strategic Plan for the International Cartographic Association 2003-2011* the ICA provides a short and a long definition of the term cartography. The short definition is "The art, science and technology of making and using maps." [ICA-03, 17]. The long definition is "A unique facility for the creation and manipulation of visual or virtual representations of geospace – maps – to permit the exploration, analysis, understanding and communication of information about that space." [ICA-03, 17]. The document also defines the term 'map' as "A symbolised representation of a geographical reality, representing selected features and characteristics, resulting from the creative effort of its author's execution of choices, that is designed for use when spatial relationships are of primary relevance." [ICA-03, 17].

This thesis is based on these definitions as well as the concepts and definitions of the cartographic communication model. A cartographic model can be understood as a composition of concepts and terms used to describe the domain and purpose of cartography, as well as the processes and parts of which it is composed.

2.1   Cartographic Communication Model

The cartographic communication model revolves around the concept of a 'map'. The model defines maps and mapping as a means of interaction between a map maker and a map user. The map maker is the sender, and the map user is the receiver of cartographic information. The map artifact can be considered the communication medium. Furthermore, the cartographic information is encoded by means of cartographic language. The following sections explain these concepts more thoroughly.

2.1.1   *Cartographic Communication*

Briefly put, the cartographic communication model describes maps and map making as a series of model transformations. There are two principal actors, the map maker and the map reader, as well as cartographic language, which act as a common code between the

two actors. In Figure 1, Koláčný introduces his seven principal factors in the communication process:

"U_1 - reality (the universe) represented as seen by the cartographer;
S_1 - the subject representing reality, *i.e.* the cartographer;
L - cartographic language as a system of map symbols and rules for their use;
M - the product of cartography, *i.e.* the map;
S_2 - the subject consuming the map, *i.e.* the map user;
U_2 - reality (the universe) as seen by the map user; and
I_C - cartographic information." [KOL-69, 48]
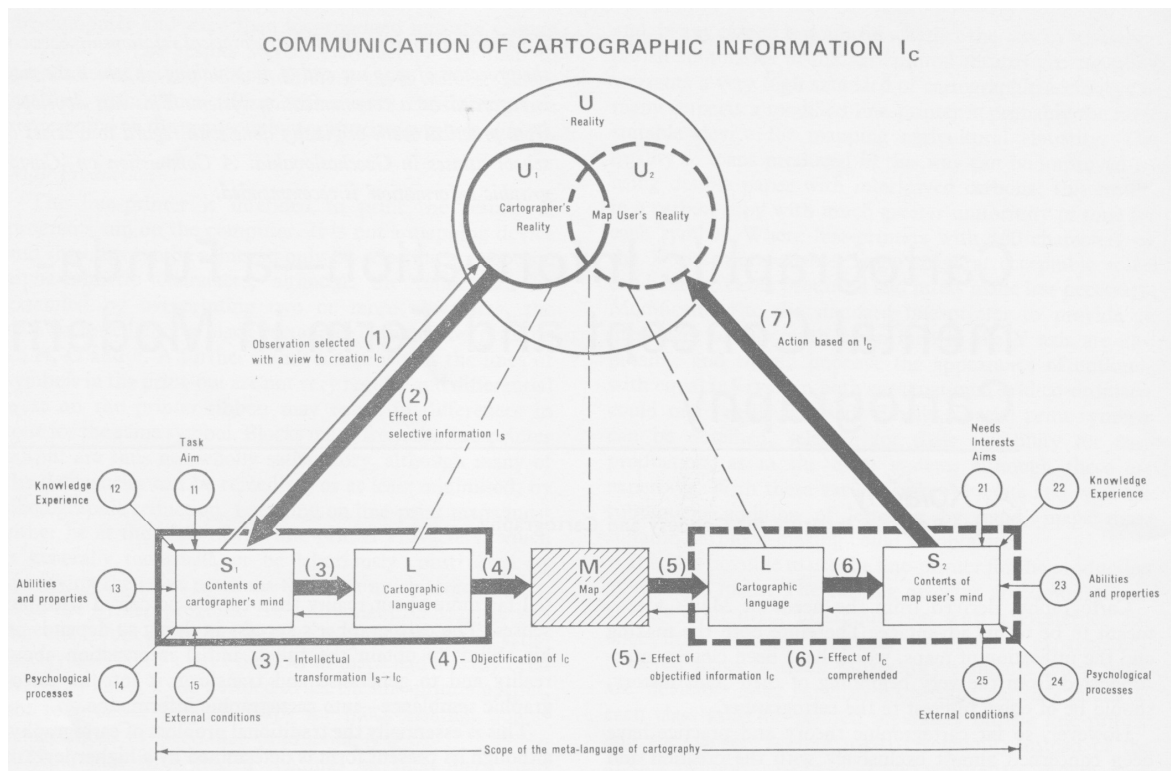
Figure 1: Communication of cartographic information according to Koláčný. [KOL-69].

A simplified description of the cartographic communication process is:

- The cartographer observes the universe or some model describing the universe and constructs a multi-dimensional mental-model of the universe. This mental-model is selective, due to the fact that it depends on the knowledge of the cartographer as well as his intent and purpose.

- In the next step, the selective multi-dimensional mental-model is transformed into a two-dimensional cartographic model. The main catalyst for the transformative process is cartographic language.

- The cartographic model is objectified by the use of graphic symbols. Then, it is part of a map object (artifact).

- The map user, who has knowledge of the cartographic language, reads the map and recreates the multi-dimensional model of the universe from the cartographic model. He integrates the cartographer's model with his own mental-model of the universe.

- The reality of the map user is enriched and expanded. He has obtained new knowledge, which affects his way of seeing the universe, as well as his actions therein.

2.1.2 Cartographic Information

Cartographic communication serves to transmit cartographic information, which, according to Koláčný, is: "The keyword and central concept of this entire process is 'cartographic information', that is the intrinsic content, meaning and sense of the cartographic portrayal of reality, as distinct from 'map content', which is a sum of graphic elements, perceived by our senses." [KOL-69, 49].

Koláčný further refines the concept of cartographic information with the following words: "It follows that every piece of cartographic information has a definite informational quantity (the quantity of information it conveys) and a definite informational quality (the meaning of the information). Cartographic information can be of a scientific, technical or economic nature. As to its thematic content, it can be topographical, geographical, geological, historical, *etc*. Depending on its purport, it can be popularising, educational, directive, *etc*." [KOL-69, 49]

In *A Strategic Plan for the International Cartographic Association 2003-2011* of the ICA, two terms are defined that are used more commonly nowadays and that roughly correspond to the concepts of cartographic information as Koláčný describes. The first is cartographic visualization, which is "defined as a map-related graphical procedure for the investigation of geospatial data and information." [ICA-03, 17]. The second is geographic/geospatial information, which is defined as "information about objects or phenomena that can be related to a location on the Earth. Objects and phenomena can be modeled as discrete objects of fields. Discrete objects are typically presented as point, line or polygon type presentations, while phenomena are often modeled as fields, either showing continuous or classified values of a function." [ICA-03, 17]. It appears that nowadays the term 'cartographic' refers mainly to the visualization of information, that is a graphical representation, instead of the information per se, which is referred to as geographical or geospatial information.

2.1.3 Cartographic Language

Cartographic language refers to the encoding of cartographic information by means of graphic symbols, as well as the rules and guidelines that govern the use of such symbols. Both sides of the communication process must have knowledge of the cartographic language in order to communicate cartographic information. The map maker, in order to encode information, and the map reader, in order to decode that information. The ability to read and draw cartographic symbols is called cartographic literacy and can be acquired by learning and practice.

Cartosemiotics is the branch of cartography that studies cartographic symbols. It distinguishes between three dimensions of a symbol: [see HAK-02, 10ff]

- The *semantic* dimension deals with the relationship between a symbol and the object that it refers to. In other words, semantics deals with the meaning of a symbol.

- The *syntactic* dimension deals with the formal properties of a symbol as well as the relationship between a symbol and other symbols. To put it differently, it deals with the form or appearance of symbols.

- The *pragmatic* dimension deals with the relationship of the symbol to the symbol-using agent. That is to say, it deals with the perception of cartographic symbols, as well as any actions that are triggered as a consequence of that perception.

2.1.4 Map Use

Map use refers to the action of decoding cartographic information, which leads to changes in the mental model of the map reader, and furthermore, changes actions taken on account of the new mental model. There are different ways to gain information from maps, the principal one is map reading, which means directly decoding cartographic language and gaining the information directly. Besides map reading, other actions permit users to derive or infer additional information; these actions are cartometry and map interpretation. Cartometry refers to measuring geometric attributes of objects on maps, such as a street's length or a building's area. Map interpretation is a process in which a map user applies his own knowledge to the map reading process in order to infer additional information from a map.

Additionally, maps are usually used with a specific aim or purpose in mind. In other words, they play a specific role or function. We can identify the following functions of map use [see BOL-01, 453]:

- orientation and navigation in a spatial environment,

- gaining information and knowledge about a spatial area,

- measuring, analyzing and checking information,

- learning with the help of spatial information, and

- documenting and archiving spatial insights and knowledge.

2.1.5   *Map Effectiveness*

Map effectiveness is the optimized communication of cartographic information with the goal of achieving the best possible transfer of information quality and quantity. As we can see in Figure 2, it is at the intersection between map making and map use. Map effectiveness can be increased in a number of ways, such as increasing cartographic literacy, applying cartographic design to map making, generalizing information properly, increasing information density on a map, and emphasizing visual clarity. Generally speaking, map makers who have studied map usage will be more effective at making maps and, vice versa, a map user with knowledge of map making will be more effective at retrieving information.
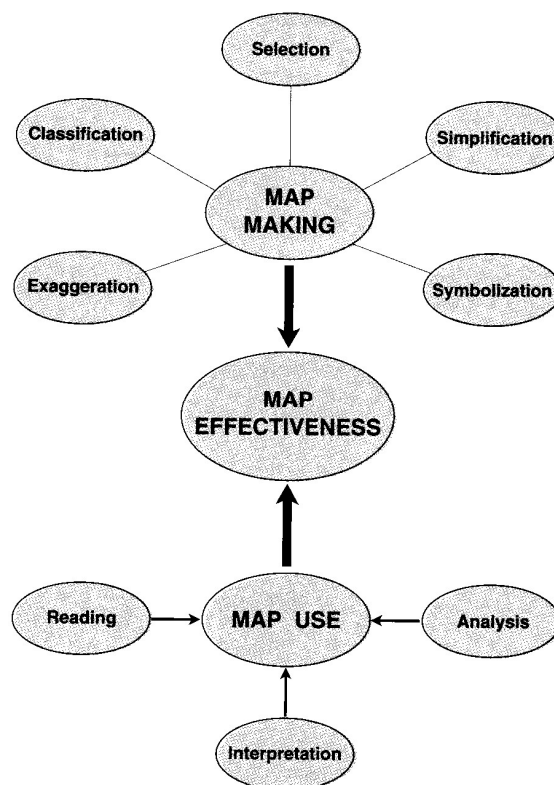
Figure 2: Map effectiveness. From [ROB-95, 17].

2.2   Map Production

Map production is a central process in the cartographic communication model and is the main activity of the map maker. In the scope of this thesis the terms map making, mapping, and map creation are synonyms for map production. Because there are many ways to produce a map, it is not possible to describe a 'one size fits all' process of map production. Nevertheless, the process can be broken down into generalized steps or phases, that are generic enough to apply to most map making endeavors.

Map production can be divided into two parts, a theoretical-conceptual part and a practical-technical part. The theoretical-conceptual part is responsible for the conception and design of a map, whereas the practical-technical part is tasked with carrying out the conceptual map design. Both parts mutually affect each other. For example, the available technical equipment dictates the scope of design; on the other hand, the conceptual design must consider if the desired graphics are technically executable. [see HAK-02, 105]

The following are definitions of some concepts that are integral for map production. These are cartographic design, generalization, mapping constraints, and conventions and principles.

2.2.1   Cartographic Design

Cartographic design is an ambiguous term. For example, Tyner states that "When we speak of map design there are two meanings: *layout* of design elements and *planning* the map. Layout involves decisions such as 'Where should I place the title, where should the legend and scale go?'; in art, this is called *composition*. Design in the sense of planning begins before a single line is drawn and includes deciding what information will be included and choosing a projection, the scale, and the type of symbols. It is at the heart of the map creation process." [TYN-10, 18]. Another example is from Robinson, "The word 'design' is used both as a verb and a noun. To avoid confusion, therefore, we must distinguish between design as a process and design as product." [ROB-95, 317].

In this thesis, cartographic design refers to the planning of the map production process. The following terms are not synonyms for cartographic design:

- Cartographic symbolization. Symbolization is an activity in which "cartographers use graphic marks to encode the information for visualization. This process of graphically coding information and placing it into a map context is called symbolization." [ROB-95, 451].

- Map style. This refers to the look and feel or overall appearance of a map.

- Map layout or map composition, which refers to the positioning of map elements relative to one another and to the medium.

Cartographic design is an important part of the theoretical-conceptual part of map production. It is a decision process, which seeks to maximize map effectiveness and quality by planning the map and the map production process. An important characteristic of cartographic design is that, "Design is a holistic process; language is a linear process. Although I can identify certain steps that must be taken in mapmaking, they are not necessarily followed in a specific order, and, in fact, several may be taken simultaneously."[TYN-10, 18]. In this sense cartographic design is about optimizing individual steps in relation to all the other steps and to the overall map goals, as well as to the needs of the map user.

2.2.2 Generalization

"Generalization refers to the selection, simplification, and even symbolization of detail according to the purpose and scale of the map." [TYN-10, 82]

"Generalization is the process of reducing the information content of maps due to scale change, map purpose, intended audience, and/or technical constraints." [SLO-05, 104]

Generalization is necessary because maps portray reality at a reduced scale. The smaller the scale of the map, the greater amount of generalization that is necessary. "Generalization is required on all maps. While it is limiting to some degree, it should not be viewed as a negative factor. Generalization enhances the communicativeness of maps because it permits the subject of the map to stand out. It is not desirable to show everything on a map; to do so would merely result in visual clutter." [TYN-10, 82]

Generalization has a number of external factors which guide its application. Tyner [see TYN-10, 87ff] calls them governing factors and lists them as topic and purpose, scale of the map, reader's abilities, cartographer's equipment and skills, as well as quality and type of data. In contrast, Robinson [see ROB-95, 458ff] calls the external factors the controls of generalization and list them as map purpose, conditions of use, map scale, quality and quantity of data, and finally graphic limits. Note that these external factors are identical to the map constraints in 2.2.3.

We can distinguish between survey generalization, model generalization, and cartographic generalization. Survey generalization takes place in the field while collecting data. The result of survey generalization is a (digital) object model. Model generalization refers to the operations applied to simplifying one (digital) object model to produce another (digital) object model of lesser semantic and geometric detail. Finally, cartographic generalization is applied to either a (digital) object model or to a cartographic model and results in a cartographic model. Cartographic generalization is strongly tied to cartographic symbolization. [see HAK-02, 168]

Generalization can also be distinguished according to the property of the object being generalized. We can distinguish between geometric (spatial-oriented), semantic (thematic-

oriented), and temporal (time-oriented) generalization. An example for geometric generalization, is the displacement of a feature. An instance of semantic generalization is, the classification of pine, cypress, and oak trees as a general class called forest. Temporal generalization could be grouping events by century or by decade, for example. [see HAK-02, 168ff]

Table 1: Elementary procedures of generalization according to Hake/Grünreich/Meng. Translated from German by Author [HAK-02, 169].

Generalization consists of various procedures. The terms methods, operations, or techniques are used synonymously to refer to these procedures. In Table 1 we can see elementary procedures of generalization according to Hake [see HAK-02, 169].

Although generalization is central to cartography, cartographic experts cannot agree on all of the procedures of generalization, as can be seen in Table 2.

Generally speaking, there are two ways to apply generalization procedures: by intuition (usually by cartographic experts), or according to generalization rules. Traditionally, both

methods are applied simultaneously by cartographers. For instance, a cartographer generalizes according to generalization tables (rules) but is free to apply the specific procedures as he sees fit (intuition). In modern cartography there has been a departure from this traditional approach towards rule based generalization. Mainly, this is because generalization rules can be automated with computer programs. This leads to standardized and uniform generalization results, as well as lower costs and shorter production times, but often also results in lesser visual quality. Rules are derived from an expert's intuition, as well as from maps that have been generalized properly. [see HAK-02 , 172]

Table 2: Operations of generalization according to various authors. From [TYN-10, 84].

Raisz	Robinson	Dent	Krygier & Wood	Slocum/Thibault	Buttenfield/McMaster	Tyner
	Selection	Selection	Selection		Selection	Selection
Simplification	Simplification	Simplification	Simplification	Simplification	Simplification	Simplification
	Classification	Classification				Classification
	Symbolization	Symbolization	Dimension conversion			Symbolizing
	Exaggeration		Enhancement	Exaggeration	Exaggeration	Exaggeration
			Displacement	Displacement	Displacement	Displacement
	Collapsing[a]			Collapse		
	Typification[a]					
Combination	Aggregation[a]			Aggregation	Combination	Grouping
Omission	Elimination[a]				Omission	
	Smoothing[a]	Smoothing		Smoothing		
				Merging		
				Amalgamation		
	Induction					
				Enhancement		
					Masking	
				Refinement	Emphasis	

[a]Robinson considers these subsets of selection, simplification, and exaggeration.

2.2.3 Constraints

A constraint is "something that limits your freedom to do what you want" [MAC-02, 292]. This can be seen as both positive and negative. Negative, because it restricts the potential decisions to choose from, and positive, because it removes potential decisions which are not adequate. With this in mind, constraints increase map effectiveness, since they eliminate potential decisions that would lead to a suboptimal map.

Constraints are hard to classify, as they can affect any step of the map production process. Furthermore, each map production process can have completely different constraints. Nonetheless, following are some examples of constraints. This list is not exhaustive and not structured in any specific way.

- Technical Constraints - printer resolution in dpi, software availability.

- Map reader constraints - color blindness, blindness, cartographic literacy.

- Medium constraints - paper quality, screen dimensions, color system, interactivity.

- Map maker constraints- cartographic expertise, ability with tools, drawing ability.

- Data constraints - copyright, completeness, correctness, accuracy, integration.

- Time constraints

- Financial constraints

Often constraints are dependent on more than one factor. For example, the minimal graphic dimensions are dependent on the map reader's perceptive abilities, the mapping technology employed, the medium used, and the environmental circumstances. Table 3 shows the minimal graphical dimension for a print map, also considering the map reader has perfect vision, is viewing the map from a normal distance and the lighting is good.

Table 3: Minimal graphical dimensions for a print map according to Hake. Translated from German by the author. [HAK-02, 110].

Minimal Graphical Dimensions	Small Figure			Line		Area	
	Point	Circle Square full / hollow	Letter Number	Width	Space between thin lines thick lines	Individual extent	Space between small area large area
Description			Aa9				
Value in mm	0,25	0,5 0,6 / 0,5 0,6	0,6	0,05	Maximum contrast: Black-White depiction		
					0,25 / 0,15	0,3 / 0,3	0,20 / 0,15
	0,45	0,7 1,0 / 0,7 1.0	1,0	0,08	Minimal contrast: Color print, colored background		
					0,20 / 0,30	0,4 / 0,4	0,25 / 0,20

2.2.4 Conventions and Principles

A convention is "a way of writing, painting, etc. that is accepted as the usual or right way" [MAC-02, 300]. In a cartographic context, the *Multilingual Dictionary of Technical Terms in Cartography* provides a definition of cartographic convention, that, although somewhat dated, still holds true, it is, a "Practice, based on custom or agreement, for Cartographic Representation."[ICA-73, 69]. Conventions can be considered rules for producing and designing effective maps. Not following conventions can confuse or irritate map users. An example of a convention is using the color blue to represent water features or the shades of green and brown for vegetation and land use.

A principle is "a basic belief, theory, or rule that has a major influence on the way in which something is done" [MAC-02, 1100]. In contrast with constraints, principles are less binding. We can think of principles as a guideline to good map production and cartographic design. Due to its holistic nature, cartographic design benefits greatly from principles. Some principles are adapted to cartography from other disciplines, such as graphic design, perceptual psychology, and process engineering. The following is a citation from Buckley describing design principles:

> "Cartographers apply many design principles when compiling their maps and constructing page layouts. Five of the main design principles are legibility, visual contrast, figure-ground, hierarchical organization, and balance. Together these form a system for seeing and understanding the relative importance of the content in the map and on the page. Without these, map-based communication will fail. Together visual contrast and legibility provide the basis for seeing the contents on the map. Figure-ground, hierarchical organization, and balance lead the map reader through the contents to determine the importance of things and ultimately find patterns. ... It's worth noting that these principles are not applied in isolation but instead are complementary to each other. Collectively they help cartographers create maps that successfully communicate geographic information." [BUC-11]

Conventions and principles have a long tradition in cartography. For example, Medyńska-Gulij states, "Without doubt, the creation of rules of map design concerning composition, contrast, levels of perception and - last but not least - pattern variants should be attributed to cartographers from the Low Countries, from the *Thetrum Orbis Terrarum* to the *Atlas Maior*." [MED-11].

3   Topographic Maps

The purpose of this chapter is to define topographic maps and to reduce the scope of the theoretical framework from in the previous chapter. This chapter then builds upon the definitions of the previous chapter but goes into more detail on the specific map type that will be produced in the practical part of this thesis.

There are a number of reasons for choosing topographic maps. First, topographic maps, especially those made by state mapping agencies generally are of high quality. Second, they usually have a high information density as well as a large variety of map content. Thirdly, they are a common map type and are a generally well known type of map. And finally, there is open data available for making topographic maps.

There is no single answer to the question of what a topographic map is. Indeed they can be defined along a number of criteria such as map content or map scale. The following chapter examines some definitions of the term, before following a systematic approach to classifying topographic maps topographic maps on the basis of the following criteria proposed by Arnberger and Kretschmer [see ARN-75, 60]:

- Representation concept (map, cartogram, pictorial map)

- Represented location (town, sea, moon)

- Map subject (cadastre map, geologic map)

- Map scale (divided into scale groups)

- Publisher or producer (national mapping agency, private mapping organization, cartographic publishing house)

- Specific purpose (school wall map, tourist hiking map)

3.1   Definitions

Wiktionary defines the etymology of topography as "From Middle English *topographye*, from Latin *topographia*, from Ancient Greek τοπογραφία (topographia), from τόπος (topos, 'place') + γράφω (graphō, 'I write')." [WIK-13]

Today the term itself is commonplace and can be found in most dictionaries. For example, the Macmillan English Dictionary has the following entry on topography, "topography / noun / 1 the features of a particular area of land: *the topography of Mars*. 2 the study of the features of land, for example hills, rivers, and roads, and the process of making maps. - topographical / adj" [MAC-02, 1494].

The Multilingual Dictionary of Technical Terms in Cartography describes a topographic map as "A map whose principal purpose is to portray and identify the features of the Earth's surface as faithfully as possible within the limitations imposed by scale." [ICA-73, 278].

Last, but not least, we can find the following entry in Elements of Cartography: "Large-scale general reference maps of land areas are called topographic maps. They are usually made by public agencies, using photogrammetric methods, and are issued in series of individual sheets."[ROB-95, 13]

3.2   Map Elements

Map elements are the distinct parts that make up a map. The layout of map elements can also be referred to as map composition. Following is a list of map elements usually found on topographic maps. Additionally, in Figure 3 we can see examples of map elements taken from the North Vancouver topographic map produced by Natural Resources Canada. Note that not all of the elements listed here must appear on every map.

- − Map Face | The map face contains the cartographic representation or map contents. In other words it contains the map itself.

- − Title and Subtitle | Name of the map. Topographic maps are usually named after the largest or most important settlement in the area. If the area is sparsely populated it is also usual to find maps named after national parks, regions or important landscape objects, such as mountain ranges, peaks, or forests.

- − Map Series Information | Information on the map series, such as its identification code and the name of the map series.

- − Legend | The legend explains the symbols used in the map contents. It lists the symbols together with a description of their meaning.

- − Glossary of terms | A glossary of terms is a translation of terms and is typical for multilingual maps. The glossary is often integrated in the legend.

- − Map Scale | Describes the relationship between reality and the map. It can be represented as a numerical value, usually in the format M = map : nature = 1 : m. 'm' is called the scale value. It can also be visualized as a scale bar, which consists of a line subdivided into sections of round values. The map scale often includes the contour interval value.

- − Direction or Orientation or North Arrow | Every map is drawn according to an orientation, following modern convention towards the north. This element indicates the orientation, for example, by indicating the map north, magnetic north, geographic north, and the magnetic declination.

NORTH VANCOUVER

New Westminster Land District

British Columbia / Colombie-Britannique

[Title, Subtitle]

Produced on October 29, 2010, by the Centre for Topographic Information, Natural Resources Canada in partnership with Geo BC.

[Map producer]

49°45'			
	92-G/12	92-G/11	92-G/10
49°30'			
	92-G/5	92-G/6	92-G/7
49°15'			
	92-G/4	92-G/3	92-G/2
49°00'			
124°00'	123°30'	123°00'	122°30'

92-G/6

SCALE / ÉCHELLE **1:50 000**

EDITION / ÉDITION **07**   VERSION **03**

SERIES / SÉRIE **A721**

[Map series information]

Railway, abandoned; railway yard
Chemin de fer, abandonné; gare de triage

Rapid transit: rail; road; footbridge
Transport rapide : voie ferrée; route; passerelle

Lookout; historic site; ruins; zoo
Belvédère; lieu historique; ruines; zoo

Golf course; campground; ski area; sportsplex
Terrain de golf; terrain de camping; station de ski; centre sportif

[Legend]

Scale **1:50 000** Échelle

1 centimetre on the map represents 500 metres on the ground   1 centimètre sur la carte représente 500 mètres au sol
Contour Interval: 20 metres   **Équidistance des courbes : 20 mètres**
Elevations in metres above Mean Sea Level   Altitudes en mètres au-dessus du niveau moyen de la mer

[Map scale]

Transverse Mercator Projection
Projection transverse de Mercator
North American Datum 1983
Système de référence nord-américain 1983

1000 metre Universal Transverse Mercator Grid   Grid Zone Designation
Zone 10   **10U**
Quadrillage universel transverse de Mercator de 1000 mètres   Désignation de la zone du quadrillage

A tutorial on how to estimate position from the UTM grid can be found at: *http://maps.NRCan.gc.ca/topo101*

Map content validity dates
· Road network, 1987 - 2008
· Hydrographic network, 1987 - 2006
· Vegetation, 2000
· Buildings, 1986 - 2008
· Boundaries, 2004 - 2009
· Toponymy, 2004 - 2009

Detailed metadata can be found at: http://GeoGratis.gc.ca

For corrections, additions or comments concerning the content of this map, please contact Natural Resources Canada at: *topo.maps@NRCan.gc.ca*
Visit our Web site: *http://maps.NRCan.gc.ca*

© 2010. Her Majesty the Queen in Right of Canada.

This map is not to be used for air or marine navigation.

[Auxiliary map]   **[Reference System]**   **[Sources information]**
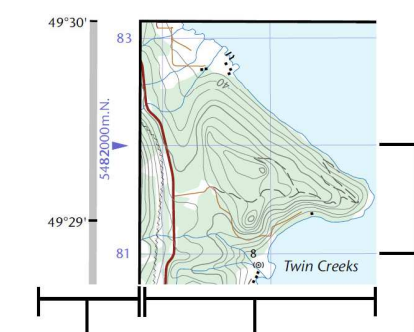
Use diagram only to obtain numeric values
Approximate Mean Declination 2010 for centre of map
Annual change decreasing 12.2'

N'utiliser le diagramme que pour obtenir les valeurs numériques
Déclinaison moyenne approximative au centre de la carte en 2010
Variation annuelle décroissante 12.2'

For magnetic declination information, visit: *http://gsc.NRCan.gc.ca/geomag*
Pour information sur la déclinaison magnétique, visitez : *http://cgc.RNCan.gc.ca/geomag*

17°37' (308 mils)
0°11' (3 mils)

Grid North-Nord du quadrillage
True North-Nord géographique
Magnetic North-Nord magnétique

Twin Creeks

[Border]   **[Map face]**   **[Gridlines]**   **[Orientation]**

Figure 3: Map elements. Details from the North Vancouver (92-G/6) topographic map produced by Natural Resources Canada. [NRC-10]

– Border | The border separates the map face from the other map elements. Normally it also includes the coordinate values for the gridlines, numbers and letters in case of a search grid, plus information about the connecting maps.

– Grid or Graticule | The gridlines represent geodetic or geographic coordinates with constant values.

– Sources and Production Information | Information about the data used to produce the map, as well as how the map was produced. It also includes the actuality of the data.

– Reference System | Information on the reference system, map projection, and datum.

– Map Producer | Information about the cartographer, issuer, publisher, mapping agency, and/or editor.

– Auxiliary Maps | Additional maps of a smaller size which display information that does not fit in the map contents or is of another nature. For example inset maps, locator maps, index maps. Scale does not have to be the same as the main map.

– Slope Guide | The slope guide indicates the slope value according to the distance between contour lines. Slope values usually range from 0° to 90°.

3.3 Represented Location
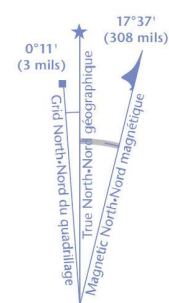
Topographic maps made by national mapping agencies are usually published as a map series. A map series is a map that is divided into several sheets according to a map sheet division system and a numbering and naming system. Mainly, this is because the national mapping agencies must map an entire national territory in a given scale and, as a result, printing the map in its entirety would lead to a map several meters across. In order to avoid such an impractical object, the map is divided into separate sheets. All sheets in a map series are characterized by a common spatial reference system, map scale, and cartographic representation. Figure 4 is a map representing an overview of the map sheet division system used by the Austrian 1:50.000 map series. [see HAK-02, 29]

Individual topographic maps often focus on an area of special interest, such as a national park or military training area, or a geographic area, such as a glacier, valley, mountain, tidal flat, or city. Topographic maps do not always have to refer to Earth; they can also refer other celestial bodies, such as the moon or mars.
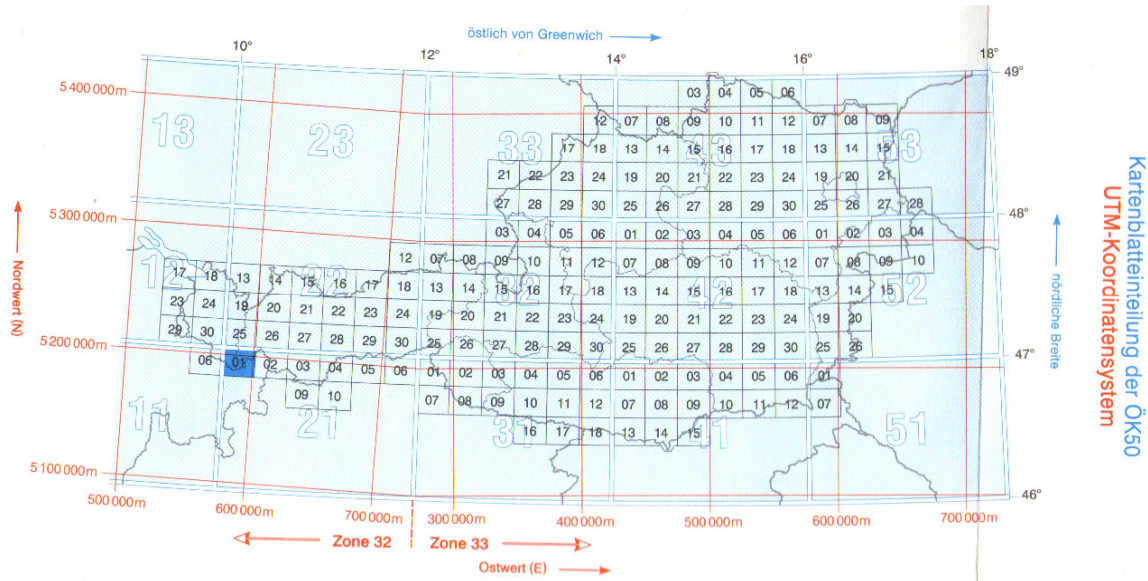
Figure 4: Overview map of the map sheet division system of the Austrian topographic map series 1:50.000. From [BEV-07].

3.4 Map Subject

The map subject is defined as "The features and phenomena selected for representation to achieve the purpose of a map." [ICA-73, 124]. The subject should not be confused with map content, which is the graphical representation of the subject. The subject of topographic maps are the features of the Earth's (or any other celestial body's) surface.

