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Master of Science in Geography

The geomorphological heritage of the Simen Mountains National Park
Inventory, evaluation and management strategies

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In collaboration with Ethiopian Wildlife Conservation Authority (EWCA)

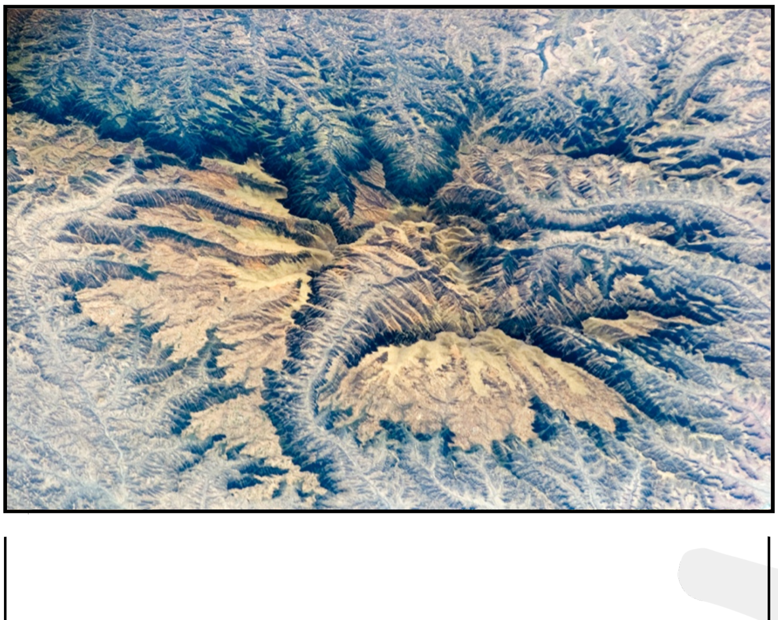

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Illustration on the front page: Astronaut photograph of the Simen Mountains taken on the 16th of November 2007; view from north (Image Science & Analysis Laboratory, Johnson Space Centre, 2007)

Unless stated otherwise, all illustrations are from the author.

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Motivation

My motivation to perform this Master's thesis in Ethiopia, in the remote region of the Simen Mountains, was besides the interesting research the direct contact with the local people. My four-month work and research experience in Ethiopia was characterised by diverse, instructive, beautiful, positive and partly also more difficult and frustrating moments for all I am very grateful.

Before, during and after completion of this work, I bear in mind, the Simen Mountains as a potential area for a UNESCO Global Geopark. For that purpose, I have done research. However, for the establishment of a Geopark it needs the full conviction and sympathy of all those involved, especially of the affected population. Although the investigation of geomorphological heritage and creating an inventory of geomorphosites, the SMNP represent the emphasis of this work, I shared ideas at various opportunities with local people, politicians, government officials, scientists, etc. Part of this work is not directly visible here, however one's own convictions and joy for conducting this research should most likely come to light.

Subsequently, we add some notable prospects and hopefuls that seem to exist in the area. The establishment of a new University in Debark has been recently announced by the national government. It remained unclear weather this should be an outsourcing branch of the Gonder University or a new University in itself (incorporating all the diverse schools, humanities, medicine, natural science, etc.). In any case, according to T. Mulu a University in Debark would provide the needed access to higher education for those living in remote areas. Simen may become a national competence centre for tourism and ecology and maybe also geoscience. M. Beyadegelegne hopes that this will help the SMNP to become an active laboratory for national and international research to support the park in its significant duties for conservation and sustainable regional development. We therefore see a positive outlook for Simen and it seems that the region develops towards the end that a Geopark is likely to become a subject in the future.

Summary

This Master's thesis focuses on the protection and outreach of the geological heritage (geoconservation) in developing countries. According to our research and experience in Ethiopia this requires a very cautious and systematic approach able to appraise the situation found on the ground (with primarily life-existential needs and a priority on economic and infrastructure development).

The central objective of this work is to investigate how a geomorphosite inventory can improve the knowledge and management of geomorphological heritage and thus contribute to regional sustainable development in contexts of developing countries. A geomorphosite inventory method developed at the University of Lausanne, Switzerland and tested several times, mainly in the Alpine region was applied to the afro-alpine environment of the Simen Mountains National Park in Ethiopia. 21 geomorphosites were identified and fully documented. The results show the geomorphological heritage of the SMNP is in almost perfect conservation state and of considerable scientific, educational, tourist and ecological interest.

A management program consisting of eight strategic objectives to increase awareness and sustainable use of geomorphological heritage of the SMNP (geotourism development) was subsequently developed. It includes for instance, thoughts to capacity building of park staff, expansion and diversification of the trekking-experience or the introduction of an accreditation system for professionalization of guided tours.

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Many thanks...

To my supervisor, **Professor Emmanuel Reynard** for his confidence in me, his sincere and competent support which has inspired me during the creation of this work.

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Teshome Mulu, Coordinator of the SMNP - Integrated Development Project (IDP) of the Austrian Development Cooperation (ADC);

Maru Beyadegelegne, Chief Warden of the Simen Mountains National Park (SMNP).

And to all those who in one way or another, contributed to the development of this Master's thesis.

[1] በድጋሚ አመሰግናለሀ means many thanks in Amharic

Glossary and Abbreviations

ADC	Austrian Development Cooperation
CDE	Centre for Development and Environment, University of Bern
COGE	IUGS Commission on Geoscience Education, Training and Technology Transfer
DTM	Digital terrain model
EWCA	Ethiopian Wildlife Conservation Authority
FZS	Frankfurt Zoological Society
GGN	Global Geopark Network
GMP	General management plan
IUCN	International Union for Conservation of Nature
IUGS	International Union of Geological Sciences
Kebele	Community (Amharic)
LIA	Little ice age
SMNP	Simen Mountains National Park
TDP	Tourism development plan
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
Walia	Walia Ibex
WCMC	World Conservation Monitoring Centre
Wereda	District (Amharic)
WH site	World Heritage site
WWF	World Wildlife Fund for Nature

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1. Introduction and research problem

1.1 Introduction

This document presents a Master's thesis in geography at the University of Lausanne. The present work targets geoconservation (and in a more general sense, the protection of nature) in developing countries, and the possibility of relating it to sustainable regional development. The research question attempts to understand to what extent an inventory of geomorphosites could improve the knowledge and management of the geoheritage, and so contribute to sustainable regional development in contexts of developing countries. To answer this question, the thesis presents an inventory of geomorphosites of the Simen[2] Mountains National Park (SMNP) in Ethiopia, as well as management perspectives.

Geoconservation (the protection of the abiotic environment) and geoparks are terms known by certain political figures, at least in some countries. Certain regions of Europe, but also the United States, Canada, China and Australia as well as South Africa, are looking to exploit the educational potential and the economic advantages offered by geotourism. Ethiopia possesses some of the most spectacular natural and cultural reserves in the world, as well as unique geological and archaeological monuments. However, until now these have hardly been systematically studied. Moreover, conservational strategies are lacking, and rarely used towards touristic ends, even though tourism has been identified as the principal sector for sustainable development of the country.

The SMNP has been studied and assessed as one of the most important geoheritage site of Ethiopia. In 1978, the park was entered into the UNESCO (United Nations Education, Science and Culture Organisation) World Heritage List, because of its naturally beautiful landscape - considered as a rival to the Grand Canyon in Colorado - as well as significant supply of habitats it offers for its native biodiversity. Today, however, the region is primarily known for its many native species, such as the Walia Ibex, a type of Afroalpine mountain goat. Geodiversity is little or rarely mentioned. Moreover, the park urgently requires new management strategies such as the development of alternative methods of subsistence, in order to reduce the overexploitation of the park's natural resources and offer a sustainable way of life for the local population. We suggest the development of better geomorphological and geological knowledge as well as improved geoheritage management strategies. A geomorphosite inventory brings to light the geomorphological and geological particularities of a region and constitutes the basis of all sorts of geoheritage enhancement and conservation strategies.

[2] "*The name **Simen** and other local names [in this work] are spelt according to the official Amharic to English transliteration system for geographic names and terms of the Ethiopian Mapping Agency, Addis Abeba, although Simen is pronounced locally and frequently written as "Simien" or "Semien*" (Hurni & Messerli, 1981 : 1)."

1.2 Research problem

In this chapter, we will address the research problem of this Master's thesis, which will include a discussion of geoconservation, the shortcomings present in this same field, as well as opportunities for sustainable development in the southern countries. The problem will be gradually broken down by the general issue (1.2.1) over the specification of the question (1.2.2) to the research question and general objective of this work (1.2.3).

Geoconservation includes all the measures that aim to manage the geoheritage (e.g. national legislation, an inventory of geosites or the placing under protection of a territory), including associated promotional campaigns and public awareness activities (Prosser, 2013) (update by Burek and Prosser, 2008). Its growth began in the 1990s in industrialised countries (Europe in particular), alongside geotourism (Reynard, 2008; Hose, 2010). The latter aims at the popularisation (Sellier, 2009) and promotion of Earth sciences and their objects of interest (Newsome & Dowling, 2010), combined with other elements of the natural and cultural heritage (archaeology, ecology, history etc.) and it combines two aspects, leisure and education (Reynard, 2008). It creates a regional awareness and contributes significantly to regional sustainable development (Megerle, 2008).

1.2.1 The general problem: important deficits in the field of geoconservation

Geoheritage - the geo(morpho)logical elements worthy of protection - constitutes an important part of the natural heritage (Reynard et al., 2009). Its universal value (ex. Grandgirard, 1995 ; 1997 ; Panizza, 2001 ; Brocx and Semeniuk 2007) is now broadly recognised by geoscientific specialists and nature conservationists (Prosser and Burek, 2008). It was approved by the large non-governmental organisms in 2008 (UNESCO, 2011 cited in Larwood et al. 2013). However, the protection of geodiversity and geosites is lagging behind its biological counterpart, the protection of biodiversity and biotopes (Gray, 2004) at all geographical and political levels (Larwood et al. 2013).

Firstly, it is important to underline that the abiotic environment is vulnerable and that precious objects are harmed or destroyed if their value is not recognised or if they are not managed adequately. The idea that the abiotic environment is fixed in time and space is a false one. Even if certain processes can sometimes appear slow on a human scale, "*all geomorphological geosites are by nature set to disappear, in the short or medium term, by the natural processes of erosion*"[3] (Lugon et al., 2003). On the other hand, man has become an important factor in morphogenesis. Geomorphosites are modified, harmed, even destroyed by the impact of human activity (Reynard and Panizza, 2005).

[3] Citations of references that are written in another language than English (and French in chapter 2.2 and 3) have been translated.

Many anthropogenic damages are possible "*including urbanisation (destruction by Earthmoving, modification of the landscape), agriculture (draining of wetlands), tourism (elevated Earthmoving, tourists' behaviour), the extraction of materials, illegal collection (minerals, fossils) etc.". "But the principal threat comes from the fact that geosites are not recognised and consequently are often destroyed or damaged by sheer* ***ignorance***" (Lugon et al., 2003).

Moreover, the bedrock and geomorphological dynamics are often closely linked with ecology. As such, any harm to geo(morpho)logical objects is also harmful to biotopes (Lugon and Reynard, 2003). For example, alluvial dynamics are a source of a great richness of vegetation in floodplains. This is why it has become an accepted notion that solutions for nature conservation can be found in an "*integrated approach to ecosystems*". In fact, it is necessary to treat the environment in its entirety and work between disciplines. It is a question of reinforcing links between heritage-related interests (cultural and natural) and a closer collaboration with local communities to obtain the best results in the field of conservation (Larwood et al. 2013).

In the last decades, European countries have begun to register the geoheritage on a national and regional scale with the help of a new instrument, the inventory of geosites (or geomorphosites). The latter allows us to systematically identify the heritage so as to manage it in a sustainable manner subsequently (Reynard, 2009b). On a global scale, the International Union of Geological Sciences (IUGS) launched the GEOSITES project with the support of UNESCO, which, between 1996 and 1999, helped to establish a list of the 310 most significant geosites in the world (De Wever, 2013). However, most countries are still lacking legislation for the protection of abiotic nature. Great Britain, Canada and Australia are exceptions, since they dispose of specific legislation to protect geosites (Gray, 2004).

Despite the efforts made to raise awareness, there is no real consciousness among the general public of the existence of a geological and geomorphological heritage, and native populations do not consider their environmental resources as a heritage worthy of protection (Pralong, 2003 ; 2006 ; Martin, 2012). The principal reason for this is the profound lack of geoscientific knowledge among the general public (Lugon et al., 2003). Because geomorphology is a particularly unfamiliar discipline (Gentizon, 2004; Sellier, 2009; Reynard and Coratza, 2013b), the objective of the "International Year of Planet Earth (2007-2009)" was to raise the general public's awareness of the importance of the geosciences (De Mulder et al., 2006; Cayla, 2009; Larwood et al. 2013).

Nevertheless, the growing interest in geoheritage, geoconservation and geotourism (Reynard and Coratza. 2013b) encouraged UNESCO to officially launch the Global Geopark Network (GGN) in 2004. The international publisher Springer has been publishing a scientific journal named "Geoheritage", specific to this field of study, since 2009. The Global Geoparks Network responds to a great need for effectiveness in the management of geosites and sustainable development in rural areas (Zouros, 2009). In theory, a geopark envisages a holistic management of the regional heritage based on local participation and the development of geotourism. The true strength of the concept lies in an international marketing campaign like that of UNESCO's World Heritage (Newsome & Dowling, 2010). "*Geoparks are based on genuine territory projects that cannot be carried or even conceived by geoscientists alone. Thus they must concern and implicate the greatest number of activities and territorial actors, including the general public and the inhabitants*" (Hobléa et al., 2011). As of September 2015 there are 120 members of the GGN, concentrated in 28 European and East Asian countries (particularly China), two members in South America and North America, one in Africa (Morocco) and none in Australia The 195 Member States of UNESCO have ratified the creation of a new label, the UNESCO Global Geoparks, on 17 November 2015. Thus Global Geopark become UNESCO Global Geopark. "*This expresses governmental recognition of the importance of managing outstanding geological sites and landscapes in a holistic manner*" (UNESCO, 2015a).

We have seen that the abiotic environment is vulnerable and that precious objects are damaged or destroyed if their worth is unknown or if they are not adequately managed. On the other hand, our analyses reveal important gaps in the field of geoconservation. In the next chapter, we shall take stock of the state of geoconservation in developing countries, especially in Africa.

1.2.2 The specific question: geoconservation on the African continent

Without a doubt, the African continent benefits from exceptional geodiversity. However, most African countries do not have a register of their abiotic richnesses (in particular Reimold, 1999; Schlüter, 2008). National geological services are called upon to register the geoheritage in order to propose classifications or protected areas in the future. However, financial resources and technical know-how are often lacking. Many precious geoheritages are endangered (Gray, 2004; Henriques et al., 2013). This is why the International Union of Geological Sciences (IUGS) and the International Association of Geomorphologists (IAG) want to invest in the development of specific activities in developing countries in order to have geomorphosites recognised as tools for regional and local development (Reynard and Coratza, 2013a; De Wever, 2013).

According to A. Asrat (2014), professor at the school of Earth Sciences at the University of Addis Ababa, Vice President of the GSAf (Geological Society of Africa) and executive member of the IAG: "*there are only few people who consider these concepts (Geoheritage, Geotourism) to be proper subjects of "Earth Sciences". Like Europe's preoccupation in the past, Africa's current preoccupation is to develop with whatever Earth resources we have right now; so the emphasis of Earth sciences in Africa right now is about "exploitation" not really about "conservation". The concepts of geoheritage and geotourism are still "exotic" concepts. There will be time they will be considered as mainstream in the future. However, we are trying (though very few) to convince people that "conservation" is not against development and could even enhance development by providing alternative means like through "geotourism"*."

A few scientists have debated on the effectiveness of the legislations and rules of geoconservation, particularly in South Africa (Cairncross, 2011; Ruban, 2012). On the other hand, many scientists (Reimold et al., 2006; Schlüter, 2008; Hadi et al, 2011; Asrat et al., 2012; Henriques et al., 2012; 2013; Kiernan, 2013 among others) see geosites as a bonus for ecotourism. Geotourism is a potential tool of sustainable development, particularly in poverty-stricken rural areas. Other authors insist on the pertinence of exploring African geodiversity as a key element for the development of sciences and support cultural initiatives for sustainable development, such as geoparks (De Wit and Anderson, 2003; Alfama et al., 2008; Johnson et al., 2010; Dawson, 2010; Fauvelle-Aymar et al., 2010; Tavares et al., 2012 among others).

The lack of information in geoscience has entailed a growing dEarth of geo-experts in Africa since 2000 (UNESCO, 2012a; De Mulder et al. 2013). This is why UNESCO (2014) launched the "*Earth Science Education Initiative in Africa*" in 2008; and in 2011, during the first international conference on African and Arabic geoparks - "*Geo-education in Africa - UNESCO and COGE initiatives"* - geoparks were described as privileged places for educational field activities (IUGS – COGE, 2011). The interest presented by the propagation of the geoparks initiative on the African territory for the promotion of geosciences and sustainable development was also underlined (UNESCO, 2012b; De Mulder et al. 2013; (www.globalgeopark.org)). However, according to the experiences of A. Asrat (2014), this is more of a political interest than an objective reflection on the potential of the candidates. This is why it is hardly optimistic to think that an African geopark will be accepted to the GGN in the short term. An African Network of Geoparks having some teething problems has been initiated in 2009 by the African Association of Women in Geosciences (africangeoparksnetwork.org).

1.2.3 Research question and general objective

We have seen in the previous chapter that the recognition of geoheritage and geoconservation is lacking in Africa and elsewhere in the world. It is difficult for geosciences to be heard, and conservationists are a minority, even though geoheritage could be appealing for the promotion of geosciences and sustainable development through geotourism, and the establishment of geoparks. It is impossible to write a thesis on a continental scale on such a complex subject. However, we can try to understand a part of the research problem - which is the following:

Can an inventory of geomorphosites foster or improve the knowledge and management of the geomorphological heritage in the context of developing countries, and thus contribute to regional sustainable development?

To answer the research question, we are basing ourselves on an analytical framework, that Reynard (2011) and Reynard et al. (2015) call "*the management of geomorphosites*" and apply it to a region of interest in Africa. The analytical framework was developed in order to improve the knowledge and management of geoheritage in protected areas. The method is divided into two phases: 1) evaluation and 2) management. This Master's thesis proposes the development of the evaluation phase - this means bringing to light the geomorphological heritage thanks to an inventory of geomorphosites in the Simen Mountains (area of study, see chapter 3). The second phase concerning the management of the geoheritage is divided into two steps: 1) the elaboration of a management strategy (with the creation of geotouristic products and the elaboration of a conservation strategy) and 2) the evaluation of scientific work by the users. This thesis proposes a simple management strategy based on the results of the first phase, bibliographical as well as empirical research (cf. chapter 6).

The application of an analytical framework allows us to situate the project in a larger context. But why make an inventory of geomorphosites? These past few years, several similar theses treating of regional inventories have been written at the Institute of Geography and Sustainability (IGD) of the University of Lausanne. Some are thematic inventories, emphasising one or another aspect of the geosite's worth, like that of Kozlik (2006), who evaluated the cultural geomorphosites of the valleys of Trient, l'Eau Noire and Salanfe (Valais, Switzerland). Other inventories made by the students fit into a pre-existing management structure. For example, Duhem (2008) and Bussard (2015) evaluated the geomorphosites of the natural regional park of Gruyère - Pays-d'Enhaut (Vaud, Fribourg, Switzerland), and Perret (2008) proposed an inventory of the geomorphosites of the Jura natural regional park (Vaud, Switzerland). Inventories that highlight value opportunities are those of Genoud (2008) in the Val de Bagnes, Maillard (2009) in the valleys of Entremont and Ferret, Pagano (2008) in the Val Bavona and the Val Rovana, and that of Grangier (2013) in the Val d'Hérens and the Vallon de Réchy, all in Switzerland.

Firstly, the inventory of geomorphosites allows us to compile a state of the art of the geomorphological heritage and to highlight the particular geomorphology of a region or a country. "*It is an interesting decision tool for the planning of the territory and it allows for sustainable management of the natural heritage"* (Kozlik, 2006). The *"database resulting from the inventory can also be put to use by tourism"* (Maillard, 2009). Thanks to a transparent method (chapter 5), it is possible to identify the most interesting objects, which are then evaluated in detail. Thus a database of the value of the geoheritage of the region under investigation is created. The evaluation procedure is therefore not an objective *per se* (Reynard, 2009b). As noted by Lugon et al. (2003) "*[understanding] the resource in order to better manage, protect and ensure its value is the objective of any inventory"*. This is why we are proposing a second phase in which we will elaborate different management strategies.

Many strategies and management measures are possible. In principle, they all have the protection and/or promotion of the inventoried sites as an objective. As noted in point 1.2.1 geology and landforms constitute the basis of all life on Earth, including Man, with his history and culture. Promoting an integrated approach to ecosystems by paying attention to the relationships between geodiversity, biodiversity and cultural diversity and thus reinforcing the links between heritage interests (cultural and natural) can prove to be an interesting management strategy (cf. point 1.2.1). This last approach is currently considered as the most effective in terms of protecting the natural heritage.

Compared to other types of geosites, geomorphosites often fulfil a passing function because of their spectacular and aesthetic appearance. This is why they dispose of an excellent potential of touristic promotion (Lugon and Reynard, 2003). Geotourism is a way of diversifying and increasing the quality of a region's tourist attractions (Cayla & Hobléa, 2011). Indeed, geotouristic activity offers interesting economic benefits for the native population, thanks in particular to a higher profitability. Moreover, the resources on which geotourism is developed are maintained, contrary to mass tourism. From an economic point of view, the geological heritage (geosites) is considered the basis of touristic development, and leisure occupies a central place in tourism (Reynard, 2008). On the other hand, one of geotourism's objectives is training in Earth sciences, thus creating awareness of geoheritage in the general public as well as reinforcing the acceptability of protective measures (Megerle, 2008).

As we have seen previously, knowledge of the geosciences is hardly developed. It is thus necessary to use geosites to educate people about the history of the Earth. "*Indeed, geosites have an educational and pedagogical function*" (Lugon et Reynard, 2003). In an era where democracy is participatory, "*an educational promotion of the interests of protected sites, as well as an informational campaign concerning the measures they are subject to, should be generalised* (Pralong, 2006)." *A management strategy that* Piacente (1989 cited by Coratza, 2003) names "**dynamic protection"**. Ignorance being an important cause of the degradation of the abiotic environment (cf. point 1.2.1), it is essential to inform and raise awareness in the native populations and the authorities about the geological particularities and geomorphosites of their territory and the existence of the rich heritage that belongs to them (Lugon and Reynard, 2003). The recognition of the importance of a geological or geomorphological form for the history of the Earth and its protection does not happen because a group of specialists decided it should. For an object to be perceived as heritage "*it is necessary that [the actors] understand, that is, that we make them understand through learning, what this value consists of*" (Martin, 2012). Indeed, the heritage does not exist in itself; it is a cultural construction based on the gaze that various different actors bring to the site. Spreading knowledge of the geosciences to a large public thus necessitates the interpretation of knowledge, to be able to then transmit it to an interested, but uninitiated audience (Sellier, 2009). A such, the application of the didactic methods of scientific mediation (e.g. signs, brochures, theme trails, maps, guided tours) is necessary. (Martin, 2012).

As we have just seen, the reason to protect the geosites is not just scientific, but also pedagogical, ecological, relation to the landscape/aesthetic and economic/touristic values (Lugon and Reynard, 2003). For example, protective measures can take place in the frame of territory planning, or as signage in tourism. The construction of tourist infrastructure on an inventoried element would thus be something to avoid. It will also make sense to guide the behaviour of tourists in order to avoid damaging geosites. The adaptation of legislation is also taken into account.

In a long term perspective, the inventory of geomorphosites and their strategic management can lead to big projects such as an application to the Global Geopark Network. Thus, a simple inventory could stir up interest from other geoscientists who come to work on the site and stimulate the promotion of geosciences and sustainable development in Africa. Based on the analyses of the research problem and the research question formulated in this chapter the next section will outline five research objectives which will structure the work and help to answer the research question.

1.3 Research objectives

This Master's thesis explores how an inventory of geomorphosites can promote or improve the knowledge and management of the geomorphological heritage in contexts of developing countries and, therefore contribute to regional sustainable development. For this purpose, an inventory of geomorphosites is conducted in the Simen Mountains National Park, in Ethiopia. Several objectives are defined and research questions are assigned as follow.

Objective 1: Compile the information on the geomorphology of the Simen Mountains.

Knowing the regional geomorphology is essential in order to select the most interesting and relevant geomorphological sites that will be integrated to the inventory. Having a good overview of the geomorphology of the study area permits us to determine the spatial representativeness. A list of potential sites is complemented consecutively and a corresponding cartographic representation is produced.

Research question

Which geomorphological and geological processes are involved in the formation of the Simen shield, the development of the extreme escarpment and the subsequent destruction of the whole massif? Which geomorphological processes and forms are inherited of the Last Cold Period in Simen (Late Glacial)? Which geomorphological process and forms are active at the present time?

Objective 2: Select the landforms that are most important for the reconstitution of the Simen Mountains.

It is impossible to inventory all the geomorphological forms that are found in the SMNP. Therefore, a selection of the most interesting landforms is necessary. The geomorphological sites are chosen according to the selection method of Perret (2014) and Reynard et al. (2015) given their spatial and temporal representativeness at the scale of the study area.

Research question

Which are the most representative forms of the geomorphology of the SMNP? Are they related to rare or very broadly represented geomorphological processes? Which are the forms that have a particular interest and thus deserve to be considered in the assessment?

Objective 3: Assess this geomorphosites according to the Inventory Method of the University of Lausanne

This important step allows us to determine, in the most objective manner possible, the intrinsic value (the scientific value and the additional values) of the sites. The goal is to characterise the geomorphology of the region and to draw up a stock-take for the management of the sites. An exemplary waterfall with aesthetic value would be recommended for teaching activities or geotouristic use, whereas a vulnerable site should rather be the object of additional protection. The results of the inventory are presented in the form of four synthesis maps.

Research question

Is the proposed assessment method applicable for the SMNP? Which are the scientific and additional values of the sites? Which geomorphosites are particularly interesting for geotourism? Which sites are most vulnerable against human encroachments and need specific protection?

Objective 4: Appraise the "state of the art" of geoheritage and geoconservation in Ethiopia.

Starting from the studies carried out by Prof. Asfawossen Asrat, the goal is a critical appraisal of Ethiopia's geoheritage management (geoconservation and geotourism). The flaws and potentials which should respectively be corrected and exploited in the future are identified. Five interviews with government experts and geoscientists stimulated our mind. On that base, innovative management strategies of the sites will be elaborated.

Research question

What are the major challenges and opportunities for the development of geoconservation in Ethiopia? What is the potential for the development of geotourism in Ethiopia? What are the difficulties to create a geopark in Ethiopia?

Objective 5: Elaborate a roadmap that indicates the guidelines for the geoheritage management of the SMNP.

This is one of the most important goals with that of the completion of the inventory. Based on the research carried out, the aim is to elaborate a roadmap that indicates the guidelines (strategic objectives translated into working tasks) to manage, protect and promote the inventoried geomorphosites in a holistic and sustainable manner. It could be seen as an invitation for future consideration and implementation of geoheritage management in the General Management Plan of the SMNP.

1.4 Structure of work

Chapter 2 provides the theoretical framework of this work. The concepts of geoheritage and geoconservation and geotourism have already been introduced in the first chapter together with the research problem. The concepts of geodiversity, geosites and geomorphosites as well as the links between the various conceptions (geoconservation, geodiversity, geoheritage, geosite) are defined and explained. Then the national and regional conservation context in the Simen Mountains is explained and the state of the art of geoheritage and geoconservation in Ethiopia is appraised.

The presentation of the study region constitutes the **chapter 3** (written in French). This includes the description of the physical context (geography, geology, geomorphology, hydrography, climate, ecology) and the human context (park administration and history, local administration, demography, human activities, transport, culture). Protection and management requirements of the park as well as the tourism development context in the Simen Mountains are also presented.

The geomorphosite inventory method of the University of Lausanne is explained in **chapter 4.** A short expert interview is conducted. Brief explanation how the interview took place and was evaluated is mentioned in the last part of this chapter.

Chapter 5 presents the results of the geomorphosite inventory of the Simen Mountains National Park. The selected geomorphosites are described and the results of the inventory, namely the scientific and the additional values as well as the use and management characteristics of the sites are analysed.

Chapter 6 is the discussion of the results. Different options and perspectives for the management of the geomorphosites are considered. This includes a road map, which has its focus on geotourism development and awareness raising of the geomorphosites rather than the development of protective measures.

Finally, the **chapter 7** comprises the synthesis and conclusion of this work.

Not to forget, the **annexe II** includes the evaluation sheets of the complete geomorphosite inventory of the Simen Mountains National Park.

2 Conceptual framework

Part one of this chapter (2.1) gives an overview and definition of the fundamental concepts used for this Master's thesis. Part two (2.2) (written in French) provides the basics to understand the conservation context in the Simen mountains and part three (2.3) aims to appraise geoheritage and geoconservation in the specific national context of Ethiopia.

2.1 Elements of definition

Geomorphology (from the Greek gê, Earth; morphê, shape; and logos, discourse, reason) is the science that describes and explains the terrestrial relief (Coque, 2006). The key concepts for the understanding of our Master's thesis are explained below.

2.1.1 Geodiversity

The notion of geodiversity has been used by geologists and geomorphologists since the 1990s to describe the natural variety of the abiotic environment. In his work entirely dedicated to geodiversity, the geographer Gray defines the term as follows (Gray, 2004 : 8):

"*Geodiversity: the natural range (diversity) of geologica (rocks, minerals, fossils), geomorphological (land form, processes) and soil features. It includes their assemblages, relationships, properties, interpretations and systems*."

According to Serrano and Ruis-Flano (2009), an inventory of geomorphosites can be used as an indicator of geodiversity. However, they stress that the assessment of geomorphosites is not the same as an estimation of geodiversity.

2.1.2 Geosites

Geosites (or geotopes[4]) are terms still relatively unknown outside of the scientific community. The literature proposes two definitions. The first is restrictive, since it only takes into account the scientific value at the time of the assessment of an object. It defines geosites as "*portions of the geosphere that present a particular importance for the understanding of the history of the Earth* (Grandgirard, 1995; 1997)." The definition proposed by Strasser et al. (1995), much more explanatory in its formulation, shares this vision.

[4] The two terms geosite and geotope are synonym. In English the term geosite is usually preferred while geotope is more often used in German and French literature.

"Geosites are portions of the territory that have value for the Earth sciences. This term thus includes mountains, hills, valleys, morainic ridges, gullies, caves, karst phenomena, banks and coasts, quarries, gravel pits, mines, erratic portions of roads, paths or blocks, sites that provide indisputable and characteristic information about a situation or event that the Earth has known during geological time, or about the history of life and climate. Geosites help to understand the spatial and temporal evolution of a region, the significance of surface processes and the importance of rocks as an element of landscape development. Geosites, in this sense, are natural monuments of great importance, perhaps even indispensable for the public as well as science."

According to a second, broader definition which does not exclude the first, geosites are considered as any geological object presenting scientific, historico-cultural, aesthetic or even socioeconomic value. (Panizza et Piacente 1993; 2003, Panizza 2001).

Of all the various types of geosites in existence, for this Master's thesis we are specifically interested in specific geomorphological geosites called geomorphosites (Panizza, 2001).

2.1.3 Geomorphosites

Research in the field of geomorphosites is relatively recent (Reynard and Coratza, 2013b) and the concept is little known by the general public or scientists of other disciplines (Reynard and Panizza, 2005). The term currently used by the geomorphologist community is defined by Panizza (2001): *"a geomorphosite is a landform to which Man attributes value"*. At their origins, they can cover anything from forms of erosion to repositories as well as processes (glacial, periglacial, gravitational, river, karst, wind, but also wetland/lake) (Lugon et al. 2003). Their scale can vary from a simple geomorphological object to great portions of the landscape, called geomorphological landscape (Reynard, 2005). Geomorphosites may constitute several levels of complexity (Grandgirard, 1997). A *geomorphological system* will comprise various types of landforms derived from several main processes. If multiple form types are derived from one main process it is a *complex of landforms*. *Isolated landforms* or *groups of landforms* constitute one type of landforms issued from one process.

Because the value assigned to a geomorphosite depends on human perception (Panizza 2001, cited by Reynard and Panizza, 2005), it is not always clear between experts what this value should be. In the activity review of the "Geomorphosites" working group of the International Association of Geomorphologists (IAG) during the 2001-2012 period, Reynard and Coratza (2013b) arrive at the following summary:

"Three groups of values can be highlighted: the scientific value (that is the interest of sites for Earth history and for the history and epistemology of geomorphology), several additional values (aesthetic, ecological, and cultural in a broad sense), and use and management values, that can be divided in three sub-groups (educational value, economic value, including the tourist value, and protection). The scientific and additional value can be considered as intrinsic values, whereas the management and use value are to be related to the societal values in the sense of Giusti & Calvet (2010)."

2.1.4 Links between the concepts

It must be specified that only the best sites, selected during an inventory process and deserving of protection or development, are considered geomorphosites. In this sense, geomorphosites (like any type of geosite) are considered as *geoheritage sites* (Brillha, 2015) (cf. point 1.2.1) which are worthy of protection and can be passed on to future generations (Reynard, 2009a; 2009b).

In order to best delineate these concepts, geodiversity refers to the quality we are trying to protect; geoconservation refers to the efforts made to protect it, and geoheritage contains a concrete collection of forms specifically defined as worthy of protection (Panizza, 2001, Gray, 2004).

2.2 Protection de la nature dans les montagnes du Simien (in French)

Pour établir un inventaire des geomorphosites et ensuite faire des propositions de gestion il est important de bien connaître le cadre institutionnel régissant la protection de la nature. L'analyse combine les droits de propriété (point 2.2.1) ainsi que les aspects de politique publique au niveau national (point.2.2.2) concernant le terrain d'étude présentées plus en détails dans le chapitre 3.

2.2.1 Les politiques publiques au niveau national

Sur le plan international, l'Éthiopie est signataire d'un certain nombre d'articles et de conventions telles que la Convention sur la diversité biologique, la Convention sur le commerce international des espèces de faune et de flore sauvages menacées d'extinction, la Convention sur les Espèces Migratrices et la Convention du patrimoine mondial. Celles-ci engagent l'Éthiopie à mettre en place des lignes directrices globales et intégrées pour le choix, la création et la gestion des aires protégées. « *En tant que pays riche en ressources naturelles, mais pauvre en ressources financières, un soutien considérable est nécessaire pour permettre à l'Ethiopie de respecter ces obligations* (FZS - ADC, 2009 : 21). »

« *La conservation de la faune a été effectuée depuis 1964 par le département de conservation de la faune du Ministère de l'Agriculture (MOA), et depuis 1970 par l'Organisation de conservation de la faune sauvage (EWCO), avec les objectifs principaux suivants: 1) conserver la faune, en particulier les espèces menacées d'extinction, 2) protéger les habitats faunistiques et les zones d'importance écologique, 3) établir des zones de conservation sous la forme de parcs nationaux, sanctuaires de la faune et réserves (cf. définitions ci-après), 4) contrôler l'utilisation et les produits de la faune, 5) sensibiliser à la la faune et à la conservation. […] Des sanctuaires de faune, par opposition aux parcs nationaux, sont conçus pour protéger seulement la faune sauvage menacée et de leurs habitats, et les réserves sont des zones réservées pour le développement ultérieur éventuel dans des parcs nationaux* (Hurni, 1986 : 10). » L'Ethiopie a maintenant 20 parcs nationaux établis dans tout le pays (EWCA, 2015b).

« *En 2005, une loi sur le développement de la faune sauvage, la conservation et l'utilisation (Wildlife Development, Conservation and Utilization Policy) est entrée en vigueur. Cette politique prévoit : 1) la participation et le partenariat de tous les acteurs, y compris les communautés locales, dans la gestion des ressources faunistiques ; 2) le zonage des aires protégées en des zones centrales et des zones à usages multiples ; 3) la participation des communautés locales dans la planification et la gestion des aires protégées ainsi que le partage des bénéfices ; et 4) la création d'aires protégées communautaires. Un nouveau décret sur la faune a été publié en 2007 (Proclamation 541/2007), à l'appui de cette politique qui stipule que les aires protégées en Ethiopie d'importance internationale et avec une faune endémique ou menacées devraient être gérées par l'autorité fédérale sur la faune, la nouvellement déclarée Agence éthiopienne de conservation de la faune sauvage (EWCA)* (FZS - ADC, 2009 : 21). » Cependant, la direction pourrait être déléguée à des autorités régionales. La loi stipule qu'aucune utilisation des ressources de toute nature est autorisée dans le SMNP.

2.2.2 Les droits de propriété

La Constitution éthiopienne (FDRE, 1995) stipule que « *[...] the ownership to rural and urban land, as well as of all natural resources, is exclusively vested in the state and in the people of Ethiopia [...] and [...] land is common property [...] and shall not subject to sale [...].* » Les États fédéraux ont reçu la responsabilité sur les terres au niveau régional, ce qui implique que les gouvernements régionaux peuvent adopter des lois relatives à la nature des droits fonciers et leur transférabilité (Hurni, 2005: 33). Dans la région du Simien, la terre a été distribuée entre 1988 et 1991 selon un système plus ou moins équitable qui attribue à toutes les personnes vivant dans une communauté des droits d'utilisation sur une parcelle de terrain (Ludi & Hurni, 2000: 18-19). Le SMNP qui a été publié sous la *Negarit Gazetta* du 31 octobre 1969 pour mettre en œuvre la protection des ressources naturelles présente l'institution la plus importante dans la zone d'étude (Hurni, 2005; Hurni, 1986). Le système actuel, parce qu'il ne garantit pas la sécurité d'occupation et sape les incitations, a des effets néfastes sur la productivité agricole et la conservation des ressources naturelles (Hoben, 2000: 7), mais d'autre part, cela permet des réaffectations locales qui pourraient être nécessaires pour parvenir à une utilisation durable des terres à moyen terme (Ludi & Hurni, 2000: 14).

2.3 Appraisal of geoheritage and geoconservation in Ethiopia

The aim of this chapter is to appraise the "state of the art" of geoheritage and geoconservation in Ethiopia in order to create a sound basis for the rest of the work.

2.3.1 Geoheritage and geoheritage research in Ethiopia

We did not go through a complete literature survey on geoheritage research and management in Ethiopia. We based in particular on the book "*Geotourism in Ethiopia*" (Asrat et al., 2008) who conducted detailed research on the topic and consider that

> *"Ethiopia hosts numerous geoheritages and geotouristic sites, some of which have been granted UNESCO World Heritage status (though defined as cultural and/or natural heritage sites when registered).*[5] *The chain of Rift Valley lakes and the world-famous archaeological and anthropological sites; the unique Afar rift, where active volcanic activities in Erta'ale and formation of new oceanic curst can be witnessed; the Simen and Bale massifs; the Sof-Omar caves are all there because of geological processes. Ethiopia is also one of the few places in the world where historical manifestations of culture and religion are imprinted in rocks. The rock-hewn churches of Lalibela and central and eastern Tigray, the stelae of Axum, etc. are all there because of the unique geological materials (rocks) available*. *[However,] little has been done to systematically investigate and document this rich heritage of Ethiopia in a comprehensive manner. Nor do the works address the general public. The only existing works partly relevant to such purposes are all grey literature (e.g. Demissie, 1988; Gerster, 1968; 1970), specialized works on specific sites (e.g. Asrat, 2002; Phillipson, 1997; 1998; Schuster, 1994), too general (e.g. Hancock et al., 1990), written in local languages (e.g. Aubert, 1997; Bekele, 2000; Hagege, 2000; Mercier, 2000), or highly specialized scientific works on the geology of the sites under consideration (e.g. Asrat et al., 1998; Ayalew et al., 2002; Bosellini et al., 1997)* (Asrat et al., 2008 : 5,12)."

[5] These include the stelae of Axum (granted World Heritage status in 1980); the rock-hewn churches of Lalibela (1978); the Simen Mountains National Park (1978); the Fasiledes Castle in Gonder (1979); the prehistoric sites of Tiya (1980); the lower Valley of the Awash River (1980); the lower Valley of the Omo (1980); the Muslim Holy city of Harar (2006); and the Konso Landscape (2011) (Asrat et al., 2012).

Many of the geological features in Ethiopia underlay major tourist attraction or constitute themselves the main interest of tourism. However, little if any attention is given to the fact, though tourism has recently been identified as a major sustainable development sector. According to the National Parks and Wildlife Sanctuaries Coordination director of the Ethiopian Wildlife Conservation Authority (EWCA), K. Wakjira, the propagation of geological knowledge is a cap. Most people do not know that something is from geology. But they use it for culture or for recreation etc. Natural heritage is a key resource but the historical and cultural resources are most important in Ethiopia. "*When I say natural heritage it includes the geological part also, not only the wildlife*." About geotourism he says. "*I heard it, but not frequently. And I found very rarely literature. It is not a very common word to me. Not only me, even the tourism people - I do not here that they rise it an important tourism product. They take them to geological features as an attraction like waterfalls, caves etc. But they do not appreciate that this is part of a geological attraction. So it is a lack of awareness.*"

The book "*Geotourism in Ethiopia*" addresses this problem, although it only presents the result of the first phase treating the geological and geographical setup of Yeha, Axum, Laibela and the rock-hewn churches of Wukro (which are the major archaeological, religious and cultural centre of the country). In fact, the work is embedded in a more extensive research project entitled "*Contribution of Geology to the Growth of the Tourism Industry in Ethiopia*" initiated in 2004 by the same authors. The research approach was divided into four phases of study based on the geographical and cultural diversity of the geotouristic sites in Ethiopia. The 1st phase addresses archaeological and ancient cities, religious and cultural centres, the 2nd phase focuses on natural scenery, the 3rd phase is on archaeological and anthropological centres and the 4th phase will treat historical and modern cities.

In the second phase, currently underway, a detailed study (Asrat, 2015) has taken a closer look at the geology, geomorphology, geodiversity and geoconservation of the Sof Omar Cave System in Southeastern Ethiopia. Several recommendations for the management of the geoheritage site have been formulated. This includes legal protection of the unique geoconservation zones of the cave system, relocation of the Robe - Ginir road especially when major road is planned and constructed as well as permanent managing and monitoring of the site (Asrat, 2015). The Simen Mountains National Park has also been examined in this phase. Asrat et al (2012) present the Simen Mountains as major geoheritage area, which should be prioritized for geoconservation in order to develop sustainable tourism (geotourism). The vast territory as a whole is identified as geoheritage territory, which strongly deserves to be preserved and transmitted to future generations. For practical reasons the authors particularly propose "*the Lemalimo pass, the Chinkwanit pass, the Awaza peaks, the Sanka Ber land bridge, the Chenek pass, the Geech Abyss, the Imet Gogo peak, and the Bwahit plateau* (sic)" to be considered as geoconservation sites (Asrat et al., 2012 : 22).

2.3.2 Geoconservation and Geoparks in Ethiopia

In order to understand the national context of geoconservation in Ethiopia, an interview with Professor A. Asrat from the School of Earth Sciences of Addis Ababa University (co-supervisor of this Master's thesis) has been conducted. All the information below is taken from this interview. Our particular interest was to understand with which challenges researchers have to deal to initiate geoparks in Ethiopia. According to A. Asrat there are people that are interested in this kind of topics (geoheritages, geoconservation, geotourism) in many parts of Africa. However, even if someone wants to initiate something, there is **not any legal framework, any policy, any law** that allow for the establishing of a geopark in Ethiopia, which is mostly true for most parts of Africa. It is possible to propose National Parks or bio-conservation sites but the same is not possible or it is not possible to get a reply so far if someone tries to come up with an idea of a geopark. There have been many trials, including from A. Asrat.

> *What happens usually when we talk with people, I mean when we go with a kind of a proposal, a concept or an idea to establish a geopark, just in a simple, very small area…, and we tried with many ministries which, I mean are in responsibility for this kind of things like the Geological Survey of Ethiopia, the Ministry of Mines, the Science and Technology Commission, the Tourism and Culture Ministry - the first thing that they ask you is: What's your investment money? Because they think you are proposing a kind of a lodge or are a kind of hotel."*

Therefore, **the priority now is to come up with a policy**.

> *"We are trying hard to convince people and ministries that this is very important. I mean even more there should be a norm for geoparks in addition to the existing national parks. Not wildlife like for example in Tansania or Kenya - its true there are some wildlife - but its more the geodiversity, which is more significant because of the geology and the geomorphology of the country that we have to capitalize."*

> *"An academician like myself cannot come up with a policy or legal framework. I can just make people aware of that. According to the law of the country, this must start from a kind of ministry, like the Tourism and Culture Ministry. And that ministry has to come up with a kind of policy framework and that has to go to the parliament and it's only the parliament of the country that can come up with the policy for this kind of establishments."*

Unless there is this policy it is going to be practically impossible to arise with the concept, the idea of a geopark. But it will be easier later to convince people if there is a policy that supports that "this" can be a geopark, "this" could be an interesting side for conservation and so on. In addition, there is **the issue that Ethiopia has a federal system**, which makes geoconservation even more complicated. So most of the national parks (there are now a few which are under the federal system, those once which are WH site, like the SMNP) where most of geosites are located under the regional governments.

> "*Thus, there is another layer to the problem and that is that you cannot simply go from Addis and tell them that this is an important geopark or something. Or it could be a geopark. So you have to do with the regional government system and so on, so far. So it's too complicated to deal with."*

On the other hand, it is important to understand the priority of the country. Many parts of the country are poor. What they need to do is roads, real water rails, construct house, etc. So what they need is resource. They are not in a position to consider that conserving something is much more important than using it ("*we are not yet at that point*"). "*I'm not saying they are correct, it should be that way, but what I'm saying is the priority is not yet there*." Thus there is an **important dilemma with (geo)conservation and development at the same time.**

> "*For example, there are numerous scoria cones (type of volcano) in many parts of Ethiopia. And scoria is used as a road surfacing material. And those are beautiful and they are very interesting educationally. We need to conserve them. But when the government plans a road – and they are constructing roads everywhere – they need materials for road surfaces. So what they do, they just go to that scoria cone they extract it and they use it."*
>
> *I go there and I tell them that this is a very interesting site, geological site, this is a geological site for this and that. I mean they do not care. Because now they want to construct the road. And I understand their position. Because it is my country. I also want it to develop. I also want more roads. We need access and so on. That's the dilemma!*
>
> *So we do not say for example don't destroy this! What we say is, if there are three cones, please do the excavation and please conserve one of them. At least this is something we can do. Do not destroy everything. Or when you do excavation, please do it professionally and do not destroy everywhere."*

It is very important to really understand this matter when dealing with conservation projects in Ethiopia. But another important point when talking about conservation is that it is necessary **to provide alternative means to the population**. The following example helps to understand this.

> *"According to me I just want all parts of the Simen Mountains (SM) to be conserved, but that is unrealistic. Because there are people living in the Simen Mountains, within the National Park itself and telling them that you have to go out of this, because it has to be conserved is very, very hard not for me but for the government. Because they have been there for, I do not remember, many hundred years. And telling them that this has to be conserved because this is geological interesting, or you shall not graze your cattle in this area because it is a geosite, this is going to take a lot of convincing. You have to provide alternative means to this people when you are going to talk about this thing. So it is a very big problem."*

It is important to recognize and to appreciate that problem too. An approach to conservation cannot consider that something has to be conserved at any price even if the object is a "*world class geosite*". Under the existing condition this is not realistic and it is not even sensible. It is not possible just to apply all the principals, for example a park that applies in Europe does not in Ethiopia. It is a **complicated social, socio-economic and political situation even in terms of thinking it is different**. In Europe the conservation issue usually is between the people and a kind of an area. In Ethiopia it is not even about people, it is about the cattle. If this people who have numerous cattle herds feel that the area conserved is not going to be utilised by their cattle, their grazing land, there will be a big problem.

> "The first question they will ask you is. If this is my country, is this country for me or for the wild animals? Because I have to live first. My cattle have to survive, then it is after that we can talk about the wildlife. So it is not a matter of choice here, it is a matter of survival. People want survive first."

This is an example with bio-conservation but it is the same with a geosite, with whatever conservation area. Unless we provide alternative means to this people - just having a park there is not going to be realistic. But what means **geoconservation is another concept that has to be really contextualised**. Because conservation in terms of soil erosion management means covering the whole area by vegetation. As a geosite it is not desirable to have it covered.

> "*When I talk with people about heritage conservation, automatically they think that I'm talking about just like soil conservation that means covering with vegetation. But when I say no, I do not want this to be covered, I want to conserve it as it is, people say no this is not conservation. Because for them conservation is just trying to protect the area from erosion. But conservation in geology means to protect as it is without modifying. Erosion is what we want to learn. Erosion process is one important geological process, so you do not want to protect it. Keep it as it is so you can learn how erosion is happening*."

To sum up, all a scientist can do while waiting a policy is to study, this means documenting. The regional or federal government will encourage studies anyway. So the idea of the book "*Geotourism in Ethiopia*" and the whole idea of the project that A. Asrat et al. (2008) is dealing with (cf. point 2.3.1) is to come up with interesting sites - show that "this" is an interesting geosite or geomorphological site - and to document and publish them in the form of books, papers etc. So they do not go to the detail of saying this is a geosite - they do not evaluate them, if they fulfil all the criteria - but they consider them simply as "*interesting geosites*" or "*geoconservation sites*". What they are trying to do is to identify the potential of geosites and hoping in the near future they will have a policy that can allow scientists and all other interested people to come up, this means establishing a geopark.

3 Région d'étude – Le parc national des montagnes du Simien, Ethiopie (Simen Mountains National Park – SMNP) (in French)

Ce chapitre fournit les connaissances essentielles sur la région d'étude. Il est divisé en cinq grandes parties : le cadre physique (3.1), incluant des sous-chapitres sur la géographie, le climat, la géologie, l'hydrographie, la géomorphologie et l'écologie ; le cadre humain (3.2) comprenant des sous-chapitres sur l'administration du parc, l'histoire du parc, les limites administratives, la population, l'impact humain, le transport et les aspects culturels ; la protection et les exigences de gestion (3.3) ; le développent du tourisme (3.4) et finalement une synthèse et justification du choix du terrain (3.5).

3.1 Cadre physique

3.1.1 Situation géographique

Le terrain d'étude (Figure 1) est constitué d'une portion du massif montagneux du Simien (ici on utilise *Simien* comme orthographe français de Simen) situé en Ethiopie septentrionale sur le plateau d'Amhara à environ 120 km au nord de Gonder, ville centré à 13° 11'N, 38° 04'E (UNEP-WCMC). La Figure 1 montre l'Ethiopie (limite rouge) au centre de la Corne de l'Afrique. Le carré blanc provient d'un zoom (non inclus) sur l'Ethiopie du nord avec la région de Gonder. La zone blanche correspond à la localisation des montagnes du Simien (extrait Figure 2).

Figure 2 L'Ethiopie et la localisation des montagnes du Simien (CDE, 2010)

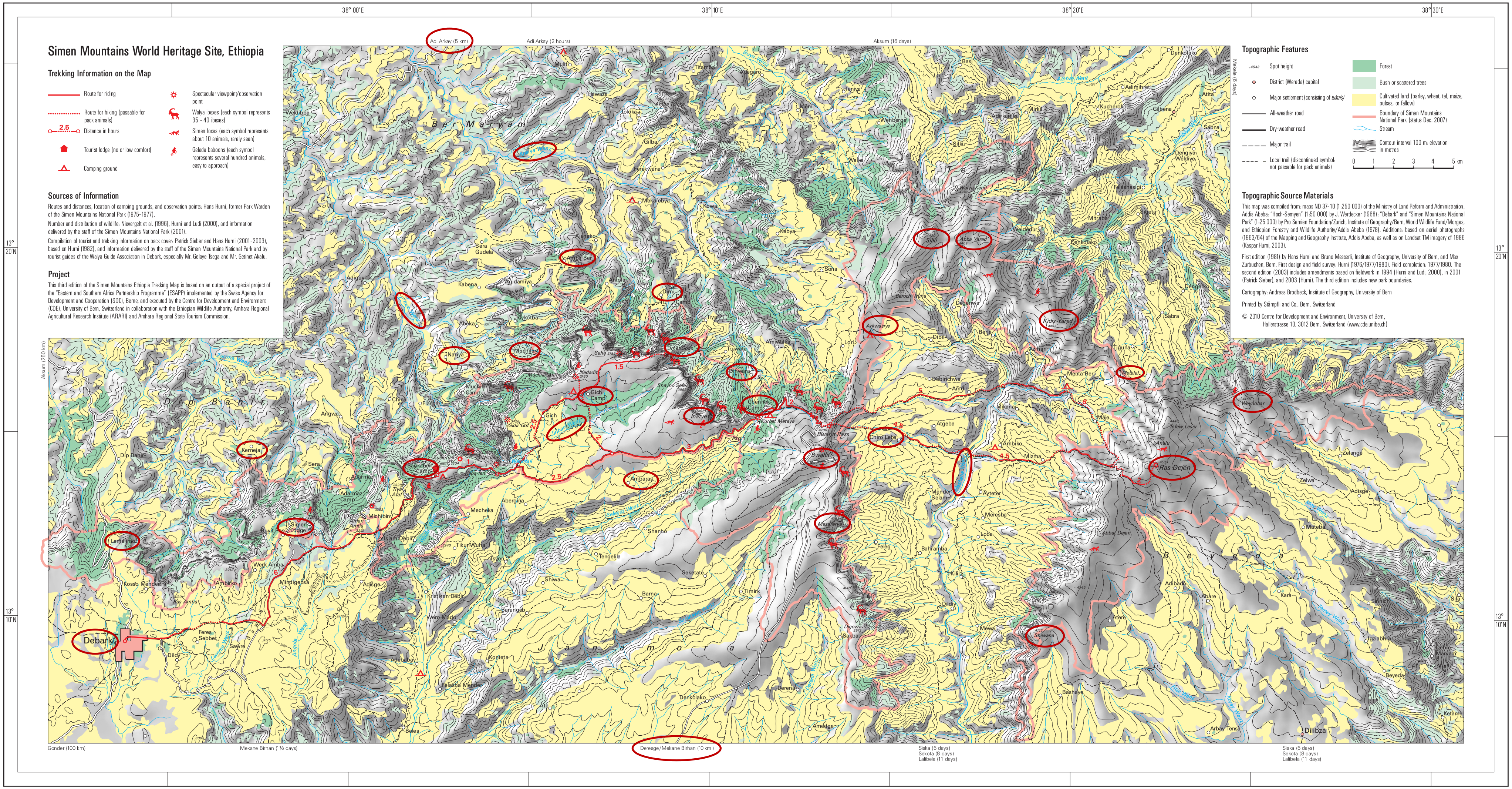


Figure 4 Situation du périmètre d'étude – le parc national des montagnes du Simien. Les principaux toponymes mentionnés dans le rapport sont entourés en rouges (basé sur CDE, 2010) (figure en format A3 dans la version imprimée)

La Figure 2 présente le périmètre d'étude. Il s'agit essentiellement de la nouvelle démarcation du Parc national des montagnes du Simien (SMNP) agrandie, soumise au Conseil des ministres de l'Ethiopie en 2014 et approuvé récemment (EWCA, 2015a). La surface du terrain qui correspond à celle du SMNP est d'environ 400 km^2 (UNESCO WHC, 2010). Le terrain d'étude est entouré par la ville Adi Arkay au nord, le bassin de la rivière Tekeze à l'est, Deresge au sud et Debark (ville la plus proche) à l'ouest. D'une part, le périmètre couvre le territoire compris entre le col de Lemalimo à l'ouest et la bande étroite du site de l'UNESCO qui s'étend de l'est et au nord-est sur 35 km au-dessus des escarpements de 1500 mètres d'altitude en direction des plateaux successifs de Gich, de Chennek et de Bwahit. D'autre part, il s'étale sur le corridor qui relie le territoire autour du sommet de Silki et du Kidis Yared ainsi que la région non cultivée de l'autre côté du canyon avec les sommets Ras Dejan et finalement Shiwana. Le point le plus bas du terrain d'étude se trouve aux alentours du col de Lemalimo à 2000m d'altitude et le point culminant est Ras Dejen, sommet le plus haut de l'Ethiopie à 4540m d'altitude.

3.1.2 Climat

Les montagnes du Simien sont caractérisées par un climat alternant une saison humide et une saison sèche, avec environ 75% des précipitations annuelles entre juin et septembre. Les précipitations annuelles sont comprises entre 1350 et 1600 mm avec une moyenne annuelle de précipitations à 3600 m d'altitude de l'ordre de 1500 mm. Les températures sont relativement constantes tout au long de l'année ; cependant, il y a une énorme variation diurne allant d'un minimum de -2 ° C à -10 ° C pendant la nuit jusqu'à un maximum de 11 ° C à 18 ° C pendant la journée (FZS - ADC, 2009).

Hurni (1982) a défini deux types de climat pour la région du Simien (types climatiques supérieur et inférieur). Sur cette base, Falch (2000) a compilé une description résumée (Tableau 1).

Major characteristics	Lower climatic type	Upper climatic type
Altitude range	2000 – 3200 m	3200 – 4500 m
Wind system	Southwest monsoon (upwardly decreasing influence), trade-winds only in the dry season	Northerly winds all year
Clouds and rainfall	Convective rains, less frequent hailstorms	Increase in cloud cover with altitude, maximum annual rainfall at about 3500m , frequent hailstorms with high erosion
Snow and frost	No snow, rare frost	Occasional snow in higher ele-vations, frequent frost
Cultivation (crop) suitability	Favourable for most Ethiopian crops and pulses	Unfavourable for most grains and pulses except barley, potatoes and some vegetables

Table 1 Types climatiques dans le Parc national des montagnes du Simien (Falch, 2000)

3.1.3 Géologie et géomorphologie éthiopienne

C'est sur le territoire de l'Éthiopie que se trouve la plus grande surface la plus élevée du continent africain ; c'est pourquoi le plateau éthiopien est souvent cité comme *« le toit de l'Afrique »*. Toutefois, le contraste d'altitude est si important que la surface continentale la plus basse en Afrique (environ 120 m en dessous du niveau de la mer) est également située en Ethiopie dans la dépression de l'Afar (Asrat et al., 2012). Trois grandes régions géomorphologiques caractérisent l'Ethiopie (Figure 3) : le plateau du nord-ouest et les basses terres (NWP), le plateau du sud-est et les basses terres (SEP), ainsi que le système du rift éthiopien ou la grande vallée éthiopienne (MER et SR) y compris la dépression de l'Afar. Ce dernier système est la partie la plus septentrionale du système du grand rift est-africain.

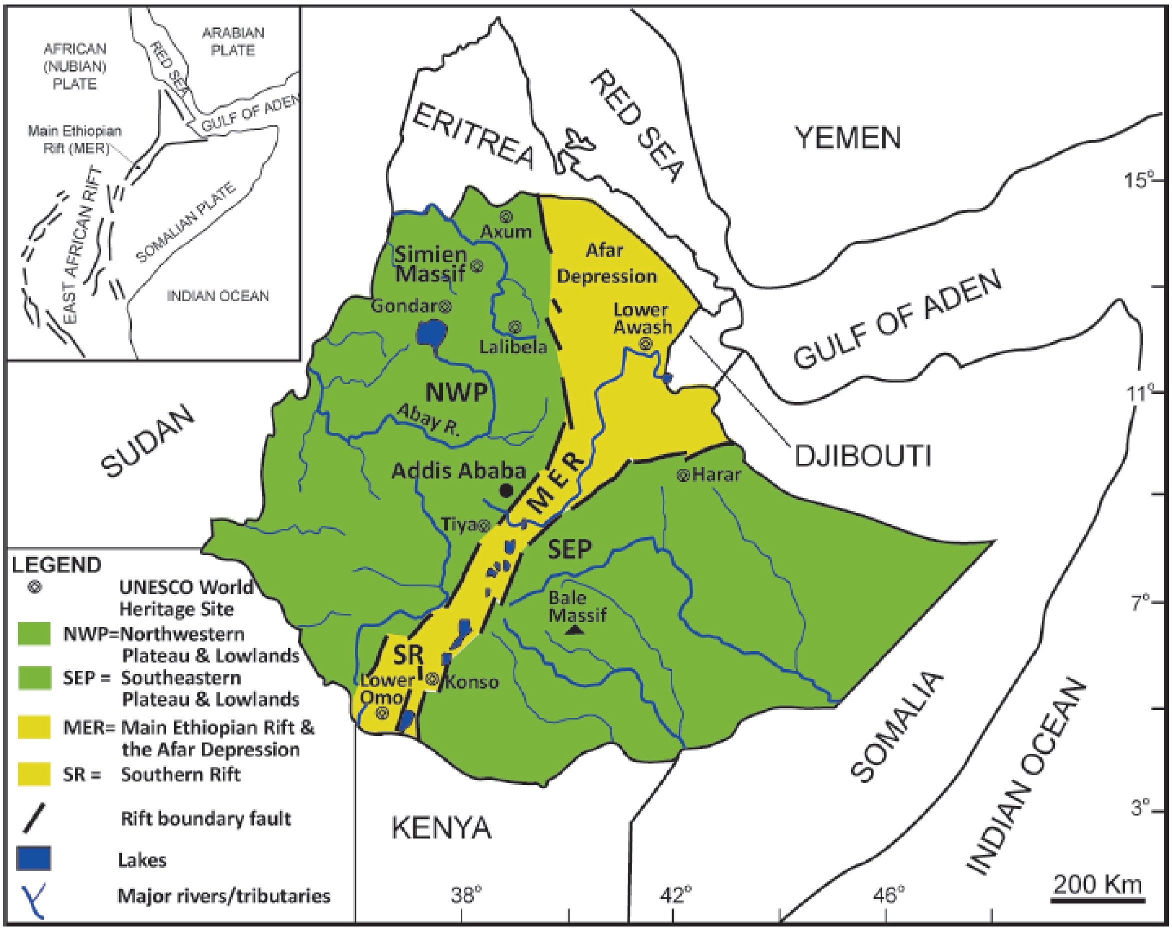


Figure 3 Localisation du plateau du nord-ouest et des basses terres (NWP), du plateau du sud-est et des basses terres (SEP) ainsi que de la grande vallée éthiopienne (MER et SR). L'image montre le système du grand rift est-africain (Asrat et al., 2012)

Un soulèvement de la plaque éthio-arabique et des fracturations profondes dans la croûte terrestre marquent l'histoire géologique durant le Paléocène jusqu'à l'Oligocène (Schlüter, 2008). Les éruptions effusives subséquentes de grandes quantités de laves basaltiques sur une courte période de temps de 1-2 Ma centrée à environ 30 Ma ans forment les plateaux éthiopiens (les séries de trappes) couvrant environ 55% - soit 600 000 km^2 - de la surface du pays et par la suite divisé en deux par l'ouverture de la grande vallée du rift (Hofmann et al., 1997 cité par Asrat et al., 2012). Les laves ont éclaté lorsque la plaque tectonique portant l'Ethiopie a passé au-dessus d'une remontée magmatique mantellique et basique connue comme le point chaud (hotspot) d'Afar provoquant un soulèvement général de l'Ethiopie et donnant lieu à un volcanisme de type tholéiitique (Nasa Earth Observatory, 2015).

Les séries de trappes forment une épaisseur variable pouvant atteindre jusqu'à 2 km dans certaines zones. Les laves s'étalent soit sur une surface de roches précambriennes soit sur les épaisses successions sédimentaires du Mésozoïque. Il s'agit principalement de basaltes aphyriques à phyriques avec des phénocristaux de plagioclases et de clinopyroxènes et rarement d'olivines. Les laves felsiques et des tufs/ ignimbrites qui sont communs vers le haut de la séquence sont pour la plupart rhyolitiques et rarement trachytiques (Ayalew et al., 1999 cité par Asrat et al., 2012).

Les éruptions ultérieures de laves et de matériaux pyroclastiques ont formé, par des évènements centralisés, d'énormes volcans boucliers se construisant par-dessus des séries de trappes au milieu et la fin du Miocène (Mohr, 1983; Mohr et Zanettin 1988; Hofmann et al., 1997; Pik et al., 1998; 1999; Kieffer et al., 2004 cité par Asrat et al., 2012). C'est l'un d'eux qui est à l'origine des montagnes du Simien. La carte géologique (Figure 4) montre les affleurements rocheux à l'échelle du pays.

Par la suite, le plateau du nord-ouest a été creusé par des gorges d'érosion profondes construites par les rivières principalement drainées en direction de l'ouest ou du sud-ouest et formant les grands bassins versants du Nil Bleu, du Tekeze et d'Omo ainsi que leurs affluents (Asrat et al., 2012).

3.1.4 Hydrographie

Les montagnes du Simien forment une partie importante du bassin du fleuve Tekeze dont l'eau est utilisée en aval pour l'irrigation. L'ancien volcan bouclier est traversé du nord au sud par la rivière Mesheha dont il constitue le bassin versant principal en formant un canyon large de 2 à 10 km et profond de 1 à 2 km sur une longueur de 40 km. Il y a des ruisseaux permanents à courant rapide et des hautes chutes d'eau qui s'écoulent au nord-est et au sud en direction de vallées profondes pour confluer dans la rivière Tekeze, qui se jette finalement dans l'Atbara (UNEP-WCMA, 2011). Le bassin versant du Tekeze fait partie du grand bassin versant du Nil, plus long fleuve sur terre et seul fleuve du monde à complètement traverser l'une des deux ceintures subtropicales sèches, ici aussi le plus grand désert du monde, le Sahara, avant de se jeter dans la mer Méditerranée en Egypte (Nil, 2014).

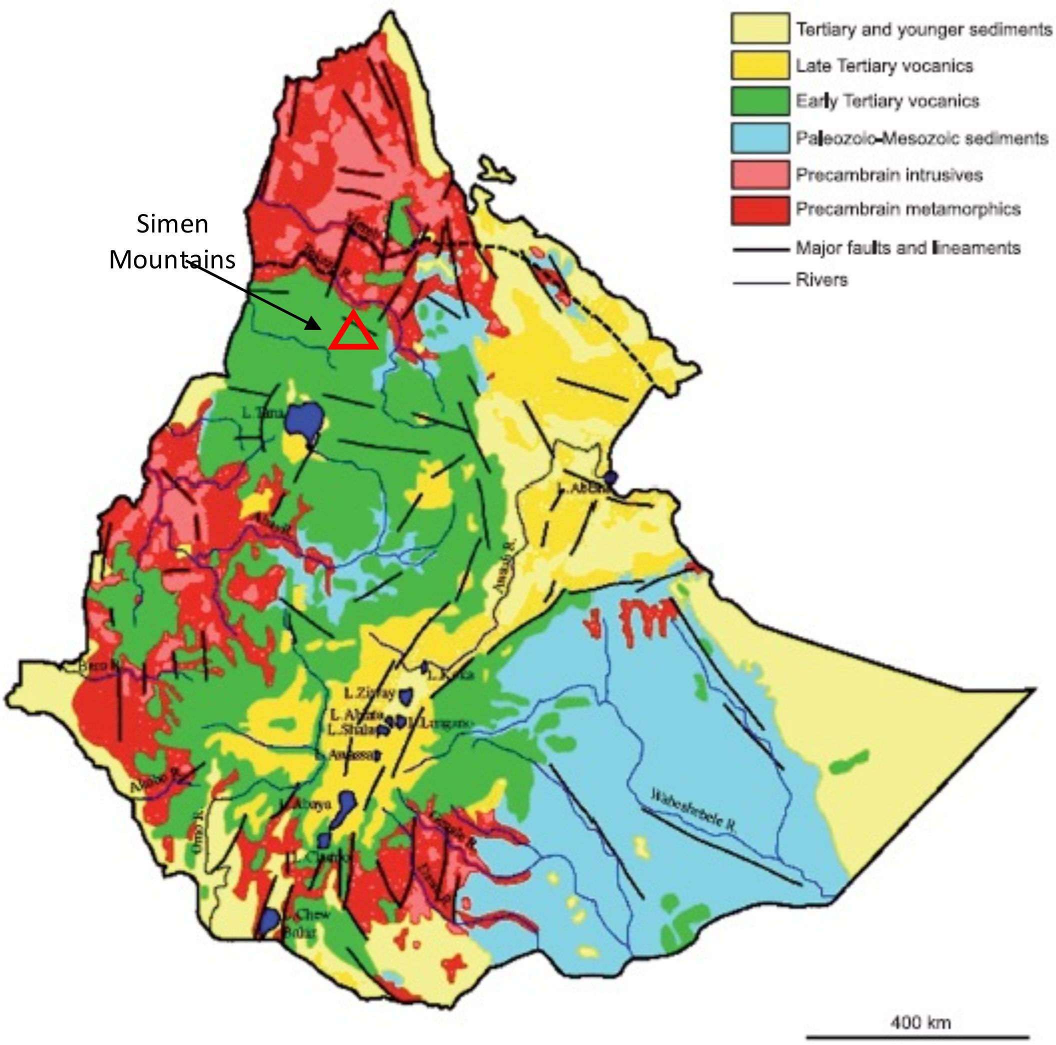


Figure 4 Carte géologique simplifiée de l'Éthiopie et l'Eritrée (adapté après Asrat et al., 2009 dans Asrat et al., 2012)

3.1.5 Morphogenèse

Le modèle numérique de terrain (Figure 5) montre le plateau éthiopien du nord-ouest ; une masse large avec principalement des sommets plats à des endroits surmontés de volcans boucliers, le principal étant celui du Simien (couleur gris blanchâtre sur la carte (Figure 5), fortement érodé et sculpté par l'incision des tributaires de la rivière Tekeze s'écoulant autour du bouclier de l'est au nord et à l'ouest.

Le diamètre basal du bouclier (shield) est d'environ 100 km (Asrat et al., 2012). L'extension totale du massif est d'environ 15'000 km^2, la zone étroite de 6000 km^2 (Burga et al., 2004). Sur la carte (Figure 5), la couleur gris foncé et verdâtre lumineux représente la séquence des trappes (en partie érodée) de 2'500 à 1'500 m d'altitude. Et les couleurs violet clair et bleue représentent les gorges de la rivière Tekeze et des plaines de l'ouest (1500 à 1000 m d'altitude et au-dessous de 1000 m d'altitude respectivement).

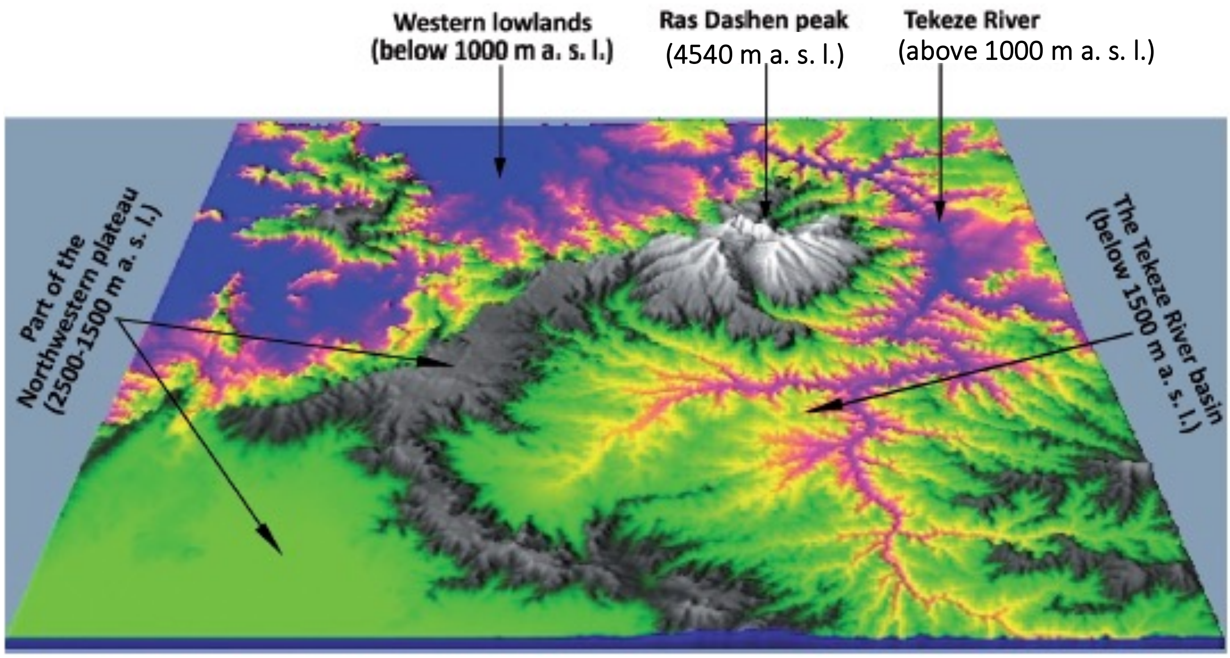


Figure 5 Modèle numérique de terrain des hauts plateaux éthiopiens du nord-ouest soulignant le bouclier du Simien (couleur gris blanchâtre et presque circulaire de la figure) (Asrat et al., 2012, altitudes corrigées).

Le volcan bouclier du Simien, l'édifice oligo-miocène, a été construit il y a 31-30 Ma alors que d'autres volcans boucliers se sont formés au sud il y a 23 Ma et il y a 11 Ma. La hauteur maximale d'origine (en tenant compte du matériau érodé) s'élève à trois kilomètres au-dessus du plateau de coulées basaltiques (par exemple, Mohr, 1967; Kieffer et al, 2004 cité par Asrat et al., 2012).

Les basaltes des boucliers présentent en général une composition qui ressemble à celle des séquences des trappes sous-jacentes, suggérant des sources et processus magmatiques similaires (Kieffer et al. 2004 cité par Asrat et al., 2012). Dans le cas du bouclier du Simien, le contact entre les coulées basaltiques et le volcan est exposé à une altitude d'environ 2700m. Trois grandes unités de boucliers (shield units) sont identifiées : en raison de l'érosion des sommets, l'unité intermédiaire (dominée par les trachybasaltes) et l'unité supérieure (hétérogène avec ignimbrites) sont pour la plupart érodées et seule l'unité inférieure (basalte porphyrique dominant) est exposée tout le long du chemin jusqu'à des altitudes de plus de 4000 m (Asrat et al., 2012).

L'érosion massive par les pluies intenses survenues au cours de millions d'années, des cycles humides-secs du Quaternaire, avec des phases de glaciation et déglaciation et l'érosion dans la topographie accidentée en cours ont disséqué un paysage très spectaculaire avec « *des pics accidentés, de profondes vallées et des précipices atteignant jusqu'à 1500 m de profondeur* (UNESCO, 2015b). » Divers phénomènes périglaciaires et glaciaires (matière fine, pile de blocs, moraines) s'étendent des sommets jusqu'à 3500 m.

Ils témoignent de la période comprise entre 20'000 à 10'000 ans BP. caractérisée par des températures en moyenne 7°C inférieures aux températures actuelles et des petits systèmes glaciaires sur les principaux sommets. Il s'agit de la Dernière période froide du Simien (Last Cold Period en anglais) qui coïncide avec le Tardiglaciaire en Europe et en Amérique du Nord (Hurni, 1982).

3.1.6 Ecologie

La richesse d'espèces et d'habitats du parc est le résultat de sa grande altitude et de la diversité topographique et climatique qui ont façonné les écosystèmes afromontagnards et afroalpins. Les montagnes du Simien font partie du centre afro-alpin de diversité de plantes et du point chaud (hotspot) de biodiversité afromontagnarde de l'est avec de nombreuses espèces végétales et animales endémiques. Ils font également partie du plus grand habitat d'oiseaux endémiques des hauts plateaux éthiopiens.

La région de la falaise du parc est le principal habitat du walia ibex (*Capra walie*), une chèvre de montagne sauvage (bouquetin) qui est endémique des montagnes du Simien et menacée d'extinction. D'autres espèces emblématiques comprennent le loup éthiopien (ou renards du Simien, *Canis simensis*) en voie de disparition et considéré comme l'espèce de canidé la plus rare au monde ainsi que le babouin gelada (*Theropithecus de gelada*) qui sont tous deux endémiques des hauts plateaux éthiopiens. La tendance prévue à long terme du réchauffement climatique devrait pousser les communautés végétales et animales vers un terrain plus élevé et est susceptible de réduire l'habitat adapté et disponible pour les espèces, en particulier, le loup éthiopien qui dépend de proies (des rongeurs) dont l'habitat correspond à la région où l'herbe en touffe diminue (UNEP-WCMA, 2011).

La population des bouquetins, maintenant chiffrée autour de 900 individus, est à la hausse, mais le loup éthiopien reste extrêmement rare (moins de 100 individus) (UNESCO WHC, 2014 ; EWCA 2014). Au total, 21 espèces de mammifères ont été enregistrées, y compris le babouin anubis, le babouin hamadryas, le klipspringer et le chacal doré. Les 137 espèces d'oiseaux recensées par Fishpool et Evans (2001 cité par UNEP-WCMA, 2011) comprennent 16 espèces endémiques de l'Ethiopie/Erythrée ainsi qu'une importante population du rare gypaète barbu. La végétation du SMNP peut être classés en trois grandes unités basées sur la gamme altitudinale et les espèces végétales dominantes (Tableau 2). La Figure 6 représente les zones altitudinales de ces trois types d'habitats. A noter que dû à l'altitude élevée du terrain la savane qui s'étale en dessous de 2000 m n'apparaisse pratiquement sur la zone d'études.

Belt	Altitudes	Dominant Species
Afroalpine	>3700 m	*Lobelia rhynochopetalum* *Festuca* spp.
Sub-Afroalpine	2700-3700 m	*Erica arborea* *Festuca macrophylla*
Montane forest	1900- 3000 m	*Hagenia abyssinica* *Juniperus procera* *Schefflera abyssinica*

Table 2 Principaux types de végétation dans le SMNP (FZS – ADC, 2009)

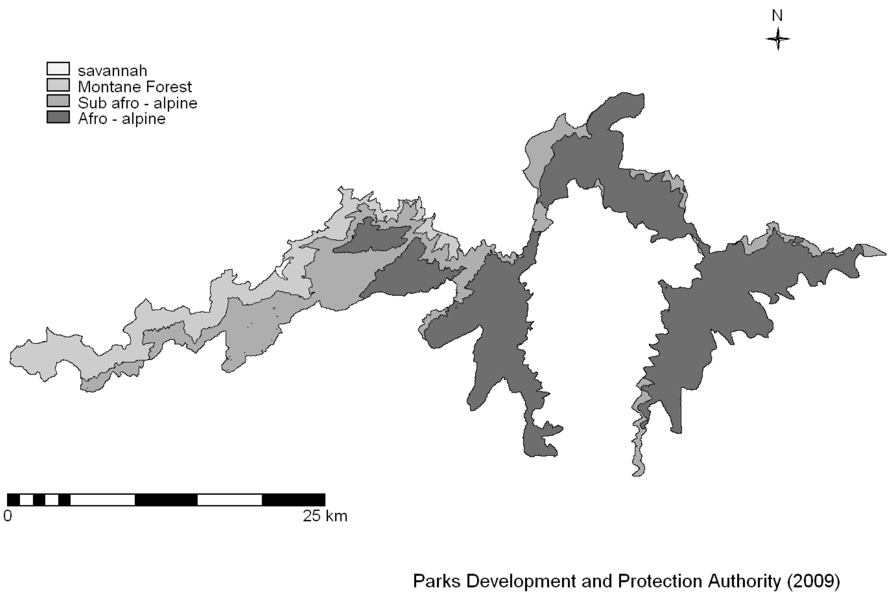


Figure 6 Zone altitudinales végétales dans le SMNP (Parks Development and Protection Authority In FZS – ADC, 2009).

3.2 Cadre humain

3.2.1 Administration du parc et valeur universelle exceptionnelle

Le Parc national du Simien a été officiellement créé en 1969. Actuellement, le SMNP est géré par l'Agence éthiopienne de conservation de la faune sauvage (EWCA). Le siège du parc chargé de l'opérationnel est stationné à Debark (FZS – ADC, 2009). Depuis 1997, le parc bénéficie du soutien du gouvernement autrichien à travers une série de projets qui ont fourni l'infrastructure du parc et ont permis le développement de moyens de subsistance alternatifs pour la population. Un Plan général de gestion (General Management Plan - GMP) de 10 ans élaboré en collaboration avec d'autres partenaires de la conservation a été approuvé par l'Etat national régional d'Amhara (Amhara National Regional State – ANRS) en 2009 (FZS – ADC, 2009).

Le parc s'inscrit dans la catégorie 2 des aires protégées de l'IUCN (parc national II - protection des écosystèmes et fins récréatives). La surface de 13'600 ha a également été inscrite sur la Liste du patrimoine mondial de l'UNESCO en 1978, comme un des quatre premiers sites au monde à être désigné comme patrimoine mondial. Les critères qui ont défini l'inscription du site sur la Liste du patrimoine mondial sont les suivants (UNEP-WCMC, 2011) :

Critère VII : *« Représenter des phénomènes naturels ou des aires d'une beauté naturelle et d'une importance esthétique exceptionnelles ».*

Critère X : *« Contenir les habitats naturels les plus représentatifs et les plus importants pour la conservation in situ de la diversité biologique, y compris ceux où survivent des espèces menacées ayant une valeur universelle exceptionnelle du point de vue de la science ou de la conservation ».*

Le parc a été placé sur la Liste du patrimoine mondial en péril en 1996 en raison du déclin de la population du *walia ibex* en raison de la pression humaine, du pâturage, de l'agriculture et la construction de routes (UNEP-WCMC, 2011). L'état de conservation souhaité en vue du retrait du bien de la Liste du patrimoine mondial en péril demande les mesures correctives suivantes : la publication officielle des nouvelles limites du parc, une stratégie et un plan d'action pour la réduction significative de l'impact du pacage du bétail ainsi qu'une stratégie et un plan d'action pour le développement des sources de revenus pour la population (UNESCO WHC, 2010). L'agrandissement récent du parc vise à intégrer des terres non cultivées qui sont aussi des corridors importants pour le *walia ibex* et d'autres espèces sauvages rares (UNESCO WHC, 2014). Actuellement il est nécessaire que le dossier de modification des limites visant à faire correspondre les limites du site patrimoine mondial avec les limites du parc récemment établies soit remis au Centre du patrimoine mondial (EWCA, 2015a).

3.2.2 Histoire du parc

Le parc a une histoire complexe. De 1978 à 1986, les habitants étaient expulsés du parc et tout développement ou utilisation des ressources du parc était interdite à la population autochtone. Les communautés locales étaient exclues de toute décision de planification ou de gestion. La préoccupation du gouvernement central était pour la faune plutôt que pour ses habitants, ce qui créa beaucoup de ressentiment et alimenta l'opposition locale au parc (UNEP-WCMA, 2011). Un plan de gestion détaillé pour préserver et réhabiliter ses habitats endémiques, la faune, la flore et les valeurs des bassins versants ainsi que la promotion de sa valeur d'enseignement, scientifiques et touristiques a été établi en 1986, avec le soutien du WWF (Hurni, 1986). Cependant, le plan et le zonage n'ont pas été appliqués en raison de la guerre civile (durant les années 1980 et en 1991) au cours de laquelle l'infrastructure du parc a été détruite. C'est seulement à partir de 1996 que les politiques ont changé, lors du transfert de l'administration du parc de l'autorité centrale à l'autorité régionale. Le parc est maintenant géré en collaboration avec ses habitants (UNEP-WCMA, 2011).

3.2.3 Limites administratives

Il est difficile de trouver des informations fiables sur les unités administratives applicables dans la région du Simien. La Figure 7 présente les données qui sont actuellement utilisées dans le bureau du parc à Debark. Cinq *Weredas* (districts) sont en bordure du parc. Ce sont Debark, Adi Arkay, Tellmet, Beyeda et Janamora. Un total de 27 *Kebeles* (communautés) sont liées avec le parc. La zone en blanc correspondant à une ancienne bordure du parc (non datée) est considérée comme une unité administrative en soi. Les numéros de Kebeles ne correspondent pas forcement au système de translittération des noms géographiques indiqué en note de bas page sous chapitre 1.1. Cependant, l'indication relative aux noms de Kebele dans les fiches d'inventaire (annexe 2) est basée sur les informations reportées ici.

3.2.4 Population

Il n'existe pas actuellement des chiffres exacts sur la population vivant dans la région d'étude. Le rapport de la mission 1996 (qui a recommandé l'inscription sur la Liste du patrimoine mondial en péril) cite 30'000 personnes vivant dans la zone du parc (faisant référence uniquement au site de l'UNESCO) et dépendant de l'utilisation de ses ressources naturelles et 4500 personnes vivant à l'intérieur du parc. Le rapport de mission de suivi réactif selon une évaluation plus récente menée en octobre 2005 conclut qu'après la réorganisation de la limite du parc (qui a entraîné l'exclusion de nombreux villages du parc) et l'inclusion des réserves faunistiques de Lemalimo et Mesarerya (aux l'extrémités ouest et sud-ouest du parc) en 2006, la population vivant à l'intérieur du parc a été réduite de 4500 à 3200 personnes (Debonnet et al., 2006). En 2004, l'étude des montagnes du Simien (*Simen Mountains Study*) réalisée par le Centre pour le développement et l'environnement de l'Université de Berne, a estimé le taux de croissance de la population de 1,5 à 2% par an, provoquant un doublement de la population tous les 35 ans (Ludi, 2005).

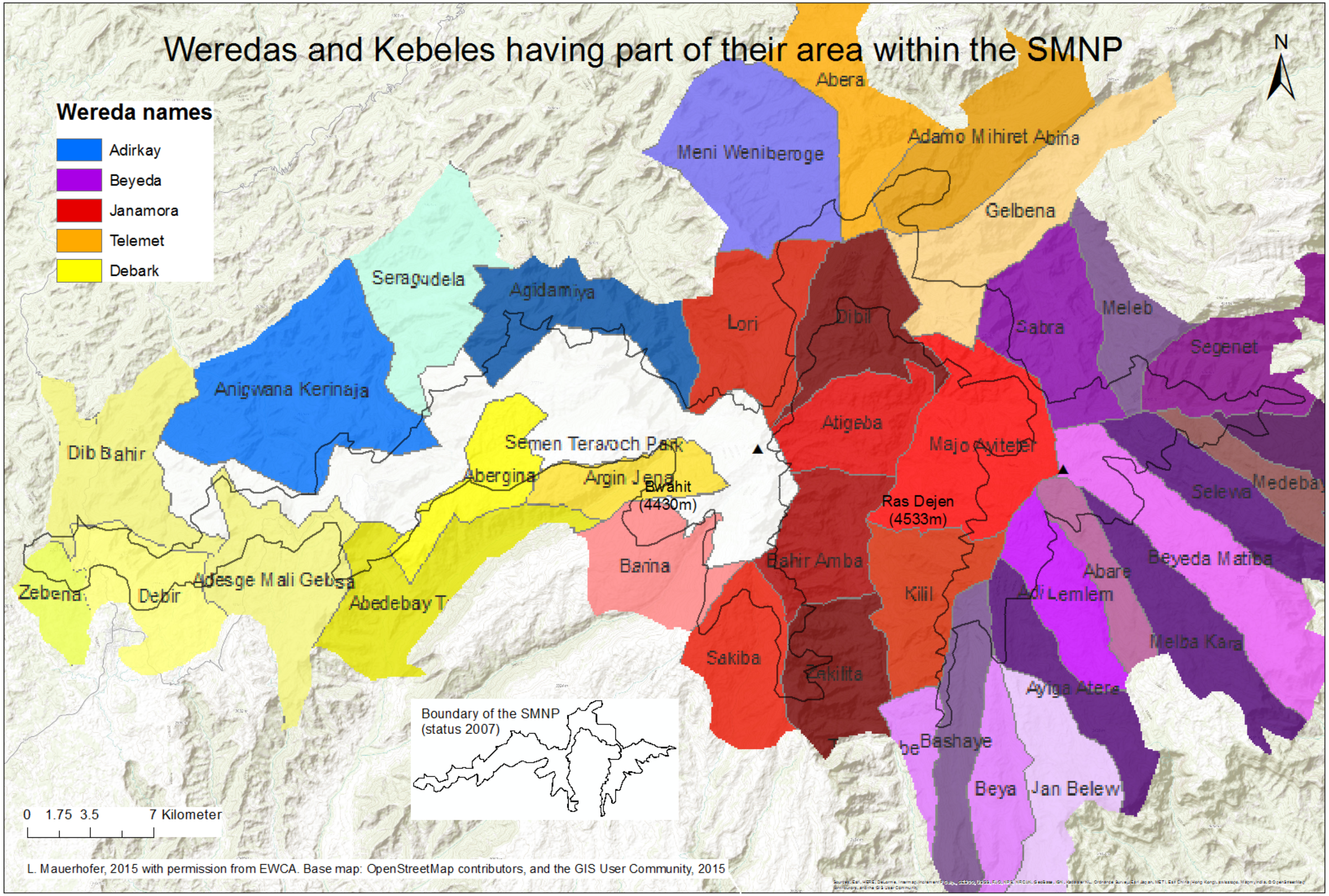


Figure 7 Weredas et Kebeles ayant une partie de leur zone dans le SMNP (donné utilisé avec la permission de l'EWCA)

3.2.5 Impacts humains

Il existe énormément de chiffres (parfois confus) et informations diverses montrant l'influence et les conséquences des activités humaines sur les ressources naturelles dans la région d'étude. Nous présentons quelques chiffres tirés de la fiche d'information du Patrimoine mondial (UNEP-WCMA, 2011). Les indications se rapportent à la zone du site de l'UNESCO ; cependant, elles donnent une idée sur l'importance des impacts humains dans l'ensemble de la région d'étude.

Les hauts plateaux éthiopiens sont parmi les zones agricoles les plus densément peuplées d'Afrique et les habitats de la faune et des populations dans le parc ont été fragmentés par un développement important : construction de routes, large déforestation et brulis, agriculture, collecte du bois de chauffage, chasse et pâturage du bétail domestique. Le gardiennage du parc a cessé en 1977 et en 1980 il a été estimé que 1000 ha de forêt avaient déjà été enlevés (Hurni, 1980 cité par UNEP-WCMA, 2011). Au moment de l'inscription du parc, 80% de la surface étaient en usage humain sous une forme ou une autre. Cependant, le pâturage ne peut être interdit tant que des populations locales résident dans le parc (UICN, 2001 cité par UNEP-WCMA, 2011). Quelque 60% des prairies observées en 1996 ont été considérées comme fortement pâturées, 25% sérieusement surpâturées, et seulement 15% sont encore dans un état naturel. Cela a provoqué une grave érosion et des changements dans l'écosystème. Le pâturage près des cours d'eau a affecté la qualité de l'eau et a augmenté la charge de sédiments provenant de berges érodées (Nievergelt, 1996 cité par UNEP-WCMA, 2011). La route de Debark a aggravé l'érosion et les dommages écologiques et a rendu l'accès plus facile pour un nombre croissant de paysans (Nievergelt et al., 1998 ; Beltran, 2000 cité par UNEP-WCMA, 2011).

3.2.6 Transports

La route qui s'étend de Debark à travers le parc en direction de Chennek jusqu'à Bwahit est le principal accès au parc. Selon notre expérience et les observations sur le terrain, plusieurs transports publics de bus et grands camions gérés par des entreprises privées fréquentent la route chaque jour pour transporter des passagers entre Debark et Mekane Birhan/Deresge. L'utilisation de ces transports pas chers et pleinement remplis de gens est cependant réservée aux populations indigènes. Les visiteurs du parc peuvent organiser soit un transport privé ou se joindre un tour opérateur. Une route goudronnée en construction entre Bwahit et Beyeda pourra rendre l'accès à la partie située à l'est du parc plus aisée dans un proche futur.

3.2.7 Aspects culturels

Entourée de vieux centres culturels comme Axoum (orthographe française de Axum en anglais ou Aksum en allemand), Lalibela et Gonder - également inscrite au patrimoine mondial -, la région du Simien a été habitée par des cultivateurs pendant au moins 2000 ans (Kirwan, 1972 ; Hurni, 1986 cité par AWF – ADC, 2009), les premiers habitants enregistrés étant des Juifs éthiopiens. « *Après le déclin du royaume juif au 14ème siècle, beaucoup de Juifs éthiopiens se sont convertis à la foi chrétienne orthodoxe. Les zones au sud du sentier Debark-Ambaras-Chennek dans le SMNP ont été données [...] aux chrétiens et les régions au nord de cette ligne ont été données aux musulmans. Dans les années 1960, il y avait encore des colons juifs dans la région du Simien, mais la plupart ont émigré en Israël entre 1988 et 1991* (AWF – ADC, 2009 : 27). » Le massif était à l'origine partie des anciennes routes de commerce et de pèlerinage entre Axoum, Lalibela, Mekele et Gonder (Figure 8). Axoum et Lalibela sont situées respectivement à six jours de marche au nord et huit jours de marche au sud-est du Simien. « *Ainsi, la région, ses habitants et l'histoire culturelle font partie d'une histoire de négoce et de commerce qui est une partie de l'histoire de l'Ethiopie en tant que nation* (AWF – ADC, 2009 : 36). »

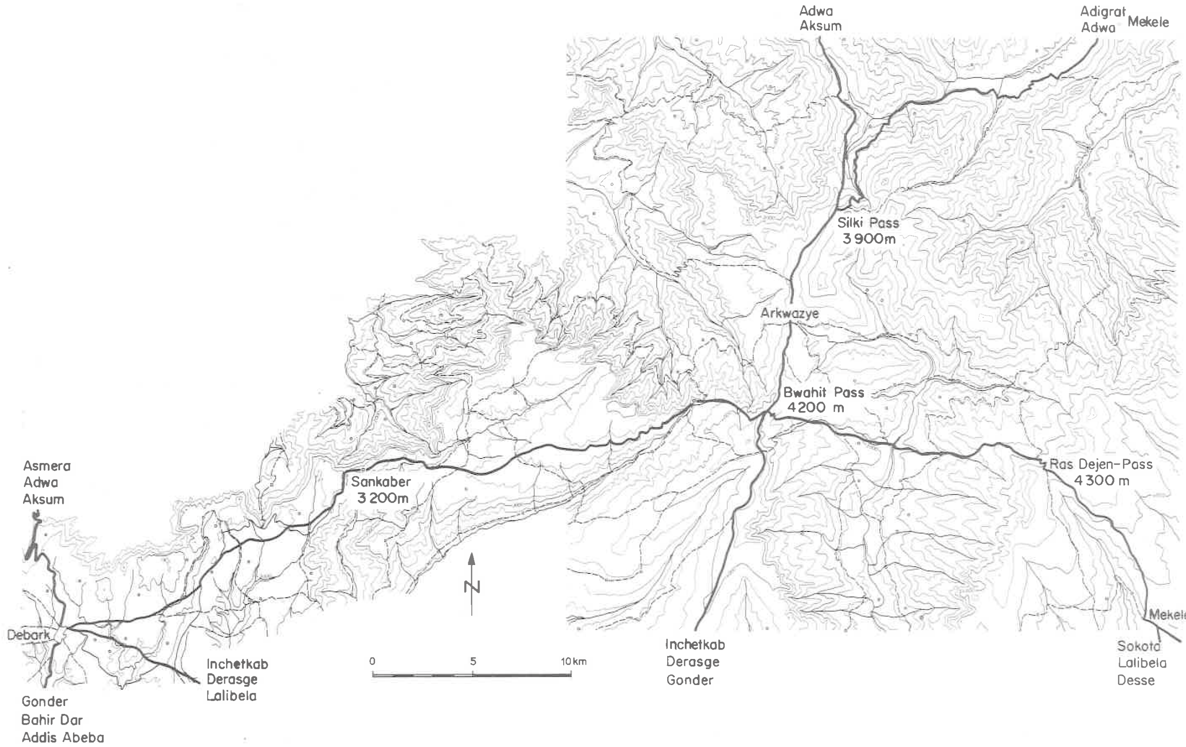


Figure 8 Importantes routes de commerce et de pèlerinage dans les montagnes du Simien (Stähli, 1978)

3.3 La protection et les exigences de gestion du SMNP

La propriété nécessite la présence d'une gestion efficace et le maintien ainsi que l'augmentation des niveaux de personnel et son entraînement. Les principales tâches de gestion du parc comprennent la protection efficace des espèces emblématiques du parc et une coopération étroite avec les communautés locales afin de réduire la dépendance de ces dernières à l'égard d'une utilisation non durable des ressources du parc national ainsi que de développer des modes de vie durables.

Un soutien financier important est nécessaire pour la gestion du parc et le développement de moyens de subsistance alternatifs pour les communautés locales. Des financements adéquats pour soutenir la réinstallation des populations vivant dans le parc sur une base entièrement volontaire et introduire une gestion efficace du pâturage est donc essentielle pour réduire la pression extrême sur la faune. L'amélioration et l'augmentation des structures d'écotourisme, sans porter atteinte aux valeurs naturelles et paysagères du parc, a un grand potentiel pour créer des recettes supplémentaires pour la propriété. Cependant, les organismes gouvernementaux et communautaires manquent de personnel, sont sous-qualifiés et sous-payés et ont peu d'expérience et pour cela ont une faible capacité de conservation et d'engagement des communautés locales. L'éducation à l'environnement et des programmes de formation sont nécessaires pour soutenir les communautés dans et autour du périmètre ainsi que pour maintenir le soutien communautaire et le partenariat dans la gestion du parc afin de s'assurer qu'il reste de valeur universelle exceptionnelle (UNEP-WCMC, 2011).

3.4 Développement du tourisme dans les montagnes du Simen

Pour faire suite à une stratégie de gestion des geomorphosites (basée sur le développement du geotourism, cf. chapitre 6) il est important de fournir quelques informations de base concernant le développement du tourisme dans la région. Le Ministère éthiopien de la Culture et du Tourisme - auquel l'EWCA est également soumis - est chargé d'élaborer et de promouvoir les produits touristiques de l'Ethiopie à l'intérieur du pays et à l'étranger. Le tourisme étant une des priorités du gouvernement éthiopien, il est censé contribuer de manière importante au développement économique et social durable du pays (Asrat et al., 2008). En 2012, la contribution directe du tourisme au PIB était ETB 33 149,8 Mio (≈ 1,6Mia $ US) soit 5,1% du PIB total et il devrait augmenter de 4,1% par an de 2013 à 2023, à ETB 51 713 Mio (≈ 2.4Mia $ US) en 2023 (World Travel and Tourism Council Economic Impact Report for Ethiopia, 2013 In AWF, 2014).

Avant les troubles civils, le SMNP accueillait 100-200 visiteurs internationaux chaque année. Les voies et infrastructures d'accès étaient pauvres et de 1983 à 1999, la région a été fermée aux visiteurs en raison de la guerre (UNEP-WCMA, 2011). Depuis 2000, le nombre de visiteurs annuel dans le SMNP présente une augmentation constante de 1289 visiteurs en 2000 à un maximum de 17 566 en 2011 (Figure 9). A l'avenir, le tourisme dans le SMNP bénéficiera certainement encore de la croissance du tourisme de nature et de l'écotourisme mondial (AWF, 2014). Les revenus du parc partagés avec les communautés locales génèrent désormais plus de 30 millions de Birr éthiopiens par an (>1.5Mio $ US) avec un autre revenu de 4 millions de Birr éthiopien (>200'000 $ US) au trésor central (EWCA, 2014).

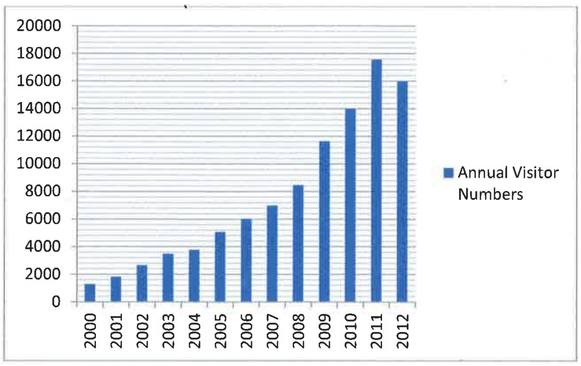


Figure 9 Nombre de visiteurs annuel dans le SMNP (AWF, 2014)

L'EWCA, en collaboration étroite avec la Fondation de la faune africaine (AWF), a récemment élaboré un plan de développement du tourisme (TDP) dans l'idée de promouvoir le SMNP comme la première destination touristique de faune sauvage du pays (AWF, 2014). Le plan fournit un cadre stratégique pour le développement du tourisme et les investissements connexes dans le SMNP et sera annexé au plan général de gestion 2009-2019 déjà développé par l'État parti (cf. point 3.2.1). Cependant, un certain nombre de défis et contraintes sont à relever pour offrir un produit touristique de qualité, allant d'un manque de logement, aux limitations dans la main-d'œuvre qualifiée, en passant par la mauvaise qualité et l'insuffisance des infrastructures touristiques. De plus, le volume de touristes en haute saison commence à avoir un impact sur la qualité de l'expérience touristique. Il est nécessaire de concevoir de nouvelles stratégies et actions pour résoudre ces défis (EWCA, 2014).

La Figure 10 montre la proportion des types de visiteurs en fonction de leurs intérêts. La catégorie « Visiteurs touristiques » représente actuellement jusqu'à 70 % de tous les visiteurs dans le SMNP. Ils sont généralement dans une plus grande tournée de l'Ethiopie axée sur la culture. La catégorie de randonnée constitue environ 20 %. Ces voyageurs suivent habituellement l'itinéraire de randonnée bien établi de Sankabar à Chennek via Gich camping. Ces visites sont souvent organisées par des tour-opérateurs internationaux ou locaux qui se spécialisent dans l'organisation d'activités en plein air. La catégorie du routard représente 5 % des visiteurs. Les routards sont considérés comme une catégorie distincte des « trekkers ». Ces jeunes voyageurs à petit budget organisent habituellement leurs activités localement depuis Debark. Ils ne font pas nécessairement une expérience de trekking (bien que la plupart d'entre eux peuvent participer une randonnée). Enfin, il y a la catégorie de la photographie de la faune (5%) dont le marché reste apparemment à ses balbutiements.

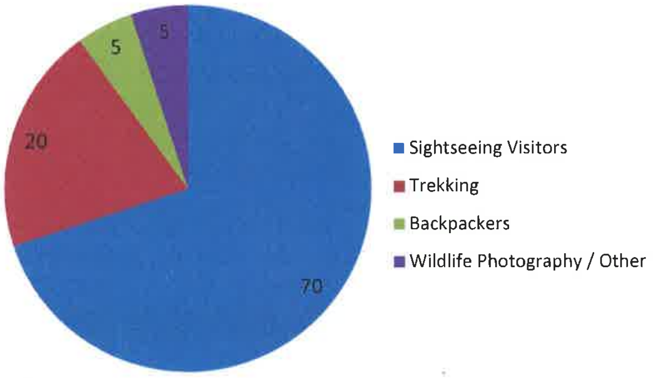
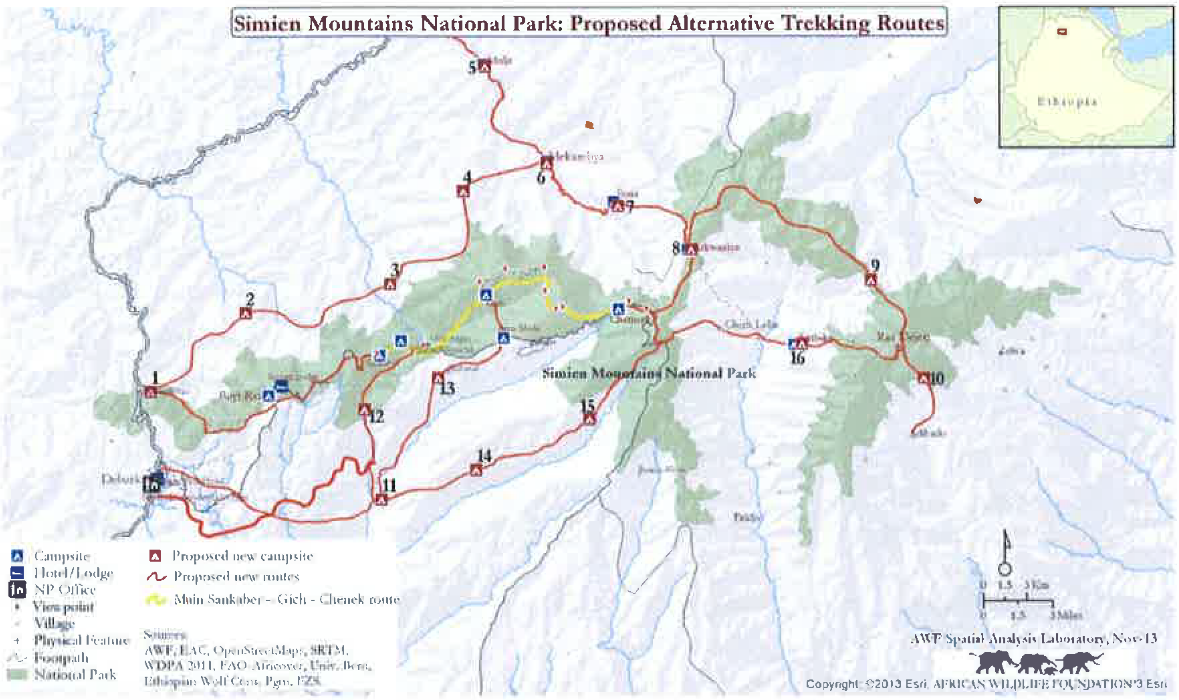


Figure 10 Types de visiteurs dans le SMNP en fonction de l'intérêt (AWF, 2014)

Comme indiqué ci-dessus, la plupart des voyageurs qui viennent à Simien pour le trekking suivra le parcours de randonnée bien établie de Sankabar à Chennek via Gich camping (*Main Gich Plateau Trekking Route* (ligne jaune, Figure 11). Ces sites sont bien connus à l'échelle internationale et les routes et distances de trekking ont été travaillées avec soin dans tous les forfaits de tourisme qui sont actuellement promus pour ce marché. Le plan de développement touristique (TDP) présente une stratégie de sept itinéraires de trekking alternatifs (ligne rouge, Figure 11). L'introduction de nouvelles itinéraires de trekking permet de diffuser l'influence de visiteur loin de plateau de Gich vers d'autres zones du parc. Ainsi, les ressources naturelles actuellement fortement utilisées à Gich peuvent être préservés et la population vivant dans les communautés autour du parc (dont la pluparts présentent des menaces particulières à la conservation des valeurs du SMNP) peut également bénéficier de revenus du tourisme (permettant au SMNP à son tour de maintenir un nombre de visiteurs plus élevé). Les nouveaux itinéraires proposés sont les suivants : 1) Lemalimo et les basses terres du nord, 2) Debark à Sankabar via Adebabay, 3) Debark à Gich via Ambaras, 4) Chennek à Adi Arkay, 5) Ras Dejen via Abba Yared, 6) Ras Dejen du Plateau Beyeda et 7) Lemalimo à Sankaber (AWF, 2014).



Key:

Proposed new routes marked in red, with existing main Sankaber – Gich - Chenek route marked in yellow.
Proposed new campsite facility locations are numbered as follows:

1 – Lemalimo	2 – Kerneja	3 – Nariya	4 – Amba Ber	5 – Mulit	6 – Dirni
7 – Diwhara	8 – Arkwasiye	9 – Metelal	10 – Beyeda/Kara	11 – Adebabay	
12 – Islam Debir	13 – Abergina	14 – Barangeb	15 – Seketate	16 - Ambiko	

Figure 11 Parc National des Montagnes du Simien : nouveaux itinéraires de trekking (AWF, 2014)

3.5 Synthèse et choix du terrain

Dans leur ouvrage entièrement consacré au géotourisme de l'Ethiopie, Asrat et al. (2008) soulignent l'attractivité et les trésors géologiques, géomorphologiques et archéologiques du pays et son potentiel pour le tourisme.

Avec sa beauté fascinante, le massif montagneux du Simien - depuis les explorations de Bruce *« Travel to discover the source of the Nile »* à la fin du 18ème siècle et l'expédition de Rüppell *« Reise in Abyssinien »* en 1840 - a déjà attiré de nombreux voyageurs, touristes et scientifiques et est devenu une zone cible essentielle de la recherche de haute montagne (Hurni, 1981). D'une part, les falaises et les plateaux afroalpins forment un refuge pour les espèces désormais endémiques de *walla ibex* et de renard du Simien (Nievergelt, 1981 cité par Hurni, 1981), pour la protection desquelles un parc national a été créé en 1969. D'autre part, ce massif montagneux est utilisé intensivement par l'agriculture de subsistance et son taux de croissance démographique humain est parmi les plus élevés au monde. On trouve aussi dans la campagne de Simien les célèbres centres culturels historiques Axoum, Gondor et Lalibela. Bien sûr, tout ceci amène le chevauchement d'influences qui aboutissent à des conflits entre l'utilisation humaine et la conservation de la nature, problèmes dont s'occupent intensivement, à côté du gouvernement éthiopien, des organisations internationales comme le Fonds mondial pour la nature, WWF (depuis 1971), la Fondation Pro Simien (depuis 1974) et le Comité du patrimoine mondial (depuis 1978).

Les montagnes de Simien sont beaucoup regardées pour leur biodiversité mais peu d'attention a été donnée à la géodiversité (Asrat et al. 2012). L'interférence de l'activité humaine affecte cependant ces deux aspects, biodiversité et géodiversité, dans les montagnes du Simien. Le vaste massif de l'ancien volcan bouclier peut être considéré comme un territoire de géopatrimoine et devrait être reconnu comme tel. En outre, les montagnes du Simien sont une zone d'étude complexe et fort intéressante pour l'étude des stratégies de gestion holistique et innovante de ce patrimoine. L'inventaire de géomorphosites proposé dans ce mémoire en est une étape indispensable. Il s'agit donc d'un site de recherche idéal pour le traitement de notre problématique.

4 Work methods – Inventory of geomorphosites

The objective of a method of inventory and evaluation of geomorphosites is to express the geomorphological value on the basis of a maximum of objective criteria (Reynard, 2009b). It is since the 1990s that the scientific community has begun to systematically study the geoheritage (Actes 1994, O' Halloran et al. 1994 cited by Reynard 2009b). In 2001, a working group working specifically on geomorphological sites was created by the International Association of Geomorphologists (IAG) (Reynard and Coratza, 2013b). It was committed to developing a universal method of evaluation to coordinate research studies in different countries. However, this rapidly proved to be a failure due to national contexts that were too diversified (Reynard and Coratza, 2013b). Consequently, there currently exist numerous evaluation methods.

This chapter aims to present the geomorphosite inventory method used in this work. The first part gives an overview of the methods developed by various universities in Europe (4.1). The second part of the chapter is devoted to the method developed by the Institute of Geography and Sustainability of the University of Lausanne (4.2). A brief expert interview is presented in the last part (4.3).

4.1 Methods of European universities

This section aims to give an overview of the existing inventory methods. Reynard (2009b) has presented an overview of the methods developed by the aforementioned working group. Only generalist methods have been taken into account. There are also more specific methods such as that of Pralong (2005) that evaluates the touristic potential and the use of geomorphosites as well as methods developed on a national scale. The methods presented below have been developed at the University of Modena and Reggio Emilia, the University of Cantabria, the University of Valladolid and the University of Minho. Each of these methods shows its own specificities.

4.1.1 Universities of Modena and Reggio Emilia

The method was developed by Coratza and Guisti (2005) and applied to an environmental impact study. It is only the scientific value that is evaluated. The method takes place in three steps: 1) it is based on a geomorphological analysis which necessitates bibliographical research, an analysis of aerial photos and field survey. 2) Then, the selection of potential sites is made in order to 3) finally proceed to the numerical evaluation of these sites. The scientific value takes seven criteria into account: number of scientific publications, educational value, area, rareness, integrity, exposition, and added values.

4.1.2 University of Cantabria

This method was developed by Bruschi and Cendrero (2005) and tested during an environmental impact study and in the framework of a regional inventory. It is not only the scientific value that is evaluated but also the potential of use and any potential threats. For each of these characters, several criteria are numerically evaluated and presented in the Table 3.

Scientific value	Potential for use	Protection needs
rareness	number of potential activities	number of inhabitants
scientific knowledge	conditions of observation	actual/potential threats
exemplarity	accessibility	possibility to collect objects
diversity of elements	area	relationship to existing planning
age	proximity to service centres	interest for mineral exploitation
link to a cultural heritage	socioeconomic conditions	land ownership
link to another natural heritage		
integrity		

Table 3 Criteria of evaluation of geomorphosites according to the method of the University of Cantabria (Reynard, 2009b)

4.1.3 University of Valladolid

This method was developed by Serrano and González Trueba (2005). Initially, a geomorphological map is constructed. On this basis, the method also consists of a selection of potential sites. As for the evaluation, three characters are taken into account: 1) the scientific value defined by morphology, chronology, lithology, the dynamics of processes, the geological structure and sedimentary structure; 2) additional values defined by the attractiveness of the landscape, cultural elements, educational value and touristic attractiveness; 3) a value of usage/management with criteria such as accessibility, fragility, integrity, conditions of observation, etc.

4.1.4 University of Minho

The method developed by Pereira et al. (2007) follows more of a regional scale approach to inventory. The totality of the procedure is divided into two parts: inventory and qualification. The inventory is divided into four stages: 1) identification of potential sites; 2) qualitative evaluation; 3) selection of potential sites; 4) characterisation of potential sites. The part that concerns quantification is divided into two stages: numerical evaluation and classification. As for numerical evaluation, the geomorphological value regroups the scientific value and additional values, and the usage value regroups a value of usage and a value of protection.

4.2 The method of the University of Lausanne

For this Master's thesis, we will use the method of the University of Lausanne published by Reynard et al. (2007) and improved in the following years (Reynard et al., 2011; 2014; 2015). This generalist method lends itself well to inventories of natural heritage sites such as the Simen Mountains National Park. Moreover, it has proved to be robust in various environment contexts (Reynard, 2014b). It takes into account not only the scientific value but also the additional values, and gives a lot of freedom for the direction of the management strategy (rather protection or promotion), which is why it will be explained in more detail in this paragraph. The evaluation is integrated into a longer process (cf. analytical framework of chapter 1.2.3) divided into two phases:

- An evaluation phase that aims to produce a list of geomorphosites, itself divided into two phases: 1) the selection of potential sites, on the basis of two criteria: spatial and temporal representativeness and 2) evaluation *stricto sensu*.
- A management phase that aims to improve the protection and promotion of the geomorphological heritage highlighted during the first phase (not the focus of this work).

4.2.1 Selection of the sites

To present an exhaustive list of geomorphological sites of a region is not *per se* the objective of an inventory. The latter rather aims to provide an overview of the most important geomorphological characteristics of the region. Thus, a distinct selection of the geomorphological and geological site is a crucial working step within the inventory procedure. In fact, the content of the inventory depends directly of this step. Several methods have been proposed. Martin (2012) gives a summary. Two approaches should be distinguished: the **integrated approach,** which tends to evaluate all sites of a region, the sites being identified using geomorphological mapping (thus it is very time consuming) and the **specific approach,** which typically means the selection of the sites by expert's advice (which is more subjective and opaque).

A. Perret (2014), within the frame of her doctoral thesis, developed a third **approach**, called "**mixed**", which lies halfway between completeness (integrated approach) and specify (specific approach). The author proposes the selection of the sites based on crossing of two simple criteria: a spatial dimension and a temporal one (Figure 12). Ideally, the list of the selected geomorphosites should be representative of the regional geomorphological processes (spatial criterion) and it should cover the various temporal stages of the regional morphogenesis with both relict and active landforms (temporal criterion). This means that more landforms related to very broadly represented processes will be selected. It also contains specific and rare landforms.

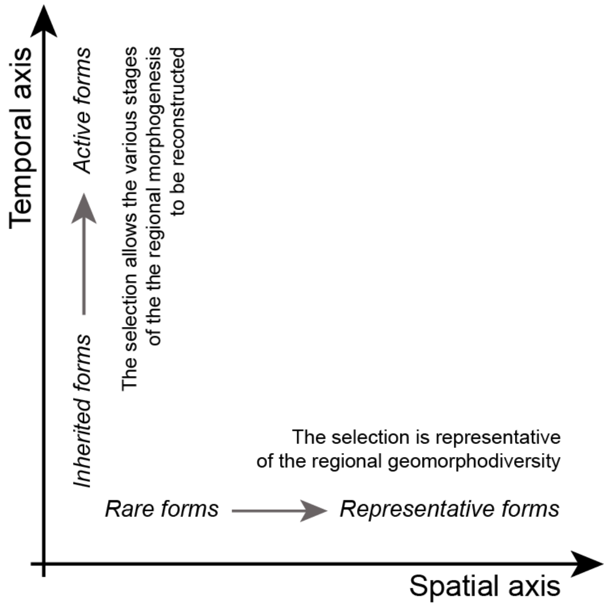


Figure 12 Selection process based on two criteria (Reynard et al. 2015).

In order to proceed to the selection a detailed study of the regional geomorphology is necessary. This preparation phase should be based on literature survey, consultation of cartographic and photogrammetric material (topographic maps, geologic maps, digital terrain models, aerial photographs) and a field survey, which permits to gain a solid knowledge of the geomorphological context and helps to complete the inventory with sites that have not been object of prior study but which nonetheless present an interest to be considered geomorphosites. The information (location, short description, references) is continually stored in a database (ex. GIS or Excel) thus allowing higher transparency and rapid classification of the potential sites following the two selection criteria (Reynard et al., 2015). The selection of the sites that are the subject of this Master's thesis has been performed on the basis of the mixed approach. As stated by M. Clivaz (2015), who recently applied the method, as a matter of time the two other approaches reveal to be inapplicable in the context of a Master's thesis. Therefore, the sites have been selected based on the criteria represented by a temporal and a spatial axis, as proposed by Perret (2014) and Reynard et al. (2015).

4.2.2 Assessment of the geomorphosites

In the applications of the first version of this method (Reynard et al., 2007), it came to light that the selection of potential sites was not clear and systematic, and that certain additional values - particularly the economic value - were difficult to evaluate, and some were not considered at all. This is why the method has gone through modifications (Reynard et al., 2015). The evaluation comprises four stages developed subsequently and presented in Figure 13.

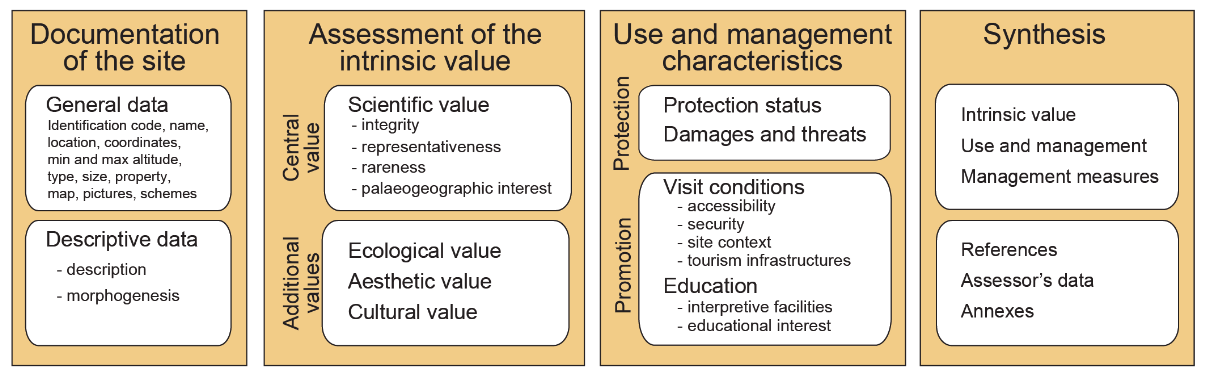


Figure 13 Method of geomorphosite evaluation (Reynard et al., 2015)

First of all, the site is documented. The first step is to collect general data from the site (name, identification code, localisation, coordinates, altitude, property) and create maps, photos and models. A description and analysis of the morphogenesis of the site are also presented. Characteristics concerning the property rights (private, association, public and common-property) as well as notifications regarding the protection status (ex. listing of the site in an inventory or nature reserve) should be assessed in an inventory procedure (Reynard et al., 2007). For technical reasons this was not possible in the Simen Mountains National Park (cf. sample project, annex 2).

Then, **the intrinsic value** of the site - that is the central (scientific) value and the additional values (ecological, aesthetic, cultural) - is evaluated in a qualitative or quantitative manner. In the last case, a numerical score is attributed that varies between 0 and 1. The scientific value corresponds to the average score obtained with the following criteria: integrity (the conservation state of the site), rarity (on the scale of the terrain of study), representativeness (on the scale of the terrain of study) and palaeogeographical value.

Three additional values corresponding to the ecological, aesthetic and cultural value are assessed. The ecological value aims to determine the importance of the geomorphosite in ecological terms. Two criteria are considered: 1) the ecological impact criterion allows us to assess the importance of the geomorphosite for the development of an ecosystem or the presence of a particular ecological diversity (we are basing ourselves on existing literature); 2) if the site is protected for ecological reasons, it disposes of a certain value. This criterion could not be assessed. Therefore, the ecological impact alone constitutes the ecological value in our study.

The aesthetic value is very difficult to evaluate objectively because beauty is relative and depends on the subjectivity of the observer. However, criteria based on the works of Grandgirard (1997) and Pralong (2006) are suggested: 1) the presence of viewpoints and 2) contrast, vertical development and landscape structure. The cultural value considers the term “culture” in a broad sense (Panizza & Piacente, 2003). It brings together religious, historical, archaeological, artistic and immaterial goods. Five criteria are applied: religious and symbolic importance, historical importance, economic importance, artistic and literature importance and geohistorical importance.

Finally, information about the management of the site are collected. In terms of protection, the protective measures in vigour at the site and the damages and threats endured have to be evaluated. Concerning the promotion of the site, visit conditions (accessibility, security, site context, touristic infrastructure) and educational possibilities (installations of existing interpretation facilities and the site’s readability) have to be evaluated. The sample project sheet (cf. annex 2) gives detailed information regarding the elements and criteria of the assessment methodology. The last part of the evaluation makes a synthesis of the collected information for the intrinsic value and the use and management characteristics and formulates recommendations for the management of the site. References, assessor data and annexes supporting for the illustration and documentation of the geomorphological context of the site are also attached.

Bussard (2014) and Clivaz (2015) thereafter added maps of the geomorphological context of the sites to their inventories. This is to complete the textual description and to facilitate the comprehension of the site’s morphogenesis. For the preparation of their maps they used the geomorphological mapping legend developed by the University of Lausanne (Lambiel et al., 2016). The tools which allow equally precise geomorphological mapping such as topographic and geologic maps at the scale of 1:25’000, high-resolution digital terrain models (DEM) or aerial photographs have not been available for the SMNP. However, Google Earth photographs and own photographs have been used to illustrate the geomorphological context of the sites. According to the above-mentioned geomorphological mapping legend structural landforms have been indicated with red colour, fluvial processes with green colour, glacial process with violet colour etc.

An inventory of geomorphosites may be a very substantial document and contain a lot of information. Therefore, a synthesis must be carried out to facilitate the comparison of the sites, in particular for the management phase and to communicate clear messages to the manager. The synthesis map is the ideal tool to meet this objective. Indeed, it not only helps to locate inventoried objects in space but also provides an overview of the main components of the sites (Clivaz, 2015). Based on prior work and advices, especially those from Bussard (2014), four synthesis maps have been developed. They render the localisation of the geomorphosites as well as the visualisation of the intrinsic value, the protection (level of protection and vulnerability) and the promotion (visit conditions and educational interest) of the sites.

4.3 Expert interviews

In order to appraise the state of the art of geoheritage and geoconservation in Ethiopia and the potential of geotourism development in the SMNP in particular, five interviews with experts have been carried out. They include interviews with Mr. M. Beyadegelegne, Chief Warden of the SMNP, Mr. K. Wakjira director of the National Parks and Wildlife Sanctuaries Coordination of EWCA, Mr. T. Mulu, coordinator of the SMNP- Integrated Development Project (IDP) of the Austrian Development Cooperation (ADC), professor H. Hurni of the Centre for Development and Environment of the University of Bern and professor A. Asrat from the School of Earth Sciences of Addis Ababa University (co-supervisor of this Master's thesis). The collection of data is inspired from the expert interview method used in environmental and planning sciences (Mieg & Naf, 2005). A questionnaire is developed (cf. annex 1). The interviews are recorded on MP3 and are available from the author. The realisation of the geomorphosite inventory constitutes the focus of this work. Only the interview with A. Asrat is transcribed *verbatim*. The data is analysed by applying a qualitative analysis of the content according to Mayring (2002 : 114-121). Key words and phrases have been noted from the recordings of the four other interviews. For literal citation a specific passage on the recordings is tapped again and only thereafter quoted.

5 Results of the inventory

The Inventory includes twenty-one geomorphological sites that have been selected and evaluated with the method of the University of Lausanne described previously (cf. chapter 4.2). This chapter provides a summary of this inventory. The first sub-chapter (5.1) is devoted to the site selection process, notably with the help of the spatial and temporal representativeness. The selected sites in the inventory are briefly described in the following sub-section (5.2), and then more in detail according to their morphogenetic process (5.3). The evaluation of these sites is summarized in the second half of this chapter. The intrinsic value (5.4) and the use and management characteristics (5.5) are treated separately.

5.1 Selection of the sites

The realisation of an inventory of geomorphosites of a region needs a selection process. As mentioned previously it is impossible to index, describe and assess all geomorphological objects within a perimeter of study (cf. chapter 4.2.1). According to the method proposed by A. Perret (2014) and E. Reynard et al. (2015), the selection is supposed to give a general overview of the visible forms and should allow us to reconstruct the morphogenesis on the scale of the area of study. In order to achieve the selection, it was necessary to identify all the geomorphological and geological forms of the Simen Mountains National Park presenting a certain interest. Therefore, detailed bibliographic research and the consultation of topographic maps and Google Earth were crucial. No usable geologic maps, digital terrain models or aerial photographs are available for the Simen Mountains.

Two publications were very particularly useful. First, the dissertation of H. Hurni (1982), which includes detailed geomorphological analyses of the Last Cold Period landforms (mainly glacial and periglacial) as well as of the present day geomorphology covering the entire area of this Master's thesis. The work comprises two geomorphological maps: one presenting the altitudinal belts of the Last Cold Period (Late Glacial) and one showing the present day altitudinal belts of Simen. Especially the former was of great help for the localisation of numerous fossil glacial and periglacial sites. In total, the publications of H. Hurni provides a complete review of all the geomorphological research carried out in Simen since J. Bruce (1790). The cited geomorphological literature involves for instance, Minucci (1938), Nilsson (1940), Büdel (1954), Hövermann (1954), Werdecker (1955; 1968), Scott (1958), Mohr (1962; 1971), Hastenrath (1974), Messerli, (1975), Williams et al (1978) and Hurni (1975; 1978; 1981b; 1981c). The second valuable bibliographic reference comes from Asrat et al. (2012) who promote the Simen Mountains as "major geoheritages". The authors consider as "geoconservation sites", the Lemalimo pass, the Chilkwanit pass, the Awaza peaks, the Sankabar land bridge, the Chennek pass, the Gich Abyss, the Imet Gogo peak, and the Bwahit plateau. These locations are mostly dominated by structural or fluvial processes except of Bwahit (glacial and periglacial). In conclusion of our literature survey, scientific contributions on Simen's geomorphology in the last 35 years are few.

However, not all objects are mentioned in literature. Our fieldwork in Simen was essential to identify forms that appear nowhere in scientific papers and could not be revealed from Google Earth either. Moreover, the field experience contributed to complete and confirm much of the information collected beforehand. Within four extremely challenging trekking expeditions, most parts of the 400 km^2 large territory of the National Park could be visited. The map of Figure 14 shows the respective expedition routes and duration of the expedition. We were based in the rural town Debark where the park headquarters is situated. Altogether we spent from January to March 2015 three months in Simen. A list of sites of geomorphological interest has been established continuously. At the end of this first phase of selection a list of 39 potential geomorphosites has been produced (cf. annex 2).

In order to facilitate the selection, these sites were thereafter classified following the dominant geomorphological processes (fluvial, structural, periglacial, etc.). The sites are not considered individually but they are grouped per form-type. All sites were allocated with spatial representation (surface, linear or punctual). We identified 39 form-types which can be attributed to 7 geomorphological processes (or contexts). Moreover, each site has been attributed a morphogenetic stage (Cenozoic volcanism, Last Cold Period (Lataglacial), Holocene, etc.) and they all have been placed on a spatial and on a temporal axis (Figure 15). The spatial axis shows the abundance of the geomorphological process in the SMNP. The temporal axis allows the morphogenesis of Simen to be chronologically reconstructed. The activity of these processes triggering the different landforms is illustrated by three icons: active forms, semi-active forms and fossil forms.

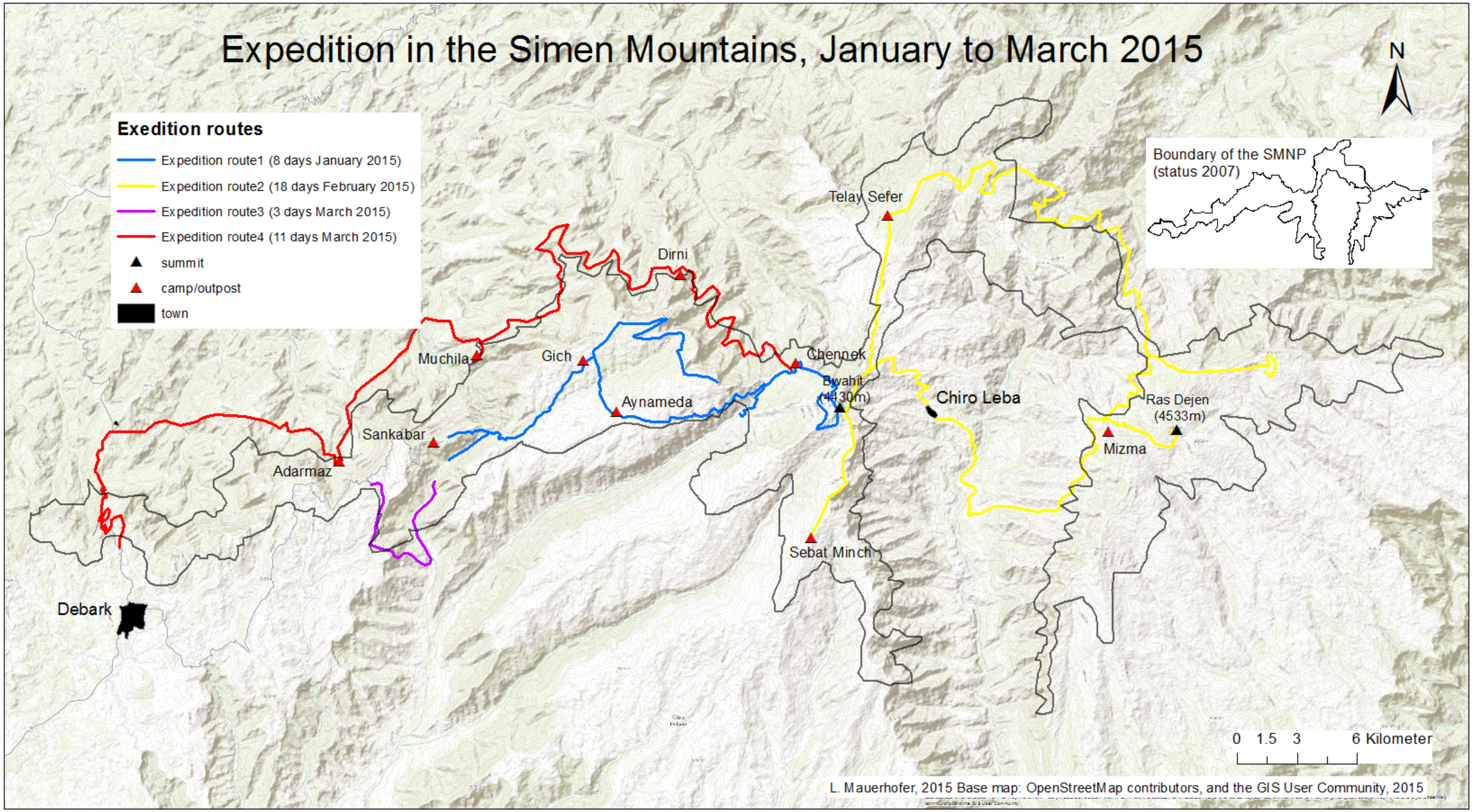


Figure 14 Expedition to the Simen Mountains, January-March 2015

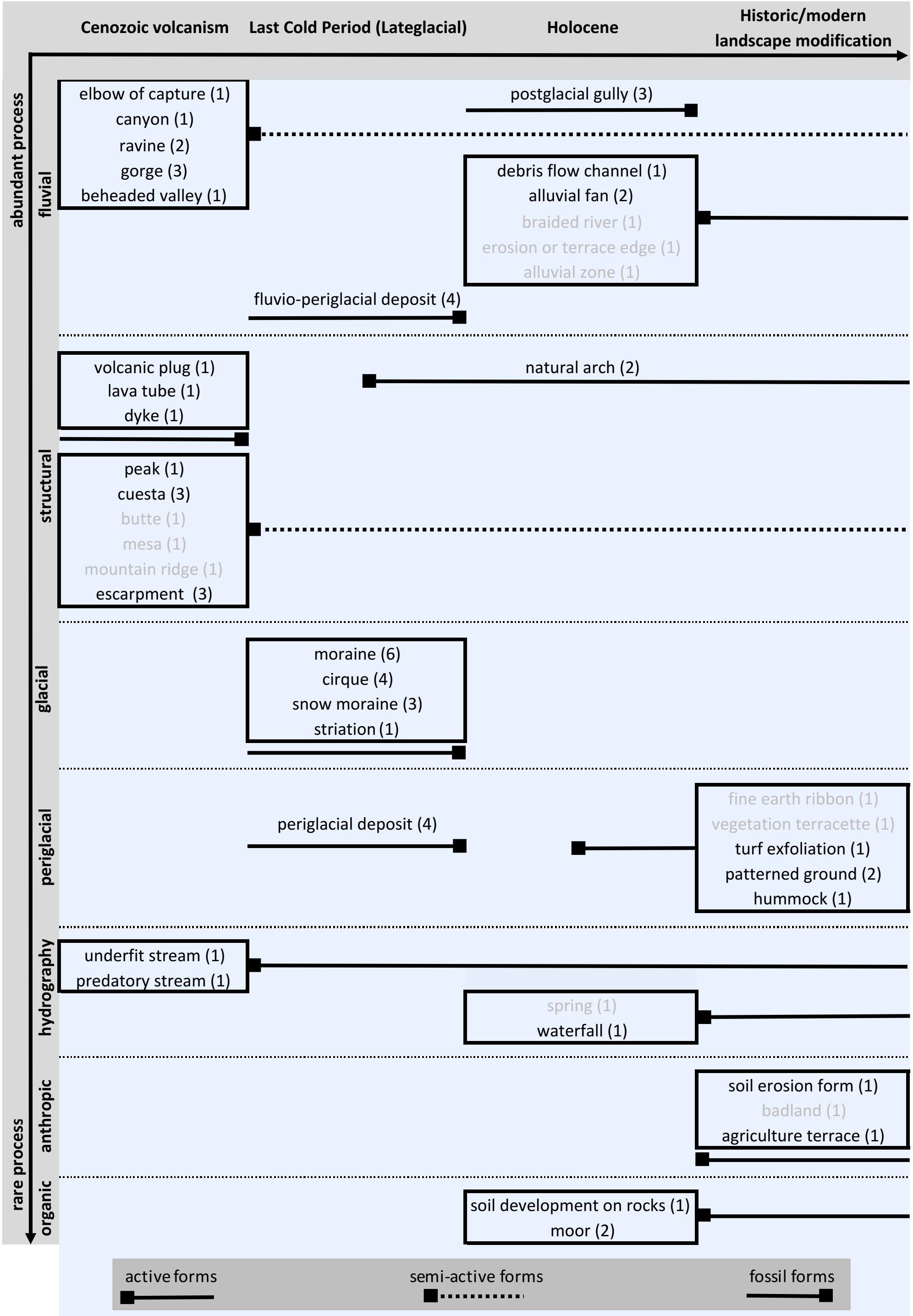


Figure 15 Spatial representativeness (ordinate) and temporal representativeness (abscissa) of landforms and processes[6]. In parentheses: number of landforms considered. Unselected form-types are in grey colour (inspired from Clivaz, 2015).

6 We do not speak of hydrographical process or landforms but some earlier authors consider hydrographical geomorphosites (glacier, spring, waterfall, etc.) (ex. Kozlik, 2006). The geomorphological mapping legend of the University of Lausanne also use different morphogenetic categories for *fluvial process and landforms* (ex. gorge, gully, alluvial fan, etc.) and the *hydrography* (Lambiel, 2016). Moreover, we do not speak of a structural process but there are tectonical, volcanic etc. processes and it is possible to consider structural landforms. For the sake of clarity however, this detail has been omitted in most figures and tables hereafter.

On this basis and following the method, a selection of the sites that is representative of the geomorphological diversity of the SMNP and that covers the entire temporal stages of the regional morphogenesis, with both active and inherited landforms was performed. In some cases geomorphological complexes and systems (for geomorphosite scale cf. point. 2.1.3) were created, in order to include a maximum of form-types. At the same time, the surface area of each site should be kept as low as possible. An excretion of excessive geomorphosites would not make sense because it strongly diminishes the value per surface and the exclusivity of the selected sites (Blum, 2012). Not included form-types are either located outside the study area (we were unable to move on the field in an early stage of work, thus the delimitation of the study perimeter was fixed relatively late in the process) or are lacking basic scientific documentation (processing of these objects would have meant a disproportionate expenditure of time and would have delivered only moderate results). The reasons for the selection or for the non-selection of each site is briefly commented in the list of potential geomorphosites (cf. annex 2). The selected sites are assessed in detail, thus they are all classified as geomorphosites. These sites will be presented more specifically in the following chapter.

5.2 Overview of the selected sites

The geomorphosite inventory of the Simen Mountains National Park includes **twenty-one sites** allocated to six processes (Figure 16). The number of sites per process is directly linked to the importance of this process in the morphogenesis of the Simen Mountains. As a result, the fluvial sites are the most numerous, followed by the structural and glacial sites. Hydrographical sites although more numerous than organic and anthropic forms are not represented through a geomorphosite. However, three (out of four) different hydrographical characteristics (waterfall, predatory stream and underfit stream) have been integrated to the geomorphological system of the Jinbar River capture (JBWflu005).

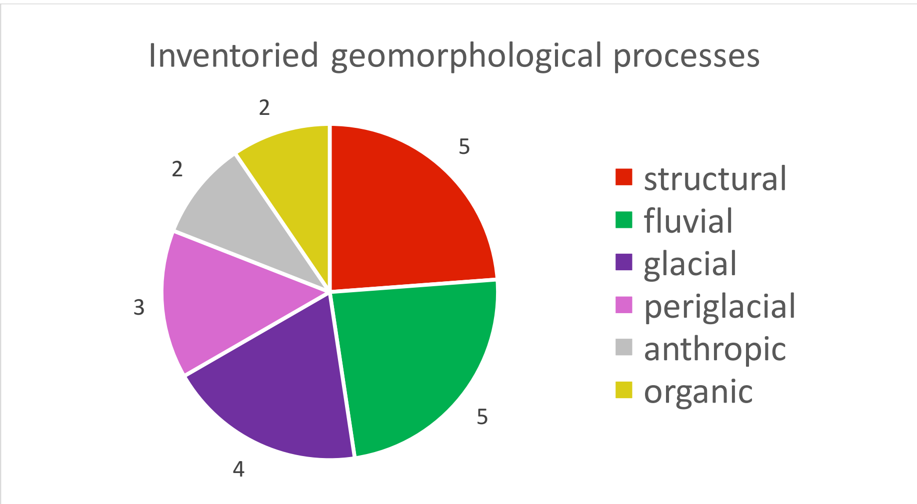


Figure 16 Distribution of the morphogenetic processes in the inventory

One only geomorphological process has been attributed to each site. In the case that more than one process was responsible for the formation of the site, it is the dominant process that has been attributed. For instance, the fluvio-solifluvial valley deposit at Argin village (ARGper009) is of mixed origin. It was formed simultaneously or immediately after the Last Cold Period with interaction of both periglacial and fluvial processes. It is the latter process that has been attributed to valley deposits at Argin. Figure 17 indicates the distribution of the forms between the six processes.

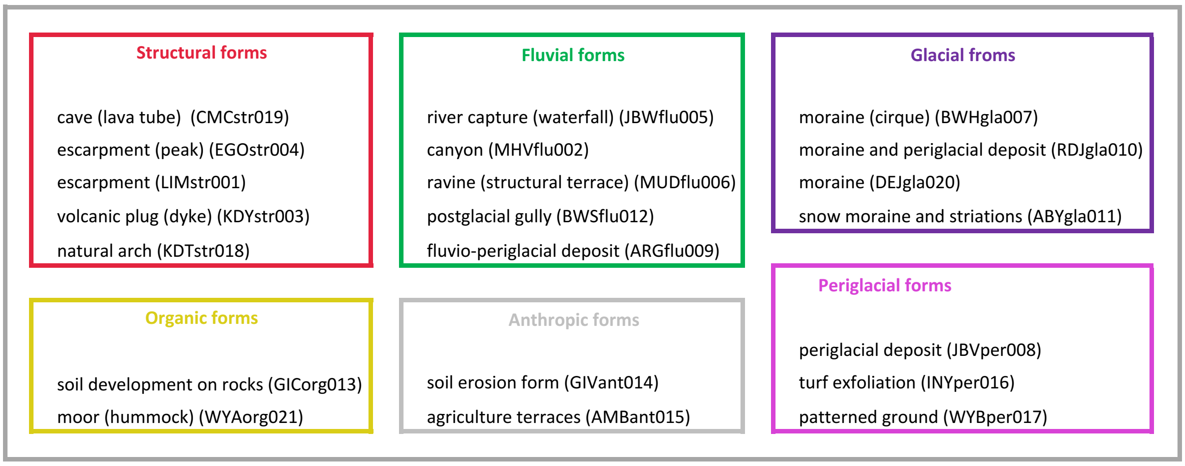


Figure 17 Distribution of the geomorphological forms according to the morphogenetic processes

The selected sites, which were assessed in this inventory, are reported to the Table 4 and can be localised on Figure 18.

N°	Identification code	Process	Name	Woreda (s)	Kebele(s)
1	LIMstr001	structural	**Lemalemo** escarpement	Debark	Debir, Zebena, Dip Bahir
2	MHVflu002	fluvial	Upper **Mesheha** valley	Janamora	Dibil, Majo Ayiteter, Kilil, Bahir Amba, Atigeba, Zakilita
3	KDYstr003	structural	Volcanic centre and dykes in the region of **Kidis Yared**	Telemet, Beyeda, Janamora	Gelbena, Sabra, Majo Ayiteter
4	EGOstr004	structural	**Imet Gogo** and the Northern Escarpment	SMNP	None
5	JBWflu005	fluvial	River capture of Jinbar river (**Jinbar waterfall**)	Debark	Abergina
6	MUDflu006	fluvial	Erosive landscape of the lowland area from **Muchila to Dihwara**	Adirkay	Seragudela, Agidamiya
7	BWHgla007	glacial	Glacial complex at **Bwahit**	SMNP	None
8	JBVper008	fluvial	Periglacial (solifluvial) slope deposit of the upper **Jinbar valley**	SMNP	None
9	ARGflu009	periglacial	Fluvio-solifluvial valley deposits at **Argin** village	Debark	Argin Jena
10	RDJgla010	glacial	Glacial system of **West** and NW **Ras Dejen**	Janamora	Majo Ayiteter
11	ABYgla011	structural	Snow moraine and glacial striations on **Abba Yared**	Janamora, Telemet	Dibil, Gelbena
12	BWSflu012	fluvial	Postglacial gullies on the **Southern** side of **Bwahit**	SMNP	Unknown
13	GICorg013	organic	Black Ando soils at **Gich campsite** (upper Jinbar valley)	Debark	Abergina
14	GIVant014	anthropic	Soil erosion forms at **Gich** village (Jinbar valley)	Debark	Abergina
15	AMBant015	anthropic	Farmland of **Ambaras** plateau	Debark	Abergina
16	INYper016	periglacial	Turf exfoliation on the **Inatye** high plateau	SMNP	None
17	WYBper017	periglacial	Patterned grounds on **Weynobar**	Beyeda	Meleb, Segenet, Medebay, Selewa
18	KDTstr018	structural	Natural arches, **Kedadit**	SMNP	None
19	CMCstr019	structural	Chennek **Medhanyalem** cave (Church)	SMNP	None
20	DEJgla020	glacial	Moraines of the Little Ice Age at **Ras Dejen**	Beyeda	Abare, Beyeda Matriba
21	WYAorg021	organic	Vegetation-derived accumulation on Weynobar and **Analu**	Beyeda	Beyeda Matriba, Selewa

Table 4 List of the geomorphosites of the SMNP: number, identification code, name, Wereda(s), Kebele(s). Based on the date (map) presented in chapter 3.2.3.