The features of the Earth's surface are usually grouped according to common object properties or thematic characteristics. A common way to group them is into settlements, transportation network, bodies of water, land cover, singular objects, terrain, toponymy, and thematic information.

3.4.1 Settlements

Settlements refer to buildings or built up areas. Settlements comprise any number of man-made structures such as houses, housing complexes, castles, palaces, hospitals, barracks, monasteries, tollhouse, cottages, hotels, motels, restaurants, religious buildings, factories, refineries, power plants, dockyards, and mining plants.

The generalization of settlements leads to three characteristic types of representation. In large scale maps buildings are represented individually in a planimetric manner. As the map scale is reduced, buildings are aggregated and represented as built-up areas. Further reduction in scale means that buildings and built-up areas are no longer identifiable. As a result the geometric dimension is collapsed and the settlements are represented as point

symbols. Two thematic characteristics, building height and/or type, are sometimes indicated in large scale maps by graphical variation of the fill or color. [see HAK-02, 418ff]

3.4.2 Transportation Network

Transportation features are structures that allow the movement of vehicles and people, or the flow of goods. Instances of transportation features are roads, motorways, bridleways, bike paths, trails, footpaths, railways, shipping lanes, tarmac, bridges, tunnels, aqueducts, oil and gas pipelines, and electricity lines. They are characterized by the width of the feature, the construction and structure type, and the type of objects transported by the feature.

Transportation network features are predominantly of a linear nature. Operations of generalization commonly applied to transportation features are selection, smoothing, exaggeration (widening), and displacement. Thematic properties, such as importance, administrative classification or load capacity, are often emphasized by use of color, lettering, or symbols. Due to exaggeration, the width of a feature in the map is many times greater than its actual width. [see HAK-02, 422f]

3.4.3 Bodies of Water

Bodies of water are surfaces which are permanently or temporarily covered by water. We can distinguish between stationary and flowing, as well as between artificial (man-made) and natural bodies of water. Additionally, objects that are bound to waterbodies, such as weirs and jetties, are sometimes included as well. Some examples of water features are lakes, seas, rivers, canals, streams, irrigation canals, reservoirs, springs, currents, rapids, and wells.

Linear water features are represented either by parallel lines or by the feature's center line. Area water features are visualized by their shoreline and fill color. Objects that are bound to waterbodies are shown in a planimetric manner or as point symbols. Water features make extensive use of the color blue. Common operations of generalization include selection, exaggeration, and smoothing of linear features, as well as collapsing, simplification, and smoothing of shorelines and area features. Lettering relating to water features is customarily blue and slanted to the right. [see HAK-02, 423f]

3.4.4 Land Cover

Land cover describes area features. The term refers either to the substrate of the surface (i.e. sand, asphalt, grass, or trees), or to complex spatial structures (i.e. landscapes such as

forests, gardens, swamps, vineyards, or cemeteries). Furthermore, land cover can be distinguished into natural and man-made features. Land cover is not the same as land use, which is a thematic property and describes the type of utilization by man. Land cover is represented in maps by fill textures, patterns, or colors. [see HAK-02, 424f]

3.4.5   Singular Objects

Singular objects are features which are characterized by having an exceptional topographic or thematic importance and by the fact that their geographic scope is very small. Because of their limited geometric extent, they are drawn as point or line symbols. Some examples of singular objects are churches, transmission masts, monuments, towers, ruins, way crosses, wind turbines, mines, lighthouses, fences, and walls. Visually, these features are represented in a planimetric manner at large scales, and as a result of the reduction of scale, they are commonly represented by point symbols. It is very common for singular objects to be displayed in a pictorial manner. [see HAK-02, 425f]

3.4.6   Terrain

Terrain refers to "the configuration and quality of the Earth's surface."[ICA-73, 118]. To put it another way, terrain is the boundary surface between solid ground (lithosphere), air (atmosphere), and bodies of water (hydrosphere). For the most part, the surface is smooth, but in reality, it has points of discontinuity, that is to say, the change in elevation from one point to another is so abrupt, that it tears the surface forming breaks and interruptions. This poses a problem for the modeling and for the representation of the terrain. For this reason, it is practical to separate terrain into two facets, relief, i.e. the smooth surface, and landforms, i.e. the breaks and interruptions. [see HAK-02, 426]

Relief is a term used to describe the quantitative measurement of the surface elevation, as well as the depiction thereof. Geometrically, the relief is a volume and is customarily described in terms of elevation, slope (steepness), and aspect (orientation). Elevation being defined as "The vertical distance above a datum; on Hydrographic Charts, the datum is usually mean high water spring tides; on land maps, it is commonly mean sea level."[ICA-73, 127]. Common methods of portraying the relief are isarithms (contour lines and hypsometric tints), shading (hill shading), hachures, and pictorial profiles.

Bathymetry is the term used for underwater relief. However, it is not measured in elevation, but in depth. Depth is the vertical distance below the water surface. Bathymetry can be, but does not necessarily have to be, included in topographic maps. The most common method of displaying bathymetry is by isarithms.

Landforms are points of discontinuity of the surface, more specifically breaks or interruptions in elevation. They can be considered discrete features which are distinct from neighboring features and the relief. Geometrically, they are usually linear or extensive

features which have a strong change in elevation within a small space. Landforms are not accurately represented by the methods of depicting relief. We can distinguish between major and minor landforms, although the transition between the two is seamless. Instances of major landforms are mountains, valleys, hills, bays, and so on. Minor landforms are, for example, embankments, escarpments, cliffs, caves, berms, ridges, mounds, small depressions, cones, dunes, eskers, and rocks. [see HAK-02, 431]

The terrain is represented in different ways depending on the map scale. [see HAK-02, 434]

- Large scale: contour lines and minor landforms.

- Middle scale: contour lines, relief shading (hill shading), and minor landforms.

- Small scale: hypsometric tints and/or relief shading (hill shading).

3.4.7 *Toponymy*

Toponymy is the study of place names. Place names cannot be represented by graphics and instead are represented by lettering in conjunction with the graphic symbols of the object they are describing. Toponymy plays an explicative role as well as greatly adding to the content and detail of a map. In topographic maps, place names are most commonly used in conjunction with settlements, bodies of water, landforms, and singular objects.

A major concern of toponymy is the spelling of place names. Spelling problems can occur from a number of reasons. Places can be renamed, mainly because of administrative changes or political motivations. Furthermore, most place names are spelled differently in different languages. Besides that, place names are distinguished into endonyms and exonyms. An endonym is a place name within a country in the language of the country. An exonym is the name of a place in a country in a foreign language. For example, "München" is an endonym and "Munich" is the English exonym. Finally, place names in foreign languages sometimes do not use the same alphabet. In this case, spelling is either written in the foreign alphabet, and/or it can be adapted to the map alphabet by transcription or transliteration. Transcription is a conversion according to the phonetics of the place name. Transliteration is a conversion of one script to another, for example from Cyrillic to Latin. For character based languages such as Chinese and Japanese, transcription is the only option. [see HAK-02, 434ff]

3.4.8 *Thematic Information*

Additional thematic information is sometimes added to topographic maps. Thematic information has already been mentioned in the other map feature groups, for example,

building type or administrative classification of transportation networks. Additionally, there are often features which do not fit into the other feature groups, for example:

- Boundaries, such as administrative boundaries or boundaries of managed land.

- Routes, for example hiking routes, public transport routes, or scenic routes.

- Touristic information, for instance tourist attractions.

3.5 Map Scale

Topographic maps are customarily classified into map scale groups, which are defined by scale ranges. There is no absolute agreement between cartographic experts on scale groups or the ranges of specific groups. In other words, the thresholds between scale groups should be considered flexible. The following classification is based on Hake [see HAK-02, 417] and Arnberger [see ARN-75, 44-56].

3.5.1 Topographic Basic Mapping and Plans

The map scale is 1:15.000 or larger, with common map scales of 1:1.000, 1:5.000 and 1:10.000. They are usually the largest scale maps produced and are characterized by planimetric representation. Basic mapping is the result of topographical survey work and is commonly used for detail planning, such as analysis of urban areas, or as a base map for city plans. Most maps in smaller scales are derived from basic mapping through cartographic generalization.

3.5.2 Topographic Maps

The map scale lies between 1:10.000 and 1:100.000. Though maps in scales of 1:25.000, 1:50.000, and 1:75.000 are the most common. They are normally derived by generalizing basic mapping. Topographic maps are characterized by a generalized planimetric representation and a widespread use of color. Generalization of the map features becomes necessary because around the scale of 1:25.000-1:50.000 the exact depiction of discrete objects is no longer possible. This is because the symbols would be under the minimum size which human eyesight can perceive. In order to prevent this from affecting the readability, the objects are enlarged so that the visual hierarchy between objects is maintained.

3.5.3   Topographic Overview Maps

This group lies between the map scales of 1:100.000 and 1:500.000. These maps are usually derived from either of the previous two categories through cartographic generalization and are characterized by sacrificing geometrical and positional accuracy in order to visualize larger areas or regions. Furthermore, the features are aggregated into more general classes, for example different types of forested areas can be grouped into a single forest class. Smaller features are no longer depicted. These maps are often used for the purposes of spatial planning, education, administration, national defense and as base maps for the depiction of geoscientific topics.

3.5.4   General Reference Maps

These maps usually have a scale of 1:300.000 or smaller. They sacrifice detail and precise depictions of the terrain in exchange for clear representations of geographical relationships. These maps are characterized by a low density of information, depiction of major features only, and a simplified depiction of the terrain or landform. Visually, these maps appear to consist of a network of nodes (cities) and connectors (highways) overlaid upon a physical map of the earth. Some examples are geographic maps, chorographic maps or physical maps. Some maps with a scale up to 1:10mio are commonly called regional or country maps and those with a smaller scale are called continental or earth maps.

3.6   Topographic Map Production

In Chapter 2.2 map production was already described in a general fashion. Here the process is further investigated with an emphasis on topographic map production. Due to advances in technology, the map making process is constantly changing. During the 20th century the predominant approach to making topographic maps was as follows:

> "In the original 7.5-minute topographic mapping program (circa 1945 - 1992), the USGS contracted aerial photography and sent government employees to the field to survey the map area. Field crews established horizontal and vertical control, located and classified cultural features, located permanent survey markers, hiked wilderness trails, classified natural features such as streams and swamps, collected boundary information from state and local governments, and investigated geographic names by interviewing local residents. This field intelligence, including heavily annotated aerial photographs, was returned to the regional mapping centers and compiled into standard maps. Control was added using aero triangulation, contours were manually compiled from stereo aerial photography, almost all text was placed by hand, almost all lines were drawn by hand, and manuscripts would typically go through at least four edit cycles before being approved for publication." [MOO-11]

The mapping process just described was time consuming and expensive. The time period from project planning to map printing was about five years and meant that the data represented on the maps was, at the time of publishing, already outdated [see MOO-11]. The cycle time, that is, the time in which the whole map series was renewed, was fairly long in relation to the area mapped. Additionally, most mapping agencies divided the area to be mapped into different sections, which were then mapped consecutively. This meant that maps of the same series but from different areas could be two or more years apart in their publication date. These disadvantages prompted cartographers to look for cheaper and faster ways to make maps.

Perhaps the most important technology to affect cartography recently, has been the computer. At first, computers were only used to assist cartography and replace individual steps in the production process, but nowadays computers are so widespread, that computers have replaced most of the traditional map making tools. In fact, the use of computers has become indispensible for modern map making. Nowadays, an important goal is to automate as much of the process as possible, in order to reduce costs and improve the speed of map production. Another trend is reusing data for multiple maps by automating the generalization processes. The new mission could succinctly be explained as:

> "Vector data workflows can be implemented in many different ways but most national mapping agencies and commercial mapping companies have a strategic goal of using a common database and common environment for all map publishing, and a 'capture once and use many times' ethos." [NEU-06, 234]
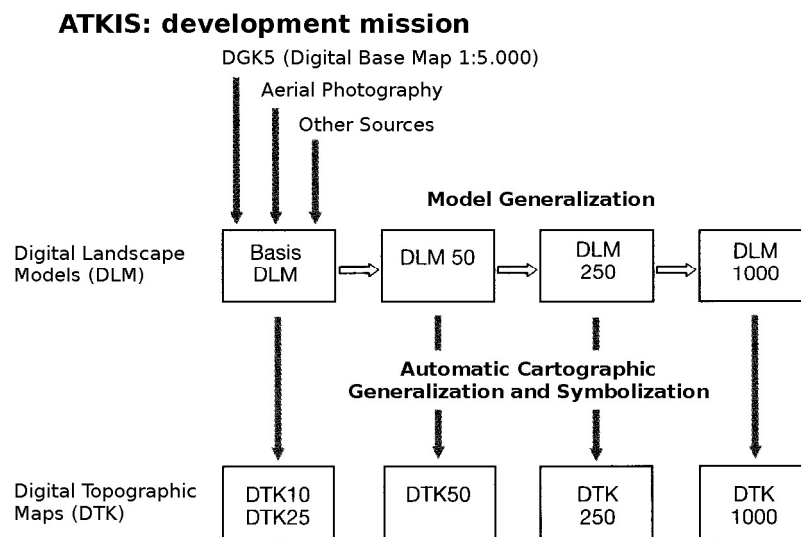

Figure 5: ATKIS, development mission. From [HAK-02, 413].

An example of a modern map production process is ATKIS, the official German topographic-cartographic information system. A simple schematic representation can be

seen in Figure 5. The basic component is the base DLM, a digital landscape model derived from different sources, such as digital scans of older topographic maps, aerial photogrammetry, and digital elevation models. Model generalization is applied to this base DLM to derive further models of reduced scale. In a next step cartographic generalization and symbolization is applied automatically on the DLMs to create digital topographic models. These topographic models are then prepared for dissemination via web or print. [see HAK-02, 410ff]

The main challenge in this process is the automation of generalization, which "encompasses both 'model generalization'(deriving the landscape model features at coarser resolution by selection, aggregation and simplification), and 'cartographic generalization'(deriving visually appropriate features by applying displacement, exaggeration and typification), taking into account symbolization widths and sizes." [NEU-06, 240]

3.7   Map Purpose

The wide range of information provided by topographic maps make them extremely useful for both professional and recreational users alike. For instance, they are used in the fields of education, geography, architecture and landscape planning, civil engineering, mining, energy exploration, natural resource conservation, environmental monitoring, environmental management, public works and urban development planning, as well as for outdoors and recreational activities such as orienteering, hiking, biking, geo-caching, mountaineering, or skiing.

The map purpose influences the map production. This is especially true for the medium used to disseminate the map, the map subject, and the cartographic representation.

Due to the explosion of digital devices, maps can be consumed in a large amount of media than never before. Digital maps have already replaced print maps as the main dissemination medium. This does not mean that print maps will disappear, indeed there are specific cases in which a print map is superior than a digital map, for example on expeditions or in places without access to electricity for powering devices.

Depending on the purpose, the subject of a topographic map can change. This is especially true for thematic information. Generally speaking, it is the amount of thematic information and perhaps more important the emphasis placed on this information that distinguishes topographic maps from thematic maps. But the distinction between topographic maps and thematic maps has become more difficult with the rise of digital maps. Briefly stated:

> "In a digital environment the differentiation between a topographic and a thematic map is less relevant, a topographic map would be a combination of separate road and railway layers, a settlement layer, hydrography, a contour lines layer, a geographical names layer and a land cover layer. Each of these layers would be a thematic layer in itself, and a combination of layers, in which

each data category had the same visual weight, would be a topographic map. If one category were to be emphasized or highlighted, and the others thereby relegated to the status of ground, then it would again change into a thematic map." [KEN-09]

4   Cartographic Representation of 1:50.000 Topographic Maps

This chapter examines the cartographic representation of topographic maps. The term cartographic representation in the context of this thesis is to be understood as a synonym for cartographic language, as it is defined in the part on the cartographic communication model. In this sense it refers to the encoding of cartographic information by means of graphic symbols, as well as the rules and guidelines that govern the use of such symbols. Another term that is often used is that of map style. A map style is a well defined and distinct cartographic representation and is usually used to refer to the cartographic representation found on a specific map or that is common for a map series.

The goal of this thesis is to produce a topographic map and assess the quality thereof. One way of assessing the quality is to take the result and compare it against another map. This thesis uses open data as the cartographic information and applies a cartographic representation that emulates the map style of a topographic map series, the Austrian topographic map series. In order to compare the two maps both maps should have a similar map style. There are two main reasons for this. One is to be able to assess the quality of the underlying data, and the second reason is to analyze in how far the map production tools used in the thesis are able to reproduce the map style of a particular topographic map series.

These goals make it necessary to take a look and describe the map style of at least one topographic map series. The following chapter describes the map styles of three topographic map series by separating the symbols used and displaying them in comparative tables. The idea is to compare different topographic map styles in order to see how they represent the information. One map style was then picked to be used in the practical example, the Austrian one.

In order to keep the scope of the thesis to an acceptable level it is sensible to focus on a specific map scale. This thesis focuses on the scale of 1:50.000. There are a number of reasons for choosing this scale. One reason is that the data used to make the map must be of a large resolution, detailed and of high quality. Another reason is, because it is a common map scale for topographic maps. In fact, most national mapping agencies produce topographic maps with this scale. A final reason is, to a certain degree, this scale normally requires both model generalization and cartographic generalization. In comparison to larger scale maps, they require more generalization, and in comparison to smaller scale maps, they usually require less generalization.

This chapter also includes some general theory on topographic representation. The chapter start by analyzing the map features according to their symbol type: point, line, and area. It then focuses on special cases as found on topographic maps, the depiction of settlements, lettering, and the terrain.

4.1 Description of the Topographic Maps Series Analyzed

The goal was to choose various maps with distinct symbolization, preferably from different cartographic traditions. The main constraints in choosing the maps where,

- availability, printed maps preferred, then digital maps available online,

- scale restricted to 1:50.000,

- preferably made by modern map making processes,

- actuality, i.e. preferably maps ten years old or less.

4.1.1 Land Information New Zealand

Land Information New Zealand (LINZ) is a New Zealand government department formed in 1996 after the restructuring of other government agencies, especially the Department of Survey and Land Information (DOSLI). Besides activities such as geodetic and cadastral surveys, and managing hydrographic information, LINZ is responsible for national topographic mapping in New Zealand.

LINZ produces the Topo50 and Topo250 topographic map series as well as maps in smaller scales, such as 1:500,000, 1:1,000,000, 1:2,000,000, 1:3,000,000, 1:4,000,000. They also make 1:25,000 and 1:50,000 maps of the Antarctic and many neighboring islands. The maps are available printed from retailers or for download via Internet as TIFF and GeoTIFF files. Additionally, the topographic data files are also freely available for download in Shapefile and IFF format. The maps are based on the New Zealand Geodetic Datum 2000 (NZGD2000) datum and the New Zealand Transverse Mercator 2000 projection, both of which correspond with international standards, such as those used by GPS. [see LIN-14]

4.1.2 Natural Resources Canada

Natural Resources Canada is a Department of the Government of Canada created from other governmental organizations in 1995. Among its many responsibilities is the creation and maintenance of the National Topographic System.

The National Topographic System consists of topographic maps series in scales of 1:50.000 and 1:250.000. The maps are produced by the Centre for Topographic Information and map coverage extends to all of Canada. There are many services available through the New GeoGratis Web portal [see GEO-14], such as CanMatrix, digital topographic raster maps made from scanned federal-government topographic maps, and

CanVec digital topographic vector maps. CanTopo is the newest generation of topographic maps. It is a multi-source digital cartographic product created from the Cartographic Data Base, which gets its data from the GeoBase initiative. The CanTopo maps are available in raster or vector formats and comply with international geomatics standards. They are based on the Universal Transversal Mercator System (UTM) and the North American Datum 1983 (NAD83). [see NRC-14]

4.1.3 Austrian Map

The Austrian map 1:50.000 is produced by the Federal Office of Metrology and Surveying (*Bundesamt für Eich- und Vermessungswesen*, BEV) in cooperation with the Institute for Military Geosciences (*Institut für Militärisches Geowesen*, IMG). The BEV also produce topographic maps in scales of 1:25.000, 1:200.000, and 1:500.000.
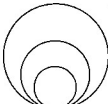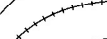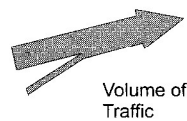
The maps are based on the Universal Transversal Mercator System (UTM) and the European Terrestrial Reference System 1989 (ETRS89). The maps are based on the cartographic model 1:50.000, a digital topographic model made from a digital landscape model and a digital elevation model. They also offer Austrian Map online (AMAP), a web-based map viewer of the digital cartographic models. [see BEV-14]

4.2 Theory of Cartographic Representation

Cartographic representation is defined as the "Graphic representation, in map form, of features or phenomena on the Earth, or other celestial body, or in Space."[ICA-73, 256]. The main graphic representations used to visualize features on a map are cartographic symbols. A cartographic symbol is "a letter, character or other graphic device representing some feature, quality or characteristic on a map."[ICA-73, 88].

The process of creating and employing these symbols to represent features on a map is called symbolization. "Symbolization begins with stylizing, or typifying, attribute values. The symbolization process includes selecting the level of measurement (nominal, ordinal, interval, or ratio) to use in the feature's visualization. It also includes choosing the dimensionality of the feature (point, line, area, or volume). All features exist in a combination of these two aspects. And all features can be mapped in a combination of these two aspects. The way features exist and the way they are mapped need not be the same." [ROB-95, 475]. Table 4 shows graphic examples of features by dimension and level of measurement. On a two dimensional map volume can only be represented by point, line, or area graphic symbols, for example the relief is commonly depicted by contour lines. Instead of referring to level of measurement, some authors distinguish between qualitative and quantitative features or attributes. Qualitative corresponds to nominal measurement and quantitative corresponds to ordinal, interval, and ratio measurements.

Table 4: Classification of geographic data. From [TYN-10, 136].

	Nominal Measurement	Ordinal Measurement	Interval/Ratio
POINT SYMBOLS	□ Building ○ City △ Mountain	○ Village ○ Town ○ City	Population 1,000,000 500,000 250,000
LINE SYMBOLS	Road Railroad Trail	Heavy-Duty Road Medium-Duty Road Light-Duty Road	Volume of Traffic
AREA / VOLUME SYMBOLS	Grassland Orchard	High-Density Medium-Density Low-Density	Population Per Sq. Mi. 100 25 0

The appearance of point, line, and area symbols can be further differentiated by means of graphic variables, also called visual variables. The variables were originally proposed by Jacques Bertin in 1983. Since then other authors have elaborated on the variables, as we can see in Table 5. [see TYN-10, 136ff]. Table 6 shows the graphic variables according to Kraak and Ormeling.

Table 5: Graphic variables by author. From [TYN-10, 137].

Dent et al.	Kraak & Ormeling	Krygier & Wood	MacEachren	Monmonier	Slocum et al.	Tyner
Size	Size	Size	Size	Size	Size	Size
Shape	Shape	Shape	Shape	Shape	Shape	Shape
Hue	Hue	Hue	Hue	Hue	Hue	Hue
Lightness/ value	Value	Value	Value	Value	Lightness	Lightness
Texture	Texture	Texture	Texture	Texture		Texture
Orientation	Orientation		Orientation	Orientation	Orientation	Orientation
Saturation/ intensity		Intensity	Saturation		Saturation	Saturation
Arrangement			Arrangement		Arrangement	Arrangement (pattern)
Focus			Focus			
					Spacing	
					Perspective Height	

Table 6: The visual variables of symbols. From [KRA-96, 110f].

differences in:	symbols		
	point	line	area
size			
value			
grain			
colour			
orientation			
shape			

The shape (or form) variable can be further subdivided into four types as shown in Table 7. The first type is called pictorial, representational, or mimetic. Pictorial symbols usually consist of a simplified image of the phenomenon they are meant to represent. Depending on the perspective of the image we can distinguish between plan, profile and oblique pictorial symbols. The second type is called symbolic, associative, or semi-mimetic. The shape of symbolic symbols only suggests the phenomena they represent. The third type is called geometric or abstract. The shape of the symbols has no relation to the shape of the phenomena, instead they are constructed from geometric shapes or abstract graphics. The fourth type is constituted by letters, numbers, and underlines. These are not suited for displaying a feature's location and are therefore usually employed in conjunction with other graphic marks. [see HAK-02, 210ff, as well as TYN-10, 137f]

Table 7: Form variable by dimension. From [HAK-02, 122].

Form		Dimension		
		Point	Line	Area
Pictorial	Plan	▣ ∏ ⌣	⊞⊞⊞⊞ —☐—☐—☐—☐—	❁❁ ❁❁ ❁❁ ⠿
	Profile	🏠 🗼 ⛺	🌳🌳🌳🌳🌳🌳	Λ Λ 🌲🌲
	Oblique	📦 🏛	🌉	📚
Symbolic		⚒ ⚓ ⚛	🚶🚶-----🚲 → ➤	+ +
Geometric		▲ ○ ✪	─·─·─·─·─· ━ ━ ━ ━ ━ ━	⸺ ⸺ ⸺ ⸺ ▦
Letter, Number, Underline		🅿 [Fe] ㉕	━━━━━━━━ ═ ═ ═ ═ ═ ═	*sL 3 Lö* *71 / 68*

In Table 8 we can see a summary of the appropriate uses of the visual variables for symbolization. Each visual variable is usually more adequate at representing either quantitative or qualitative features.

Table 8: Appropriate uses of the visual variables for symbolization. From [ROB-95, 491].

Feature Dimension	Level of Measurement	
	Nominal	Ordinal/Interval/Ratio
	Qualitative	Quantitative
Point	hue (color) shape *orientation*	size value (color) *chroma (color)*
Line	hue (color) shape *orientation*	size *value (color)* *chroma (color)*
Area	hue (color) shape *pattern* *orientation*	value (color) chroma (color) *size*
Volume	hue (color) shape *pattern* *orientation*	value (color) chroma (color) *size*

The visual variable in *italics* are of secondary importance.

4.3 Point Symbol

On topographic maps, point symbols are used to represent point, line, and area features, depending on the features extent and the map scale. During generalization, it is not unusual for line and area features to be reduced in dimension to point features or symbols. This means that the smaller the map scale, the more features are represented as point symbols.

Point symbols are included in the map contents depending on their relevance to the map purpose. It is therefore common for point symbols to be included, that would otherwise no longer be visible due to the minimal graphical dimensions. As a result, it is common for point symbols to be over emphasized and represented larger, in relation to the map scale, than they are in the environment.

On topographic maps, point symbols are used to represent the location of features and are typified and differentiated by visualizing non-spatial attributes. They are most commonly used to represent nominal (qualitative) attributes. There are exceptions, such as spot heights, which, customarily in conjunction with a height notation, display the ordinal value of elevation. With this in mind, the most important graphic variables employed are form and hue (color).

Table 9 shows a comparison of point symbols found on the Austrian, Canadian, and New Zealand topographic map series 1:50.000. The map series names are abbreviated by the country codes: Canada - CAN, New Zealand - NZL, Austria - AUT.

The following observations were made from the comparison of point symbols on topographic maps 1:50.000.

- Form is the most used graphic variable. Geometric and oblique symbols are hardly used. The most prolific types of form are associative and pictorial symbols, in plan or profile perspective.

- Three (color) hues are used. Most symbols are black. Blue is used for water features or features related to water. Red is used by a handful of signs, apparently to indicate heat (hot spring, fumarole) or danger (power station).

- The Canadian topographic map series has the largest amount of distinct symbols. This seems to be due to a greater emphasis on building use and water features.

- The Austrian topographic maps series displays more catholic features, such as wayside shrines, chapels, and crosses.

- There are some symbols, which could be considered line or area symbols instead of point symbols. For example breakwaters, jetties, piers, sports tracks, reservoirs, airfields.

Table 9: Point symbols comparison. Symbols taken from [BEV-11, LIN-11, NRC-10]

Features	CAN	NZL	AUT
Church		♦	♀ ♂
Chapel			♦
Religious building	♦		♂
Educational building	♦		
Hospital / Medical center	⊕ ⊕		
Senior citizens home	⊔		
City hall	🏛		
Municipal hall	🏛		
Courthouse	⊞		
Correctional institute	⊟		
Community center	⸬		
Fire station	⛊		
Police station	⛊		
Armory	⛊		
Customs post	⚒		
Ranger station	⚑		
Stockyard		⊞	
Glasshouse / Greenhouse		▭	
Cemetery	⊡	⌐+ + +⌐	⊡
Castle / Palace			♠ *Schl.*
Castle / Palace, small			⛫
Ruins	⚊		⌐
Hotel / Inn / Shelter	⊢⊣		↙
Alpine hut / Cabin	⌂		⊙
Power station	⚡		⌐° *Krw.*
Chimney / Flare stack	●		
Wind turbine	⟙	⟙	⟙
Transformer substation			⚡ ⟐
Transformer			⚡
Transmitting station	⟨⊙⟩		⟙
Radar antenna / Radio telescope	⟊		

Table 9 continued on the following page.

Table 9 continued from the previous page.

Features	CAN	NZL	AUT
Mine (underground, opencast)	⊾	◩ ⚒	⚒
Blast furnace			◇*HO*
Silo	◑		⊠
Grain elevator	⌂		
Water tank, tower	▮	○	⊓
Fire tower	⛫		
Oil tank / Gas tank	▮	○	⊖
Oil drill / Gas drill	⚚		◆
Factory with chimney			▬*Fb.*
Waste depot	Ⓓ		
Mill			✿
Sawmill			✿
Lumberyard	⊟		
Wayside shrine			⛾
Memorial tree			⛾ ⛾
Cross			†
Signpost / Plaque		★	ⴹ
Camping site	⅄		⅄
View tower	◨	▮	⊓
Mast		△	
Monument		▲	▫
Historic site	⬦	⊐ ⊠	
Lighthouse	✳	⛫	
Beacon	⊛	⋀	✳
Coast guard station	⚐		
Seaplane anchorage	⚲		
Marina	⚓		
Control tower	⧈		
Airfield	✈		
Helipad	Ⓗ	Ⓗ	

Table 9 continued on the following page.

Table 9 continued from the previous page.

Features	CAN	NZL	AUT
Ski jump			⊏
Ski slope	⚡		
Golf course	⚐	⚐	
Sportsplex	⊕		
Sports track	⬭	⬭	
Arena	⬟		
Zoo	☻		
Train station / platform	▬	●	*Bhf.* *Hst.*
Reservoir (open, covered)	▦ ▫	○ ○	▪ ▫
Spring (cold, warm)	●	× ×	⚘
Disappearing stream	↪	→	
Waterfall, rapids	≈	⊢⊢⊣	⊨ ⊬
Weir, sluice		+	⊢
Warf, jetty	⊤	⊤	⊿
Breakwater	⌐	⁄	
Pier, dock	⊤	⊬	
Dry dock	⊓		
Slip	⌐		
Dam	◢	◁	
Small dam	⚓		
Fish ladder	⊖		
Lock	⊸		
Floodgate		FG	⚡
Boat ramp	⌐	⚐	
Fumarole		×	
Shipwreck	⚓	⊿	

4.4 Line Symbol

Line symbols are used to depict linear and area features. When symbolizing elongated area features, such as rivers, normally either the centerline or the outline of the area feature is represented. For area features without an elongated form, normally only the outline is represented, as is the case with borders. In this last case, they fulfill an auxiliary role in facilitating the identification and spatial definition of area features, which are not easily depicted by other means.

Similar to point symbols, lines are also drawn according to their importance. For this reason, it is common for line symbols to be over emphasized and represented wider, in relation to the map scale, than they actually are. Additionally, line symbols, except rivers, commonly suffer from displacement due to generalization.
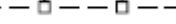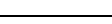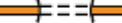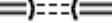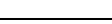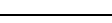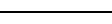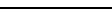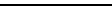
On topographic maps line symbols represent both qualitative and quantitative attributes. The most common quantitative attribute depicted is feature width. Form and color hue are used to differentiate quality and size is used to distinguish quantity or quality.

Table 10: Line symbol comparison. Symbols taken from [BEV-11, LIN-11, NRC-10]

Features	CAN	NZL	AUT
Normal Gauge - Multiple track			
Normal Gauge - Single Track			
Narrow gauge			
Railway yard			
Rapid transit			
Tramway			
Abandoned railway			
Fence			
Wall			
Power lines			
Power lines on poles			
Power lines submerged			
Pipeline oil			
Pipeline gas			
Pipeline multi			
Pipeline underground oil			

Table 10 continued on the following page.