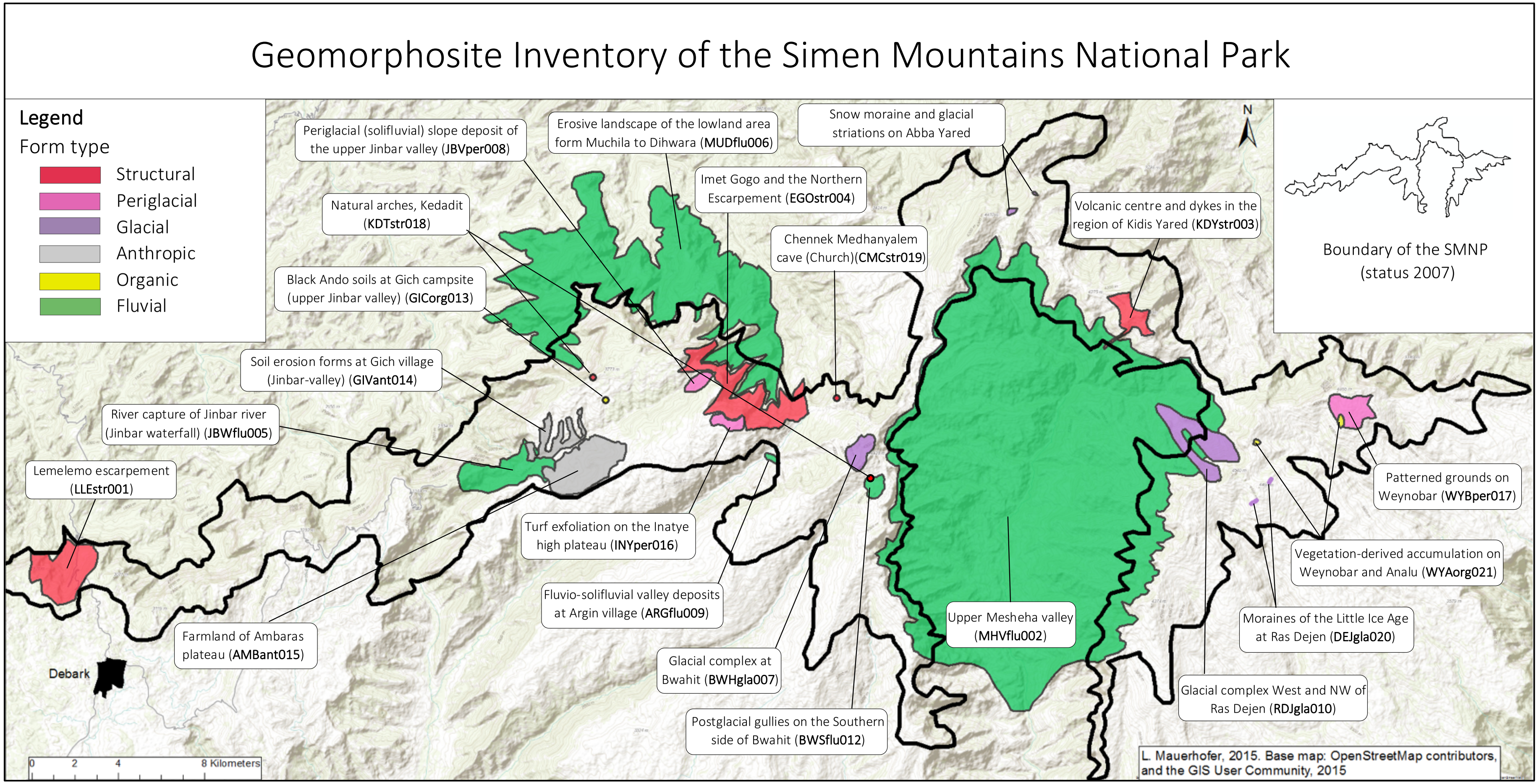


Figure 18 Localisation of the geomorphosites

The distribution of the sites is relatively homogenous throughout the study area, although a higher concentration and diversity of forms is observed on the Gich plateau up to Bwahit summit. The great majority of the inventoried sites have a surface-based spatial impact (17 of the 21). There is only one linear site (small moraines) and three point sites (natural arches, andosol-soil profile and entrance to a cave). The surface covered of the sites is very diverse. The most extensive site is clearly the Mesheha valley (MHVflu002), which spreads over an area of 212 km^2. Also much larger than other sites is the torrent system and structural terraces of the lowland area from Muchila to Dihwara (MUDflu006) which extent over 56.4 km^2. In fact, those two sites have most of their surface area outside the study area. Nevertheless, we felt that a geomorphosite inventory of the SMNP without the huge canyon (Mesheha valley) and the typical structural terraces included, would be missing out two very important features of the study region. Both sites border the park over tens of kilometres, thus they should be part of the inventory.

In terms of the landforms activity, the type of the dominant process which triggered the forms often decides whether it is an active or a fossil site. The typical example are the glacial sites which are all inherited from the Last Cold Period. Some structural and fluvial sites, have been active over millions of years. They are considered as semi-active as they actually do not much change their shape over human generations. On the other hand, specific structural sites mostly of volcanic origin are fossil forms; they developed within a different tectonical regime before the Simen shield became extinct. Other sites remained active since the beginning of the Holocene. The high number of active forms together with fossil sites of various characteristics shows that the Simen Mountains have been an active geomorphological zone over thousands and millions of years.

It is further possible to analyse the occurrence of the sites according the altitude above sea level. Glacial sites occur mainly above 4000 m. Periglacial sites can be observed above 3500 m up to the summits. Organic sites are found along a more humid zone above ca. 3700 up to ca. 200 m below the highest summits mostly at locations of Last Cold Period glacial deposits. Anthropic sites are found in the heavily cultivated zones below 3600 m. Structural sites constitute the skeleton of the Simen Massif. Typically, flat summit areas dip down like stairs into a series of escarpments with approximately 5 to 15 m jump height; on the other hand, they can also lead to the almost 2000 m high rock face of the Northern Escarpment (Hurni, 1975b). Fluvial sites follow the line of technical weaknesses clearly inserting around 3800 m through. They overcome deep gorges and ravines before reaching the valley bottoms at various altitudes.

5.3 Morphogenetic processes

5.3.1 Structural forms

The Simen Mountains constitute a Hawaiian type shield volcano with 100 km basal diameter. The **volcanic centre** in the region of **Kiddis Yared summit** (KDYstr003) gives a special insight. Intrusive rocks, granite and gabbro are suggested to originate from slowly, within the mountain cooled magma thus being part of the volcanic plug (Hurni, 1986). More than 600 m meter long, unveiled dykes crossing each other, extend from the summit and indicate closely contemporaneous tensional strain during basalt extrusion. The scientifically unexplored **Chennek Medhanealem cave** (CMCstr019), that seems to show the entrance of a long and perhaps extended tunnel-like corridor, was suggested by us to point to a lava tube. Lava tubes are formed below crusted surfaces when the supply of lava at the vent has ceased and the last slug of lava may have drained downslope leaving an empty conduit.

Figure 59 View of the Northern Escarpment on the way to Bwahit

The Northern Escarpment (or Great Escarpment) that extends on a stretch of 150 km around west of Gonder and Lake Tana has in Simen a vertical development of more than 2 km (Hurni, 1986). Two particular exemplary portions of this prominent geological feature have been retained in the inventory, the **Lemalimo escarpment** (LIMstr001) and the **Imet Gogo peak** including the **vertical precipices below and above Chennek** (EGOstr004) (Figure 19). Almost a complete sequence of generally horizontal flood basalt flows and the lower parts of the shield volcanic sequence is exposed at Lemalimo. Imet Gogo is a vertical edifice exposing horizontally layered shield volcanic series of basalts, trachybasalts, rhyolites and tuffs, a single cliff wall reaching more than 100 m (Asrat et al., 2012). The extreme escarpment appears to be preconditioned by an extended uplift of the whole massif during the Tertiary, comprising major faults which can be attributed to the Rift system extending over most of East Africa to the Red Sea (Hurni & Ludi, 2000). While these tectonic forces still persist, the shield volcanism has stopped (probably forever) some 16 million years ago (Kieffer et al., 2004).

Two very similar looking **natural arches** are found in Simen, one called **Kedadit** (3710 m) next to Gich and a second one hidden below to the public route at the Bwahit southern slope (at 4150 m). Both almost circled rock holes have a maximal diameter of approximately 1 m and remind an observer of a natural window. They are formed through the natural, selective removal of rock. The principle factors involved in carving out these arches should be water erosion, gravity and frost weathering given the diurnal frost thaw conditions (at least outside the rainy season) at the altitudes where they occur. Natural arches generally remain stable provided the load is transmitted into the abutments; however, they are short-lived landforms on geological time scales and continuous erosion may provoke their collapse in a rather near or distant future. "*It is safe to say that no natural arch is older than about 30 thousand years. Most are probably between 5 and 15 thousand years old, i.e., not incomparable to the span of recorded history. Certain types of natural arch, however, are much younger than this on average* (NABS, 2015)." For example, caprock natural arches that might correspond to the forms observed in Simen are relatively weak structurally and have a much shorter lifespan.

5.3.2 Fluvial forms

The whole Simen shield has undergone intense fluvial erosion since the beginning of its formation due to high precipitation in the area, enforced by rapid and on-going uplifting of the whole Ethiopian Plateau (Asrat et al., 2012). Thus, fluvial forms are widespread in Simen and show a great diversity. The 1700 m deep and 10 km large **Mesheha valley** (MHVflu002) running in a north-south direction over 40 km cuts the Simen massif in its core sparing three mountain ranges as well as the eastern and western flanks of the shield volcano. They are intersected by gully heads called barrancas and form triangular facets called planezes. The Mesheha valley, which actually has the dimension and characteristics of a canyon (Goudie, 2004) is mainly the result of powerful glaciofluvial and pluvial-accumulate river action during the Pleistocene Pluvials following an original line of tectonical weakness, and successively revealing structural terraces (Mohr, 1963).

At the **foot of the Northern Escarpment** from **Muchila to Dihwara**, the monumental cliff wall has been strongly dissected by the **channel system** of the tributaries of the Ansiya and Inzo rivers. **Terrace-like steps**, bordered by very deep and narrow ravines (MUDflu006) characterise the areas situated at elevations between 2000 m and 3000 m. This jagged morphology is triggered by the incision of the uncounted mountain streams against the uplifting landmass (headword erosion) as well as by the unequal scarp retreat of more resistant lithological units protecting underlying less resistant rocks from erosion and denudation (differential erosion) (Goudie, 2004). In the distance rugged-canyon like lowlands and the prominent landmass known as the Awaza peaks appear. These needle-shaped rock pinnacles (buttes) and steep-sided, flat-topped table mountains (mesas or Amba in Amharic) are remnants of a deeply eroded ridge forming the most distant fringes of the pyroclastic flows associated with the shield volcanism (Asrat et al., 2012).

Like many other valleys in the South, the **Jinbar** valley first runs in east-west direction parallel to the Northern Escarpment, but unlike them, it does not turn south, but breaks with a waterfall over the edge of the escarpment to the North (Figure 20). The valley seems to possess no natural upper end but performs with its almost U-shaped cross-section over the steep scarp in the air. Likewise, it has at the bottom an original sequel to the Southwest (Wazla River), which is now interrupted to the North due to the outbreak of the river (Hurni, 1975a). This clearly is a **river capture** (JBWflu005) (Figure 21). Permanent headward erosion of the Inzo River working back towards its head and eventually reaching the neighbouring Jinbar valley cuts through the divide. The oversized valley stretch in which the rivulet of Wazla River now continues to flow forms its beheaded valley.

Figure 20 Jinbar waterfall

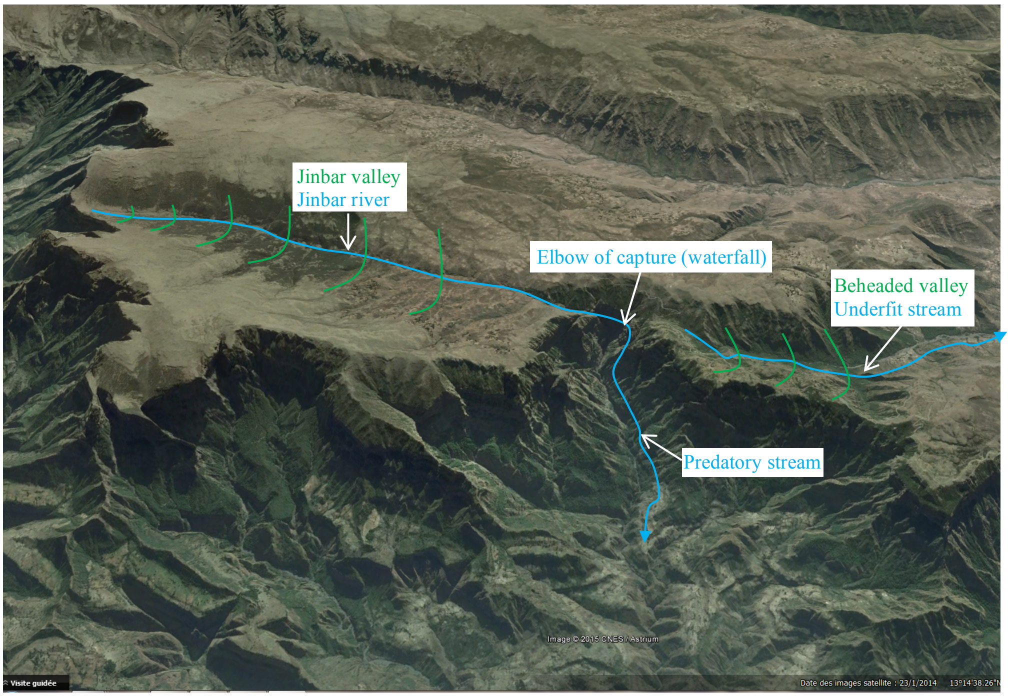


Figure 21 River capture of Jinbar valley. The Jinbar valley is truncated at its upper end, as is Belegez valley at Chennek and many others.

While the fluvial process triggering the Jinbar River capture, the giant canyon of Mesheha or the deep ravines and terrace like steps on the foot of the escarpment have been active for several million years, the so-called **fluvio-solifluvial valley deposits** at **Argin village** (ARGflu009) are fossil forms. They constitute of up to 40 m thick valley rubble, generally found on the bottom of steep valleys above 3000 m. It bears the traces of both fluvial and periglacial (solifluvial) processes of the Last Cold Period respectively of the end of the Last Cold Period in Simen. Its genesis reveals debris flows on soil creep up to solifluction (Hurni, 1981b). Also inherited from a different external environment are the **postglacial gullies** on the **Bwahit southern side** (BWSflu012). At the beginning of the Holocene (10'000 BP), with onset of monsoonal activity, but ahead of the repopulation of the Last Cold Period periglacial belt with dense vegetation, a period of intense morphodynamic natural erosion took place, which has carved the Last Cold Period glacial and periglacial deposits (cf. point 5.3.3 and 5.3.5) through relief building gullies (Hurni, 1981a). Such erosion channels set very often below current seasonal sources and unite in the lower part of the slope deposits. Up to 5 m thick accumulations are cut down in the valley floor. Gullies in the slope deposits at the side of the valley are less deep (up to about 5 m). The same erosion phase is also detectable as erosion surface in soil profiles but the described erosion gap was not found in the deeper attitudinal belts of the Last Cold Period, below approximately 3500 m.

As mentioned in chapter 5.2, some fluvial geomorphosites also include hydrographical features such as rivers, streams or waterfalls. In fact, as the most upper catchments areas of tributaries to the Tekeze River, Simen has an important role in maintaining perennial river flow. Overuse of this system would make the water flow seasonal and decrease dry season water availability for downstream irrigation and livelihoods (FZS – ADC, 2009).

5.3.3 Glacial forms

Glacial processes and forms are inherited of the Last Cold Period in Simen between 20'000 and about 12'000 BP. At **Bwahit** summit (4430 m) on the south-western mountain group of Simen two **glacial cirques** and groups of **moraines** are well observed above and below the public road at about 4150 m (BWHgla007). In the northern slope the overdeepening of the glacial cirque or corrie marks the accumulation zone of a cirque glacier, which developed two tongues with four frontal moraines. The western slope shows a similar hollow, marking the accumulation zone of a second glacier, which also left a group of moraines downhill. Moors are observed on both sides, as the highly compact frontal and ground moraine deposits are at the origin of the formation of humid catchments triggering the accumulation of organic material. The southern slope was not glaciated while on the eastern slope no glaciers were formed due to a precipice that falls down to 3800 m.

Figure 22 Largest moraine of Simen on Ras Dejen

The **NW** escarpment of the Beyeda High-Plateau with **Ras Dejen** (4540 m) in the middle bears the traces of the most extensive glaciation of the Last Cold Period in Simen (RDJgla010). Below the highest peak of Ethiopia, a succession of all Last Cold Period form groups can be observed in the present day morphology including the glacial process (**moraine** ridge) and the (fluvio-)periglacial process (**slope deposits**, valley deposits). The largest moraine of Simen with 50 m thickness is found at the Dejen western slope at the altitude from 4250 down to 4000 m (Figure 22). The Silki - **Abba Yared** group on the northern mountain range shows the most pronounced glacial traces of Simen (ABYgla011). In particular, glacial **striations** are visible at 4100 m on a basaltic hard rock on the NE slope of Abba Yared and an impressive, well visible **snow moraine** below the Silki Pass (4150 m). Since a catchment of glacial formation is missing, seasonal firn snow and nivation processes must have created this fossil landform (Hurni, 1982).

Below the Eastern peak of **Ras Dejen**, at ~4360 m two relatively fresh and un-vegetated (~5 m high) debris deposits maybe interpreted as **moraines** of the **Little Ice Age** (DEJgla020) (Grab, 2001). Even though H. Hurni (1982) negates the possibility of fluctuation of the snowline below the highest summit of Simen in historical times, Grab (2001 : 1) states that "*given the glacial advances elsewhere in east Africa during the Little Ice Age (e.g. Hamilton, 1982; Mahaney, 1989), it is possible that small pockets of glacial ice last occurred on such Simen Mountain slopes during this time. Several historical reports dating to 1624–1627 mention permanent snow caps on the Dashen Range (sic), with the last perennial snow patches apparently dis-appearing by the early 1900s (Miehe and Miehe).*"

5.3.4 Periglacial forms

Since the last glacial period the altitudinal belts have risen quite exactly one step, so that the Last Cold Period periglacial belt is covered of the present afro-alpine grasslands steppe and the Last Cold Period glacial belt corresponds to the present day periglacial frost detrital belt. The snowline, in the cold period at 4250 m, would today lie around 700 m higher at around 5000 m well above the highest peaks (Hurni, 1981a). In the upper **Jinbar valley** up to 15 m powerful so-called periglacial solifluvial deposits or **periglacial slope deposits,** described as rubble on a trough-shaped slope reaching down as far as the lower limit of the Last Cold Period periglacial belt at ~ 3500 m are well traceable until the valley bottom (JBVper008). These relict periglacial landforms are the expression of solifluction composed of mass movements triggered by soil water in the diurnal freeze-thaw cycle.

"*The distances of solifluvial movements, along the slope over a distance of up to 1000 m [indicate], even with 100-300 days of frost change and sufficient soil moisture per year, a formation period of several millennia (Washburn, 1973 : 179 In Hurni, 1981b : 134).*" The moraines and periglacial slope deposits were created or revised at the same time (Late Glacial period about 20,000 to 12,000 BP) under the same climatic condition, as they merge into each other all over the highlands, but do not overlap. It is difficult to fit solifluvial slope deposits into the system of periglacial forms as it was prepared for high latitude locations and forms of cold periods of the mid-latitudes. They lie somewhere between periglacial "*talus slopes*" by A. Rapp (1960, 1962) and "*grèzes litées*" by Y. Gullien (1951), both cited in M.A. Embleton and A.M.C. King (1968 : 522 In Hurni, 1982 : 103). Rock glaciers which occur in most alpine-mountainous regions and are distinct tongues of rock rubble which flow slowly downhill and a clear evidence of permafrost are not found in the Simen (Goudie, 2004).

Sharp weathered bedrock and frost debris accumulations, arranged in random to ordered patterns such as observed on **Weynobar** (4464 m) constitute the micro-relief close to the highest peaks (WYBper017). These altitudinal belt of extensive active natural processes is the present day frost detritus belt, with free solifluction (lacking vegetation cover) above the lower frost detritus limit of 4225 m and bound solifluction in a strip underneath. Stone stripes and stone tongues with dimension ranging around 5 to 20 cm (up to 1 m for the tongues) and only a few cm deep are the typical ground cover down the lower limit of **patterned ground** (structural soil limit in Hurni, 1982) (at ~ 4300 m). The genetically related form of stone polygons could be observed only rarely, because flat terrain features in this altitude is largely missing. Mud polygons and mud bands dominate the high range immediately above the vegetation limit (i.e. periglacial limit). In contrast to the stone polygons and stripes, these patterns consist predominantly of fine material and contain very few larger pebbles. A gradual transition can be observed in the field form near-symmetric polygon nets on horizontal terrain to elongated polygons and bands on slopes (Hurni, 1982).

Vegetation terrassettes respectively circular **turf exfoliations** on a plain are the most frequent solifluction forms below the present day lower periglacial frost detrital limit (defined and mapped as a sharp onset of the upper limit of the afro-alpine vegetation with over 50% ground cover). Although observed as lowest laying frost action at 3700 m (Hastenrath, 1974) and at 3600 m (Werdecker, 1955), they dominate as bounded solifluction form in a strip at 100-150 m below the vegetation limit vs. periglacial limit (Hurni, 1982). On the **Intaye high plateau** above 4000 m such turf exfoliation (Figure 23) is found in abundance (INYper016). "*[Turf exfoliation] is a denudation process that is particularly prevalent in periglacial areas and leads to the destruction of a continuous vegetation cover through the removal of soil exposed along small terrace fronts. Among the processes that lead, possibly synergistically, to this phenomenon are needle-ice (pipkrake) action, desiccation, rain wash erosion, zoogeomorphic activities and aeolian deflation* (Goudie, 2004 : 1075)." Thus, in Simen, influence of root-eating baboons cannot be excluded for an interpretation.

Figure 23 Turf exfoliation on Inatye high plateau

5.3.5 Organic forms

Figure 24 Soil profile of the Ando soils in High-Simen

At **Gich campsite** a pedological analysis of a typical soil profile was carried out and classified as humic andosol (GICorg013) (Figure 24). The site represents the **black Ando soils,** which under natural condition overlay the whole highland of Simen (above 3000 m) more or less uniformly with 70 cm in depth but now mainly degraded by erosion in cultivated areas (cf. point 5.3.6). It appears that the black A-horizon started to develop with the vegetation regrowth on the Last Cold Period periglacial belt after an intensive natural erosion phase took place (cf. point 5.3.2). The periglacial solifluction deposits on trough-shaped slopes build the cambic horizon (brown B-horizon) of the soil profile. The humic top soils represent the actual andosol horizon (black A-horizon) consisting of very fine-grained, mouldy black soil with up to 30 % organic material and 60 to 80 % clayey silt, which dries out quickly from the top in the dry season and changes to a brown colour. Many quartz and feldspar corns coming from the supply of volcanic ash of nearby by eruptions are found in both horizons showing that they correspond in a pedogenetic point of view (Hurni, 1982).

Mounds of organic material (peat) resembling to small-shaped **hummocks** (thufurs) with dimensions of tens of cm, covered with moos occur at **Weynobar** on the SW aspect at ~ 4300 m (WYAorg021). Hummocks are known from subpolar regions although similar forms have for instance been observed in the mountains of Southern Africa (Hastenrath, 1984). Their formation is caused by movements of cryoturbation (corresponding to soil circulation within each feature, driven by moisture redistribution during freezing and thawing) and cryogenic swelling in organic materials (peat) and silt (Goudie, 2004). In the cold and humid environment of Simen such processes leading to similar relief forms would be possible close to the highest peaks. Below **Analu** at 4300 m on the NE slope is observed one of the largest **moors** of Simen. Such moors formed in hallows of frontal and ground moraine deposits after the ice of the last glacial period melt away (cf. chapter 5.3.3). It leaves highly compact ground material, which is at the origin of the formation of humid catchments triggering the accumulation of organic material (Hurni, 1982).

5.3.6 Anthropic forms

Figure 25 Soil erosion next to Gich Village

H. Hurni (1982) distinguishes three main Holocene morphological processes chronologically, namely a morphodynamic (cf. natural erosion, point 5.3.2), a pedogenetic (cf. soil formation, point 5.3.5) and an anthropogenetically-generated phase, and he describes the environmental conditions favouring these processes. **Soil erosion** is the third and last phase, which started about 2000 years ago, when the first human settlers began with agriculture of grains and pulse (peas, lentils. etc.). Nowadays, except for the National Park, the entire Simen highlands are very heavily cultivated: almost 50 % of the area is used for agriculture (cultivations and fallow land) and the total area under cultivation in the park was recently estimated at 3126 ha, some 7.6% of the park area (FZS and ADC, 2009).

In a series of publications Hurni (1975a; 1975b; 1978) conducted detailed research on soil erosion damage, soil erosion processes, and initiated a soil and water conservation program for Simen. The 30 km^2 large Jinbar valley, with 20 km^2 undisturbed woods and grassland served as major study area. For this inventory, only the area in the heavily degraded region around **Gich village** on the northern slope of Jinbar river has been selected and assessed as a geomorphosite (GIVant014) (Figure 25).

"*Soil erosion is caused by man's impact on nature, he disturbs the natural rate of soil formation and soil reduction, and causes an accelerated process of soil movement. Denudation, sheet erosion, rill erosion, gully erosion and accumulation are the forms of soil erosion, caused by water and wind* (Schultze, 1952 : 4; Richter, 1965 : 2 In Hurni, 1978 : 94)." "*It does not only lead to diminishing soil depth and physical alteration of the soil but also to selective removal of specific nutrients, thereby causing chemical degradation and loss of soil productivity* (Hurni & Ludi, 2000 ; 58)." A morphogenetic idea of the development of soil erosion forms can be presented, which is:

1. *"Mixed soil horizons develop on convex spots by ploughing the reduced black horizon together with the brown one. Wind denudation and drying out of the soil are intensified.*
2. *Rainfall effects a wash off of the mixed soil to the bare rock, because little soil depth cannot absorb a lot of water and the surface runoff increases proportionally.*
3. *The denuded rock remains without vegetation the whole year and soil erosion is effective all year long.*
4. *Accumulations arise where slope inclinations decrease on the foot of such destroyed spots.*
5. *When deep enough, secondary gullies carve the accumulations again* (Hurni, 1978 : 99)."

Soil degradation since the human settlement for the Jinbar valley varies between 0 cm and 45 cm mean levelling per slope area, according to exposure. On the average, this loss is about 1000 tons per hectare, or about 15 cm in soil depth. Current soil erosion processes on an average slope of 50 m length and 30% inclination cultivated with barley, amounts about 20 tons per hectare per year, calculated with the Universal Soil Loss Equation (USLE), whereas the grass-steppe has less than 2 t per ha soil loss (Hurni, 1979, In Hurni 1982). "*Soil erosion, therefore, is in the order of 10-15 times too high for an average cultivated slope, so that it will degrade within some 80 years of cultivation, to soil depths of less than 10 cm. This is the case for many slopes in Simen, especially at altitudes between 2500 and 3000 m which have a very old history of land use, dating back to the first centuries AD but also for most other cultivated areas in Simen* (Hurni, 1986 : 38)."

The **Ambaras plateau** spreading at about 3600 m on the opposite of Gich represents the largest contiguous area of **cultivated land** dotted within the park (AMBant015). The strongly weathered and eroded plateau surfaces is cultivated by farmers living in villages close to the park border on the southern side of the plateau. Each side of the plateau is ploughed every second year, while the other side lies fallow. Agriculture terraces built by local farmers protect the northeastern slope from more severe soil loss (Hurni, 1978).

As stated above, through the cultivation by ox-ploughs soil erosion started to destroy the fertile andosols. Covering climatically and topographically favourable altitudes around 3000 m first, the peasants had to move up slope – in the course of the centuries – for two reasons: One is the accelerated soil erosion on their fields, destroying the first cultivated soils even on flat slopes, and the other is increasing population. Today, cultivation reaches as far as the climatic limit of barley cultivation, at 3700 m. Why human settlement in lower lying areas, between 2900 m and 3400 m must have happened previously, can be shown next to the explanation by the much larger soil erosion losses despite significantly shallower relief by the following observations:

1. The two main centres of Beyeda and Janamora, Dilibza and Deresge that lie just above 3000 m are today surrounded by badlands on which grass vegetation cannot even grow.
2. Agroclimatic is the altitudinal belt between 3000 m and 3400 m (upper Dega) more favourable than the overlying belt until the barley border at about 3700 m (High Dega), because frost occurs far less frequently.
3. The tendency to shifting upwards in the marginal altitudinal belt in the area of the barley limit continues today (Hurni, 1982).

5.4 Intrinsic value of the geomorphosites

As has already been mentioned in the chapter on the assessment method of the University of Lausanne (cf. chapter 4.2), the intrinsic value of a geomorphosite includes the central value (scientific value) and additional values, that are ecological, aesthetic and cultural. These values are treated separately in the following sections.

The synthesis map of the intrinsic value (Figure 26) illustrates not only the scientific value (number) but also indicates the sites with high ecological, or aesthetic or cultural value (pictograms).

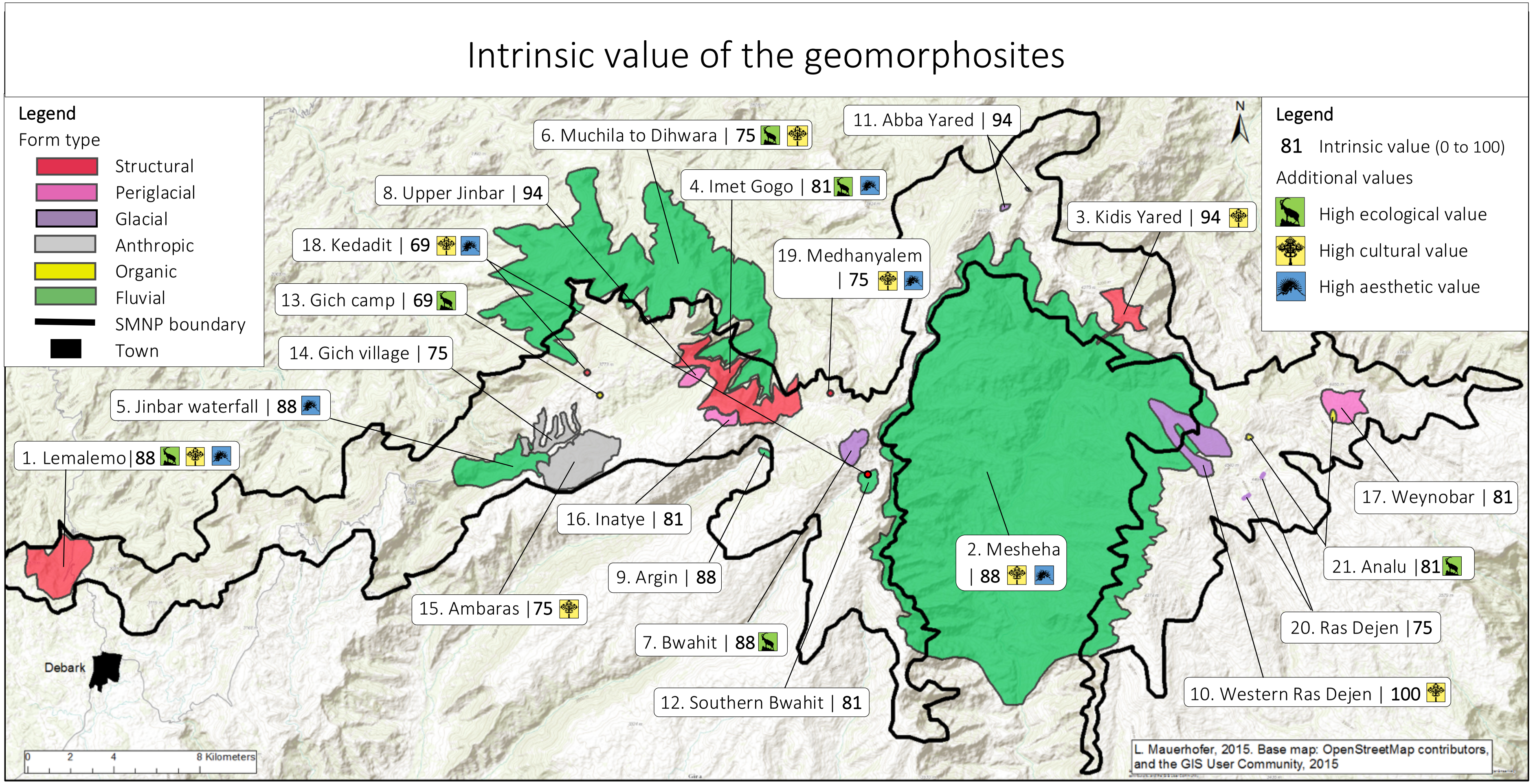


Figure 26 Intrinsic value of the geomorphosites. The scientific value is indicated without decimal (ex. 0.75 becomes 75)

5.4.1 Central value – scientific value

The evaluation of the central value or scientific value of a geomorphosite is based on four criteria which are assigned a score between 0 and 1: integrity, representativeness, rareness and paleogeographic interest. The scientific value of a geomorphosite is estimated by the arithmetic mean of these four criteria.

The average scientific value of the 21 inventoried sites amounts to 0.83 and its standard deviation is 0.09. The median value of the distribution is 0.81 indicating that half of the sites has a greater scientific value than this score. Figure 27 summarizes the scores obtained for the scientific value for each site.

One site stands out with the maximum score possible for this inventory which is 1. This is the glacial system on the western and NW slope of Ras Dejen (RDJgla010). Four other sites also classify with a very high score of 0.94. These concern two structural sites, the Lemalimo escarpment (LLEstr001) and the volcanic centre and dykes in the region of Kidis Yared (KDYstr003) as well as the periglacial slope deposit of the upper Jinbar valley (JBVper008) and the snow moraine and glacial striations on Abba Yared (ABYgla011). The lowest scientific value of this inventory amount to 0.69 and has been achieved by one organic site, the black Ando soils at Gich campsite (GICorg013) and one structural form, the natural arches called Kedadit (KDTstr018). Numerous sites have a scientific value close to the mean value. In fact, there are nine objects having either a score of 0.81 or 0.88. Four out of nine are fluvial landforms and two are periglacial.

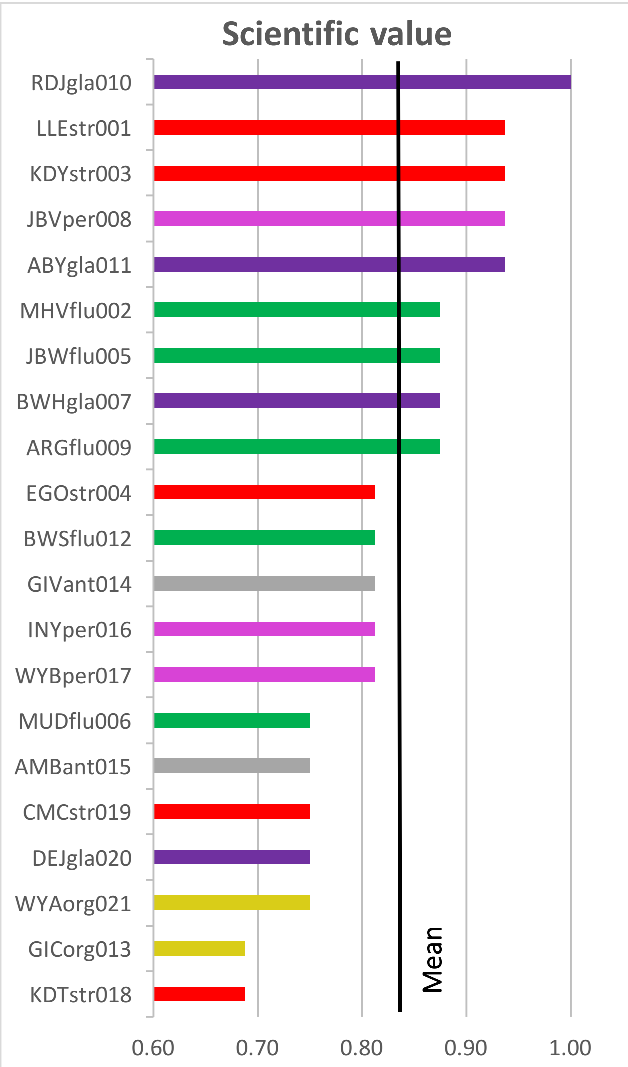


Figure 27 Scientific value of the 21 geomorphosites. The colour indicates the morphogenetic process

In order to compare the six morphogenetic processes with themselves, the average scientific value of each process was calculated (Figure 28). Forms related to glacial processes have a particular high average scientific value that is 0.89 – superior to the one of sites related to other processes. On the contrary sites of organic origin have a scientific value relatively weak compared with other geomorphosites (0.72). The average scientific value of sites related to the four remaining processes is close to the average of all sites (0.82) It should however be noted that the majority of processes only combine 2 to 4 sites.

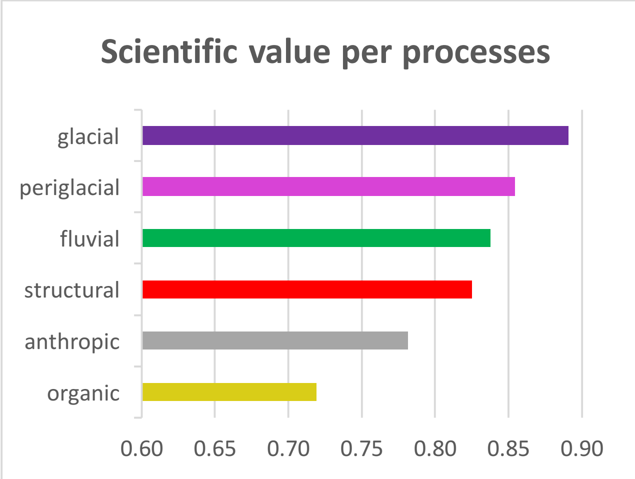


Figure 28 Average scientific value of the morphogenetic processes

Table 5 includes the average scores of the four criteria that constitute the scientific value for each of the morphogenetic processes.

Table 5 Average scores of the criteria for each morphogenetic process

	integrity	representativeness	rareness	paleogeographical interest	scientific value
glacial	0.94	0.81	0.94	0.88	0.89
periglacial	1.00	1.00	0.67	0.75	0.85
fluvial	0.95	1.00	0.75	0.65	0.84
structural	1.00	0.75	0.90	0.65	0.83
anthropic	0.88	1.00	0.63	0.63	0.78
organic	1.00	0.75	0.63	0.50	0.72
mean	0.96	0.89	0.75	0.68	0.83

The 21 inventoried geomorphosites are highly representative of the geomorphology of the Simen Mountains National Park. In fact, the average representativeness of all sites amount to 0.89 and the median is 1 as only three sites do not achieve the maximum value. Moreover, all the sites find themselves in good or excellent state of conservation since the average integrity obtains the score 0.96 and the median is 1. In contrast, the paleogeographical interest of the totality of sites is rather lower (0.68). Especially forms of anthropic (0.63) and organic origin (0.50) have a lower paleogeographical interest while glacial (0.88) and periglacial sites (0.75) receive much higher scores for the same criteria. The latter are often indicative of a glacial or periglacial stage during the Last Cold Period. The average rareness (0.75) lies slightly below the score of the average scientific value (0.82) but is still high. In particular, structural sites (0.90) apart from glacial geomorphosites (0.94) achieve high average rareness.

In fact, glacial sites which are provided with the highest average scientific value obtain high scores for all the four criteria. It is the overall higher rareness and paleogeographical interest which distinguish them from other geomorphosite types. This observation explains the higher score of the scientific value. Organic sites are very well conserved (1), but unlike the forms of other processes they are not as much representative of the geomorphology of Simen (0.75), they are not particularly rare forms either (0.63), and their paleogeographical interest is only average (0.5). Thus their average scientific value is lower than that of other processes.

The four criteria considered in the assessment of the scientific value of a site – the integrity, rarity, representativeness and paleogeographic interest –, exert a different influence on the final score of the scientific value. Although calculation of the arithmetic mean of the criteria includes no weighting, the correlation between each of these scientific values varies between -0.01 and 0.74. The integrity shows a negative value but is the least well correlated criterion (-0.01). The paleogeographic interest, for its part, is best correlated with the scientific value since their correlation amount to 0.74. Therefore, this criterion would seem to be the most influential on the scientific value. We note also that the best correlated criterion is that having the lowest average while the least well correlated has the highest average.

The influence of the paleogeographic criteria remains small and it is not enough to explain the scientific value. The significance of these correlations was not tested. Table 6 summarizes the statistics of the scientific value.

Table 6 Statistic of four criteria that constitute the scientific value

	integrity	representativeness	rareness	paleogeographical interest	scientific value
mean	0.96	0.88	0.79	0.69	0.83
median	1.00	1.00	0.75	0.75	0.81
minimum	0.75	0.25	0.25	0.25	0.69
maximum	1.00	1.00	1.00	1.00	1.00
standard deviation	0.09	0.25	0.22	0.20	0.09
correlation	-0.01	0.51	0.32	0.74	1.00

5.4.2 Additional values

Additional values correspond to the ecological, aesthetic and cultural value. Unlike the evaluation of the scientific value that was made in a quantitative manner, the evaluation of the additional values is qualitative. No score is therefore assigned to the criteria for evaluating these values. Six qualifiers describe the additional values: very high, high, average to high, average to low, low, very low to nil.

5.4.2.1 Ecological value

As a reminder, only the ecological impact, that is the importance of the site for the development of ecosystems, determines the ecological value of a site; the second criterion regarding the protection of the site for ecological reasons was not assessed (cf. section 4.2.2). The ecological value of the majority of the sites is rather low. In fact, ten sites have an ecological value qualified very low to nil (Figure 29) and three more sites have it qualified low or medium to low. However, we also note that seven sites have an impact on the ecological and the biodiversity deemed important or very important and that the remaining form has a medium to high ecological value.

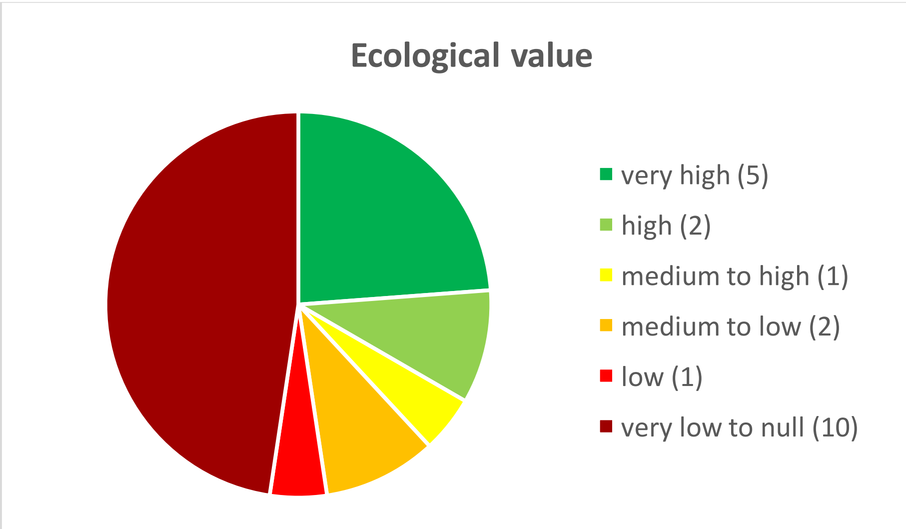


Figure 29 Ecological value of the geomorphosites, assessed qualitatively

The Simen Mountains are still a little explored territory thus scientific information on the ecology and biodiversity is only punctually available. Generally, the area around the Gich plateau is better known than the regions to the East and Northeast of the national park. Thus, it is possible that several sites with low ecological values are scientifically not enough well known to assess their value properly. On the other hand, our literature review on the topic is certainly not exhaustive.

Figure 30 provides a summary of the number of sites whose ecological impact is described as very low to nil, low, medium to low, medium to high, high or very high depending on the morphogenetic process.

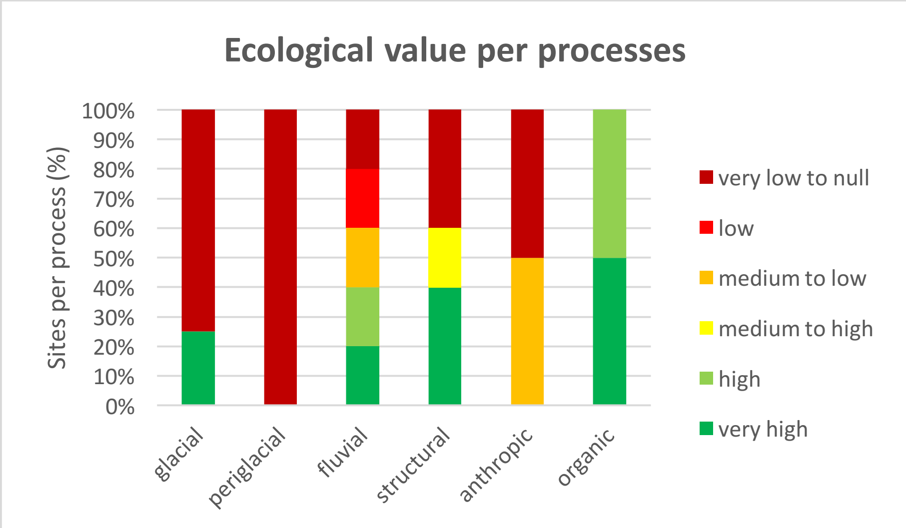


Figure 30 Ecological value according to the morphogenetic processes

Three glacial sites are endowed with a very low ecological value. However, one glacial form exerts an important ecological impact. This is the glacial complex at Bwahit (BWHgla007). In fact, the highland swamps that occur on Bwahit within hallows of frontal and ground moraine deposits support a number of resident and migratory water bird populations (FZS – ADC, 2009). Periglacial sites have very little or no impact on the ecology and biodiversity. All three periglacial sites qualify very low to nil.

The ecological value of sites created by the fluvial process is very diverse. Three forms have rather low ecological impact deemed as medium to low, low or very low to nil. However, two more sites – the Jinbar River capture (Jinbar waterfall) (JBWflu005) and the erosive landscape of the lowland area from Muchila to Dihwara (MUDflu006) – have high and very high ecological value. The absence of fishes on the Gich plateau is due to waterfall preventing their upstream movement (negative impact). Nevertheless, sightings of frogs or toads indicate the presence of amphibians on the Gich plateau. Generally, it is assumed that the Simen mountains have a unique aquatic fauna. The channel system of the tributaries of the Ansiya and Inzo rivers offers important habitats of specialized species restricted to the high altitudes of the Simen Mountains. A total of 27 aquatic invertebrate taxa were recorded on a survey below the escarpment from Muchila to Dihwara (Nievergelt, 1998).

Structural forms also have a variable ecological value. Two sites were attributed a very low, one site a medium to high and two more sites a very high ecological impact. It is the Lemalimo escarpment (LLEstr001) and the Imet Gogo peak including the vertical precipices of the Northern Escarpment below and above Chennek (EGOstr004) that are deemed with the highest qualifier. The escarpment area around Chennek was repeatedly identified as a crucial wildlife corridor and important vegetation zone (Hurni, 2005; AWF, 2014). In fact, Ibexes need steep gradients (> 45 °) and large height differences to neighbouring areas for their habitats. High altitudes and the exposure of the area are important for their thermal comfort and food preferences (Bircher, 2006). The General Management Plan (FZS – ADC, 2009) adds that due to the "extreme altitudinal variation" the escarpment extends through a number of habitat types including montane forest (1900-3000 m), sub-Afroalpine (or Ericaceous belt, 2700-3700 m), and Afroalpine grasslands (3700 – 4600 m). Relatively large patches of intact montane forest are "*found on the less steep parts of the escarpment leading to the lowland plateaux at the northern end of the park and the newly included Limalmo Wildlife Reserve (LWR) (sic) on the western side* (2009: 32)." "*The biodiversity in the montane forest is generally much higher than on the highland plateau. Most common trees are* Juniperous procera*,* Hagenia abyssinica*,* Olea chrysophylla*,* Cordia africana*,* Ficus spp*. and* Szygium guineense*, almost all of which are endemic to Ethiopia and threatened* (2009: 33)." The volcanic centre and dykes in the region of Kidis Yared (KDYstr003) is a potential Walia habitat (Hurni, 2005) thus, the ecological value of the site was estimated medium to high. A high or very high value has been attributed to sites where Walias actually live (ex. escarpment area). However, the relatively erosion resistant rock of the Northern Mountains Massive including the volcanic plug leaves a very remote high altitude area in which Walias could live undisturbed (it used to be a habitat some human generations ago).

Anthropic sites are endowed with a low ecological value. Soil erosion as for instance observed at Gich village (GIVant014) affects the ecosystems and the biodiversity negatively. It leads to reduced vegetation cover and badlands. The General Management Plan, states that Simen's unique biodiversity and ecological processes simply cannot tolerate extensive human use (FZS – ADC, 2009). Paradoxically (Nievergelt, 1998) also states that extensive cultivation has a positive impact on the number of bird species as many grain eating birds have come there.

Finally, the two organic landforms have a high or very high ecological impact. The black Ando soils of Simen, for instance found at Gich campsite (GICorg013), are very fertile soils encouraging the high ecological diversity of the region (Hurni, 1978, Nievergelt, 1998). Highland swamps such as the vegetation-derived accumulation on Weynobar and Analu (WYAorg021) support a number of resident and migratory water bird populations (FZS – ADC, 2009).

5.4.2.2 Aesthetic value

The aesthetic value of a geomorphosite depends on its visibility, its vertical development, its contrast compared to its environment and its role in the structuration of space (see section 4.2.2). More than half of the sites are doted with a relatively high aesthetic value. In fact, over the twenty-one inventoried geomorphological forms, four have an aesthetic value qualified very high, two have it high and five more sites have it medium to high (Figure 31). On the other hand, two geomorphosites have an aesthetic value qualified very low to nil, five have it low and three have it medium to low.

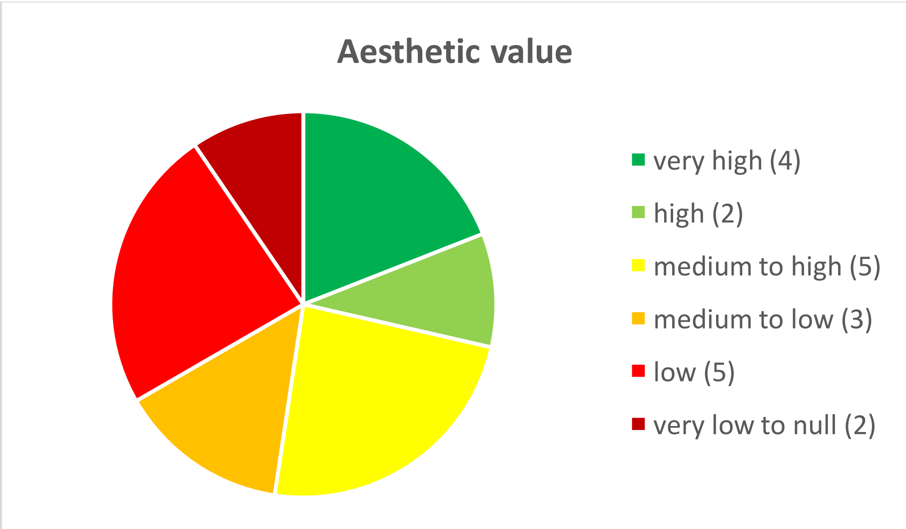


Figure 31 Aesthetic value of the inventoried geomorphosites

In his Master's thesis, J. Bussard (2014) showed the influence of the size of the sites on the aesthetic value. In his inventory large sites have a higher aesthetic value than small ones. Figure 32 links the aesthetic value to the size of the inventoried geomorphosites.

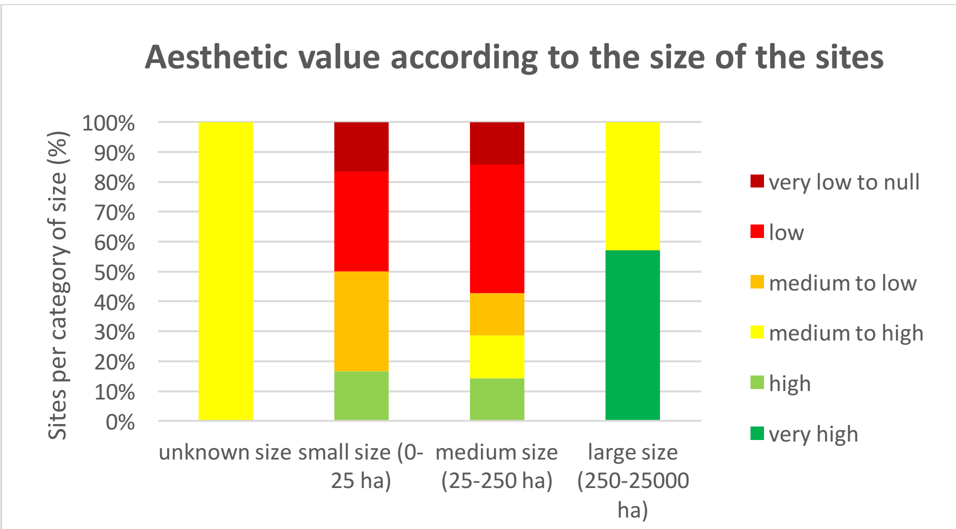


Figure 32 Aesthetic value of the geomorphosites according to the size of the sites

The only site of which its size is unknown, the Chennek Medhanealem cave (CMCstr019) is characterised with a medium to high aesthetic value. More than 80% of small size forms have an aesthetic value which is rather low. Among sites of size between 25 to 250 ha, about 70% have a rather low and about 30% a rather high aesthetic value. The large size forms have a medium to high respectively a very high aesthetical value. Thus, the size of the sites impacts on the aesthetic value also in this inventory. However, small size forms such as the natural arches called Kedadit (KDTstr018) due to a high contrast and impressive viewpoints can also be allocated a high aesthetic value. We also note that the evaluation of the aesthetic value remains rather subjective despite the two criteria used in order to reduce the subjectivity.

The size is not the only criteria which influences the aesthetic value of a geomorphosite. The morphogenetic process has also an impact on the visibility of the sites and thus on the aesthetic value. In fact, among the sites that have a high or very high aesthetic value, we find exclusively structural and fluvial forms (Figure 33). The four sites with the highest ranking aesthetic value, Imet Gogo and the Northern Escarpment (EGOstr004), Lemalimo escarpment (LLEstr001) as well as the Mesheha valley (MHVflu002) and the Jinbar waterall (JBWflu005) represent features that are essential components to the Outstanding Universal Values (OUV), under criteria vii (area of exceptional natural beauty) for which the park was inscribed as a World Heritage Site.

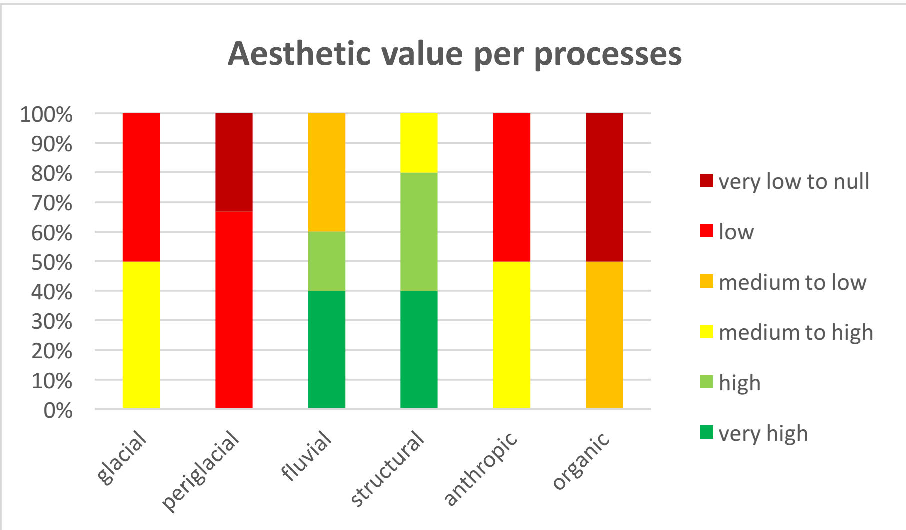


Figure 33 Aesthetic value according to the morphogenetic processes

5.4.2.3 Cultural value

The cultural value is the third and final additional value. It is based on the religious or symbolic importance, the historical importance, the artistic and literature importance, the economic importance or the geohistorical importance. The evaluation of this value requires substantial research in various fields as the word "culture" covers diverse concepts. The evaluation of the cultural value may not be exhaustive. Several elements have certainly been omitted.

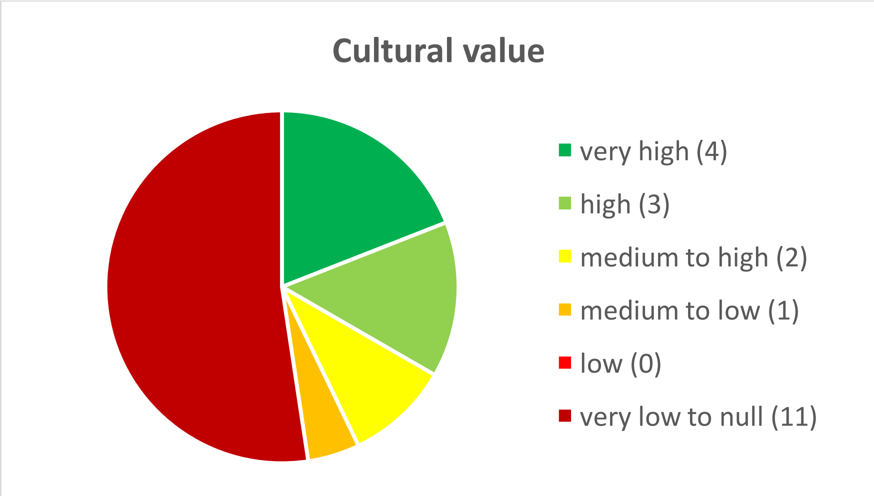


Figure 34 Cultural value of the inventoried geomorphosites

Among the twenty-one inventoried sites, the cultural value of more than half of the sites is very low to nil, seven sites have it high or very high and the remaining three sites have it in the average range (Figure 34).

Certain sites with medium to high, high or very high cultural values have either a religious or symbolic, a historical, and/or economical importance. Four inventoried forms have a religious or symbolic importance because they represent a spiritual location or because their names appear in local legends. For instance, in the indigene culture the natural arches are interpreted as a sign of the Satan who has broken to the hole, thus the hill situated North of Gich camp is named “Kedadit” by the Amharic term corresponding to this phenomenon (KDTstr018). The Chennek Medhanealem cave (or Church) is a sacred site of the local community which is inhabited by Ethiopian Orthodox priests and can only be accessed by someone of the same religion (CMCstr019). The large entrance hall of the cave (40 m long, 20 m wide and 3 m high) releases a pool of almost stagnant, very pure, cold water covered by algae, where believers can wash their body with “holly water” and thus recover from bad sicknesses. Furthermore, they could undergo a longer more challenging process, which is believed to grant liberation of all the sins. Hence, the person could achieve that his (her) body remains fresh forever (won’t decompose after death). The looked up area where the priests actually live must be a longer narrower corridor whose total length is unknown. It seems that even the clergies never reached the end of the aisle (oral communication by B. Abebe, park expert).

The region of Kidis Yared summit where the volcanic centre is assumed to be located bears the name of a spiritual man (KDYstr003). According to the legend, Saint Kidus Yared brought the Walia ibex to Simen by using it to carry his holy books. As a result, the Walia ibex is important in the folklore and oral literature of the Simen communities. The name of the highest peak of Ethiopia (RDJgla010) is linked to the "Ras Dejen Legends", which says that "King Dawit (1367-1396 G.C) of Ethiopia had three children: Shebele, Dejenie and Gubaie. Accordingly, he divided the whole of his country three sub-divisions for easy administration, the protection of forests and wildlife, and the security of the people [sic]. One of these sons, Dejenie, was given the area from Abay Gorge to the Simen Mountains to administer. Thus the name "Dejen" (ketema) (or Dejen town) was associated with the area between the former border of Shewa and Gojjam provinces and to Ras Dejen (the highest summit) in the Simen Mountains (FZS – ADC, 2009 : 36) ."

Geomorphosites with historical importance are the Lemalimo escarpment (LLEstr001), the Mesheha valley (MHVflu002) and the farmland of Ambaras plateau (AMBant015). The first two sites are related to historical trade routes connecting the old centres Aksum/Adwa in the North, Gonder in the Southwest and Lalibela in the Southeast (Figure 8 of point 3.2.7). "*The western caravan route led from Aksum/Adwa over Adi Arkay, Debark to Gonder, closely following the course of today's main road built by the Italians. The main obstacles were the crossing of the Tekeze, and in the north of Debark the negotiation of the escarpment ("Limalmon, Wulkifit"). [Another] very important trade route for Simen crosses the Mesheha valley from Debark over the Bwahit (4200 m) and Ras Dejen (4300 m) eastwards to the significant old towns Mekele (incense, salt), Sokota (grains), Desse (salt) and Lalibela (place of pilgrimage). It is this route which became the main route to the market place of Debark for the highland population of the subdistricts of Beyeda, east of Ras Dejen, and Jannamora, around Bwahit* (Stähli, 1978 : 43)." The third mentioned site above is linked to the history of human settlement and land seizure in Simen. The Ambaras plateau has been densely populated and cultivated 150 years ago. The plateau though at the climatic limit of barley cultivation (at 3700) offers relatively flat arable land to local farmers. "*At Ambaras we see a clear tendency of the settlements to shift up the slope, towards climatically and agriculturally unfavourable areas. This indicates a space and land shortage in the original lower and more favourable zone. Thus, new dwelling places were created 100 to 200 m above the old hamlets located on the upper edge of the valley slope. The highest situated buildings are already at 3750 m in the immediate proximity of the borders of the national park and the upper limit of cultivation* (Stähli, 1978 : 62)."

Finally, two sites that benefit of economic importance are the Lemelemo escarpment (LIMstr001) and the Ras Dejen complex(RDJgla010). Both are main attractions for visitors to Ethiopia (FZS – ADC, 2009). Moreover, the beer of one famous brewery of Ethiopia, located in Gonder is named “Dejen beer” after the name of the country’s highest peak. In addition, the fluvial site (MUDflu006) consisting of the channel system of tributaries of the Ansiya and Inzo rivers on the foot of the Northern Escarpment between Muchila and Dihwara has an economic importance founded in the field of water management. As the most upper catchments areas of tributaries to the Tekeze river, Simen has an important role in maintaining perennial river flow. Overuse of this system would make the water flow seasonal, and decrease dry season water availability for downstream irrigation and livelihoods (FZS – ADC, 2009).

One sites with a medium to high cultural value demonstrates geohistorical importance. This concerns the soil erosion forms at Gich village in the upper Jinbar valley (GIVant014). In fact, the Jinbar valley catchment has been an important site for the study of soil erosion and hydrology in Simen over the last 40 years. Several pioneer works (in particular Hurni, 1975a; 1978; 1982) in the related fields of study have been performed at his location. The section of the Northern Escarpment above and below Chennek (EGOstr004) has a certain artistic importance. The cultural value has been estimated average to low. Many people do actually recognize the design-pattern of a human visage when they observe the scenery from Chennek camp towards the monumental cliff of the Northern Escarpment. Imet Gogo is the nose, Inatye marks the front and the eye socket and the remaining peaks, Saha and Set Derek constitute the mouth.

5.5 Use and management characteristics

As a reminder, the use and management characteristics refer to information relating to the management of the site, both in terms of protection and valorisation. The current level of protection of sites and the damages and potential threats are the subject of the first part of this chapter (5.5.1). Visit conditions and the educational interest of sites constitute the second section (5.5.2).

5.5.1 Protection and vulnerability of the geomorphosites

5.5.1.1 Protection status

The presence or absence of legislative measures of protection generally determines the level of protection of a geomorphosite. The institutional framework governing the nature conservation in Ethiopia has been described in chapter 2.2 on which the reader is referred to. The Simen Mountain's National Park represents alone the relevant institutional framework of the study area (national inventories etc. are not available). Description of the level of protection, referring to the site's affiliation to a national inventory, a natural reserve or a regional regulation as it is done in previous geomorphosite inventories carried out at the University of Lausanne was not possible.

The level of protection of the geomorphosites was determined on a scale of four grades: very low or nil, low, medium, and high. Geomorphosites with a **medium** level of protection are in its entire extend located within the national park boundaries. A **high** level of protection characterizes a site, which is fully situated within the national park boundaries and in addition, has high conservation priority in the General Management Plan of the SMNP (FZS & ADC, 2009) or benefits of religious taboos which are considered as informal rules. Sites which are allocated a **low** protection status have parts of their surface area located outside the national park. Finally, a **very low or nil** level of protection typifies a geomorphosite which is tangent to the national park but has most parts of its surface area outside (this was the case of one specific site).

As the study area was defined according the perimeter of the national park, the level of protection of three quarters of the inventoried sites is deemed medium (Figure 35). Solely, two sites benefit of good protection measurements. Three sites demonstrate a low level of protection and one site has a protection status estimated very low to nil.

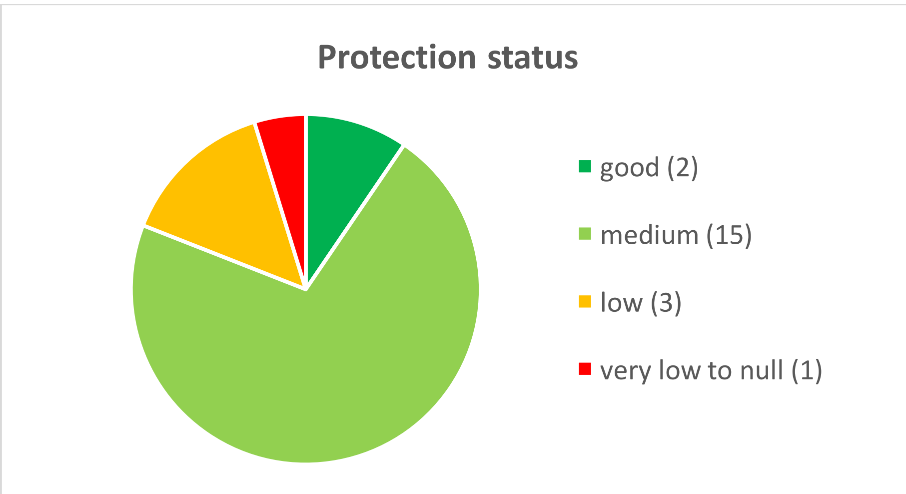


Figure 35 Level of protection of the geomorphosites

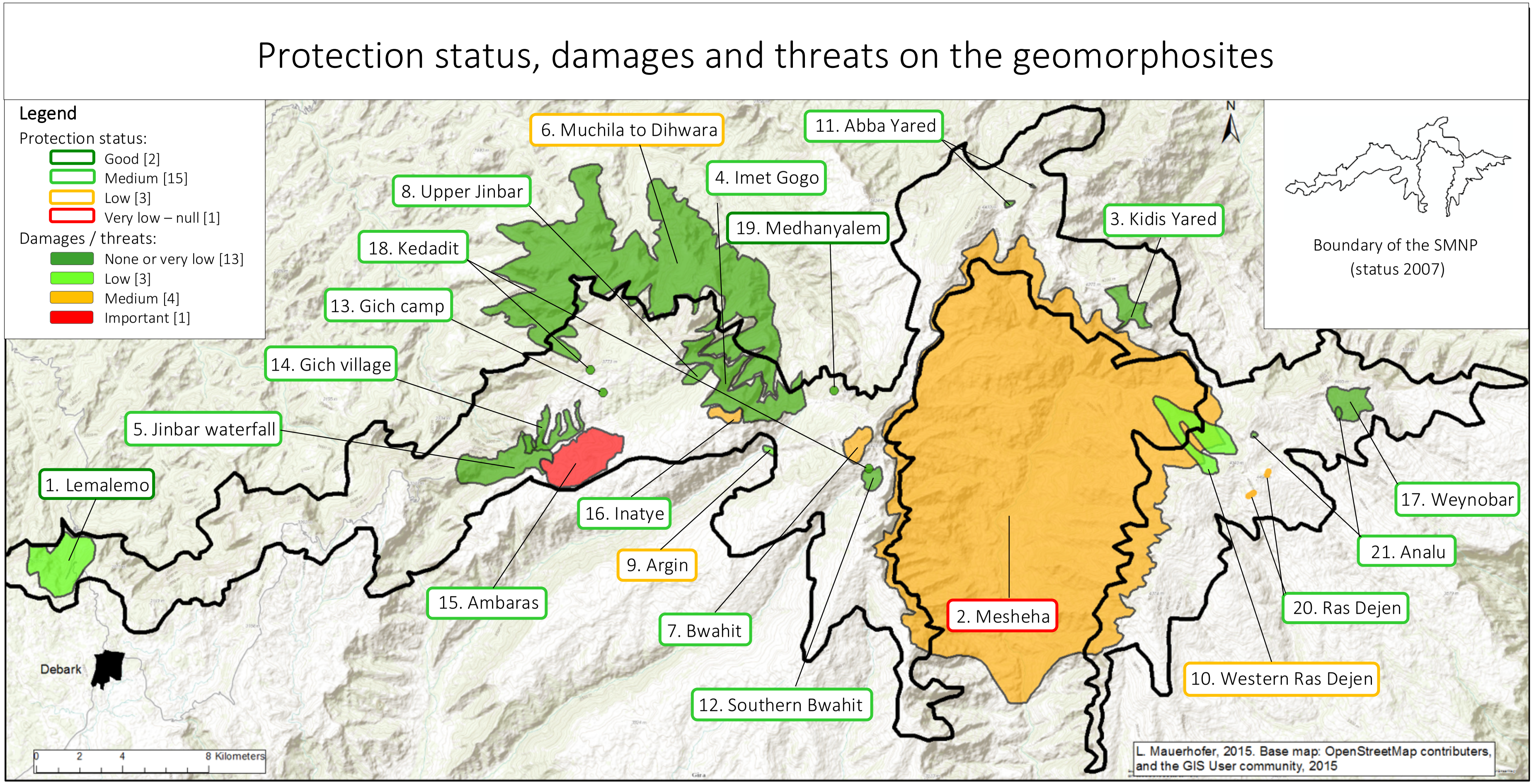


Figure 36 Protection of the geomorphosites

The synthesis map of the protection of the geomorphosites (Figure 36) brings to light the level of damages and threats as well as the protection status of the geomorphosites. As indicated earlier (cf. point 1.2.1), the protection of geomorphosites often happens through the protection of elements of the fauna or flora. In this context, Bussard (2015) uses the notion of indirect protection. Although the SMNP was published to implement protection of all natural resources (cf. point 2.2.2), most attention since the establishment of the park management has been given to conservation of the endemic flora and fauna and more recently to the ecological qualities in general. Nevertheless, the protective measures exerted through the park management not only contributed to the protection of the endemic wildlife species and flora of Simen but they also limit man-made damages and threats that could affect the geomorphosites. In 2006 the park authorities for instance argued strongly against a road project over Silki-Yared – Kidis Yared mountains and Ras Dejen, which clearly would have endangered the quality of the geomorphosites in this area, especially the volcanic centre in the region of Kidis Yared (KDYstr003) (FZS – ADC, 2009).

The Lemalimo escarpment (LIMstr001) is another example of indirect protection. The level of protection of this geomorphosite is qualifies as "good". In fact, in 2003 the park boundaries were extended to include the former Lemalimo Wildlife Reserve, which comprises one of the last remaining patches of montane forest (sometimes called forest "graveyards") on the less steep slopes of the escarpment. The current General Management Plan (FZS and ADC, 2009 : 33) records that these patches of primary forests need "highest conservation priority and require priority protection". The other geomorphosite, which stands out with a good protection status is the Medhanealem cave (CMCstr019). In addition of being fully located within the park boundaries the site is a sacred place of the indigenous population. The cave clearly is a religious taboo which belongs to the Church and cannot be exploited otherwise. Non-religious visitors of Ethiopian Orthodox Christianity are not allowed to enter the cave.

The erosive landscape of the lowland area from Muchila to Dihwara (MUDflu006), the glacial system of the Western and NW slope of Ras Dejen (RDJgla010) and the fluvio-solifluvial valley deposits at Argin village (ARGflu009) are the three sites which have parts of their territory outside the national park. Their protection status is low. The geomorphosite with a level of protection that qualifies very low to nil is the Mesheha Valley (MHVflu002). Almost the entire area surface of the site lies outside the national park boundaries thus no protection of the natural resources is guaranteed.

5.5.1.2 Damages and threats

The overall state of conservation of the inventoried geomorphosites is good or excellent (Figure 37). Three quarter of the sites are not at all or only little damaged or threatened. Four geomorphosites sustain medium damages and threats. Solely one site jeopardises important degradation and is at risk of destruction.

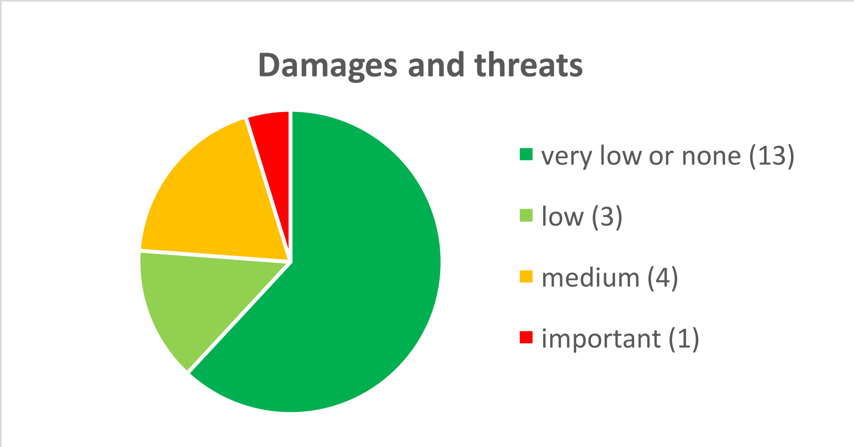


Figure 37 Damages and threats of the geomorphosites

The extremely high integrity (average = 0.96) confirms that the damages and threats affecting the geomorphosites of the SMNP are low. Only three geomorphosites received a lowered score of 0.75. These are the Mesheha valley (MHVflu002), the glacial complex at Bwahit (BWHgla007) and the farmland of Ambaras plateau (AMBant015). The relative damages and threats experienced by the sites are considered medium for the first two and important for the last one. The integrity of all other sites achieves the maximal score of 1. The latter is therefore strongly correlated with damages and threats suffered by geomorphosites.

The Mesheha valley is the site with the lowest level of protection and at the same time exposed to serious damages and threats. In fact, the asphalt road through the Mesheha valley currently under construction relying Bwahit with Beyeda in the northeastern Simen has its own impact. Rapid, unsustainable rural development in the valley area may seriously affect the site's integrity in a near future. Regarding the geomorphosite on Bwahit, road construction has already cut off the upper part of one moraine on the northern slope. The area is further exposed to tourism development, which may easily overlook the highly vulnerable glacial landforms inherited of the Last Cold Period that constitute this geomorphosite. The farmland at Ambaras, although situated within the national park boundaries, suffers from continuous soil degradation. Without intensification of soil and water conservation measures the soils will be completely washed away and the plateau area is likely to become unproductive within the next human generation. Hence, it experiences the same fate as Gich village on the opposite side of the Jinbar River, where the farmland is transformed into badlands (Ludi, 2005).

The two other geomorphosites sustaining medium degradation are the glacial deposits of the Little Ice Age at Ras Dejen (DEJgla020) and the turf exfoliation on the Inatye high plateau (INYper016). The geomorphological forms of both sites are intact but they are relatively small in size, thus more vulnerable than other forms and they are exposed to tourism. Of the three geomorphosites sustaining low damages and threats (Lemalimo escarpment (LLEstr001), glacial system West and NW of Ras Dejen (RDJgla010) and fluvio-solifluvial valley deposits at Argin village (ARGflu009), the impacts are related to tourism, construction of infrastructure such as power lines, and nearby human settlements. All sites are situated on the park border, two of them (ARGflu009 and RDJgla010) have parts of their surface area outside the national park, thus they are clearly more exposed to human interference than other sites in remote areas. Generally, it comes out that structural and fluvial sites, which comprise the most voluminous landforms are less vulnerable to human impacts, than glacial and periglacial sites (Figure 38), which are much smaller forms.

To sum up, it is mostly the regional rural and tourism development, which increasingly puts under pressure the generally very high integrity of the geoheritage sites of the Simen Mountains National Park. Geomorphosites that would be at risk due to natural degradation by highly active erosional processes leading to their self destruction in short- or medium-terms do not appear in this inventory.

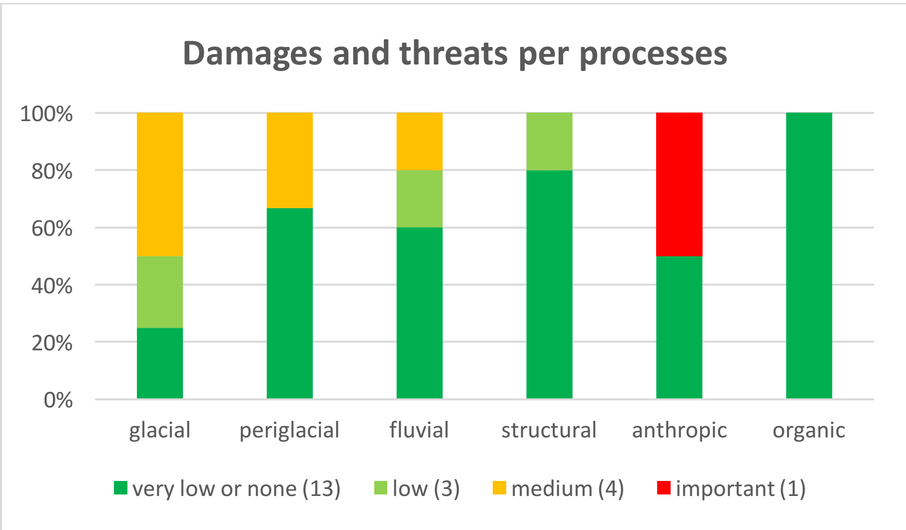


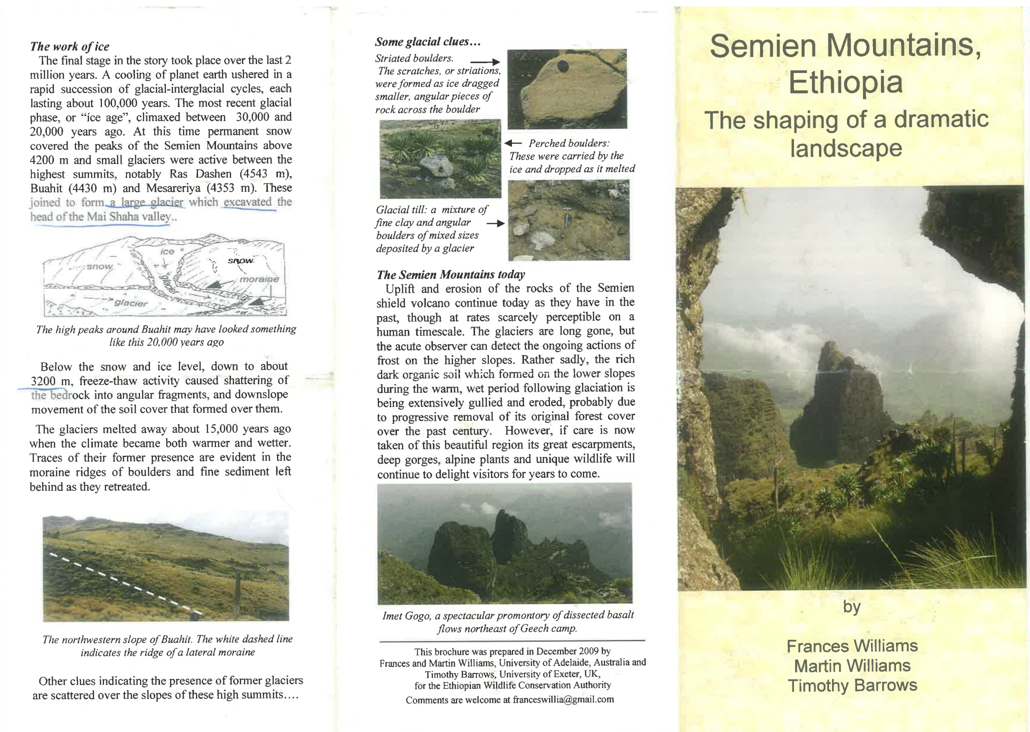
Figure 38 Damages and threats according the morphogenetic processes

5.5.2 Promotion of the geomorphosites

This chapter aims to provide an overview of existing and potential promotion of geomorphosites. Interpretation tools such as interpretive panels, thematic trails or brochures represent an enhancement of geomorphosites. Their existence is treated in the first subchapter. Then the visit conditions and the educational interest of the sites identifying opportunities for promotion that could potentially be implemented are documented.

5.5.2.1 Existing promotion of the geomorphosites

To our expectations, the analyses show that there have not been much attempts for promotion or enhancement of the geomorphosites in Simen. Several geomorphosites are often visited by tourists because they present prominent viewpoints or because they are part of a spectacular sceneries (examples are Imet Gogo, Kedadit, Jinbar waterfall, Chennek, Bwahit, Ras Dejen or Lemalimo) but no interpretation facilities neither on animals and plants nor on geomorphological and geological assets have been developed at such locations. The Chief Warden of the Simen Mountains National Park, Mr. Maru Beyadegelegne explains: “*We do not have geo-experts, we only have ecologists, so they teach more about animals and plants*.” A few year ago, a group of scientists from Australia visited the park to study the geology. They produced a leaflet with information on the shaping of the dramatic landscape of Simen (Figure 39). However, it presented some inaccuracies and could not be published.



The work of ice

The final stage in the story took place over the last 2 million years. A cooling of planet earth ushered in a rapid succession of glacial-interglacial cycles, each lasting about 100,000 years. The most recent glacial phase, or “ice age”, climaxed between 30,000 and 20,000 years ago. At this time permanent snow covered the peaks of the Semien Mountains above 4200 m and small glaciers were active between the highest summits, notably Ras Dashen (4543 m), Buahit (4430 m) and Mesareriya (4353 m). These joined to form a large glacier which excavated the head of the Mai Shaha valley..

The high peaks around Buahit may have looked something like this 20,000 years ago

Below the snow and ice level, down to about 3200 m, freeze-thaw activity caused shattering of the bedrock into angular fragments, and downslope movement of the soil cover that formed over them.

The glaciers melted away about 15,000 years ago when the climate became both warmer and wetter. Traces of their former presence are evident in the moraine ridges of boulders and fine sediment left behind as they retreated.

The northwestern slope of Buahit. The white dashed line indicates the ridge of a lateral moraine

Other clues indicating the presence of former glaciers are scattered over the slopes of these high summits….

Some glacial clues…

Striated boulders. The scratches, or striations, were formed as ice dragged smaller, angular pieces of rock across the boulder

Perched boulders: These were carried by the ice and dropped as it melted

Glacial till: a mixture of fine clay and angular boulders of mixed sizes deposited by a glacier

The Semien Mountains today

Uplift and erosion of the rocks of the Semien shield volcano continue today as they have in the past, though at rates scarcely perceptible on a human timescale. The glaciers are long gone, but the acute observer can detect the ongoing actions of frost on the higher slopes. Rather sadly, the rich dark organic soil which formed on the lower slopes during the warm, wet period following glaciation is being extensively gullied and eroded, probably due to progressive removal of its original forest cover over the past century. However, if care is now taken of this beautiful region its great escarpments, deep gorges, alpine plants and unique wildlife will continue to delight visitors for years to come.

Imet Gogo, a spectacular promontory of dissected basalt flows northeast of Geech camp.

This brochure was prepared in December 2009 by Frances and Martin Williams, University of Adelaide, Australia and Timothy Barrows, University of Exeter, UK, for the Ethiopian Wildlife Conservation Authority

Comments are welcome at franceswillia@gmail.com

Semien Mountains, Ethiopia

The shaping of a dramatic landscape

by

Frances Williams
Martin Williams
Timothy Barrows

Figure 39 Leaflet with information of the shaping of the dramatic landscape of Simen, by Williams et al., 2009

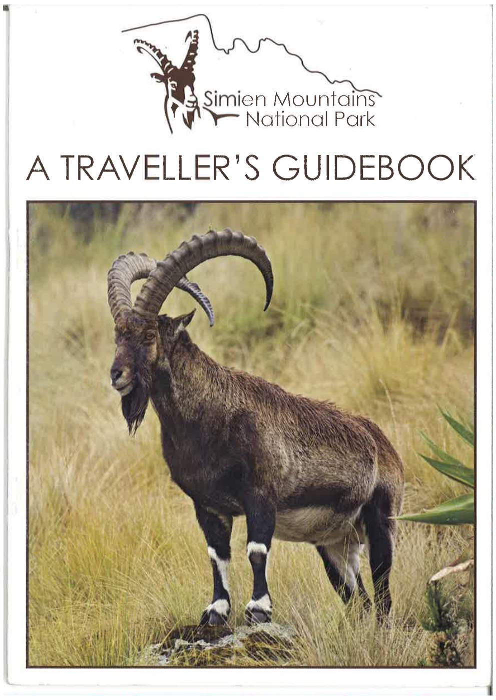


Figure 40 Guidebook of the SMNP including a chapter on geology and landscape

The Frankfurt Zoological Society (FZS) published a guidebook (Figure 40) that provides information on Simen Mountains National Park, its location and size, flora and fauna, history and culture, hydrology, which also gives technical advices to plan a trip to Simen and contains a visitors' code of conduct (EWCA, 2013). This booklet, though not on all the subjects up-to-date does also include a chapter on geology and landscape. Such information and photographs of wildlife, landscapes and local culture is also available on the official website of the park (simenmountains.org). The Simen Mountains - World Heritage Site, Trekking map on a scale of 1:100'000 published by the University of Bern (CDE, 2010), indicates special wildlife (Walia ibexes, Gelada baboons, Simen foxes), viewpoints, camping grounds/tourist lodges and trekking routes with pictograms (Figure 41). These documents, postcards and small replicas of animals are on sale at the information centre at the park headquarters in Debark (Figure 42). In a showcase next to the desk there is also a relief model of the SMNP and a stuffed leopard on the sale cabinet. Generally, the displays are limited and could be greatly improved to international standards (FZS – ADC, 2009).

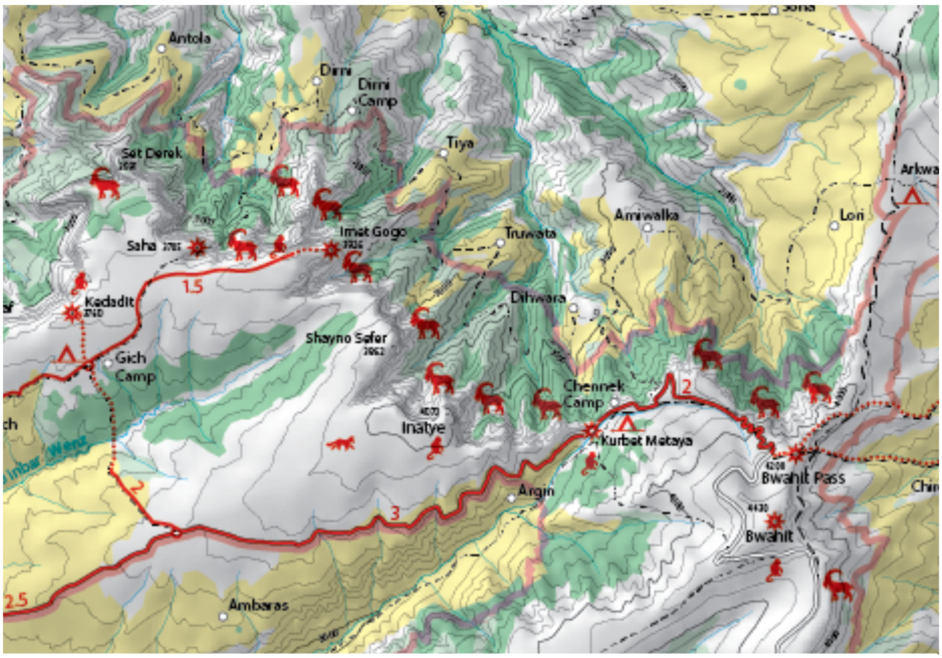


Figure 41 Touristic products (guidebook, trekking map, postcards, small replicas of animals) on sale at Debark information centre at the park headquarters

Figure 42 Simen Mountains -World Heritage Site, Trekking map (1:100'000) with icons for wildlife, viewpoints, campsites and trekking routes

Local guides organise themselves in an organisation called Walia Local Guides Association. The Ethiopian Wildlife Conservation Authority (EWCA) together with Japan International Cooperation Agency (JICA), have conducted guide training programmes. The tourism market requires "*knowledgeable, courteous and imaginative guides who possess a deep knowledge of the SMNP, its natural and cultural value and also the regulation and etiquette of trekking and tourism operation in the SMNP* (AWF, 2015: 24)." JICA, in the context of SIMCOT-Project (Project on Community Tourism Development through Public - Private Partnership in SMNP and surrounding area), assists the local communities to run Community Tourism Associations. A leaflet proposing Village Tours at Argin with Injera baking and local gastronomy in combination with ecotourism in the park (wildlife watching and scenery) is available at the desk of the park headquater.

The current General Management Plan (GMP) of the SMNP outlines for the time period 2009-2019 a range of activities to improve tourism marketing and promotion and to rise awareness of the importance of the exceptional resources of the SMNP. They consider for instance producing, updating and renewing of high quality visitor information and promotional materials, particularly a guidebook and map (action 1.2.3), planning and developing of interpretation points at key sites in the park (action 1.1.2), developing better educational materials such as newsletters and videos (action 1.3.6), extending environmental education activities (various actions) or diversifying visitor attractions with cultural initiatives (action 1.3.2) and adventure sports (action 1.3.1). Moreover, a marketing strategy and a SMNP brand that reflects the unique attractions of the park will be developed in cooperation with all stakeholders (action 1.4.2) (FZS-ADC, 2009).

The current Tourism Development Plan (TDP) although based on the trend of the growth of global nature vs. ecotourism, does not mention geotourism as an opportunity for tourism development in Simen. Instead, it identifies the following five categories as future tourism opportunities: Sightseeing, trekking, adventure activities, wildlife tourism and cultural tourism. Nevertheless, the TDP states that, in many respects the physical landscape is the key tourism product attribute (“*SMNP boast one of the most spectacular settings in Africa – if not the world – in terms of physical landscape. The scale and drama of the escarpments and views are unrivalled in Africa and there are few other locations globally which can compare*”). And it is the combination of striking physical landscape and the presence of charismatic and rare wildlife species which make the SMNP truly distinctive in terms of tourism potential (“*the Grand Canyon in the USA cannot offer this unique combination of dramatic scenery and fascinating wildlife*”) (AWF, 2014 : 6).

5.5.2.2 Visit conditions

The visit conditions include the accessibility (driving time from Debark, walking time and walking difficulty), the security, the site context, and the presence of touristic infrastructure near the geomorphosites.

The Simen Mountains National Park is generally accessible from Debark town where the park headquarters is located. Debark offers various hotels and pensions, generally at low international standards which are frequently used by trekkers and other visitors on their night before and/or after heading to the park. The park entrance where all vehicles have to pass through is situated at Swaris a few kilometres to the park border. Even if road access has been improved (and is still improving) in recent years, the Simen Mountains National Park is in a remote area, at high altitudes above 4000 m with several exposed relief locations. Nights on the highlands are freezing while extremely hot temperatures can be felt after midday in the lowland area. Healthcare services often are difficult or impossible to receive within a few hours. All these aspects have to be kept in mind when reading through this section. Visits during the wet season, particularly during June to August period are normally not much advisable. Heavy thunderstorms with hail are frequently observed in the higher region of Simen. Parts of the road are often flooded and very difficult in access, and crossing of larger rivers might not be possible.

The geomorphosite which clearly offers the best visit conditions is the Lemalimo escarpment (LIMstr001). Located on the highway connecting Gonder with Northern Ethiopia the area is accessible by vehicle within 15 minutes from Debark. Currently a new ecolodge offering high range accommodation at the international standards is under construction at Lemalimo. Six geomorphosites (JBWflu005, BWHgla007, ARGflu009, BWSflu012, AMBant015, KDTstr018) located along the public road leading from Debark through the national park up to Bwahit are accessible on a one-day trip (Figure 44). They all can be reached without much complications from the car in 5 to 20 minutes (one way). Six geomorphosites (EGOstr004, JBVper008, GICorg013, GIVant014, INYper016, KDTstr018) situated on the Gich plateau and Inatye are accessible on a regular two-day trekking (over the Main Gich Plateau Trekking Route, cf. section 3.4) starting from Sankabar camp or Jinabar waterfall and spending the night at Gich campsite. Very poor touristic infrastructure (bankhouses and campsites providing basic facilities of water and toilets) is available at Sankabar, Gich and Chennek camps (AWF, 2014).

The Mesheha valley and the Ras Dejen area can also be approached by vehicle from Debark and there are a few small shops and restaurants available at Chiro Leba (largest town in the Mesheha valley). Thus the visit conditions of the Mesheha valley (MHVflu002) as well as of the two glacial sites on Ras Dejen (DEJgla020 and RDJgla010) are not as problematic but a long and exhausting car-drive (one day almost non-stop there and back) is necessary. Generally, limited accessibility and the complete lack of touristic infrastructure (except of ranger outposts) over the entire northern and eastern mountains ranges as well as in the lowland area of the park make visit conditions in these regions very difficult. Five geomorphosites (KDYstr003, MUDflu006, ABYgla011, WYBper017, WYAorg021) are concerned. They are all accessible within two-day trekking including the more or less long car-drive to approach the site on the first day (one way), meaning that the second night has to be spent at the site and a third or fourth night on the field is necessary before driving back to Debark. Trekking to the structural terraces, ravines and gorges between Muchila and Dihwara (MUDflu006) in the lowland area of the park requires a minimum of six days.

Most trails leading to geomorphosites including the Lemalimo region, the Gich area as well as Ras Dejen are safe and visible but demand caution if not to slip on dry rubble on steep slopes (Figure 44). A maximum of 6 hours daily walk might be necessary to visit the most distant sites. The path from Imet Gogo (EGOstr004) to Intaye (INYper016) leads only a few meters away of the escarpment but it is possible to walk away of the abyss and thereby obtain greater safety. The trails leading to the five sites with more difficult visit conditions, mentioned above have some risky sections and are physically much more demanding with long daily walks (6 to 10 hours) and very steep slopes. Good trails have to be searched regularly and in the area close to the peaks no trails are available. Some climbing grips are necessary to reach the striations on the NE slope of Abba Yared (ABYgla011) and there is small risk of rock fall when traversing at the foot of the Northern Escarpment from Muchila to Dihwara (MUDflu006).

The site context of almost all the geomorphosites is very positive (Figure 44(. This is mostly due to breath-taking scenery to the rugged terrain like lowlands and the Tekeze River to the North as well as the assets of the wild and natural environment. Geomorphosites for which important aesthetical nuisance and noise are perceptible are indicated with a pictogram (Figure 44). Only two sites have a disturbed site context. In the Mesheha valley (MHVflu002) many new settlement constructions, the presence of the public road and heavy traffic noise impact upon the ability of visitors to enjoy the views and general wild and natural qualities. On Bwahit (BWHgla007) the presence of the public road, traffic noise and power lines compromise the "natural feel" (African Wildlife Foundation, 2014). Some frequently visited sites, ex. Jinbar waterfall (JBWflu005), Imet Gogo (EGOstr004) or Lemalimo (LIMstr001) offering outstanding sceneries, however risk overcrowding during the high season. In a few cases the dense canopy of the montane forest (MUDflu006) or the grass cover of the afroalpine mountain steppe (JBVper008 and GICorg0013) hinder the direct exposure of the relief. The site context of the Chennek Medhanealem cave (CMCstr019) is a particular case. Since it is a sacred site no entry is allowed to non-Ethiopian Orthodox visitors.

In the context of their promotion it is essential to consider the visit conditions of the sites, but it is not the only criterion to be considered. Indeed, the interest of the site for education is central. The enhancement of a site with very good visit conditions but with no educational interest may be obsolete.

5.5.2.3 Educational interest

The educational interest of a geomorphosite documents the potential for interpretation. This means to determine whether the form or the process can be identified only by a specialist (low educational interest) or also by non-specialist visitors (high educational interest). For future promotion, it is necessary to know the "readability" of the site in order to define the public targeted by the mediation tool. Specialists will be able to grasp more complex concepts and processes than non-specialist visitors. As stated by Clivaz (2015), to dispose of a clear idea of the difficulty of interpretation of a site, the opinion of a non-specialist should be obtained. This was not possible, however. The scale from low, medium, rather high, to high qualifies the educational interest in this inventory.

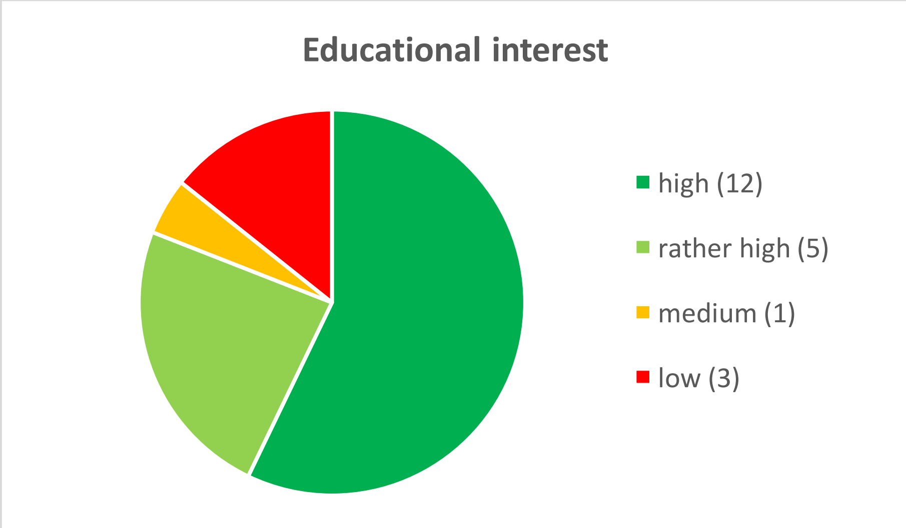


Figure 43 Potential for interpretation of the geomorphosites

More than three quarters of the inventoried sites are easily interpretable by all types of public (Figure 43. Using these geomorphosites for teaching references in nature, the whole formation and evolution of the Simen massive revealing several millions of Earth's history could be explained. The monumental cliff wall of the Northern Escarpment, for instance shows clearly visible volcanic layers exposing both, the early Trap Series volcanism and the later erupted lava flows of the shield volcano (with well visible tuff intercalations) (LIMstr001, EGOstr004). A careful consideration of the rock formations could help the larger public to recognise that the Simen Mountains are remnants of a deeply eroded volcanic 'cone' or shield, with Kidis Yared being the centre and Ras Dejen, Silki and Bwahit forming the outer rim of the crater (KDYstr003). The large canyon of the Mesheha valley is well illustrative of the dominant fluvial erosion in Simen (MHVflu002) and the Jinbar River capture demonstrates an all inspiring insight of the powerful erosion coming from the northern lowlands (JBWflu005). Postglacial gullies may look less spectacular at the first glimpse, but they represent remarkably well the incision of the natural erosion phase triggered by increased precipitation and monsoonal activities at the beginning of the Holocene (BWSflu012). Cryogenic weathering and frost action is well observed on the Inatye high plateau where numerous circular turf exfoliation (INYper016) are evident, or on Weynobar where large covers of patterned ground and weathered bedrocks are found (WYB). The striking valley rubble at Argin should be associated with fluvial and solifluvial processes of the Last Cold Period (ARGflu009). Boulder forms and sorting can be observed so that even non-specialists could learn from this site. But it is not the goal to specify the potential for interpretation of all the sites here. For details we refer to the inventory sheets (cf. annex 2).

However, the interpretation of four sites is considered to be rather difficult or very difficult. (Figure 43). For instance, the glacial deposits of the Little Ice Age (DEJgla020) and the Chennek Medhanealem cave (CMCstr019) first need better scientific examination. The Ando soils at Gich campsite (GICorg013) are completely hidden under the grass cover of the alpine meadow, thus the soil pedon is not visible. This also partly applies to the periglacial slope deposit of the upper Jinbar valley (JBVper008).

A correlation of the site's readability according the morphogenetic processes, the aesthetical value or the size of the sites, as observed by Bussard (2014), is not clear here. Three of the largest and most aesthetical structural and fluvial geomorphosites as highlighted previously are not deemed with a high but solely with a rather high education interest because the geological processes of rifting and uplifting of the landmass involved for example in the formation of the Simen shield, the extreme Northern escarpment or the Mesheha valley appear rather complex to grasp especially for non-specialists. But it is true that none of the largest sites have an educational interest qualified medium or low. Point and linear sites (in our inventory small glacial deposits, caves or soil profiles) seem less readable than sites of larger size, which sometimes are easier to decipher, as noted by Bussard (2014).

Finally, due to the relative remoteness of the study area, sites combining a high potential for interpretation and ideal visit conditions are relatively rare. The Lemalimo escarpment (LIMstr001) is probably the only site that manages to unite these two conditions. However, a significant portion of the sites present "rather high" qualities, both in terms of visit conditions and readability. These geomorphosites are particularly interesting for geotourism and will be treated more in detail in the next chapter. Figure 44 summarizes the visit conditions and the educational interest of the geomorphosites.

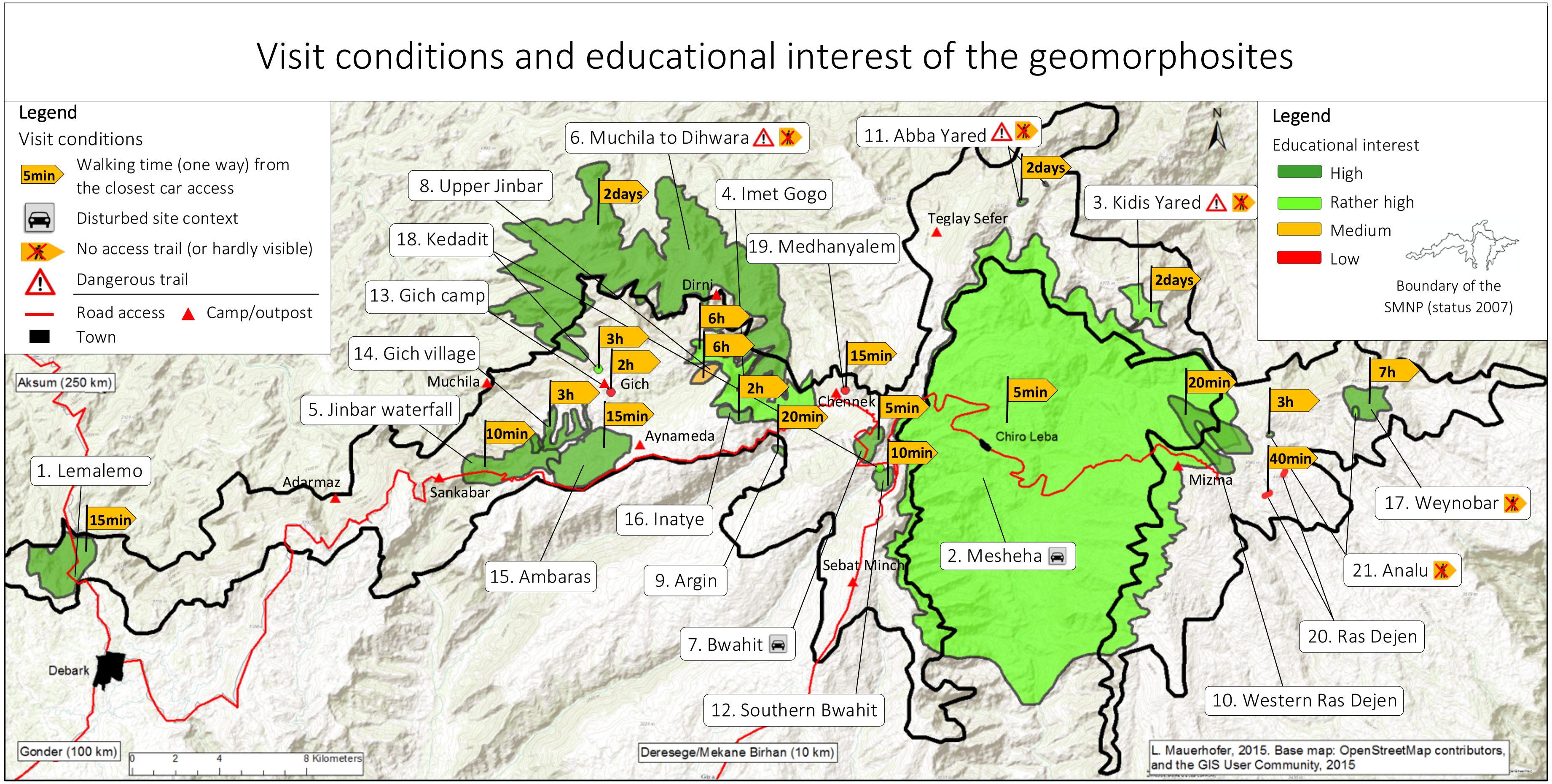


Figure 44 Promotion of the geomorphosites

6 Management of the geomorphosites of the SMNP

The geomorphosite inventory conducted as part of this thesis has allowed us to compile information on the geomorphology of the SMNP. The main characteristics of the inventoried forms have been presented in the previous chapter. Numerous geomorphosites are of interest for the development of geotourism but no management strategy and interpretation facilities currently increase their prominence or make use of the potential. No explicit provision on the protection of the forms of the geomorphological heritage exist in Simen. At the same time most of the sites are in very good state of conservation. The overriding goal of this research was to investigate how the inventory of geomorphosites can contribute to regional sustainable development in the Simen Mountains. At the beginning of this work (cf. chapter 2.3) we discussed the difficulties, conflicts and paradoxes that rise when conserving Ethiopia's natural resources (with focus on the abiotic assets) while developing its economy and own infrastructure. The chapter on the study region (cf. chapter 3) stressed the challenge for sustainable rural development in Simen and the protection of the park resources with the great need of the surrounding native population for livelihood improvement. The logical continuation of the result for the management of the geomorphosites of the SMNP is to emphasis geotourism development and outreach activities.

In the following section (6.1) a road map that indicates the guidelines for the management of the geomorphological and geological heritage of the SMNP is presented. Eight strategic objectives and working tasks have been defined. They structure the section into eight sub-sections. Management of the Lemalimo escarpment (sub-section 6.1.1), complete the existing Simen Mountains - World Heritage Site, Trekking Map with information on geosites (6.1.2), develop theme trails for self guidance dealing with geological and geomorphological subjects (6.1.3), install didactic panels to promote geosites which are main attraction points, especially at Lemalimo, Jinbar waterfall and Chennek (6.1.4), initiate geo-sightseeing tours to the SMNP (6.1.5), consider the potential of geo-guided trekking in a phase of new tourism development towards the western end of the park and the lowland areas to the North and South (6.1.6), give geo-trainings to tour guides in cooperation with specialist geotourism guiding operators and initiate an accreditation system for local geotour guides (6.1.7) and increase capacity of park staff for geoheritage outreach and conservation (6.1.8). The last section (6.2) of the chapter management of the geomorphosites of the SMNP treats the prospects of the SMNP for application to the Global Geopark Network.

6.1 Road map for SMNP’s geomorphosite management: eight strategic objectives and working tasks

6.1.1 Management of the Lemalimo escarpment (LIMstr001)

Figure 45 Lookout at Lemalimo

The Lemalimo escarpment (LIMstr001) (Figure 45) is the geomorphosite, which manages to unite excellent visit conditions with a high potential for interpretation. This entitles us this site to be treated specially. In fact, the site is accessible on the road from Debark within 10 min or even from Gonder (2 hours) and it illustrates particularly well the structural geomorphology and geology (contact of the flood basalt flows and shield volcanic sequences at 2700 m) of the Simen Mountains. As a whole the site demonstrates a unique evidence for the Ethiopian Plateau (NW-Highlands) ceding to the North-Western Ethiopian Lowlands over the dramatic escarpment (Northern Escarpment). The site it is not only highly attractive for tourism but also for awareness raising of the local population. Local stakeholders in each Woreda surrounding the park, including administration, communities, police and judiciary are essential partners and supporters of effective Park management (FZS – ADC, 2009). If workshops are organised for them in Debark short little formal but experience-oriented visits to Lemalimo are highly recommended. This can be in the form of an excursion with offered lunch at the lookout. A short input on landscape interpretation highlighting the major geomorphological and geological features and strong links to cultural and ecological values of the site could then be given (cf. annex 2). School excursions should also be encouraged. But for this it is first necessary to sensitize teachers in Debark on the importance of the site and its potential as a teaching material also for school children. In terms of tourism development, a special geo-tour package for a day or half-day visit from Gonder including an overnight stay for example at the high-end standard Lemalimo Logde (currently under construction) could be proposed. Such an imaginative offer would respond to the frequent request of visitors for more specific information and exclusivity on their tours (AWF, 2014). The installation of interpretive panels next to the highway (cf. point 6.1.4) and the development of a trail dealing with geological subjects (geo-trail) for a self-guided visit with booklet available at the park headquarter in Debark are also suggested (cf. point 6.1.3). Moreover, targeted visitor management and limitations is strongly recommended to prevent the negative impact of mass tourism without what the individual experience and economic value of the site will be greatly reduced within a short time.

6.1.2 Complete the existing Simen Mountains - World Heritage Site Trekking Map with information on geomorphosites

One of the easiest implementable goals is to complete the existing Trekking Map with indications on geomorphosites (call them major geological features or geosites) to be visited on a trekking to the Simen Mountains. Currently special wildlife (Walia ibexes, Gelada baboons, Simen foxes), viewpoints, camping grounds/tourist lodges and trekking routes are represented with easy understandable symbols. A similar specific symbol should also indicate the location of geomorphosites interesting for visits. The following sites (also indicated on Figure 52) combining good visit conditions with high educational interest and often high aesthetic values are recommended to figure on the map The Lemalimo escarpment (LLEstr001), Mesheha valley (MHVflu002), Imet Gogo and the Northern Escarpment (EGOstr004), Jinbar waterfall (JBWflu005), glacial complex at Bwahit (BWHgla007), fluvio-solifluvial valley deposits at Argin village (ARGflu009), glacial system West and NW of Ras Dejen (RDJgla010), postglacial gullies on the Southern side of Bwahit (BWSflu012), soil erosion forms at Gich village (GIVant014), turf exfoliation on the Inatye high plateau (INYper016), natural arches, Kedadit (KDTstr018) and the farmland of Ambaras plateau (AMBant015).

Two sites which can be observed from distance but cannot be approached easily on a trekking – the torrential systems and structural terraces in the lowland area between Muchila to Dihwara (MUDflu006) and the volcanic centre and dykes in the region of Kidis Yared (KDYstr003) – should also figure on the map. In fact, their observation from distance is already quite informative for the understanding of the formation and evolution of the Simen Mountains. Some sites, or parts of them are also remarkable viewpoints thus they already figure on the map (e.g. Kedadit and Imet Gogo or Deche Nedala for Jinbar waterfall). They should however also be considered as geomorphosites and not just as viewpoints. The information on the backside of the trekking map should be reorganised. It would be advisable to give very brief explanation of each site (one or two phrases) so that the map user can actually appreciate the landforms.

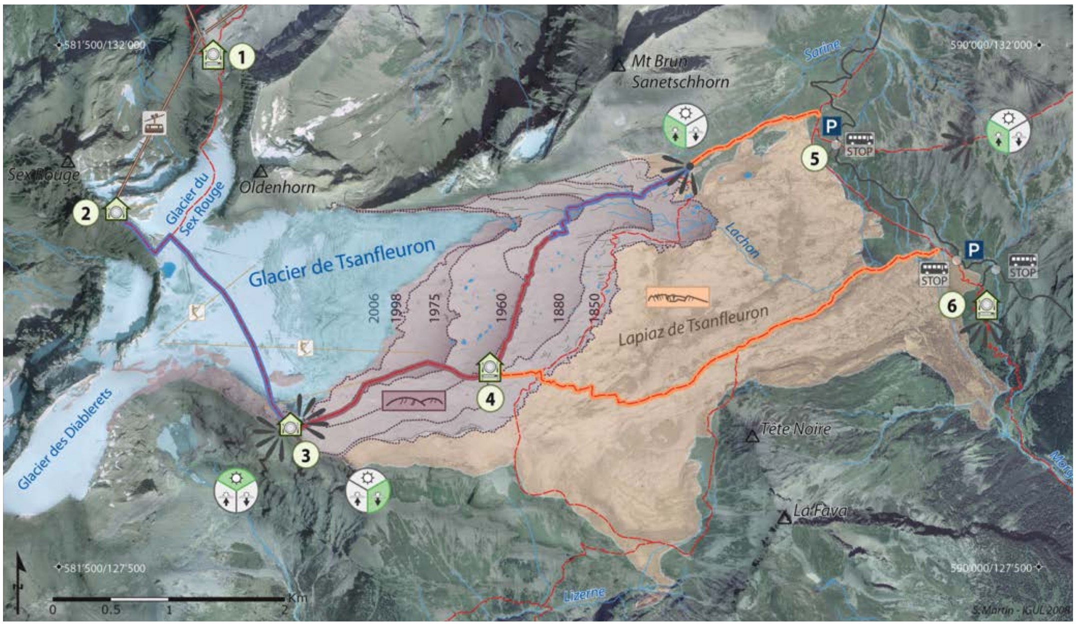


Figure 46 Example of a geotourist map in the Tsanfleuron region (Switzerland) (Martin, 2010)

„*A map that is used to communicate with a public of non-specialists and that visualises geoscientific information as well as tourist information*" is called geotourist map (Regolini-Bissig, 2010: 3) (Figure 46). In a classification based on a statistical analysis of more than fifty geotourist maps Bissig (2008) differentiates between five groups with different levels of scientific content and tourist information: index maps, tourist maps, two types of geoscientific maps for amateurs of Earth sciences, and interpretive maps. In her paper Regolini-Bissig (2010) focuses on the implementation of interpretive maps by pointing out the advantages of using an interdisciplinary approach to improve map effectiveness. Based on Coratza & Regolini-Bissig (2009) the author proposed guiding principles for geotourism mapping. At the moment of implementation this literature should be considered. The completion of the above mentioned trekking map with information on geomorphosites is one option. The production of a more advanced quality geotourist map or interpretive map could also be considered.

6.1.3 Develop theme trails for self guidance dealing with geological and geomorphological subjects

Figure 47 Various products of the Via GeoAlpina (Cayla & Hobléa, 2011)

Autodidactic theme trails dealing with geological or geomorphological subjects (geo-trails or treks) are usually presented in the form of leaflets or small booklets accompanied with maps and should encourage visitors to discover certain geosites (Figure 47). They facilitate the interpretation of geomorphological features to non-initiated audiences and improve the comprehension of geomorphological processes. In that sense theme trails contribute to awareness raising on pertinent regional topics related to geomorphology and geology. Martin et al. (2010) have formalised the development process of geotourism products. They propose *four domains of questioning* - the *target public*, the *site*, the *content/theme* and the *medium* - which raise a series of questions. Their resolution is to get a *coherent* mediation product, basis for an educational undertaking. They stress the importance of focusing on the specificity of the site when developing interpretive products. Multiplying the topics mainly has the effect of smothering the extraordinary in the ordinary and too much information kills the information. The information although simplified should be well researched and scientifically correct. The methodological guideline of Martin et al., (2010) has seen its excellent application by Bouvier (2015) for the promotion of the periglacial and glacial geomorphology in the Combin massif (Valais, Switzerland) through the development of two geo-trails.

The area that is most suitable for the development of self-guided geo-trails is the Gich plateau. Most trekkers visit the park on a well established 2-3 days trekking from Sankabar over Gich to Chennek camp. This is what is called the Main Gich Plateau Trekking Route (cf. section 3.4) (AWF, 2014). If they leave the park on the second day, some of them will use the shorter path leading down to the Jinbar River and again up to Aynameda camp (Figure 52). On the longer trekking variant to Chennek eight or nine geomorphosites could be visited or observed from distance, this is almost the half of all inventoried sites. There are different options that might be interesting for the valuation of the geomorphosites. One focus point is the curious relief-formation of the Jinbar valley, which seems to have no natural upper end but performs with its almost U-shaped cross-section over the steep scarp (EGOstr004) in the air. Downward the valley breaks with a waterfall (JBWflu005) over the edge of the escarpment to the North. In the following we develop another relevant idea more in detail.

Soil erosion and the development of soil and water conservation are serious issues in Simen, with destructive consequences for ecosystems and human life far downstream the Tekeze River. The interconnection of the three sites presented below (2 days trekking option on Figure 52) is a good option for the development of a theme trail on the topic. Various aspects could be discussed. Natural soil formation of the black andosoils at Gich campsite (GICorg013), the impact of anthropogenic soil erosion at Gich village (GIVant014) and the construction of soil and water conservation measures on the Ambaras plateau to solve the problem (AMBant015). The measuring stations of the University of Bern down at the Jinbar River could be a fourth interest point. In fact, Hoblea (2011), proposes the concept of hybrid research, which is to combine the actions of basic research with a more- or less-developed public element, allowing public participation. Thus visitors could participate to the measuring of river flow and sediment load of Jinbar river. This is most interesting during the wetter months while there is less tourists in the park, but local researchers operating the research stations conduct daily measurements year-round (own observation). Supported with innovative illustration and easy understandable projections of the sediment load related to one short rainfall and one wet season or the restricted part of the Jinbar valley and the whole park area, this would for instance allow the visitor to be aware of the amount of sediments which is lost in Simen. In Gich camp the soil profile could be disclosed in one place, so visitors could actually become to see it. A geotouristic event could be organised, where tourists could assist scientists to perform a pedological analyses of the Ando soils. The resulting profile should then be maintained for any subsequent visits.

In order to facilitate their distribution and to attain attention the brochures proposing autodidactic theme trails should not only be available at the information centre at the park headquarter in Debark, but they should also be distributed in collaboration with ecolodges, hotels and other tourism providers in Debark or Gonder for a small price (ex. 1 US-Dollar or 20 Ethiopian Birr). For the development of a geoguide established on an existing trekking route the Via GeoAlpina provides a good example (www.viageoalpina.eu). During the International Year of Planet Earth (2007-2009), a trans Alpine project, Via GeoAlpina, was created to showcase educationally geology and geomorphology of landscapes crossed along the route Via Alpina. The article of Cayla & Hobléa (2011) takes stock of the progress of the project country by country by developing the questions that guided the implementation of the French part.

Finally, the second region (apart from Gich plateau) that should be suggested for the development of theme trails is the Ras Dejen area. It bears the traces of the most extensive glaciation of the Last Cold Period in Simen. The largest moraine of Simen with 50 m thickness is found at the Dejen western slope. A leaflet proposing a trek to discover these geomorphological peculiarities and the popularisation of Simen's climate history is a way to attract more visitors towards the eastern side of the park where the highest peak of Ethiopia is a major attraction.

6.1.4 Install interpretive panels to promote geosites, which are main attraction points, especially at Lemalimo, Jinbar waterfall and Chennek.

Figure 48 Interpretive panel on geomorphology and glacier dynamics (Switzerland) (Martin, 2010)

Figure 48 shows an example of an interpretive panel in the Tsanfleuron region (Switzerland). Panels and signposting in the SMNP should generally be limited to very few locations where their presence has been identified as appropriate. Too big is the risk of "furnishing" the landscape with panels that rather disturb the visitor than that they arouse interest (Megerle, 2008). Three locations have been identified where interpretive thematic panels are most suitable for the valorisation of geomorphosites (Figure 52). This is next to the park road on the way to Deche Nedela lock out (Gich abbys), next to the highway on the top of the Lemalimo escarpment and at Chennek camp in proximity of the escarpment. These are locations where the aesthetical impact is minimal (next to the road or next to the camp). All of the three location are frequently visited by tourists. During high season these locations risk to be overcrowded, the visitor's experiences might be enhanced through intelligent visitor management, for instance by controlling the timings of groups who access the Jinbar waterfalls (AWF, 2014). While waiting to get access to the site the tour guide could point to the geomorphological particularities using the panel. Interested visitors could read themselves the information and learn about the capture of the Jinbar River, the formation of the Gich abyss and the waterfall (JBWflu005). The Lemalimo escarpment (LIMstr001) offers great possibilities to link geomorphological and geological features with cultural and ecological values. At Chennek a panel could inform about the development of the fascination Northern Escarpment (EGOstr003) and its importance for the Walia as a habitat. Generally, it is important that all signs are aesthetically pleasing to visitors and locals and meet environmental standards (FZS – ADC, 2009: 89). The methodological guidelines from Martin et al. (2010) for development of geotourism products with educational or awareness raising goals also apply to the conception of interpretive thematic panels (cf. section 6.1.3). The text laid out on a panel should be structured into chapters and boxes, thematic links can be set colour, important concepts in bold. Again the objective is to highlight the specificity of the site not the generalisation of the geomorphological context of the Simen Mountains.

6.1.5 Initiate geo-sightseeing tours to the SMNP

A high priority for geotourism development in Simen must be the development of "sightseeing tours" to discover the geoheritage of the SMNP. Although the SMNP is an important trekking destination in Ethiopia and maybe in Africa, 70% of all visitors to the SMNP are "sightseeing" visitors. "*This category of visitors is typically on a wider culture-focused tour of Ethiopia and will stay usually for one night in either Gonder or at the Simen Lodge Hotel [just outside the park at Buyit Ras] and will undertake a short, primarily vehicle-based, guided tour of the SMNP. […] The experience which presently exists for this market is fairly limited and its delivery appears generally quite unimaginative* (AWF, 2014 : 18; 21)." As an opportunity to improve visitors' experience stops at geomorphosites which are within easy access of the road and which have high educational interest or high aesthetical values are proposed for the development of geo-sightseeing tours and to raise awareness of the value of the geomorphological heritage of the SMNP worthy of protection (Figure 52). On a drive from the main SMNP west entrance up to Bwahit seven geomorphosites fulfil these criteria and are within easy access of the road (5 to 20 minutes walk). It is the river capture of Jinbar River (Jinbar waterfall) (JBWflu005), the farmland of Ambaras plateau (AMBant015), fluvio-solifluvial valley deposits at Argin village (ARGflu009), Imet Gogo and the Northern Escarpment at Chennek (EGOstr004), moraines of the Last Cold Period at Bwahit (BWHgla007), the natural arch on the Bwahit southern slope (KDTstr018) and postglacial gullies below Bwahit pass (BWSflu012). At Bwahit pass it is possible to look over the Mesheha valley, which would be an additional geomorphosite to be valorised on a geo-sightseeing tour to the SMNP (MHVflu002). On the way to Axum (or from Axum, old centre to the north of Simen) a stop at the Lemalimo escarpment (LIMstr001) will further allow to valorise this highly attractive geomorphosite individually (cf. point 6.1.1). Detailed explanation of the educational potential, geomorphological subjects and possible links with other types of heritages (biological and cultural) to be treated can be found in the evaluation sheets of each site (cf. annex 2).

6.1.6 Consider the potential of geo-guided trekking in a phase of new tourism development towards the western end of the park and the lowland areas to the North and South

Figure 49 Geotourists hiking in Heleakala National Park on Maui (Newsome & Dowling, 2010)

Figure 49 presents geotourists on a trekking. The group is hiking in the backcountry of Heleakal National Park on Maui (Hawaii). Trekking in Simen is mostly booked with a local guide that is hired in Debark. The development of new and exciting trekking has been recently proposed in the Tourism Development Plan (TDP). The goal is to reduce pressure on the current routes and campsites and thereby spreading the benefits of tourism to other region of the SMNP, (especially to those communities who represent the major conservation threat to the natural values of the SMNP) (AWF, 2014). Two out of the eight *alternative trekking routes* considered of the TDP have particular potential for geotourism development (cf. chapter 3.4). Firstly, this is the Trekking Route 1 *Lemlemo and the northern lowlands* which incorporates several remote villages (Kerneja, Nariya, Amba Ber, Mulit, Dirni and Diwhara) located on the elevation of the terrace-like steps at the foot of the Northern Escarpment (Figure 52). The stretch along the trek leading through a highly fissured terrain between Muchila and Dihwara has been selected and described as a geomorphosite (MUDflu006). Visiting the lowland area is very challenging (cf. chapter 5.5.2) but offers also quite unique and different landscapes from that one on the highlands. Guides should valorise the rich geomorphological heritage for their trekking product. With interpretive supports (which have to be developed) they could familiarise visitors with two essential geomorphological concepts: 1) headwards erosion and 2) differential erosion. Perhaps a link with another important erosion process, soil erosion in Simen could be made. This would interest many curious visitors who wonder about the spectacular deformation of the landscape. That applies in particular to the emergence of the Awaza peak that are needle-shaped rock pinnacles (buttes) and steep-sided, flat-topped table mountains (mesas or Amba in Amharic) and the development of the extreme escarpment. Links with additional values notably the importance of the Simen mountains as a water catchment area for critical water source for downstream irrigation and livelihoods (cultural value), the escarpment area as one of the last natural reserves of Sub-Afro-Alpine forests and its habitat functionality for unique aquatic fauna (ecological value) should also be emphasised.

The second proposed trekking route which has a high potential for geotourism development (Figure 52) is the Route 5 *Ras Dejen via Abba Yared* which is a high level alternative route via Abba Yared and Kidis Yared to the summit of Ras Dejen. About five to six geomorphosites could be valorised on this trekking. The trail actually follows a short section of the old eastern trade and travel route whose trail has been maintained up to the present day (Stähli, 1978) (cf. section 3.2.7). Just below Silki pass (4150m) where the two routes coming from the old centres, Axum and Adwa, join is found the best preserved fossil snow moraine of Simen (ABYgla011). The landform is well visible also for non-initiated visitors. The whole NE-slope of Abba Yared has been glaciated during the Last Cold Period of Simen and offers great potential for landscape interpretation. From Silki pass the proposed trekking to Ras Dejen leaves the old trade route and turns east over the flat elongated mountain ridge of Kidis Yared summit (4453). On Kidis Yared the occurrence of intrusive rocks, granite and gabbro which reflect slowly, within the mountain cooled magma, marks the second geo-interest point (KDYstr003). It is believed that these rocks (which differ from the usual basalt lava expelled by the volcano) are parts of the volcanic plug and centre of the Simen shield with Ras Dejen, Silki and Bwahit, forming the outer rim of the crater. In addition, well exposed dykes on the southern slope below the summit indicate closely contemporaneous tensional strain during basalt extrusion. From Kidis Yared the path leads over the saddle of Metelal to the eastern mountain range with Ras Dejen being the highest summit. Three more geomorphosites are found on the way to Ras Dejen: the largest moor of Simen (WYAorg021), the glacial deposits of the LIA (DEJgla021) and the largest moraine of Simen (RDJgla010). Cryogenic phenomena such as patterned grounds could be observed at various locations above the present day periglacial limit (WYBper017). A journey through several millions years of the Earth's history could be told. The story could start with the construction of the shield volcano due to fissure volcanism in the region at some point during the Cenozoic Era. It goes on with the subsequent continuous erosion phases mainly related to heavy rainfalls in combination with wet-dry cycles (glaciations and deglaciation) during the Quaternary. It would finish with the periglacial processes affecting the highest region of Simen nowadays (Asrat et al., 2012). Landforms at the origin of the various geomorphological processes (structural, glacial, periglacial and organic) are encountered. This permits the consideration of most geomorphological contexts of Simen. For all these a geo-trekking along this route (with development of appropriate touristic infrastructure primarily outside the SMNP boundaries, in accordance with the GMP) would be particularly interesting. It is an option to diversify the visitor experience and to increase the exclusivity of the trekking product. However, this requires knowledgeable, courteous and imaginative guides who possess a deep knowledge of the values of the SMNP's geomorphology and geology and also of all other subjects (AWF, 2014). The issue is treated in the next sub-section.

6.1.7 Give geo-trainings to tour guides in cooperation with specialist geotourism guiding operators and initiate an accreditation system for local geotour guides

6.7.1.1 Contextualisation of guide trainings for geo-guided tours in the SMNP

Figure 50 Guided tour on the geomorphosites of the Park of Vaud Jura, Switzerland (Martin, 2010)

According to Megerle (2010 : 139) guided visits offer, through the personal contact between leaders and group as well as the hereby given interaction diverse advantage in comparison to self-guided offerings. Dowling & Newsome (2006: 13) see even in the finest materials no substitute for a personal interpretation in the field. However, the time-limited offer, the attachment to a group as well as the applicable fees are perceived disadvantages of guided visits. Figure 50 presents a group on a geo-guided tour in the Park of Vaud Jura (Switzerland). Due to very limited internet access and low connection rates many new technologies - using mobile data transfers - now applied to the management of the geoheritage in Europe and elsewhere in the world, such as geovisualisation, virtual tours and augmented reality (Cayla, 2014) are less valuable in Simen at present time. An advantage of guided tours in contrast to billboards is that the aesthetical impact is equal to zero. Guided visits present a lucrative job opportunity to the local population. Whenever possible, local guides should be preferred over national guides when selecting candidates for geo-trainings. Apart from the requirement of competent experts and the drafting of a quality textbook no additional or unrealistic consume of material or financial resources is forecasted to initiate guide trainings. However, a challenge is the receiver-oriented transfer of expertise and didactics to the local and regional tour and tourist guides. Trainings would probably hold in the native language, Amharic of the guides respectively they would be translated simultaneously and the content and language had to be adapted to previous knowledge of the participants. H. Hurni (during the interview) highlights that most young people when they have been at university do not want to be guides anymore. They want to be experts for the park or they will go somewhere else for work. Thus it may be difficult to find people with the required qualifications or compromises must be found.

A training of all guides would make little sense. The achieved market profit would probably be very low and the visitors would not have much of it, too different are the guiding standards in Simen with some excellent guides and also various levels of poorer standard guides (AWF, 2014: 42). The TDP stresses the need for further capacity building of tourist guides to the SMNP. It also strongly encourages the formation of Tourism Operator Partnerships (AWF, 2014). Based on these recommendations a market-oriented guide training on geomorphosites and landscape interpretation of the SMNP could be proposed in cooperation with specialist geotourism guiding operators. In this way it will be ensured that the new geo-products are commercially relevant. A limited number of certified guides which meet the demand would have to guarantee the exclusivity of the geotourism product. With the now existing tourism infrastructure in Simen the development of a geo-trekking along the Gich plateau route is the most promising option. There are about seven to nine sites on the Gich plateau which could be visited or observed from distance. Proposals for the subjects, which could be treated on the basis of geomorphosites following the Gich plateau route have already been mentioned (cf. point 6.1.3). However, in an effort to spread the benefit of tourism to other surrounding areas of the SMNP alternative geo-trekking to the lowlands north of the park and over the northern mountain range to Ras Dejen should be proposed (cf. point 6.1.6). It is recommended in a pilot project of guide trainings on geoheritage to focus on the possibilities on the Gich plateau and that the idea could later be used for geotourism development in other regions. A pilot project should further involve the training of guides to initiate geo-sightseeing tours to the SMNP (cf. point 6.1.5).

A second option to train tour guides on the issue of geomorphosites and to improve the quality of guided tours to the SMNP is that EWCA together with the SMNP initiates an accreditation system for geotour guides to encourage existing guides to enhance their skills and to align their knowledge with the principles of geotourism. This has been for instance done at the Hong Kong Global Geopark of China. A study investigated the travel motivations of visitors to this geopark and their willingness to pay for an accredited geo-guided tour. It shows that "*geopark visitors are willing to pay extra for the high-quality geotour because they believe that they may receive higher quality and more environmentally friendly services. They were willing to pay an average HK$165.3 for the accredited tour, which is HK$34.5 higher than the price that they were willing to pay for the non-accredited counterpart* (Cheung, 2014: 1)." In order to receive qualification, all accredited geotour guides were assessed with respect to their geological knowledge, interpretation skills and awareness of geological conservation. Visitors' travel motivations were found to play an important role in willingness to pay. Novelty seeking, enjoyment and social interaction were found to be significantly associated with visitor willingness to pay.

6.7.1.2 Conceptualisation of guide trainings for geo-guided tours in the SMNP

A sound design is of great importance for the development of professional tours, which are embedded in an overall concept of geotourism and which aim to achieve defined objectives. Megerle (2010) delivers a guideline for the conceptual realisation of guided tours. Firstly, a clear mediation objective – the guiding theme has to be developed based on the regional characteristics. An emphasis has to be put on the choice of the mediation forms (specialist tour vs. adventure tour). In Simen thematic guided tours with a focus on activating mediation (including sensory and motoric suggestions) seems appropriate. Teaching of cross-references – these are interrelations of the topic range of Earth and landscape history to vegetation, fauna, cultural landscape history, and to today's land use by humans – is further suggested. In this way a holistic understanding of a landscape is created. This may for instance be possible at Chennek where Walia Ibexes prefer the steep territory of the escarpment for their habitats. Important "*quality criteria"* for successful landscape interpretation are "*interest generation, development of relationships and hidden meanings, clear regional reference, target-group-oriented, alignment to the living world of the visitors, thematic focus, overall interpretation plan and professionalization* (free translation from Megerle, 2010: 100-107)."[7]

Pralong (2003) proposes a method of scientific mediation, which - considering that any landscape contains three stories in it - the history of rocks, tectonic deformations and landforms -, allows a dynamic lecture of the landscape focusing on the temporal depth of any landscape and on the spatial discontinuity of composing elements. Hence, any relief is also the result of three stories that are combined in a sometimes difficult tangle to clear up: the history of rock, the history of tectonic deformation and the history landforms. For the uninitiated public, these three stories are essential to remember. Applied to the Northern Escarpment, all started with the outpouring of huge quantities of flood basalts forming the Early Tertiary Trap Series volcanics later topped by the Simen shield volcanic edifice (**first story**, history of rock during the Tertiary, centred about 30 Mio ago). Further raising and shifting of the whole massif resulted in cracking of the Earth crust along the escarpment (**second story**, history of tectonic deformation process beginning during the early Cenozoic Era and lasting up to present time). Powerful erosion coming from the Northern Lowland enforced by rapid and on-going uplifting made possible those differences of elevation observed in the Simen Mountains nowadays (**third story**, history of landforms over the last 30 Mio years).

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[7] Interesse wecken, Zusammenhänge sowie verborgene Bedeutungen erschliessen, eindeutiger Regionalbezug, Zielgruppenorientiert, Bezüge zur Lebenswelt des Besuchers herstellen, Themenorientierung, Gesamtinterpretationsplan, Professionalisierung

In reality the story is more complicated, the tectonic processes for instance persist across all three phases and are still not complete. The model is of course very simplistic (this is the goal) and can be criticised but it does not falsify the ideas or data behind its main principles. It has been developed in collaboration with specialist trekking guides in the Swiss Alps where it is now in use for their clients and it could also be applied in Simen.

Megerle (2010) proposed the application of “creative approaches” to diversify the offer. Tours with meditative or poetic elements can be used primarily to establish a deeper emotional relation to a landscape and if necessary to reach other audiences. A tour that can connect myths and legends with the actual scientific explanations, without interfering with the special atmosphere can build up an intense relation to the geomorphological heritage and works out convincing Unique Selling Propositions (USP’s). These approaches can be very useful for conceptualisation of guided geo-trekking in Simen (cf. cultural values of the geomorphosites, point 5.4.2). The exclusivity of geo-trekking products could be enhanced with a special offer for photography courses for landscape and wildlife photos accompanied by an expert photographer of a famous journal. These might have a double positive effect for the SMNP if it contributes to dissemination of professional reports and photography in popular magazines (such as National Geographic or international travel magazines). This should improve the image and increase awareness of the rich geoheritage of Simen especially in western countries where most of the readers of such journals live. Geo-trekking in combination with horse trekking, rather than walking with pack horses are another possibility to profile the offer. To the author of this research, at least one third of the training input should include practice on the field. The learning content should consider expertise on the geomorphological and geological heritage of the SMNP, awareness raising on geoconservation and the princips of geotourism, and technics of landscape interpretation. Practical advices for the realization of guided tours in the field can be looked up in Megerle (2010) and are not listed here.

6.1.8 Increase capacity of park staff for geoheritage outreach and conservation

Figure 51 Geo-related awareness raising activity on the field in Senegal (Errami et al., 2015)

There are currently 10 technical staff working in the park operation in Debark among a Chief Warden, a Warden, a Deputy Warden, an ecologist, senior and junior wildlife officers, senior tourism and community development officers. *"The staff and capacity of the SMNP has been considerably strengthened over time, as resources have been allocated from EWCA and conservation partners and capacity development initiatives have been implemented. However, gaps still remain both in the number and skill of staff, and their commitment to work* (EWCA, 2015a)." M. Beyadegelegne, Chief Warden of the SMNP was delighted about the idea of employing a new geo-expert staff member. According to him, it is clear that ecologists teach about wildlife (and little about geology). Especially the 70 scouts based in outpost camps which are at the front-line to resource protection activities should be strengthened knowledge to ensure that they are motivated, effective and professionally committed.

Figure 51 shows a group of local people in Senegal learning about geological heritage on the field. All technical staff should be trained and raised awareness on the geomorphological and geological heritage resource which constitute the SMNP. Several workshops and conferences could be given. Excursions to the park should be organised. They should explain the concepts of geoheritage (geosites and geomorphosites), geoconservation, geotourism and geopark. Technical links to the SMNP should be made whenever possible. The final objective is to enable the technical staff to carry out own geoheritage outreach and conservation programmes. They should train scouts and opinion leaders. Workshops and discussion forums for police and judiciary could be hold and excursions for school environmental clubs and community leaders could be organised.

It would make sense to employ at least one geo-expert in the operation office in Debark. This can be alone justified through the fact that the park was not only included on the World Heritage List because it contains endemic wildlife species and a unique mountain flora (criterion x) but also because it offers a spectacular landscape of natural beauty (criterion xii). With the employment of the geo-expert staff newsletters, brochures and other educational material that outline and promote the importance of the exceptional geoheritage of the SMNP could be developed. This could be the preparation of a pedagogical dossier in the local language for school teachers and children published in-house. For instance, a textbook on how to interpret the landscape of the SMNP. With professional assistance and financial support, a geoheritage outreach video could be produced. Teachers should be provided with several ideas for the sort of activities they can undertake with children to teach them on the geomorphological heritage of the SMNP. The association of the underlying geological features with human culture and biodiversity should come forth during lessons with children. Outdoor learning methods and environmental education could be proposed. One of the most famous approaches in the domain is "*Flow learning*" after J. Cornell (1989) who considers four stages (learning phases): awaken enthusiasm focus attention, offer direct experience and share inspiration. Although, the method was originally developed for teaching outdoor nature classes it can be used to teach any subject matter, indoors or outdoors. The focus is on direct experience, inspiration and true understanding and appreciation. Further readings and recent literature is available on the website (www.sharingnature.com).

In addition to the Lemalimo escarpment (cf. section 6.1.1) the glacial complex at Bwahit (BWHgla007) could be an interesting site for outreach programmes and excursions whether for trainings for the park staff or for awareness raising activities given by the staff. Bwahit is quite easily accessible from Debark (one-day trip) and it offers very diverse and unique landscapes different from what can be seen around Debark. The subject would be glacial geomorphology. Glaciers are an extraordinary term to discuss in Ethiopia where ice and cold only occurs on the highest peaks, such as the Simen Mountains. Many visitors are surprised when they encounter frozen ice at some locations also found on Bwahit during dry season. The moraines and glacial cirques next to the road represent a great teaching material to raise awareness on the glacial process and climatic history of Simen using a solid specimen in nature. Pictures of existing glaciers on Kilimanjaro, in the Alps and elsewhere in the world could be used for illustration and comparison. Simple educational materials, figures and schemes of glacial advance and retreat should be used to explain the glacial process (ice flow) and how glacier modify the landscape. Links to global warming could be made and discussed. Links between the relief and the presence of specific biotopes (moraine deposits and presence of moors) could also be shown.

The overall aim of capacity building of the technical park staff is to foster autonomy of the park operation and to create multiplier-effects. Geomorphosites could be used in a positive way for sustainable geotourism development. On a long term capacity building empowers the local population in the surrounding area of the SMNP, enables them to participate and better manage their park and helps them to get better economic benefits. Ultimately, the awareness and the tolerance to the protection of the park resources, abiotic and biotic, will be increased. Figure 52 illustrates the eight proposed management strategies of the roadmap presented in this chapter.