Table 10 continued from the previous page.

Features	CAN	NZL	AUT
Pipeline underground gas			
Pipeline underground multi			
Telephone lines			
Cableway			
Gondola			
Chair lift			
Drag lift			
Goods cableway			
Bridge			
Footbridge			
Ford			
Tunnel			
Gallery			
Opening			
River, canal >20m			
River, canal >5m			
River, canal <5m			
River, stream intermittent			
Water conduit			
Water conduit underground			
Seawall, dike			

Following are some observations on Table 10, a comparison of line symbols found on the Austrian, Canadian, and New Zealand topographic map series 1:50.000.

- Form is widely used. The line features are symbolized by solid, dashed, or dotted lines and by repeating geometric or associative point symbols positioned at regular intervals along the line. Additionally some line symbols are composed of parallel lines, with or without a fill.

- The main color hue is black. Rivers and other water features are blue. Roads use yellow, orange, and red color hues in addition to black.

- Size is used to describe either feature width or the amount of lanes/tracks. Beyond a certain symbol width, the line symbols are eventually split into parallel lines.

- The Austrian topographic map series differentiates more types of aerialways. Furthermore, it does not include pipelines.

- Some symbols could be considered point symbols. For example, footbridges, bridges, or openings.

The different map series have distinct ways to classify and represent roads as is seen in Figure 6. All the map series use form to differentiate roads. In general they follow a similar hierarchy of importance from path to highway: dot > dash > solid line > parallel lines. Besides this they use distinct classification schemes. The New Zealand map series uses color fill between parallel lines to indicate road importance and the form of the color fill describes the road surface. Size (width) is used to symbolize number of lanes. The Austrian map series uses color fill between parallel lines to indicate road importance. Size (width) and form is used to symbolize road classes, which are classified by road width. The Canadian map series uses color to indicate road surface. Size (width) is used to indicate the number of lanes. In contrast to the other two map series, the Canadian series does not use parallel lines in its representation of roads.
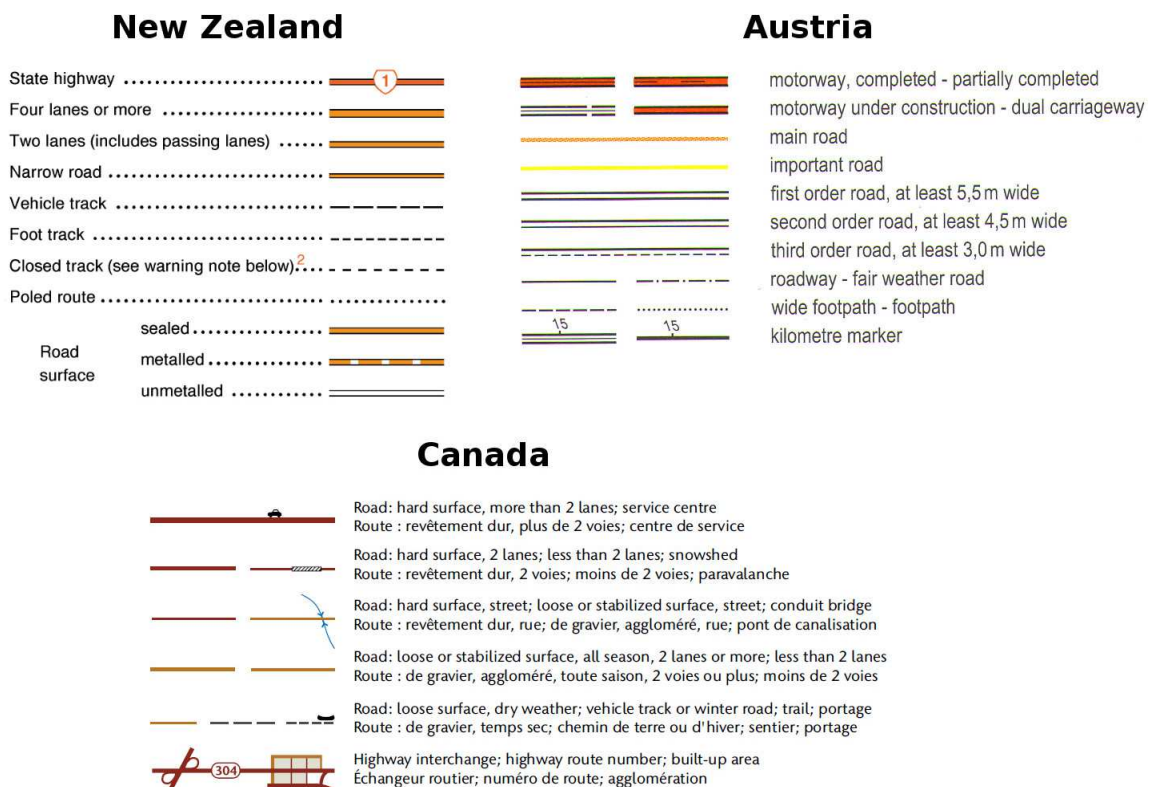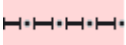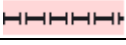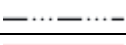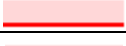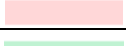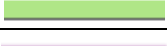
Figure 6: Roads and paths in 1:50.000 topographic map series. Symbols taken from [BEV-11, LIN-11, NRC-10]

The border symbols of the Austrian and Canadian series are shown in Table 11. The New Zealand map series does not include borders. Borders use variation of size and color hue to differentiate between type and importance. Many administrative border symbols consist of two superimposed lines, a wider colored background line and a thinner dashed, dotted, or solid black line in the foreground.

Table 11: Border comparison. Symbols taken from [BEV-11, NRC-10]

Features	CAN	Features	AUT
		Austrian Border	
International		International Border	
Provincial or Territorial		Federal State	
Unsurveyed Provincial			
Administrative		Verwaltungsbezirk (Admin)	
		Gemeinde (Admin)	
		Military area	
		Customs	
Recreational		National Park	
Geographic			

4.5 Area Symbol

Area symbols are used to represent area features. Area symbols are characterized by their fill and their borders, which can be depicted by line symbols. There are four types of fill:

- Pattern | points or lines spaced at regular intervals. Rarely used on topographic maps.

- Texture | geometric or schematic pictorial forms, placed at regular intervals. e.g. forest in New Zealand and Austrian maps.

- Structural | arranges textures in addition to other elements in non regular intervals to visualize the structure of a landform. e.g. swamp in Austrian map.

- Color | usually solid colors, but influenced by hill shading. Mainly used to distinguish qualitative features. Follow coloring conventions.

Table 12: Area symbol comparison. Symbols taken from [BEV-11, LIN-11, NRC-10]
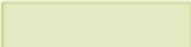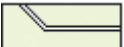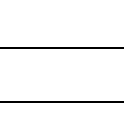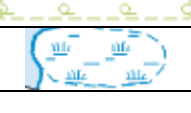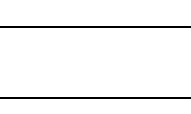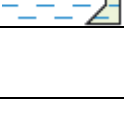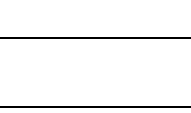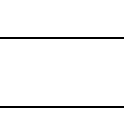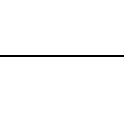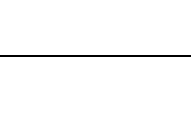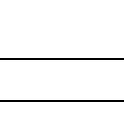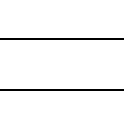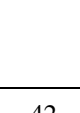
Features	CAN	NZL	AUT
Forest			
Exotic conifer			
Exotic non-conifer			
Mountain pine			
Scrub			
Scattered scrub			
Shelterbelt			
Trees			
Orchard			
Vineyard			
Hop garden			
Mangroves			
Swamp			
Marsh, wetlands			
Palsa bog			
String bog			
Tundra ponds			
Tundra polygons			
Sand			
Permanent snow/ice			
Waterbody			
Dry river bed			
Sand and mud			
Sand			
Intermittent lake			
Marine farm / Fish pound			

Table 12 shows the area symbols found on topographic maps of Canada, New Zealand, and Austria. The main observations are:

- The main color hues are browns, greens, blues, and black. Forest and other vegetation is colored in green tones. Blue is used for water features, as well as for ice and glaciers.

- Austria and New Zealand differentiate more types of forest than Canada.

- Canada depicts bogs and tundra.

4.6 Settlement

Each map series has a different way to represent map settlements. Figure 7 shows the way the different map series display settlements. The columns separate the map series and the rows show the density of the built-up area, from very dense in the top to sparse at the bottom. The images are not to scale, they are meant to show the visual style and the development of the cartographic representation.
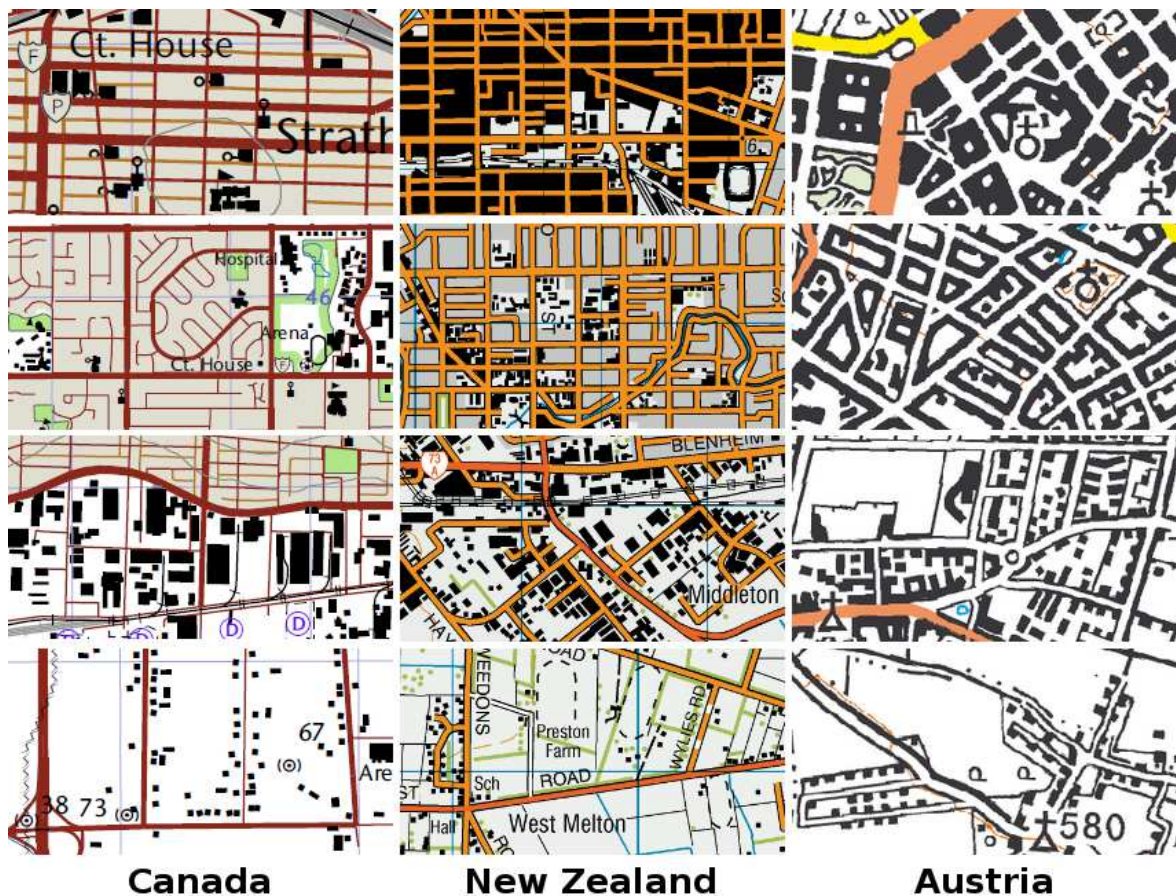
Figure 7: Comparison of settlements in 1:50.000 topographic map series.

The Canadian map series displays individual buildings in a planimetric manner and colored black. When the buildings become so dense that they form closed blocks, they are no longer displayed. Instead the representation changes to a gray color fill. Important buildings are drawn on top of the gray fill, as well as roads.

The New Zealand map series is similar to the Canadian, but with one exception. In very dense built-up areas the color fill is changed from gray to black. It is hard to identify whether this is due to the aggregation of buildings.

The Austrian map has a different approach to representing settlements. The most noticeable characteristic is that the black, parallel lines of the roads merge with the buildings. In dense built-up areas the roads seem to fade into the background and the emphasis shifts to the buildings. Generally, the visual weight of the individual features is more equal and results in a well integrated image. Important streets are easily noticeable by their color fill. The denser the buildings the more generalized they are.

4.7 Lettering

Lettering plays a vital descriptive role in maps. Lettering is inadequate for depicting location, but excellent at representing information that is unique to a specific feature and which cannot be easily grouped. For example, names cannot be represented by other graphic means, neither can height notations. Besides unique information, lettering can also be used to represent quantitative attributes by means of typographic variables. [see ARN-75, 214f]

On topographic maps, lettering is used to describe place names, generic names, abbreviations, and numerical values. It is seldom used as individual point symbols. [see HAK-02, 435f]

- Place names consist of the proper names of features, such as settlements, landforms (i.e. mountains, valleys, gorges, basins, islands), land cover areas (i.e. forest, heath), streets, bodies of water (i.e. rivers, lakes, coves, bays), and singular objects. Place names are unique to a feature.

- Generic names are shared among all features of the same type. For example, post office, national park, police station, and so on.

- Abbreviations are used in place of generic names and their main purpose is to disencumber the map. They should be explained in the legend.

- Numbers describe either spatial or non-spatial attributes. Common examples of spatial attributes are height notation on spot heights and contour lines, as well as kilometer markers on roads. Non-spatial information depicted by numbers is house and street numbering, for example.

4.7.1   Typographic Variables

"The variations in size, form, spacing, orientation, value, and color of type makes it useful as a symbol in establishing visual and conceptual hierarchies and differences in kind. Size, tonal value, and spacing can indicate importance, while color and form indicate differences in kind. Orientation can be used to indicate direction. Larger type and bolder type indicate importance, form, for example, roman or italic, and hue indicate differences such as roads or rivers. Textual hierarchy is also used for titles and subtitles." [TYN-10, 52f]. Figure 8 shows the visual variables according to Tyner.

Los Angeles Long Beach	Size	S i e r r a N e v a d a Signal Hill	Extent (letter spaced, normal)
Land *Water*	Form (Roman, Italic)	Los Angeles Long Beach	Extent (normal, condensed)
Los Angeles Long Beach	Form (type face)	Los Angeles Long Beach	Hue
Los Angeles Long Beach	Intensity (bold, normal)	Los Angeles Long Beach	Value
Los Angeles Long Beach	Value		

Figure 8: Variables of type according to Tyner. From [TYN-10, 148]

4.7.2   Lettering - Positioning
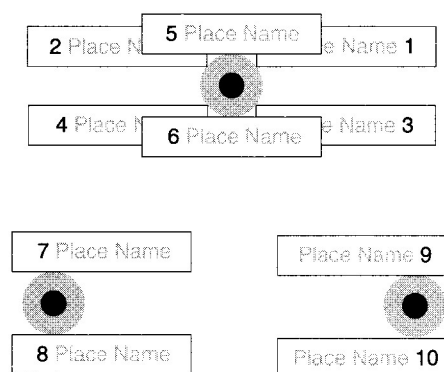
Figure 9: Lettering positioning in relation to a point feature. From [ROB-95, 419]

Lettering is inadequate for representing the location of phenomena, and is usually used to display non-spatial attributes, such as names. Therefore, it is commonly used in conjunction with other cartographic symbols. This allows for some freedom in its placement on a map. Lettering is placed in relation to the graphic symbols of the feature it is describing. For example, Figure 9 shows lettering positions in relation to a point feature.

When positioning lettering, one must always keep other features and lettering in mind, as well as the overall density of information.

There are no hard and fast rules for letter positioning, but there are conventions and guidelines. There are many guidelines and will not be covered here. For more information see Robinson [ROB-95, 416ff], Tyner [TYN-10, 46ff], and Arnberger [ARN-75, 344-350].

4.7.3   Comparison of Lettering on Topographic Maps

Table 13: Comparison of lettering on 1:50.000 topographic map series.

Settlements	CAN	Sans serif. Cities use capitals, have a larger spacing, and are larger. Neighborhoods use capitals, extra large size. Town and village mixed case, different sizes, usually small or medium, italic.
	NZL	Sans serif. Cities use a larger size, bold and all capitals. Towns are medium size, bold intensity and mixed case. Village medium size and mixed case.
	AUT	Serif. All settlements use size variation to show settlement importance. Cities use capitals. Towns used mixed case. Villages use mixed case and a right slope.
Singular Features	CAN	Sans serif, mixed case, extra small to small size, none or right slope.
	NZL	Size varies from extra small to medium, sans serif, and mixed case.
	AUT	Serif, right slope, and mixed case. Size variation, usually extra small to medium.
Transportation	CAN	The Trans-Canada-Highway uses sans serif, right slope, red hue, mixed case, and a medium size.
	NZL	Extensive use on most streets, railways and even tracks. Sans serif, all capitals, extra small to medium size. Tracks use mixed case, sans serif and small size.

Table 13 continued on the following page.

Table 13 continued from the previous page.

Linear Water Feature	CAN	Large features such as rivers are characterized by right slope, sans serif, blue hue, all capitals, large or medium size, and spaced letters. Smaller features such as creeks and streams are characterized by the above attributes but with mixed case and a smaller size.
	NZL	All are characterized by blue hue, sans serif, mixed case, right slope, spaced letters, and size varies from small to large according to the feature size and importance.
	AUT	All features are characterized by serif, right slope, blue hue, and letter spacing. Larger features also use capitals and larger size. Smaller features use mixed case and medium to smaller size.
Borders	CAN	Sans serif, black hue. More important borders are capitalized, bold intensity. Less important borders use mixed case and normal intensity. Size is varied but usually medium.
Area Water Features	CAN	Sans serif, right slope, and blue hue. Size varies from small to large. Larger features use capitals, if not mixed case is the norm. The letters are commonly spaced to fit the area.
	NZL	Sans serif, right slope, blue hue, and mixed case. Size varies from small to large. The letters are commonly spaced to fit the area.
	AUT	Lakes use serif, right slope, blue hue, mixed case, small to medium size. Glaciers are sans serif, no slope, variable size, mixed case, and blue hue. The letters are commonly spaced to fit the area.
Landforms	CAN	Sans serif, capitals or mixed case, varied size, no slope. The letters are commonly spaced to fit the area.
	NZL	Sans serif, right slope. According to the importance or size of the feature, letter size is varied, as well as important features often shown in capitalized and/or bold letters. The letters are commonly spaced to fit the area.
	AUT	Sans serif, no slope. According to the importance or size of the feature, letter size is varied, as well as capitalization. The letters are commonly spaced to fit the area.

Table 13 continued on the following page.

Land Cover	CAN	Sans serif, capitalized or mixed case, size varied according to the area size and importance. The letters are commonly spaced to fit the area.
	NZL	Sans serif, capitals, right slope, size varies. The letters are commonly spaced to fit the area.
	AUT	Sans serif, right slope, mixed or capitalized case, size varies. The letters are commonly spaced to fit the area.

4.8   Terrain Representation

As we have already seen in the section on map subject (3.4.6), the terrain is commonly separated into two parts, relief and landforms. These have different geometric properties and therefore require different means of representation. Hachures, contour lines, and relief shading are common ways to visualize relief. Minor landforms and rock bodies are challenges for cartographic representation and have been solved in a number of ways. We will cover these topics individually. Finally, at the end we will compare the terrain representation on the national topographic map series.

4.8.1   Hachures

Starting in the 17th and 18th centuries hachures came into use and became the predominant form of land relief representation in the 19th century. They consist of short line segments or curves drawn in accordance with the slope orientation. They are usually black and are drawn perpendicular to contours. Although contour lines are used as a basis, they are many times not included in the final representation. Hachures created a vivid representation of terrain on large scale maps. On small scale maps hachure representation was less effective and often degenerated into "caterpillars". In modern maps, they are commonly used to depict minor landforms.

Through variation of line thickness and line spacing, hachures can create a three dimensional effect. There are two main forms, slope hachures and shade hachures. Slope hachuring was the first of the two developed and was standardized by the German topographer Johann Georg Lehmann in 1799. Slope hachures are sometimes described as hachures under vertical illumination, but they can be better described by the premise, the steeper the slope, the darker the hachure. Shaded hachures developed later and assumed

that the source of illumination came from an oblique angle. Examples of hachures are shown in Figure 10. [see IMH-65]
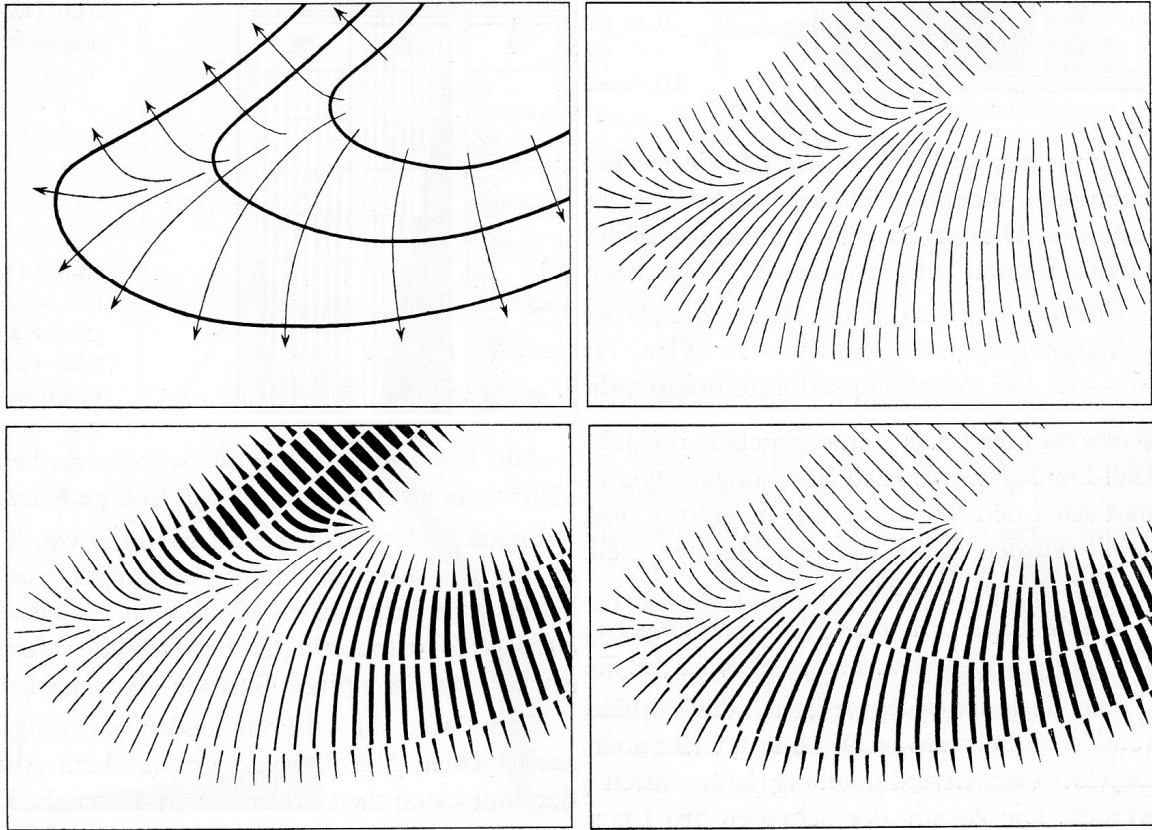
Figure 10: Hachure method examples. (Above left: Contours and lines according to slope direction - Above right: Hachures - Below left: Slope hachures - Below right: Shaded hachures). From [IMH-65].

The Swiss cartographer Eduard Imhof [see IMH-65, p238] set the following rules for drawing slope hachures. For shaded hachures the fourth rule is modified.

- Hachures are densely grouped short segments of slope lines. They always follow the direction of steepest gradient.

- Hachures are arranged in horizontal rows.

- Hachure length corresponds to the local horizontal distance between assumed or actual contours of a certain interval.

- Hachure width is thicker for steeper slopes. Some cartographers prefer to modulate the line spacing instead.

- Hachure density should remain constant throughout the map area.

The main advantage of hachures is that they provide a vivid image of the terrain. Some of the disadvantages of hachures are:

- they do not represent exact height information;

- in areas of steep gradient the hachure representation is so dark, that little space is left for other map content;

- finally, the emphasis on slope depiction create the false impression, that the landform is composed of terraces.

Due to these disadvantages and the development of geometrically exact elevation data, hachures were replaced by contour lines or shaded relief as the main forms of landform representation in large scale maps.

4.8.2   Contour Lines

Brandstätter [BRA-83] notes that the change from hachures to contours was not an easy one and that it was widely felt as if the maps had been "clear-cut". Many of the first contour maps employed very small intervals in order to create a darker and denser image, in an attempt to make the new method resemble the old and thus claim greater acceptance. Hachures and relief shading methods create far more dramatic visualizations of the landform surface if done properly, but the main reason why contours have become the standard for large scale topographic maps is that height information is portrayed accurately.

> "Contouring is the most precise way to give elevation information to map readers. Contours are isorithms - lines connecting points of equal elevation. They are the traces that result from passing parallel, equally spaced, horizontal surfaces through the three dimensional land surface and projecting these traces orthogonally to the map surface. The vertical distance between the parallel surfaces is called the contour interval." [ROB-95, p538]

Modern topographic maps make use of a contour line system, which usually consists of:

- Contour lines - Elevation isorithms with a constant value interval.

- Index contour lines - Thickened or otherwise distinguished contour lines usually repeated at multiples of the contour interval.

- Auxiliary contour lines - An extra contour introduced to show the relief adequately, in areas where contours at the standard interval are too far apart on a map, such as flatlands or terraces. Usually they are drawn in a thinner or lighter manner than regular contour lines and at half the contour interval.

Originally contours were drawn in one color, but it has become common for contours to be colored according to the ground type, such as black for bare rock and scree, brown for earth-covered ground, blue for water bodies and glaciers, and green for forests. This use of

color should not be mistaken for hypsometric tints, which use color ramps to visualize areas of similar elevation.

The choice of contour interval is based on a number of factors [see ROB-95, 538f]:

- The accuracy and completeness of landform data. Better data allows for a smaller interval.

- Map scale. A small contour interval which is appropriate for large scale maps would probably lead to contour crowding in a smaller scale map using the same interval.

- Map purpose. General purpose maps require a different interval than maps used for engineering. The first needs to create a vivid depiction of the terrain whilst the other needs exact renditions to measure and plan on.

- Symbol precision. Very exact graphics can tolerate smaller contour intervals before contour crowding becomes a problem. Thin and precise lines make for a less saturated map.

Generally speaking, for areas which are mainly steep, the tendency is to employ larger contour intervals; for predominantly flat areas, the tendency is towards small contour intervals. In order to produce the most dramatic three-dimensional effect, an adequate contour interval should be selected according to the average slope gradient of the mapped area. [BRA-83]

Table 14: Contour interval values for topographic maps, by map scale. Values in meters. Redrawn from [IMH-65, 137].

| | | | **Recommended Values for** | | |
Map Scale	Typical Interval Values	Ideal Interval Values	High Mountains	Low Mountains and Hill lands	Flatlands
1: 2 000	2	2,7	2	1	0,5
1: 5 000	5	5,7	5	2	1
1: 10 000	10	10	10	5	2
1: 20 000	10	17	20	10	2,5
1: 25 000	10, 20	19	20	10	2,5
1: 50 000	20, 25, 30, 40	29	20, 30	(10), 20	5
1: 100 000	50	47	50	25	(5), 10
1: 200 000	50, 100	75	100	50	10
1: 250 000	100	85	100	50	10, (20)
1: 500 000	100, 200	130	200	100	20
1: 1 000 000	200	200	200	100	20, (50)

An overview of contour interval values by map scale can be found in Table 14. The first column is filled with common map scales and the second column states the most widely used interval values. Column three shows the theoretical ideal interval values for 45° slopes as calculated by Eduard Imhof according to his own formula. The remaining columns, four, five and six, give recommended values for different landform types. The landform types are classified according to the magnitude of the steepest slopes that occur abundantly in the mapped area. The values are 9° for flatlands, 26° for low mountains and hills, and 45° for high mountains. This means that in an area classified as flatland the majority of slopes will be between 0° and 9°, and will rarely exceed 9°. [see IMH-65, 133ff]

4.8.3   Relief Shading

Relief shading is also referred to as shaded relief, plastic shading, or hill shading.

> "Whatever the method of preparation, hill shading is essentially a map of brightness differences resulting from incoming (or incident) light being reflected to an observer. Producing effective light-and-shade relationships depends upon certain assumptions. First, we assume that the light is coming from a constant direction and elevation. We also assume that the light is being reflected by various orientations and slopes of an ideally reflective land surface. We assume that the observer is viewing the map orthogonally (from directly overhead at all points). Thus, different hill-shaded maps result from changing the direction and elevation of the light source." [ROB-95, p545]

Depending on the position of the light source, we can identify two main types of shaded relief, vertical and oblique. Vertical illumination assumes that the light source is at the zenith or vertical viewing position. It produces an image where horizontal surfaces are white, regardless of their elevation, and all other surfaces are darker according to their inclination away from horizontal. The shading is relative to slope steepness. It is not as effective at creating a three-dimensional image of the surface, but this type of shading is very interesting if one's main concern is an analysis of slope steepness.

Oblique illumination assumes the light comes from any other direction other than the zenith. Most shaded reliefs follow the convention that the light source is at the top left corner of the map. Maps illuminated from behind the viewer, usually at the bottom or south-east, cause a phenomenon called relief inversion. It is a perception illusion where elevations and depressions appear reversed. Figure 11 shows oblique relief shading from different directions. The two left images are illuminated from opposite directions and show a relief inversion.

The elevation of the light source also affects the appearance of the relief shading. A lower illumination emphasizes low relief landforms and increases the apparent relief by increasing contrast. At the same time detail is lost, especially in darkened areas.
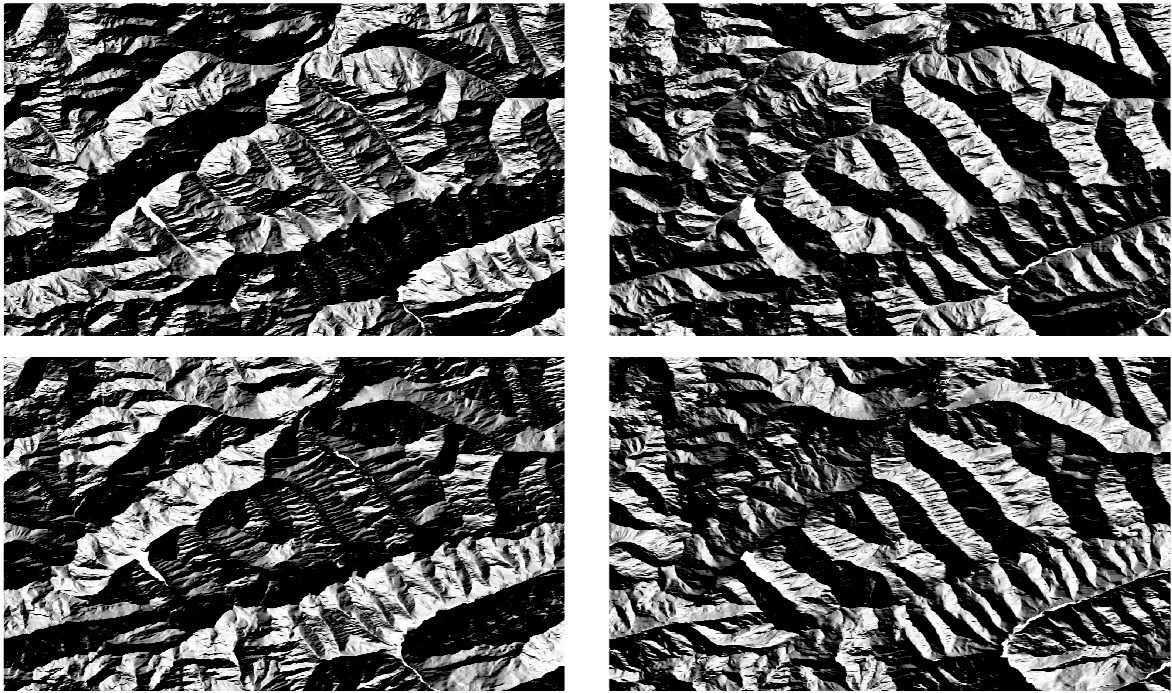
Figure 11: Shaded Relief of the Mayerhofen area illuminated from four different directions. (Above left: NW - Below left: SE - Above right: NE - Below right: SW). Data from Viewfinder, rendered by the author with Maperitive.

Relief shading is normally in shades of gray, but in some maps color shading is added to increase the vividness of the landform depiction. For example, applying yellow tone is an effective method for improving the three-dimensional appearance of a shaded relief. The gray relief shading is combined with a bright yellow tone on the sunlit slopes.

Shaded relief is seldom used for large scale maps under 1:20,000. For smaller scale general reference maps the method is very popular, as it creates highly vivid relief representations. In topographic maps in a scale of 1:50.000 relief shading is used in a complementary manner to contour lines.

4.8.4   Minor Landform Depiction

The main goals are to spatially and semantically define the minor landforms, as well as symbolize them appropriately. Minor landforms are breaks or interruptions in the otherwise smooth surface. They are not visualized by the relief depiction and therefore need special visualization. Examples are embankments, escarpments, cutaways, dolines, and ditches.

A number of graphic methods are used to depict minor landforms, such as wedge-shaped hatching, hachures, vertical and horizontal hatching, linear symbols, dot fields, and halftone figure shading. [see ARN-75, 299]

A challenge when depicting minor landforms is to generalize them and at the same time keep their individual form and typical structure. Minor landforms are generally represented in a planimetric faithful or near faithful way and there is emphasis on maintaining their geometric accuracy. That being said it is fairly typical for them to be displaced during generalization.

4.8.5   Rock Drawing

Rock drawing is "The stylized representation of steep rock faces which cannot be portrayed by other methods of representing relief."[ICA-73, 105]. Rock drawing is a creative process, in which free line drawing attempts to capture the individual character of a rock body. The graphic methods used to depict rocks are vertical and horizontal hatching, as well as slope lines and (sometimes) contour lines. In order to create the more plastic drawing the cartographer modulates the lightness and darkness by modulating the line density or the line width. There are three cartographic methods that have been developed for rock drawing: genetic, geometrically bound, and geometrically integrated. [see ARN-75, 299-311]

Genetic rock drawing is also called free rock drawing (here free is used in the sense of geometrically unconstrained). It does not include contour lines. The emphasis in this method is the vivid depiction of the rock body. It is a very dense drawing, which is geometrically inaccurate and depicts the rock body larger than it is in reality.

Geometrically bound rock drawing is characterized by being geometrically accurate and the most important goal is to maintain this accuracy. There are various methods that are considered geometrically bound rock drawing. First, is genetic rock drawing with contour lines drawn through it at large intervals. Second, is a merging of rock drawing with contour lines according to Eduard Imhof. Third, a combination of contour lines with other graphic elements as equivalent rock depiction. Finally, contour lines as a primary rock depiction with other graphic elements as auxiliary rock depiction.

The geometrically integrated rock drawing method is characterized merging rock drawing with contour lines in a consistent manner. Whereby the contour lines are considered more important and the rock drawing is drawn according to structured rules. Here are the graphic elements according to Brandstätter:

- equidistant contour lines (and the three-dimensional effect they produce),

- feathering replacement (when contour lines touch because of the steepness they are replaced by vertical hatching),

- ridge drawing,

- drawing of structural lines,

- auxiliary shading,

- modulated land cover depiction.

4.8.6   Comparison of Terrain Symbolization

All three maps use a combination of methods to represent the terrain, namely contour lines and minor landforms depiction, as well as additional point symbols. In addition, the Austrian and New Zealand maps use relief shading. In both cases the shading assumes that the light source is located at the upper-left corner (NW). None of the maps use any type of colored shading, such as sun shading.

The maps differ greatly when it comes to rock drawing. New Zealand maps visualize rocks as point symbols on land and have a special line symbol for coastal rocks. Canada uses a linear-like symbol to depict the border of rocky areas and it is used to represent coastal rocks, quarries, and rock bodies. Austrian maps have a geometrically bound rock drawing.

Table 15: Comparison of terrain symbolization in 1:50.000 topographic map series. Symbols taken from [BEV-11, LIN-11, NRC-10]

Relief	CanTopo50	NZTopo50	ÖK50
Index contour line	⌒	—100—	—1200—
Contour line		≈	—
Auxiliary contour line	- - -	- - -	- - -
Contour line on glacier		≈	≈
Trigonometric point		▲ A1B2	△713
Spot height	.32	▪130	×436
Peak		▲130m	
Rock		⌂ ⌂ ⌂	
Pingo	✳		
Gorge			∘S
Cave	⊖	▲	⌂
Saddle		≍	
Embankment, dike	≈	⊥⊥⊥⊥⊥	∿∿∿∿∿

Table 15 continued on the following page.

Table 15 continued from the previous page.

Trench, Ditch			
Cliff, cutaway			
Stopbank			
Esker			
Slip			
Depression			
Shallow depression			
Sand, clay, or gravel pit			SG
Quary			Stb.
Moraine wall			
Scree			
Coastal rock, rock ledge			
Reef, shoals			
Submerged rocks			

Table 15 shows the symbols used to represent the terrain in the different 1:50.000 topographic map series. From this comparison we can derive the following:

- Canadian maps use a single color for contour lines, gray. The other two maps series both use brown color for contour lines and blue contour lines on glaciers.

- All the map series compared, use an equidistant contour interval of 20 meters. The index contour interval is every 100 meters, which would be every fifth contour line.

- The Austrian and New Zealand maps number only the index contour lines at irregular intervals. Canada seems to have no systematic approach towards numbering contour lines.

- Austrian maps include blue bathymetric lines with a depth interval of 10m for lakes and other water bodies. The other maps do not include bathymetry.

- Canada does not use wedge-shaped hatching. Whereas New Zealand and Austrian maps are fairly similar in their usage of wedge-shaped hatching to depict cutouts, embankments, dikes, trenches and ditches.

- Generally speaking the Austrian and New Zealand maps represent the terrain in a similar fashion. Canadian maps on the other hand have a different style, which is somewhat simpler in execution and is not quite as vivid.

5   Open Movement

This chapter focuses on the open movement. Here movement is to be understood as "a group of people who share the same goal and work together to achieve it." [MAC-02, 915]. The goal that the open movement is trying to achieve is "openness". The term itself is difficult to describe because it has many interpretations. To further complicate the issue, there are several degrees of "openness". This thesis focuses on "openness" in its recent contexts since the development of the open source software movement.

It is important to define "openness" since the thesis uses pre-collected data to make a topographic map. The important restriction on the data used is that it must be "open" data. Using "open" data primarily affects the legal and copyright status of products crated with it. Maps are commonly made with data from different sources, which further complicates the legal status. It is therefore necessary to explain what makes data "open" in order to have a good working knowledge of the legal implication of using "open" data.

Some of the advantages of "open" data are that it does not cost anything (in the sense of paying a fee to use) and that it can be manipulated and reused. Because of this, "open" data creates many possibilities for map production, especially for persons and organizations lacking means of using conventional data sources.

The chapter describes the development of the "open" movement and how it has spread from software development to other disciplines. It then describes some of the sub-movements within the "open" movement. Finally, it examines the underpinning of "openness" in the legal system and the development of legal instruments used to achieve its goals.

5.1   Brief History of the Open Movement

The origin of the open movement can be traced to the early days of computing. Back then, a part of computer development took place at research institutions, where computers were shared between small groups of experts. It was commonplace for developers to develop source code and programs together, as well as share them with scientist from other research institutions. An important reason for this was, and still is, scholarly tradition. This tradition dictates that research results must be published for peer review. This work and research ethic spread and became the status quo in computer programming and software development communities. [see WHE-07]

The situation started to change in the early 1980s, when many of the communities collapsed. This was mainly due to two reasons. First, many of the programmers went to work for software development companies and therefore abandoned their research communities, as well as their software development ethics. Second, software companies

changed their software development ethics and business models to a proprietary scheme. This meant that source code was no longer available to study and work upon. [see WHE-07]

Richard Stallman, one of the computer scientists who worked at the Artificial Intelligence Laboratory (AI Lab) at the Massachusetts Institute of Technology (MIT), was very upset due to the collapse of his development community and the commercialization of the source code the AI lab had developed. He wondered what he could do to foster the growth of a new community and after much deliberation decided that the first necessary step was to develop an operating system. In the following citation he describes his goals.

"As an operating system developer, I had the right skills for this job. So even though I could not take success for granted, I realized that I was elected to do the job. I chose to make the system compatible with Unix so that it would be portable, and so that Unix users could easily switch to it. The name GNU was chosen following a hacker tradition, as a recursive acronym for 'GNU's Not Unix'. An operating system does not mean just a kernel, barely enough to run other programs. In the 1970s, every operating system worthy of the name included command processors, assemblers, compilers, interpreters, debuggers, text editors, mailers, and much more. ITS had them, Multics had them, VMS had them, and Unix had them. The GNU operating system would include them too." [STA-99]

Besides the challenge of developing an operating system, there was a second problem to solve. The question was: how could one prevent the software from being turned into proprietary software? The solution was 'copyleft'. This principle, which is sometimes referred to as share-alike and reciprocal licensing, has become a foundation of openness and is explained in more detail further on. To put it briefly: "It's a pretty simple concept really — if you build on someone else's work you have to use the same license they used for their stuff for your contributions. It's kind of like the golden rule, but for software licensing." [HAT-10]. In the specific case of the GNU project the GNU General Public License (GNU GPL) was created to copyleft the software and therefore ensure its openness. [see GNU-14]

The culmination of the effort put in by the GNU project came in the early 90's. The GNU project had created many components for an operating system but was missing a central piece, the kernel. They decided to integrate the Linux kernel, which was created by a community effort organized by Linus Torvalds. The result was the GNU/Linux operating system, which has become very popular and is in continuous development by a community of programmers that adhere to an open software development ethic. [see WHE-07]

It must be noted that, the term 'open source' was not the original term used to refer to the software, instead the term 'free software' was used. The term was conceived by the developers of Netscape, an internet browser. They wanted to release their source-code, but wanted to distance themselves from the "free software" moniker due to it having a moralizing and confrontational attitude. Additionally, many members of the community were concerned that, the term 'free' was confusing and therefore being misunderstood. This

all led to a dispute among the community which ultimately led to it splitting into two groups. One group, including Stallman, stayed true to the tenets of the free software movement and continued with the Free Software Foundation. The other group coined the term "open source" created a new definition and founded the Open Source Initiative to promote the new concept. Furthermore a new term was used to refer to both movements, Free and Open Source Software (FOSS). [see OSI-14a]

According to Stallman the differences between the two terms are: "The two terms describe almost the same category of software, but they stand for views based on fundamentally different values. Open source is a development methodology; free software is a social movement. For the free software movement, free software is an ethical imperative, essential respect for the users' freedom. By contrast, the philosophy of open source considers issues in terms of how to make software "better"—in a practical sense only. It says that non-free software is an inferior solution to the practical problem at hand." [STA - 14]

From this beginning in the software development community the open ethic has spread to other fields such as data, government, design, and so forth. This has all resulted in a proliferation of alternative definitions of openness, as well as copyleft licenses.

5.2   Sub-Movements

The following is a list of sub-movements that have developed in the wake of the open movement. It is not exhaustive and is not structured in any meaningful way.

5.2.1   Free Software

The word 'free' is ambiguous in its meaning and it was therefore necessary to define it or to find an alternative. In order to avoid these misunderstandings the following additional terms have come into use:

- Gratis | Free as in free beer. Something which can be obtained without any payment.

- Libre | Free as in free speech. To be able to act, do, or say, without influence, manipulation, or fear of repercussion.

The Free Software Foundation is the main governing body for free software. It sponsors the GNU project and maintains a number of licenses:

- GNU General Public License (GNU GPL)

- GNU Lesser General Public License (GNU LGPL)

- GNU Affero General Public License (GNU AGPL)

- GNU Free Documentation License (GNU FDL)

The Free Software Definition considers software free if the program's user has the following freedoms [FSF-12]:

- The freedom to run the program, for any purpose (freedom 0).

- The freedom to study how the program works and change it so it does your computing as you wish (freedom 1). Access to the source code is a precondition for this.

- The freedom to redistribute copies so you can help your neighbor (freedom 2).

- The freedom to distribute copies of your modified versions to others (freedom 3). By doing this you can give the whole community a chance to benefit from your changes. Access to the source code is a precondition for this.

5.2.2   Open Source

Open Source is a philosophy that encourages free access and distribution of the design and implementation information of a product. The term became popular with the open-source software movement. It is used to describe the new developments in software production, communication models, peer communities and the changed copyright and licensing environments. The main focus is open access to the source code of software and the collaborative development thereof by community effort.

The main organization promoting open source is the Open Source Initiative. It maintains the Open Source Definition, which is a ten-point list of criteria that open source software must fulfill. According to its website its mission is:

> "The Open Source Initiative (OSI) is a non-profit corporation with global scope formed to educate about and advocate for the benefits of open source and to build bridges among different constituencies in the open source community.
>
> Open source is a development method for software that harnesses the power of distributed peer review and transparency of process. The promise of open source is better quality, higher reliability, more flexibility, lower cost, and an end to predatory vendor lock-in.
>
> One of our most important activities is as a standards body, maintaining the Open Source Definition for the good of the community. The Open Source Initiative Approved License trademark and program creates a nexus of trust around which developers, users, corporations and governments can organize open source cooperation." [see OSI-14b]

The following are widely used OSI-approved open source licenses:

- Apache License 2.0

- BSD 3-Clause "New" or "Revised" license

- BSD 3-Clause "Simplified" or "FreeBSD" license

- GNU General Public License

- GNU Library or "Lesser" General Public License

- MIT License

- Mozilla Public License 2.0

- Common Deveplment and Distribution License

- Eclipse Public License

5.2.3 Open Content

Open Content is another term that refers to the granting of rights above and beyond those given by traditional copyright. According to the Open Content Website, it is a gradual construct, which means that content can be more or less open, depending on how much it complies with the "5Rs Framework". This framework contains a list of requirements (usage rights) according to which something can be considered open content:

1. "Retain - the right to make, own, and control copies of the content (e.g., download, duplicate, store, and manage)

2. Reuse - the right to use the content in a wide range of ways (e.g., in a class, in a study group, on a website, in a video)

3. Revise - the right to adapt, adjust, modify, or alter the content itself (e.g., translate the content into another language)

4. Remix - the right to combine the original or revised content with other open content to create something new (e.g., incorporate the content into a mashup)

5. Redistribute - the right to share copies of the original content, your revisions, or your remixes with others (e.g., give a copy of the content to a friend)" [OCD-14]

The Open Content Project created two licenses: the Open Content License and the Open Publication License. The project has since been merged with Creative Commons and recommends using the Creative Commons licenses instead:

- Creative Commons Attribution (CC BY)

- Creative Commons Attribution Share Alike (CC BY-SA)

- Creative Commons Attribution No Derivatives (CC BY-ND)

- Creative Commons Attribution Non-Commercial (CC BY-NC)

- Creative Commons Attribution Non-Commercial Share Alike (CC BY-NC-SA)

- Creative Commons Attribution Non-Commercial No Derivatives (CC BY-NC-ND)

- Creative Commons Rights Waiver and Public Domain Dedication (CC0)

5.2.4 Open Data

In analogy to the other movements, the main goal of open data is that data should be available to anyone to use and redistribute as they see fit without restrictions. Open data focuses on non-textual materials, such as geospatial data, government data, science data, medical data, maps, chemical compounds. A major source of open data has come from government and administrative institutions, i.e. Open Government Data (OGD).

The Open Data Commons is a project of the Open Knowledge Foundation that provides legal solutions for open data. The licenses they provide are [see ODC-14]:

- Public Domain Dedication and License (PDDL) — "Public Domain for data/databases"

- Attribution License (ODC-By) — "Attribution for data/databases"

- Open Database License (ODC-ODbL) — "Attribution Share-Alike for data/databases"

The OpenStreetMap project publishes its data under the ODC-ODbL.

5.2.5 Open Knowledge

Open knowledge focuses on a more collective term than most of the other sub-movements. It distinguishes between data, information, and knowledge and promotes openness in all of them. The main advocacy group is the Open Knowledge Foundation, which has targeted open knowledge at the mainstream and aspires to the movement being as commonplace as the 'green movement' is today. Here is a brief description of their definition of openness and knowledge:

> "'Open knowledge' is any content, information or data that people are free to use, re-use and redistribute — without any legal, technological or social

restriction. We detail exactly what openness entails in the Open Knowledge Definition. The main principles are:

- Free and open **access** to the material

- Freedom to **redistribute** the material

- Freedom to **reuse** the material

- **No restriction** of the above based on who someone is (such as their job) or where they are (such as their country of residence) or their field of endeavour (including whether they are working on a commercial or non-commercial project)

Open knowledge is what open data becomes when it's **useful, usable and used** - not just that some data is open and can be freely used, but that it is useful – accessible, understandable, meaningful, and able to help someone solve a real problem." [OKF-14]

5.2.6   Open Government

Open government is a term which is used to describe a political process with the goal of developing public policy with tools and mechanisms similar to the open movements. Typical implementations are the use of digital mass media such as blogs, email, twitter and blogs to create a rapid feedback mechanism between political organization, their supporters and the public; the promotion of a transparent democratic process; fostering the freedom of information; and providing government data according to open data standards. [see MEZ-14]

5.2.7   Open Access

Open Access is a movement that encourages scientist and scholars to publish their research in an open manner. Peer reviewed journals are the usual means of distribution for scientific papers, but are criticized because they require a subscription. The Budapest Open Access Initiative (BOAI) recommend two complementary strategies for the publication of scientific articles [see BOA-02]:

- Self-archiving. This means that scholars deposit their refereed journal articles in open electronic archives themselves.

- Open-access journals. These are either explicitly created as open journals or are old journals which have changed their policy to conform to the open standards. Open-access journals use open copyright mechanisms to ensure permanent open access to all the articles they publish.

5.3 Legal Background

The legal background of the Open Movement is based on copyleft licensing. In order to fully understand the copyleft, one must first understand the concepts of intellectual property rights, copyright law, copyright licenses and the public domain.

5.3.1 Intellectual Property

Intellectual property (IP) is a fairly recent term which is used to describe legal concepts. In general, it means laws under which owners are granted exclusive rights over a variety of intangible objects (i.e. immaterial things, such as thoughts, concepts, and ideas). The following are some of the main types of intellectual property rights [see IPO-14]:

- Patents protect inventions, which are processes, mechanisms, methods, and so forth, that are characterized by their novelty and innovation.

- Trademarks are signs which can distinguish products and services of a particular company or organization. Common examples are words, logos or a combination thereof.

- Product or industrial designs protect the visual appearance of a product or ornamentation. The look of a product is the result of an unique arrangement of features such as contours, shapes, colors, textures, or materials.

- Copyright protects creative works.

5.3.2 Copyright and Licenses

Copyright is a form of protection provided by the laws of a nation to the authors of original creative works. It gives the owner of copyright the exclusive right to reproduce the work; prepare derivative works; distribute copies to the public by sale or by rental, lease or lending; perform or display the work in public; and also to authorize the transfer of these rights to other people. [see USC-08]

Licenses are tools for the management of intellectual property rights. Traditionally, copyright licenses are drafted and signed by two parties, the licensors, who are the holders of copyright, and the licensees, who wish to utilize the creative works under copyright protection. The licenses record which rights of use have been granted by the licensor. The goal is to facilitate licensors getting the credit they deserve. They are not an alternative to traditional copyright instead they should be thought of as extensions to copyright, with the obvious advantage that the existing copyright laws can remain intact. [see CRE-14]

5.3.1 *Public Domain*

In a legal sense, the Public Domain refers to information that is free from access and reuse restrictions that arise from copyright protection. Intangible objects generally enter the Public Domain because copyright is not applicable, or it is applicable but has expired, or the authors waive their rights and dedicate their creations to the Public Domain. [see PDM-12]

Beyond its legal definition, the Public Domain "is the basis of our self-understanding as expressed by our shared knowledge and culture. It is the raw material from which new knowledge is derived and new cultural works are created. The Public Domain acts as a protective mechanism that ensures that this raw material is available at its cost of reproduction - close to zero - and that all members of society can build upon it. Having a healthy and thriving Public Domain is essential to the social and economic well-being of our societies. The Public Domain plays a capital role in the fields of education, science, cultural heritage and public sector information." [PDM-12]

5.3.2 *Copyleft*

When the problem of securing the GNU operating system from becoming proprietary software, the developers decided not to put it in the Public Domain. This was because of the following reason: "The simplest way to make a program free is to put it in the public domain, uncopyrighted. This allows people to share the program and their improvements, if they are so minded. But it also allows uncooperative people to convert the program into proprietary software. They can make changes, many or few, and distribute the result as a proprietary product. People who receive the program in that modified form do not have the freedom that the original author gave them; the middleman has stripped it away." [GNU-14]

Therefore a new concept was developed:

> "To copyleft a program, we first state that it is copyrighted; then we add distribution terms, which are a legal instrument that gives everyone the rights to use, modify, and redistribute the program's code *or any program derived from it* but only if the distribution terms are unchanged. Thus, the code and the freedoms become legally inseparable.

> Proprietary software developers use copyright to take away the users' freedom; we use copyright to guarantee their freedom. That's why we reverse the name, changing "copyright" into "copyleft". " [GNU-14].

Copyleft licenses provide a standardized and simple way to grant copyright permissions on creative works. Copyleft licenses have gained a wide acceptance and the number of licenses has expanded to cover many possible scenarios. One problem this has led to is

license incompatibility, which affects usage and distribution of creative works, that are made from other creative works with different copyleft licenses.

6 Exemplary Procedure

This chapter describes the procedure and individual steps used to produce a topographic map from open data. The purpose is to see whether it is possible to make a map from open data. The map production workflow is based on the cartographic communication model, as well as the workflow described in the section on topographic map making, and has been adapted to the requirements of this thesis. The main requirements are the guiding questions, but some additional requirements have been formulated in concordance with the knowledge gained from the previous chapters.

After the workflow the chapter focuses on the choice of geospatial data and mapping tools used. There are two main types of data used, vector data and elevation data, as well as a main cartographic tool to choose, the map renderer. It can be difficult to choose a combination that leads to successful map making, since some data sources are not compatible either with one another or with mapping tools. This thesis uses the following combination: OpenStreetMap vector data, Viewfinder panorama and SRTM V3 elevation data, and the Maperitive map rendering software.

Once the combination is selected it is necessary to prepare the data and resources for use with the cartographic tools. An important step is to choose the map style to use for the map. The map style used is derived from the chapter on cartographic representation of topographic maps 1:50.000. The reason for this is, that it is easier to assess the quality of the resulting maps if the map style of both maps is as similar as possible. The map style used in the thesis is based on the style of the Austrian topographic map series. Once the map style was chosen, special icons, textures, and style rules were created for use with Maperitive.

The final part of this chapter describes the rendering process, as well as explaining how the Maperitive rendering rules work.

The results of this chapter are a number of map extracts, which are placed side by side to the extracts of the Austrian topographic map series covering the same geographical areas. This comparison forms the basis of the next chapter, which goes into a detailed comparison of the map extracts.

6.1 Workflow

The map making process is a holistic process and, as such, it is difficult to organize it into a concise step-by-step structure. Furthermore the process used in this thesis developed over a longer period and was characterized by a highly iterative development. This means that individual steps were repeated and repeated until all the pieces fit into place. Nonetheless, the workflow of the map making process can be broken down into two separate processes.

It must be noted that these two processes must be understood as overlapping and therefore should not be strictly separated.

The first process involves choosing data sets and a renderer that is capable of rendering a map from the data. This is important in order to select data and a renderer that are compatible with one another and, if necessary, to discover ways to make them compatible. The second process is the map production once the various components have been selected.

In Figure 12 we can see a diagram that depicts the workflow for choosing data and a renderer. The first step to selecting data and a renderer is to define a purpose, in case of the thesis it is to make a topographic map which mimics the style of the Austrian topographic map series 1:50.000. Once the purpose has been defined, requirements can be formulated. These are more concrete than the purpose.

After that the workflow is very similar for both the data and the renderer. A specific set of data or renderer is chosen and is checked to see if it complies with the other data, as well as the renderer. If the first check is successful, it is then checked to see if it complies with the requirements and purpose.
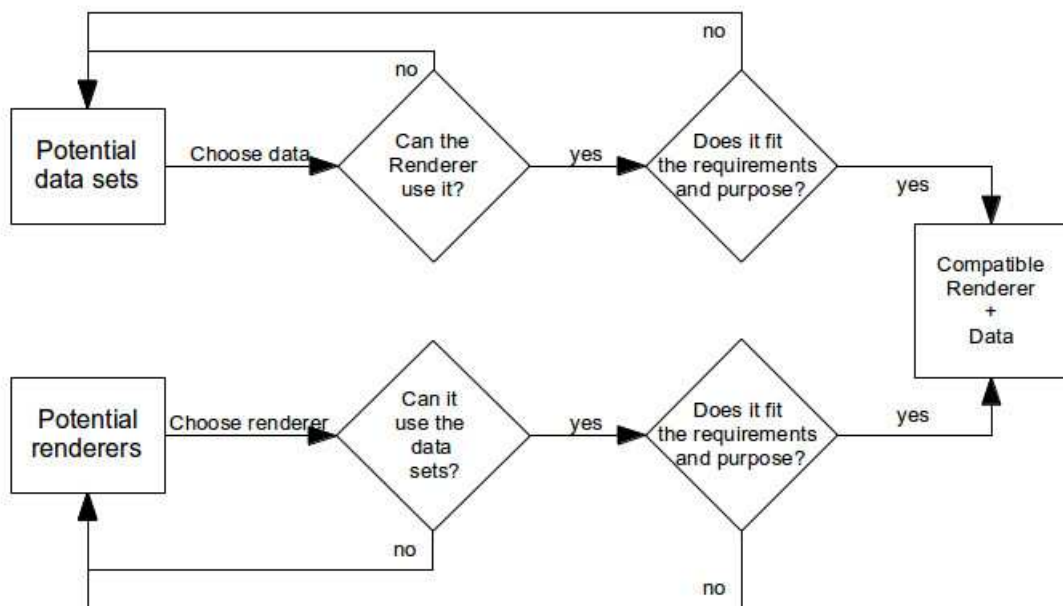
Figure 12: Workflow for choosing data sets and renderers.

This workflow looks like a chicken or egg problem. In other words, a renderer cannot be chosen until a data set is chosen, and a data set cannot be chosen until a renderer is chosen. Where to start? In practice this is rarely the case, as one will usually start with either a set of data or a renderer of choice and select the other one from there. In the case of this thesis

the main starting point was OSM data. Once a starting point has been established, it is much easier to follow the workflow.

Figure 13 shows a workflow diagram for the map production process. It consists of a number of steps that must be taken in order to produce the map. The various steps can be grouped into vector and elevation data preparation, creation of graphic resources, definition of the rendering rules, configuring and using the renderer, and finally exporting the map. The following is a quick run-down of the workflow.

The vector data is OSM data, which does not require much preparation. Larger OSM datasets must be split up into smaller areas, because Maperitive cannot handle large datasets.

The elevation data is left fairly generic. This is because the individual data sets are easily interchangeable in the renderer. In order to be used by the renderer they must conform to the SRTM .hgt format. Making the datasets compatible can require two steps: they formatted into the SRTM .hgt format, and the areas must be extracted.
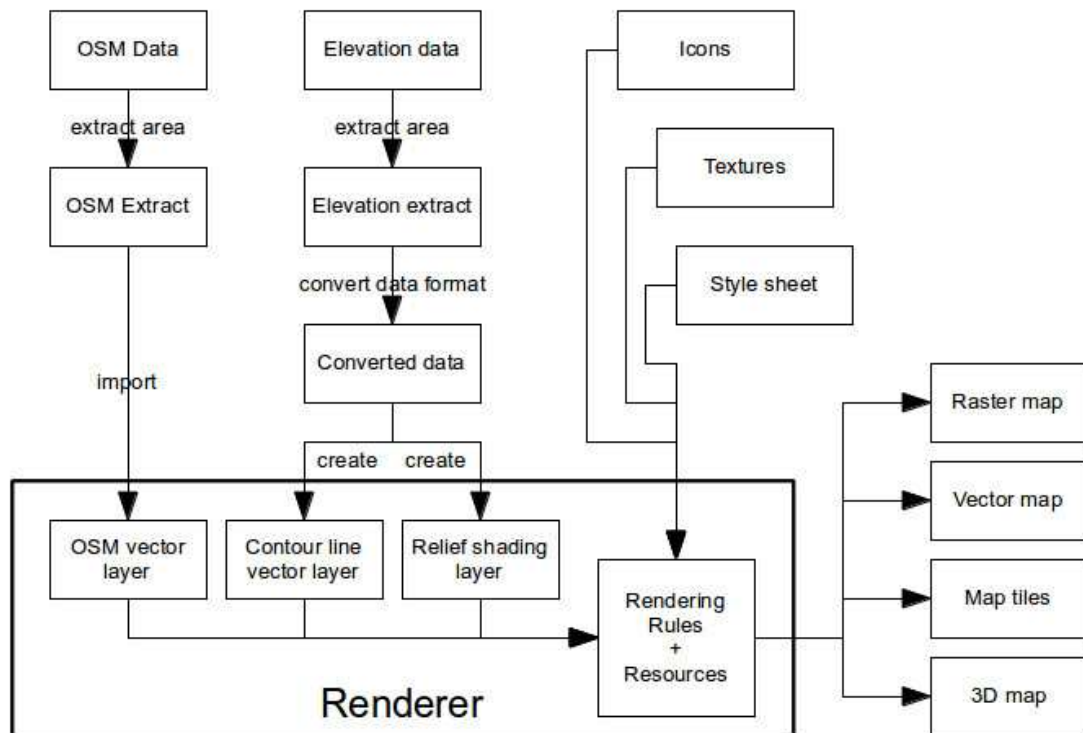
Figure 13: Map production workflow.

The graphic resources consist of icons and textures used by the renderer to visualize features. The rendering rules are defined in a style sheet. This is a text file formatted in a special way and consisting of two sections: a feature selection section and a rendering rules section.

Once the data and resources have been prepared, the renderer is configured and the various data and resources are imported. The renderer is used to generate relief shading and contour line vectors from the elevation data. The renderer renders a map on the fly and is capable of exporting the map into a number of formats.

The next sections will give an overview of the vector data, elevation data and renderers that were considered for this project, as well as the requirements that were defined for the data. Following that it will describe the individual steps covered Figure 13. Finally at the end of the chapter, some extracts from the resulting maps are included, as well as corresponding extracts scanned from the Austrian topographic series 1:50.000 printed maps.

6.2 Data Requirements

The following list of requirements was defined with the purpose of further defining the mapping purpose. The mapping purpose is to produce a topographic map that mimics the Austrian topographic maps series style.

- Open data. Data sets are either in the public domain or available with an open license. Furthermore, data sets must be technically available, for example downloadable over the internet. An additional plus, is the absence of any type of registration.

- Topographic subject. Data sets focus on the map subjects described in chapter 3.4: settlements, transportation network, water features, land cover, singular features, terrain, toponymy, and thematic info.

- Data integration. The different data sets should be well integrated, which means absence of or few overlapping or duplicate features, as well as feature layers that geometrically coincide, for example streams match the edges formed by the contour lines. If possible, the data sets should come from as few distinct sources as possible, because data integration usually suffers when the data comes from different sources.

- Resolution. Data sets must be detailed enough to be adequately represented in a scale of 1:50.000. The map content from data sets with improper detail will be either too sparse or too dense. An approximate rule for raster data sets (digital elevation models) is: the optimum is for one pixel to represent 30 meters or less.

- Area focus. The focus area is Austria. Data sets must include Austria. Furthermore, data sets that include the whole globe should be preferred over more local ones.

- Data quality. Data sets should have a high level of quality. Data quality is hard to measure, but generally speaking they should have a good degree of positional and thematic accuracy, as well as being as complete as possible.