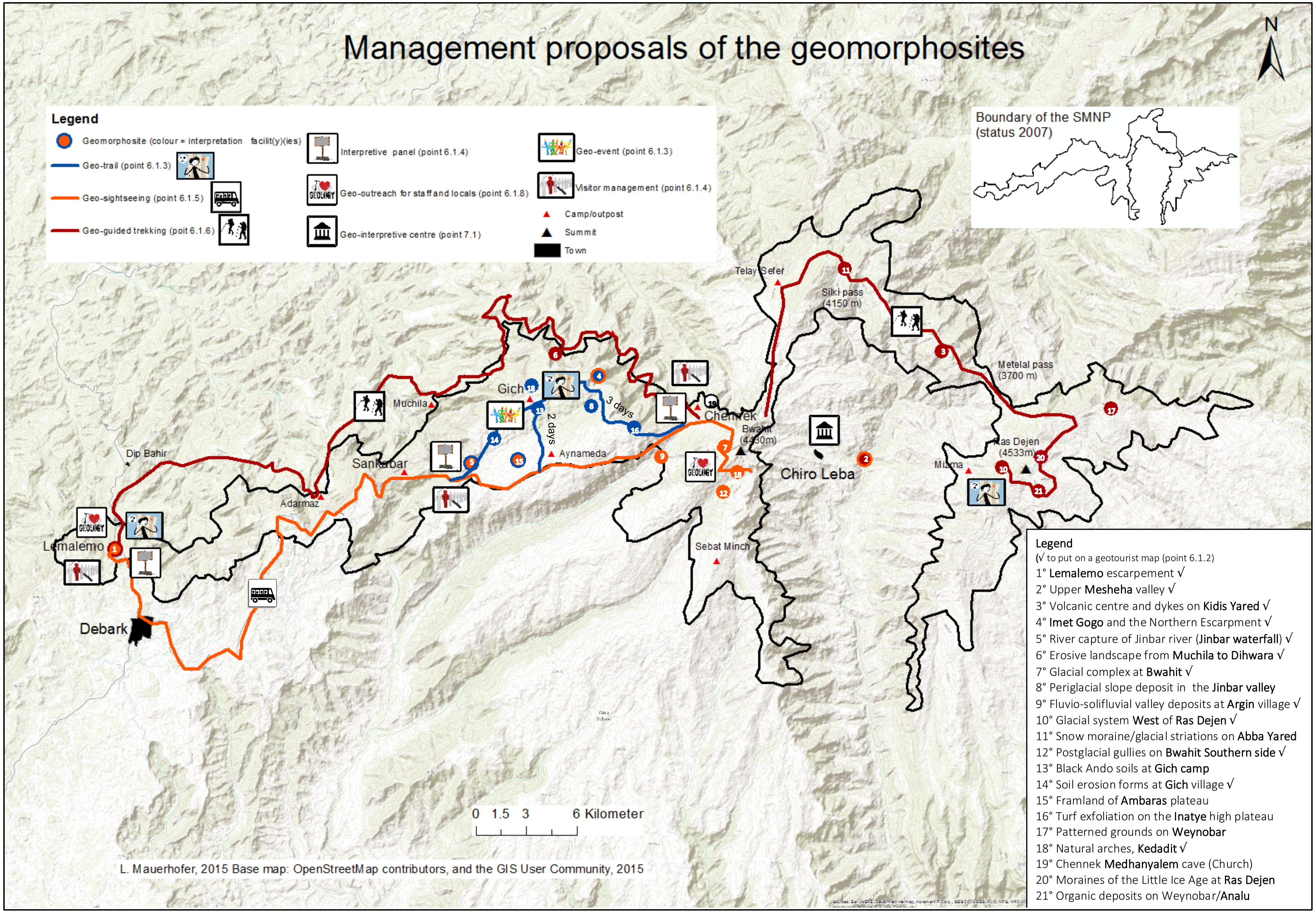

Figure 52 Road map for the geomorphosite management of the SMNP: eight strategic objectives and working t task (A3 format in the print version)

6.2 Prospects of the SMNP for application to the Global Geopark Network

"*UNESCO Global Geoparks are single, unified geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education and sustainable development* (UNESCO, 2015a)." It is at the discretion of the GGN to decide whether an area is of international geological significance, but there are remarkably few arguments why the Simen Mountains, should not meet this criterion. With this work, we have highlighted the importance and uniqueness of the geological and geomorphological diversity of the SMNP. The branding of an area as "Geopark" does not necessarily affect the legal status of the land. However, legal protection of certain geosites within a Geopark must be in accordance with national regulations (GGN, 2014). The chapter (2.3) on geoconservation and geoparks in Ethiopia has shown that it is almost impossible to come up with the idea of geopark because it not possible to get a reply from the government and local stakeholders. It seems that as long as there is no policy which supports the designation of geosites and development of geopark it is hardly possible that the Simen Mountains could become a Global Geopark. But the idea may persist as a vision for the development of the entire Simen region beyond the actual area of the SMNP.

In order to create comprehension for the geomorphological heritage worthy of protection it is first necessary to raise awareness on its existence (Martin, 2012). We have shown in this chapter a number of activities and strategies to strengthen consciousness among the park operation, the government, the general public and visitors on the geomorphological heritage of the SMNP. The potential of geomorphosite promotion for diversification of the tourism offer and revenue creation for the park and the local community through sustainable geotourism development has been demonstrated. The suggested road map indicates the guideline for the management of geomorphosites in the SMNP. It proposes several innovative strategies which could be considered for future park management. The geological and geomorphological features and values are too often neglected. Our analyses clearly show it. The GMP (FZS – ADC, 2009) dedicates a whole Programme to the ecological management but the words geomorphology or geology do not appear in one phrase. Remembering that the park has been inscribed in the World Heritage List for two reasons (criterion x and criterion xii, cf. section 3.2.1), equal emphasis on both aspects of natural heritage should be placed for mutual and successful management of the SMNP.

We agree with H. Hurni that the SMNP could for instance form the core area of a Simen Geopark, whereas the surrounding Simen region, considering far-reaching limits of the shield volcano may form the buffer zone in which sustainable use of natural resources is allowed and actively promoted. The GMP stresses, that there is currently no SMNP logo or unique corporate image which is consistently used in all marketing and promotion (FZS – ADC, 2009). Our suggestion for a uniform umbrella brand strategy would be to really capitalise on the geo-aspects and to keep using the Walia Ibex image as an additional value without bringing it to the forefront (currently the park and consequently most tourism providers give the image with a large ibex with some contours mountain (Figure 40, contours of Imet Gogo peak).

Figure 53 Chinfira mountain (peaks in the central background) North of the SMNP, taken on the Northern slope of Abba Yared at 3900 m

7 Conclusion and perspectives

To recap, five research objectives have been proposed in the introduction of this memory. This chapter provides an opportunity to revisit these objectives. First of all, we take a look if a response was found at each of the questions asked in connection with the research objectives. We also return to the difficulties encountered in achieving the objectives and this work in general.

7.1 Review of the research objectives

The general objective of this Master's thesis was to show how an inventory of geomorphosites can improve the geomorphological knowledge and heritage management of a region and thus contribute to regional sustainable development in developing countries. The research objective was applied to the SMNP. In order to structure the work, six research objectives have been proposed and several research questions have been posed in relation to each of these objectives.

Objective 1: Knowing the geomorphology of the Simen Mountains National Park

It is essential to have sufficient knowledge of the geomorphology of the study area for which an inventory of geomorphosites shall be done. Although the Simen Mountains are maybe one of the better researched territories in Africa or Ethiopia, literature on geomorphology is less dense and topographic maps are less detailed than in other regions. We have spent a lot of time looking up information in geomorphological dictionaries to build our own hypothesis for some characteristic landforms, which we thought had to be part of a geomorphosite inventory of the SMNP. However, due to time pressure it was not possible to include all the sites that we felt merited to figure in such an inventory. This is in particular the case of an alluvial zone of the Wazla River at Islam Debir, which is the only alluvial zone within the park perimeter and springs at Sebat Minch (seven springs in Amharic). No scientific literature is available for these sites and to document them from the very beginning was not possible. However, it is recommended to consider them in further phases of geoheritage research or projects in Simen. They show distinct landforms of active fluvial and hydrological processes in Simen.

It is clear that the context of our research was different from that one of earlier Master's thesis studies at the University of Lausanne which conducted geomorphosite inventories in several regions of Switzerland (Kozlik, 2006; Genoud, 2008; Perret, 2008; Duhem 2008; Pagano, 2008; Maillard, 2009; Grangier, 2013; Bussard, 2014; Clivaz, 2015). Topographic and geological maps at the scale of 1:25,000, aerial photographs (orthophotos) of extremely precise resolution (25 cm) and high resolution DTM's are perceived useful working tools for geomorphological analysis and the establishment of geomorphosite inventories (Bussard, 2014). We had to deal with the fact that no digital terrain models (DTM), aerial photographs other than from Google Earth or geological maps were available.

Another limiting factor was the extreme remoteness of the study area. Our time in Ethiopia and the Simen Mountains was limited to four months. It was clear that it would not be possible to return back for a quick survey for something we had forgotten during the fieldwork. Even from Debark where we had our base camp access to the park was not simple. Each trekking is connected to a lot of effort and organization. Moreover, very high administration workload and cultural differences were apparent during our field work. Diplomacy was important at various stages of work. It is to a large extent thanks to the welcoming and helpful people in Debark and Simen, some which have been working hard as cookers or muleteers during expeditions, welcoming and helpful ranger scouts in the SMNP, the great effort of several park experts and generosity of the Chief Warden of the SMNP that this research could be carried out. In fact, the field work proved to be essential. Numerous geomorphosites for which it was not possible to find information in literature or which were too small to discover on Google Earth photographs could be identified. All selected geomorphosites could be visited except for one moor on Analu (WYAorg021), moraines of the LIA on Ras Dejen (DEJgla020), and the summit of Kidis Yared where the volcanic centre is suggested (KDYstr003).

Which geomorphological and geological processes are involved in the formation of the Simen shield, the development of the extreme escarpment and the subsequent destruction of the whole massif? Which geomorphological processes and forms are inherited of the Last Cold Period in Simen (Late Glacial)? Which geomorphological processes and forms are active at the present time?

Geomorphological processes involved in the formation of the Simen Massif including the Northern Escarpment are mainly of structural and fluvial origin. The processes related to the geological structure could be distinguished between volcanic and tectonic processes. While the original volcanic process has stopped, tectonic and fluvial processes remain active up to present time. There are mainly two processes inherited of the Last Cold Period in Simen. Above 3500 m the overall landscape of Simen was periglacial and above 4000 m it was glacial reworked during the Last Cold Period. At present time fluvial, periglacial, anthropic, and organic processes are the most active processes in the SMNP. Fast-flowing streams and rivers and impressive waterfalls can be well observed during the wet season. In addition, there are numerous natural springs in Simen. It was not possible to represent these features through a separate geomorphosite, which must be regretted, however, most fluvial sites include characteristics of the hydrography. During our field work we also discovered certain gravity processes, however fluvial or periglacial process dominate over them. At the beginning of the Holocene a phase of more pronounced fluvial processes compared to today must have taken place. Evidence (gullying) is visible in the higher regions of Simen.

Objective 2: Select the sites

In an area of study like the SMNP covering more than 400 km^2, generally difficult of access with only limited scientific knowledge and cartographic material available that do not permit claiming the entire territory in a homogenous manner, the process of selection of sites that are documented and evaluated is essential. Determined by the relative extent of the study area which we did not know prior to the research and a limit of time and energy to spend on the inventory a mixed selection approach has been applied. The geomorphological sites were chosen according to the selection method of Perret (2014) and Reynard et al. (2015) given their spatial and temporal representativeness at the scale of the study area.

Certain sites were considered as geomorphological complexes or systems from the beginning of the selection process. Other sites were later grouped to form geomorphological complexes and systems where aggregates of sites were apparent. In this way a maximal diversity of forms could be inventoried. The applied method of the University of Lausanne implies an important phase of documentation with drafting a detailed description and reconstruction of the morphogenesis of the selected sites. If we share the opinion with other authors that in the context of regional inventories the interest to prepare detailed files is greater than assessing a large number of sites - the choice to write long and well-documented sheets results in reducing the number of potentially assessable sites (Perret, 2014). Although the selection of geomorphosites at a high scale-complexity is mostly preferable, in some cases we had to compromise on a unique isolated landform which may better be assessed individually and the creation of more complex sites and thus reducing the total number of sheets and time spent on the inventory. For instance, the Jinbar Waterfall had to be included and assessed with the river capture of Jinbar River (JBWflu005) or the largest moraine of Simen is part of the glacial system of the Western Dejen slope (RDJgla010).

Which are the most representative forms of the geomorphology of the SMNP? Are they related to rare or very broadly represented geomorphological processes? Which are the forms that have a particular interest and thus deserve to be considered in the assessment?

All the geomorphological processes, active in the past or at the present time, must be taken into account in the inventory so that it is considered to represent the geomorphology of the SMNP. The choice made by the person conducting the inventory is crucial since it determines the content of the latter. Hence, to represent the geomorphology of the Simen Mountains, structural, fluvial and glacial forms but also periglacial, anthropic and organic forms must be included in the inventory. More forms of the most frequently observed processes – these are at first place the structural and fluvial processes – have been included to the inventory. The rarity of the geomorphological forms in the

SMNP is diverse. Escarpments, gorges, glacial and periglacial deposits are frequently observed while glacial striations, natural arches or moors are rare landforms. Among the form-types found in abundance only two or three landforms were taken into consideration in the inventory. As stated by Clivaz (2015) the choice to include in the inventory several similar forms is justified through their abundance in the study area. The fact of including several moraines in the inventory indicates that the study area counts several, making the inventory truly representative.

Finally, it should be remembered that "*despite the well-defined protocol, the subjectivity and authors' choices are part of the selection process and inventory. This fact is certainly not a weakness. It must be considered whenever such inventory is made* (Perret & Reynard, 2014)." We believe that we have been able to extract from the ground a number of sites that all present interest from the geoheritage point of view.

Objective 3: Assess the geomorphosites

This objective is certainly the one to which we have devoted the most time. The realization of the evaluation sheets held the bulk of this work. The determination of the scientific value and additional value had to be made in the most objective manner possible, as it determines the priority of protective measures as well as the touristic and educational potential of the geomorphosites.

Research question

Is the proposed assessment method applicable for the SMNP? Which are the scientific and additional values of the sites? Which geomorphosites are particularly interesting for geotourism? Which sites are most vulnerable against human encroachments and need specific protection?

The goal was to asses the geomorphosites of the SMNP with the method developed at the University of Lausanne. The method has previously been used in regional studies in Switzerland, carried out within Master's theses at the University of Lausanne (Kozlik 2006; Duhem 2008; Genoud 2008; Pagano 2008; Perret 2008; Maillard 2009; Bussard, 2014; Clivaz, 2015) and was also applied, with some adaptations, in regional studies in Québec (Massé et al. 2011; Vigneault et al. 2011), Romania, Malta (Coratza et al. 2012) and Morocco (Boukhallad and El Khalki 2014). It is now possible to review the method for its suitability in a different area context, the Simen Mountains. This is likely to be of interest for future application of the method in other national parks and regions in Ethiopia or Africa.

It turns out that the method for the SMTP works relatively well. The method has provided useful results. The present geomorphological knowledge of the SMNP has been detected and is now accessible in a single document. In addition, some new findings on certain geomorphological sites have been provided. The scientific and additional values of the inventoried sites have been assessed. It has been possible to produce four synthesis maps. They show the geomorphological processes, intrinsic values, protection status and vulnerability as well as tourist and educational potentials of the sites. However, some adaptations to the method had to be made, mainly because national or regional inventories for the protection of natural and cultural heritage are not available in Ethiopia.

The method, which collects detailed information on the reconstruction of the morphogenesis, requires that the geomorphology of the study area is well known. Here comes the method to its limits. The available scientific documentation in Simen were just enough for an inventory, 21 sites could be documented. However, some tedious and detailed literature research have been necessary to find enough facts and data to justify the inclusion of certain sites in the inventory. The creation of new geomorphological knowledge can be a sub-target of an inventory as stated by Bussard (2014). But it must not be that the opening up of new geomorphological knowledge makes the bulk of the work. In this case, another inventory method is preferable, or the terrain may first have to be explored geomorphologically and geologically.

The "*Geoheritage Tool-kit*" developed by Brocx & Semeniuk (2009) could be an alternative method. Based on earlier works (Brocx & Semeniuk; 2007; Brocx, 2008) the authors propose a method to identify inter-related geological features at various scales for designating geoparks. "*Sites of geoheritage significance*" are allocated to four conceptual categories of geoheritage, scale of reference and level of significance and can be assigned to geosites, sites of special scientific interest, and geoparks. The Geoheritage Tool-kit developed in Western Australia and applied to a wide variety of geological settings is suggested being applicable worldwide. In the context of Northern Africa, it has already been applied to the Anti-Atlas of Marocco (Errami et al. 2011). The method applies a different "wider" conceptual framework and goes clearly less into details than thematic methods developed in Europe or Britain applicable to well-known terrains (Brocx & Semeniuk, 2015).

In summary, the chosen scientific method with the mentioned adjustments (cf. annex 2) was suitable to detect the geomorphological heritage of SMNP. However, the method cannot be recommended without reservation for other national parks and regions in Ethiopia and Africa. It would have to be decided case by case, depending on how well the terrain is already known. To our experience, the method is not preferable and probably not applicable for little explored areas.

Objective 4: Appraise geoconservation in Ethiopia

The goal was to critically appraise the management of geoheritage in Ethiopia. The flaws and potentials which must respectively be corrected and exploited in the future had to be identified. Five interviews with government experts and geoscientists have been conducted. Most of the information was received from one interview with Professor A. Asrat. The Chief Warden Mr. M. Beyadegelegne, the director of the National Parks and Wildlife Sanctuaries Coordination of EWCA K. Wakjira, the coordinator of the SMNP- Integrated Development Project (IDP) of the Austrian Development Cooperation (ADC) T. Mulu as well as Professor H. Hurni of the Centre for Development and Environment of the University of Bern did not hear about geopark before. And only K. Wakjira already knew something about the concept of geotourism. All of the discussions we had with experts were very stimulating for our research and interests but it was not possible to interweave equally information and knowledge from all interviews, as this would have gone beyond the scope of this work. The result presented in previous chapters and summarised below constitute a solid basis to develop own strategies for the management of the geomorphological heritage in the SMNP.

Research question

What are the major challenges and opportunities for the development of geoconservation in Ethiopia? What is the potential for the development of geotourism in Ethiopia? What are the difficulties to found a geopark in Ethiopia?

There is no doubt, Ethiopia has a very unique geology and geodiversity. The country constitutes one of the most significant environmental and cultural reserves on Earth. It hosts numerous geoheritage sites some of which are granted World Heritage status. Geoscientists have indicated the potential of geotourism in view of the development endeavours of Ethiopia. They also call the attention of the general public and the government to manage and conserve the resource in a more sustainable manner. Although still neglected, there is a growing interest among government people and the tourism industry that the country has to capitalise on the geological, geomorphological, archaeological, cultural etc. particularities, which make Ethiopia truly unique and distinct from other regions. Like Kenya or Tanzania for example have unique wildlife, Ethiopia offers similar qualities in terms of its geodiversity and important geoheritage.

In theory Global Geoparks supported by UNESCO are the opportunity to promote and manage the heritage of a region in the most holistic manner possible and to inform and educate the wider public about Earth's history through the development of geotourism based on local participation. In Ethiopia, there have been various attempts to rise up with the concept of geopark. However, as long as there is no policy to support it, it is virtually not possible to present the idea and the benefit it is to engender to the public. In other words, it is not possible to receive a reply from local stakeholders and the government. This is mainly because there is currently no legislation which allows the protection of any sites of geoheritage significance in Ethiopia. A group of geoscientists is currently pushing the government to develop some policy framework, so there is hope for geosite and geopark nomination in the future. But, what comes to add another layer of complication is that Ethiopia is a federal state. To initiate geoconservation and geopark, one has to deal not only with the national but also with the regional government.

On the other hand, it is important to understand the priority of the country. Many parts of Ethiopia are poor. What they need is resource, economic development and infrastructure. So there is an important dilemma with (geo)conservation and development at the same time in general. Now that capitalism is coming very strongly people just want to grow. This may be a problem for future generation but it is the realty we face. In addition, Ethiopia has a complicated social, socio-economic and political situation and in terms of thinking it is different from Europe. The principles that have been proven to be reliable elsewhere, cannot simply be applied in Ethiopia. To consider that something has to be conserved under whatever conditions, even if the object of interest is a "world class geosite" will be unrealistic or even immoral. Land which the farmers use to meet their livelihoods by cultivating or grazing their cattle and this is the case in most parts of Ethiopia cannot simply be taken from them because it has to be conserved or because it is geologically interesting. Alternative livelihoods must be given to these people. Conservation in many parts of Ethiopia is not a matter of choice; it is almost always a matter of survival of people living in a particular area. These problems are extremely important to be recognized and appreciated when dealing with conservation projects. All the approaches should be within this context unless what it is going to be very mechanical and without application. Conservation has to be approached in a very systematic way because it is very much complicated in Ethiopia.

Objective 5: Elaborate a roadmap for the geoheritage management of the SMNP

Based on the research carried out, the aim was to elaborate a roadmap which helps to the holistic and sustainable management, protection and promotion of the inventoried geomorphosites. In the previous chapter (6) eight strategic objectives and working tasks have been considered and mapped: These are proposals for geotourism development such as production and establishment of geotourist maps, geo-trails, geo-trekkings, geo-sightseeing tours, interpretive panels as well as training of geo-guides and capacity building of the park staff and specific management of the Lemalimo site. Strategies and objectives whose feasibility is realistic, considered the limited financial and technical and human resources of the park and that bring only minor or no risks for the park have been preferred. The goal was to increase diversity and quality of tourism services through geotourism development and thus to create consciousness for geomorphosites without affecting the natural resources. The focus is on raising awareness of the Park on existence, vulnerability and tourist potential of geomorphosites. Through capacity building of technical park staff it is to ensure that the knowledge will be passed to scouts and the native population in the surroundings of the park. Local people should be empowered and benefit from geotourism.

Some thoughts, which we have been considering did not find place in the previous chapter. However, they may be worth to mention now. That is the case of an idea for a geo-interpretive centre in Chiro Leba (3300 m), the most important town in the Mesheha valley, located in the core of Simen but outside the National Park. With the recent development in the region Chiro Leba could become a new tourism centre (for gentle tourism). Trekking with pack animals to the surrounding peaks and the development of a geological museum (or environment education centre) in town could be proposed. A very particular geoheritage enhancement would be the introduction of zeppelin flights along the Northern Escarpment. This is an offer that exists for visitors of the Bernese Oberland, Switzerland (Schelling, 2015). Zeppelins run silently but for instance the shade of the airship may have an impact on wildlife disturbance (oral communication of a biologist). This had to be seriously checked beforehand. A more environmentally friendly alternative may be balloon flights but there is a problem with the need to return back to the starting point. On foot would be too far and to get back to a road might be very challenging or impossible either. Involvement of the local community is encouraged through the development of local crafts that are sold to tourists (Mulugeta, 2010). Ideally cooperation with hotels, tour operators, etc. should be formed. Agriculture products could present geological replicas of certain geomorphological features of the Simen Mountains.

As mentioned earlier (cf. point 6.1.7) due to limited internet resources many digital technologies especially those using mobile data transfers (for instance received with smart phones or tablets) are not fully functional on the ground. Nevertheless, the design of an interactive website with illustrative information that allows the localisation of geomorphosites (geovisualisation) may be useful and would allow international visitors to learn more on geomorphosites, to plan or track back their trekking itineraries back in their home countries (if not from a good internet coffee in Debark or Gonder). Ideally the information is accessible from the official park website (www.simienmountians.org). Though, one can wonder about the local sustainability of the idea. The technology would rather compete local job opportunities such as guided tours. An organisation from abroad would have to establish and maintain the website for the park since the resource are not available, not for the moment, at least not in Debark and perhaps not even in Addis Abeba. It can be understood as a long term input to be kept in mind with advanced economic and social development of the region. N. Cayla (2014) gives an updated overview of publications and web technologies applied to the management of geoheritage. For the time being it is still possible (and advisable) to integrate information about geomorphosites on the existing park site without greater interactivity. Last but not least a high quality guidebook for instance titled "The geoheritage of the SMNP or "Geotourism in Simen" could be published as a sort of popularisation of this Master's thesis.

In our discussion we have hardly dealt with the protection of geomorphosites. This is partly because most sites are in almost perfect state and the risks of damage or destruction are relatively low. In addition, there is a clear interest for promotion of the geomorphosites. Additional protective measures except visitor restrictions to certain sites are hardly practicable at present time and also make little sense. Nevertheless, let us remind that four sites sustain moderate and one site even important anthropic threats or damages (Figure 36). In particular, in construction projects (such as new eco-lodges and roads) within the park (which in accordance with the GMP generally are not accepted) the management should become active and check that no damage is unnecessary caused to geomorphosites. Guides should be made aware of certain vulnerable sites (ex. INYper016 and DEJgla020) so that they are cautious when visiting them and possibly inform visitors. We have not discussed so far the case of the farmland of Abmaras plateau (AMBant015) even though the site is under serious threats. The plateau makes subject to intensive cultivation by the farmers living in the surrounding settlements. Soil erosion processes heavily affect this land so that it is likely to change into badlands in a short term. The park encourages the farmers to implement Soil and Water Conservation Measures but only with limited success. Tourism however, should hardly have a negative impact on this site.

A Geopark could greatly improve the image of the park thus attract more visitors and researchers coming to conduct their study. The chance of the Simen Mountain's to make a Geopark is currently low although physically the region has all the potential. This is mainly because, the provision of appropriate legislation is required for which further awareness and support of the national government is necessary.

7.2 Conclusion and perspectives

This Master's thesis has revealed if an inventory of geomorphosites can foster or improve the knowledge and management of the geomorphological heritage in contexts of developing countries and so contribute to regional sustainable development. A geomorphosite inventory in the Simen Mountains National Park (SMNP), Ethiopia has been conducted. The work has been structured as follow: Identification, selection and assessment of the geomorphosites according the method of Reynard et al. (2015), appraisal of the national context of geoheritage and geoconservation in Ethiopia, elaboration of a road map for the management of the inventoried sites in the SMNP.

Ethiopia hosts numerous geoheritage sites, some of which of highest international significance. Therefore, geotourism has recently been promoted throughout the country (Asrat et al., 2008). Despite numerous trials of the scientific community there has been no chance until now to convince the government with a national policy for geoconservation (interview with A. Asrat). Many parts of Ethiopia are poor. What these people need is infrastructure and economic development. Conservation for them can simply not be a priority. Ethiopia has a very complicated social, socio-economic and political situation. This absolutely needs to be considered and appreciated when dealing with whatever conservation in Ethiopia. The study has shown that the Simen Mountains have potential to become a UNESCO Global Geopark. However, as long as there is no legislation which would support the idea it seems to be difficult to come up with geoparks in Ethiopia. Most authorities do not know or understand the concept.

Twenty-one geomorphosites have been identified and assessed. The main geomorphological contexts of the SMNP are fluvial, structural, glacial, periglacial, anthropic and organic in origin. The temporal stages which allow the reconstitution of the morphogenesis of the Simen Mountains are Cenozoic volcanism, Last Cold Period of Simen (Late Glacial), Holocene and historic/modern landscape modification. Four synthesis maps present the results of the assessment phase. The average scientific value of the inventoried geomorphosites is very high (0.83) compared to other inventories (around 0.68 in average) using the same method (Maillard & Reynard, 2011). Particularly the site's integrity is extremely high (0.96). Almost all geomorphosites are in a good state of conservation. Only few sites are vulnerable to human encroachment. The educational interest of most sites is high but interpretation facilities are absent. With some minor adjustments the application of the inventory method to the SMNP has proven successful and can be recommended for application to other park areas in Ethiopia of similar well documented geomorphology.

Based on the preceding studies and results of the inventory a road map for SMNP's geomorphosite management has been proposed. Eight strategic objectives and working tasks have been considered, which include the development of geotourism products such as geotourist maps, geo-trails, geo-trekkings, geo-sightseeing tours, and interpretive panels as well as the training of geo-guides and capacity building of the park staff and specific management of the Lemalimo site. The road map has been put on a map for visualisation. The overall goal is to raise awareness on the rich geomorphological heritage through geotourism development and empowerment of locals and thus contributing to long-term protection of the geomorphosites.

In conclusion, the study has revealed important potential for sustainable rural development in Simen. Applied research will be necessary on how exactly the mediation products should be developed. Many Global Geoparks may be interested on how to perform efficient geo-trainings to their staff or how to conceptualise guided geo-tours. Little research is available on the transmission of geosciences on the field to non-initiated audiences. What should be thought? Which are the most efficient interpretive methods? How is it possible to overcome the cultural and social differences as well as language barriers? Another research topic may deal with the implementation of a geoconservation policy in Ethiopia. What should be the policy and how to come forward under the current legal and socio-political situation in Ethiopia? The study has been successful for Simen. However, further experience and research is necessary in order to verify the result. For instance, what would be the result of a similar research in an urban region of Ethiopia or metropolis such as Addis Abeba?

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Corrections and additions of the expert H. Hurni

The altitude of Ras Dejen (4540 m) is now correct in this work except for figure 3. It has more recently been defined at 4540 m (oral communication H. Hurni). Indications of older measurements such as 4624 m, 4543 m or 4533 m are out of date and should not be used.

The transliteration of Lemalimo is wrong on figure 18, 26, 36, 44, 52 and on tables 4. Correct is Lemalimo and not Lemalemo.

The transliteration of the Chennek Medhanealem Cave (Church) on figure 18, 26, 36, 44 and on tables 4. Correct is Medhanealem and not Medhanyalem.

Remark: The Jinbar Valley is truncated at its upper end, as is Belegez Valley at Chennek and many others these should be other geomorphosites.

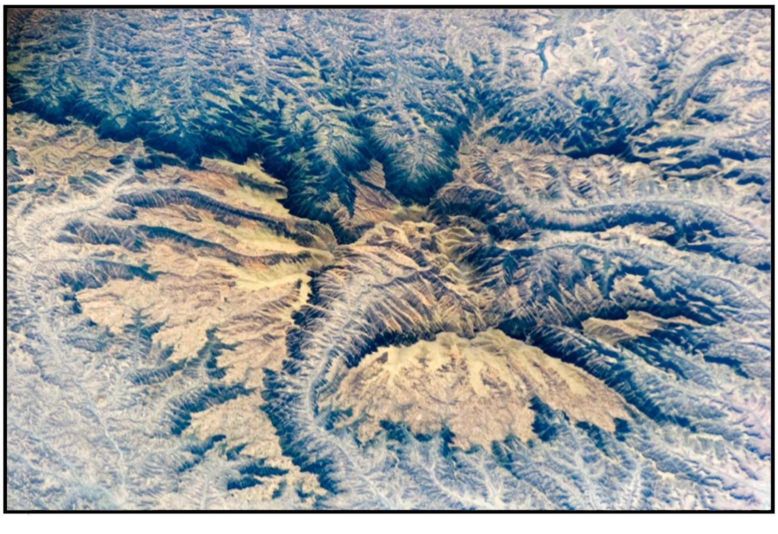
UNIL | Université de Lausanne
Faculté des géosciences
et de l'environnement

Master of Science in Geography

Geomorphosite Inventory of the Simen Mountains National Park
Methodology and inventory sheets

Lukas Mauerhofer

Under the supervision of Prof. Emmanuel Reynard (University of Lausanne)
and under the co-supervision of Prof. Asfawossen Asrat (Addis Ababa University)
Expert Prof. Hans Hurni (University of Bern)
In collaboration with Ethiopian Wildlife Conservation Authority (EWCA)



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Secrétariat du master en géographie | www.unil.ch/mastergeographie

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Illustration on the front page: Astronaut photograph of the Simen Mountains taken on the 16th of November 2007; view from north (Image Science & Analysis Laboratory, Johnson Space Centre, 2007)

Unless stated otherwise, all illustrations are from the author.

List of annexes

Annex 1: Interview guideline - expert interview on geoheritage and geoconservation in Ethiopia

Interview characteristics

Date: Place:

About the expert

Age:

Current function/position:

Professional and academic career (short):

Reference to the thematic:

Leading research question: What are the major challenges and opportunities for the development of geoconservation in Ethiopia? What is the potential for the development of geotourism in Ethiopia? What are the difficulties to found a geopark in Ethiopia?

The interview will take about 45 minutes.

1) What scientific work has been done in the field of geoheritage, geoconservation and geotourism in Ethiopia? What is the importance of geoheritage in Ethiopia?

2) Within what context do you see the research on geoheritage and geoconservation in Ethiopia? What difficulties and challenges to you face as a geoscientist in this country?

3) Is it possible to have a Geopark in Ethiopia (why)? Is the concept of Global Geopark suitable (applicable) for Ethiopia?

4) Which opportunities do you see for geotourism development in Ethiopia and the SMNP in particular?

5) Which major threads for the geoheritage of the SMNP do you see in the next 10 years? Would you recommend protective measures (which)?

Thank you!

Annex 2: Geomorphosite Inventory of the Simen Mountains National Park

This annex contains the inventory sheets of the geomorphosites of the Simen Mountains National Park. It is in divided in four parts. Part 1 encloses a sample project which describes the elements of the inventory sheet and the geomorphosite assessment methodology. Specific adaptations of the method to the study area are highlighted. The list of all the potential sites and the particularity of each site with a phrase justifying the site's selection or non-selection is found in part 2. Part 3 includes the list of the 21 assessed geomorphosites as well as the inventory sheets.

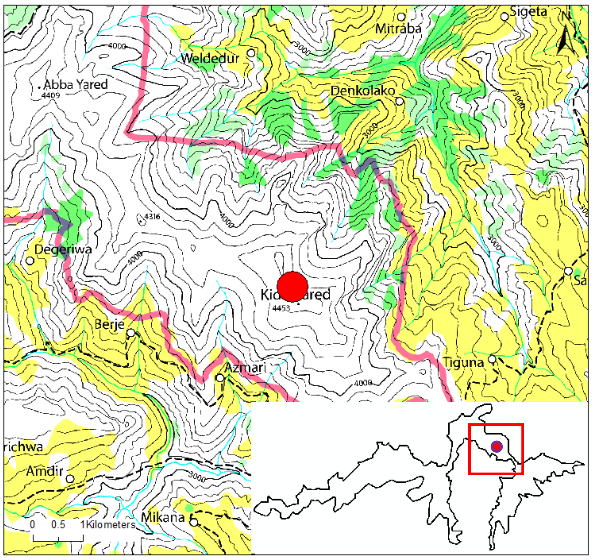
Contents

 SIMstr001[1]

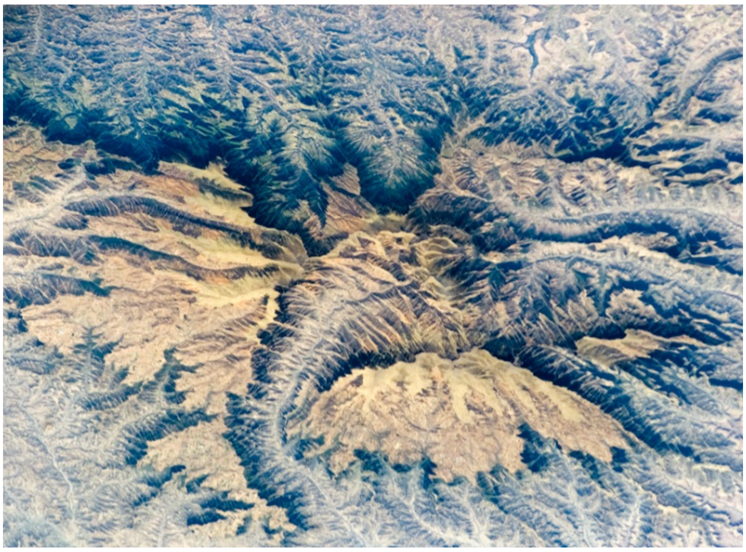
Sample project (Simen Mountains)[2]

Wereda(s) (Kebele(s)

Short description: Short statement on the site's composition and the dominant geomorphological process acting on it.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.



Source: Image Science & Analysis Laboratory, Johnson Space Centre, 2007

Coordinates**: N 13°18'1.30" / E 38°19'38.45"** Altitude: **2000 to 4533 m** Type: **AER**[3] Surface: **400 km²**

Property status: **PUB**[4] Characteristics: **natural and/or anthropic, inherited and/or active**

Protection status:

- The protection status could not be assessed as such database is not available (the method intends listing of the name or the number of elements of an inventory or of a regulation of protection which concern the site).
- The Simen Mountains National Park (SMNP), which was published under the Negarit Gazetta (No. 4 of 31st October 1969, Order No. 59 of 1969) to implement protection of the Park resources is the most prominent institution in the study area (Hurni, 2005).

[1] Identification code: CAPITAL LETTERS FOR THE REGION; small letters for the process or geomorphological context, numerical code for the site. Each code has three characters (e.g. SIMstr001 means Project Simen Mountains, structural form, geosite n°1). Codes used for the processes are the following: str=structural landforms, flu=fluvial, gla=glacial, per=periglacial, org=organic, ant=anthropic. Mixed forms (e.g. fluvio-periglacial) are classified under the dominant process.

[2] The specifications of this sample evaluation sheet are mostly adopted from Reynard et al. (2007) and Reynard et al. (2015). The text with **orange beige back colour** marks specific adaptations of the method to the study area.

[3] Type: PCT=point (e.g. spring, soil profile), LIN=linear (e.g. moraine ridge, river), AER=areal (e.g. a large canyon), useful information for GIS processing.

[4] Property status: As in Ethiopia land is owned by the State this information is superfluous. For the sake of completeness, the same notice (PUB) for "*public ownership*" was assigned to all sites (the assessment method was developed in Europe, particularly in the Swiss Alps with a much more complex institutional framework thus four characteristics "*private (PRI), association (ASS), public (PUB) and common-property (COM)*" were proposed).

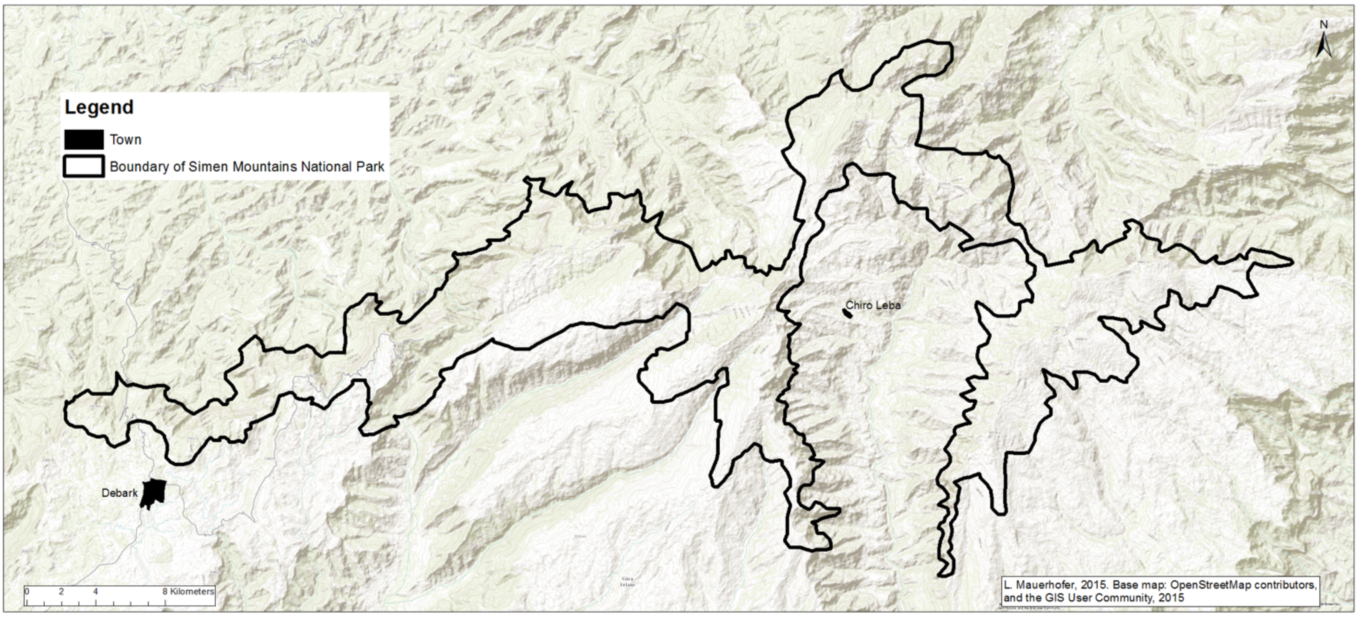
Description

The description is based on observations made by the assessor during fieldwork, as well as on document analyses (maps, air photographs) and literature survey. The description not only presents the geomorphological features, but also archaeological findings, human infrastructures, biotopes, etc.

Morphogenesis

The morphogenesis analysis emphasises the processes responsible for the landform genesis and development, and can include temporal information (dating) and information about landform activity. In a second phase, human transformations – if existing – are also analysed.

A simplified geomorphological map containing the site perimeter and other useful geomorphological information can be included (e.g. map below).



Map: Boundary of the Simen Mountains National Park (SMNP) demarcating the perimeter of the sample project.

Intrinsic value (The intrinsic value is divided into the central and additional values.)

Central value (The central value is the value of the site for the geosciences. It is evaluated relatively to the studied area.) *The four criteria of the scientific value are assessed by a brief description and by assigning a score from 0 (nil) to 1 (very high) rounded to the quarter point. The scientific value is the average of these four criteria.*		
Integrity	State of conservation of the site. Bad conservation may be due to natural factors (e.g. erosion) or human factors.	x.xx
Representativeness	Concerns the site's exemplarity. Used with respect to a reference space (here the SMNP). The selected sites should cover the main processes, active or relict, in the study area.	x.xx
Rareness	Concerns the rarity of the site with respect to a reference space (here the SMNP). The criterion serves to illustrate the exceptional landforms (e.g. unique in its shape, size or quality) in the area.	x.xx
Paleogeographical interest	Importance of the site for the Earth or climate history (e.g. reference site for a glacial stage).	x.xx
Scientific value	**0-0.19=nil, 0.2-0.39=low, 0,4-0.59=medium, 0.6-0.79=high, 0.8-1=very high**	**x.xx**

Additional values (In assessing the additional values, the aim is not to give an exhaustive analysis of the site in terms of ecology, culture or aesthetics but to highlight the possible links between geomorphology and other aspects of nature and culture based on bibliographical data and simple criteria)	
Ecological value (Determines the value of the geomorphosite in terms of ecology that is to say on the presence of certain species or habitats, the ecological diversity or on the ecological dynamics. In particular, it is interesting to assess the influence of geomorphological forms or processes on biodiversity)	
Ecological impact	Takes into account the importance of the geomorphosite for the development of a particular ecosystem or the presence of a particular fauna and vegetation. An escarpment area that constitutes an important habitat of the Walia Ibex for example, may be given a high score.
Protected site	It is considered that if the site is protected in a national inventory, or at cantonal or local level for ecological reasons (ex. marshes, alluvial zones, etc.), it has some ecological value. However, as such information was not available this criterion had to be dismissed.
Ecological value	**The ecological importance is synthesised semi-quantitatively (scale: very high, high, medium to high, medium to low, low, very low to nil). As the "protected site" criterion was elusive the ecological impact alone is the decisive factor.**

Aesthetic value (The aesthetic value is difficult to evaluate and quite subjective. This value is assessed based on the works of Grandgirard (1997), Droz and Miéville-Ott (2005) and Pralong (2006).	
View points	Takes into account the visibility of a site. A site covered by a forest or very difficult to access would, in this case, have a lower score than a site visible from several viewpoints.
Contrast, vertical development and space structuration	Indicates that the contrasting landscapes, landscapes with high vertical development or landscapes with presence of individual elements structuring the landscape are generally considered the nicest. Consequently, sites with colour contrasts (e.g. contrasts due to lithological changes), with high vertical development (e.g. peaks) or with spatial structures (e.g. large canyons or escarpments) will receive a higher score.
Aesthetic value	**The aesthetic importance is synthesised semi-quantitatively (scale: very high, high, medium to high, medium to low, low, very low to nil)**
Cultural value Based on the work of Panizza and Piacente (2003), the term "culture" is considered in a broad sense.	
Religious importance	Concerns sites that have a "religious", "mythological" or "mystic" value.
Historical importance	Covers history in a broad sense, thereby including archaeology, prehistory and history, and takes into account the presence of vestiges. In Simen this concerns in particular the choice of a historical route due to an appropriate location, which allows overcoming the mountainous reliefs. For example, the Northern Escarpment is reasonably easy to overcome at Lemalimo even with pack animals. The same with the Mesheha valley, it is easily to overcome when compared to narrow gorges. On the other hand, the occurrence of flat structural terraces and high plateaux suitable for cultivation have influenced the history of human settlement and land seizure in Simen.
Artistic and literature importance	Concerns the presence of the site in artistic realisations (e.g. paintings, sculptures) and in books and poems. There is not much artistic documentation available in Simen. Some people may recognise a human face in the monumental cliff wall of the Northern Escarpment when observed from Chennek. We consider this an artistic importance because it is an interesting artistic interpretation of the rock wall by locals.
Economic importance	Is obtained by a qualitative - and, if possible, quantitative - assessment (e.g. number of visitors, benefits) of the products generated by the geomorphosite. Only the income actually produced by the presence of the geomorphosite is evaluated (e.g. number of entrances in a tourist site), and not potential income or indirect income (e.g. the presence of a hotel in the surroundings of a tourist cave). It can be for instance said that Ras Dejen as the country's highest peak is a main attraction for visitors to Ethiopia (however visitor number is not quantified). As the most upper catchments areas of tributaries to the Tekeze river, Simen has an important role in terms of water resource supply and management for downstream irrigation and livelihoods. The dense channel system of tributaries of the Ansiya and Inzo river on the food of the Northern Escarpment between Muchila and Dihwara supplying fresh water even during the driest months of the year highlights this. We consider specific water resource supply also as a sort of economic importance which can be attributed to the cultural value of a geomorphosite.
Geohistorical importance	Sites of key discoveries in the history of Earth Sciences or operating places of geological resources.
Cultural value	**The cultural importance is synthesised semi-quantitatively (scale: very high, high, medium to high, medium to low, low, very low to nil)**

Use and management characteristics (The goal is to gather information about the site's management. This is important in the perspective of the development of management measures of the site)

Protection of the site	
Protection status	Serves to describe the level of protection of the site, which in previous geomorphosite inventories was done by referring to the site's affiliation in an inventory, listing of natural reserves, regulation of protection, etc. The SMNP provides alone the relevant institutional framework of the study area (national inventories etc. are not available in Ethiopia), thus the level of protection basically is the same for all sites. However, it was assessed whether a site was fully or partly comprised within the national park boundaries, if priority regarding the biological conservation is mentioned in the General Management Plan of the SMNP (FZS & ADC, 2009) and if the site has religious taboos (that can be considered as informal rules).
Damages and threats	The objective is to document the effective and potential degradations which jeopardise the quality of the site. Natural (fluvial erosion, weathering) and anthropogenic (soil erosion, constructions) degradations are considered. Only the potential damage in a short and medium term (i.e. 5 to 20 years) related to concrete changes is recorded. This is the case of sites concerned with tourism or transport infrastructures or sites subject to active erosional processes. Long-term potential threats (more than one human generation) are not documented.

Promotion of the site	
Visit conditions	
Accessibility	Three characteristics are documented: a. location of the closest car access (ex. a campsite, a village or a hop-off point along the road) and approximate driving time from Debark. b. walking time from the closest location accessible by car. c. walking difficulty (steep slopes, slippery trail, no tracks).
Security	The risk of accidents is documented here. Only the natural hazards, related to the geosite context (e.g. potential rockfall, high cliffs) are documented. The risks related to inappropriate behaviour are not documented.
Site context	Positive (e.g. great landscape, calm environment) and negative aspects (noise, presence of vegetation or constructions hiding the site) of the geomorphosite environment are documented here.
Touristic infrastructure	Tourism infrastructures close to the site are documented: camping grounds, community or ecolodges, restaurants, ranger outposts, open markets etc.
Visit conditions	**Synthesis of the visit conditions in one phrase.**
Education	
Education interest	The potential for interpretation is documented qualitatively. The focus is on the evaluation of the "readability" of the site. This means to determine whether the form or the process can be identified only by a specialist (low educational interest) or also by non-specialist visitors (high educational interest).
Interpretation facilities	The existence of interpretive facilities, both in situ (e.g. panels) and ex situ (booklet, website, flyer, etc.) as well as guided visits have been checked for each of the sites. For none of the geomorphosites in Simen exist such promotion tools.
Educational interest	**Synthesis of the education interest (scale: low, medium, rather high, high).**

Synthesis

Global intrinsic value

Gives a global intrinsic value of the site and makes a global comment on the central and additional values of the site.

Use and management

Brief description of the situation concerning the use and management issues (protection and promotion).

Management measures and proposals

Allows the assessor to propose protection (e.g. technical measures such as fencing, and institutional measures such as protection decree, management policy) and promotion measures (e.g. educational program, interpretive facilities development, networking with other sites).

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Author

L. Mauerhofer (2016)

Annexe(s)

List of potential geomorphosites

***selection remarks:** selected sites, regrouped sites, (non-selected sites)

ID	name (toponym)	form-type	process	temporal stage	complexity	location	description	selection remarks*	reference
1	Badlands at Dilibiza	badland	**anthropic**	historical times	group of forms	surrounding of Dilibiza (Beyeda) at approx. 3200m	former cultivations, now eroded not even grass vegetation grows	(outside the study area)	Hurni, 1982, p. 148
2	Cultivated land at Ambaras plateau	agriculture terrace	**anthropic**	historical times to present time	group of forms	13°14'03.72" N / 38°08'17.46" E	"The Ambaras plateau is inhabited by subsistence farmers leading to deep erosion of the deeply weathered basalts."	best specimen of this form-type with good access	field observation, Asrat el al., 2012
3	Soil erosion at Gich village	soil erosion form	**anthropic**	historical times to present time	group of forms	below Gich village	the erosion forms caused by surface run-off are sheet erosion, rill erosion and gully erosion	exemplary site	field observation, Hurni, 1978
4	Conical deposit (Mey valley)	alluvial fan	**fluvial**	last cold period	isolated form	Mey valley, (Beyeda) at 3420 m	rubble on valley floors	(outside the study area, not not much exemplary specimen)	Hurni, 1982, p. 108
5	Postglacial gullies on the Southern side of Bwahit	postglacial gully	**fluvial**	Holocene	group of forms	Southern side of Bwahit	periglacial slope deposits carved by postglacial gullies	most exemplary site of this form-type with good access	Hurni, 1982, p. 100, 143
6	Postglacial gullying in the Jinbar valley	postglacial gully	**fluvial**	Holocene	group of forms	upper Jinbar river downwards towards WSW, 3900 - 3350 m	up to 15 m thick deposits are intersected on the valley floor	(form-type already represented with ID 14)	Hurni, 1982, p. 103, 144

ID	name (toponym)	form-type	process	temporal stage	complexity	location	description	selection remarks*	reference
7	Postglacial gullies on the Northern side of Bwahit	postglacial gully	**fluvial**	Holocene	group of forms	Northern side of Bwahit	funnel-shaped converging gullies	(form-type already represented with ID 14)	Hurni, 1982, 123, 144
8	Alluvial zone of Wazla river (near Islam Debir)	alluvial zone, braided river, erosion or terrace edge, alluvial fan	**fluvial**	Holocene to present time	geomorphological complex	13°12'54.59" N/ 38°02'14.19" E	the only area within the SMNP with dominant alluvial processes, deposition of heavy boulders and gravel dragged along by numerous mountain torrents, braided river	(missing scientific data, missing time for more profound study)	observation on Google earth, field observation
9	Canyon of Mesheha	canyon, cuesta, ravine, gorge	**fluvial**	Cenozoic (to present time)	geomorphological system	Mesheha valley	large valley said to be as spectacular as the Grand Canyon in Arizona, USA (Hurni, 1986)	unique and exemplary site	observation on maps, Google earth, field observation
10	Structural terraces and torrential system on the foot of the Northern Escarpment	cuesta, ravine, gorge, debris flow channel	**fluvial**	Cenozoic to present time	geomorphological system	on the foot of the escarpment from Muchila to Dihwara	channel system of the Ansiya and Inzo river	unique and exemplary site	field observation
11	River capture (Jinbar waterfall)	waterfall, elbow of capture, predatory stream, underfit stream, beheaded valley	**fluvial**	Cenozoic (to present time)	geomorphological system	13°14'21.70" N / 38°04'29.72" E	headward erosion of the Inzo river and stream capture of the Jinbar river. Site named Gich Abyss in Asrat et al., 2012	unique and exemplary site with good access	observation on maps and Google earth, Asrat et al., 2012

ID	name (toponym)	form-type	process	temporal stage	complexity	location	description	selection remarks*	reference
12	Fluvio-solifluvial valley deposit (Argin village)	fluvio-periglacial deposit	**fluvio-periglacial**	last cold period	group of forms	13°14'42.00" N / 38°10'32.48" E (at Argin)	rubble on valley floors	one of the most exemplary fluvio-periglacial deposit	Hurni, 1982, p. 108, 123
13	Solifluction deposit near Atgeba village	periglacial deposit, fluvio-periglacial deposit	**fluvio-periglacial**	last cold period	geomorphological system	10km from Atgeba village	rubble on trough-shaped slopes 3650 m (solifluvial slope deposit) / rubble on valley floors below 3650 m (fluvio-solifluvial valley deposit)	(there is specimen in the region which better represents these form-types)	Hurni, 1982, p. 108
14	Fluvio-solifluvial deposit (Ambaras Tekokor river)	fluvio-periglacial deposit	**fluvio-periglacial**	last cold period	isolated form	Ambaras Tekokor river (3605 m), SSW aspect	transition forms (not mapped)	(not much exemplary specimen)	Hurni, 1982, p. 110
15	Solifluction deposit on the NW aspect of Ras Dejen	periglacial deposit, fluvio-periglacial deposit	**fluvio-periglacial**	last cold period	geomorphological system	below 3900 m and above 3400 m	valley of Maje best example of flowing transition of periglacial and fluvial forms	one of the most exemplary site of periglacial and fluvio-periglacial deposits, regrouped with ID 12 to project 010	Hurni, 1982, p. 111
16	Glaciation on Bwahit-Mesarerya mountains	cirque, moraine, moor	**glacial**	last cold period	geomorphological system	Bwahit 4430 m and Mesarerya 4353 m, above 4100 m	last cold period glaciation surface of 1.6 km2	Bwahit is exemplary of glacial forms with good access, represented by project 007	Hurni, 1982, p. 113
17	Glaciation on Silki-Abba Yared summit group	cirque, moraine, striation, snow moraine	**glacial**	last cold period	geomorphological complex	above 3750 m, NW-NE aspect, striation at 4200 m	Silki 4420 m and Abba Yared 4409 m, most pronounced glacial forms of Simen	unique and exemplary snow moraine and striation, represented by project 011	Hurni, 1982, p. 114

ID	name (toponym)	form-type	process	temporal stage	complexity	location	description	selection remarks*	reference
18	Glaciation on Kidis Yared summit	cirque, moraine, snow moraine	**glacial**	last cold period	geomorphological complex	N-NW aspect above 4000 m (snow moraine S slope at 4400)	Kidis Yared (4453 m),glaciation surface of Yared-group 4.5 km2 (with Silki)	(not the most exemplary specimen of this form-type)	Hurni,1982, p 114
19	Glaciation on the Dejen massif	cirque, moraine, snow moraine	**glacial**	last cold period	geomorphological system	mostly NW aspect above 3900 m	Ras Dejen highest peak of Ethiopia (4553 m), most extended glacial forms of Simen (6.9 km2), largest moraine of Simen with 50 m thickness	exemplary and unique site, regrouped with ID 8 to project 010	Hurni, 1982, p. 115
20	Moraine crests of a former glaciation before the LGM (Loba village)	moraine	**glacial**	Cenozoic (Paleocene)	group of forms	Loba and Bahramba village between 2600 and 2800 m	left-overs of eroded deposits on valley floors often interpreted as moraines (ex. Nillson 1940 p. 61, Werdecker 1955 p. 314), more detailed field analyses are needed	(outside the study area)	Hurni, 1982, p. 100, 143
21	Possible moraines of the Little Ice Age (Ras Dejen summit)	moraine	**glacial**	historical times	group of forms	13°13'27.19" N / 38°22'36.53" E	the only glacial deposits of the LIA	rare landform	Grab, 2002; Google earth

ID	name (toponym)	form-type	process	temporal stage	complexity	location	description	selection remarks*	reference
22	Water source at Sebat Minch	spring	**hydrographic**	Holocene to present time	group of forms	13°10'35.90"N / 38°11'50.88"E (below the ranger outpost)	"Sebat Minch" means seven springs in Amharic, recent construction of a water supply for the outpost	(missing scientific data, missing time for more profound study)	Oral transmission of park staff, Google earth
23	Andosol-soils (Jinbar valley)	soil developed on rocks	**organic**	Holocene to present time	group of forms	natural grassland and forest 20 km2 of in total 30 km2	pedogenesis was most active after a period of intensive natural erosion and before anthropic soil erosion; 20t/ha annual soil loss on cultivated land, 2t/ha on natural grassland (Hurni, 1975)	one soil profile at Gich selected, represented by project 013?	Hurni, 1982, p. 147, 150, 152
24	Moor on Analu	moor	**organic**	Holocene to present time	isolated form	13°15'26.06" N / 38°24'47.22" E	moor triggered by a humid catchment of last cold period glacial deposits	most exemplary specimen of this form-type, regrouped with ID39 to project 021	Hurni, 1982, 115; Google earth
25	Solifluvial slope deposit (Jinbar valley)	periglacial deposit	**periglacial**	last cold period	group of forms	upper Jinbar river downwards towards WSW, 3900 - 3350 m	rubble on trough-shaped slopes	one of the best visible periglacial deposit	Hurni, 1982, p. 103
26	Slope development through periglacial solifluction (Jinbar valley)	periglacial deposit	**periglacial**	last cold period	group of forms	upper Jinbar valley (southern aspect), 2 km SW of Imet Gogo	rubble on trough-shaped slopes (horizon forming)	(site not clearly identifiable)	Hurni, 1982, p. 106

ID	name (toponym)	form-type	process	temporal stage	complexity	location	description	selection remarks*	reference
27	Fine earth ribbons (Bwahit summit)	fine earth ribbon	**periglacial**	Holocene to present time	group of forms	above 3600 m up to summits, ex. Northern facing aspect of Bwahit at 4300 m	needle ice effect, cf. Hastenrath, 1974, p. 178; Furrer and Graf, 1978, p. 445	(site not clearly identifiable)	Hurni, 1982, p. 160, 162
28	Vegetation terracettes and turf exfoliation on a plain (Mesarerya resp. Inatye)	vegetation terracette (turf exfoliation)	**periglacial**	Holocene to present time	group of forms	ex. Northern aspect of Mesererya at 4200 m (and Inatye high plateau at 4000 m)	dominant solifluction form at the high range of 100-150 m below the limit of vegetation at 4225 m,	Inatye high plateau is an exemplary specimen of this form-type with good access, represented by project 010	Hurni, 1982, p. 161, 162
29	Mud bands or mud polygons on a plain (Weynobar resp. Mesarerya)	patterned ground	**periglacial**	Holocene to present time	group of forms	ex. Southern aspect of Weynobar at 4400 m (and Northern facing aspect of Mesarerya at 4200 m)	dominant above the limit of vegetation (4225 m) up to limit of structural soil at 4300 m,	Weynobar is the most exemplary specimen, regrouped with ID22 to project 017	Hurni, 1982, p. 161, 163
30	Structural soil (Weynobar resp. Mesarerya)	patterned ground	**periglacial**	Holocene to present time	group of forms	summit area down to 4300 m, ex SW aspect of Weynobar at 4350 and N aspect of Mesarery at at 4340	stone stripes, stone tongues and stone polygone on a plain (stone polygones are rare bc litte plain area)	Weynobar is the most exemplary specimen, regrouped with ID 21 to project 017	Hurni, 1982, p. 163, 164
31	Peaty mounds like hummocks on Weynobar	hummock	**periglacial**	Holocene to present time	group of forms	13°15'30.73"N /38°24'45.06"E	hummocks (thufur, Islandic name) with dimensions of tens of cm, covered with moos	rare form-type, regrouped with ID 40 to project 021	field observation

ID	name (toponym)	form-type	process	temporal stage	complexity	location	description	selection remarks*	reference
32	Lemelemo escarpment (Northern Escarpment)	escarpment, cuesta, gorge	**structural**	Cenozoic (to present time)	geomorphological system	13°11'18.80" N / 37°53'33.34" E	"Horizontally to sub-horizontally bedded trap basalt sequences." In addition, deep valley gorges showing the interaction of fluvial process, rain erosion and man-made activities.	unique and exemplary site with good access	Asrat el al., 2012
33	Awaza peaks	outlier (butte and mesa)	**structural**	Cenozoic (to present time)	geomorphological complex	13°24'33.75"N / 38° 6'49.05"E	"The landmark view of the Simen Mountains. [...] These peaks are remnants of a deeply eroded ridge which forms the most distant fringes of the pyroclastic flows associated with the shield volcanism."	(outside the study area but partly documented of project 006)	Asrat el al., 2012
34	Chilkwanit escarpment (Northern Escarpment)	escarpment	**structural**	Cenozoic (to present time)	isolated form	13°12'30.69" N / 37°59'28.09" E	"Precipice of more than 1,000 m". A succession of both shield volcanic materials and the topmost part of the flood basalt sequence is exposed."	(Lemalimo (ID23) is the better specimen of this form-type)	Asrat el al., 2012

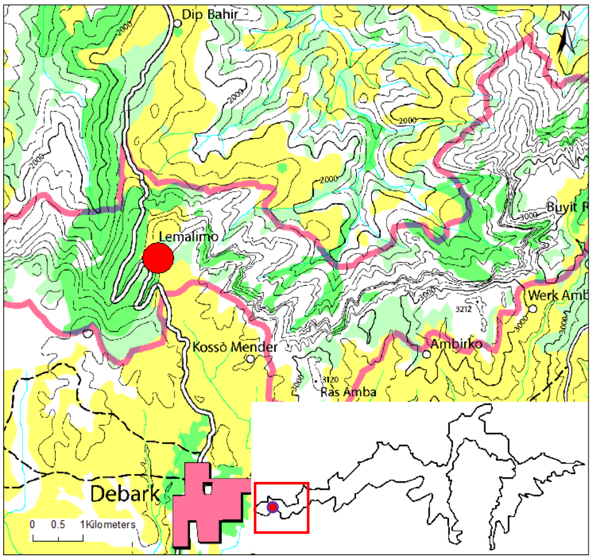
ID	name (toponym)	form-type	process	temporal stage	complexity	location	description	selection remarks*	reference
35	Sankabar land bridge	mountain ridge	**structural**	Cenozoic (to present time)	isolated form	13°13'48.25" N / 38°01'48.'1" E	"Narrow land bridge only about 0.5 km wide. To the north and south of this land bridge are very deep ravines and gorges more than 1,500 m deep bordered by vertical walls and precipices, with narrow but long waterfalls during the rainy season."	(similar to the form-type "escarpment" already represented by ID23 and ID27)	Asrat el al., 2012
36	Imet Gogo peak and Northern Escarpment (Chennek camp)	peak, escarpment	**structural**	Cenozoic (to present time)	geomorphological complex	13°17'11.02"N / 38°08'44.99" E	"A vertical edifice exposing horizontally layered volcanic sequences. A single cliff wall reaches more than 100 m."	unique and exemplary site with good acces	Asrat el al., 2012
37	Centre of the shield volcano	volcanic plug, dyke	**structural**	Cenozoic	geomorphological complex	Kidis Yared	several hundred meter long dykes	unique and exemplary site	Nillson 1940; Peters In Hurni, 1982, p. 96; Google earth
38	Chennek Medhanaelem cave	lava tube	**structural**	Cenozoic	isolated form	13°16'3.28" N / 38°12'12.23" E	the only known cavity of this size in the region	unique site	Oral transmission of local people , field observation
39	Natural arches (Kedadit outlook)	natural arch	**structural**	last cold period to present time	group of forms	13°14'9.82" N / 38°13'10.84" E and 13°16'36.93" N / 38° 6'12.50" E	circled rock holes (1m diameter)	unique site	field observation

List of the assessed geomorphosites and inventory sheets

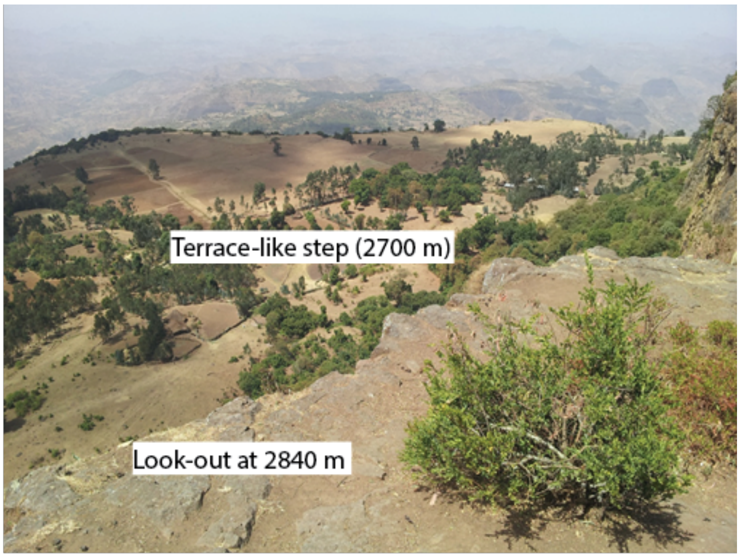
Lemalemo escarpment

Debark (Debir, Zebena, Dip Bahir)

Short description: The Lemalemo escarpement denotes a small section of the prominent and dramatic Northern Escarpement of the Simen Massif where the continuous interplay of natural erosion and man-made activities results in complete exposure of the volcanic sequences to the extent that individual layers can be easily discerned from a distance of tens of kilometres (Asrat et al., 2012).



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.



Coordinates: **N 13°11'48.58" / E 37°53'27.29"**	Altitude: **2000 m** to **2900 m**	Type: **AER**	Surface: **5.9 km^2**

Property status: **PUB** Characteristics: **natural, active**

Description

The site includes a small section of the prominent and dramatic **Northern Escarpment** of the Simen massif, 3.5 km north of Debark at 2900 m, from where the slope almost vertically falls down 200 m to the cultivated **terrace-like step** at Lemalemo village (2700 m) and over a second **scarp face** down to the ridges and valleys, which form the northern lowlands. The lower limit is given by the park border at approximatively 2000 m at the valley bottom of the **ravine** to the west, meaning a gradient of 50% (900 m) on 1.8 km horizontal distance (cf. annex 2). A. Asrat et al. (2012) already proposed the Lemalemo pass as a "geoconservation site". According to these authors "*almost a complete sequence of generally horizontal **flood basalt flows** and the lower parts of the **shield volcanic sequence** are exposed at the Lima Limo escarpment along the Zarema-Debark road [which connects northern Ethiopia from the town Shire (also known as Inda Selassie) with Gonder (cf. annex 3).] Lima Limo pass is a very famous stretch of highland road because of the monumental cliff walls above, and very deep and narrow ravines below the road, which follows the major scarp at the western margin of the Simen Mountains. Individual cliffs form nearly vertical walls of a couple of hundred meters'* height [(cf. annex 1)]. […] *A continuous interplay of natural erosion and man-made activities resulted in complete exposure of the volcanic sequences to the extent that individual layers could be easily discerned from a distance of tens of kilometres* (Asrat et al., 2012 : 16 & 18)."

Morphogenesis

The North-Western **Ethiopian Plateau** (NW-Highlands) cedes west to the North-Western **Ethiopian Lowlands** over a sharp escarpment (Asrat et al., 2012) most pronounced at the Simen Mountains referred to as the **Northern Escarpment** or Great Escarpment which extends about 150 km around west of Gondar and Lake Tana (Hurni, 1986).

Since it classifies as mega-landform, the morphogenesis of the Northern Escarpment is understood in the context of the whole Simen **shield** and formation of the Ethiopian Plateau. The Ethio-Arabian landmass witnessed intense **uplifting** that peaked during the Eocene (56 million to 34 million year ago) (Asrat et al., 2008). "*The tectonic force triggering the uplifting was so intense that it fractured the crust in several places, through which huge quantities of **flood basalts** poured out* (Asrat et al., 2008 : 21) ", "*during the Oligocene over a short time period of 1–2 Ma centred at about 30 Ma ago* (Hofmann et al. 1997, in Asrat et al., 2012 : 10)", "*forming the Early Tertiary Trap Series volcanics now underlying the highland plateaus of Ethiopia* (Asrat et al., 2008 : 21)". Shield volcanic edifices were later built over the **Trap Series** through eruptions from centralised vents "*at 31–30 Ma ago for the Simen shield, 23 Ma ago, and 11 Ma ago for other shields to the south* (Kieffer et al., 2004, in Asrat et al., 2012 : 16)." Further rising and shifting and "*powerful erosion coming from the northern lowland* (Aerni, 1978 : 101)" made possible those differences of elevation observed in the Simen Mountains nowadays.

A. Asrat et al. (2012 : 16) give an summary of the **petrogenesis** and **stratigraphy** at the Lemalemo escarpement that Kiefer et al. (2004) studied in detail.

> "*The **Lower Flood Basalt** formation is exposed between 1,200 m and ~1,800 m altitude and is comprised of 10–15 m thick, aphyric or sparsely phyric, massive basaltic flows at the bottom and sparsely to highly porphyritic, 10–15 m thick, massive basalt flows at the top, with no felsic rocks.*
>
> *The **Upper Flood basalt** formation is exposed between ~1,800 and ~2,700 m altitudes. It consists of highly Plag-porphyritic, 10–15 m thick, massive basalt flows and 30 m columnar-jointed basalt flow overlain by ~200 m thick rhyolitic tuffs and ignimbrites at the bottom, and intercalations of sparsely porphyritic, 10–15 m thick, massive lava flows and thin beds of columnar-jointed obsidians and tuffs, at the top. Thin beds of scoriaceous basalts and numerous palaeosols are also commonly exposed interspersed within the lava flows.*
>
> *The contact between the upper flood basalt formation and the **shield volcano** is exposed at an altitude of ~2,700 m, and dips about 5° away from the summit of the shield. [The shield volcanic sequences form up to 3 m thick], discontinuous beds of slightly to highly porphritic basalts at the bottom, highly propyritic trachybasalt flows in the middle, and more heterogeneous intercalations of columnar-jointed slightly porphyritic basalt, highly porphyritic trachybasalt, trachytic and rhyolitic tuff, as well as columnar-jointed, slightly porphyritic alkali basalt, at the top*."

The terrace-like step at Lemalemo village originates from **differential erosion** of more resistant lithological units (called **caprocks**), protecting underlying softer rocks (cf. sheet nr. 6).

Intrinsic value

Central value		
Integrity	The road could be seen as harmful to the site's integrity; however, it appears to us as an integral part of the site.	1
Representativeness	The site represents extremely well the structural geomorphology and geology respectively the Northern Escarpment for which Simen is so famous.	1
Rareness	It is one of the places where the Northern Escarpment is most impressive and individual lava layer of volcanic sequences can be well observed even from a distance of tens of kilometres.	0.75
Paleogeographical interest	The stratigraphy of the volcanic sequences were analysed here and exact dating of the active volcanic period of Simen could be achieved.	1
Scientific value	**Very high**	**0.94**

Additional values	
Ecological value	
Ecological impact	The General Management Plan (FZS and ADC, 2009 : 32-33) states that "*the remarkable natural value of SMNP, particularly its huge diversity of fauna and flora, is partly attributed to its extreme altitudinal variation. […] [Relatively large patches of intact montane forest are] found on the less steep parts of the escarpment leading to the lowland plateaux at the northern end of the park and the newly included Limalmo Wildlife Reserve (LWR) on the western side. […] The biodiversity in the montane forest is generally much higher than on the highland plateau. Most common trees are Juniperous procera, Hagenia abyssinica, Olea chrysophylla, Cordia africana, Ficus spp. and Szygium guineense, almost all of which are endemic to Ethiopia and threatened* (2009 : 32-33)."
Ecological value	**Very high**
Aesthetic value	
View points	The Lemalimo lookout is situated on the edge of the highest step of the Northern Escarpment with the drop to the more than 1500 m deeper laying gorges in front. Individual vertical cliffs wall are well observed from the main road from the distance of tens of kilometres.
Contrasts, vertical development and space structuration	The vertical development of the Northern Escarpment (up to 2000 m) is so important that it remains a structural feature of the Earth's surface even when seen from an aircraft. The contrast depends on the sun light and the season, the northern to northwestern facing slope remains longer hidden in the shadow in winter months during the morning hours.
Aesthetic value	**Very high**
Cultural value	
Historical importance	"*Simen is located between the old centres Aksum/Adwa in the north, Gonder in the southwest and Lalibela in the southeast. […] The western caravan route led from Aksum/Adwa over Adi Arkay, Debark to Gonder, closely following the course of today's main road built by the Italians. The main obstacles were the crossing of the Tekeze, and in the north of Debark the negotiation of the escarpment ("Limalmon, Wulkifit")* (Stähli, 1978 : 43)."
Economic importance	Nowadays the Lemalimo escarpment is an important touristic attraction.
Cultural value	**Very high**

Use and management characteristics

Protection of the site	
Protection status	Lemalemo is part of the National Park and particularly its montane forest is referred to have "*high conservation priority and require priority protection* (FZS and ADC, 2009 : 33)."
Damages and threats	No damages. The construction of infrastructure such as power lines and modern human settlement might threaten the site in the medium term (20 years).