6.3 Overview of Available Vector Data

6.3.1 Natural Earth Data

The data is available for the whole globe in scales of 1:10m, 1:50m, and 1:110m. It contains topographic map subjects and the individual subjects are well integrated. The quality of the data is very good and it is in the public domain. Nonetheless, the natural earth data cannot be used for the thesis project, because the detail is not suitable for making a map in the scale of 1:50.000. More information on natural earth data can be found on the webpage. [NED-15]

6.3.2 BEV Digital Landscape Model (DLM)

The Federal Office of Metrology and Surveying *(BEV - Bundesamt für Eich- und Vermessungswesen)* is Austria's national mapping agency (see 4.1.3) and is in charge of producing the national topographic map series as well as managing the national geospatial data. Topographic vector data is available covering all of Austria in a very high quality. The data is separated into separate layers by subject: settlements, transportation, water features, and toponymy. The data has been generalized for a scale of 1:50.000 and the layers are well integrated. However, the data from the BEV is not open. It is not licensed openly and charges are applied based on square kilometers. For more information visit the website. [see BEV-14]

6.3.3 Open Government Data (OGD)

Several organizations in Austria offer open government data. Information on this data is summarized on the data.gv.at website [see DAT-14]. This data is not considered in depth because the data sets are restricted to regional or local areas. Furthermore, the map subjects consist of separate datasets, which means that the data integration and resolution might not be good. For example, many of the federal states make street data available, but it is restricted to state roads, this means they do not include small roads or motorways.

6.3.1   *OpenStreetMap Data (OSM)*

OSM is a collaborative project that creates and distributes open geospatial data. It is open data and is licensed under the Open Data Commons Open Database License (ODbL) [see OSM-14]. It includes a very large amount of different features and contains all the features included in the topographic map subjects. Because of the amount of features included and the quality thereof, the integration of the data is not always optimal. The resolution of the data is adequate, although some features might need generalization. It covers the whole world, although the quality of the coverage can vary greatly from place to place.

The main strength and at the same time main weakness of the OpenStreetMap project is the collaborative nature of collecting data. Data can be created by any individual registered with the project. Common data creation methods are: uploading GPS tracks, tracing aerial imagery, and appending information gained from local knowledge. This all leads to very inconsistent data quality. Sadly there is no space for a lengthy discussion of the quality of SOM data, but it is an important characteristic of the data and must be mentioned.

In Austria the quality of the OSM data is quite good and is constantly improving. One should also note that, OSM collaborators integrate OGD datasets when they comply with the OSM charter and licenses. Because of the mentioned characteristics as well as the good quality of the data in Austria, it is selected for the practical example of this thesis.

6.4   Overview of Available Elevation Data

6.4.1   *Natural Earth*

Natural Earth also has various terrain raster datasets available. They are a mix of relief shading and hypsometric tints derived from SRTM Plus elevation data. As with their vector data, their resolution is not appropriate for a 1:50.000 topographic map. [NED-15]

6.4.1   *BEV DEM*

The BEV offers Digital Elevation Model (DEM) datasets in a number of resolutions. Resolutions of 10m, 25m, and 50m are only available against a fee. Additionally, they offer resolutions of 100m, 250m and 500m for free, but under a license agreement. They are generated by photogrammetric extraction from aerial imagery. [see BEV-14]

6.4.2   SRTM

"The Shuttle Radar Topography Mission (SRTM) obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth. SRTM consisted of a specially modified radar system that flew onboard the Space Shuttle Endeavour during an 11-day mission in February of 2000."[JPL-09]. A second version was released with corrected data, but it still has many missing data areas ('voids'). The resolution is approximately 90 meters and includes building and vegetation height. The data is in the public domain and uses a .HGT file format. There have been many projects to increase the quality of the SRTM data, especially trying to fill the voids. The newest release is the LP DAAC SRTM V3.0, which filled the voids with ASTER GDEM2 data.

6.4.3   ASTER GDEM v2

The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) is a joint project between the Ministry of Economy, Trade and Industry of Japan (METI) and the North American Space Agency (NASA). One of the products of this joint venture is the Global Digital Elevation Model (GDEM). The second version of the data was released on October 17, 2011 and improves the resolution and elevation accuracy of the first version. GDEM data is available free to use, but users must agree to conditions of data use set by METI and NASA. The resolution is approximately 30 meters and includes buildings and vegetation. The data uses the geoTIFF file format. [see JSS-14]

6.4.4   EU-DEM

"The Digital Elevation Model over Europe from the GMES RDA project (EU-DEM) is a Digital Surface Model (DSM) representing the first surface as illuminated by the sensors. The EU-DEM dataset is a realisation of the Copernicus programme, managed by the European Commission, DG Enterprise and Industry." [EEA-13]. The data is free to use, but requires registration and accepting licensing conditions. The data has an accuracy of 25 meters. "The EU-DEM is a hybrid product based on SRTM and ASTER GDEM data fused by a weighted averaging approach and it has been generated as a contiguous dataset divided into 1 degree by 1 degree tiles, corresponding to the SRTM naming convention."[EEA-13]

6.4.5   Viewfinder Panoramas

Viewfinder Panoramas is a website maintained by Jonathan de Ferranti. It is a site dedicated to terrain cartography and it also contains digital elevation data. The data has a resolution of 1", 3", and 15". The 3" dataset recently covers the whole world and the 1"

data is available only for smaller regions, such as the US and the Alps. The data is mainly based on SRTM data, but is corrected and enhanced by a number of other data sources, such as ASTER GDEM data, Landsat images, and topographic maps. The data comes in .hgt file format. The data is free to use, but it is not open source. This is because it is generated from different sources and therefore underlies different licenses or agreements. [see VFP-14]

6.4.6 OGD

Digital elevation models are available of the federal states of Tirol, Upper Austria, Vienna, and Carinthia. The datasets have a resolution of 5-10m. [see DAT-14].

6.4.7 Comparison of Elevation Data

The different DEM datasets can easily be exchanged in the renderer once they have been properly prepared. This means that the DEM dataset best suited to the specific area mapped can be used. In order to have a better feel for their quality, the DEM datasets are compared.

Table 16 shows a comparison of the following characteristics: the file format the DEMs use, the tile size, the approximate resolution, the reference system used, and whether they are open data or not.

Table 16: Comparison of Available Elevation Datasets.

Name	Format	Tile Size (px)	Resolution (in meters)	EPSG	Open Data
SRTM V3.0	.hgt	3601x3601	90m	4326	Yes
ASTER GDEM2	.tiff	3601x3601	30m	4326	Partial
VF Alps DEM	.hgt	3601x3601	10-20m	4326	Partial
EU DEM	.tiff	18000x18000	25m	4258	Partial
Tirol DEM	.asc	-	10m	31254	Yes

The following three figures represent a visual comparison of the DEM data. Figure 14 shows the data voids which are present in SRTM and ASTER datasets. Figure 15 shows a mountain ridge, which is rocky. Figure 16 shows a flat valley with a river meandering in the center.
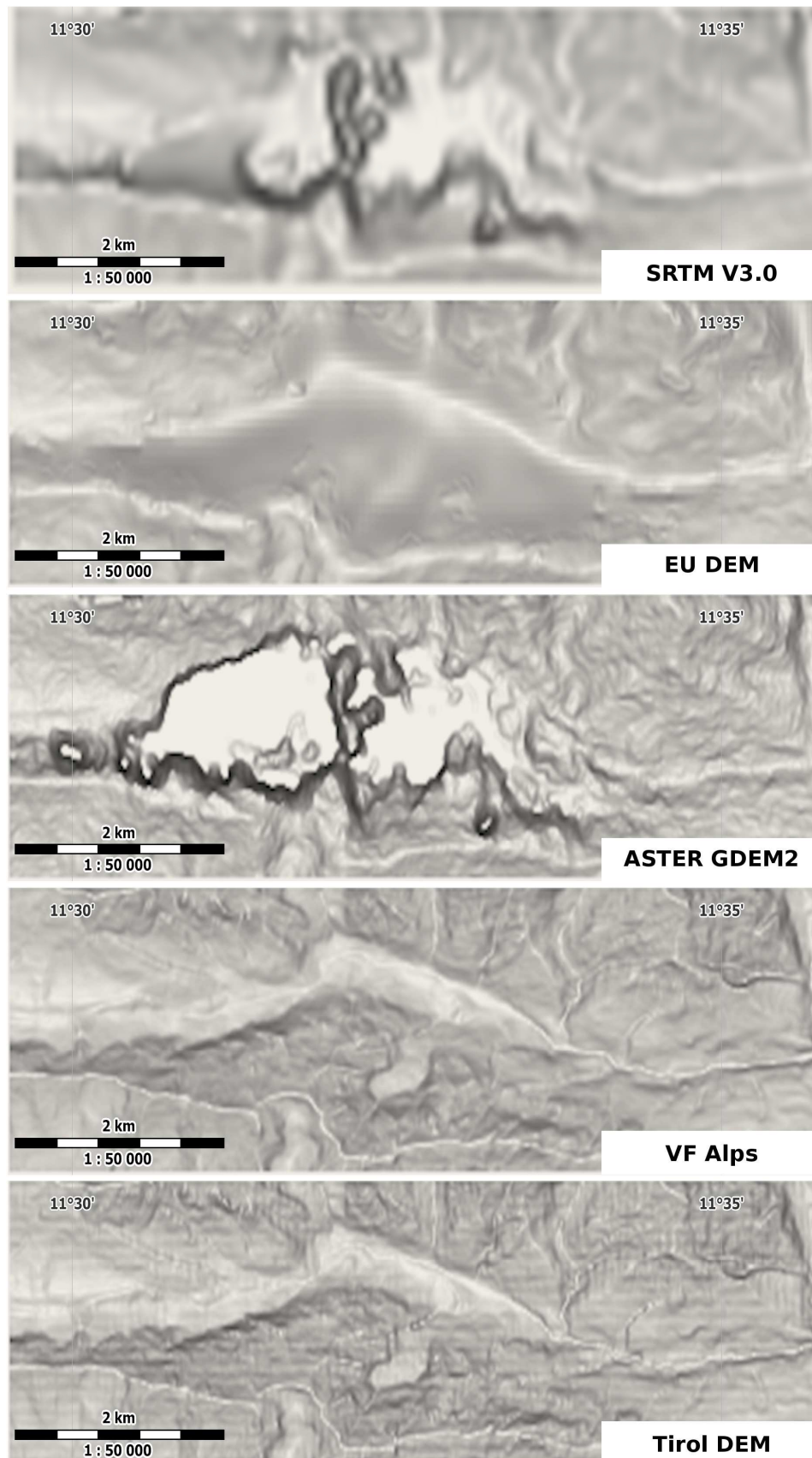
Figure 14: DEM relief shading comparison. Data void.
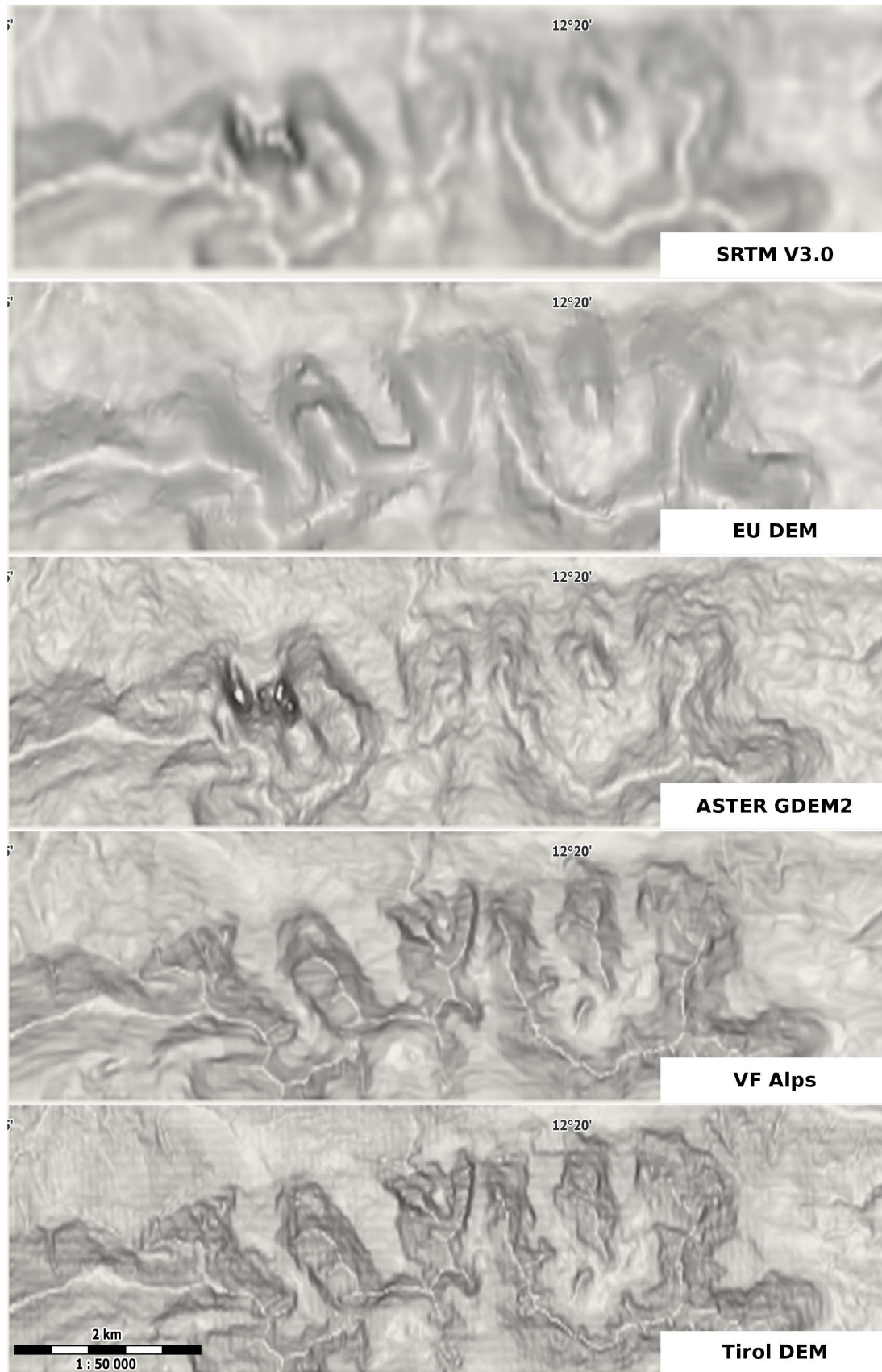
Figure 15: DEM relief shading comparison. Mountain ridges.
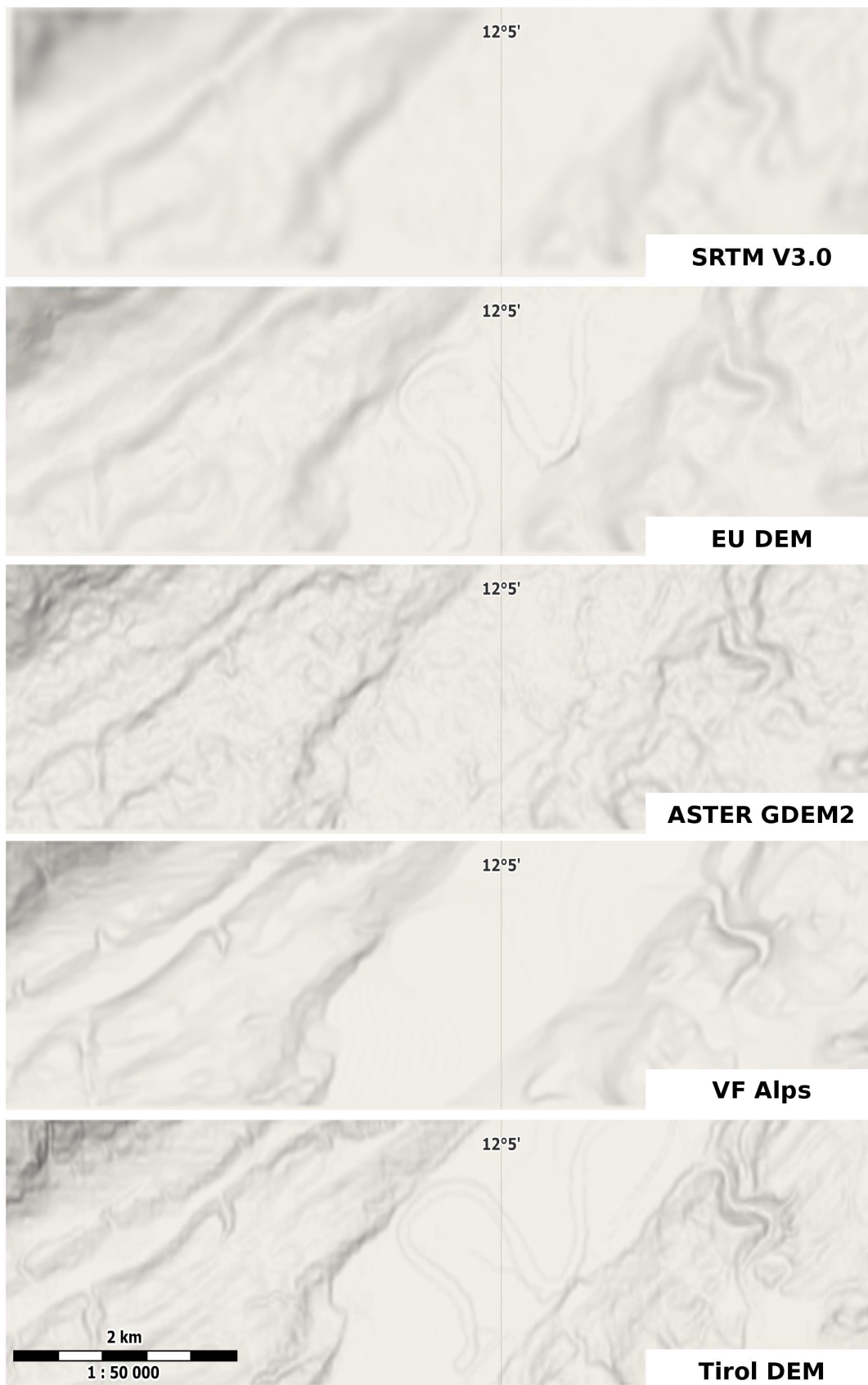
Figure 16: DEM relief shading comparison. Valley and river.

6.5   Overview of Map Renderers

A renderer is a computer program that creates an image from a data model. There are a number of requirements that were formulated for choosing a renderer. First, it should be able to render OpenStreetMap data. Second, it should be able to use DEMs to generate relief shading and contour lines. Third, it should be simple to set up and configure, but provide a flexible way of specifying the cartographic representation. And finally, it should be able to export maps in a number of formats, especially as a raster image. Maperitive was chosen to be used for the thesis, because, at the time the decision was made, it matched the requirements better than the other renderers listed here.

6.5.1   *Maperitive*

Maperitive is a map rendering software for rendering OSM data. It can generate contours line vectors, relief shading, and hypsometric tints from DEM files. Currently, it only understands the SRTM HGT format for DEM datasets. The style of the map is defined in a rendering rules file, also called a style sheet, and it comes with some predefined styles. Maps can be exported to bitmap, 3D map, or SVG files as well as web map tiles. It is possible to automate processes by using scripts. Users can interact with the software either via a GUI or by an integrated command line. [see MAP-14]

Maperitive is developed and maintained by Igor Brejc in his spare time. The source code is not open, but it is free to use for non commercial purposes. Maperitive does not read data from a database; instead it loads the data directly from a file. It cannot load very large data files so mapping is restricted to smaller areas at a time. The advantage is that it is very simple to set up and start making maps. [see MAP-14]

6.5.2   *Mapnik*

Mapnik is a rendering toolkit for rendering maps and/or developing mapping applications. It is written in C++ and supports scripting with Python, Ruby, Java, and Javascript. It uses the AGG rendering library, which allows for anti-aliasing rendering with sub-pixel accuracy. Mapnik supports a wide range of data formats, such as ESRI shapefiles, PostGIS, TIFF raster, OSM XML files, and all OGR/GDAL formats. Even though it supports many formats the most common way to use Mapnik is together with a PostGIS database. Because of the reliance on other software, the setup is more complex than Maperitive. Mapnik is free and open source software and is released under a LGPL (GNU Lesser General Public License v2.1). [see MPN-14]

Rendering rules control the rendering process and are defined in an XML language specific to Mapnik. This language is complex and hard to use, so some external tools have been

developed to facilitate the creation of rendering rules, for example Cascadenik, Spreadnik, Quantumnik and TileMill. [see OSW-14a]

6.5.3   TileMill

TileMill is a map rendering framework developed by MapBox. It uses Mapnik as a renderer, node.js as a local web tile server and Backbone.js as a client. Rendering is controlled by Carto, an enhanced version of the Mapnik XML language for defining rendering rules. It also offers a GUI for interacting with the different software and rendering rules. TileMill can load shapefiles or connect to a PostGIS database, as well as render raster data such as TIFF files. It can export maps in various formats, namely MapBox Tiles, PNG or PDF files. [see MBX-14]

6.5.4   MapSurfer.NET

MapSurfer.NET is a rendering framework, which means it is designed to be used in other software. It is free to use, but not open source. It is written in C# and "is able to provide functional cartographic output of the highest quality." [MSU-14]. It can use OSM data and DEMs. A very important feature seems to be the sophisticated labeling engine. It can also export to a number of formats, including PDF, raster, and web tiles.

6.6   Preparing Vector Data

6.6.1   OpenStreetMap Data Model and Format

The data model of OSM is quite simple. "Elements (also data primitives) are the basic components of OpenStreetMap's conceptual data model of the physical world. They consist of nodes (defining points in space), ways (defining linear features and area boundaries), and relations (which are sometimes used to explain how other elements work together). All of the above can have one of more associated tags." [OSM-12a]. Note that OSM does not have polygons; these are modeled as closed ways. Relations are most commonly used to model routes, turn restrictions, and multi-polygons. Tags are attached to the other elements and are used to describe functions or attributes. Tags consist of 'key' and 'value' fields.

OSM uses a free tagging system, which means there are a potentially unlimited number of attributes for describing each feature. To increase the quality of the tagging, the community agrees on certain tagging rules and key-value pairs, which then act as informal standards. Because of this, the list of map features changes often, with new features being added and older features being removed. On the OSM wiki there is a list of map features, as well as lists for proposed and deprecated features. [OSW-14b]

OSM data is stored in various formats; the main ones are OSM XML, PBF, and o5m. OSM XML is a XML (Extensible Markup Language) format and is the original format used for OSM data. One of its most important characteristics is that it is human readable. The PBF or "Protocolbuffer Binary Format" is intended to replace the XML format. The main goals are a reduction in file size and a faster read time. The format was designed to support future extensibility and flexibility. The o5m format was designed to be a compromise between .osm and .pbf format, but has not gained widespread acceptance. Table 17 shows the main advantages and disadvantages of each format. There are tools to convert from one format to another, for example Osmosis or osmconvert.

Table 17: Comparison of OpenStreetMap formats. Based on [OSW-14c].

Format	Advantages	Disadvantages
.osm	- human readable - random access - can be edited with common text editors - can be compressed with every packer program - flat hierarchy, can be processed as data stream - two or more files can be merged easily	- huge file size - slow when being processed - slow when being written (because of file size)
.pbf	- small file size - can be processed much faster than .osm - build in compression obviates need for external compression	- not human readable - cannot be edited easily - no significant random access as currently implemented - applications need zlib packer functions library
.o5m	- small file size - fast processing - flat hierarchy, can be processed as data stream - easy merging of two or more files - user may choose compression method and compress the file	- not human readable - no editing with common text editors - currently no random access

6.6.2 Downloading OSM Data

The primary OSM dataset is the planet file, which is a single OSM file that contains the whole world. It can be downloaded from a number of mirror websites. The planet file is quite large though and it usually makes more sense to download a smaller geographic area instead of the whole world. There are a few services which offer smaller geographic areas, for example Geofabrik [see GEF-14]. Here we can download the OSM data file for

Austria, which is approximately 287 MB large. Even though it is a smaller area, it is still too large for Maperitive, so smaller areas will be extracted from the dataset.

6.6.3   Extracting the mapped area

There are a number of tools for extracting areas from a larger OSM file. Osmosis was used in this project. "Osmosis is a command line Java application for processing OSM data. The tool consists of a series of pluggable components that can be chained together to perform a larger operation. For example, it has components for reading from database and from file, components for writing to database and to file, components for deriving and applying change sets to data sources, components for sorting data, etc. It has been written so that it is easy to add new features without re-writing common tasks such as file or database handling." [OSW-14d]

The following commands require Osmosis to be installed on the computer. Osmosis runs on the Java Virtual Machine and used via the operating system command line. The following commands should be run on a single line, but have been separated into individual lines for readability.

```
osmosis

  --read-pbf file=../osm_data/austria-latest.osm.pbf

  --bounding-box top=47 left=10 bottom=46.8 right=10.33

  --write-pbf file=../osm_data/silvretta.osm.pbf
```

6.7   Preparing Elevation Data

The elevation datasets come in different formats and sizes. Depending on the software in which they will be used, i.e. the renderer, it is sometimes necessary to prepare the data. Common steps are: changing the data format, resizing the datasets, interpolating the data, and down- or upsampling the resolution.

Maperitive only accepts data formatted according to the SRTM HGT data model. This means that data from other formats must be converted to this format. HGT datasets consist of tiles, which cover the entire globe. The tile size must be either 1201x1201 or 3601x3601 pixels in size and the individual files must be named according to the convention, for example N00E000.hgt.

SRTM and Viewfinder data is natively integrated in Maperitive and is downloaded automatically. Alternatively, SRTM DEMs can be downloaded from the Reverb | ECHO

website and Viewfinder Panoramas DEMs can be downloaded on the Viewfinder Panorama website. [see NAS-14, VFP-14]

In order to convert the elevation data we will use GDAL, the Geospatial Data Abstraction Library. "GDAL is a translator library for raster geospatial data formats that is released under an X/MIT style Open Source license by the Open Source Geospatial Foundation. As a library, it presents a single abstract data model to the calling application for all supported formats. It also comes with a variety of useful command line utilities for data translation and processing." [GDA-14]

GDAL/OGR is written in ANSI C and C++ and it also offer a python binding through a python API. It supports most of the common raster data formats. Examples of the utility programs used are gdalinfo, gdal_translate, gdalwarp, and gdal_merge.py.

6.7.1 Preparing EU-DEM

EU-DEM data can be downloaded from the European Environmental Agency website. [see EEA-13]

First, the dataset is reprojected into the coordinate reference system used by Maperitive.

```
gdalwarp -s_srs EPSG:4258 -t_srs EPSG:4326 eudem_dem_5deg_n45e010.tif
eudem_dem_5deg_n45e010_wgs84.tif
```

GDAL can only convert to HGT format if the size of the file is either 1201x1201 or 3601x3601 pixels or lines. The EU DEM files are 18000x18000 pixels, which means that smaller areas must be extracted from the large dataset. A 3601x3601 corresponds to a 1 arc second and approximately 30 meter resolution.

```
gdal_translate      -srcwin      3600      7200      3601      3601
eudem_dem_5deg_n45e010_wgs84.tif N47E011.tif
```

After extracting out the desired area from the larger file, it is converted into the HGT format. The second code is a batch script that runs the conversion on all tif files in a directory.

```
gdal_translate -of SRTMHGT N47E011.tif N47E011.hgt

for f in *.tif; do echo "Processing $f"; gdal_translate -of SRTMHGT $f
${f%.tif}.hgt; done
```

6.7.2   *Preparing ASTER GDEM2*

ASTER data can be downloaded from the Reverb ECHO download portal, but requires registration. Furthermore, one must agree to redistribution and citation policies. The citation: "ASTER GDEM is a product of METI and NASA." must be used whenever ASTER data is used. [see NAS-14]

The area downloaded is separated into individual ZIP files, which contain the DEM, a QA file, that describes the quality of the data, and a readme file with general information. The first step is unziping all the files into a new directory. Working at the command line this can be done by the following script.

```
for z in *.zip; do unzip $z -d ./temp; done
```

Next the QA files are erased, since they are not really necessary.

```
for n in *_num.tif; do rm $n; done
```

After that the ASTER GDEM files must be renamed to fit the SRTM convention. The first script erases ASTGTM2_ and the second script erases _dem from any tif files in the directory.

```
for f in *.tif; do mv "$f" "${f#ASTGTM2_}"; done
```

```
for f in *.tif; do mv "$f" "${f%_dem.tif}.tif"; done
```

Finally, the files can be converted to SRTM HGT format. The following script loops through all the .tif files in the directory and converts them via gdal_translate.

```
for f in *.tif; do echo "Processing $f"; gdal_translate -of SRTMHGT $f
${f%.tif}.hgt; done
```

6.7.3   *Preparing Tirol DEM*

Tirol DEMs can be downloaded from the website of the Land Tirol. The DEMs are split according to the nine administrative divisions of Tirol.[see TIR-14] After downloading, the individual DEMs are merged using the gdal_merge.py python script. Note that Python must be enabled on GDAL for the script to work. It is important to use the -n flag, which commands the script to ignore cells with no value during the merging process. This tool also converts the data into a geoTIFF file, as this is the native format of GDAL. The -o flag indicates the output file.

```
gdal_merge.py -o tirol.tif -n -9999 ibk_10m_float.asc il_10m_float.asc
im_10m_float.asc   kb_10m_float.asc   ku_10m_float.asc   la_10m_float.asc
re_10m_float.asc sz_10m_float.asc
```

GDAL does not register the coordinate reference system for this file, so the proper coordinate system must be assigned. In this case it is MGI_Austria_GK_West with EPSG-Code: 31254.

```
gdal_translate -a_srs EPSG:31254 tirol.tif tirol_mgi.tif
```

After the proper reference system has been assigned, the data can be reprojected into the WGS 84.

```
gdalwarp -s_srs EPSG:31254 -t_srs EPSG:4326 tirol_mgi.tif tirol_wgs84.tif
```

The next step is to cut the DEM into tiles according to the SRTM HGT scheme, that is, tiles of 1"x1" arc second. The coordinates for the bounding box of the merged DEM are West: 10d 5'37.57"E, North: 47d45'33.45"N, East: 12.7115471, and South: 46d44'24.92"N. This is divided into six tiles, from 10 to 13 degrees east and from 46 to 48 degrees north via gdal_translate.

```
gdal_translate -projwin 10.0000000 48.0000000 11.0000000 47.0000000
tirol_wgs84.tif N47E010.tif
```

```
gdal_translate -projwin 11.0000000 48.0000000 12.0000000 47.0000000
tirol_wgs84.tif N47E011.tif
```

```
gdal_translate -projwin 12.0000000 48.0000000 13.0000000 47.0000000
tirol_wgs84.tif N47E012.tif
```

```
gdal_translate -projwin 10.0000000 47.0000000 11.0000000 46.0000000
tirol_wgs84.tif N46E010.tif
```

```
gdal_translate -projwin 11.0000000 47.0000000 12.0000000 46.0000000
tirol_wgs84.tif N46E011.tif
```

```
gdal_translate -projwin 12.0000000 47.0000000 13.0000000 46.0000000
tirol_wgs84.tif N46E012.tif
```

In order to convert the geoTIFF to HGT the pixel count must be 3601x3601, but the tiles currently have a larger pixel count, because they are more detailed and have smaller pixels for the same geographic area. Therefore, the tiles are down sampled, which means that the individual pixels will be enlarged to double the original size. This is achieved with the gdal_translate tool and the -outsize flag, which defines the size of the output raster.

```
for f in *.tif; do gdal_translate -outsize 3601 3601 $f
${f%.tif}_desampled.tif; done
```

Finally, we can change the format from geoTIFF to HGT.

```
for   f   in   *_desampled.tif;   do   gdal_translate   -of   SRTMHGT   $f
${f%_desampled.tif}.hgt; done
```

6.8   Preparing Resources

Maperitive requires a number of resources in order to render a map. The most important is a style sheet, which defines the rendering rules. In other words, which features will be rendered and how they will be rendered.

Besides the style sheet, some graphic resources are necessary as well. Icons and textures are necessary for drawing point and area features. The icons and textures have been created with Inkscape [INK-14], a vector drawing program that is Free and Open Source Software licensed under the GPL.

6.8.1   Icons

The icons in Figure 17 were created in the style of the Austrian 1:50.000 topographic maps. The icons are created in Inkscape and exported as PNG files. The icons are vector drawings and have no size in Inkscape, instead they are sized appropriately during the export process. They are exported as 64x64px icons, but are set to 16px in the map for the scale of 1:50000. This gives better results if the map export function in Maperitive is set to 300 dpi.

Figure 17: Icons for the practical example. Created by the author in Inkscape in the style of the Austrian Topographic map series.

6.8.2   Texture Tiles

In analogy to the icons, the texture tiles in Figure 18 have also been created in Inkscape. They are exported as PNG files with a size of 32x32 pixels for use in Maperitive.

Figure 18: Texture tiles for the practical example. Created by the author in Inkscape in the style of the Austrian Topographic map series.

6.9 Rendering

Once the data and resources have been prepared, these are loaded into Maperitive and the rendering can take place. The main parts of the rendering process are importing the data, generating relief shading and contour line vector data from a DEM, setting the rendering rules, and finally exporting the map. Additionally, a typical Maperitive script is included at the end. The script automates the configuration and the rendering process.

6.9.1 Loading Data

Depending on the format of the data one wishes to load, there are different commands. OSM XML, OSM PBF, GPX, or contour line files can be loaded with the load-source command. Images, such as TIFF and JPG, can be loaded with the load-image command. For example:

```
load-source data_sources/osm_file.pbf
```

```
load-image file=data_sources/hillshading.jpg background=false
```

Elevation data is not directly loaded into Maperitive. Instead, DEM files are copied into the Maperitive program files under Maperitive/Cache/Rasters/my_dem/. The DEM files must follow the SRTM HGT naming convention (see Figure 19). Besides placing the DEM files into this directory, one must also copy an XML file. The purpose of the XML file is to define the name and type of the DEM files. The name of the XML file is used as the name of the DEM source. The XML file contains one line, which defines the type of DEM, for example <dem><type>srtm1</type></dem> means the DEM is of type SRTM1. SRTM 1 means the tiles conform to the SRTM HGT format with 1x1 arc second extent. Maperitive only supports either SRTM1 or SRTM3 formats.
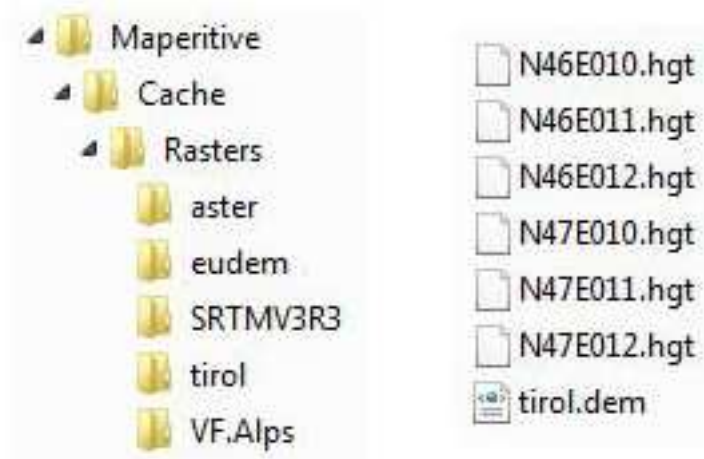
Figure 19: Maperitive DEM location and naming convention.

Once the DEM files have been placed in the correct directory and the XML file has been configured, the elevation data source can be set with the set-dem-source command.

```
set-dem-source name=tirol
```

6.9.2   Generating Relief Shading

Maperitive can generate relief shading from a DEM source with the generate-relief command. There are three separate versions of the command: standard, igor, and slopeshading. The main differences are in the sun-azimuth and sun-altitude values. The following is the command with its possible parameters.

```
generate-relief-[-standard -igor -slopeshading]
```

  – bounds=<value> (geometry bounds, optional) [default=current map view
    or set boundaries]

  – color=<HTML color of the shading> (value, optional) [default=black
    #000000]

  – intensity=<intensity of the shading> (value, optional) [alpha value
    larger than 0. default=1]

  – sample-rate=<The sample rate to use when fetching original DEM data.
    Use larger than default 1 if the map area is very big.> (value,
    optional)

  – sun-altitude=<altitude of the sun in degrees above horizon> (value,
    optional) [value between 0 and 90. default=25]

```
– sun-azimuth=<azimuth of the sun in degrees to the east of north>
   (value, optional) [value between -180 and 180. default=-45]
```

For cartographic purposes the most important parameters are color, intensity, sun-altitude, and sun-azimuth. Explanations of the effect that they can have on relief shading can be found in the section on terrain representation in the chapter on cartographic representation of 1:50.000 topographic maps.

6.9.3 Generating Contour Line Vector Data

Maperitive can generate contour lines vector data from the elevation data via the generate-contours command. The rendering rules in the style sheet can then be used to style the vector data.

```
generate-contours
```

```
– bounds=<boundaries> (geometry bounds, optional) [default=current map
   view or set boundaries]
```

```
– interval=<elevation interval> (integer, optional)
```

```
– max-ele=<maximum elevation (inclusive) up to which Maperitive will
   look for contours.> (value, optional)
```

```
– min-ele=<minimum elevation from which Maperitive will start looking
   for contours. set to 1 if you don't want relief contours at
   elevation 0.> (value, optional)
```

The Austrian map has a contour interval of 20 meters with index contour lines every 100 meters. With this in mind, the command for the project is used to create contour lines every 20 meters. The actual visualization of the contour lines will be defined in the style sheet.

```
generate-contours interval=20
```

6.9.4 Select Rendering Rules

Maperitive rendering rules are defined in style sheets. These are text files that use a special format, which will be described in more detail further on. The rendering rules are set with the use-ruleset command. The default style sheets are located in the Maperitive/Rules/ directory, but style sheets can be accessed as long as they are on the local file system. After the rendering rules have been set, they must be applied with the apply-ruleset command. For example:

```
use-ruleset location=C:\Maperitive\Rules\default.mrules

apply-ruleset
```

6.9.5 Exporting the Map

After all the previous steps the map is rendered on the fly and is displayed in the rendering engine. In order to use the map in other applications it must be exported. Maperitive can export maps in a number of formats:

- Vector map | The map is rendered in the Scalable Vector Graphic (SVG) format, which is based on XML. Vector files are good if you want to work on the map post-rendering. The vector files can be imported into vector drawing programs such as Adobe Illustrator or Inkscape. SVG files are also capable of limited animation.

- Map Tiles | The main purpose of map tiles is to accelerate sending a map over the internet. A map is cut up into a set of tiles, which are then sent individually, instead of sending the whole map as one large image. Map tiles are usually served by a tile server and are viewed by web map tools, such as OpenLayers or Leaflet. The map tiling in Maperitive follows the MapBox tiling convention.

- 3D Map | Via the export-3d command, Maperitive generates a 3D mesh using a digital elevation model and places the map texture on top of it. The 3D model uses the COLLADA format, which can be imported into various 3D programs.

- Bitmap | Bitmaps are raster images. They can be used to display a static map on a screen, or can be printed. Bitmaps can be edited with raster graphics software, such as Adobe Photoshop or GIMP. Maperitive supports various bitmap formats: PNG, JPEG, GIF, TIFF, BMP.

The project uses the export-bitmap command to export the maps as raster images. The following is a description of the export-bitmap command. The other commands are not relevant and will not be further described here.

```
export-bitmap

   – file=<output file> [default= output.png]

   – width=<bitmap width> [default= current map view]

   – height=<bitmap height> [default= current map view]

   – zoom=<zoom> [default= current map zoom level]

   – map-scale=<map scale> [default= calculated automatically]
```

– scale=<scale> [default= 1; cannot be set at the same time as DPI]

– dpi=<DPI> [default= 100dpi; cannot be set at the same time as scale]

– aspect=<true/false> [default= true]

– subpixel=<subpixel precision> [default= 1]

– color-depth=<8 or 32> [default= 32; only works for PNG]

– world-file=<true/false> [default= false]

– kml=<true/false> [default= false]

– ozi=<true/false> [default= false]

6.9.6   Automation via Script

Maperitive commands can be automated by using a script. It is basically a text file with a .mscript extension. Each line can contain one command, written as if they were executed individually at the command line. The script is therefore just a chaining of commands. The following are the contents of an example .mscript file:

```
clear-map

set-geo-bounds 11.66,47.9473,12,47.2

set-print-bounds-geo

set-dem-source name=SRTM

use-ruleset location=D:\Maperitive\Rules\default.mrules

apply-ruleset

load-source D:\Data\default.osm.pbf

zoom-bounds
```

6.10 Rendering Rules

Maperitive uses rendering rules to define the features that are included on a map, as well as how these features are drawn. Rules are specified in a simple text file with an .mrules

extension. This file is also referred to as a style sheet and it can be edited with a text editor. Each style sheet is separated into two parts, the feature specification and the rendering rules. The following is a barebones schema of a style sheet. Note the properties section, which is used to define global rendering properties. The rest of this section will describe the various parts of a style sheet in greater detail. The style sheet of the project can be found in the annex of this thesis.

```
features

        areas

        lines

        points

properties

rules

        target  :  feature1

        target  :  feature2
```

6.10.1 Feature Definition

The feature definition section of a style sheet specifies which data features are included in the map. Briefly stated, it maps data features to rendering features (map features). Rendering features are defined by a number of attributes: feature type, feature name, target, and spatial conditions. In the following example tree is the feature name, node is the target, and natural tree is the spatial condition.

```
tree : node [natural=tree]
```

The feature types are point, line, and area. Note that in OSM many tags can be appended to different feature types. For example, a church tag can be added to both an area feature and a point feature. The feature name is used to reference the feature in the rendering rules section.

A target is a more specific way of describing a feature type. Targets are not necessary, since Maperitive can deduce the target from the feature type and the spatial condition, but are useful since they eliminate ambiguity. The following targets are currently supported:

- node (= OSM node)

- way (= OSM way)

- relation (= OSM relation)

- contour

- gpstrack

- gpsroute

- gpswaypoint

- gpspoint

Spatial conditions are mainly used for OSM data and basically act as a filter. They specify which attributes the data features must have in order to be selected. The spatial conditions test against OSM key=value tags. There are various types of spatial conditions:

- Simple test conditions that check the existence of a tag by specifying the tag name, i.e. [highway].

- Comparison conditions that compare the tag value with either a string value or a numerical value. For example: [highway=motorway] or [width=100].

- Function conditions, which call a function that takes arguments and calculates whether the condition is fulfilled or not. For example, the @isOneOf function takes a tag and multiple values as an argument and tests feature values for compatibility.

- Negative (or inverted) condition using the "NOT" keyword. i.e. [NOT highway].

- Combined conditions using logical operators, such as "AND" and "OR". For example, [highway=motorway OR highway=primary].

- Nested conditions, which are made up of several conditions joined by the "." syntax. The second condition operates on the results of the first. For example, [barrier=toll_booth.highway=motorway].

When using this method for defining features a question comes up: why is it necessary to specify the features a second time, when OSM features are already specified using key=value tags? This is a justified question, since specifying features a second time adds complexity to the map making process and requires additional effort to map the data features to the rendering features. In spite of the disadvantages it is worthwhile, because it offers some advantages, such as:

- Support for other data sources besides OSM,

- Freedom to name features in a different manner,

- Data features can be grouped together,

• Generalization by selecting features.

6.10.2 Rendering Properties

Rendering properties define the graphic representation of the data features. They correspond to the graphic elements and the graphic variables. The rendering properties in Maperitive can be accessed by entering 'help-properties' in the command line. Table 18 shows most of rendering properties supported by Maperitive.

Table 18: Maperitive Rendering Properties.

line-color	fill-color	shape	text
line-end-cap	fill-hatch	shape-aspect	text-align-horizontal
line-hatch	fill-hatch-color	shape-def	text-align-vertical
line-hatch-color	fill-hatch-opacity	shape-mode	text-avoid-overlaps
line-hatch-opacity	fill-opacity	shape-orientation	text-color
line-join	fill-texture	shape-size	text-decoration
line-offset	map-background-color	shape-spacing	text-direction
line-offset-miter-limit	map-background-opacity	icon-image	text-halo-color
line-offset-sides	map-sea-color	icon-width	text-halo-opacity
line-opacity	map-sea-opacity	shield-padding-bottom	text-halo-width
line-start-cap	map-sea-texture	shield-padding-right	text-letter-spacing
line-style	font-family	shield-padding-top	text-line-spacing
line-width	font-size	shield-padding-left	text-max-width
border-color	font-stretch	shield-resize-mode	text-offset-horizontal
border-opacity	font-style	align-horizontal	text-offset-vertical
border-style	font-weight	align-vertical	text-opacity
border-width			text-orientation

Rendering properties are defined in two places within a style sheet, in the properties section and in the rendering rules. The properties section consists solely of rendering properties and is usually used for specifying global rules. For example:

```
properties
```

```
map-background-color: #F1EEE8

map-background-opacity : 1

map-sea-color : #B5D0D0

font-weight : bold

font-family : Verdana
```

6.10.3 Rendering Rules

After the features have been selected in the feature definition section, the next step is to specify the rendering rules. A rendering rule specifies how a feature should be rendered, or, in other words, the visual characteristics a feature will have after rendering. Rendering rules consist of a feature selector, the "define" keyword, rendering properties, and a "draw" keyword. Additionally, some rules may contain conditional flow statements after the "define" keyword: "if", "elseif", "for", "elsefor", and "else".

```
rules

   target : motorway

      define

         line-color : green

         line-width : 5

      draw : line
```

The "target" keyword starts a rule definition and is followed directly by a feature selector. The feature selector defines which feature the rule applies to. Features can be selected based on feature type or by feature name. Additionally, wildcards or regular expressions can be used to match against feature names.

The "define" keyword is followed by one or more rendering properties, which are then set as the rendering values of the feature. The rule is eventually finished by a "draw" keyword. The "draw" keyword commands Maperitive to draw a map symbol. Currently, Maperitive supports a number of map symbol types: fill, icon, shape, line, text, and shield.

6.10.4 Rendering Order

Besides the formal syntax of the style sheet, it is also important to know the order in which features will be rendered. All features are drawn individually according to a rendering

order and there are a number of things which have an effect on the order: intrinsic drawing order, OSM layer tag, rendering rules ordering, and feature ordering.

Maperitive has an intrinsic drawing order for individual drawing stages, with each stage drawing over the previous stage. This order cannot be modified by the user. The drawing order is:

- MapBackground = land or sea polygons.

- Landmass = land polygons, if sea background was drawn before.

- BitmapBackground = raster images and Web map tiles.

- LandUse = all fill symbols.

- BitmapForeground = raster images.

- Infrastructure = all contour and line symbols.

- Symbols = all icon and shape symbols.

- Labels = all text symbols.

- BitmapOverlay = Web map tiles.

- MapLegend = map grid and map scale.

OSM data has a layer tag, which describes vertical relationships between objects. It is mainly used to tag objects such as bridges and tunnels, which are located above or below other features, for example a bridge is located above a river. The default value is layer=0 and should not be used. The value range allowed is from -5 to 5, with negative values indicating "under" and positive values meaning "above". Maperitive supports these tags, but relies on the OSM features to be tagged properly. These tags and values cannot be modified in Maperitive, instead the data itself must be modified.

Rule ordering and feature ordering only apply to features of a same drawing stage as specified in the drawing order above. First, features are ordered according to the rule ordering. Rendering rules specified before others, will be rendered above the others. In other words, rendering rules that come first in a style sheet will be rendered last.

If a rule applies to multiple features, then the feature order is taken into account as well. Analogous to rule ordering, features specified first will be rendered above features specified later. With the rule ordering and feature ordering in mind, another concise way of putting it is, a style sheet is rendered from the bottom up.

6.11 Results

It is not possible to include the whole maps produced in the thesis. Therefore only a handful of extracts are included. For each extract there is a corresponding extract from the Austrian topographic map series 1:50.000 (the print maps were scanned). With both map areas the same it is possible to compare the graphic quality as well as the data quality of the maps produced. The maps were created with the following resources:

- OSM data file in .osm.pbf format covering Austria downloaded from Geofabrik. The individual map areas were extracted with Osmosis.

- SRTM V3.0 and Viewfinder Alps DEM data was used. Both datasets are default values in Maperitive and are downloaded automatically.

- A style sheet, which was created to mimic the Austrian map style. The topographic map style comparison was instrumental in the creation of this style sheet. It can be found in the annex.

- Graphic resources that mimic the Austrian map style. The topographic map style comparison was instrumental in the creation of these resources. They can be seen in 6.8.

Each map was created with the help of a script. The following is the script file for the Silvretta extract (Silvretta is in the Alps, between Vorarlberg, Tyrol, and Switzerland). The other scripts only vary minimally and are not included here.

```
clear-map

set-geo-bounds 10.005,46.805,10.325,46.995

set-print-bounds-geo

set-dem-source name=VF.Alps

use-ruleset location=D:\Maperitive\Rules\oek50.mrules as-alias=oek50

apply-ruleset

generate-relief-igor

generate-contours interval=20

load-source D:\Maperitive\osm_data\silvretta.osm.pbf

zoom-bounds

export-bitmap dpi=300 map-scale=50000
```

The extracts were chosen to represent different landscape types. The areas selected are restricted to those landscape types found within Austria. The landscape types were chosen because their geographical characteristics make them challenging to represent in a cartographic manner.

- Tulln and surrounding area | Figure 20 and Figure 21 | SRTM3V3 DEM | This area is characterized by flat terrain, sparse population besides the larger town, agricultural fields, and the Danube river and the wetland forests along its banks. This area is interesting for the thesis because of the low feature density, which allows more features to be included in the map. Besides that it includes a number of transport structures such as power lines, motorways, and rail lines. The area also includes a large number of embankments and dikes along the transport structures and along the rivers and streams.

- Wallersee and surrounding area | Figure 22 and Figure 23 | SRTM3V3 DEM | This area is characterized by mixed land use, rolling hills, a large number of mid- and smaller sized settlements, a lake. The challenge will be displaying the density and variety of features correctly. Especially because of the large number and variety of settlements, the mix of small wooded areas with smaller agricultural areas, and the large number of small roads.

- Silvretta | Figure 24 and Figure 25 | Viewfinder Alps DEM | This is a mountainous area that is characterized by steep slopes, deep valleys, mountain peaks and ridges, rocky outcroppings, scree, glaciers. Furthermore it is also characterized by a lack of settlements and man-made features, as well as a sparse vegetation. This area is mainly interesting because of the terrain. This will pose a challenge because the tools used are not especially designed for representing these type of features, for example rocks and scree. The remoteness of the areas will also be a good indicator of the data completeness in non-settled areas.

- City of Vienna | Figure 26 and Figure 27 | SRTM3V3 DEM | This is an urban area and is characterized by a large feature density, consisting mainly of buildings and other man-made features. One challenge will be in representing the various degrees of building density. Another challenge will be the interplay between roads and buildings. Other characteristics are the representation of some buildings with symbols, for example monuments and churches. Perhaps the most interesting facet will be the generalization of features or lack thereof.
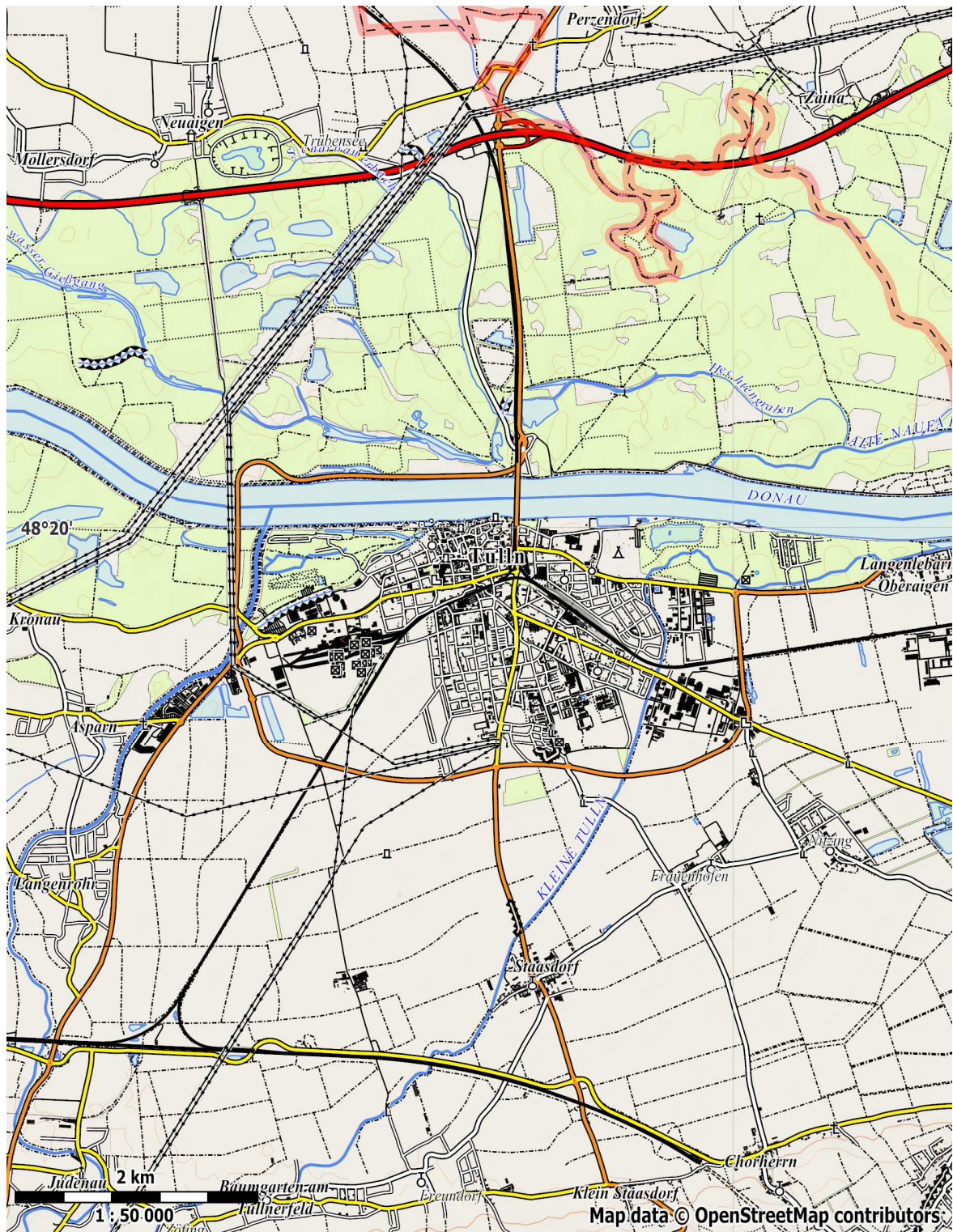
Figure 20: Result extract 1, Tulln and surrounding area.
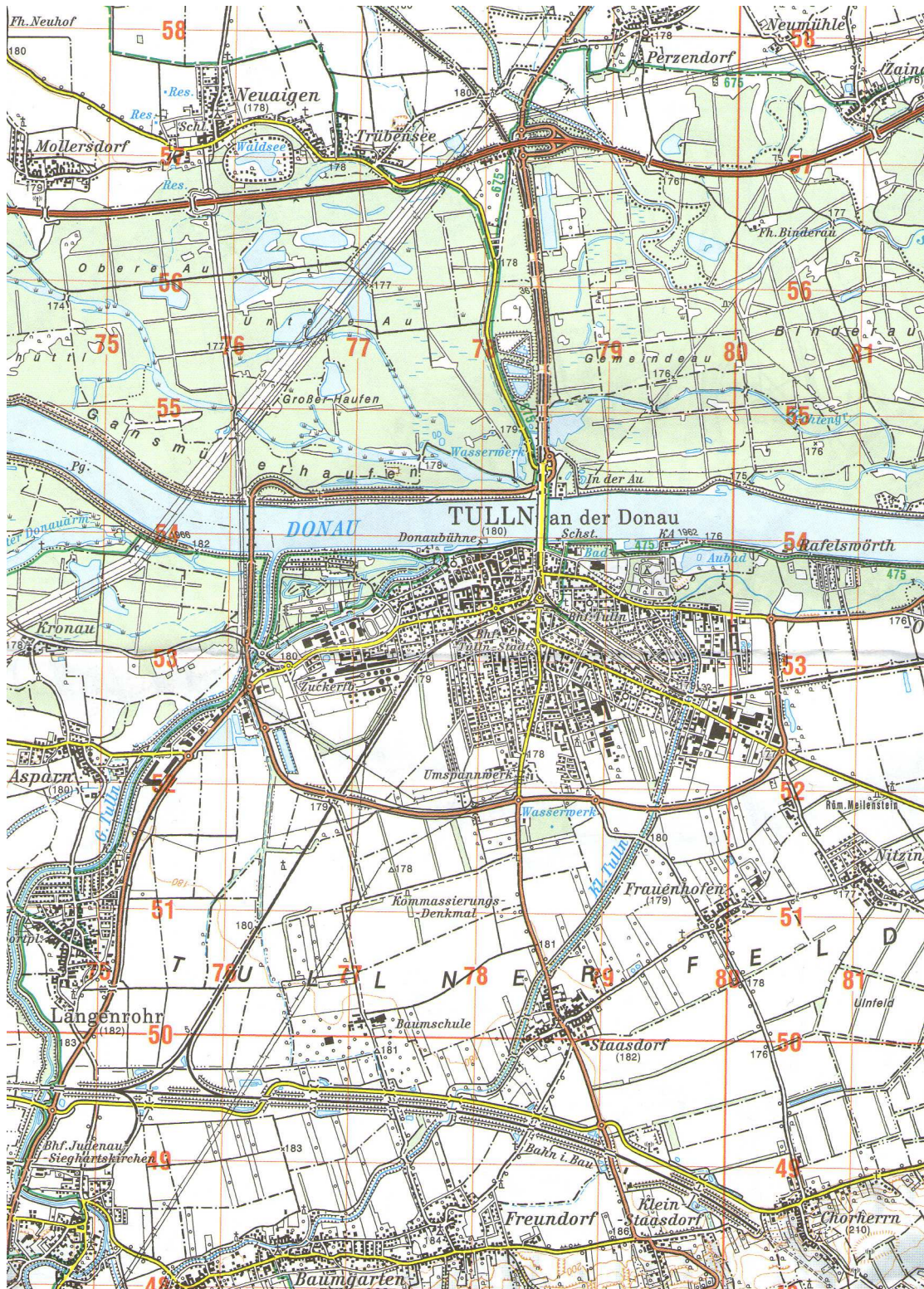
Figure 21: Austrian map extract 1, Tulln and surrounding area. From [BEV-10]
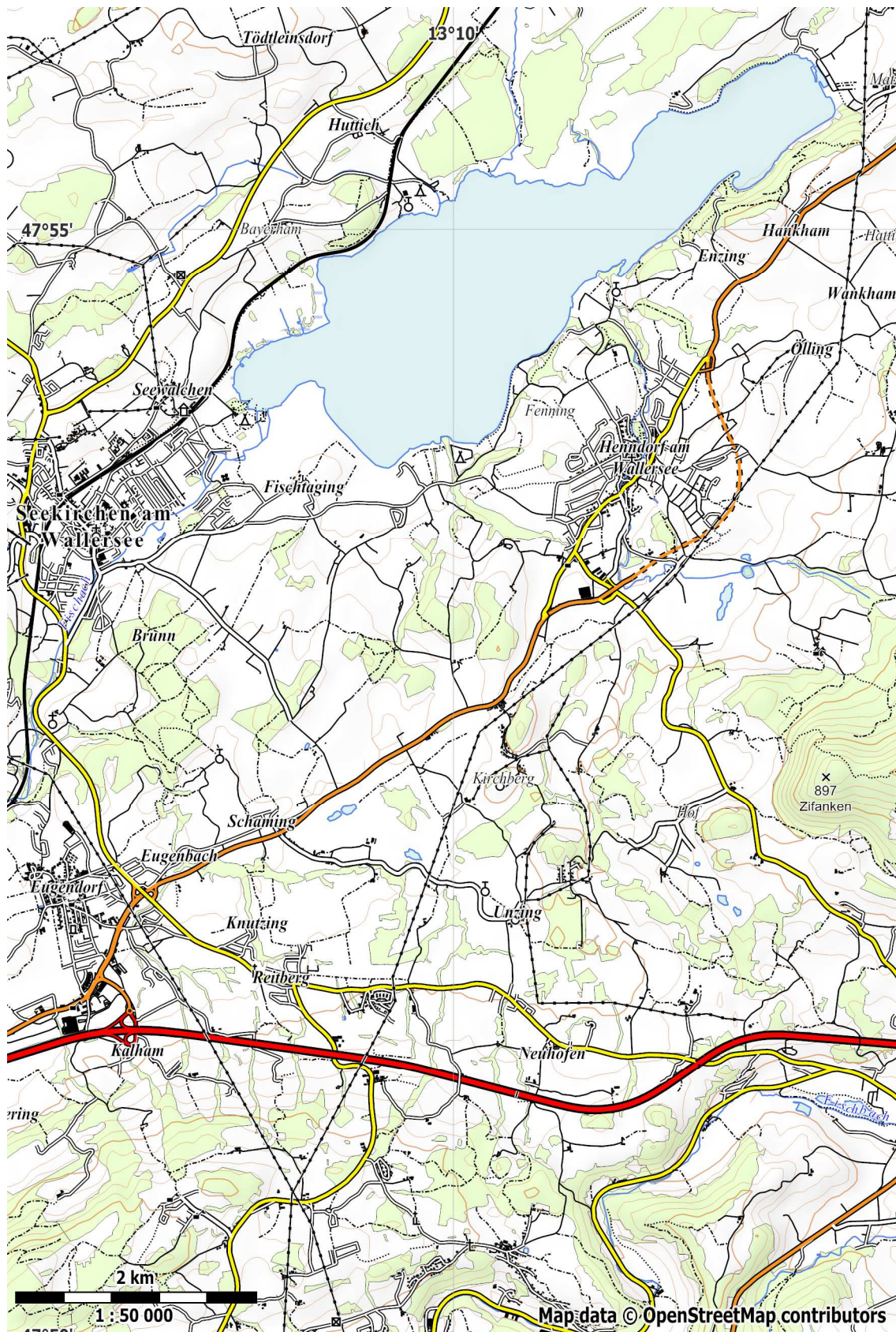
Figure 22: Result map extract 2, Wallersee and surrounding area.