Promotion of the site	
Visit conditions	
Accessibility	Well accessible within few minutes by car from Debark or Dip Bahir over the main road. Walking from Lemalemo on the top of the escarpment to the lookout takes 15 minutes. There is a possibility to take the path, which leads down the escarpment to Lemalemo village. This longer walk takes between 2 and 3 hours (down and up). There is no special walking difficulty to reach the lookout. The trail leading down to Lemalemo village is steep, not easy to recognise and dry rubble may be very slippery.
Security	The trail down to Lemalemo village bears no real danger to fall over the scarp but it is easy to slip on the dry rubble and thus have an accident. As the temperature is much hotter down the escarpment, carrying enough water is crucial.
Site context	Lemalemo lookout offers breath-taking scenery in very calm and natural environment with birds singing on the trees and Gelada Baboons often seen on the top of the escarpment (African Wildlife Foundation, 2014). During rainy season a waterfall dropping over the escarpment adorns the site context.
Touristic infrastructure	Kids sell cool beverages and next to the road there is a ranger outpost. However, for accommodation visitors have to stay in Debark (and possibly at Dip Bahir). Currently under construction is the Lemalemo lodge, which will be a high range ecolodge located on the top of the hill at Lemalemo.
Visit conditions	**Within close proximity to Debark and the new Lemalemo lodge under construction, visit conditions will be excellent.**
Education	
Education interest	Volcanic sequences can be well observed also by non-specialist visitors. Even though the contact of the flood basalt formation and the shield volcano is hard to find in the lithology, the transition zone can be indicated as the geological unit at the altitude of the terrace-like step at 2700 m. This characteristic structural landform capped with a resistant rock unit demonstrates the concept of differential erosion. As a whole the site demonstrates a unique evidence for the Ethiopian Plateau (NW-Highlands) ceding to the North-Western Ethiopian Lowlands over the dramatic escarpment (Northern Escarpment). The geological processes of rifting and uplifting of the landmass involved in the formation of the escarpment are difficult to understand just by observing this site.
Interpretation facilities	No interpretation facilities.
Educational interest	**High**

Synthesis

Global intrinsic value

The global intrinsic value is very high as the site is exemplary of the structural geomorphology and geology of the region and of great importance for the reconstruction of the region's history of Earth. The very high additional, ecological, esthetical and cultural values underline this statement.

Use and management

The site is easily accessible on the road from Debark or even from Gonder (2 hours) and offers unique opportunities for geotourism as it illustrates particularly well the structural geomorphology and geology of the Simen Mountains. Moreover, it offers great possibilities for geoheritage enhancement by highlighting the links between geomorphology and other aspects of nature and culture (cf. very high additional values above). However, there are currently no existing interpretation facilities available. The fact being located inside the National Park has certainly a positive effect on the site's conservation even though recognition and protection status regarding the geological value is missing.

Management measures and proposals

As the site is in easy walking distance from Debark, it could be used to raise awareness of the geological and geomorphological importance of the local population (for instance excursions with school classes). Furthermore, a special geo-tour package for a day or half-day visit from Gonder including an overnight stay for example at Lemalemo logde could be proposed. Such an offer would respond to the frequent request of visitors for more specific information and exclusivity on their tours (African Wildlife Foundation, 2014).

A training for tourist guides should be proposed in cooperation with one or several specialist geotourism operator(s) so that a concrete demand would be satisfied. Another option is that the SMNP itself together with EWCA invests on the training of professional guides. The training should be given to a limited number of carefully selected candidates able to satisfy the demand for such exclusive visits and who will be officially certified guides of the SMNP if they guarantee a certain (high) standard on their tours.

The installation of educational panels next to the road and a booklet available at the information centre at the park headquarters proposing a trail dealing with geological subjects (geo-trail) for a self-guided visit are also suggested. Moreover, targeted visitor management and limitations is strongly recommended to prevent the negative impact of mass tourism without what the individual experience and economic value of the site will be greatly reduced shortly.

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Annex(s)

1. Cliffs showing individual lava layers as it is seen from the Zarima-Debark road (Asrat et al., 2012)

2. Almost vertical drop interrupted by the terrace-like step at Lemalemo Village, main road winding above to Debark.

3. Stratigraphic exposure at the Lemalemo escarpment showing a complete sequence of the flood basalt flows and the lower parts of the shield volcanic sequence (Kieffer et al., 2004)

Annex 1: Cliffs showing individual lava layers as it is seen from the Zarima-Debark road (Asrat et al., 2012)

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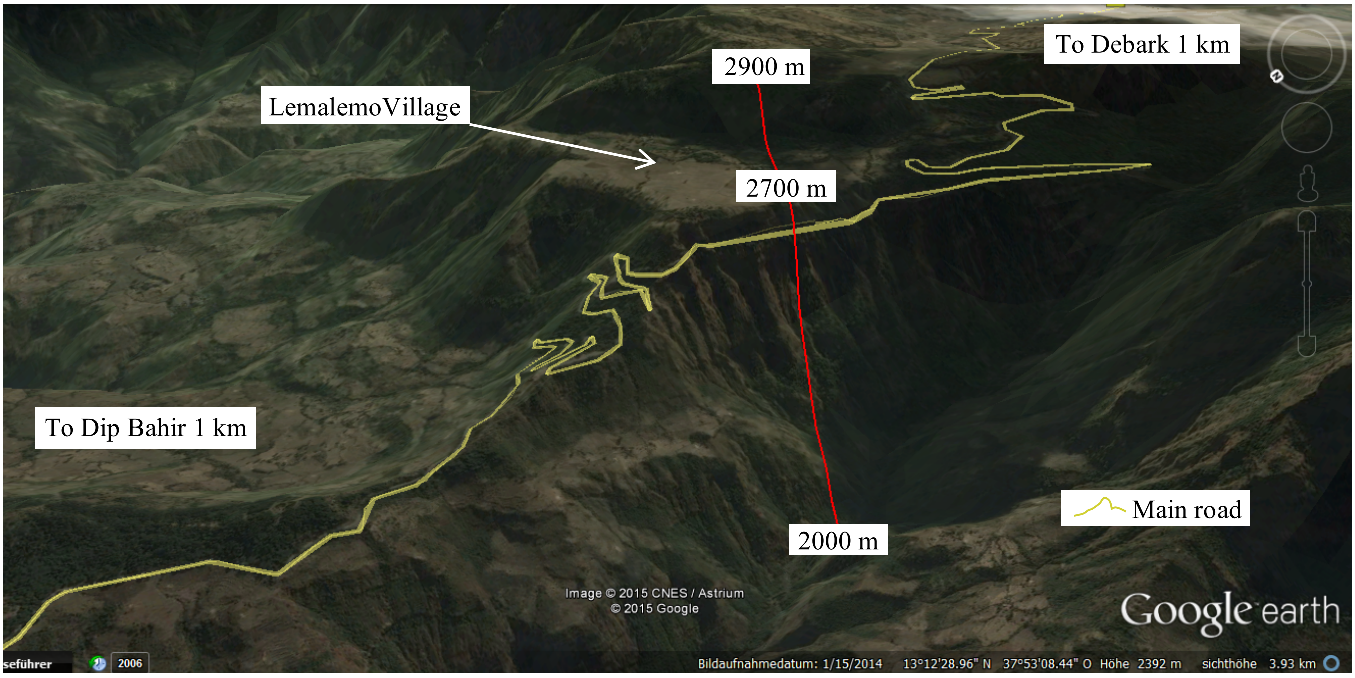


Annex 3: Stratigraphic exposure at the Lemalemo escarpment showing a complete sequence of the flood basalt flows and the lower parts of the shield volcanic sequence (Kieffer et al., 2004)

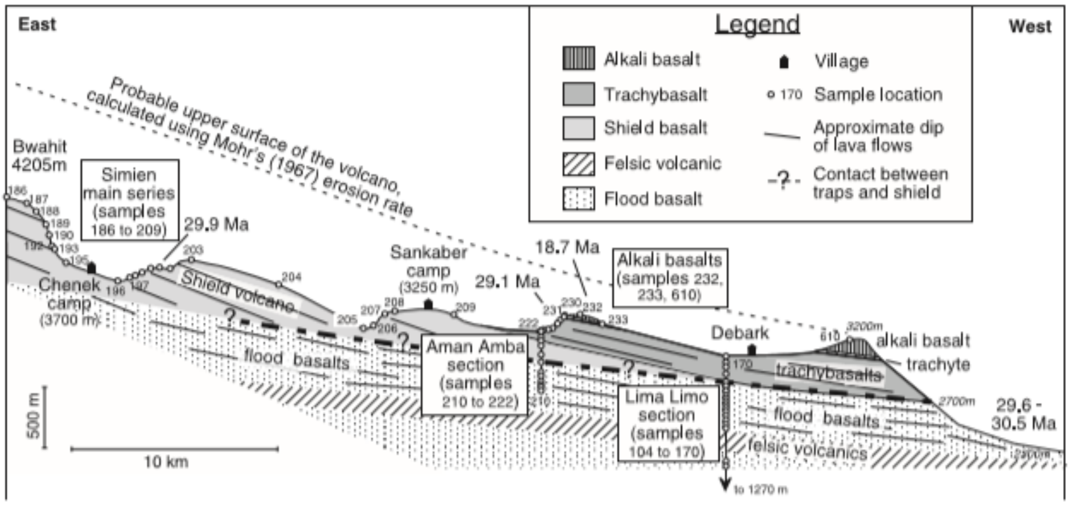


Fig. 3. Diagrammatic section through the Simien shield volcano and underlying flood basalts.

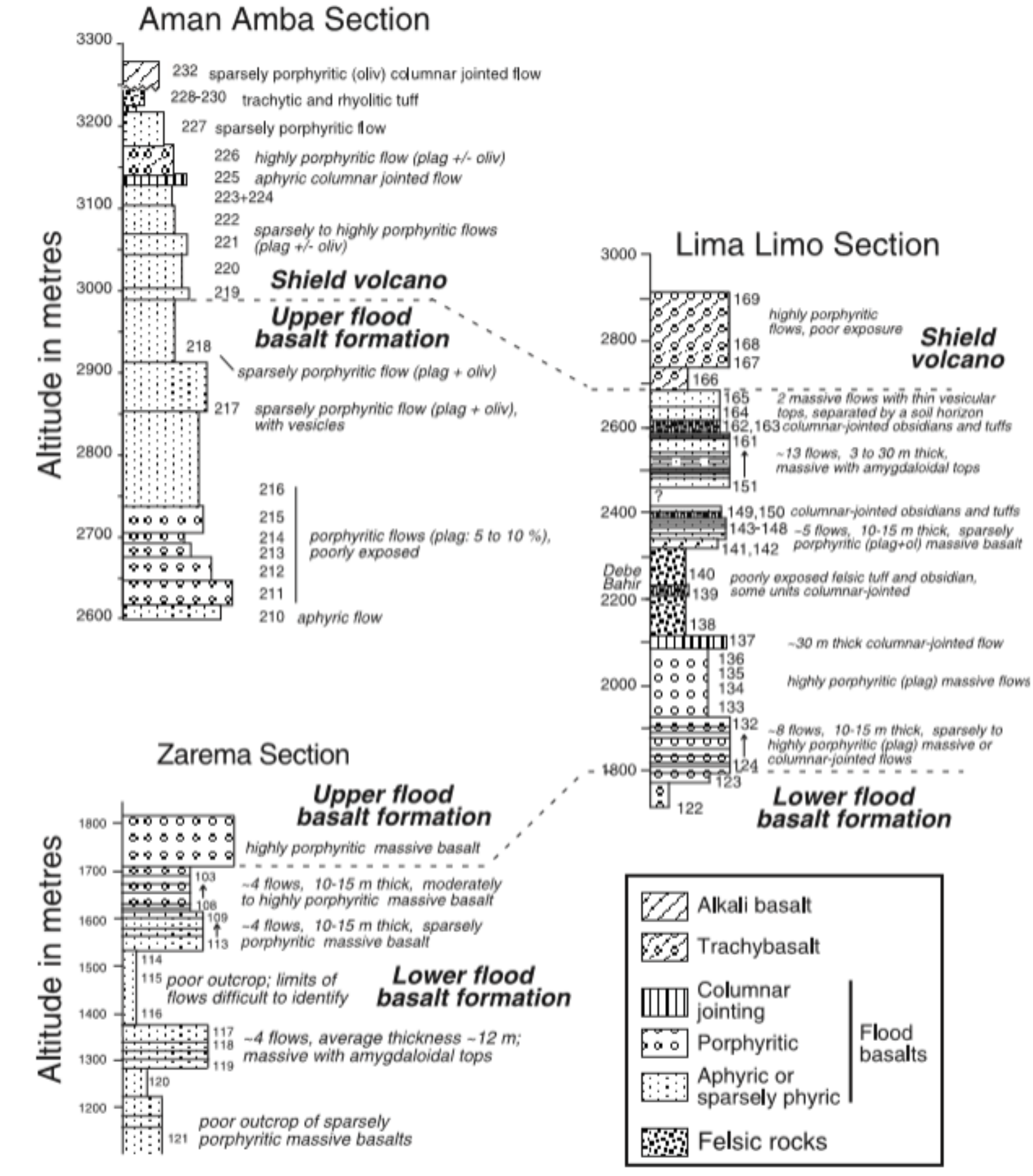
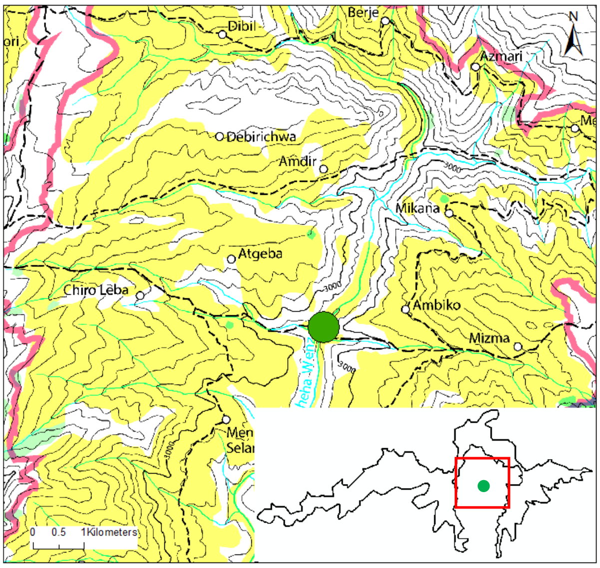


Fig. 4. Stratigraphic logs through the Simien volcano and underlying flood basalts showing rock types and sample locations.

Upper Mesheha valley

Janamora (Dibil, Majo Ayiteter, Kilil, Bahir Amba, Atigeba, Zakilita)

Short description: The Mesheha valley, which has the dimension and characteristics of a canyon, 10 km large, 40 km long and 1700 m deep, cuts the Simen Massif in its core sparing three mountain ranges and the south-western and south-eastern flank of the Simen shield. The valley is mainly the result of erosive river action during the Pleistocene pluvial periods, following an original line of tectonical weakness and further provoked by on-going uplift of the landmass.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.

Coordinates: **N 13°14'25.52" / E 38°17'16.79"** Altitude: **2600 m** to **3400F m** Type: **AER** Surface: **212 km^2**

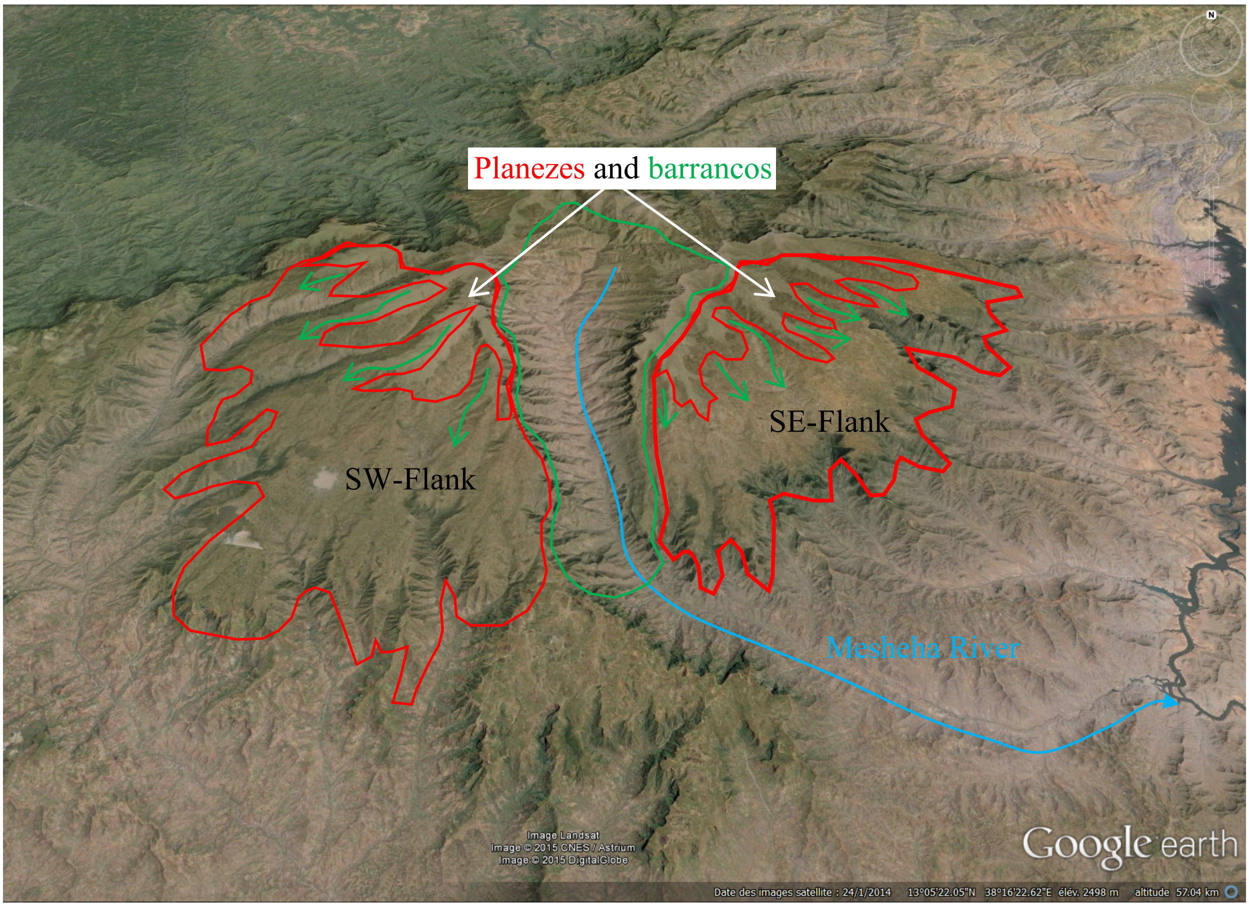
Property status: **PUB** Characteristics: **natural, active**

Description

The 1700 m deep and 10 km large Mesheha valley (measured between Bwahit (4430 m) and Ras Dejen (4540 m) running in a north-south direction over 40 km divides the Simen **shield** in a south-western and a south-eastern flank, which are intersected by gully heads called **barrancos** and from triangular facets called **planezes** (Goudie, 2004). Northwards the valley is delimited by the peaks Silki (4420), Abba Yared (4409 m) and Kiddis Yared (4453 m) where the volcanic centre is assumed (cf. sheet nr. 3). The Mesheha River, whose drainage during the dry season (cf. annex 1) is restricted to a small rivulet but mutating into a powerful stream during the rainy season, flows with a small arc southeast into the Tekeze. Numerous very steep **lateral valleys** and the flatter, gorge-like main valley, in whose base there is a warmer and drier climate than in the upper regions, characterise the inner relief of the valley (cf. annex 2) (Hurni, 1975). Moreover, the valley shows the characteristics of a **canyon**, which is "*a long, deep, relatively narrow, steep sided valley, often cut through bedrock which forms precipitous cliffs along the valley walls* (Goudie, 2004 : 116)." The term is typically used for such features in arid and semi-arid regions, such as the western United States (e.g. the Grand Canyon in Arizona, USA) and canyons are typical of mountainous regions, but are also found cutting high-elevation plateaus, as it is the case here.

Morphogenesis

Little consideration is given in scientific literature for this quiet amazing geological feature. According to P.A. Mohr (1963) "*faulting in the Mesheha valley suggests that the straight N-S alignment of this topographic feature hast been tectonically determined. The presence of slick-ensiding with this faulting however, allows of no easy explanation, as the Miocene faulting of Afar is not associated with thrusts or crush-faulting. From a very brief acquaintance with the region, therefore, it is suggested that Minucci (1938) is correct in considering the Mesheha valley to have been excavated by powerful glaciofluvial and pluvial-accumulate river action during the Pleistocene Pluvials, erosion following an original line of* ***tectonic weakness****, and successively revealing* ***structural terraces.***" To sum up we suppose that the Mesheha River and its tributaries cut their channels through layer after layer of rock while the Simen shield was uplifted, process which is still in progress.



Aerial view of the Simen shield with the Mesheha valley in the middle

Intrinsic value

Central value		
Integrity	Recent human encroachment (modern human settlement and road access) throughout the valley reduces the integrity.	0.75
Representativeness	The Mesheha valley is very representative of the dominant process of Simen, which is fluvial erosion with intervention of structural (tectonical) forces (uplifting).	1
Rareness	The almost gigantic dimension of the Mesheha valley separating the Simen massif in a south-western and south-eastern flank makes this valley to a unique geological feature in the area.	1
Paleogeographical interest	The main gorge is very unlikely to be excavated by a glacier, contrary to some reporting of the earliest researchers in the region. The site proves of tectonical activity in geo-historic times.	0.75
Scientific value	**Very high**	**0.88**

Additional values	
Ecological value	
Ecological impact	Although the study area of the Master's theses of K. Bircher (2006) on current and potential wildlife habitats in eastern Simen includes parts of the area of the upper Mesheha valley no significant ecological impact could be listed.
Ecological value	**Low**
Aesthetic value	
View points	The view of the Simen Mountains including the Mesheha valley, which is observed from the top of the highest peaks and passes of all the surrounding mountains, provides extremely breath-taking scenery which has often been referred to as being more spectacular than the Grand Canyon (Hurni, 1986).
Contrast, vertical development and space structuration	The Mesheha valley is well observed from sky as its vertical development is between 1000 and almost 2000 m over a stretch of 40 km. The colour of the mostly arid valley is rather monotonous grey-brownish. The contrast might be better from July to September when the valley is green and its nature flourishing.
Aesthetic value	**Very high**
Cultural value	
Historical importance	"*A very important trade route for Simen crosses the Mesheha valley from Debark over the Bwahit (4200 m) and Ras Dejen (4300 m) eastwards to the significant old towns Mekele (incense, salt), Sokota (grains), Desse (salt) and Lalibela (place of pilgrimage). It is this route which became the main route to the market place of Debark for the highland population of the subdistricts of Beyeda, east of Ras Dejen, and Jannamora, around Bwahit* (Stähli, 1978 : 43)."
Cultural value	**Medium to high**

Use and management characteristics

Protection of the site	
Protection status	The site has no protection and only the upper area of the lateral valleys is included in the National Park.
Damages and threats	Damage is caused to the site by the asphalt road through the Mesheha valley currently under construction relating Bwahit with Beyeda in the northeastern Simen Mountains. Unsustainable rural development in the area may seriously disturb the site's integrity in the future.

Promotion of the site	
Visit conditions	
Accessibility	The site is accessible by car on the all-weather gravel road from Debark in approximately 4-6 hours. During the raining season (May-Sept) access could however become complicated and crossing of the Mesheha River may be risky. Walking treks frequently used by local people are common in the valley and can be very steep and hot.
Security	It is not necessary to go on a trek in order to observe the site. There is no danger except for having a car accident. For hiking in the valley there is a risk of accident on slippery steep paths all year around.
Site context	Many new settlement constructions, sections of the new asphalt road running through the valley and heavy traffic noise compromise "*the natural feel"* (African Wildlife Foundation, 2014: 30). On the other hand, the exposure of the relief in the arid area is remarkable when observed from a pleasant environment a bit off the settlements.
Touristic infrastructure	There is a very basic campsite at Ambiko (3200 m) on the eastern side of the Mesheha River, which is usually used on a trek to Ras Dejen. In Chiro Leba (3300 m) on the western side of the river small shops and food in restaurants are available. In Mizma (3800 m) below Dejen is a ranger outpost under construction.
Visit conditions	**The experience of the Mesheha valley itself is rather unspectacular because of construction work, traffic noise and lacking touristic infrastructure. Chiro Leba is accessible within 3-4 hours from Debark.**
Education	
Education interest	It could be demonstrated to non-specialist visitors that the Mesheha valley does not have the characteristic U-shaped profile, or other indications of being glacial and thus, has been primarily excavated by powerful river action during the Pleistocene Pluvials. It is also possible to explain that the straight N-S alignment of the valley goes parallel to faulting in the Afar region and erosion most likely follows an original line of tectonical weakness.
Interpretation facilities	No interpretation facilities.
Educational interest	**Rather high**

Synthesis

Global intrinsic value

Although the site's <u>integrity</u> is reduced due to human interferences, the central value is very high as the site is highly <u>representative</u> of the fluvial erosion process and as the great Mesheha valley is also a very <u>rare</u> geological feature. The <u>aesthetic</u> value is very high and the cultural value is medium to high, thus the global intrinsic value very high.

Use and management

While the Mesheha valley now receives socioeconomic development, touristic infrastructure is still lacking. As it is currently not attractive to visit the site on a one-day trip from Debark (this could change with new road access), most of visitors miss the spectacular scenery offered by the Mesheha valley. Even though the site has a rather high educational interest no facilities support the interpretation of the geomorphology. There is no protection status for the Mesheha valley as it lies mostly outside the National Park boundaries.

Management measures and proposals

This site should be mentioned in an information leaflet on the geology and geomorphology of the Simen Mountains available at the Park headquarters in Debark. In case financing for the geovisualisation of the geomorphology of Simen (virtual visit on the web) could be found, the site should be also included. Chiro Leba (3300 m) is the most important town in the Meshaha valley, located in the core of Simen but outside the National Park and thus could be developed to a new touristic hub of geotourism (gentle tourism). Trekking with pack animals to the surrounding peaks and for instance a geological museum or exhibition (and environment education centre) in town could be proposed.

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Annex(s)

1. Mesheha River below Chiro Leba Village in February 2015

2. Arid conditions on the valley bottom at ~2600 m and temporary village for the road construction in the background; view from Loba Village (image taken in February 2015)

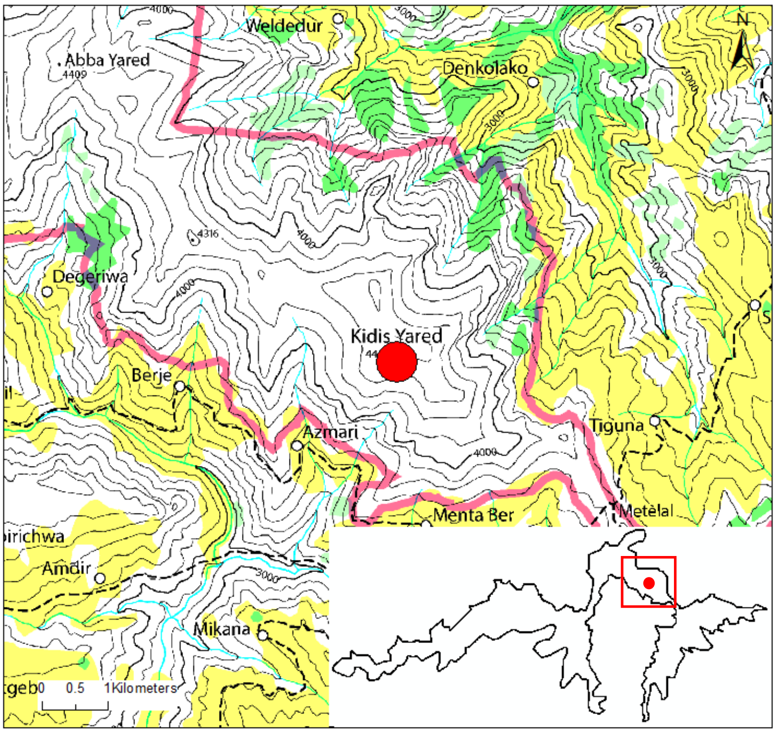
Annex 1: Mesheha River below Chiro Leba Village in February 2015

Annex 2: Arid conditions on the valley bottom at ~2600 m and temporary village for the road construction in the background; view from Loba Village (image taken in February 2015)

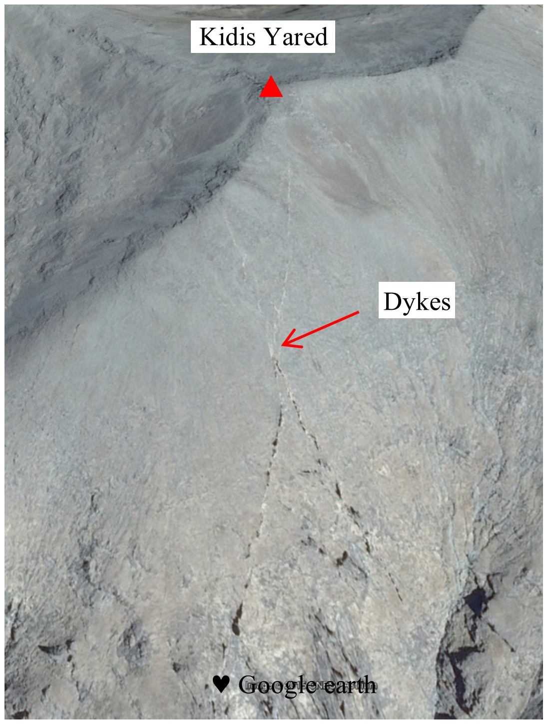
Volcanic centre and dykes in the region of Kidis Yared

Janamora (Gelbena, Sabra, Majo Ayiteter)

Short description: Intrusive rocks – granite and gabbro – found in the region of Kidis Yared are suggested to originate from slowly cooled magma, thus being part of the volcanic plug and centre of the Simen shield with Ras Dejen, Silki and Bwahit forming the outer rim of the crater. More than 600 m meter long, well highlighted dykes crossing each other, extend from the summit and indicate closely contemporaneous tensional strain during basalt extrusion.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.



Coordinates: **N 13°17'45.63" / E 38°19'30.62"**	Altitude: **3525 m** to **4430 m**	Type: **AER**	Surface: **2.1km²**

Property status: **PUB** — Characteristics: **natural, inherited**

Description

The Oligocene-Miocene volcanic system of Trappean basalt layers, more than 3000 m thick (Mohr, 1971) has been deeply eroded and tectonically cut forming a **radial system** of valleys around the centre of the Simen **shield volcano (**Hurni, 1982), which probably lies northwest of the peak of Kidis Yared, with Ras Dejen, Silki and Bwahit forming the outer rim of the **crater** (cf. annexs 2-3) (Ludi and Hurni, 2000). On the southeastern slope of Kidis Yared close to the peak there are two long well visible **dykes** corresponding to magma veins, cutting across the **stratification** and highlighted by **differential erosion**. One is 1200 m long, running in a NE-SW direction with a 400 m long extension beginning 150 meters west at 3820 m and finishing at 3520 m, and another one 600 m long running in a N-S direction, crossing each other at 4285 m (cf. annex 1).

Morphogenesis

A study by P. A. Mohr (1963) of the regional **dips** of the lava flows of Simen Massif confirmed the hypothesis of earlier authors (Minucci, 1938; Nilsson, 1940) that the volcanic centre lays in the present-day region of the Beroch Wuha, Silki and Abba Yared peaks. "*These mountains are not composed of the usual sub-horizontal basalt flows but of thick massive **tuffs** and basaltic **sheet intrusive**. The presence of steep northerly dipping lavas on the lower south slopes of Abba Yared seems to indicate original marginal crater subsidence* (Mohr, 1963 : 161)." However, Professor T. Peters, of the Mineralogical Institute of the University of Berne, conducted a **mineralogical analysis** in the laboratory and located the centre like E. Nilsson first in the northern mountain range but in the region of Kidis Yared where he encountered small occurrences of granite and gabbro, unlike the extrusive basalt rock which normally makes up the underground in Simen. It was suggested that this **intrusive rocks,** which are usually formed by the slow cooling of the magma chamber and crystallization at a depth within the Earth are part of the plug (Hurni, 1986). Numerous **dyke swarms** in the shield basalts indicate closely contemporaneous tensional strain during basalt extrusion (cf. annex 4). "*The dykes of western and northern Simen are parallel to the Tana rift trend (NNE-SSW) and to the Ethiopian Plateau-Afar margin to the east. The Simen volcanic centre could thus be considered situated on a zone of rift tension, but the existence of NW-SE (and E-W) dykes complicates the picture* (Mohr, 1967 : 88)."

Intrinsic value

Central value		
Integrity	Kidis Yared summit is located in an area where human interference is very rare thus this geological feature is well conserved.	1
Representativeness	Structural geology and geomorphology are very important to understand the formation of Simen. Since the region at Kidis Yared is assumed to be the centre of the volcano and dykes and dyke swarms are common geological features of Simen this site is highly representative of the region's geomorphology.	1
Rareness	The site is unique in Simen as it represents the main volcanic vent. It seems to be the only site in Simen where intrusive rocks, granite and gabbro, are observed.	1
Paleogeographical interest	The crater area of the volcano is of high general peleogeographical interest.	0.75
Scientific value	**Very high**	**0.94**

Additional values	
Ecological value	
Ecological impact	Kidis Yared summit is a potential Walia habitat (Hurni, 2005).
Ecological value	**Medium to high**
Aesthetic value	
View points	There are numerous points from where Kidis Yared is seen as for example from the southwestern summit complex, Bwahit-Mesarerya Mountains and from the southeastern complex, the Dejen group. However, the dykes are only seen from the distance of a few kilometres with a very good eye or binoculars.
Contrast, vertical development and space structuration	The vertical development of hundreds of meters and space structuration is important although the Northern Escarpment and the Mesheha valley give a much higher score. The contrast between the dykes and the rocks is weak.
Aesthetic value	**Medium to high**
Cultural value	
Religious importance	A legend tells that Saint Kidus Yared brought the Walia ibex to Simen by using it to carry his holy books. As a result, the Walia ibex is important in the folklore and oral literature of the Simen communities. Kidis Yared summit seems to be named after this legend bearing the name of this spiritual man (FZS - ADC, 2009).
Cultural value	**High**

Use and management characteristics

Protection of the site	
Protection status	The site is located inside the National Park boundaries and therefore under protection.
Damages and threats	In 2006 the park authorities argued strongly against a road project over Silki-Yared – Kidis Yared Mountains and Ras Dejen. Currently good alternative route options are found thus the site remains undamaged and all threats seem to be eliminated (FZS – ADC, 2009).

Promotion of the site	
Visit conditions	
Accessibility	The nearest road access is from the Bwahit road leading down to Chrio Leba in the Mesheha valley. At the vintage point at 3920 m the road must be left and a trail (which is part of the old eastern trade road) leads further away over the saddle of Arkwasiye. The walking distance to Kidis Yared exceeds what is normally done within one day but it can be reached within two or three days. Steep slope can be omitted for the most part and there are tracks available but not on the ridge from Abba Yared to Kidis Yared.
Security	There are no particular risks on that trail during the dry season but in such remote area already small accidents may become serious.
Site context	A 360° panoramic view of all the high peaks of Simen, the Mesheha valley to the south and remote landscapes to the north is particular to this site since it is located in the centre of the Simen Mountains. The site context is totally calm and as the ground surface is unvegetated rocks are well exposed.
Touristic infrastructure	No infrastructure is available in this area. Teklay Sefer north of Arkwasiye is the closest ranger outpost. A local guide, cook and mule including muleteer and the compulsory community scout to enter the park can be hired from Debark.
Visit conditions	**The visit of Kidis Yared summit is a real challenge. From Debark three days should be planned to reach the site. No touristic infrastructure can be expected in the remote area.**
Education	
Education interest	With support of a satellite image non-specialists can locate Kidis Yared as the volcanic centre with Ras Dejen, Silki and Bwahit forming the outer rim of the crater, thus they realise that the Simen Mountains are in fact remnants of a deeply eroded volcanic 'cone' or shield with basal diameter of about 100 km (Asrat et al., 2012). The long and large dykes can be seen from tens of kilometres, thus their origin and evolution from magma veins, cutting across the stratification and highlighted by differential erosion can be explained to adult non-specialist visitors on any tour to Ras Dejen or Bwahit.
Interpretation facilities	No interpretation facilities.
Educational interest	**Rather high.**

Synthesis

Global intrinsic value

With the scientific value to be very high due to perfect integrity, high representativeness and rareness and quite high additional values especially the cultural value, the global intrinsic value is close to very high.

Use and management

Even though its access is difficult, the site has its interest to be visited as it marks the centre of the shield volcano offering a 360° panoramic view all over Simen. It is from this point that non-specialist visitors could actually recognise the form of the whole shield and thus understand that the Simen Mountains are remnants of a deeply eroded volcano. As the land is unproductive for agriculture and the site is not located on the main touristic route its protection is granted for the moment.

Management measures and proposals

For the geological enhancement the dykes seen on the trek to Ras Dejen as well as the high cultural and medium to high ecological value are of interest. A visit of the site could be proposed to well-trained trekking tourists on behalf of the introduction of a new trekking route leading along the historic eastern trade road (cf. sheet nr.11) respectively on a high level alternative route via Abba Yared and Kidis Yared to the summit of Ras Dejen as proposed recently in the SMNP Tourism Development Plan (AWF, 2014). The site should be documented on any *ex-situ* interpretation facilities as it is an important site to understand the formation and evolution of the Simen Mountains as part of a huge shield volcano. The site could also be visited from Chiro Leba in the future (new touristic centre, cf. sheet nr 2). However, it should remain in the intact context as it is found now and should be protected against mass tourism.

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[1] Unable to adapt source correctly to the APA (American Psychological Association) – citation style (6th).

Annex(s)

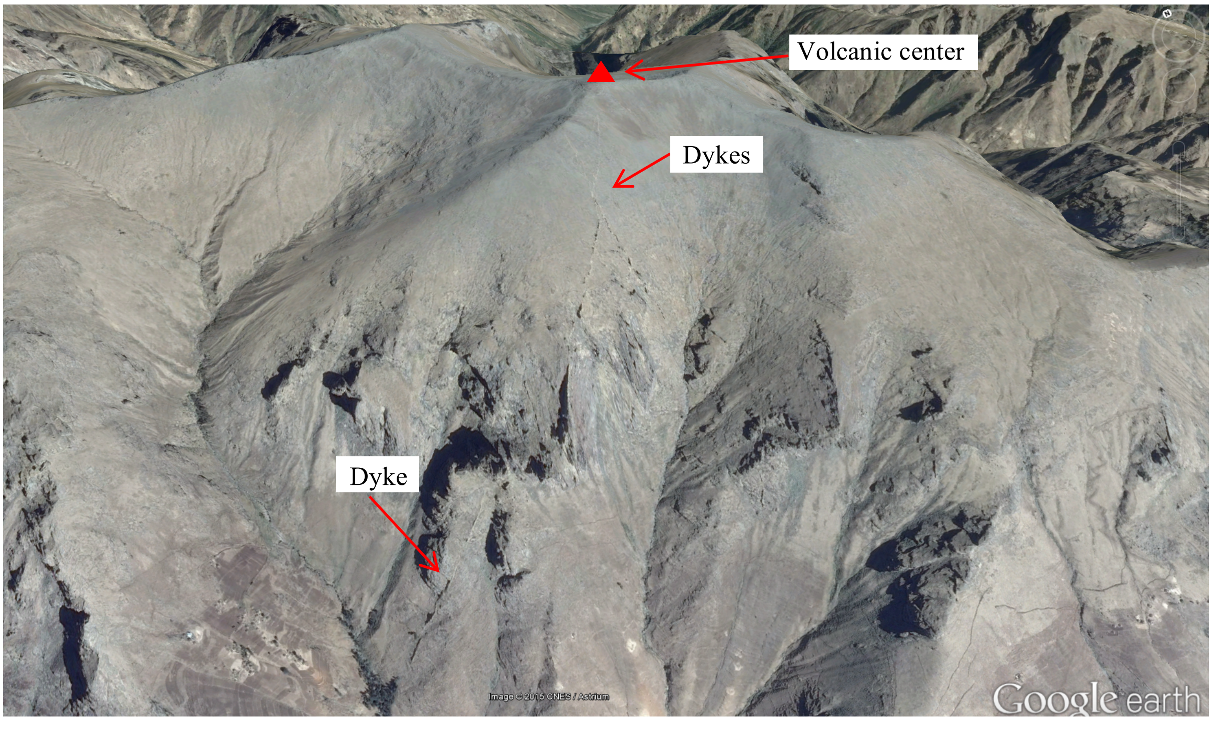
1. Area of the volcanic centre of the Simen shield with Kidis Yared peak in the middle and dykes extending down to the Mesheha valley; southern aspect of Kidis Yared

2. Silki and Beroch Wuha peak forming the northwestern outer rim of the crater with Walya Kent in the right background; view from Dirni

3. Volcanic centre in the region of Kidis Yared with Bwahit, Ras Dejen and Silki forming the outer rim of the crater

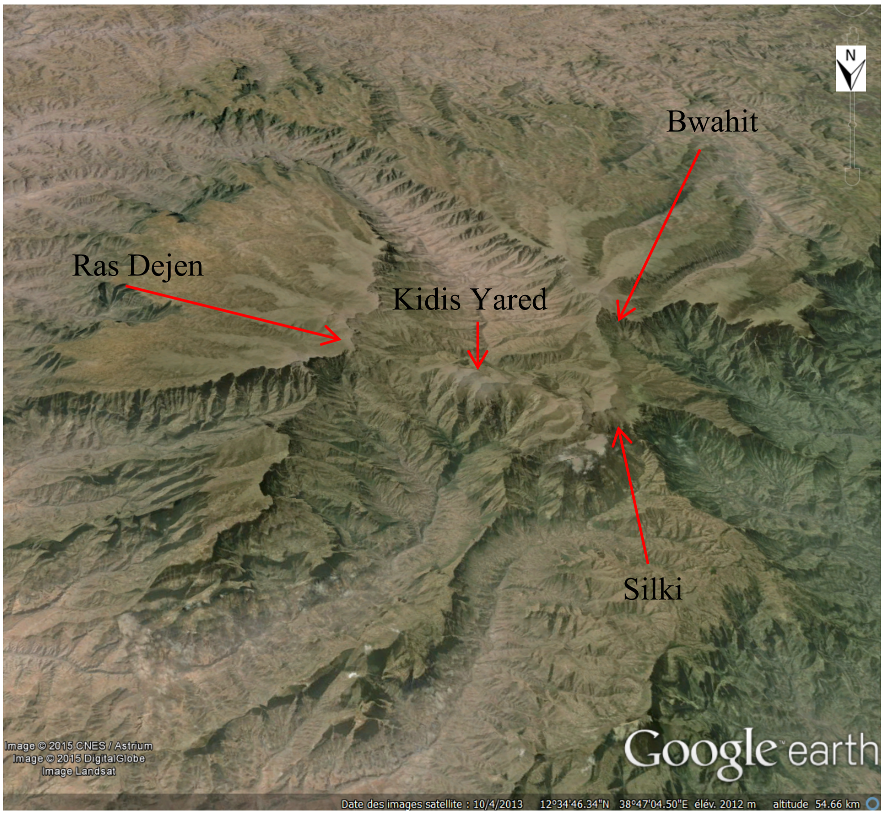
4. Dyke at Deche Nedala, opposite of Jinbar Waterfall, running in NE-SW direction

Annex 1: Area of the volcanic centre of the Simen shield with Kidis Yared peak in the middle and dykes extending down to the Mesheha valley; southern aspect of Kidis Yared



Annex 2: Silki and Beroch Wuha peak forming the northwestern outer rim of the crater with Walya Kent in the right background; view from Dirni

Annex 3: Volcanic centre in the region of Kidis Yared with Bwahit, Ras Dejen and Skili forming the outer rim of the crater

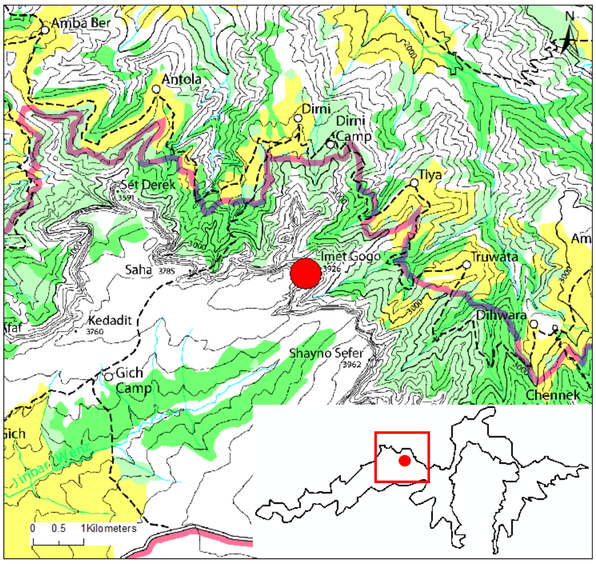


Annex 4: Dyke at Deche Nedala, opposite of Jinbar Waterfall, running in NE-SW direction

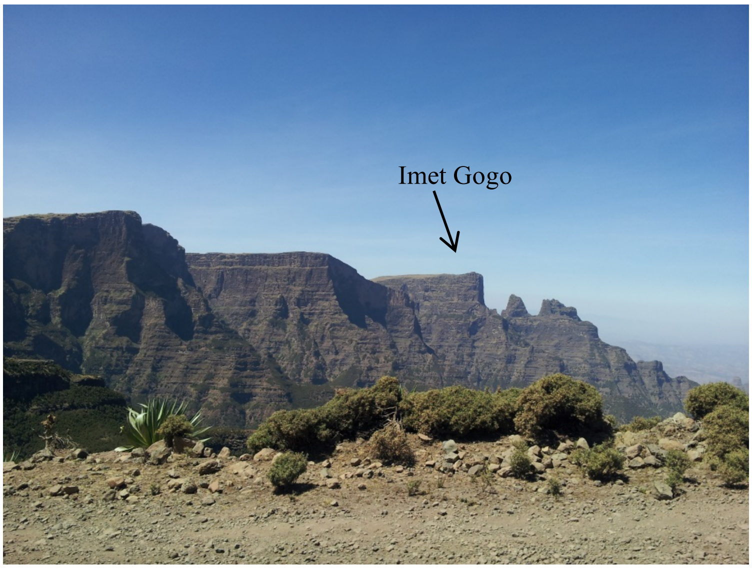
Imet Gogo and the Northern Escarpment

SMNP

Short description: The vertical section of the Northern Escarpment below and above the Chennek campsite exposing horizontally layered volcanic sequences with Imet Gogo peak as one of the highest crags are constituting this site. Extended uplift and rifting together with fluvial weathering and erosion formed the dramatic landscape for which Simen is most famous.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.



Coordinates: **N 13°17'11.76" / E 38°8'45.60"**	Altitude: **3000 m** to **4000 m**	Type: **AER**	Surface: **8.3km^2**

Property status: **PUB** Characteristics: **natural, active**

Description

Considering the nearly vertical section of the **Northern Escarpment** below and above Chennek including Imet Gogo peak, A. Asrat et al. (2012) have already recommended this site as a "*geoconservation site*" (cf. annex 4). *Deep cutting and erosion resulted in curiously shaped spires and crags resembling high-rise buildings when viewed from distance* (Asrat et al., 2012 : 22)". **Imet Gogo** peak as one of those crags is a "*vertical edifice exposing horizontally layered [shield volcanic series of basalts, trachybasalts, rhyolites and tuffs], a single cliff wall [reaching] more than 100 m* (cf. annex 1) (22)." Imet Gogo is also a prominent view point from where "*the panorama shows the vast basalt shield of the Simen Highlands from NE over S to W with the Ras Dejen (4540 m) as highest point in Ethiopia. The area between opens the view into the lowland, from where the uncounted tributaries of the Ansiya Wenz have cut themselves into the highland by retrograde erosion* (Aerni, 1978 : 101)."

Morphogenesis

The morphogenesis of the Northern Escarpment is already explained in sheet nr. 1. In the following additional, more specific information of researchers not cited in sheet nr. 1 and the authors considerations are presented. Even though P.A. Mohr (1967 : 88) believes that the northwestern precipices of Simen are "*erosional*" and are not determined by any **faulting** as the dipping stratoids of Beroch Wuha across the dissected country towards Adi Arkay are continuous and no **tectonic displacement** is visible in this area, it most probably is the result of both, heavy erosional processes and tectonic forces. But what makes it so huge and dramatic? H. Hurni and E. Ludi (2000 : 10) state that "*the extreme escarpment appeared to be preconditioned by an extended **uplift** of the whole massif during the Tertiary, comprising major **faults** which can be attributed to the **Rift system** extending over most of East Africa to the Red Sea.*" According to H. Hurni (personal communication) and our own observations fissure volcanism activity in the region is visible on the road from Gonder to Bahr Dar, where numerous **volcanic necks** (plugs) are observed (cf. annex 2), and the mountains in Tegede about 60 km north-west of Simen could geologically belong to Simen but rifting separated them from Simen in geo-historic times. **Fluvial erosion** due to high precipitation in the area, enforced by rapid and on-going uplifting of the whole Ethiopian Plateau, certainly played a role in washing out of the deep valleys and gorges and sculpting the rugged morphology of Simen (Asrat et al., 2012).

Intrinsic value

Central value		
Integrity	No damage to the site has been recorded.	1
Representativeness	The site represents extremely well the structural geomorphology of Simen.	1
Rareness	The monumental cliff wall below and above the Chennek campsite with the exposure of horizontally layered volcanic sequences at Imet Gogo are an absolutely spectacular sight within the Northern Escarpment.	0.75
Paleogeographical interest	The escarpment in general and the volcanic sequences in particular inform about the history of Earth but have not been studies in detail for this site.	0.5
Scientific value	**High**	**0.81**

Additional values	
Ecological value	
Ecological impact	H. Hurni (2005) indicates the escarpment area at Chennek as a current Walia habitat and the Tourism Development Plan (AWF, 2014 : 5) states, "*the Chennek area was repeatedly identified during the consultation process as a crucial wildlife corridor and important vegetation zone*". In fact Ibexes need steep gradients (> 45 °) and large height differences to neighbouring areas for their habitats. High altitudes and the exposure of the area are important for their thermal comfort and food preferences (Bircher, 2006). The General Management Plan (FZS – ADC, 2009) adds that due to the "*extreme altitudinal variation*" the escapement *"extends through a number of habitat types including montane forest (1900-3000 m), sub-Afroalpine (or Ericaceous belt, 2700-3700 m), and Afroalpine grasslands (3700 – 4600 m).*"
Ecological value	**Very high**
Aesthetic value	
View points	Imet Gogo peak and Chennek are famous viewpoints themeselves but there are numerous locations, such as Teklay Sefer or Sona, from where the escarpment at Chennek and Imet Gogo is observed.
Contrast, vertical development and space structuration	The almost vertical section of the escarpment below Chennek up to the top of Imet Gogo reaches 2000 m and as already noted (Lemalemo escarpement, cf. sheet nr. 1) the space structuration of the Northern Escarpment is extremely significant but its contrast varies according to the sunlight and shadows.
Aesthetic value	**Very high**
Cultural value	
Artistic importance	It is possible to recognize the design-pattern of a human visage – due to differential erosition – when looking at the Northern Escarpment from Chennek and rotate the image at 90° (cf. annex 3).
Cultural value	**Medium to low**

Use and management characteristics

Protection of the site	
Protection status	The site is located inside the national park boundaries and therefore under protection.
Damages and threats	No damages and threats.

Promotion of the site	
Visit conditions	
Accessibility	Chennek campsite is accessible on an all-weather gravel road from Debark within 2 hours. Imet Gogo has to be reached via Gich on the first day and to Imet Gogo on the second day (about 2-3 hours one way). No special walking difficulties occur on this trekking except for the passage of some narrow ridges on the top of Imet Gogo.
Security	The trail is general in a good condition and there is no natural hazards related to the site, which could cause a higher risk of accident.
Site context	During high season the fact of numerous tourist groups visiting Imet Gogo and Chennek camp compromises the single tourist experience. However, the view is spectacular from both of these places.
Touristic infrastructure	At Gich and Chennek a community lodge and a campsite offer accommodation at a very low standard (African Wildlife Foundation, 2014).
Visit conditions	**Compared with other locations in Simen the visit conditions are good as the site is easily accessible and very basic touristic infrastructure is available.**
Education	
Education interest	The erosion process coming from the Northern Lowlands can be explained to amateur geologists using the example of this site. Volcanic sequences are clearly visible even for children and non-specialist visitors.
Interpretation facilities	No interpretation facilities.
Educational interest	**Rather high**

Synthesis

Global intrinsic value

The central value is high as the site exposes volcanic sequences and demonstrates an exceptional (rare) part of the Northern Escarpment highly representative of the structural geomorphology of the region. Together with the very high aesthetic and ecological values the global intrinsic value is considered as very high.

Use and management

The site is located on the Main Gich Plateau Trekking Route leading from Sankabar over Gich to Chennek, for this reason the visit conditions compared to other location in Simen are good and the site is frequently visited because it offers spectacular sceneries to the rugged canyon like lowlands. However, visitors know nothing about the formation and scientific value of this amazing geological feature although the educational interest is rather high. All together this site is well protected as it is situated within the National Park.

Management measures and proposals

An original geoheritage enhancement would be the introduction of zeppelin flights along the Northern Escarpment as it is for example possible in the Bernese Oberland (Switzerland) for visitors who would like to enjoy the unique panorama in a special way (Schelling, 2015). Zeppelin flights run silently and leave virtually no impact even though the shadow can be disturbing for the wildlife and of course fuel is needed. On such flight the formation of the Simen shield and the Northern Escarpment could be explained. At Chennek camp interpretive panels should be installed to explain the morphology of the Northern Escarpment and it should be noted that the endemic *Walia Ibex* finds its home here thanks to the steep untouched slopes of the escarpments. Networking with other sites is possible for guided tours in the National Park focusing on the geology and geomorphology. On Imet Gogo we do not propose interpretative facilities as this would harm too much the integrity of the site.

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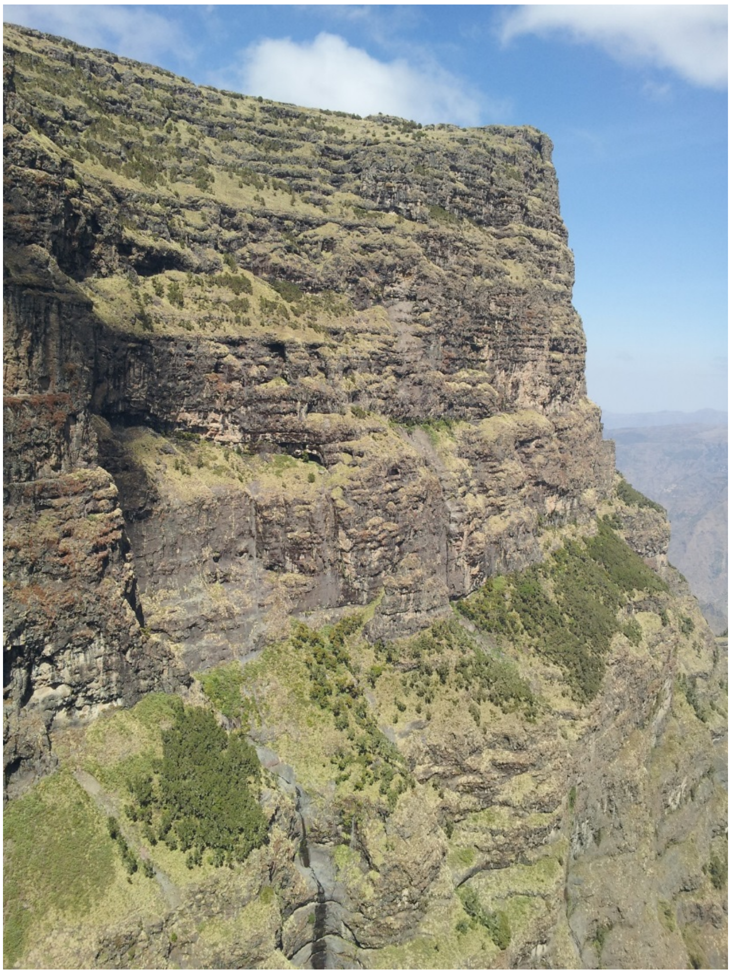
Author

L. Mauerhofer (2016)

Annex(s)

1. Imet Gogo horizontally layered volcanic sequences
2. Volcanic necks (plugs) along the Gonder-Bahr Dar road
3. Human visage in the Northern Escarpment (image turned at 90°); view from Chennek camp
4. Northern Escarpment seen from Teklay Sefer outpost

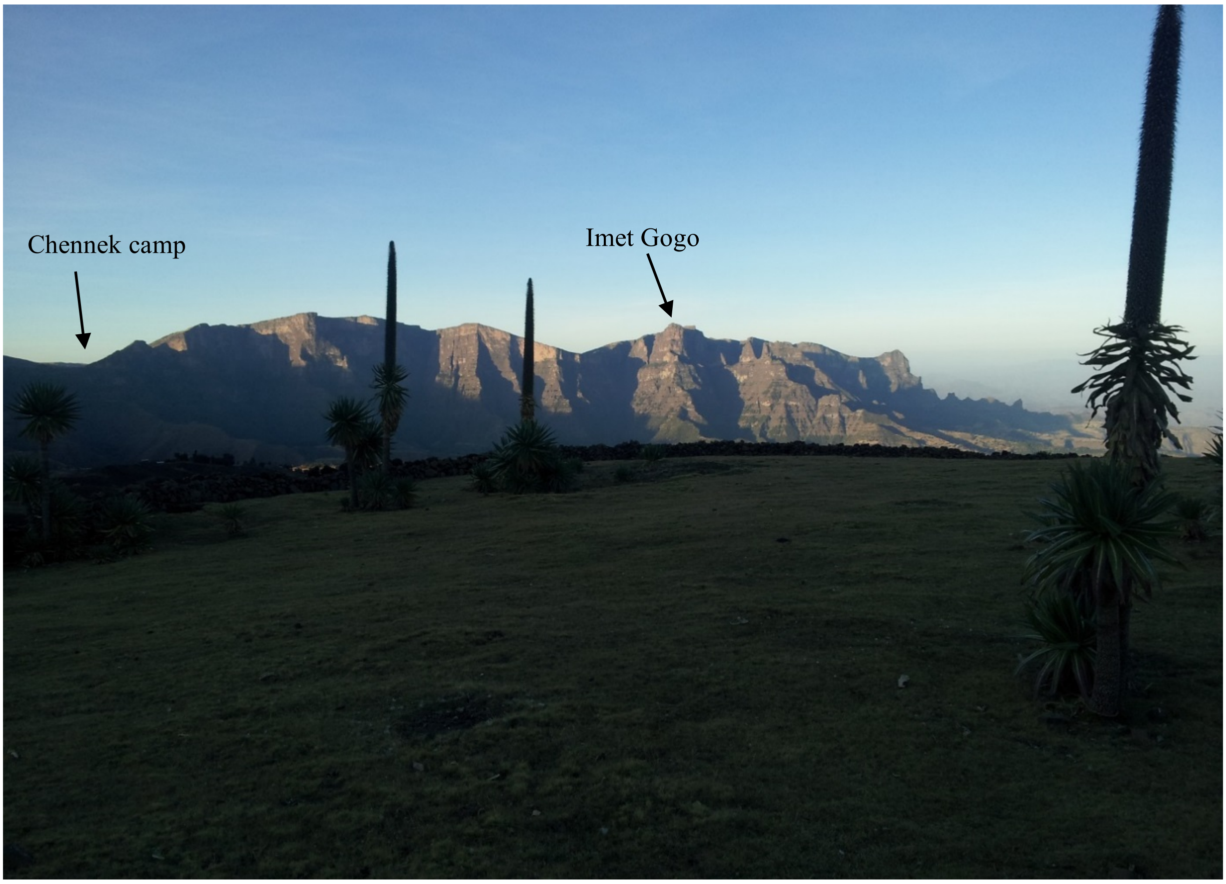
Annex 1: Imet Gogo horizontally layered volcanic sequences



Annex 2: Volcanic necks (plugs) along the Gonder-Bahr Dar road

Annex 3: Human visage in the Northern Escarpment (image turned at 90°); view from Chennek camp

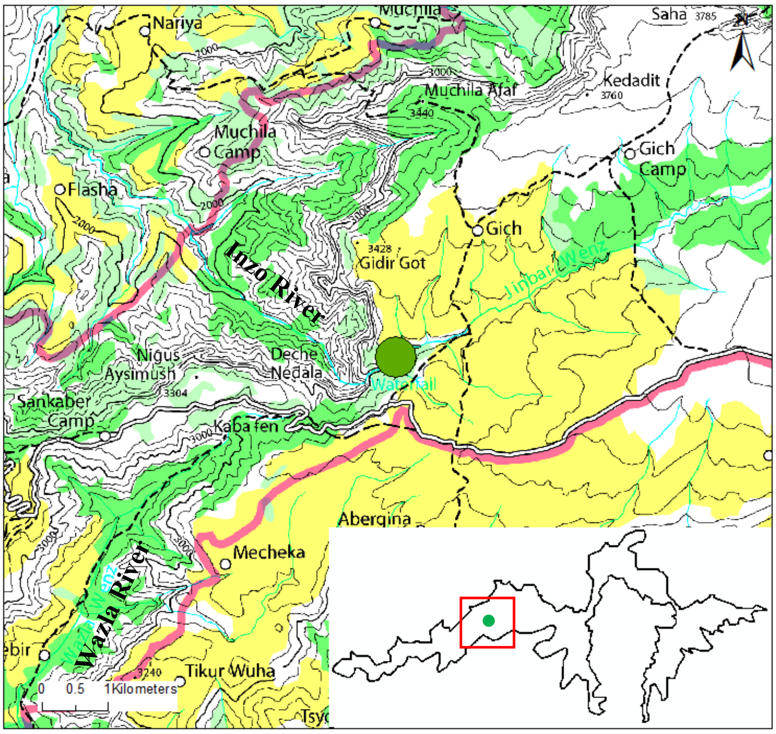
Annex 4: Northern Escarpment seen from Teklay Sefer outpost



River capture of Jinbar River (Jinbar waterfall)

Debark (Abergina)

Short description: Headward erosion of the Inzo River working back towards its head and eventually reaching the neighbouring Jinbar valley cuts through the divide. Thus the waterfall marks the river capture of the Jinbar River where it bends sharply into the pirate stream (Inzo River) while the valley stretch in which the Wazla River continues to flow forms its beheaded valley.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.

Coordinates: **N 13°14'23.31" / E 38° 4'28.09"E** Altitude: **2200 m to 3200 m** Type: **AER** Surface: **5.6 km^2**

Property status: **PUB**

Characteristics: **natural, active**

Description

Like many other valleys in the south, the Jinbar valley first runs in east-west direction parallel to the Northern Escarpment, but unlike them, it does not turn south, but breaks with a **waterfall** over the edge of the escarpment to the north. The difference in height from the ridge height at 3650 m to the sole (3050 m) is 600 m; the waterfall drops 350 m into the deep river gorge down to 2700 m.

Geologically interesting is the fact that the valley seems to possess no natural upper end but performs with its almost U-shaped cross-section over the steep scarp in the air (cf. annex 1 and 2). Likewise, the valley has at the bottom an original sequel to the southwest (Wazla River), which is now interrupted to the north due to the outbreak of the river (Hurni, 1975).

Morphogenesis

Beside the topographic description of the Jinbar valley by H Hurni (1975) no author has given consideration of the particular geomorphology of the Jinbar valley, which actually demonstrates a **river capture**, sometimes called stream capture or stream piracy, referring to the occurrence of the seizure of the waters of a stream or drainage system by a neighbouring one. *"It is based on the difference in local **base level** heights, with the captured stream having a higher base level and for that reason with a low erosion potential. The **predatory stream** [(here the Inzo River)],* with *a lower base level, is capable of diverting in its favour the waters of the less active stream, and in this way enlarging its drainage net and catchment area. [But] it does not only occur because of a steeper gradient but also because the pirate stream is cutting its valley in softer rock* (Goudie, 2004 ; 860).

Headward erosion is the cause of the stream captures. *"It takes place when the tributaries of the high energy stream are working back towards its head, and eventually reach the neighbouring valley head and cut through the divide. At the point at which the capture takes place, the captured stream bends sharply, forming a right angle turn into the pirate stream, which is called the **elbow of capture*** (cf. annex 2). […] *The valley stretch in which the captured stream continues to flow after losing the upper part of its catchment becomes a **beheaded valley** [(here the valley of Wazla River)]. This valley is then too large for the stream called that continues to flow in it and thus becomes an **underfit stream** that is a stream too small to be hydrologically related to the valley in which it now flows* (Goudie, 2004 ; 861)."

Intrinsic value

Central value		
Integrity	The site shows no damage.	1
Representativeness	Fluvial erosion is the main active geomorphological process in the area and this site is highly representative of it.	1
Rareness	There is no other river capture found in the region.	1
Paleogeographical interest	The site testifies to the continuous fluvial activity in the region.	0.5
Scientific value	**Very high**	**0.88**

Additional values	
Ecological value	
Ecological impact	The absence of fishes on the Gich plateau is due to waterfalls preventing their upstream movement (negative impact). Nevertheless, sightings of frogs or toads indicate the presence of amphibians on the Gich plateau (Nievergelt, 1998). No other ecological impact related to the river capture has been documented.
Ecological value	**Medium to low**
Aesthetic value	
View points	Decha Nedala (3100 m) is an impressive and frequently visited viewpoint of the Jinbar waterfall.
Contrast, vertical development and structuration of the space	Jinbar waterfall is a vertical drop of 300 during the rainy season the colour of the usually reddish rock wall turns green as vegetation starts growing and a considerable amount of water drops over the precipice.
Aesthetic value	**Very high**
Cultural value	
Cultural value	**Very low to null (not known)**

Use and management characteristics

Protection of the site	
Protection status	The site is located inside the National Park and therefore under protection.
Damages and threats	No damages and threats.

Promotion of the site	
Visit conditions	
Accessibility	The site is accessible on the all-weather gravel road from Debark in about 1 hour. A short path (10 min walk) leads to the platform at Decha Nedala from where the view of the waterfall is most impressive. Caution is advised when crossing a narrow rocky ridge just before reaching the lookout.
Security	There is no particular risk for visiting this site with appropriate behaviour.
Site context	The site context is good but the lookout risks to become overcrowded.
Touristic infrastructure	No tourist infrastructure is found in the immediate vicinity but Sankabar camp, which offers very basic accommodation, is at 1 hour walking distance. Moreover, the Simen Lodge hotel which provides accommodation at a high standard (in the present Ethiopian tourism sector context and medium standard in international terms) is 20-minute drive away (African Wildlife Foundation, 2014).
Visit conditions	**The visit conditions are reasonable. It is a very pleasant site, which is often visited from Debark on a one-day trip, very basic at Sankabar and reasonable accommodation at the Simen loges is available.**
Education	
Education interest	Using this aesthetically attractive site non-specialist visitor can understand the meaning of a river capture. It is generally well "readable" if explanations of the geomorphological context together with interpretative facilities were available. Visitors could identify the predatory stream, the elbow of capture and the beheaded valley as well as understand the concept of retrograde erosion as a fundamental geomorphological concept.
Interpretation facilities	No interpretation facilities.
Educational interest	**High**

Synthesis

Global intrinsic value

The global intrinsic value is very high as the site combines a very high scientific value with almost perfect integrity, highest representativeness and rareness together with a very high aesthetic value.

Use and management of the site

Even though the site has reasonable visit conditions and a high educational interest no interpretation facilities are available. The site is less vulnerable than others to the impact of tourism thus the protection of the site is guaranteed in the short and medium term.

Propositions of management measures

This site is with easy access from Debark thus short geo-trips with park staff (or external guides) trained in outdoor educational and regional geology and geomorphology could be established and organised for the local population (ex. school classes, teachers, elderly and indigenous leaders, church priests, women) and local stakeholders of the SMNP (e.g. Kebele and Woreda administrators, local tour operator). Interpretation support and a pedagogical dossier for the classroom should be particularly developed for school classes and teachers (FZS – ADC, 2009).

Networking with other easy accessible geosites (such as at Lemalemo, Ambaras, Argin, Chennek and Bwahit) is possible thus it is also recommended to address the international 'sightseeing market' with the idea of Jinbar waterfall as part of a one-day sightseeing tour to discover the geoheritage of the Simen Mountains. The nearby-located mid-range Simen Lodge hotel offers an appropriate accommodation for this target audience. At the hotel reception geoheritage merchandising products such as geological replicas of local crafts or guide books as well as a leaflet presenting the geomorphological context and flyers with information on the diverse geotouristic offer in SMNP could be distributed.

The number of people visiting the lookout at Decha Nedala should be limited, thus the problem of overcrowding at the attraction point lowering the experience of all visitors would be avoided The installation of interpretive panels next to the road where it best fits into the environmental and aesthetic context is recommended in order to enhance the value of the site. People waiting for the visit could inform themselves on the key features and importance of the site (African Wildlife Foundation, 2014).

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Author

L. Mauerhofer (2016)

Annex(s)

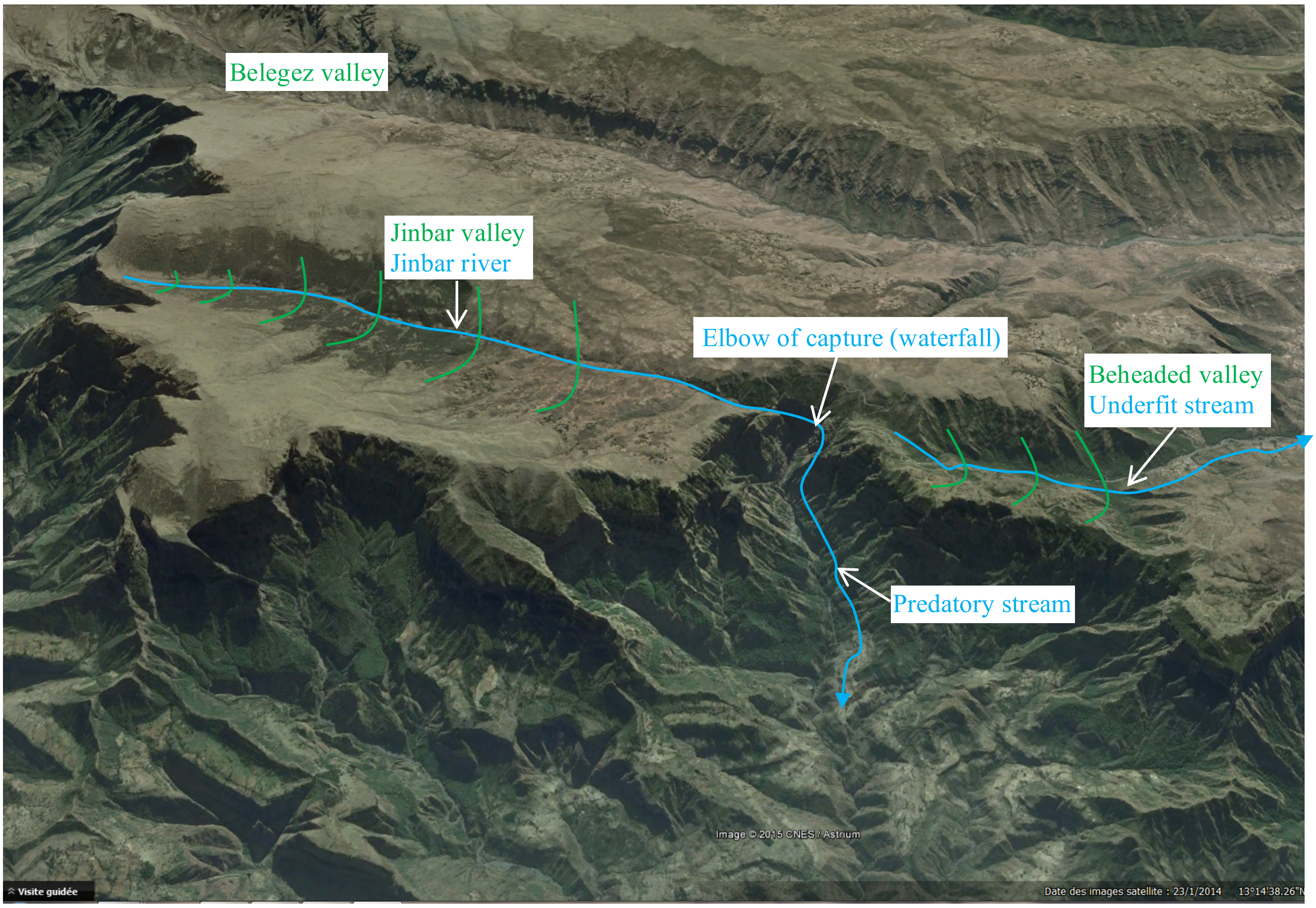
1. U-shaped cross-section of the upper end of Jinbar valley leading over the steep scarp in the air; viewed from Tiya Village at the foot of the escarpment

2. River capture of Jinbar valley and truncated valley tops in Jinbar and Belegez Rivers, and many more not visible on this image.