Figure 23: Austrian map extract 2, Wallersee and surrounding area. From [BEV-05].
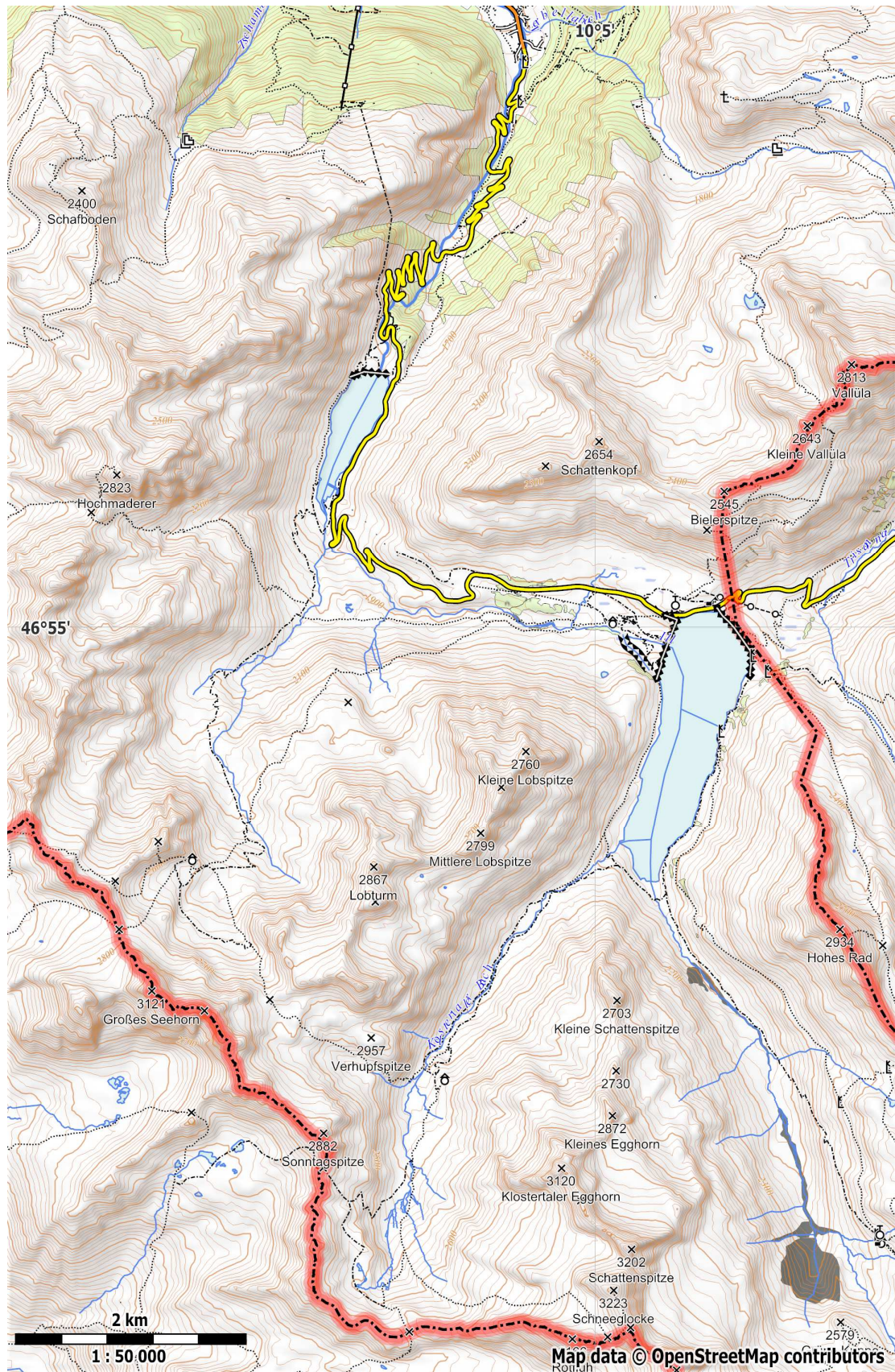
Figure 24: Result map extract 3, Silvretta.
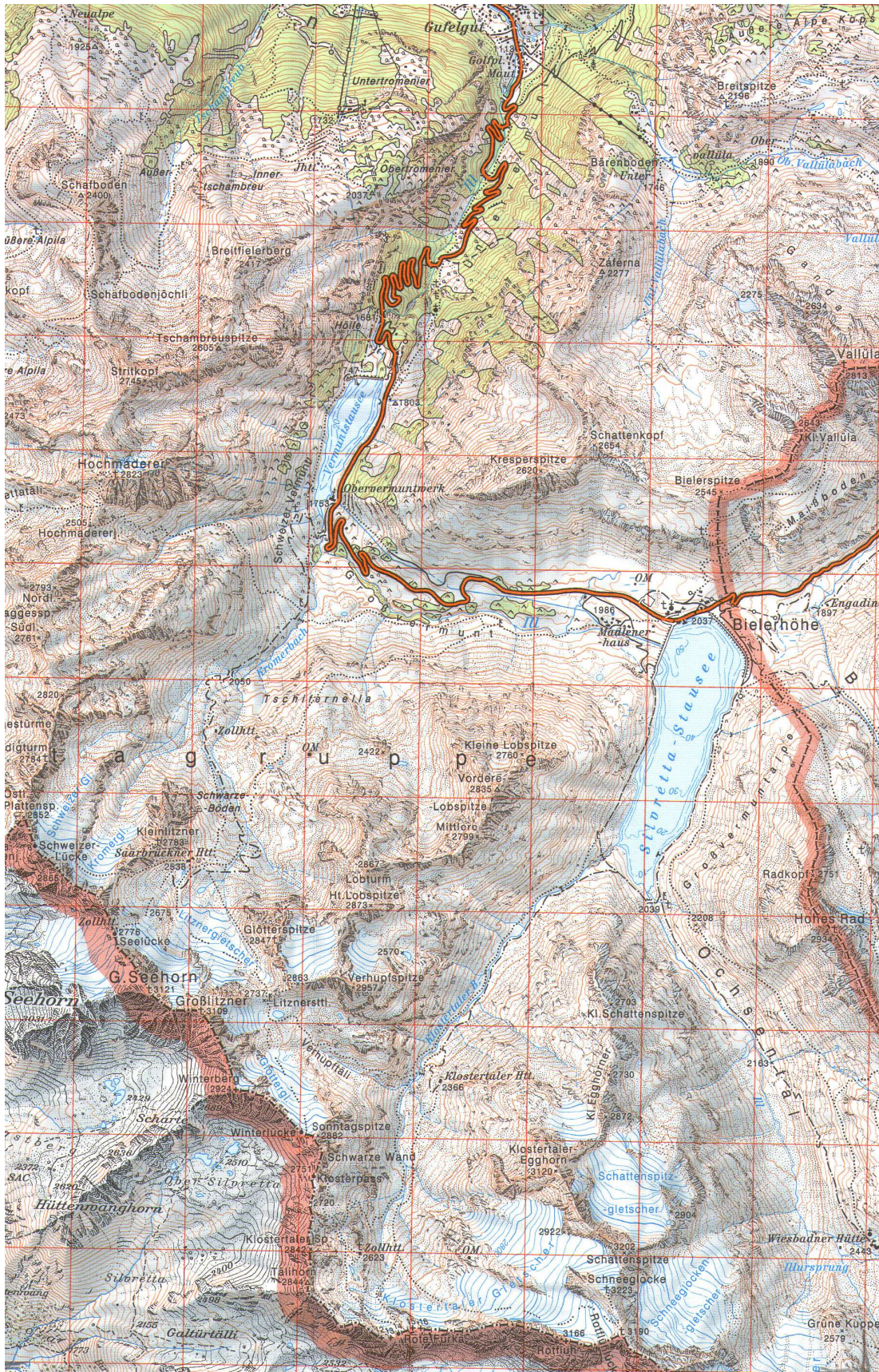
Figure 25: Austrian map extract 3, Silvretta. From [BEV-07].
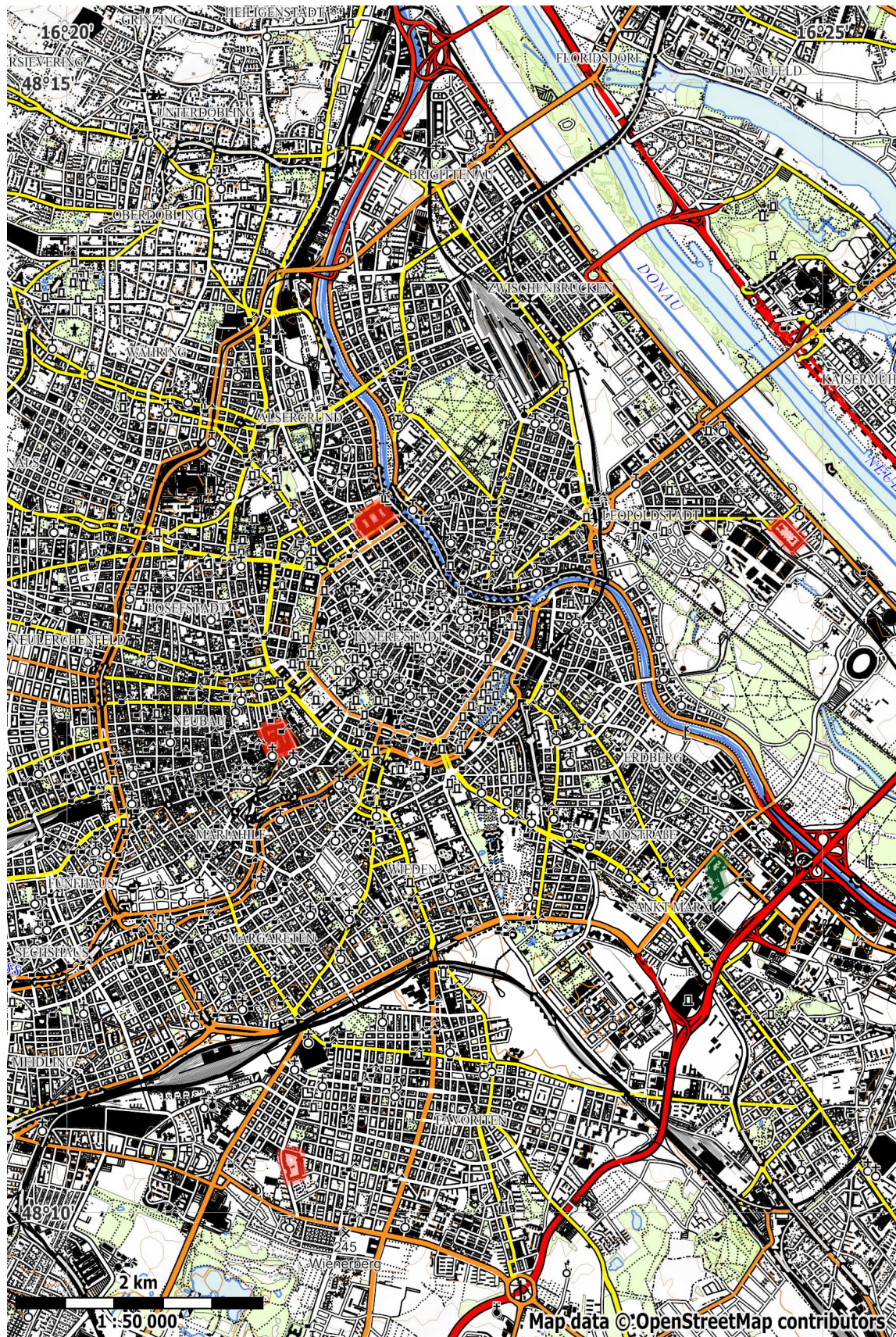
Figure 26: Result map extract 4, City of Vienna.

Figure 27: Austrian map extract 4, City of Vienna. From [BEV-10].

7 Conclusion

The concluding chapter consists of three parts. The first is the evaluation of the results of the practical example. The second part is a discussion on whether the guiding questions were adequately answered. The third part is the outlook, where further research is discussed.

7.1 Evaluation

For the evaluation details were taken of the map extracts from the previous chapter and placed side by side. The details are magnified. On the left hand side are the details of thesis maps and on the right hand side are details of the Austrian topographic maps.

7.1.1 Tulln
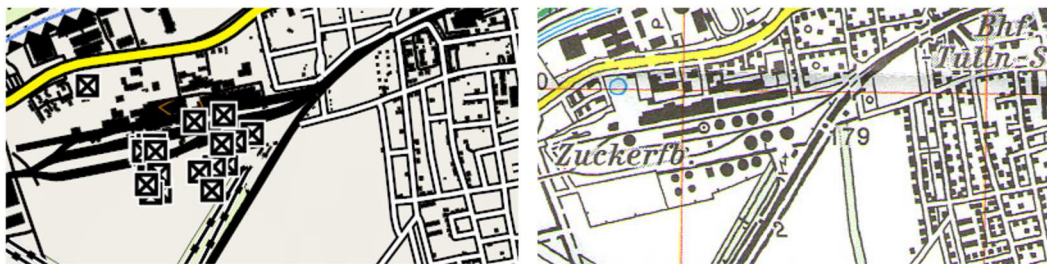
Figure 28: Detail comparison of the Tulln extracts No. 1. [BEV-10].

Figure 28 shows a detail of the west side of the town of Tulln. There are three main issues in this detail. First, some silos, which are part of a sugar refinery, are displayed as individual symbols on the thesis map. The problem is that there are so many in such a small area that they overlap one another, as well as the features that lie under them.

The second issue is, in the thesis map rail lines and buildings are both displayed in a single color, black. This fact has lead to the buildings and rail tracks in the refinery to overlap and visually merge together into a black figure. It is impossible to distinguish between the rail tracks and the buildings because of this. On the other hand, in the Austrian map the same features are easily distinguishable. This can be attributed to generalization. The Austrian map also includes the generic name for the sugar refinery.

The third issue is that on the thesis map there are very few buildings in the town in comparison to the Austrian map. This is most probably either because they are not present in the OSM data (at the time of writing), because they were improperly selected, or because they are displayed below the streets and therefore not visible. This last reason

could also indicate that the buildings are potentially displaced in relation to the roads on the Austrian map.
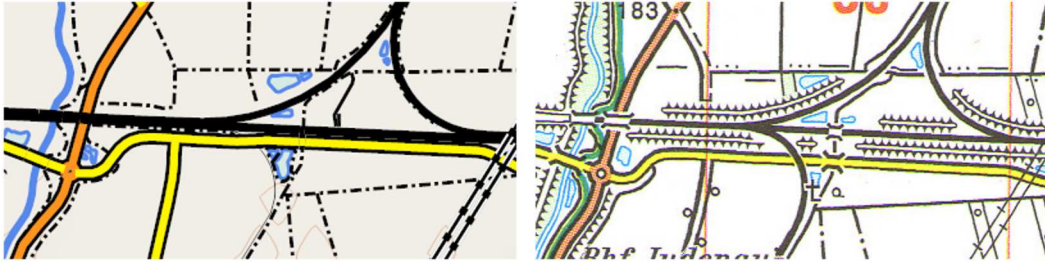
Figure 29: Detail comparison of the Tulln extracts No. 2. [BEV-10].

Figure 29 shows infrastructure found on the Tulln extract. This detail was selected because it shows a number of issues. The first issues is that there are no embankments displayed on the thesis map. Second, in the Austrian map there is quite a bit of feature displacement between the roads, embankments, and rail tracks. Third, bridges and over/underpasses are not represented on the thesis map in comparison to the Austrian map. In the thesis map the features are bunched up together and therefore less distinguishable. The Austrian map on the other hand uses generalization techniques to better display them in the available space.

Figure 30: Detail comparison of the Tulln extracts No. 3. [BEV-10].

Figure 30 shows some agricultural fields on the Tulln map extract. It is included to illustrate a number of missing features on the thesis map. There are no hedges, tree lines, windbreaks, or individual trees on the thesis map. Additionally, the trigonometric point is missing, as well as the way cross near the road. And finally, the monument name is displayed on the Austrian map but not in the thesis map.

This detail (Figure 30) also illustrates a problem with line styling in the thesis map. It was not possible to reproduce the design used for the field tracks in the Austrian map with the Maperitive rendering software. The design consists of a white line with a solid border on one side and a dashed border on the other.

Figure 31: Detail comparison of the Tulln extracts No. 4. [BEV-10].

Figure 31 shows a floodplain forest along the banks of the Danube. There are five issues of note in this detail comparison. First, in the thesis map the forest is displayed as a large continuous area, whereas in the Austrian map the forest is criss-crossed by many (predominantly straight) cuttings.

Second, the smaller waterways are displayed as simple lines in the thesis map and as either areas or as lines with borders in the Austrian map.

The third issue is the lettering along the waterways in the thesis map. In the name 'Hechtengraben' the spacing between the third and fourth letter ('c' and 'h') seems to be wider than the other letters, whereas it is narrower between the eleventh and twelfth ('b' and 'e') letters. This is a mild example because the river is fairly smooth, but the issue is aggravated the more winding a line is. This problem is directly attributed to the rendering software. In contrast the lettering along the same stream on the Austrian map has consistent letter spacing.

Fourth, in comparison to the Austrian map, the thesis map is missing the power lines in the forest, as well as the dike (or embankment) along the Danube river in the bottom of the detail.

Fifth, contour lines appear to be absent in the Austrian map. In contrast the thesis map includes a number of contour lines, that mostly form closed polygons. This indicates very subtle changes in elevation. Whether these contours are correct or represent flaws in the elevation data cannot be ascertained from this detail comparison.

7.1.2   Wallersee
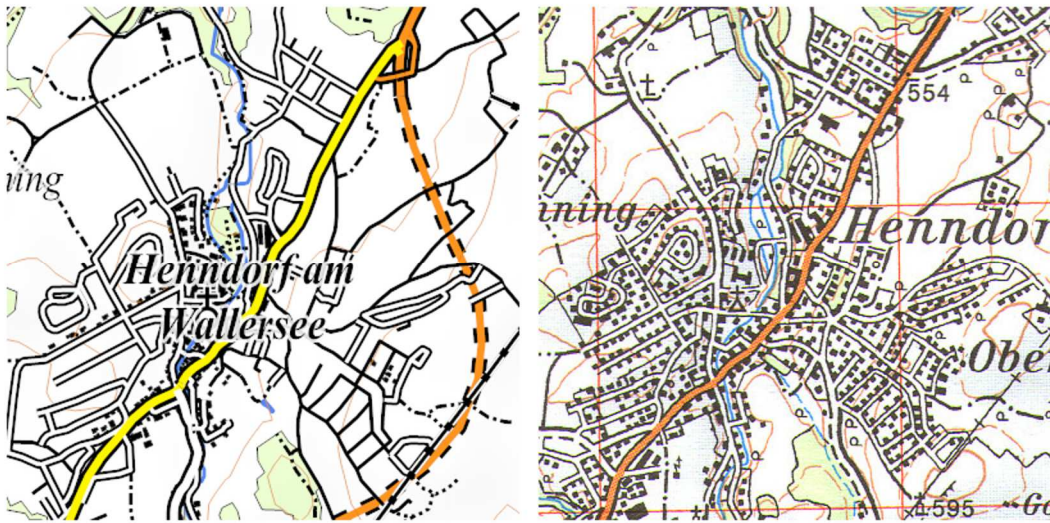
Figure 32: Detail comparison of the Wallersee extracts No. 1. [BEV-05].

Figure 32 shows the town of Henndorf am Wallersee. There are four main issues in this detail comparison. The first issue is the tunnel bypass which is present in the thesis map but is not present in the Austrian map. This indicates that the bypass was built after the year 2005, the year the Austrian map was published. Second, in contrast with the Austrian map the thesis map has very few buildings. Third, the placement of the lettering in the thesis map is not optimal. It is placed directly over the center of the town and because of this the town structure can no longer be discerned. Finally, the contour lines on both maps do not seem to correspond to one another.

Figure 33: Detail comparison of the Wallersee extracts No. 2. [BEV-05].

Figure 33 shows an area on the shores of lake Wallersee. There are a few observations to make on this map detail. First, although the contour lines match up on both maps, the Austrian map does seem to have more detailed lines. Additionally, the Austrian map includes auxiliary contours lines (the dashed brown lines). Second, the depiction of the wetlands in the thesis maps is barely noticeable. It is the very blurry horizontal light blue lines along the lake shore. This seems to be due to the resolution of the texture tiles used to fill in area features. The third issue is the missing bathymetric lines in the lake. This is

either due to the elevation data not being included for water bodies or because the lake polygon is drawn above the bathymetric lines. Fourth and finally, in the thesis map the embankments along the road are missing, as well as the buildings. Additionally, on the Austrian map the smaller roads and tracks along the main road appear to be displaced.
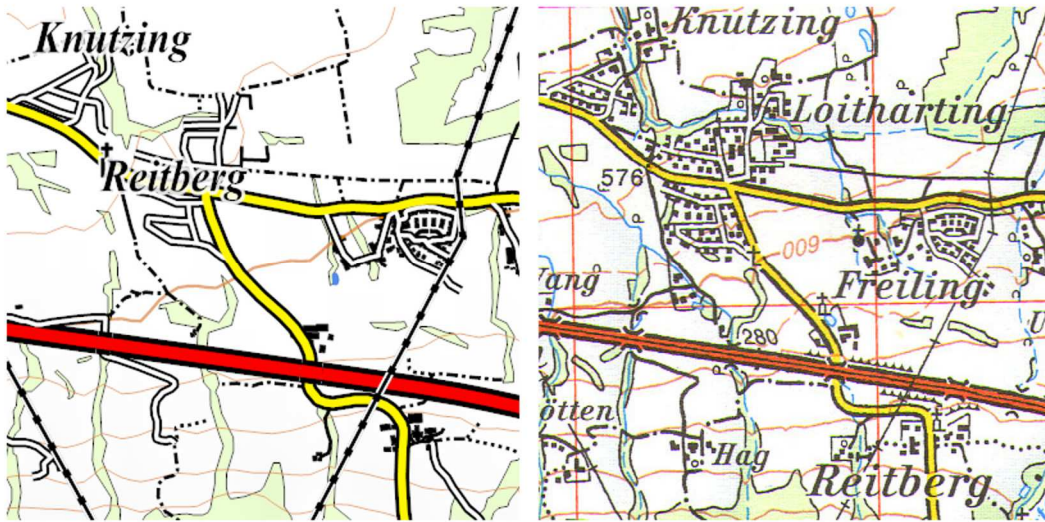
Figure 34: Detail comparison of the Wallersee extracts No. 3. [BEV-05].

Figure 34 includes a number of issues which have already been pointed out in the previous details and that will not be commented further, such as missing buildings in the thesis map. However there are three that should be mentioned. The first issues is the missing names of the settlements. This issues is evident when one considers the whole map extract (see Figure 22). This is probably due to either missing data or due to the classification of the settlements in the data and the selection process in the rendering software.

The second issue is the settlement of Reitberg. In the Austrian map it is a small settlement just south of the motorway and in the thesis map it is a settlement north of the motorway. Considering that the Austrian map should be an authoritative source of place names, the error must then lie in the OSM data. It seems that the town of Loitharting has been incorrectly named Reitberg.

The third issue is the depiction of the motorway. In the Austrian map it is represented by a red line with black borders and a black centerline. In the thesis map it appears to be represented by a single red line with black borders. It would be possible to draw such a line with Maperitive, but the truth of the matter is that the motorway is modeled as two separate roads in the OSM data. These are drawn side by side, but are so near one another that they overlap. Because the red lines are drawn in one layer and the black lines (to visualize the borders) in another layer, it appears that only one line is drawn.
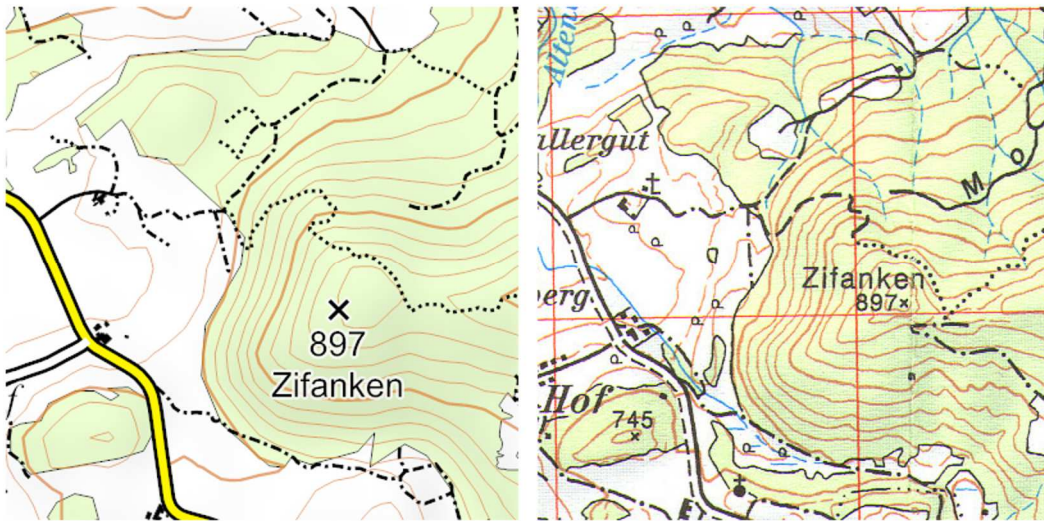
Figure 35: Detail comparison of the Wallersee extracts No. 4. [BEV-05].

Figure 35 shows a detail of a hill on the Wallersee extract and is included in order to compare the contour lines created with SRTM data. The contours seem to correlate in representing the general structure of the terrain. However, in the thesis map the contour lines are both rounder and more straightened out, whereas in the Austrian map the contour lines are more detailed and somewhat ragged. Also in the Austrian map the contour lines correspond well with the streams flowing down the north face of the hill. On the thesis map detail the peak symbol does not seem to correspond with the contour lines. It is hard to tell where the problem lies, but in comparison with the Austrian map it seem the peak in the thesis map is positioned slightly more to the west than the peak in the Austrian map.

7.1.3 Silvretta
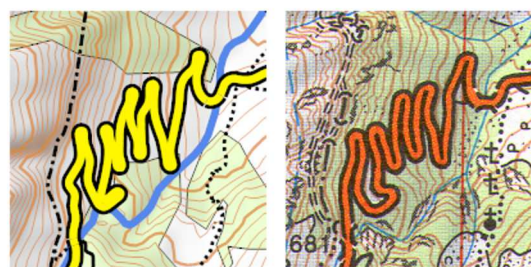
Figure 36: Detail comparison of the Silvretta extracts No. 1. [BEV-07].

Figure 36 is included to show one difference between the thesis map and the Austrian map. Both details show a winding road along a steep slope in the Silvretta. However, in the Austrian map the road appears to be generalized. Each individual hairpin turn is distinguishable and the road lines do not seem to overlap. Compare this to the thesis map, where the lines overlap each other and, although the general characteristics of the road are visible, it is not as distinguishable as the depiction on the Austrian map.
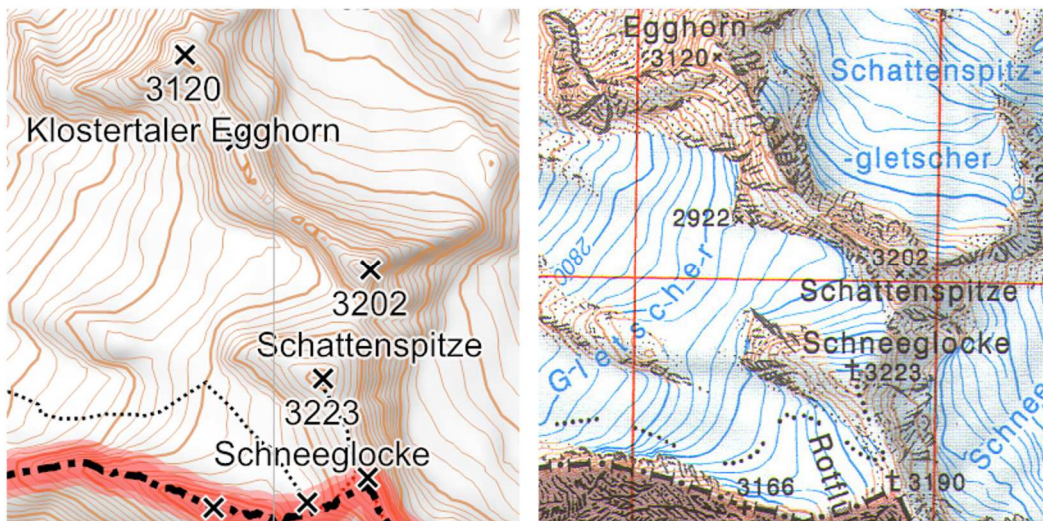
Figure 37: Detail comparison of the Silvretta extracts No. 2. [BEV-07].

Figure 37 shows a mountain ridge and glaciers found on the Silvretta map extract. This detail illustrates the missing rock depiction in the thesis map. In contrast the Austrian map includes rock depiction. The detail also illustrates a second issue, the representation of glaciers. In the thesis map, glaciers are included, but are not visible because they are represented by areas with a white fill. In the Austrian map they are visible due to two reasons. The first and perhaps more important reasons is that the contour lines within a glacier are colored blue instead of brown. The second reason is that the glaciers are indicated by the name of the glacier represented by blue lettering.
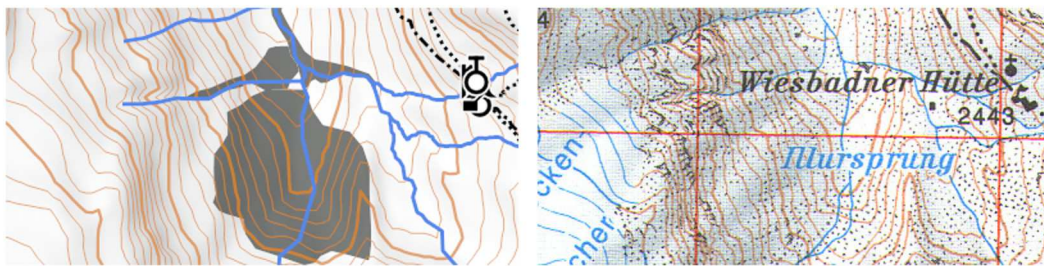
Figure 38: Detail comparison of the Silvretta extracts No. 3. [BEV-07].

Figure 38 illustrates the way scree is currently included in the OSM data. In the thesis map the gray polygons represent areas designated as scree. Scree could have been represented better in the thesis map by a texture fill. The main point to be made is that the area does not seem to correspond well with the Austrian map. The area of designated as scree is much too small. In the Austrian map almost the whole detail is covered by scree. Indeed this area of scree was one of the very few that seemed to be included in the OSM data.
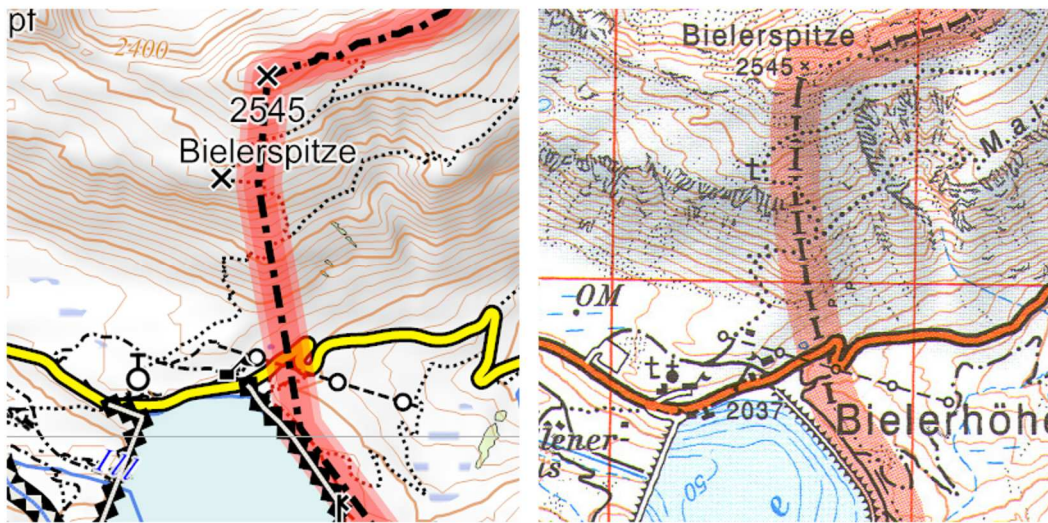
Figure 39: Detail comparison of the Silvretta extracts No. 4. [BEV-07].

Figure 39 shows the Bielerhöhe in the Silvretta. There are a number of issues in this map detail. The first issue consists of a number of missing features on the thesis map: mainly rocks, scree, and bathymetric lines. Besides that, there is a double hairpin turn in the road in the thesis map which is not present in the Austrian map. Additionally, it appears that the hiking trails leading up to the Bielerhöhe are different from the Austrian map.

The second issue is the depiction of the dam walls. In the Austrian map a dam is depicted by a line with triangles along one or both borders indicating a steep slope. It was not possible to reproduce this design with Maperitive and a workaround was tried. The workaround is drawn much too large and is not at all satisfactory.

The third issue is the depiction of the aerial way. In the Austrian map it is represented by a dashed line with hollow circles at the beginning and end, as well as at regular intervals along the line. In the thesis map they are represented by a dashed line with hollow circles at regular intervals along the line, but with no circles at the beginning and end.

The fourth issue is the positioning of the 'Bielerhöhe' lettering in the thesis map. The lettering could be interpreted as referring to either of the two peaks present, because the lettering is positioned between two separate peak symbols and because the second peak is not named. The Austrian map solves this by positioning the lettering higher up in a place where there is no doubt to which peak it refers to.

The final issue is the representation of the borderlines on the thesis map. There are two issues here. First, the line symbol (dashed line with 'serifs') used on the Austrian map was not reproducible with Maperitive. Instead a line with point-dashes was used. The red transparent border 'highlight' was reproducible. The second issues with the border lines is how they are present in the OSM data. In the OSM data each administrative unit is represented by an individual polygon. This means that when the polygons are drawn in Maperitive, each individual polygon will be drawn. This leads to the lines being drawn several times in the same position.
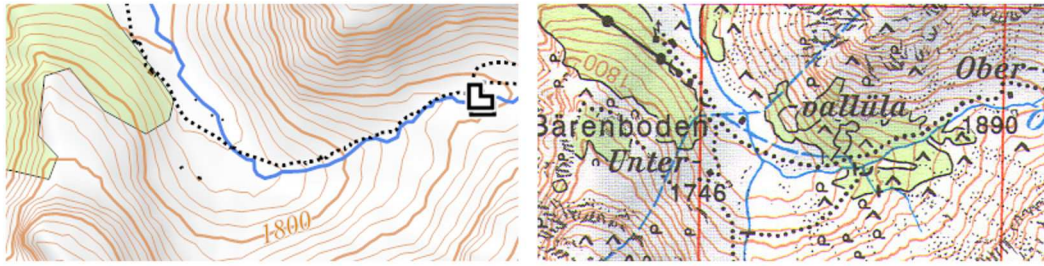
Figure 40: Detail comparison of the Silvretta extracts No. 5. [BEV-07].

Figure 40 is included to illustrate missing features in mountain areas in the thesis map. In comparison to the Austrian map, the thesis map lacks: forest areas, individual tree symbols, hiking trails, aerial ways, streams, scree, rock depiction, spot heights, and lettering. The thesis map looks 'empty' in comparison to the Austrian map.
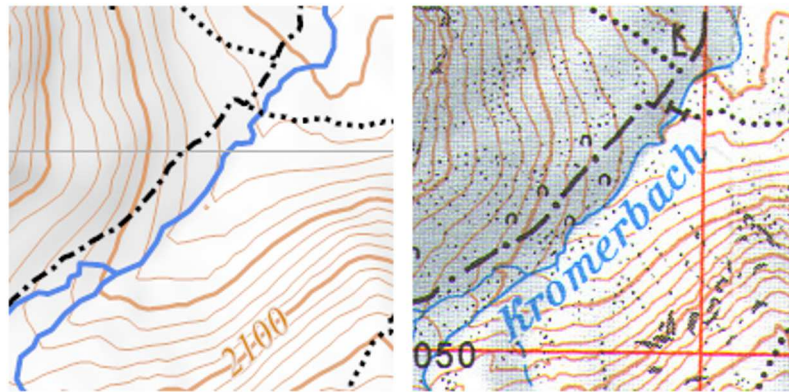
Figure 41: Detail comparison of the Silvretta extracts No. 6. [BEV-07].

Figure 41 is intended to compare the contour lines in both maps. The contour lines correspond quite well across both maps. The general structure and form of the landscape seems to be the same. However, in the thesis map, the contour lines do not correspond well with the line of the mountain stream. The stream line should be positioned directly on top of the 'kinks' in the contour lines, which indicate a trench in the landscape, where the stream would naturally flow. Instead the position of the stream line is just off to the west of the 'kinks'. Compare this to the Austrian map where the stream line and the contour lines correspond perfectly.

7.1.4 Vienna

Figure 42: Detail comparison of the Vienna extracts No. 1. [BEV-10].

Figure 42 shows the city center of Vienna. The main issue with this detail is the large amount of individual symbols on the thesis map. The symbols represent churches, monuments, and hotels. In the Maperitive rendering rules it was not possible to select less features. The symbols are so numerous that they overlap one another and cover all other features underneath them. The symbols are also drawn too large in comparison with the symbols on the Austrian map. In contrast, the Austrian map includes only a selection of churches and monuments in the same area. These are smaller and much better integrated with the other map contents.

Figure 43: Detail comparison of the Vienna extracts No. 2. [BEV-10].

Figure 43 shows a part of the city of Vienna. The main issue in this detail is that a section of the thesis map seems to be missing buildings, as indicated by the white areas. The same section in the Austrian map does include buildings.

Besides the missing buildings, there is another issue of note in this detail. The buildings in the Austrian map appear to be generalized. Buildings within a city block have been aggregated together and result in individual city blocks represented as a 'solid' black

polygon with few 'holes'. In contrast the thesis map displays the buildings as they are represented in the data. This leads to city blocks which are less 'solid' and contain many more smaller 'holes'. Due to the generalization in the Austrian map, the visual emphasis is on the city blocks and the structure of the city, instead of the individual buildings.

Figure 44: Detail comparison of the Vienna extracts No. 3. [BEV-10].

Figure 44 shows a cemetery in the city of Vienna. In the Austrian map cemeteries are represented by areas filled with cross symbols in regular or irregular intervals. In the thesis map the cemetery is currently represented by a area with black fill. This is a mishap in the definition of the style rules by the author.

Figure 45: Detail comparison of the Vienna extracts No. 4. [BEV-10].

Figure 45 shows the area of the former Südbahnhof (now Hauptbahnhof) in Vienna. The Austrian map, which is a little older, still includes the old Südbahnhof with its buildings, train tracks and train yards. The same area appears as a white area in the thesis map, because at the time of writing the area was under construction.
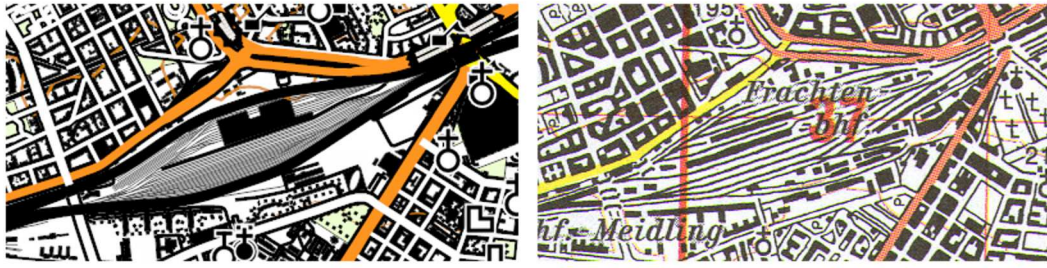
Figure 46: Detail comparison of the Vienna extracts No. 5. [BEV-10].

Figure 46 shows a detail of a train yard in Vienna. In the thesis map the main trail tracks are represented as thick black lines and the tracks of the train yard are represented as thin gray lines. The gray lines are so numerous that they are poorly distinguishable. In the Austrian map all train tracks are drawn be thin black lines, which are all equally thick. Additionally, it seems that the lines have been generalized and are easily distinguishable.

7.2 Discussion

In the introduction, the guiding questions for the thesis were postulated. Now after examining cartographic theory and conducting a practical experiment, it is time to consider the questions again and see if they have been adequately answered.

7.2.1 Main Guiding Question

The main guiding question is: Is it possible to make high quality topographic maps from open data using open source or free-to-use tools? As has been demonstrated in the practical example, it is possible to create a topographic map from open data and using free-to-use tools, albeit with a number of caveats. The software used was only free-to-use and not open source, although there are open source alternatives. The real debate is whether the results can be considered high quality topographic maps. From the comparison and evaluation it is clear that the results have a number of issues. Some of these issues are minor and could probably be corrected by adapting a few steps of the mapping process, but some issues are major and would require significant changes to the mapping process. The quality of the map also varies depending on the area mapped, because there are differences in the type and amount of issues found in each mapped area. Due to these reasons the resulting maps can be considered of lesser quality than the maps of the Austrian topographic map series.

7.2.1   Map Production Process

The mapping process is responsible for a good number of the issues found. The process itself was loosely based on the map making processes described in section 3.6, topographic map production, but adapted to the data and tools at hand. The advantage of the mapping process used in this thesis is that it is fairly easy to set up and therefore results can be produced fairly rapidly. This is especially true if some resources are available beforehand. The main resources that are time consuming to create are the map rendering rules, the icons, and the textures. If these resources are available beforehand then the mapping process is quite fast and a map producer could spend more time tweaking the process to suit his needs.

The resources previously mentioned were created by hand based on the map style of the Austrian topographic map series 1:50.000 in chapter 4. This procedure was very time consuming and be improved upon. Issues such as lines and point symbols drawn too large, the depiction of cemeteries, or the use of texture fills on areas are direct results of these resources and therefore of the procedure used to create them. These issues could be corrected by modifying the resources.

There are a number of issues encountered in the thesis, that are direct results of the rendering software used. Issues that can be attributed to the map rendering software are: the positioning and spacing of lettering along lines, a lack of possibilities to position lettering in general, a lack of flexibility of defining the drawing order of individual or groups of features, and few options for drawing complex lines. Since rendering software itself cannot be modified by the map maker, the most tangible options available are to either wait for the issues to be corrected by the software developers or to use another map rendering software. Although every rendering software will have its own issues.

The next issues is the depiction of the terrain, or rather lack thereof. The thesis maps either do not visualize rocks and scree at all or depict these in an unsatisfactory manner. Mainly this is because there is no special way to draw them in Maperitive, besides using polygons filled with either solid colors or textures tiles. Many minor landforms are commonly visualized by complex lines, such as wedge lines, but as has been noticed in the previous paragraph, Maperitive has very few options for drawing complex lines. For glaciers there is potentially a workaround for drawing contour lines of different colors. Vector lines and glacier polygons could be intersected in a GIS to produce two contour line datasets, one with only those lines covered by glaciers and the other with the rest. Both layers could then be imported into Maperitive separately and rendered in different colors.

In the practical example, the only method of generalization applied was the selection of features. The selection of features used in Maperitive, which selects features by the OSM tag schema are too limited. This has resulted in issues such as overlapping symbols in the city center of Vienna. Maperitive offers no other means of generalization. Applying generalization to the thesis maps would certainly enhance the map quality thereof. Taking an example from the Austrian map for example, the thesis maps could benefit from

aggregation, selection, and simplification applied to buildings, or the displacement of features along roads.

One way to apply generalization would be to derive a new data model from the OSM data. The data could be especially prepared for the representation at a scale of 1:50.000. This type of data preparation seems to be commonplace in the production of topographic maps. Further research into available tools is necessary since this procedure was not considered at the time of making the thesis map.

7.2.1 Openness and Open Data

The concept of 'openness', the history of the open movement, some definitions of openness, and the legal background were covered in a theoretical manner. The practical chapter lists a number open data sources and open tools, although the list is not exhaustive. It is foreseeable that the quality and quantity of open data and open tools will increase in the future and there are two things to look out for. First, many governmental institutions are releasing more and more data as open data. Open government data is usually characterized by high quality and is therefore very useful for making maps. Second, most open source tools are being improved and, in addition to this, many new open source tools are constantly being developed. Cartographers should also be on the lookout for open tools that have not been developed specifically for cartographic purposes, but can be adopted and used for cartography. Cartographers can, and should, play an important role in the creation of new data, as well as the development of new tools.

One issue found on most of the thesis maps is missing features. Although this could be due to other reasons, such as improper selection of features, there is no doubt that many features are simply not present in the OSM data. Since OSM data can be created by just about anyone, the easiest solution would be for map makers to simply add the missing features to the OSM data. Otherwise map makers will have to wait for somebody else to add the features. The number of features in the OSM database will probably continue increasing as time goes on and more people join the OSM community. Another option could be to use another data source were available, such as open government data.

Some issues in the thesis maps have to do with the thematic accuracy of OSM data. The thematic accuracy suffers due to two characteristics of OSM data: it is collected in a collaborative manner and it has a flexible tagging scheme. This means that an OSM data creator can tag features as he sees fit. The main way that this is counteracted is by creating best practices that should be followed by every single OSM editor. However it is very difficult to enforce these best practices. Besides that, new tools are being developed for finding strange or uncommonly used tags and correcting these in order to enhance the thematic accuracy of the data. Since the OSM project has matured and the data in some regions is very complete some OSM contributors have turned their attention to the quality of the data and have started initiatives with the goal of reviewing and correcting OSM data.

The elevation datasets have been compared visually in 6.4.7. Because the elevation datasets are easily interchangeable in Maperitive, it makes sense to try the various datasets out and select the one that best fits the specific area being mapped. From the comparison we can say that there are two main characteristics that differentiate the elevation datasets: resolution and errors. The differences in resolution become evident when one compares the relief shading in Figure 15 and Figure 16. SRTM DEM, ASTER GDEM, and EU DEM all have lower resolutions than Viewfinder Alps DEM and Tirol DEM. The mountain ridges are very rounded in the SRTM DEM and well defined in the Tirol DEM. It is preferable to use the highest resolutions DEM where possible. The main errors to look out for are data "voids". These are areas where the sensors did not collect data. These voids are especially prevalent in the SRTM and ASTER datasets. Most of the newer versions of these datasets fill in the voids with data from other elevation datasets or by interpolation methods.

7.3 Outlook

A number of topics have sprung up for further research. These are some of topics that warrant a closer look, but were not covered in this thesis.

- It would be very interesting to repeat the practical example for different scale groups, especially 1:25.000 and 1:100.000 - 1:250.000.

- It would also be very interesting to create other map styles and compare the results with other topographic maps series, for example the CanTopo or NZTopo map series, which were analyzed in this thesis.

- New Zealand has released the data used to make their topographic maps series. It would be interesting to use this data instead of OSM, in order to better assess the capabilities of the renderer, as well as the rest of the map making process used in this thesis.

- It would be interesting to try out a different rendering engine, such as Mapnik.

- Research could be undertaken to find ways of deriving a data model from OSM data for the sole purpose of creating a topographic map from it. For example, researching how to apply generalization techniques on OSM data.

- Research possibilities for visualizing bodies of rock and scree.

- Research ways to improve OSM data, especially concerning thematic accuracy and completeness.

8   References

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Annex: Style Sheet

```
// Ruleset created by Norman Herold in the context of the master thesis:
// Topographic Maps from Open Data.
// Institute for Geography and Regional Studies, University of Vienna.
// This ruleset for maperitive aims to mimic the style of the austrian map ÖK50.


//---------------------------------------------------------------------------------------
-------------
features

  points
    // ======  Places  ======
    place_city : place=city
    place_town : place=town
    place_village : place=village
    place_hamlet : place=hamlet
    place_suburb : place=suburb


    // ======  Icons  ======
    trigonometric_point : man_made=survey_point
    spot_height : mountain_pass=yes OR natural=saddle
    peak : natural=peak AND NOT (man_made=summit_cross OR summit:cross=yes)
    cave : natural=cave_entrance
    spring : natural=spring
    stone : natural=stone
    tree : natural=tree
    sinkhole : natural=sinkhole


    // ======  Shield  ======
    junction : highway=motorway_junction

  points, areas
    // ======  Building icons  ======
    train_station:  railway=platform  OR  public_transport=platform  OR  railway=halt  OR
railway=station OR railway=subway_entrance OR railway=tram_stop
    cathedral : building=cathedral OR cathedral=yes
    church : building=church OR church=yes
    chapel : building=chapel OR chapel=yes OR building=wayside_chapel OR wayside_chapel=yes
    religious : amenity=place_of_worship
    castle : historic=castle
    ruins : historic=ruins OR ruins=yes
    lodging : amenity=shelter OR @isOneOf(tourism, guest_house, hostel, hotel, motel)
```

```
   alpine_hut : @isOneOf(tourism, alpine_hut, wilderness_hut)
   wind_turbine : power=generator AND generator:source=wind
   transmitting_station : man_made=tower AND tower:type=communication
   mine : @isOneOf(man_made, adit, mineshaft)
   silo : man_made=silo
   oiltank : man_made=storage_tank
   mill : man_made=watermill OR man_made=windmill OR craft=sawmill
   wayside_shrine   :    building=wayside_shrine    OR    wayside_shrine=yes    OR
historic=wayside_shrine
   cross  :  historic=wayside_cross   OR   man_made=cross   OR   man_made=summit_cross   OR
summit:cross=yes
   signpost : information=guidepost
   camping : @isOneOf(tourism, camp_site, caravan_site)
   observation_tower : man_made=tower AND tower:type=observation
   monument : historic=monument OR historic=memorial
   border_post : barrier=border_control OR barrier=toll_booth
   // reservoir : man_made=reservoir_covered

 lines
   // ======  Railways  ======
   rail_normal : railway=rail AND NOT @isOneOf(service, siding, spur, yard)
   rail_yard : railway=rail AND @isOneOf(service, siding, spur, yard)
   rail_narrow_gauge : railway=narrow_gauge
   tramway : railway=light_rail OR railway=tram
   subway : railway=subway


   // ======  Boundaries  ======
   boundary_country : boundary=administrative AND (admin_level=2 OR admin_level=4) AND NOT
natural=coastline
   boundary_province : boundary=administrative AND admin_level=6 AND NOT (admin_level=2 OR
admin_level=4)
   //boundary_municipal : boundary=administrative AND admin_level=8
   boundary_gemeinde :
   boundary_military : military=barracks
   boundary_customs :
   national_park   :    boundary=national_park    OR    boundary=protected_area    OR
leisure=nature_reserve


   // ======  Other  ======
   fence : barrier=wall OR barrier=fence
   hedge : barrier=hedge OR natural=tree_row
   power_lines : power=line OR power=minor_line


   // ======  Aerialways  ======
   aerial_cableway : aerialway=cable_car OR railway=funicular
```

```
    aerial_gondola : aerialway=gondola OR aerialway=mixed_lift
    aerial_chair_lift : aerialway=chair_lift
    aerial_drag_lift : aerialway=drag_lift
    aerial_goods_cableway : aerialway=goods


    // ======  Roads  ======
    road_motorway : highway=motorway
    road_major : @isOneOf(highway, trunk, primary, secondary, tertiary)
    road_link : @isOneOf(highway, motorway_link, trunk_link, primary_link, secondary_link,
tertiary_link)
    road_minor : @isOneOf(highway, residential, living_street, pedestrian)
    road_way : @isOneOf(highway, unclassified, service)
    road_track : highway=track AND (@isOneOf(tracktype, grade1, grade2, grade3) OR NOT
tracktype)
    path : @isOneOf(highway, path, footway, pedestrian, steps) OR (highway=track AND
@isOneOf(tracktype, grade4, grade5))
    bridge : bridge=yes //rail
    footbridge : bridge=yes AND (foot=yes OR highway=footway)
    tunnel : tunnel=yes
    gallery :
    culvert : tunnel=culvert


    // ======  Hydro  ======
    // River, canal >20m
    hydro_riverbank : waterway=riverbank
    // River, canal >5m
    hydro_river : waterway=river OR waterway=canal
    // River, canal <5m
    hydro_stream : waterway=stream OR waterway=drain OR waterway=ditch
    hydro_conduit :
    hydro_conduit_underground :
    hydro_waterfall_rapids :
    hydro_sluice : waterway=weir OR waterway=lock_gate OR lock=yes
    hydro_warf : man_made=groyne
    hydro_floodgate :
    hydro_dam : waterway=dam


    // ======  Terrain  ======
    embankment : man_made=embankment OR barrier=retaining_wall OR embankment=yes OR
man_made=dyke
    ditch : barrier=ditch OR waterway=drain OR waterway=ditch OR cutting=yes
    cutaway : cutting=yes


    // ======  Contour  ======
    contour_major : contour[@isMulti(elevation, 100)]
```

```
   contour_minor : contour[@isMulti(elevation, 20) and not @isMulti(elevation, 100)]


  areas
    // ======  Man-made  ======
    building : building=yes
    residential : landuse=residential
    aeroway_area :


    // ======  Natural  ======
    scree : natural=scree
    forest : (landuse=forest OR natural=wood OR leisure=park) AND NOT wood=coniferous
    mountain_pine : (landuse=forest OR natural=wood) AND wood=coniferous
    scrub : natural=scrub
    orchard : landuse=orchard
    vineyard : landuse=vineyard
    wetlands : natural=wetland
    water : natural=water OR waterway=riverbank OR landuse=reservoir OR landuse=basin
    glacier : natural=glacier
    cemetery : landuse=cemetery OR amenity=grave_yard


//-----------------------------------------------------------------------------------
-------------
properties
  map-background-color : #FFFFFF
  map-background-opacity: 1
  map-sea-color : #B0C4DE
  text-halo-width : 15%
  text-halo-opacity : 0.75


//-----------------------------------------------------------------------------------
-------------
rules

// ======  Labels  ======

  // ======  Places  ======
  target : place*
    define
      //font-weight : bold
      font-family : Times New Roman
      text-align-horizontal : center
      text-align-vertical : center
      font-stretch : 0.9

      if : *city
```

```
    define
      text : @up(name)
      font-size : 20
  elseif : *town
    define
      font-size : 15
      text-letter-spacing : 0.1
      font-weight : bold
  elseif : *village
    define
      font-size : 12
      font-style : italic
      font-weight : bold
  elseif : *hamlet
    define
      font-size : 11
      font-style : italic
  elseif : *suburb
    define
      text : @up(name)
      font-size : 9
      text-halo-width : 20%
  else
    stop
  draw : text


// ======  Peaks  ======
target : peak
  define
    // text : @if(name, name @if(ele, "\n(" ele ")"), ele)
    text : @if(ele, ele @if(name, "\n" name), ele)
    text-color : black
    font-size : 9
    text-max-width : 10
    text-offset-vertical : 40%
    text-align-vertical : near
  draw : text


// ======  Hydro  ======
target : hydro_*
  define
    text : name
    text-color : blue
    font-family : Times New Roman
    font-style : italic
```

```
      text-offset-vertical : -60%
      text-letter-spacing : 0.1
      text-orientation: flow
      map.rendering.lflp.min-buffer-space : 5
      map.rendering.lflp.max-allowed-corner-angle : 120
      map.rendering.lflp.max-compression : 5
    if : *river
      define
        text : @up(name)
        font-size : 10
    elseif : *stream
      define
        text : name
        font-size : 9
    else
      stop
    draw : text

// ====== Icons - Points ======

  // ======  Buildings  ======
  target : $featuretype(point, area)
    define
      icon-width : 16

    if : cathedral
      define
        icon-image : D:\Maperitive\icons\oek50\cathedral.png
    elseif : church
      define
        icon-image : D:\Maperitive\icons\oek50\church.png
    elseif : chapel
      define
        icon-image : D:\Maperitive\icons\oek50\chapel.png
    elseif : religious
      define
        icon-image : D:\Maperitive\icons\oek50\religious.png
    elseif : castle
      define
        icon-image : D:\Maperitive\icons\oek50\castle.png
    elseif : ruins
      define
        icon-image : D:\Maperitive\icons\oek50\ruins.png
    elseif : lodging
      define
```

```
    icon-image : D:\Maperitive\icons\oek50\lodging.png
elseif : alpine_hut
  define
    icon-image : D:\Maperitive\icons\oek50\alpine_hut.png
elseif : wind_turbine
  define
    icon-image : D:\Maperitive\icons\oek50\wind_turbine.png
elseif : mine
  define
    icon-image : D:\Maperitive\icons\oek50\mine.png
elseif : silo
  define
    icon-image : D:\Maperitive\icons\oek50\silo.png
elseif : wayside_shrine
  define
    icon-image : D:\Maperitive\icons\oek50\wayside_shrine.png
elseif : cross
  define
    icon-image : D:\Maperitive\icons\oek50\cross.png
elseif : signpost
  define
    icon-image : D:\Maperitive\icons\oek50\signpost.png
elseif : camping
  define
    icon-image : D:\Maperitive\icons\oek50\camping.png
elseif : observation_tower
  define
    icon-image : D:\Maperitive\icons\oek50\observation_tower.png
elseif : monument
  define
    icon-image : D:\Maperitive\icons\oek50\monument.png
elseif : trigonometric_point
  define
    icon-image : D:\Maperitive\icons\oek50\trigonometric.png
elseif : spot_height
  define
    icon-image : D:\Maperitive\icons\oek50\spot_height.png
elseif : peak
  define
    icon-image : D:\Maperitive\icons\oek50\spot_height.png
elseif : cave
  define
    icon-image : D:\Maperitive\icons\oek50\cave.png
elseif : transmitting_station
  define
```

```
      icon-image : D:\Maperitive\icons\oek50\transmitting_station.png
    else
      stop
    draw : icon


// ======  Lines  ======

  // ======  Boundaries  ======
  target : boundary_country
   define
     line-style : dashdot
     line-width : 2
     line-color : #000000
   draw : line
  target : boundary_country
   define
     line-style : solid
     line-width : 12
     line-color : #FF2509
     line-opacity : 0.5
   draw : line


  target : boundary_province
   define
     line-style : dashlong
     line-width : 1
     line-color : #000000
   draw : line
  target : boundary_province
   define
     line-style : solid
     line-width : 8
     line-color : #FF2509
     line-opacity : 0.5
   draw : line


  target : boundary_municipal
   define
     line-style : dot
     line-width : 3
     line-color : #000000
   draw : line


  target : boundary_military
   define
```

```
      line-style : solid
      line-width : 2
      line-color : #CC1E07
    draw : line
  target : boundary_military
    define
      line-style : solid
      line-width : 8
      line-color : #FF2509
      line-opacity : 0.5
    draw : line


  target : national_park
    define
      line-style : solid
      line-width : 2
      line-color : #004C20
    draw : line
  target : national_park
    define
      line-style : solid
      line-width : 8
      line-color : #00732F
      line-opacity : 0.5
    draw : line


  // ======  Power lines  ======
  target : power_lines
    define
      line-style : solid
      line-width : 1
      line-color : #000000
    draw : line
  target : power_lines
    define
      line-style : dash
      line-width : 2
      line-color : #FFFFFF
    draw : line
  target : power_lines
    define
      line-style : solid
      line-width : 2
      line-color : #000000
    draw : line
```

```
// ======  Aerialways  ======

target : aerial_cableway
 define
   shape : square
   shape-size : 3
   shape-spacing : 8
   fill-color : white
   line-width : 1
 draw : shape
 define
   line-width : 1.5
 draw : line


target : aerial_gondola
 define
   shape : square
   shape-size : 3
   shape-spacing : 8
   fill-color : white
   line-width : 1
 draw : shape
 draw : line


target : aerial_chair_lift
 define
   shape : circle
   shape-size : 2
   shape-spacing : 10
   fill-color : white
   line-width : 1
 draw : shape
 draw : line


target : aerial_drag_lift
 define
   shape : circle
   shape-size : 2
   shape-spacing : 10
   fill-color : white
   line-width : 1
 draw : shape
 define
   line-style : dash
```

```
  draw : line


target : aerial_goods_cableway
  define
    shape : circle
    shape-size : 2
    shape-spacing : 10
    fill-color : black
    line-width : 1
  draw : shape
  draw : line


// ======  Roads  ======

target : road_motorway*
  define
    line-style : solid
    line-width : 2
    line-color : #FF0000
  draw : line


target : road_major
  define
    line-style : solid
    line-width : 2
  for : highway=trunk
    define
      line-color : #FF2509
  for : highway=primary
    define
      line-color : #FF9521
  for : highway=secondary
    define
      line-color : #FFF600
  for : highway=tertiary
    define
      line-color : #FFFFFF
  draw : line


target : road_link
  define
    line-style : solid
    line-width : 1
  for : highway=motorway_link
    define
```

```
      line-color : #FF0000
  for : highway=trunk_link
    define
      line-color : #FF2509
  for : highway=primary_link
    define
      line-color : #FF9521
  for : highway=secondary_link
    define
      line-color : #FFF600
  for : highway=tertiary_link
    define
      line-color : #FFFFFF
  draw : line


target : road_minor
  define
    line-style : solid
    line-width : 1
    line-color : #FFFFFF
  draw : line


target : road_way
  define
    line-style : solid
    line-width : 1
    line-color : #000000
  draw : line


target : road_track
  define
    line-style : dashdot
    line-width : 1
    line-color : #000000
  draw : line


target : path
  define
    line-style : dot
    line-width : 1
    line-color : #000000
  draw : line


// ======  Road background  ======
```

```
target : road_motorway
  define
    line-style : solid
    line-width : 5
    line-color : #000000
  for : tunnel=yes
    define
      line-style : dot
  draw : line


target : road_major
  define
    line-style : solid
    line-width : 4
    line-color : #000000
  for : tunnel=yes
    define
      line-style : dot
  draw : line


target : road_link
  define
    line-style : solid
    line-width : 3
    line-color : #000000
  for : tunnel=yes
    define
      line-style : dot
  draw : line


target : road_minor
  define
    line-style : solid
    line-width : 2.5
    line-color : #000000
  for : tunnel=yes
    define
      line-style : dot
  draw : line


// ======  Railways  ======
target : rail_*
  define
    line-style : solid
    line-width : 2
```

```
   line-color : #000000
  for : tunnel=yes
   define
     line-style : dash
     line-width : 1
  if : *yard
   define
     line-width : 0.5
     line-color : #404040
  draw : line
target : rail_narrow_gauge
 define
   line-style : dashlong
   line-width : 1
   line-color : #000000
  for : tunnel=yes
   define
     line-style : dash
     line-width : 1
  draw : line
target : tramway
 define
   line-style : solid
   line-width : 1
   line-color : #000000
  for : tunnel=yes
   define
     line-style : dash
     line-width : 1
  draw : line
target : subway
 define
   line-style : solid
   line-width : 1
   line-color : #000000
  for : tunnel=yes
   define
     line-style : dash
     line-width : 1
  draw : line

// ======  Terrain, Minor Landforms  ======
target : embankment
 define
   shape : diamond
```

```
    shape-spacing : 0
    shape-size : 5
    shape-mode : linear
    shape-orientation : flow
    line-style : none
    fill-color : black
  draw : shape
  define
    shape : square
    shape-spacing : 0
    shape-size : 1
    shape-mode : linear
    shape-orientation : flow
    line-style : none
    fill-color : #F1EEE8
  draw : shape

target : ditch
  define
    line-style : solid
    line-width : 7
    line-color : black
  draw : line
  define
    shape : diamond
    shape-spacing : 0.3
    shape-size : 4
    shape-mode : linear
    shape-orientation : flow
    line-style : none
    fill-color : #F1EEE8
  draw : shape
  define
    shape : square
    shape-spacing : 0
    shape-size : 1
    shape-mode : linear
    shape-orientation : flow
    line-style : none
    fill-color : #5689EB
  draw : shape

  // ======  Hydro  ======
  target : water
    define
```

```
    line-style : solid
    line-width : 1
    line-color : #5689EB
    fill-color : #B6E6E8
    fill-opacity : 0.5
  draw : fill


target : hydro_river
  define
    line-style : solid
    line-width : 2
    line-color : #5689EB
  draw : line


target : hydro_stream
  define
    line-style : solid
    line-width : 1
    line-color : #5689EB
  for : intermittent=yes
    define
      line-style : dash
  draw : line


// ======  Contour lines  ======
target: contour*
  define
    line-color : #DE8709
    line-opacity : 0.8
    curved : true
  if : *_minor
    define
      line-width : 0.4
  elseif : *_major
    define
      line-width : 0.8
      map.rendering.contour.label : true
      text-color : #DE8709
      font-family : Times New Roman
      font-style : italic
      font-size : 7
      text-halo-width : 10%
      text-halo-opacity : 1
      text-halo-color : #F1EEE8
  //else
```

```
    //stop
  draw : contour


// ======  Areas, Landuse  ======


 target : $featuretype(area)
   define
     line-style : none
     line-width : 1


   if : building
    define
      fill-color : #000000
      line-style : solid
      line-width : 0
      line-color : #000000


   elseif : scree
    define
      fill-color : #7B7D7B


   elseif : forest
    define
      line-style : solid
      line-width : 0.5
      line-color : #000000
      fill-color : #DBFF96
      // fill-color : #edffcc (without alpha)
      fill-opacity : 0.5


   elseif : mountain_pine
    define
      line-style : solid
      line-width : 0.5
      line-color : #000000
      fill-texture : D:\Maperitive\Textures\oek50\mountain_pine.png


   elseif : scrub
    define
      line-style : solid
      line-width : 0.5
      line-color : #000000
      fill-texture : D:\Maperitive\Textures\oek50\scrub.png


   elseif : orchard
```

```
  define
    line-style : solid
    line-width : 0.5
    line-color : #000000
    fill-texture : D:\Maperitive\Textures\oek50\orchard.png


elseif : vineyard
 define
    line-style : solid
    line-width : 0.5
    line-color : #000000
    fill-texture : D:\Maperitive\Textures\oek50\vineyard.png


elseif : wetlands
 define
    fill-texture : D:\Maperitive\Textures\oek50\wetlands.png


elseif : glacier
 define
    fill-color : white


elseif : cemetery
 define
    line-style : solid
    line-width : 0.5
    line-color : #363535
else
 stop
draw : fill
```

Lebenslauf

Bachelorstudium Umwelt- und Bio-Ressourcenmanagement
an der BOKU, Wien
2004 - 2008

Bakk. Arbeit
„Borkenkäferproblematik und Klimawandel"
Betreuerin: Dr. Sabine Rosner

Bakk. Arbeit
„Wandel im Umgang mit Hochwassergefahren am Beispiel des Wienflusses"
Betreuer: DG Dr. Sven Fuchs

Ich versichere:

- dass ich die Diplomarbeit selbstständig verfasst, andere als die angegebenen Quellen und Hilfsmittel nicht benutzt und mich auch sonst keiner unerlaubten Hilfe bedient habe.

- dass ich dieses Diplomarbeitsthema bisher weder im In- noch im Ausland (einer Beurteilerin/ einem Beurteiler zur Begutachtung) in irgendeiner Form als Prüfungsarbeit vorgelegt habe.

- dass diese Arbeit mit der vom Begutachter beurteilten Arbeit übereinstimmt.

Datum   Unterschrift