Annex 1: Almost U-shaped cross-section of the upper end of Jinbar valley leading over the steep scarp in the air; view from Tiya village at the foot of the escarpment.

Comment: This geomorphology, typically attributed to glacial valleys is here inserted to a cuesta landscape to explain with concepts of structural geomorphology.

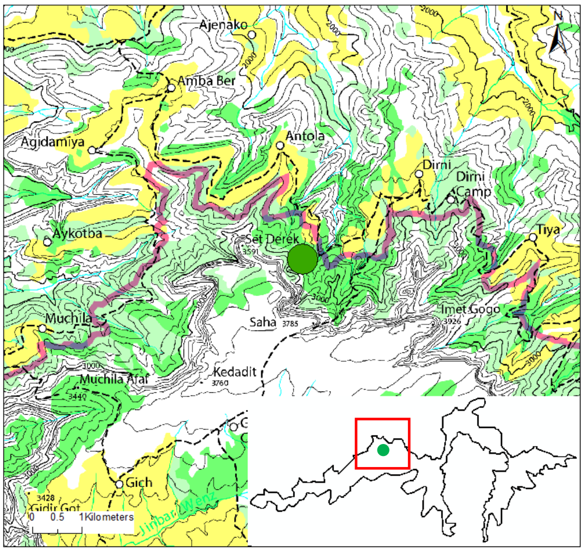
Annex 2: River capture of Jinbar valley and truncated valley tops in Jinbar and Belegez Rivers.



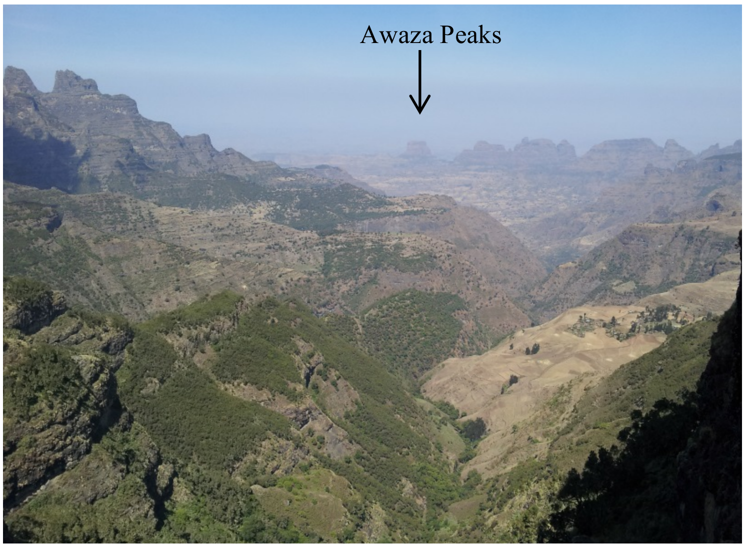
Erosive landscape of the lowland area from Muchila to Dihwara

Adirkay (Agidamyia, Seragudela)

Short description: The channel system of the Ansiya and Inzo rivers and terrace-like steps extending at the altitude ranging from 2000 m to 3000 m a.s.l. characterise the relief at the foot of the Northern Escarpment from Muchila to Dihwara. In the distance the prominent landmass known as the Awaza peaks can be seen. Different resistance of the lithological units and continuous erosion of the volcanic massif have resulted in the exposure of isolated landmasses and sharp peaks of exceptional natural beauty.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.



Coordinates: **N 13°18'11.96" / E 38° 6'20.22"** Altitude: **2000 m** to **3000 m** Type: **AER** Surface: **56.4 km²**

Property status: **PUB**

Characteristics: **natural, active**

Description

Terrace-like steps characterise the relief at the foot of the Northern Escarpement extending between 2000 m and 3000m from Muchila to Dihwara where the **channel system** of the tributaries of Ansiya and Inzo rivers have cut uncounted deep ravines and gorges into the steep rock wall. Small plateaus are formed which are normally cultivated and inhabited while the ravines and gorges are covered with natural forest (cf. annex 1). In the distance, rugged-canyon like lowlands and the prominent landmass known as the **Awaza peaks** can be seen (cf. annex 2). These peaks, which are described as needle-shaped rock pinnacles (**buttes**) and steep-sided, flat-topped table mountains **(mesas** or Amba in Amharic), "*are remnants of a deeply eroded ridge forming the most distant fringes of the pyroclastic flows associated with the shield volcanism* (Asrat *et al*., 2012 : 19)". The evaluation reported below focuses on the delicate **fluvial system** of highly fissured terrain and terraces-like steps just below the escarpment; the dissected lowlands in the distance and the Awaza peaks are located outside the study area, thus their scientific value and additional values are not evaluated.

Morphogenesis

The complicated channel system cutting deeply into the rock face is caused by incision of the river against the **uplifting** landmass. The small but deep valleys widen by **lateral stream erosion** and by weathering, mass movements and fluvial processes on their sides and they lengthen by **headward erosion** (cf. sheet nr. 5). Terrace-like steps appear mainly due to **differential erosion** of more resistant lithological units (called **caprocks**) protecting underlying less resistant rocks from erosion and denudation. **Outliers** such as mesas and buttes have a similar origin, with flat-lying soft rocks capped by a more resistant layer. "*In volcanic terrains [such as the Simen Mountains] a former lava flow may act as a caprock; […] mesas originate due to unequal scarp retreat, in the course of which parts of the plateau become isolated and remain standing in front of the retreating scarp. […] With time, they are reduced to buttes, but there are no agreed criteria as to when a mesa becomes a butte* (Goudie, 2004 : 668)."

Intrinsic value

Central value		
Integrity	No reduction of the integrity	1
Representativeness	The site is exempla of the erosional landforms and erosional processes (mainly fluvial) for which Simen is well known.	1
Rareness	The hydrographic system of mountain streams and the exposure of terrace-like steps are most pronounced in the lowland area from Muchila to Dihwara.	0.5
Paleogeographical interest	The site gives evidence for prolonged intense fluvial erosional processes.	0.5
Scientific value	**High**	**0.75**

Additional values	
Ecological value	
Ecological impact	According to B. Nievergelt (1998) it is assumed that the Simen mountains have a unique aquatic fauna. A total of 27 aquatic invertebrate taxa were recorded on a survey below the escarpment from Muchila to Dihwara. It appears that the channel system offers important habitats of specialized species restricted to the high altitudes of the Simen Mountains.
Ecological value	**High**
Aesthetic value	
View points	The channel system including deep ravines and gorges is difficult to see from distance while the terrace-like steps are observed from numerous points on the path along the escarpment and from the highlands such as Imet Gogo and Chennek.
Contrast, vertical development and structuration of the space	The space structuration of the fluvial system is rather low, it is medium for the terrace-like steps, the vertical development of both forms is tens to hundreds of meters and the colour contrast of the shady north wall is rather low.
Aesthetic value	**Medium to high**
Cultural value	
Economic importance	As the most upper catchments areas of tributaries to the Tekeze river, Simen has an important role in maintaining perennial river flow. Overuse of this system would make the water flow seasonal, increase flooding and decrease dry season water availability for downstream irrigation and livelihoods (FZS – ADC, 2009). Moreover, the terraces-like steps are favourable for cultivation and human settlement and thus have a local economic importance.
Cultural value	**High**

Use and management characteristics

Protection of the site	
Protection status	The site is partly located inside the National Park but the larger zone is outside the protection zone of the park.
Damages and threats	No damages and threats.

Promotion of the site	
Visit conditions	
Accessibility	The lowland area of the National Park has no road access. Muchila is reached from Dip Bahir on foot within two days. The walk is physically extremely challenging as the trail leads of necessity down into the deep gorges and up again to the elevated terrace-like steps. From Muchila to Dihwara a minimum of 3 days is recommended; the daily goal often seems within reach, however, this appearance can be extremely deceiving. From Dihwara a direct, very steep but safe trail leads up to Chennek from where it is possible to reach Debark by vehicle on the same day.
Security	Risk of rock fall when walking at the foot of the escarpment cannot be ruled out.
Site context	The canopy of the montane forest and drainage of numerous streams even during the dry season offer a refreshing and pleasant environment. However, plants also cover up the relief, which is sometimes a hindrance for its observation. The view to the rugged-canyon like lowlands and the Awaza peaks is impressive.
Touristic infrastructure	Except of the ranger outposts at Muchila and Dirni, there is absolutely no tourist infrastructure available in this region and unlike the inhabitants of the highland local people in the lowland area are little used to tourism.
Visit conditions	**The visit conditions are rather problematic as access is difficult and basic tourist infrastructure is lacking.**
Education	
Education interest	The formation of the channel system and the fluvial erosion processes (especially headward erosion) mainly acting on this site are sufficiently simple to be understood by non-specialist visitors. The formation of the northern rugged terrain and isolated peaks and mountains in the distance as well as the terrace-like steps can be explained to amateur geologists using the concept of differential erosion.
Interpretation facilities	No interpretation facilities
Educational interest	**High**

Synthesis

Global intrinsic value

As the site's paleogeographical interest and rareness are medium the overall score of the central value is reduced but it still classifies as high due to high representativeness and integrity. As the additional values are quite high, especially the ecological and cultural values, the global intrinsic value is high.

Use and management

The educational interest of the site is high but the site is located in a relatively remote area of Simen where tourist infrastructure is lacking. However, tourism development opportunities have been discussed and among other projects a new trekking route to the lowlands was proposed as this would help for *"diversifying the product and routes away from the main Gich plateau towards lower elevation areas surrounding the SMNP in an effort to bring benefits to those communities who represent the major conservation threat to the natural values of the SMNP* (African Wildlife Foundation, 2014 : 22)."

Management measures and proposals

The site should figure in *ex situ* interpretation facilities, such as a well-illustrated guidebook entitled "*The geoheritage of the Simen Mountain's"* or "*Geotourim in the Simen Mountains*" available for sale at the information centre at the park headquarters or the geovisualisation of the geoheritage of Simen on the web. The link with additional values notably the importance as a water catchment area for critical water source for downstream irrigation and livelihoods (cultural value) and the function as habitat for unique aquatic fauna (ecological value) are of interest for the promotion of the site. Networking with other sites is rather difficult as the site is isolated from the highlands. However, the site could be promoted as an important attraction on the new trekking route. Moreover, an interpretive panel regarding this site should be installed at Chennek camp as this frequently visited place opens the view into the lowland.

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Author

L. Mauerhofer (2016)

Annex(s)

1. Fluvial erosion process working at the foot of the Northern Escarpment (Muchila to Diwhara)
2. Erosive landscape seen in the distance when walking along the Northern Escarpment

Annex 1: Fluvial erosion process working at the foot of the Northern Escarpment (Muchila to Diwhara)

Deep incision of the Inzo River forming one of the gorges observed between Muchila and Agidamyia.

Above right: Mass movement showing lateral stream erosion between Muchila and Agidamyia.

Above: Terrace-like steps at Aykotba with a resistant caprock layer topping softer volcanic sequences.

Annex 2: Erosive landscape seen in the distance when walking along the Northern Escarpement

To the left: Needle-shaped rock pinnacles (buttes) and steep-sided, flat-topped table mountains (mesas or Amba in Amharic); view from Anatola towards NE

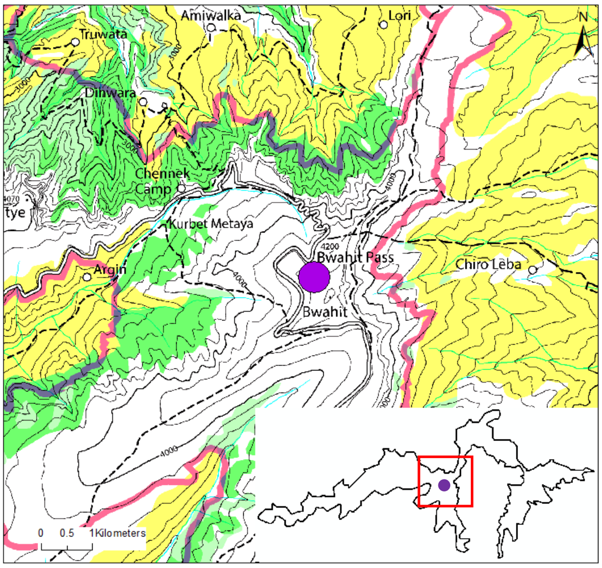
Above right: Awaza peaks observed from Anatola

Above: Rugged-canyon like lowlands, view from Kerneja

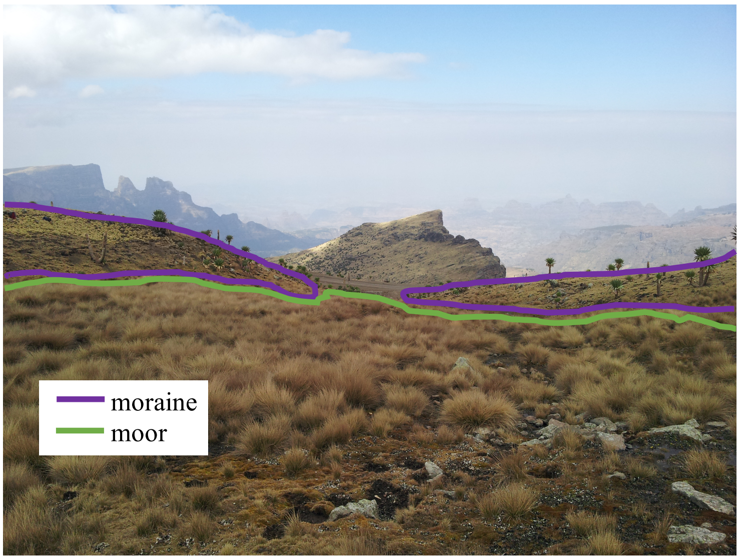
Glacial complex at Bwahit

SMNP

Short description: The site denotes the relict moraines and glacial landscape at Bwahit including three moors associated to the geomorphology of the Last Cold Period. Bwahit is named after the highest peak and surrounding plateau on the southwestern flank of the shield volcano. The site constitutes one of the most well-preserved and "readable" specimens of the glacial geomorphology and processes of Simen. The scientific and especially paleogeographic value of the moraines is of great importance for the understanding of the region's climate history.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.



Coordinates: **N 13°15'09.5" / E 38°13'01.0"**	Altitude: **4150 m** to **44k00 m**	Type: **AER**	Surface: **1.4 km²**

Property status: **PUB**

Characteristics: **natural, active and inherited**

Description

At Bwahit (4430 m) on the southwestern mountain group of Simen two **glacial cirques** and groups of **moraines** inherited from the Last Cold Period in Simen are observed above and below the public road (and electric power lines), which connects Debark through the National Park and over Bwahit to eastern Simen. H. Hurni (1981a; 1981b; 1982) conducted a detailed geomorphological and paleoecological study in Simen and genetically interpreted **rubble ridges** of "*angular boulders (ø2-100 cm), which are unsorted, unbedded, and without alignment of their longitudinal axes, lying in a brown-yellowish, indurated matrix of clayey silt. The ridges, which in most cases do not follow the fall line, have depth of 2-50 m, lengths of 100-500 m, widths of 25-150 m* (1981b : 129)" as moraines.

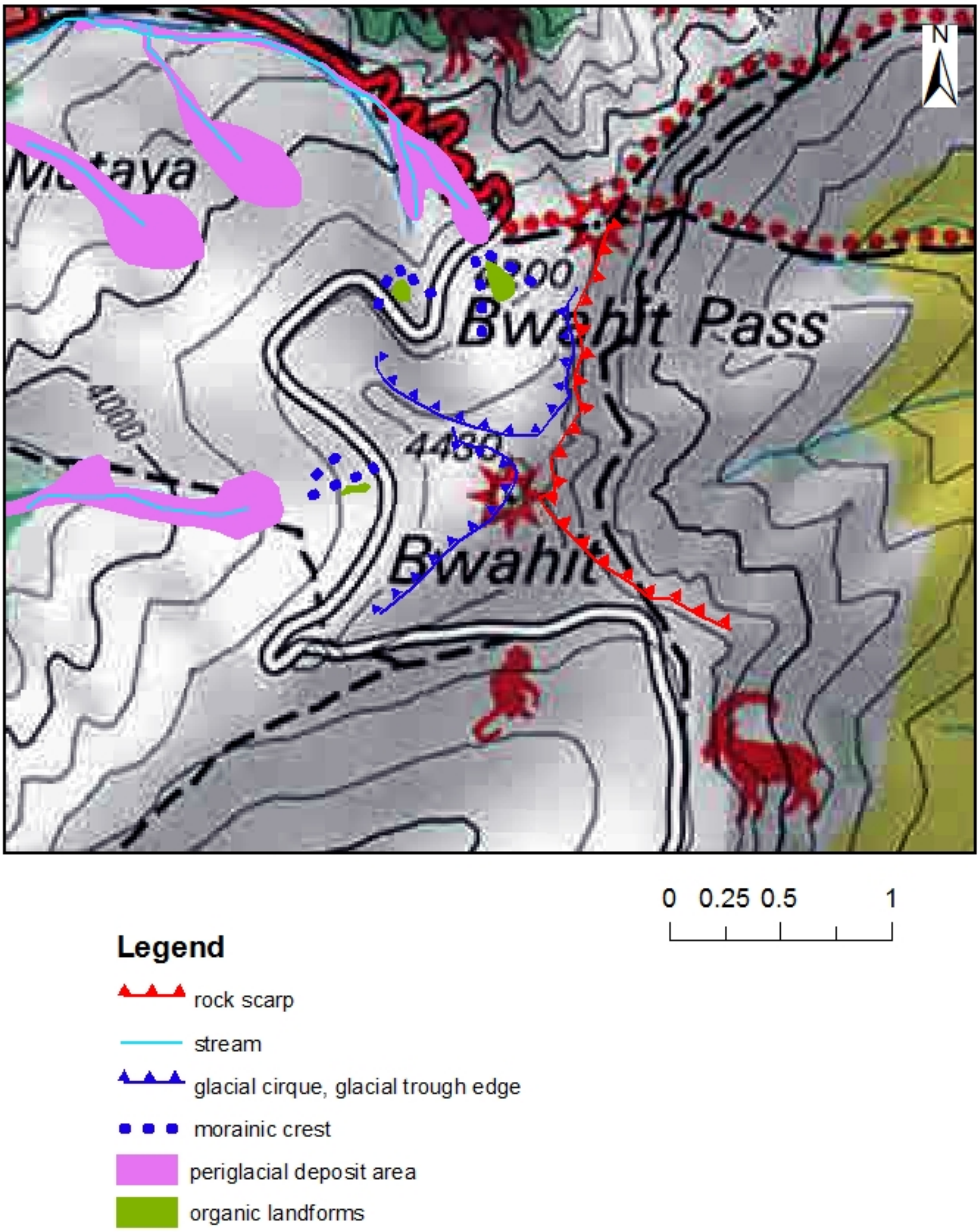
In the northern slope the overdeepening of the glacial cirque or **corrie** marks the **accumulation zone** of a **cirque glacier**, which developed two **tongues** with four **frontal moraines** (cf. annex 2 catchment I; and annex 3), all of them beginning at about 4200 m and ending at 4150 m. The western slope shows a similar hollow that marks the accumulation zone of a second glacier (cf. annex 2, catchment II), which also left a group of moraines downhill. One moraine, about 80 m long, is clearly identifiable (cf. annex 3) and several other glacial deposits, more difficult to distinguish, expand at the altitude of 4270 m to 4190 m. **Moors** are observed on both sides, as the highly compact frontal and ground moraine deposits are at the origin of the formation of humid zones favouring the accumulation of organic material. The southern slope was not glaciated while on the eastern slope no glaciers were formed due to a precipice that falls down to 3800 m (Hurni, 1982).

Morphogenesis

As this applies to Bwahit most glaciers of Simen occurred on a W to NE exposition down to the lowest limit at 3760 m (at Abba Yared) and almost no glaciation is found on the southern facing slopes. The reason for this **asymmetric distribution** of the glacial forms (and incidentally also periglacial) is explained by two climatic factors: **radiation and cloud cover**. "*Winter precipitation, as mountain-top snowfall, favoured snow accumulation and soil moisture storage on north facing slopes, because of the southern orbit of the sun* (Hurni, 1981b : 135)." The general tendency to cloud cover in the afternoon protected the W-slopes from insolation causing the same effect. "*Monsoon storms in summer with intensities similar to the present day, were not possible because of the fact that little run-off occurred on the unvegetated slopes. On the other hand, a complete lack of summer cloud cover would have intensified snowmelt and reduced soil moisture in northern facing slopes, between 12 April and 3 August, which is rather unlogical as well. Therefore, winter precipitation (temperate cyclonal?) and occasional summer cloud cover (from SE?) seems to be the most likely hypothesis favouring the formation of the observed geomorphic deposits* (Hurni, 1981b : 135)."

The Last Cold Period in Simen seems to be related to the "*world-wide glacial episode*" at the end of the Pleistocene. Integrated into the **climatic history** of Ethiopia, the Last Cold Period paleoclimate of Simen is best correlated with "*the last dry period in the Pleistocene, with reduced run-off, low lake levels in the Afar region and in the southern Sahara, and missing monsoonal summer precipitation north of approximately 10° N, […] between 20,000 and about 12,000 BP (J. A. Coetzee, 1967 : 88; Gasse, 1975; Williams & Adamson 1980 : 287; or K. W. Butzer, 1980 : 272), with a cold maximum between 17,000 and 15,000 BP (Jaekel 1977; Lauer & Frankenberg, 1979)* (Hurni, 1981 : 135)." The mean annual temperature appears about 7° C cooler than today thus the medium **snowlin**e is expected at 4250 m +/- 150 m depending on slope aspect (cf. annex 1). This means that summit areas with highest peaks below 4300 m did no longer show glaciation even on a northern slope. At the Bwahit-Mesarerya Mountain group the glacial ice covered a surface of approximately 1.6 km^2 during the maximum stage (Hurni, 1982). This has to be seen with in total 50 moraines or 20 accumulation zones in Simen allotted to three different mountain groups, only 15 km away from each other and covering the total area of 13 km^2 (Yared group 4.5 km^2; Dejen group 6.9 km^2). Today the theoretical snowline would be 700 meter higher at around 5000 m, clearly above the highest peaks (Hurni, 1981a).

Moraines and moors around Bwahit



L.Mauerhofer, 2015. Base map: © Centre for Development and Environment, University of Bern, 2010

The limits of the mapped landforms especially of the periglacial deposits are indicative, for precise cartography compare the map of the altitudinal belts of the Last Cold Period in Hurni 1981a.

Intrinsic value

Central value		
Integrity	The frontal moraines and moor of the glacier tongue above the public road in the eastern part of the northern facing slope (cf. annex 2, catchment I) are well-preserved while the frontal moraines of the second glacier tongue in the same zone is slightly affected by the road (at 4180 m).	0.75
Representativeness	This site is representative of the glacial process and landforms of the Last Cold Period characterising the area below the highest peaks of Simen.	1
Rareness	Well-visible moraines are as rare as the highland swamps or moors associated to the glacial complex. There are however even larger and better preserved moraines on Ras Dejen and Abba Yared (cf. sheet 10 and 11).	0.75
Paleogeographical interest	The Last Cold Period glacial and periglacial forms at Bwahit represent an important site for the study of the last glacial extension and reconstruction of the paleoclimate of Simen. All the significant work related to the topic in chronological order of publication comes from the following authors: Minucci (1938), Nilsson (1940), Buedel (1954), Hoevermann (1954), Werdecker (1955; 1968), Scott (1958), Mohr (1962), Hastenrath (1974), Messerli, (1975) and Williams et al (1978) and Hurni (1981a; 1981b) all cited in Hurni (1982).	1
Scientific value	**Very high**	**0.88**

Additional values	
Ecological value	
Ecological impact	Highland swamps, a key feature of the Afroalpine grasslands support a number of resident and migratory water bird populations (FZS – ADC, 2009).
Ecological value	**Very high**
Aesthetic value	
View points	No particular viewpoint is noted but, the whole glacial complex including the cirque and moraines is observed from the Bwahit road.
Contrast, vertical development and space structuration	The vertical development of the corries is of some hundred meters and shows some significance for the space structuration at Bwahit. This cannot be said of the moraines, which are small to medium size forms. The stronger or in colour distinct vegetation cover of the moors and glacial deposits contrasts with the surroundings.
Aesthetic value	**Medium to high**
Cultural value	
Cultural value	**Very low to null**

Use and management characteristics

Protection of the site	
Protection status	The site is located inside the national park boundaries and is therefore under protection.
Damages and threats	The construction of the public road has damaged the upper part of one moraine on the northern aspect of Bwahit. Other human interventions in the area are a potential threat for the integrity of the site, especially for the easily overlooked and destructible moraines.

Promotion of the site	
Visit conditions	
Accessibility	The site is accessible on the all-weather gravel road from Debark in about 2-3 hours. No walking is necessary. However, trekking from Chennek campsite to Bwahit summit is possible and takes about 2h one way (uphill). There is no special walking difficulty.
Security	No security issues.
Site context	The presence of the public road, traffic noise and power lines "*impacts upon the ability of visitors to enjoy the views and general wild and natural qualities* (African Wildlife Foundation, 2014 : 6)."
Touristic infrastructure	Very poor standard accommodation is reached within 20 minutes driving at Chennek (African Wildlife Foundation, 2014).
Visit conditions	**Reasonable visit conditions with direct access from Debark by car within 2-3 hours and very basic touristic infrastructure available at Chennek camp.**
Education	
Education interest	Especially the glacial tongue with the two frontal moraines and moor deposit on the northern slope above the road present an excellent specimen of the glacial process, simple enough to be understood by non-specialist visitors. The largest moraine on the western slope could also be used for educational purposes as it is well seen from the road.
Interpretation facilities	No interpretation facilities.
Educational interest	**High**

Synthesis

Global intrinsic value

The scientific value is very high, in particular the paleogeographical interest and representativeness are the strengths of the site but the rareness and integrity are quite important too. Combined with the very high ecological value the global intrinsic value is very high.

Use and management

The site is very well accessible by car or walking from Chennek. The visit conditions quite reasonable but the road and power line cutting through the site reduce the aesthetic and environmental quality. More human interventions in the area are a potential threat even though Bwahit is included into the National Park perimeter. Interpretation facilities, which would use the high educational interest and enhance the understanding of the glacial processes are lacking.

Management measures and proposals

It appears that the public road has been planned and built without knowing of the geoheritage of the Simen Mountains. To fill this gap, it is suggested to highlight Bwahit in the next version of the General Management Plan as a significant and highly vulnerable geomorphosite. Awareness rising of the glacial geomorphological and paleoclimatic interest will be crucial in order to enhance the value of the site to better protect it from other human interferences.

"Glaciers" are an extraordinary term to discuss in an African country like Ethiopia where ice and cold conditions only occur on the highest peaks, such as the Simen Mountains and many visitors of Simen are even surprised to encounter frozen ice there. Indeed, the site has its own interest; it represents a great teaching material of the glacial process and curious climatic history using a solid specimen in nature. Pictures of glaciers on Kilimanjaro, in the Alps and elsewhere in the world as well as simple interpretive materials, figures and schemes of glacial advance and retreat should be collected and used for illustration. As most Ethiopians may not be familiar with the topic, awareness rising and training on glacial geomorphology should be first offered to the park staff by visiting Bwahit and other relevant places for glacial evidence in Simen (cf. sheet nr. 10 and 11).

In a second step official tourist guides should be trained in this matter as Bwahit could be included in the "*sightseeing tour*" on the "*geoheritage of the Simen Mountains*" as proposed before (cf. sheet nr. 1 and 5). An environmentally and aesthetically integrated signpost next to the road could inform about the importance of this site. It could also be treated in *ex situ* interpretation facilities as a chapter on the topic of glacial geomorphology, climatic history and perhaps in association with current climate change. Furthermore, the site offers good evidence for awareness rising regarding the links between the relief and the presence of specific biotopes (moraine deposits and presence of moors) and this information should not be lost in any geological enhancing of Bwahit.

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Annex(s)

1. Snowline of the Last Cold Period as reconstructed from moraines and cirques (Hurni, 1982)
2. Last Cold Period glacial forms of the southwestern mountain complex of Simen (Hurni, 1982)
3. Moraines and moors around Bwahit

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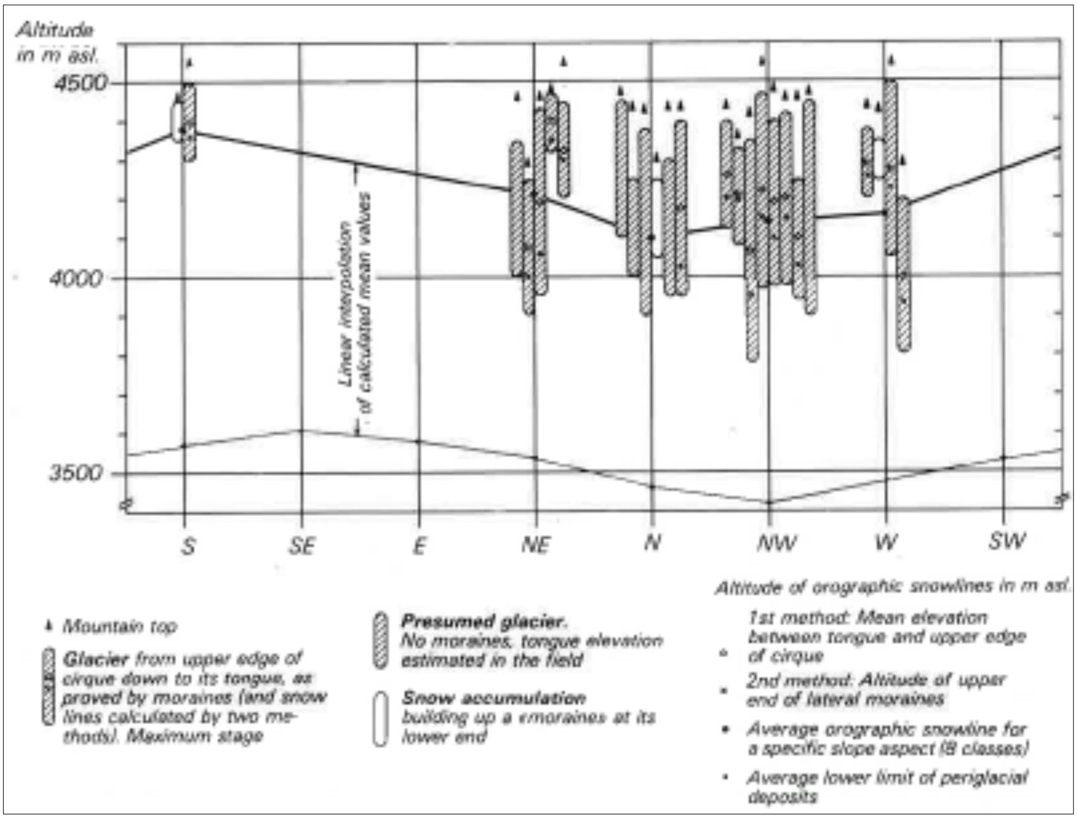
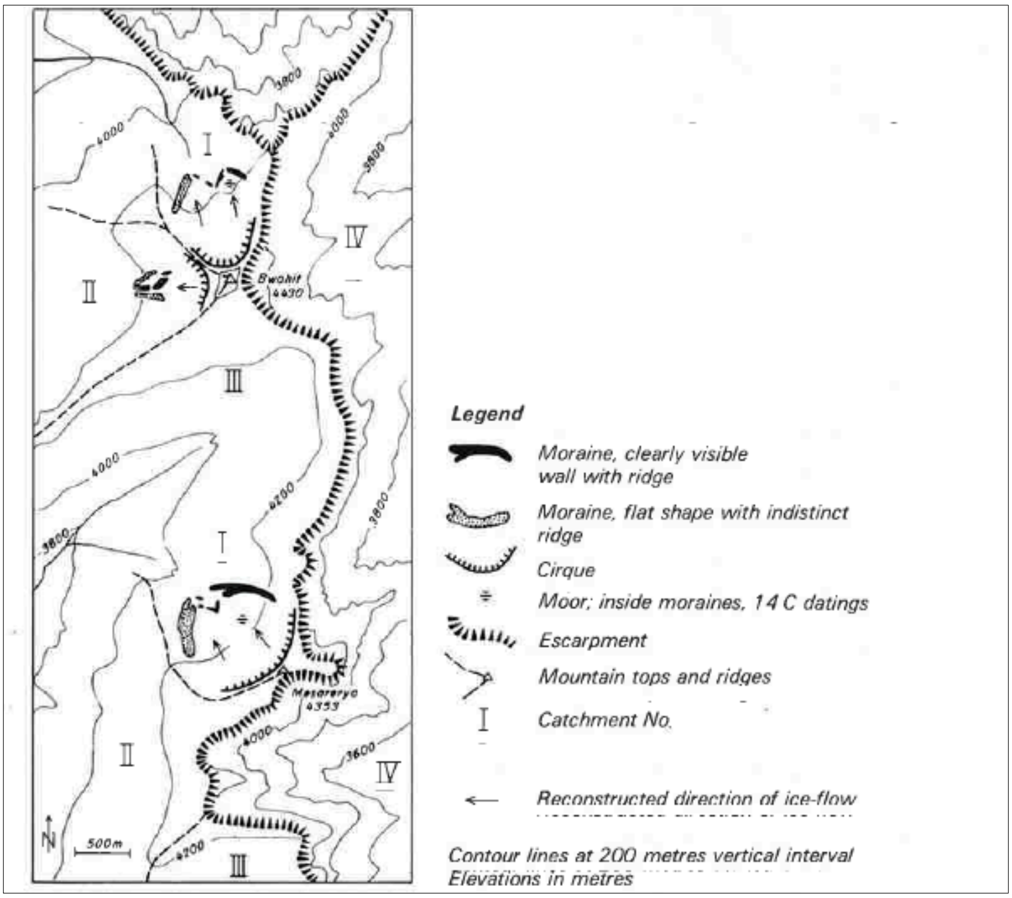
[2] Citation in Hurni, 1982
[3] Unable to adapt source correctly to the APA (American Psychological Association) – citation style (6th).

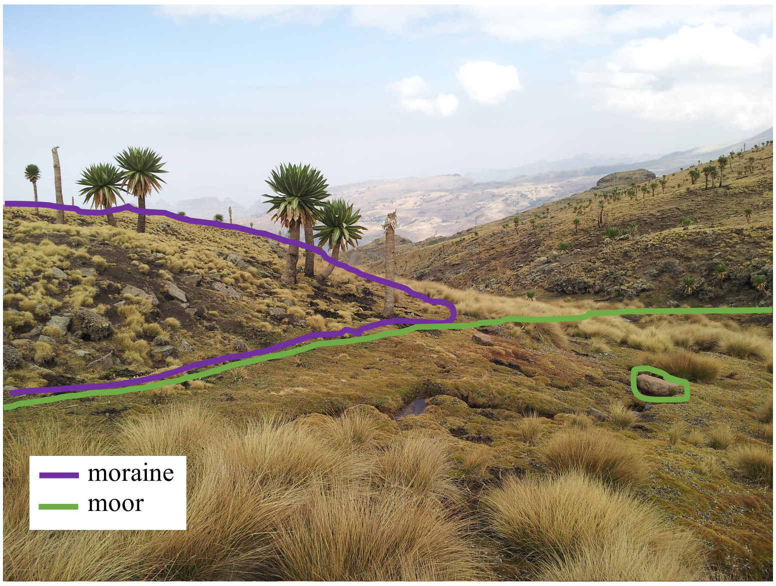
Annex 1: Snowline of the Last Cold Period as reconstructed from moraines and cirques (Hurni, 1982)



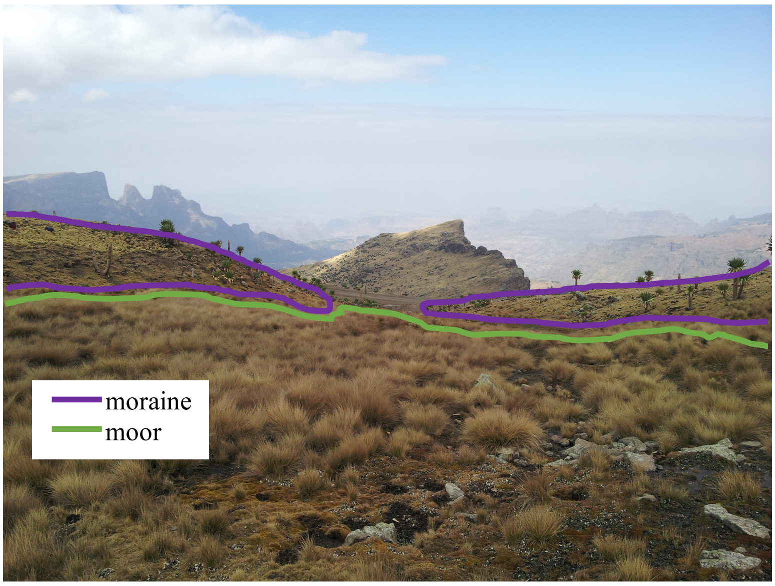
Annex 2: Last Cold Period glacial forms of the southwestern mountain complex of Simen (Hurni, 1982)



Annex 3: Moraines and moors at Bwahit



Left: Frontal moraine and moor at the Northern side of Bwahit, below the road.



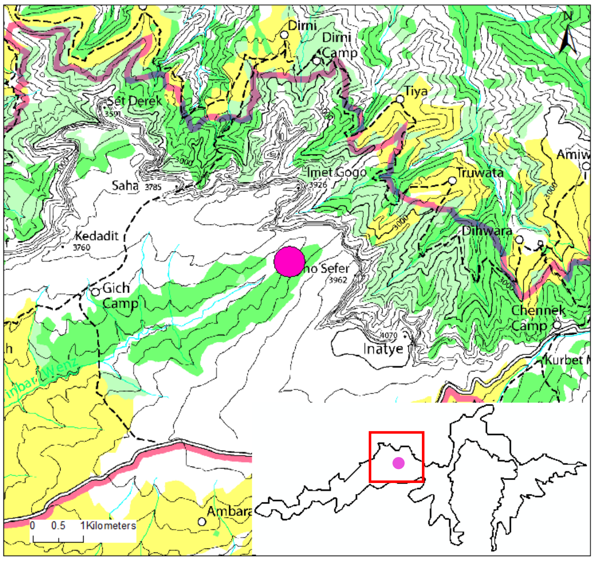
Left: Well-preserved moraine and moor at the Northern side of Bwahit, above the road.

Left: Longest moraine of Bwahit, about 80 meters long, on the Western side of Bwahit with small moor.

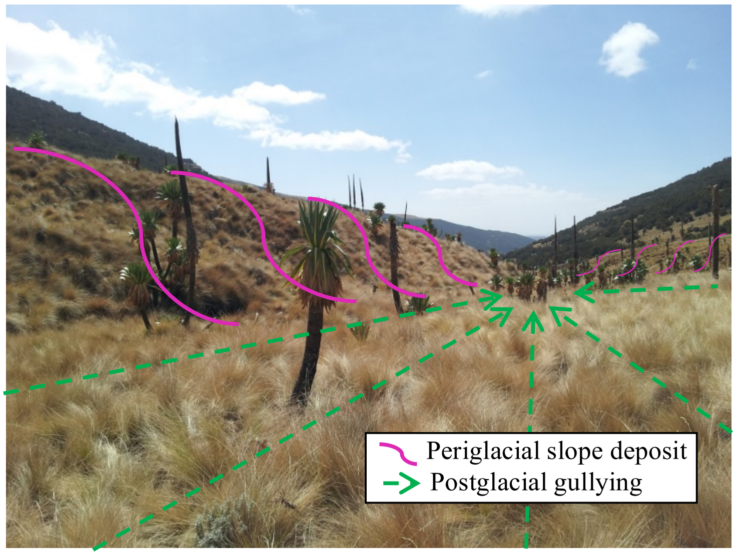
Periglacial (solifluvial) slope deposit of the upper Jinbar valley

SMNP

Short description: In the upper Jinbar valley an up to 15 m powerful specimen of so-called periglacial solifluvial deposits (or periglacial slope deposits), described as rubble on a trough-shaped slope reaching down as far as the lower limit of the Last Cold Period periglacial belt at ~ 3500 m are well traceable until the valley bottom. These relict landforms are the expression of solifluction composed of mass movements triggered by soil water in the diurnal freeze-thaw cycle.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.



Coordinates: **N 13°16'23.49" / E 38° 8'30.15"**	Altitude: **3550 m** to **3800 m**	Type: **AER**	Surface: **72 ha**

Property status: **PUB**

Characteristics: **natural, inherited**

Description

The **periglacial solifluvial deposits** inherited of the Last Cold Period consist of 0.1 m to 15 m powerful **rubble on trough-shaped slopes** made up of "a*ngular boulders (ø 10-20 cm, up to 100 cm), which are unsorted and unbedded, but partly aligned parallel or rectangular to the fall line, lying in a very uniform, brown-yellowish, indurated matrix of clayey silt* (cf. annex 2) (Hurni, 1981b : 129)."

In the upper Jinbar valley such periglacial deposits on trough-shaped slopes are well traceable until the valley bottom. The left-sided deposit begins at approximately 3900 m and reaches downwards at 3550 m up to 15 m thickness (cf. annexs 1 and 4). The right-sided deposit of the S-flank starts at about 3650 m and reaches 5 m thickness. The large **gully** in the centre has emerged after the Last Cold Period (cf. postglacial gullies, sheet 8) (Hurni, 1981a).

Morphogenesis

The genesis of the slope deposits results in processes of **mass movements** composed of soil water in the diurnal **freeze-thaw cycle (**Hurni, 1981a)**.** This explanation reflects what A. L. Washburn (1979 : 201) in Goudie (2004 : 984) understands as **solifluction** in a *broad sense* referred to *"frost creep (soil creep associated with freezing) resulting from nearly vertical settlement of soils heaved normal to the slope and gelifluction representing downslope displacement of ice rich soils during thawing."*

Slope rubble is generally increasing in thickness downhill. For thickness over 2 m, the slope deposits are a "*shape-forming*" element of the landscape including a surface of some 100 km^2. "*Deposits on through-shaped slopes with over 0.1 m powerful overlays define the lower limit of dominant solifluction processes; this shallow deposits are no longer morphologically forming but only pedologically horizon building."* Following their occurrence on an imaginary line through the landscape the lower limit of the **Last Cold Period periglacial belt** is on medium at 3500 meters and runs parallel to the **snow line** 3400 m in Northern, 3600 m in Southern exposures (cf. annex 3). "*In addition, the limit is at the foot of long and / or steep slopes on medium by 50 m deeper, respectively in short and / or shallow slopes higher than the medium*." These trends are typical of periglacial-solifluvial processes as the transport of frost debris along long and steep slopes undergoes a reinforcing effect and thus remains effective down into deeper altitudes. Thus, the periglacial belt during the Last Cold Period covered a total surface of approximately 470 km^2 (translated from Hurni, 1981a : 101).

"*The distances of solifluvial movements, along the slope over a distance of up to 1000 m require, even with 100-300 days of frost change and sufficient soil moisture per year, a formation period of several millennia* (Washburn, 1973 : 179, in Hurni, 1981b : 134)." It can be demonstrated that the **moraines** and periglacial slope deposits were created or revised at the same time (**Late Glacial about 20,000 to 12,000 BP**) under the same climatic conditions (Last Cold Period paleoclimate, cf. sheet nr. 7), as they merge into each other all over the highlands, but do not overlap (Hurni, 1982).

It is difficult to fit solifluvial slope deposits into the system of periglacial forms as it was prepared for high latitude locations and forms of cold periods of the mid-latitudes. They lie somewhere between periglacial **"*talus slopes*"** by A. Rapp (1960, 1962) and **"*Grèzes litées*"** by Y. Gullien (1951), both cited by M.A. Embleton and A.M.C. King (1968 : 522, in Hurni, 1982 : 103). **Rock glaciers** which "*occur in most alpine-mountainous regions and are distinct tongues of rock rubble which flow slowly downhill [and a clear evidenced of permafrost]* (Goudie, 2004 : 876)" are not found in the Simen Mountains. However, past sporadic permafrost occurrence was suggested in the stronger clouded and more humid Bale Mountains (at N 7°52' / E 39°24') at the same altitude on the South Eastern Ethiopian Plateau (Grab, 2002).

Intrinsic value

Central value		
Integrity	No impact on the integrity.	1
Representativeness	Highly representative of the relict periglacial landforms and periglacial process of the Last Cold Period in Simen	1
Rareness	With thickness of up to 15 meters the periglacial slope deposits of the upper Jinbar valley are the most impressive specimens of this form type.	0.75
Paleogeographical interest	An important reference site for the geomorphic and morphogenetic study of this form type and their climatic prerequisites for the reconstruction of the Last Cold Period climate.	1
Scientific value	**Very high**	**0.94**

Additional values	
Ecological value	
Ecological impact	No ecological impact is known.
Ecological value	**Very low to null**
Aesthetic value	
View points	No view points
Contrast, vertical development and space structuration	The vertical development between 5 and 15 meters is impressive for periglacial slope deposits but their impact on space structuration is low. No comment on the contrast (neutral)
Aesthetic value	**Low**
Cultural value	
Cultural value	**Very low to null**

Use and management characteristics

Protection of the site	
Protection status	The site is located inside the national park boundaries and is therefore under protection.
Damages and threats	No damages and threats.

Promotion of the site	
Visit conditions	
Accessibility	There is access from Debark via Gich and / or Chennek on the first day plus 2-4 hours walking on the Main Gich Plateau Trekking Route the next day. No particular walking difficulty on this trail.
Security	No security issues.
Site context	The high grass is not serving for the detection of the periglacial landforms but the calm and natural environment of grassland and "*Tree-heather forest*" offers a positive site context (Nievergelt, 1998).
Touristic infrastructure	Accommodation and camping infrastructure at a very poor standard are available at Gich and Chennek.
Visit conditions	**Reasonable visit conditions with good access on a frequently used trekking route, very basic accommodation opportunities in proximity and a positive site context.**
Education	
Education interest	Even though the site presents one of the most spectacular examples of relict periglacial landforms in Simen the geomorphological process working on this site is rather complex and could be only fully appreciated by non-specialist visitors with appropriate interpretation facilities or with guided visits. However, for specialist visitors or university scholars the site offers an interesting case to study the Last Cold Period periglacial processes in Simen.
Interpretation facilities	No interpretation facilities.
Educational interest	**Medium**

Synthesis

Global intrinsic value

The global intrinsic value is composed of a very high central value characterised by a high representativeness, a very significant paleogeographical interest and a great integrity and very poor additional values.

Use and management

The site is located in a pristine part of the National Park where traces of human intervention are hardly visible. Access to the site requires two days from Debark. But since it is only a few hundred meters away from the main trekking route it can still be relatively easily visited. The education interest is medium, which means it is of interest only for aspiring specialists and visitors interested to geomorphology.

Management measures and proposals

There are numerous geosites located on the trek from Sankabar via Gich to Chennek (such as Jinbar waterfall, natural arch at Kedadit, volcanic sequences at Imet Gogo, etc.) thus visits to those sites can be connected. As the site is not visited currently by tourists (on the contrary to the Jinbar waterfall for example) and as the educational interest is medium it is suggested to bring to this particular site only amateur geomorphologists and scholars who have booked a specific geoheritage product and explicitly wish to focus and learn on that topic. In that way the integrity of the site is maintained and an adequate level of exclusivity is guaranteed. As described in sheet nr. 1 specialised geotourism operators or official SMNP tourist guides had to be trained. They have to be well-versed in the subject and meet with the high expectation that is required to ensure exclusivity.

Moreover, a self-guided geo-trail should be proposed and presented as an appealing booklet available for little money at the park headquarters and at other important sailing point or guesthouses. The trail should follow a 2 or 3-days trekking from Sankabar to Chennek via Gich with visits to most of the geosites found on the way (there are about 10 sites) including appropriate explanation of the geomorphological context of each site. The periglacial slope deposits of the upper Jinbar valley could be one attraction point.

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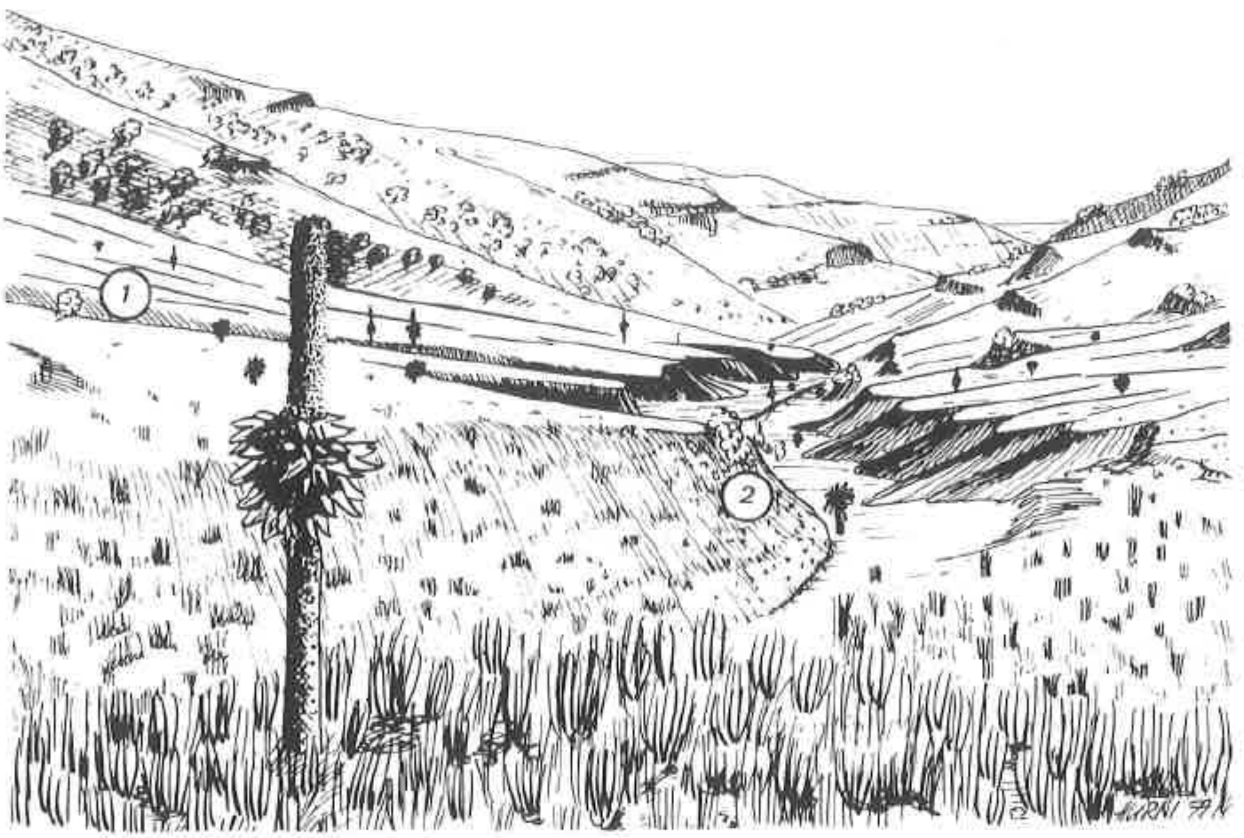
Author

L. Mauerhofer (2016)

Annex(s)

1. Sketch of the Last Cold Period periglacial slope deposits in the upper Jinbar Valley (Hurni, 1982)
2. Two natural profiles showing Last Cold Period periglacial deposits (Hurni, 1982)
3. Lower limit of the Last Cold Period periglacial slope deposits in Simen (Hurni, 1982)
4. Periglacial slope deposits in the upper Jinbar Valley at 3600 m

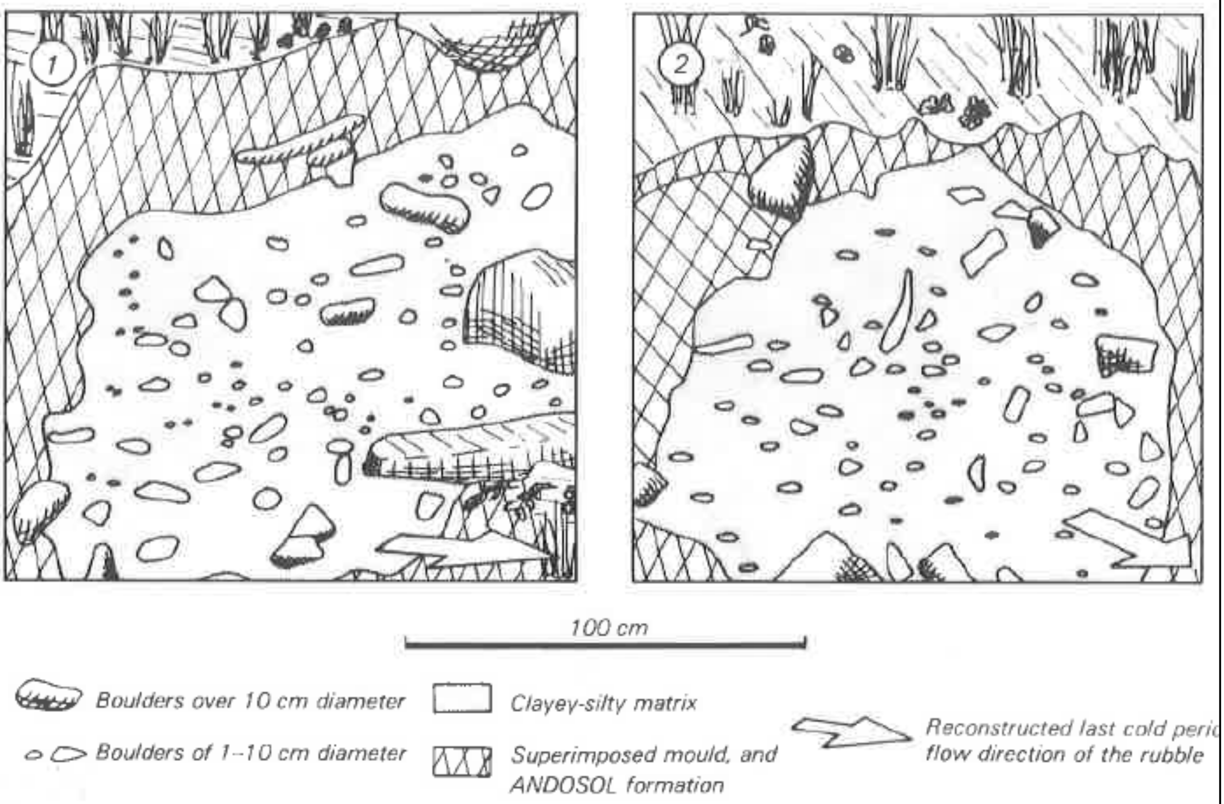
Annex 1: Sketch of the Last Cold Period periglacial slope deposits in the upper Jinbar Valley (Hurni, 1982)



Figur 32 Ansicht des Oberlaufs des Jinbartales mit periglazialen Hangmuldenverfüllungen der letzten Kaltzeit bis in die Talsohle (im Vordergrund eine blühende Lobelie). Blickrichtung talabwärts nach WSW. Die linksseitige Ablagerung setzt bei zirka 3900 m ein und erreicht hier unten bei 3550 m bis 15 m Mächtigkeit. Die rechtsseitige Ablagerung an der S-Flanke setzt bei zirka 3650 m ein und erreicht bis 5 m Mächtigkeit. In der Mitte die nachkaltzeitliche Erosionsrinne des Jinbarflusses zirka 500 m unterhalb seiner Quelle. 1 und 2 bezeichnen die Profilausschnitte von Figur 33. 25.10.1974; 8.2.1977.

View from the sources of the Jinbar river downwards towards WSW, with a flowering Lobelia in the foreground. Last cold period periglacial slope deposits on the left side descend from 3900 m asl. to here 3550 m, and reach 15 m thickness. The right side deposits descend from 3650 m asl. and reach 5 m thickness. In the middle post glacial gullying of the Jinbar river about 500 m below its source. The figures give profile numbers of Figure 33.

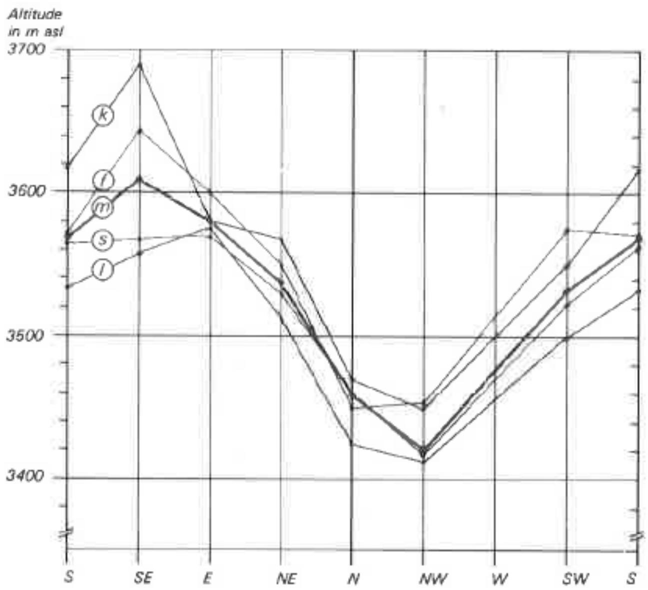
Annex 2: Two natural profiles showing the Last Cold Period slope rubble (Hurni, 1982)



Figur 33 Ansicht der beiden Profil-Ausschnitte 1 und 2 von Figur 32. Beide Profile wurden in fast senkrechten Seitenwänden von (sekundären) Erosionsrinnen im mittleren Bereich der mächtigen kaltzeitlichen solifluvialen Hangmuldenverfüllungen der Jinbar-N-Flanke angegraben. Anteil von unsortiertem, kantigem Geröll ca. 40 bis 50%; Matrix sehr hart, tonig-siltig, gelb-braun. Einregelungen hangparallel flach und mit Längsachse hangabwärts. Einheitliche Struktur und Textur mit homogener Matrix . Aufnahme 25.10.1974.

View of two natural profiles situated as indicated in Figure 32, showing last cold period periglacial deposits. Both profiles were dug only in the central part into the almost vertical side-walls of the gullies. Angular rubble forms 40–50% of the deposit. The homogenous matrix is very hard, yellow-brown, and consists of clayey silt, with longitudinal axes of boulders regulated in the direction of former flow.

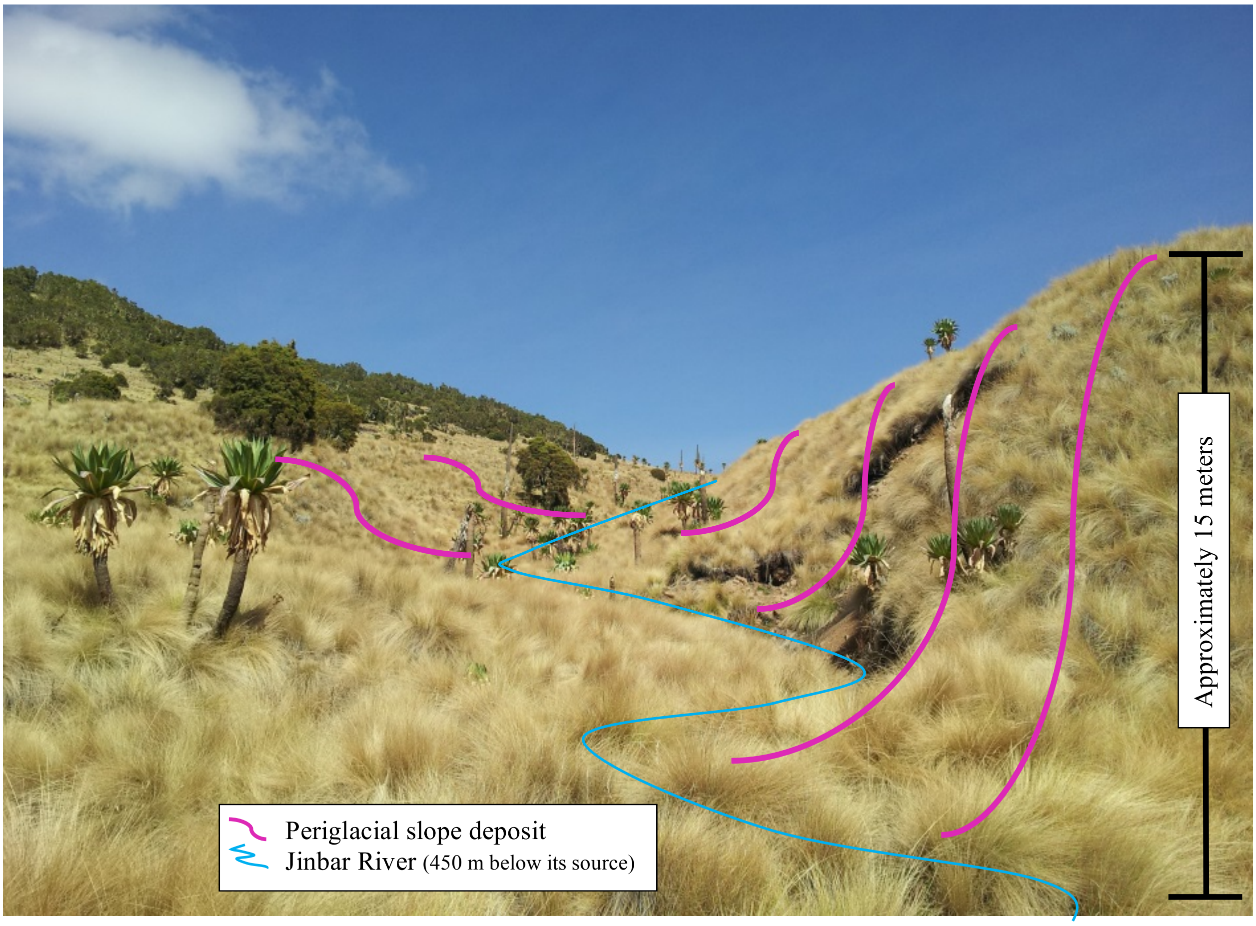
Annex 3: Lower limit of the Last Cold Period periglacial slope deposits in Simen (Hurni, 1982)



Figur 43 Topographische Analyse der Untergrenze der letztkaltzeitlichen periglazialen Hangmulden-verfüllungen (= Frostschuttstufe) mit den Parametern Höhe, Exposition, Hangneigung und -länge: k: Untergrenze kurzer, l: langer Hänge; f: Untergrenze flacher, s: steiler Hänge, und m: Mittlere Untergrenze aller kartierter Hänge.

Topographic analysis of the lower limit of the mapped last cold period periglacial slope deposits (= frost detrital belt), dependent on altitude, slope aspect, gradient, and length. Lower limit on short (k), long (l), flat (f), and steep (s) slopes alone, and mean lower limit (m) of all mapped slopes.

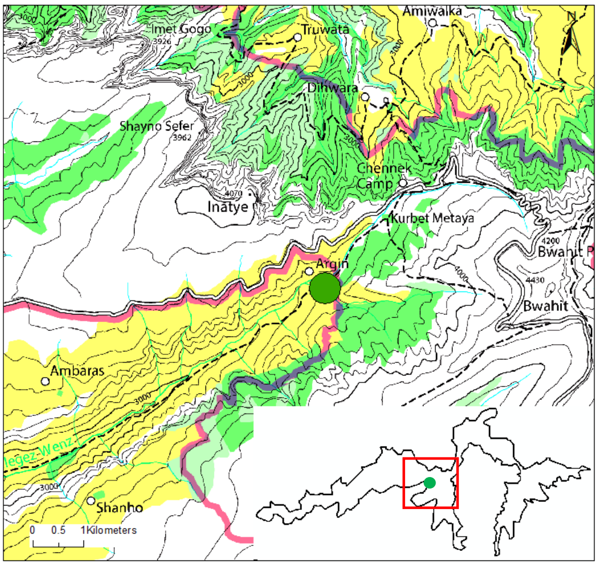
Annex 4: Periglacial slope deposits in the upper Jinbar Valley at 3600 m



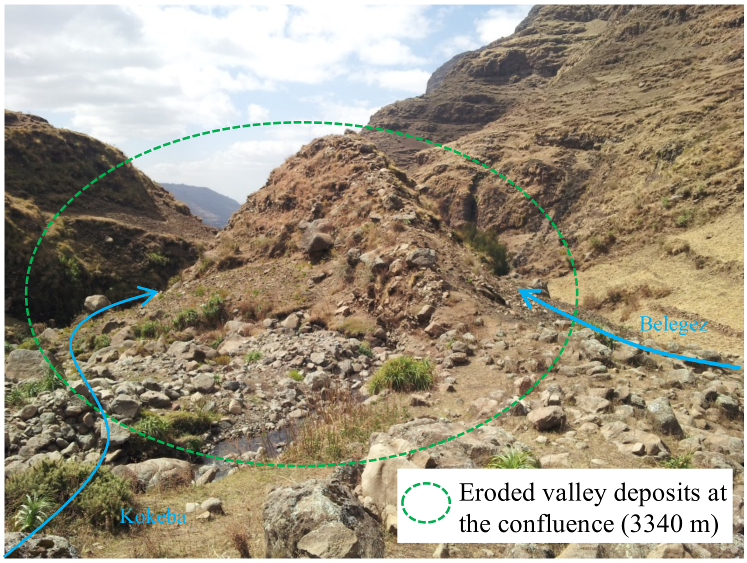
Fluvio-solifluvial valley deposits at Argin village

Debark (Argin Jena)

Short description: At Argin village up to 40 m thick rubble deposit is interpreted as fluvio-solifluvial valley deposit. Such valley rubble is found on the bottom of steep valleys above 3000 m and bears the traces of both fluvial and periglacial (solifluvial) processes of the Last Cold Period or of the end of the Last Cold Period in Simen.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.



Coordinates: **N 13°14'41.94" / E 38°10'30.78"**	Altitude: **3340 m** to **3470 m**	Type: **AER**	Surface: **20 ha**

Property status: **PUB**

Characteristics: **natural, inherited**

Description

With fluvio-solifluvial **valley deposits** is understood *"rubble in valley floors (valley rubble) of boulders (ø 2-200 cm), which are partly angular, differently bedded or sorted, in an irregular, changing, brown-yellowish matrix ranging from clay to sand* (Hurni, 1981b : 129)." The occurrence of valley rubble is locally limited to the bottom of steep valleys above 3000 m, with thicknesses of 1-40 m (Williams et al. 1978). At Argin village up to 40 m thick exemplar of eroded valley deposits, especially visible at the confluence of the Kokeba with the Belegez River at 3340 m are extending upstream along the Kokeba (cf. annex 1). The form constitutes a **conical fan** at the exit of the side valley (Kokeba) to the main valley (Belegez) with a slightly convex cross-section, while it has in the bottom of the steep valley itself a +/- horizontal surface in cross-section.

Morphogenesis

Unlike the slope rubble (cf. periglacial **slope deposits**, sheet nr. 8), the valley rubble was not formed through purely periglacial processes but formed most likely simultaneously or immediately after the Last Cold Period (Hurni, 1981a). Its genesis reveals that a combination of fluvial and solifluvial processes took place, with **debris flows**, **soil creep** and **solifluction** processes. "*Same as the rubble ridges (**moraines**, cf. sheet nr. 7) and the slope deposits (slope rubble) occur side by side, without overlap, this is also true of slope deposits and valley deposits (deposits on valley floor) (cf. annex 2). The latter are mostly below the former, with relatively smooth transitions, from about 3700 m inserting [and extending to below the Last Cold Period periglacial limit (at 3500 m in average)]* (Hurni,1982 : 107)."

H. Hurni (1981b : 129) recapitulates two common characteristics of the three related form groups (rubble ridges, slope rubble and valley rubble cf. annex 3) partly difficult distinguishable from each other in the field. "*They are fossil, because they were all fluvially eroded after their formation (**gullies**, cf. sheet nr. 12), and then altered by formation of about 70 cm deep Andosol A-horizons, the latter enriched with volcanic ash deposits (cf. sheet nr. 13). Below the climatic barley limit at 3700 m, these A-horizons layers are again damaged by man-made **soil erosion** during the last two millennia or so (cf. sheet nr. 14). The second common characteristic is the simultaneous formation of at least the first two form groups: Rubble ridges and slope rubble merge into each other, but do not overlap*".

Intrinsic value

Central value		
Integrity	No harm.	1
Representativeness	The site is exemplary of fluvio-solifluvial valley deposits and of the interaction of fluvial and solifluvial processes at the transition zone of the lower limit of the Last Cold Period periglacial belt in Simen.	1
Rareness	It is rare that specimen of fluvio-solifluvial valley deposits are so impressive and well preserved	0.75
Paleogeographical interest	The site significantly contributed to the understanding of the periglacial process, setting of the Last Cold Period periglacial belt as well as the reconstruction of the Last Cold Period paleoclimate.	0.75
Scientific value	**Very high**	**0.88**

Additional values	
Ecological value	
Ecological impact	No ecological impact is known.
Ecological value	**Very low to null**
Aesthetic value	
View points	The site can be observed from the public road on the Ambaras plateau to Chennek.
Contrast, vertical development and space structuration	Fluvio-solifluvial valley deposits are not an important space structuring feature but this site presents the most powerful specimen of this form type with 40 meter in height. The contrast is rather weak dominated by brownish colour.
Aesthetic value	**Medium to low**
Cultural value	
Cultural value	**Very low to null (unknown)**

Use and management characteristics

Protection of the site	
Protection status	The site lies on the boarder of the National Park
Damages and threats	No damage but the site is located in the surroundings of Argin village thus human interferences are a potential threat.

Promotion of the site	
Visit conditions	
Accessibility	The site is accessible on the all-weather gravel road from Debark to Chennek in about 2h hour plus 20-minute walk to Argin down to the valley. There is no particular walking difficulty.
Security	No security issues.
Site context	The relief forms are well exposed as there is only little vegetation cover in the river basin so that the matrix of the valley rubble can be observed. The site is located in Argin village; no calm there but nice and welcoming people.
Touristic infrastructure	Basic infrastructure is available at Chennek camp.
Visit conditions	**Reasonable visit condition but as everywhere in Simen good touristic infrastructure is lacking.**
Education	
Education interest	The striking valley rubble at Argin illustrates well the fluvial and solifluvial processes of the Last Cold Period. Boulder forms and sorting can be observed so that non-specialist visitors could understand the process.
Interpretation facilities	No interpretation facilities.
Educational interest	**Rather high**

Synthesis

Global intrinsic value

The rather high global intrinsic value is especially due to the great integrity and representativeness of the site and poor additional values.

Use and management of the site

The site is surrounded by the settlement of Argin village and the area has been highly cultivated in the past. There is easy access from Debark via Chennek and the educational interest is rather high but only few visitors go to Argin. The new Tourism Development Plan proposes community-based tourism (cultural tourism) and in this context visits to local communities have been organised at Argin (African Wildlife Foundation, 2014).

Management measures and proposals

Since visits to local communities are suggested at Argin it is recommended to valorise the site as an additional attribute of this product. Leaflets promoting these visits with appropriate explanation of the geomorphological context and the cultural particularities should be available at the park headquarters and at Chennek camp. Moreover, the site could be one stop on the "*sightseeing tour to discover the geoheritage of the Simen Mountains*" (cf. sheet nr. 5). Scholars or amateur geomorphologists taking a geomorphology course or a training on geomorphosites should visit the fluvio-solifluvial valley deposits on the last day of their trekking before returning back to Debark (cf. sheet nr. 8). For all these visits specialised guides should be available.

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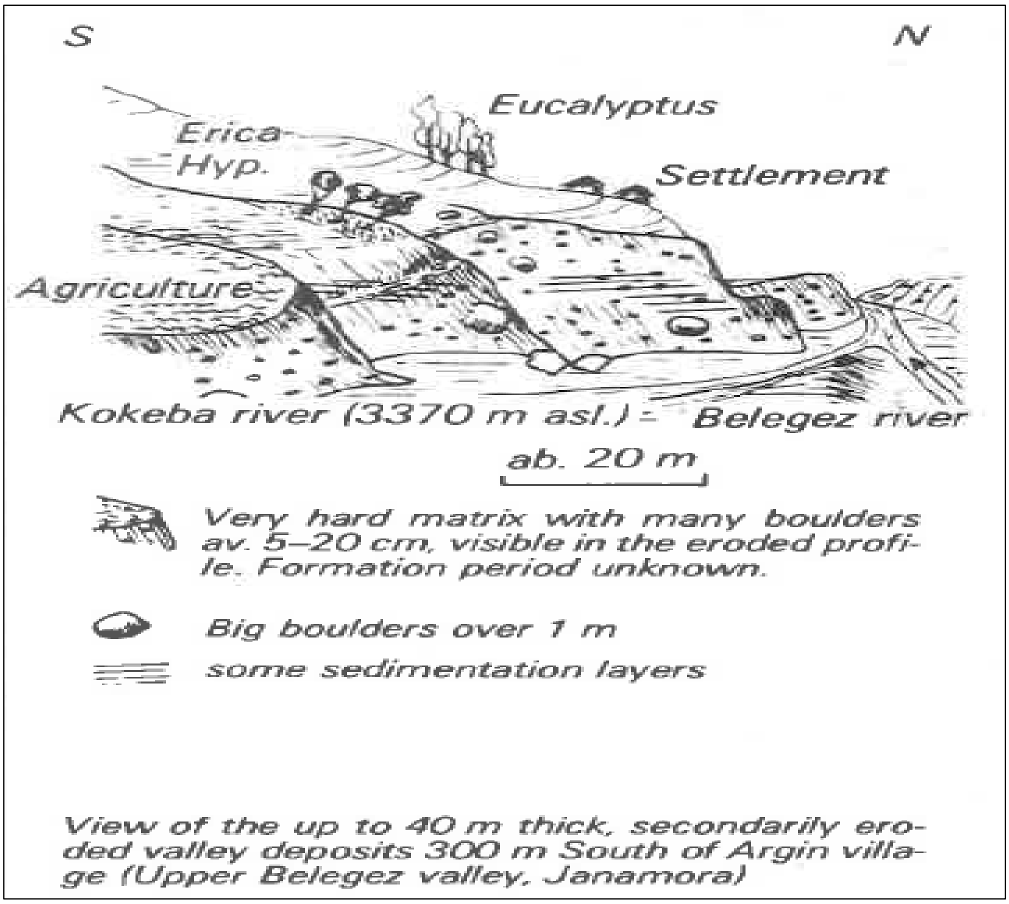
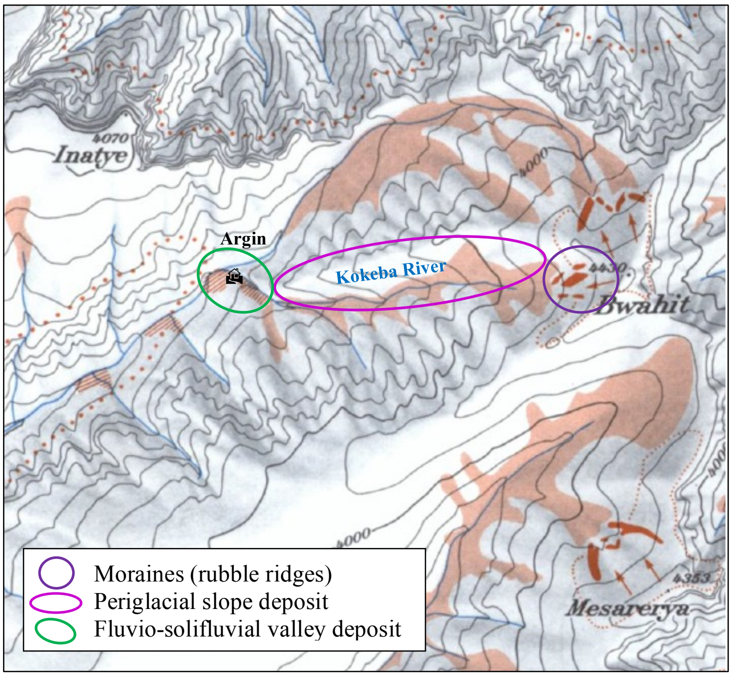
Annex(s)

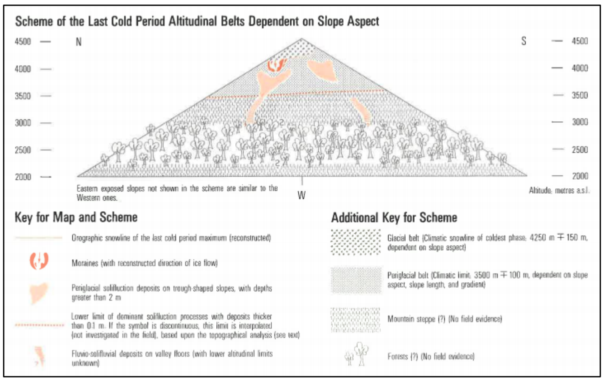
1. Deposits on valley floor at the confluence of Kokeba with Belegez River (Hurni, 1982)
2. Succession of the three main Last Cold Period form groups from Bwahit Pass, down the Kokeba Valley to Argin village (modified from Hurni, 1982)
3. Geographical context of the fluvio-solifluvial valley deposits at Argin village

Annex 1: Deposits on valley floor at the confluence of Kokeba with Belegez River (Hurni, 1982)



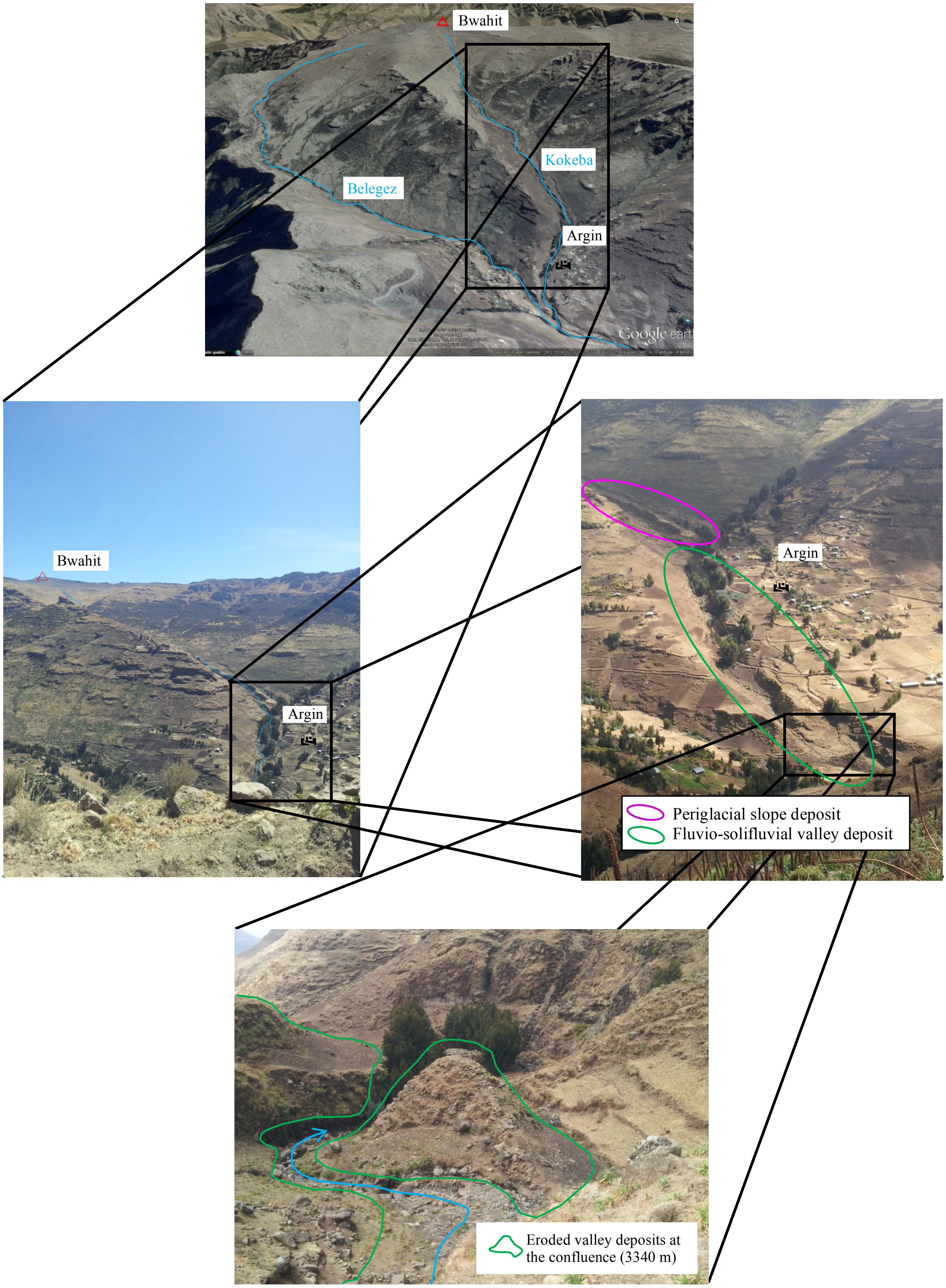
Annex 2: Succession of the three main Last Cold Period form groups from Bwahit Pass, down the Kokeba Valley to Argin village (modified from Hurni, 1982)





Key of the map *"Simen Mountains - Altitudinal Belts of the Last Cold Period (Late Wurm)"* of H. Hurni (1982) with information (scheme above) on Last Cold Period altitudinal belts dependent on slope aspect.

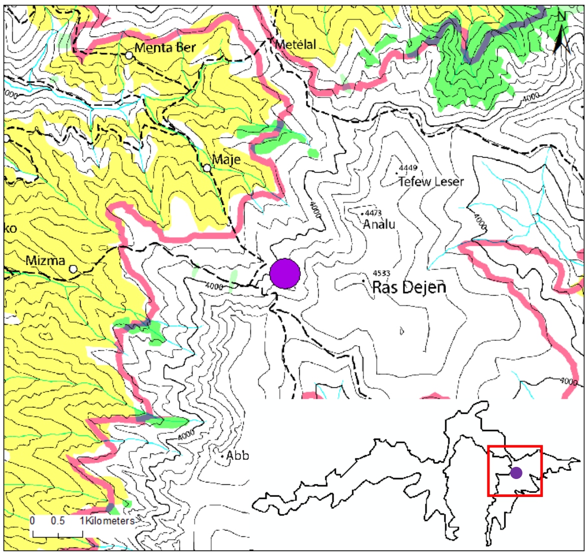
Annex 3: Geographical context of the fluvio-solifluvial valley deposits at Argin village



Glacial system West and NW of Ras Dejen

Janamora (Mayo Ayieteter)

Short description: The NW-escarpment of the Beyeda High-Plateau with Ras Dejen in the middle bears the traces of the most extensive glaciation of the Last Cold Period in Simen. Below the highest peak of Ethiopia, a succession of all Last Cold Period form groups can be observed in the present day morphology including the glacial processes (moraine ridge) and the periglacial processes (slope deposits, valley deposits). The largest moraine of Simen is 50 m thick and is found at the Dejen western slope.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.

Coordinates: **N 13°15'6.00" / E 38°20'50.41"** Altitude: **3320 m** to **4300 m** Type: **AER** Surface: **5.2 km^2**

Property status: **PUB (Kebele) and PRI** Characteristics: **natural, inherited**

Description

The NW-escarpment of the Beyeda High-Plateau with Ras Dejen (4540 m, highest peak of Ethiopia) in the middle bears the traces of the **most extensive glaciation** of the Last Cold Period in Simen with a glaciated area of 6.9 km^2. Western and North-western of Ras Dejen, topping the south eastern summit complex of Simen, all Last Cold Period **form groups** can be detected fairly easily in the present day morphology, with strikingly sharp vertical **moraine ridges** vertically below the summit and significant secondary eroded periglacial solifluvial **slope deposits** (cf. sheet nr. 8) and fluvio-solifluvial **valley deposits** (cf. sheet nr. 9) in the valley of Maje down to ~3300 m (cf. annex 1). The overall landscape has been periglacially reworked above 3,400 m to 3,600 m, and glacially reworked above 3,800 m.

The **largest moraine** of Simen (50 m thick) is located on the Dejen western slope, from 4250 m to 4040 m (cf. annex 4); it was partially notched by secondary gullies (postglacial erosion, cf. sheet 12). In addition, much moraine material on the left side of the slope is available. On the northwestern slope (left of Dejen, cf. annex 1), 2-3 short **glacier cirques** are visible with steep, arcuate headwalls and significant **medial moraines**, but bad differentiable **lateral moraines** because of secondary erosion (cf. annex 4) (Hurni, 1982).

Morphogenesis

The formation processes of Last Cold Period landforms in Simen are already explained in sheet nr. 7 to 9. The following contribution is not very specific concerning the site, but it considers the Last Cold Period glaciation in Simen - whose traces are particularly impressive here on the Dejen western slope - in connection with the glacial extend of other Ethiopian and East African mountains. If the aim is to bring the for layman hardly tangible issue of glacial extend of current and past glaciation near the equator to the broad audience (for example in guided tours, etc.) then it must be done here at Ras Dejen. The site offers an excellent introduction. In this regard we anticipate, exceptionally, a little, also because we have hardly to report more detail on the specific landforms than the already mentioned (sheet nr. 7-9). Also this significant information should not be lost but could not find its place in this work.

Of the eight mountain complexes in Ethiopia, which extend above 4000 m (cf. annex 2), Simen is the highest and demonstrates one of three known glaciated massifs in Ethiopia. "*No other [Ethiopian high] mountains north of Addis Abeba (9° N) were glaciated in the Last Cold Period, because the tops were not penetrating the snowline. Periglacial deposits, however, as well as the Holocene processes could be verified on all mountains* (Hurni, 1989 : 105)". The mountains South of Addis Abeba (Arsi Mountains N 6°50' / E 39°48' and Bale Mountains N 7°52' / E39°24') with the same altitudes were more extensively glaciated in the Last Cold Period with the **largest glaciation** in the **Bale Mountains** (Sanetti Plateau). An area of about 700 km^2 (that has to be seen with a total glaciated area of 13 km^2 in Simen only) was probably covered by an **ice shield** extending over the highland plateau, reaching as **individual glaciers** with considerable thicknesses of up to 250 m down to 3200 m in the South-Tegona valley (near Goba town) (Hurni, 1989).

Contrary to expectations that somewhat higher latitudes (also associated with higher altitudes) would experience intensified glacial (and cryogenic) activity, the **snowline** was higher in Simen (at 4225 m in average) than in Bale (between 3900 and 4000 m). Both the relict and contemporary glacial and periglacial morphology are considerably more pronounced in southern Ethiopia than in the Simen Mountains to the north. "*The palaeo-climatic variation between northern and southern Ethiopia may thus have resembled the contemporary situation of cooler, wetter conditions towards the southern mountains [...]. The more restricted glaciation in the northern Ethiopian mountains may be attributed to somewhat drier conditions with higher insolation receipts than the mountains to the south* (Grab, 2002 : 75). The lowest limit of Pleistocene glacial process and landforms through northeastern Africa was found at Mount Kenya (5199 m) at 3100 m located on the equator and annex 3 shows evidence that paradoxically the limit of glacial (and periglacial) activity due to **stronger cloudiness** and more **humid conditions** in the vicinity of the Equator tends to be lower in the inner tropics than towards the outer tropics.

Finally, several authors mention glacial traces of an earlier, **more profound glaciation in Simen** before the **Last Glacial Maximum**. E. Nilsson (1940) and J. Werdecker (1955) both observed moraines in two side valleys of the Mesheha valley at the height of the villages Loba and Bahramba between 2600-2800 m and H. Scott (1958) also mentions such findings at the same location (all cited in H. Hurni, 1982). Hurni (1982 : 138) does not negate the occurrence of an older glaciation but concludes that there is rather no compelling evidence of such remained in the field. Since they are the only forms found in Simen at this low altitude, they receive a **key position** for deciding whether there are older, deep-reaching glacial tracks or not. Thus the specimen should be considered as a geomorphosite but could not be included in this inventory as it is located outside the study area.

Intrinsic value

Central value		
Integrity	The high elevation road winding up the Ras Dejen pass (close to the summit) does not affect moraines and other Last Cold Period deposits.	1
Representativeness	The site is exemplary of the most extensive glacial system in Simen exposing both glacial and periglacial processes and landforms of the Last Cold Period.	1
Rareness	The moraine at the Dejen W-slope is the most powerful specimen of fossil glacial landforms in Simen. The site is one of the few locations in Simen in which the successions of the three from groups of the Last Cold Period can be easily traced in the field.	1
Paleogeographical interest	The site has been used by numerous researchers for examining the Last Cold Period landforms, the last glacial extension and climatic conditions during the Last Cold Period in Simen (ex. Minucci (1938), Nilsson (1940), Werdecker (1955; 1968), Scott (1958), Hastenrath (1974), Williams et al (1978) and Hurni (1981a; 1981b) all cited in Hurni (1982).)	1
Scientific value	**Very high**	**1**

Additional values	
Ecological value	
Ecological impact	No ecological impact has been discovered
Ecological value	**Very low to null**
value	
View points	The largest moraine of Simen can be detected from the distance of tens of kilometres for example from Bwahit on the other side of the Mesheha valley. The entire glacial system is well observed for example from Ras Dejen pass.
Contrast, vertical development and space structuration	The height difference of the glacial system extending from the valley of Maje up to the peak of Ras Dejen exceeds 1000 m. The space structuration of a single form and of the entire system is average and the contrast rather weak.
Aesthetic value	**Medium to high**
Cultural value	
Religious importance	According to the General Management Plan (FZS – ADC, 2009) there are the "*Ras Dejen legends*". They tell us that "*King Dawit (1367-1396 G.C) of Ethiopia had 3 children-Shebele, Dejenie and Gubaie. Accordingly, he divided the whole of his country 3 sub-divisions for easy administration, the protection of forests and wildlife, and the security of the people. One of these sons, Dejenie was given the area from Abay Gorge to the Simien Mountains to administer. Thus the name "Dejen" (ketema) (or Dejen town) was associated with the area between the former border of Shewa and Gojjam provinces and to Ras Dejen (the highest summit) in the Simien Mountains*."
Economic importance	"*Ras Dejen is the highest mountain in Ethiopia and thus one of the main attractions for visitors to Ethiopia* (FZS – ADC, 2009)". Moreover, the beer of one famous brewery of Ethiopia, located in Gonder is named "Dejen beer" after the name of the country's highest peak
Cultural value	**Very high**

Use and management characteristics

Protection of the site	
Protection status	The upper part of the site (above approximately 3700 m) is located inside the national park boundaries and therefore under protection. The valley of Maje however is outside of the park perimeter and thus is not guaranteed protection.
Damages and threats	No damages but there are potential threats regarding this site as it is exposed to tourism.

Promotion of the site	
Visit conditions	
Accessibility	The highest peak of Ethiopia (Ras Dejen) is accessible from Debark within one day by car. A walk down to Maje would take several hours up and down. Without leaving the main trails and route there is no particular walking difficulty except for steep slopes.
Security	No security issues.
Site context	Ras Dejen peak offers a spectacular 360° panorama. The road passing only a few meters away of the largest moraine of Simen is detrimental to the natural and value of the site (African Wildlife Foundation, 2014).
Touristic infrastructure	There is no touristic infrastructure in this region. The closest camp would be Chennek, several hours drive away. At Ambiko in the Mesheha Valley there seems to be a very basic campsite used by trekkers climbing the highest mountain of Simen though we did not use it.
Visit conditions	**The visit conditions are rather poor, given that it concerns a reputed major tourist attraction in the country. However access from Debark is reasonable.**
Education	
Education interest	The site illustrates better than any other location in Simen the succession of glacial and periglacial processes of the Last Cold Period. The high crest of the largest moraine can almost not be overlooked and other moraines on the NW slope are also clearly visible for non-specialist visitors. However, distinguishing periglacial deposits is more difficult and probably only possible for specialists or amateur geomorphologists.
Interpretation facilities	No interpretation facilities.
Educational interest	**Medium to high**

Synthesis

Global intrinsic value

The site represents the highest scientific value of all sites evaluated in this inventory with absolute maximum value for all the criteria (integrity representativeness, rareness and paleogeographical interest). Overall the intrinsic value is very high as the cultural value is also very high.

Use and management

The highest peak of Ethiopia is an important touristic attraction but geotourism has not been promoted even though the site presents the highest scientific value of the study area and its education interest is high. The site has fortunately not been damaged by the road construction but the geoheritage value is not approved and explicit protection status is not granted.

Management measures and proposals

As stated by the Tourism Development Plan (AWF, 2014 : 21) the "*sightseeing market*" should follow two alternative routes – "*either driving south out of the SMNP via the arm which leads to Mekane Birhan (and, subject to future access arrangements, visiting the apparently fascinating Derasge Mariam church where Emperor Tewodros ll was crowned) or by descending from the Bwahit Pass and following the new main road around to the southern and western reaches of Ras Deshen on the Beyeda side*." Thus, we share the opinion that the high elevation road which has been constructed close to the summit of Ras Dejen should not be maintained but left to fall into its rapidly progressing own disrepair "*as its presence is detrimental to the natural values of the SMNP and diminishes the Ras Deshen experience for trekkers (who prefer the challenge of walking from a lower elevation and following small trails rather than an unsightly vehicle access road)* (AWF, 2014 : 21)." Hence, the site should be preserved and used for the "*trekking category*" promoting gentle tourism in this area. Tourist guides going on the trek to Ras Dejen should be given training on the geomorphological context and specific features in the area in order to enhance and diversify the visitor experience. Such training should be proposed in cooperation with a specialist geotourism guiding operator so that a demand can be served directly (cf. sheet nr. 1). On the top of Ras Dejen pass an environmentally and aesthetically appropriated interpretation point should explain the key features and the importance (FZS – ADC, 2009 : 87).

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Annex(s)

1. NW-escarpment of the Beyeda High-Plateau with Ras Dejen in the middle
2. Location map of Simen and other Ethiopian high-mountains (Hurni, 1989)
3. Moraines on Western and North-western aspect of Ras Dejen
4. Lower limit of (Pleistocene) glacial and periglacial activity through NE Africa (Grab, 2002)

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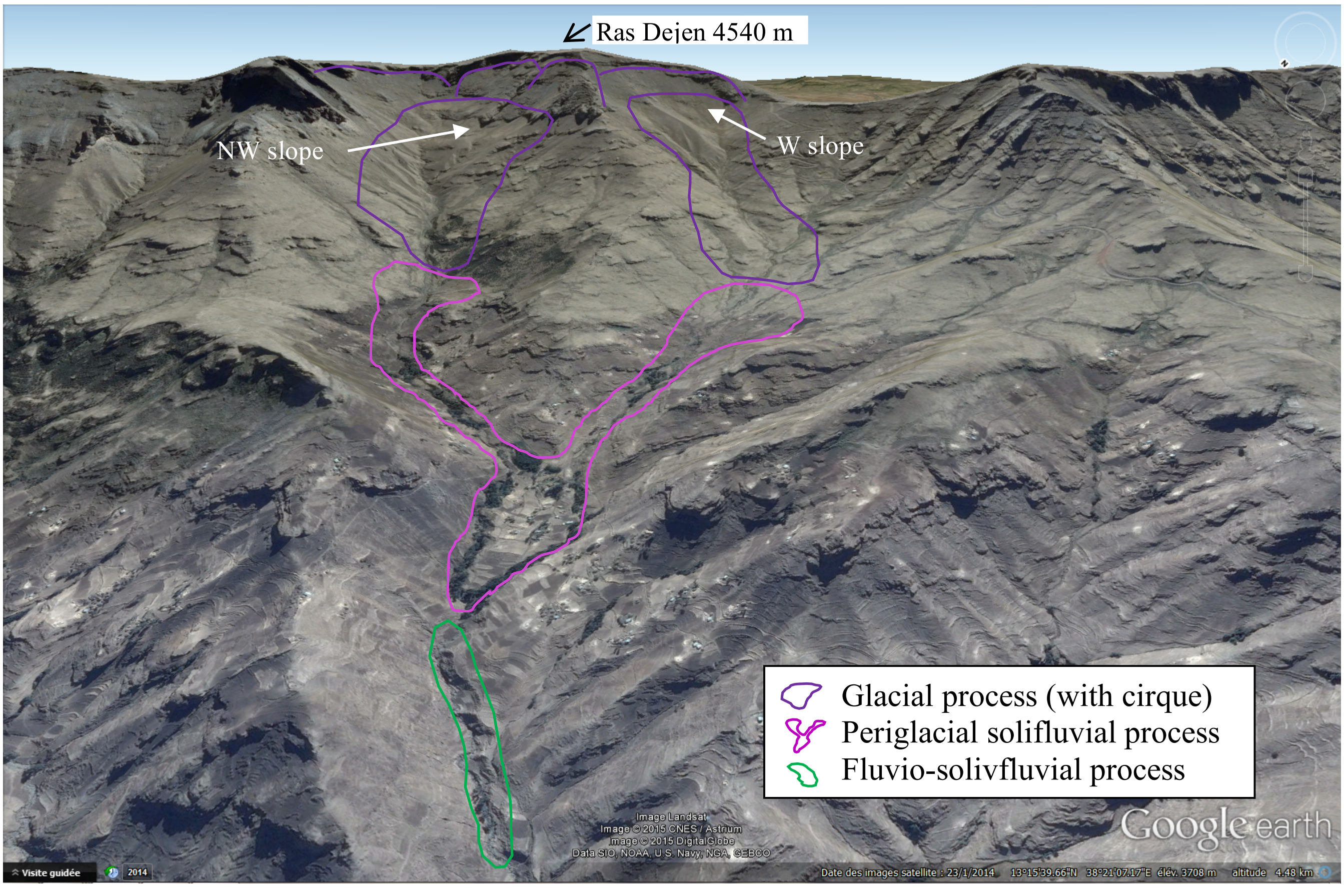
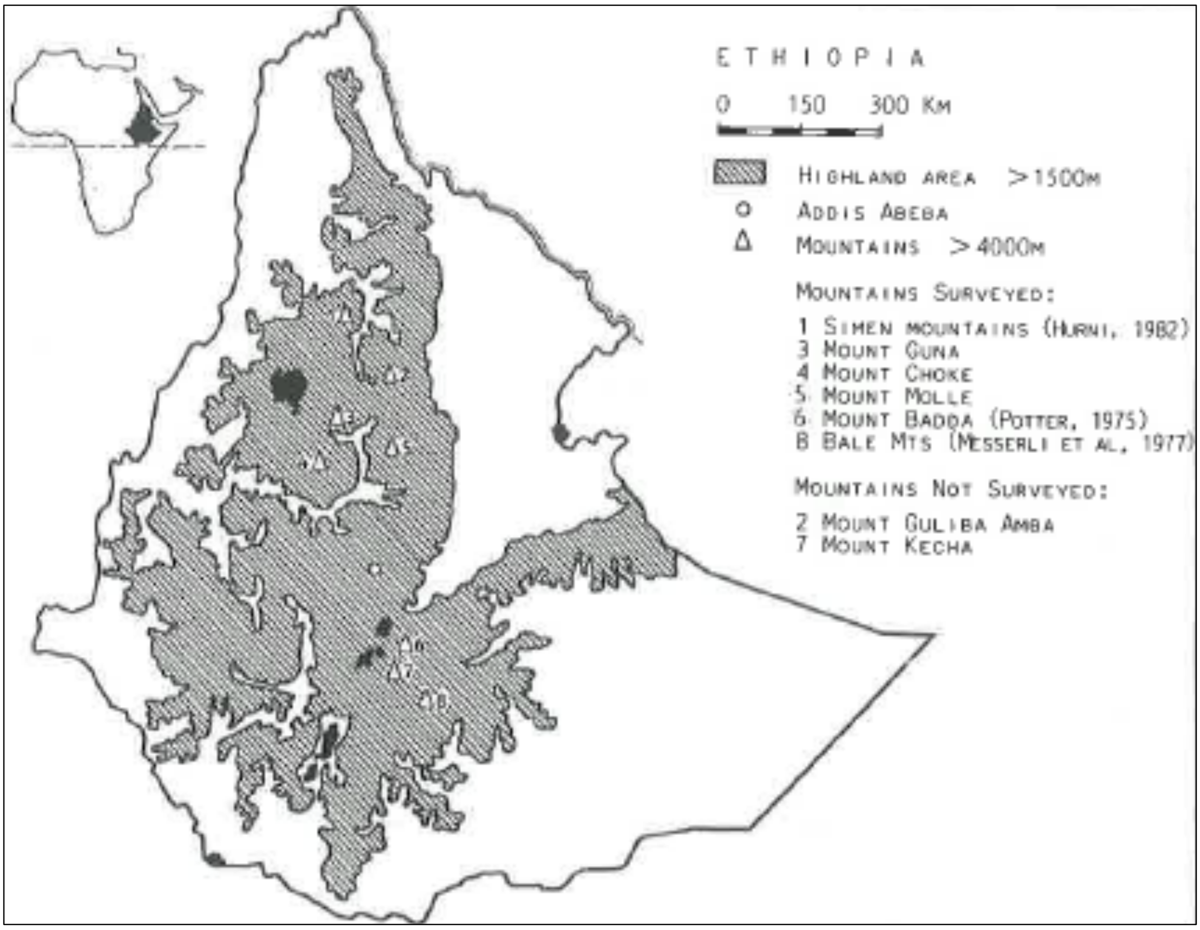
[4] Citation in Hurni, 1982

[5] Unable to adapt source correctly to the APA (American Psychological Association) – citation style (6th).

Annex 1: NW-escarpment of the Beyeda High-Plateau with Ras Dejen in the middle.



Annex 2: Location map of Simen and other Ethiopian high-mountains (Hurni, 1989)



Annex 3: Lower limit of (Pleistocene) glacial and periglacial activity through NE Africa (Grab, 2002)

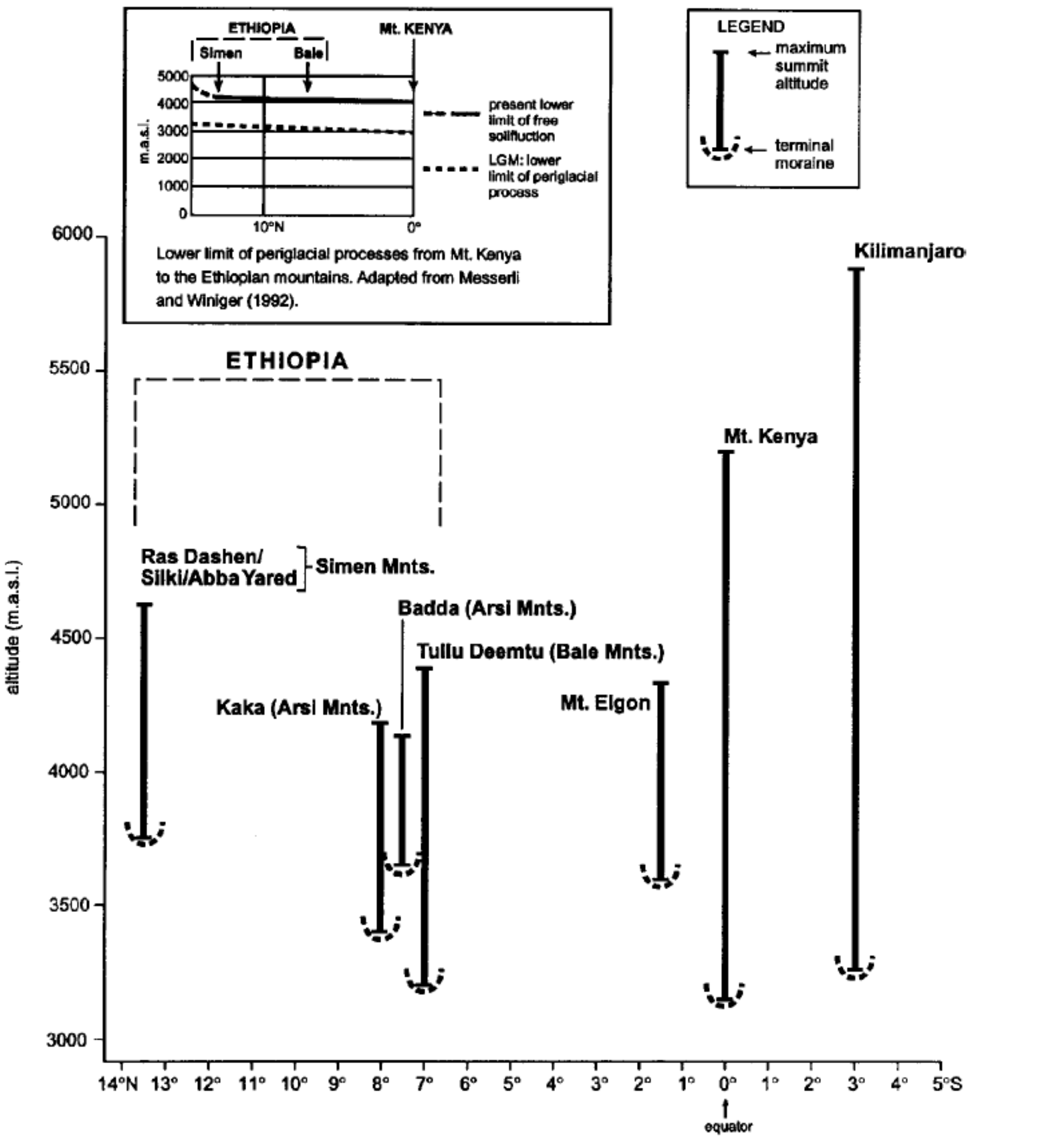
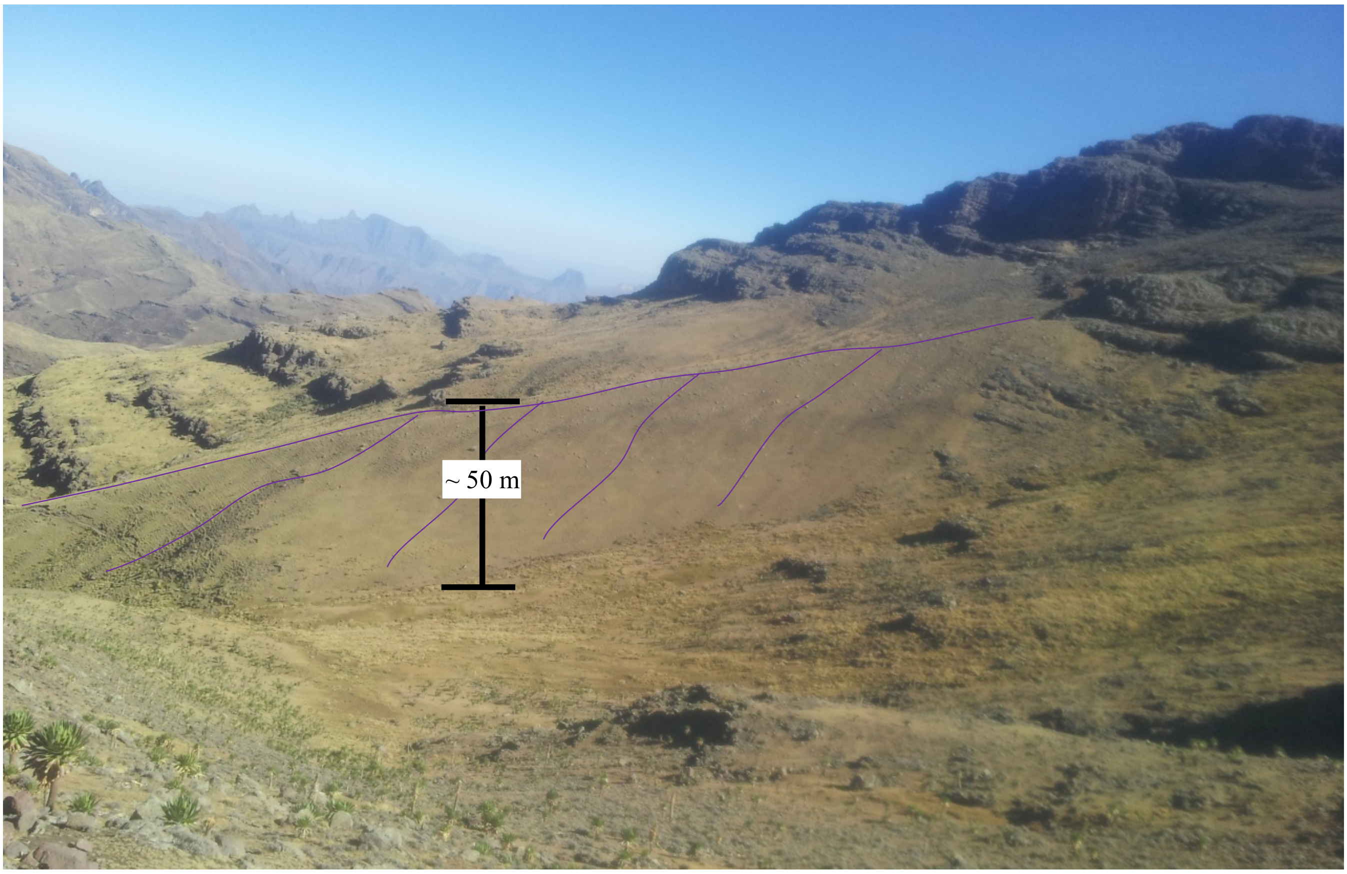


Figure 3 Lower limit of periglacial and glacial processes/landforms through northeast Africa (compiled from published records: Hastenrath, 1974, 1977; Potter, 1976; Messerli *et al.*, 1977; Hurni, 1982; Hamilton, 1982; Mahaney, 1989). Top left inset from Messerli and Winiger, 1992, reproduced with permission from the International Mountain Society (IMS) and the United Nations University (UNU).

Annex 4: Moraines on Western and Northwestern slope of Ras Dejen



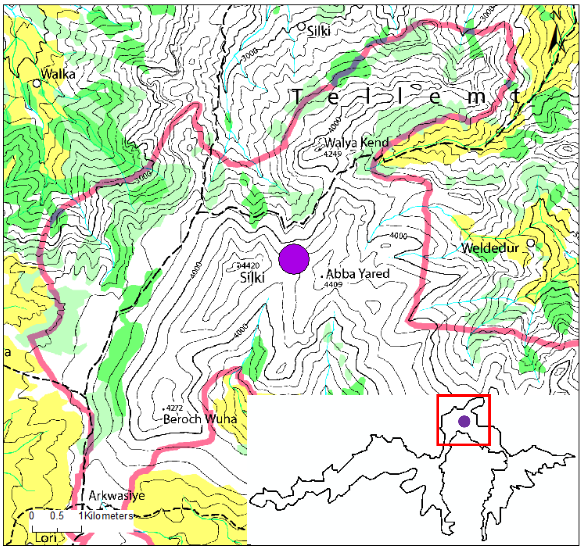
Largest moraine of Simen about 50 m height, extending from 4300 to 3900 m on the western facing slope of Ras Dejen.

Moraines in the NW trending valley on the Ras Dejen: Point of view 3980 m on lateral moraine; in the background moraines from glacial tongue below the peak Analu (Hastenrath, 1974)

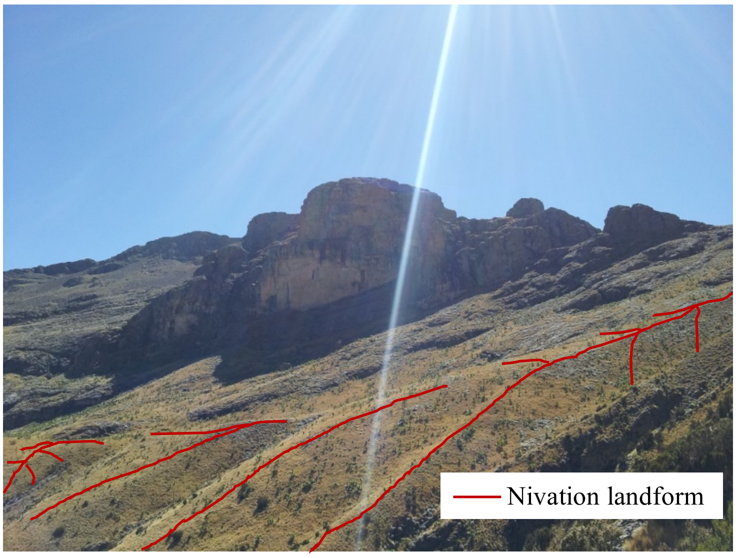
Snow moraine and glacial striations on Abba Yared

Janamora and Tellmet (Dibil, Gelbena)

Short description: The Silki - Abba Yared group on the northern mountain range shows the most pronounced glacial traces of Simen. In particular, glacial striations are visible at 4100 m on a basaltic hard rock on the NE-slope of Abba Yared and an impressive, well visible snow moraine can be seen below the Silki Pass (4150 m). Since a catchment of glacial formation is missing, seasonal firn snow and nivation processes must have created this fossil landform.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.



Coordinates: **N 13°20'41.18" / E 38°16'32.11" (moraine)** and **N 13°21'3.10" / E 38°17'14.02" (striation)**

Altitude: **4000 m** to **4100 m** Type: **AER** Surface: **14 ha**

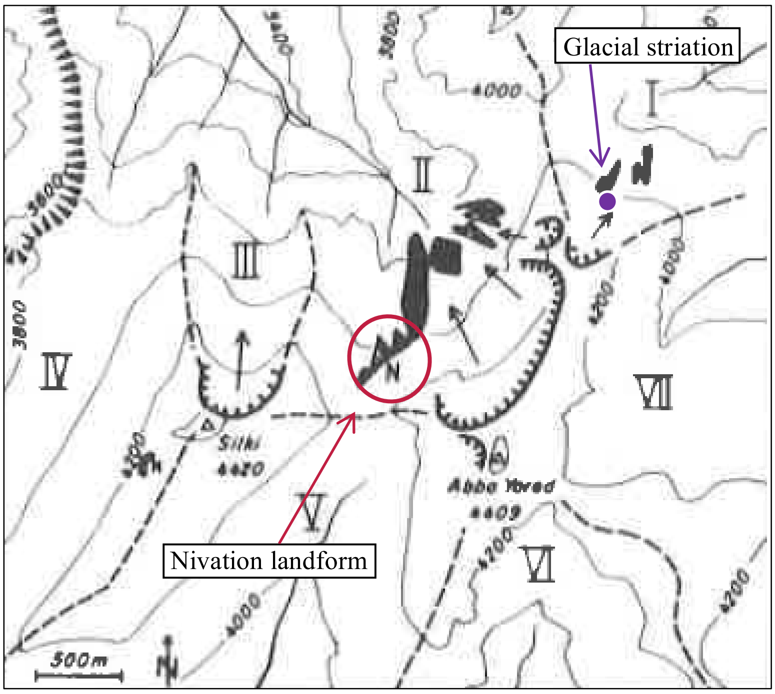
Property status: **PUB** Characteristics: **natural, inherited**

Description

While the Ras Dejen summit group (cf. sheet nr. 10) bears the traces of the most extensive glaciation of the Last Cold Period, the Silki (4420 m) - Abba Yared (4409 m) group demonstrates the **most pronounced glacial landforms** of Simen in the NW- to N-exposure (Hurni, 1982). On the NE-slope of Abba Yared four lateral moraines are made out with two glacial stages (cf. map below, catchment I). In addition, small **glacial striations** are visible at 4100 m on a basaltic **hard rock** (cf. annex 2). The NW-slope of Abba Yared has two accumulation zones and three tongue ends with lateral moraines because a glacier had been divided by a rocky outcrop (catchment II). Below the Silki Pass (4150 m) a **snow moraine** is laterally deposited, presenting one of the best-preserved glacial specimens of Sime (cf. photograph p. 1 and annex 1). Only these latter specificities (snow moraine, striation) are considered for the assessment below.

Morphogenesis

Snow moraines are derived from the processes called **nivation**. "*It is a concept of weathering and transport intensification that invokes no unique processes but which is [associated with late-lying seasonal* ***snow patches****]. While Matthes (1990) identifies a form continuum from nivation hollow to cirque, he distinguishes sharply between nivation and glacial effects and does not claim that* ***nivation hollows*** *enlarge into cirques. [Moreover], late-lying snow does indeed accelerate or intensify periglacial mass wasting processes (e.g. solifluction, surface wash) by several factors, even by orders of magnitude, in comparison to nearby snow-free (or thinly snow-covered) surfaces* (Goudie, 2004 : 719)." "*[****Glacial striation****] occur widely in areas of former glacial erosion where rock fragments, sand and silt grains transported in the basal ice have impacted surfaces as the ice moved forward jerkily by basal sliding (2004 : 1006).*" Especially on fine-grained physically hard rocks such as quartzites and massive limestones or like in the Simen Mountains on hard basalt rocks, glacial polish often occurs with striae.



Map of the Last Cold Period glacial forms (moraines, glacial cirques and ice flow direction, dashed lines are ridges) in the Silki – Abba Yared summit group (modified from Hurni, 1982)

Intrinsic value

Central value		
Integrity	No harm to this site	1
Representativeness	The site is exemplary of the glacial respectively nivation process and the occurrence of snow moraines in Simen	1
Rareness	Snow moraines and particularly glacial striations are rare in Simen (Hurni, 1982)	1
Paleogeographical interest	It is a reference site for the glacial stage of the Last Cold Period in Simen	0.75
Scientific value	**Very high**	**0.94**

Additional values	
Ecological value	
Ecological impact	No ecological impact known.
Ecological value	**Very low to null**
Aesthetic value	
View points	There are no viewpoints for this site.
Contrast, vertical development and space structuration	Contrast, vertical development and space structuration are weak.
Aesthetic value	**Low**
Cultural value	
Cultural value	**Very low to null (unknown)**

Use and management characteristics

Protection of the site	
Protection status	The site is located inside the national park boundaries and therefore under protection.
Damages and threats	No damages and no threats.

Promotion of the site	
Visit conditions	
Accessibility	From Debark the northern mountain range is approached by car over Bwahit pass The site is accessible on a trek from Arkwasiye over Tegley Sefer outpost and along the northern side of Silki. The first night can be spent at Tegley Sefer and on the second day a 4-6 hours walk is necessary to reach the area of Abba Yared. The path is not exposed and well visible. But the 150 m ascent to the snow moraine below the Silki pass and the climb to the striations on the NE-slope go without trail.
Security	There is a risk of rock fall in this area. Climbing (about level 3 on the UIAA-scale) on bare and sharp rock is necessary to reach the striations.
Site context	It is a very calm environment.
Touristic infrastructure	There is no touristic infrastructure in the near proximity.
Visit conditions	**The site is located in a very intact environment and the trail to the Abba Yared region is in reasonable condition however, it takes two days to get there from Debark and touristic infrastructure is not available.**
Education	
Education interest	The snow moraine is well visible also for non-specialists and the glacial process can be well explained using this site. On the other hand, glacial striations are hard to find and only identifiable for amateur geologists or specialists.
Interpretation facilities	No interpretation facilities.
Educational interest	**High**

Synthesis

Global intrinsic value

The very high central value thanks to the perfect integrity, high representativeness and rareness of the site is compromised by very poor additional values. Therefor the global intrinsic value is medium to high.

Use and management

The site is located in the remote and intact area of the northern mountain range of Simen where tourism is still absent. The area is included in the national park territory and the educational interest of the glacial complex in particular of the snow moraine is high.

Management measures and proposals

Similar to what is suggested for the promotion of the crater region in the area of Kiddis Yared visits to this site could be organised for experienced trekking tourists on behalf of the introduction of a new trekking route to Ras Dejen (cf. sheet nr. 3.). Once trekking tourism is established an aesthetically and environmentally appropriated signpost on the Silki pass could inform about the key features of the landscape observed on the NW slope below AbbaYared.

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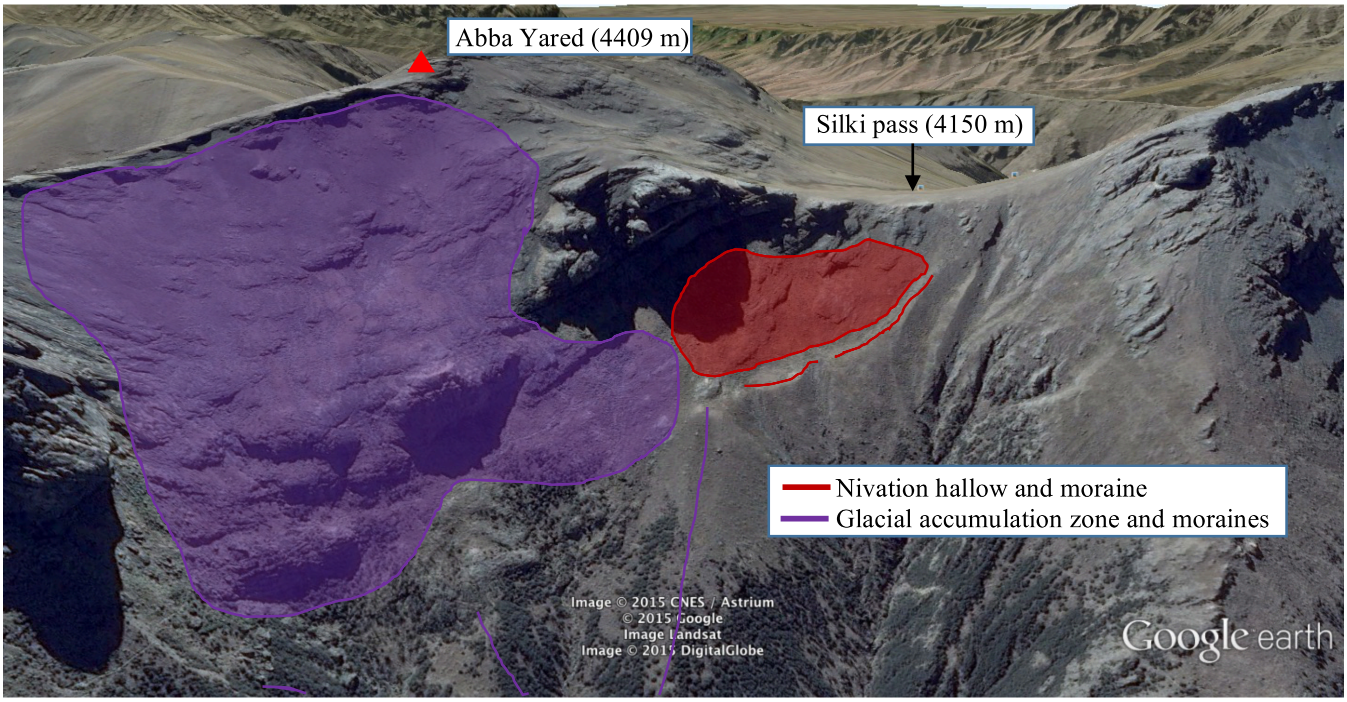
Annex(s)

1. Last Cold Period moraines, formed predominantly under the influence of firn snow below a steep rock wall, since a catchment for glacial formation is missing. View from 4150 m towards the East (Hurni, 1982)

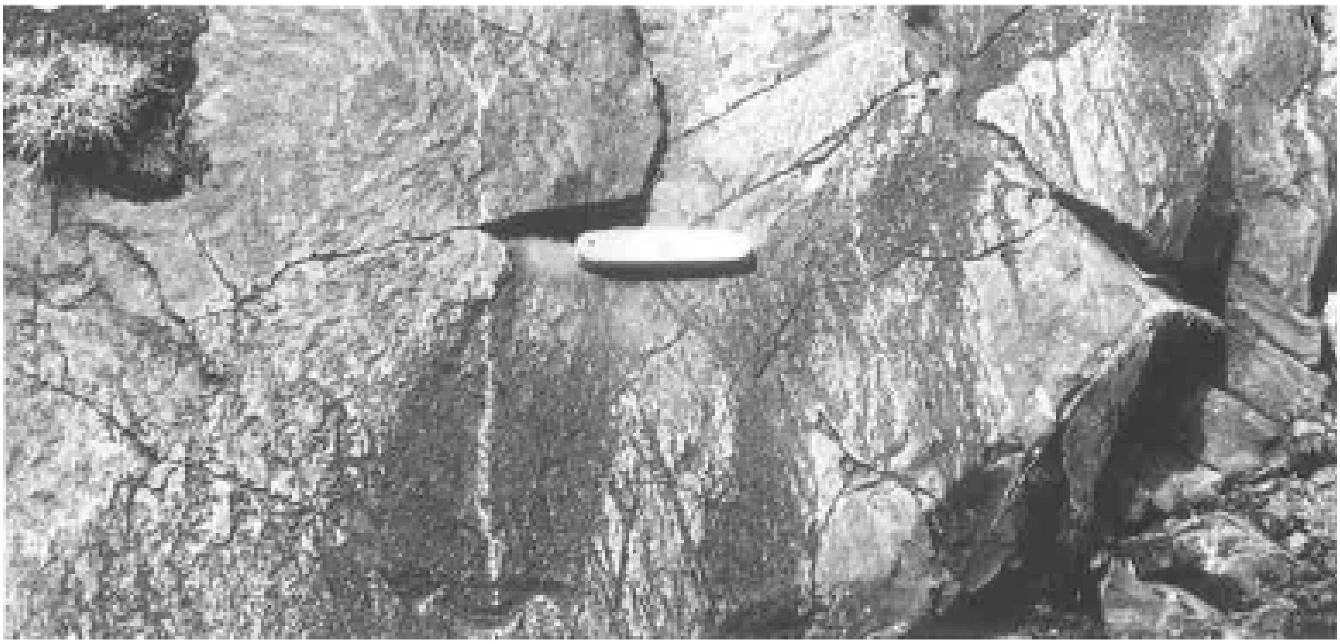
2. Traces of glacial striation on a hard basalt outcrop in the Abba Yared North-eastern catchment at 4100 m (Hurni, 1982)

Annex 1: Glacial complex of Abba Yared NW-slope (catchment II)

Comment: Below Silki pass the Last Cold Period moraine, formed predominantly under the influence of firn snow. A catchment for glacial formation is missing because of the steep rock wall above (in the middle of the photograph).



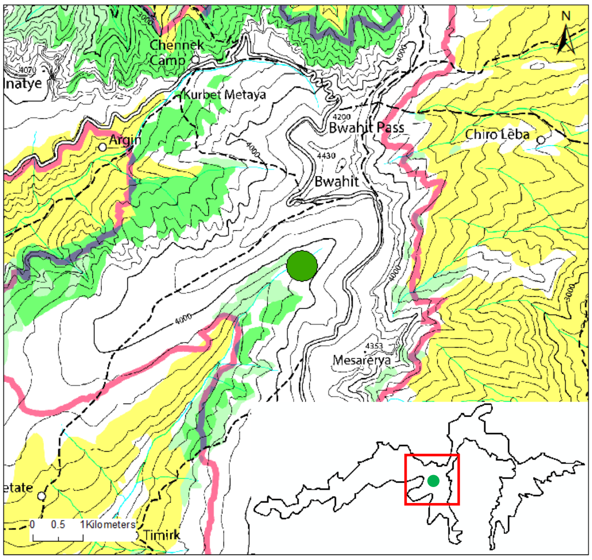
Annex 2: Traces of glacial striation on a hard basalt outcrop in the Abba Yared North-eastern catchment at 4100 m (Hurni, 1982)



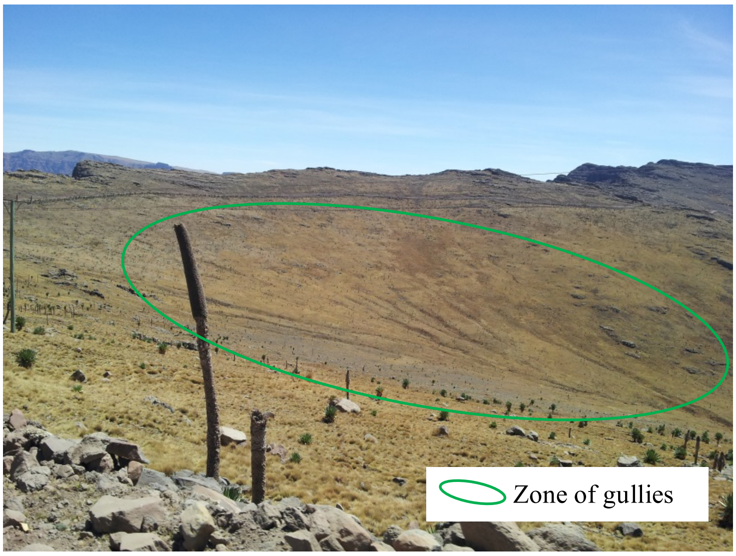
Postglacial gullies on the Southern side of Bwahit

SMNP

Short description: On the Bwahit Southern side gullies, several meters deep, have carved the Last Cold Period periglacial deposits. They bear witness of an intense natural erosion phase, which must have taken place immediately after the Last Cold Period with the onset of the monsoonal activity and before the regrowth of the vegetation cover.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.



Coordinates: **N 13°13'53.5" / E 38°13'15.97"**	Altitude: **4000 m** to **4150 m**	Type: **AER**	Surface: **76 ha**

Property status: **PUB** Characteristics: **natural, inherited**

Description

"*At the beginning of the Holocene (10'000 BP), with onset of monsoonal activity, but ahead of the repopulation of the Last Cold Period periglacial belt with dense vegetation, a period of intense morphodynamic* ***natural erosion*** *took place, which has carved the Last Cold Period* ***glacial and periglacial deposits*** *through relief building* ***gullies*** (translated form Hurni, 1981 : 101). Such erosion channels set very often below current seasonal sources and unite in the lower part of the slope deposits (cf. annex 2). Up to l5 m thick accumulations are cut down in the valley floor. Gullies in the slope deposits (for slope deposits cf. sheet nr. 8) at the side of the valley are less deep (up to about 5 m). The same erosion phase is also detectable as erosion surface in **soil profiles** (cf. annex 1) but the described erosion gap was not found in the deeper attitudinal belts of the Last Cold Period, below approximately 3500 m.

Morphogenesis

The erosion forms directly emerged after the cold period, but before the formation of the **Ando soils** (cf. sheet nr. 13) and **erosive rainfalls** had played a major role in the morphogenesis of the postglacial gullies. "*The sharp edges of the gullies with their V-shaped notch in cross section show that they occurred after the formation of the periglacial slope deposits. Accumulation and gully formation are relays of processes and cannot run simultaneously […]. If gullies were created during the periglacial active cold period, the effect of solifluction would have filled the gullies again. The fact that the large lateral* ***moraines*** *have gullies on their inside shows further that the formation occurred after the Last Cold Period, since the glaciers had to be melted at the time of erosion* (translated from Hurni, 1982 . 144)."

"The black, about 70 cm thick soil-horizons lie uniform on the ground surface, i.e. also in larger gullies and small valleys (cf. sheet nr 13). The overlay of this horizon is therefore determined after the erosive phase. [Furthermore, the individual gullies can be traced clearly between the boulders layer in the soil profile (cf. annex 1) Thus,] the vegetation cover during the erosive phase allowed ***erosion on an areawide basi****s [in the described altitudes and] the precipitates were so erosive that they produced the extended, extensive erosion* (translated from Hurni, 1982 : 144-145)."

Intrinsic value

Central value		
Integrity	No harm to this site	1
Representativeness	The site is exemplary of the numerous gullies above 3500 m of intense fluvial erosion (gulling) at the beginning of the Holocene.	1
Rareness	There are gullies of this period everywhere in Simen but at this location they are particularly well visible.	0.5
Paleogeographical interest	The site gives evidence of erosive rainfalls creating intense natural erosion on the unvegetated zones above 3500 m immediately after the Last Cold Period.	0.75
Scientific value	**High**	**0.81**

Additional values	
Ecological value	
Ecological impact	Along the streams green vegetation is more common (Nievergelt, 1998).
Ecological value	**Medium to low**
Aesthetic value	
View points	From the Bwahit road the gullies are well observed.
Contrast, vertical development and space structuration	Up to 15 m deep curved the gullies into valley deposits, the space structuration is weak and the contrast as well.
Aesthetic value	**Medium to low**
Cultural value	
Cultural value	**Very low to null (unknown)**

Use and management characteristics

Protection of the site	
Protection status	The site is located inside the national park boundaries and therefore under protection.
Damages and threats	No damages and no threats.

Promotion of the site	
Visit conditions	
Accessibility	The site is accessible from Debark within 3 hours car drive. From the road only a few minutes' walk through the afroalpine grasssteppe are necessary to reach the gully head.
Security	Security is no issue.
Site context	The Bwahit road nearby the site makes traffic noise and thus takes away of the natural feel that many visitor of Simen are looking for (African Wildlife Foundation, 2014).
Touristic infrastructure	Chennek campsite about 30 min drive away is the nearest touristic infrastructure.
Visit conditions	**Relatively easy access and very basic accommodation in the vicinity at Chennek campsite**
Education	
Education interest	Onset of monsoonal activity after the Last Cold Period creating intense natural erosion on the bare ground surface can be understood by non-specialists when watching at the postglacial gullies on the Southern side of Bwahit.
Interpretation facilities	No interpretation facilities.
Educational interest	**High**

Synthesis

Global intrinsic value

The central value is high thanks to the very high integrity and representativeness and high paleogeographical interest of the site. The additional values are less important thus the intrinsic value is quite high.

Use and management

Southern Bwahit is easily accessible on the road from Debark and the site presents a high educational interest. As it is located inside the national park protection of the geomorphology should be guaranteed though not explicitly.

Management measures and proposals

Since the site is located next the road it would be advisable to use it as an attraction point of a geotouristic sightseeing tour to the SMNP in combination with visits to other easy accessible sites as suggested before (ex. Jinbar waterfall sheet nr. 5 or Bwahit moraines sheet nr. 7). Attempts of interpretation should show the relation of postglacial gullies with Last Cold Period landforms visited at previous stops and explain their representation of different temporal stage of the morphogenesis of Simen. If visitors heard about soil degradation and conservation on their tour it could also be clarified that the natural erosion phase precedes a second main Holocene morphological process which is the soil formation followed by soil erosion thus they can make the link.

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Hurni, H (1982). *Klimatische und geomorphologische Studien im Hochgebirge von Semien - Aethiopien* [Ph.D thesis]. Bern: Geographica Bernensia, G13.

Nievergelt B. (ed.) (1998). *A survey of the flora and fauna of the Simen Mountains National Park, Ethiopia.* Zürich: Pano Verlag, 109 pp.

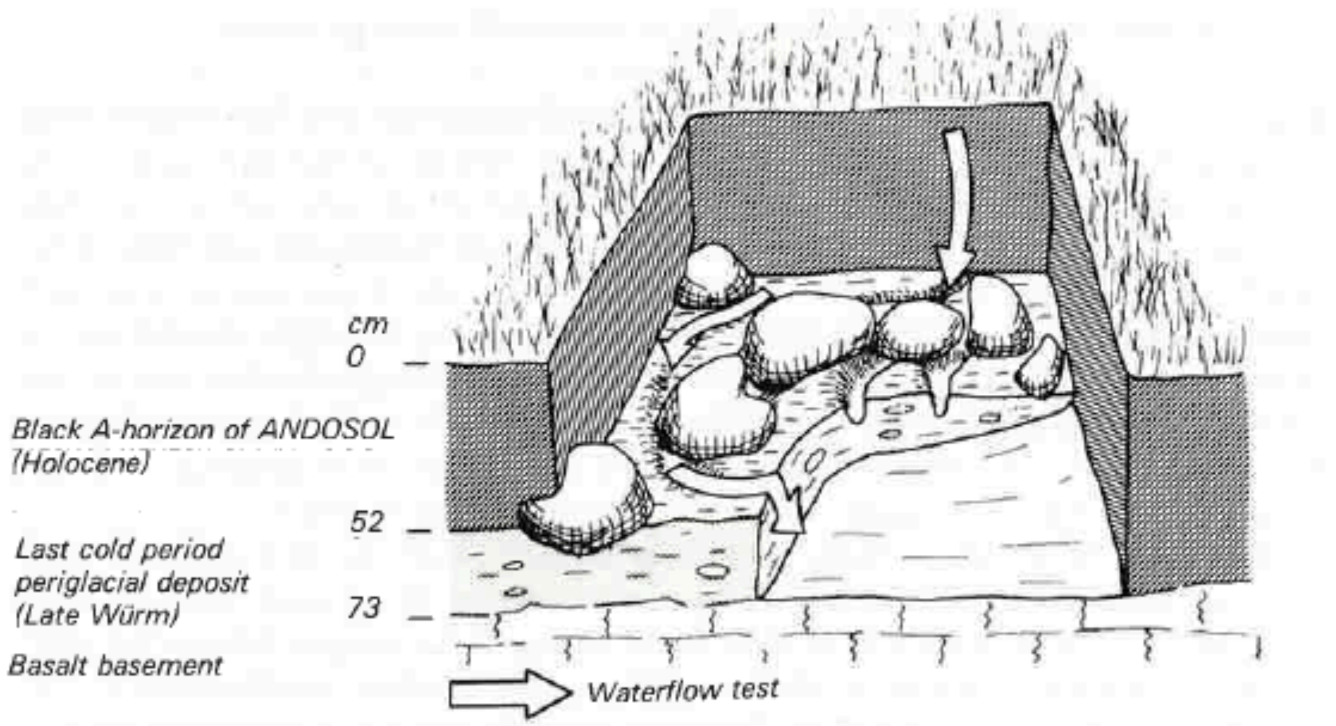
Author

L. Mauerhofer (2016)

Annex(s)

1. Postglacial erosion surface in the soil profile (Hurni, 1982)
2. Postglacial gullies uniting in the lower part of the slope deposits

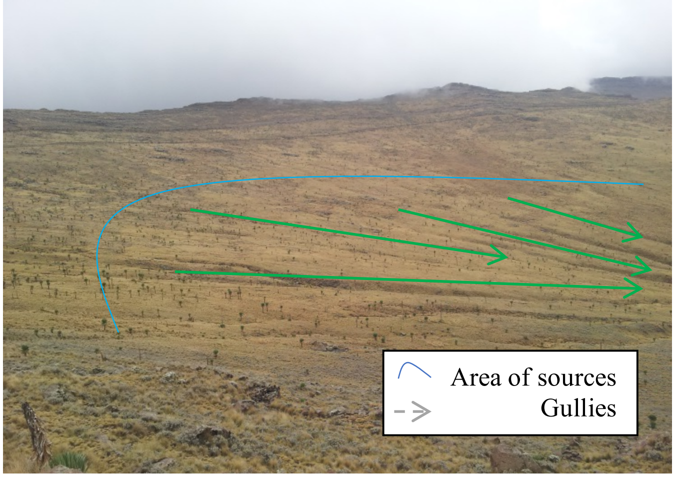
Annex 1: Postglacial erosion surface in the soil profile (Hurni, 1982)

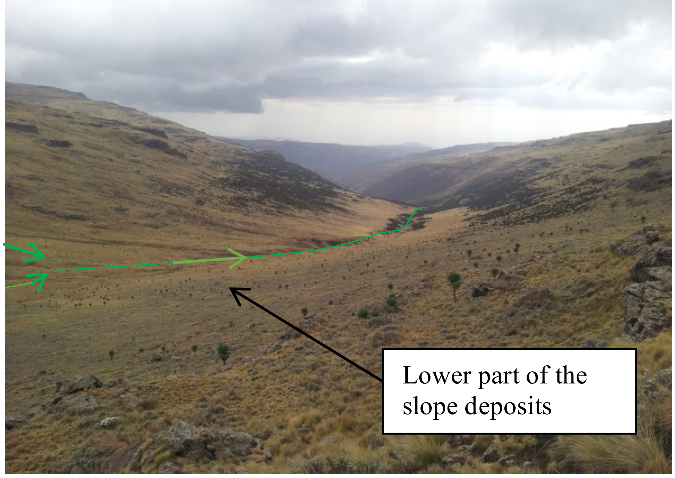


Figur 48 Dreidimensionaler Aufschluss der nachkaltzeitlichen Spülfläche im Bodenprofil auf einer 1 m x 1 m grossen Fläche. Die Viertelsfläche vorne rechts wurde bis zum basaltischen Untergrund abgetragen. Jinbar-Tal, 3700 m, SW-Exposition, 22% Neigung. (Aus H. HURNI, 1975b: 23).

Three dimensional exposure of the post glacial erosion surface in the soil profile on an area of 1 sq m. The quarter in front to the right is removed to the basalt basement. Jinbar valley, 3700 m, SW aspect, 22% slope (From H. HURNI, 1975b: 23).

Annex 2: Post glacial gullies unifying in the lower part of the slope deposits



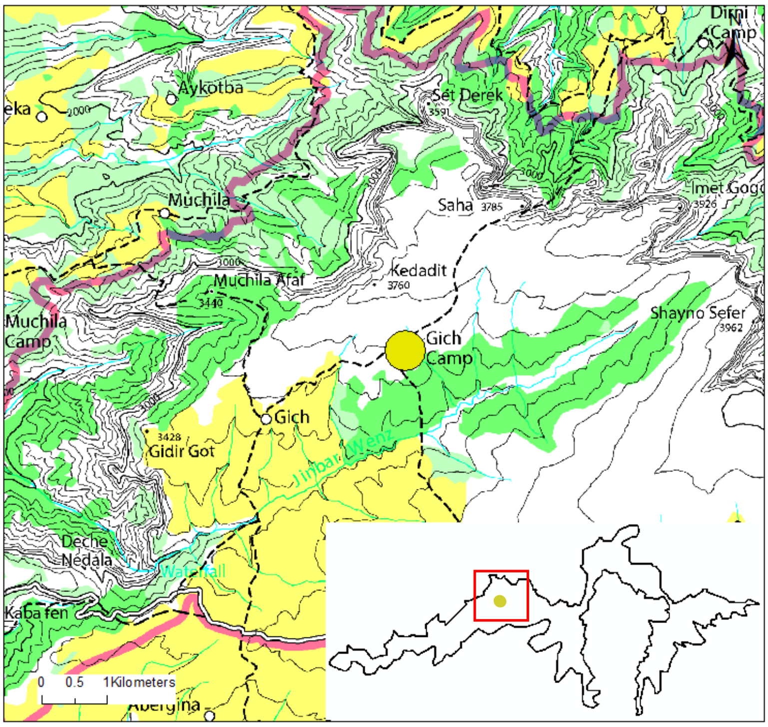


View towards the south, from the road on the Southern side of Bwahit at 4200 m.

Black Ando soils at Gich campsite (upper Jinbar valley)

Debark (Abergina)

Short description: At Gich campsite a pedological analysis of a typical soil profile was carried out and classified as humic andosol. The site represents the black Ando soils, which overlay the whole highland of Simen more or less uniformly with 70 cm in depth but now mainly degraded by erosion in cultivated areas. The black A-horizon started to develop with the vegetation regrowth on the last cold period periglacial belt after an intensive natural erosion phase took place and its formation was supported with the blowing in of **volcanic ashes** of nearby eruptions.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.

Coordinates: **N 13°16'01.63" / E 38°06'23.62"**	Altitude **3535 m**	Type: **PCT**	Depth: **70cm**

Property status: **PUB**

Characteristics: **natural, active**

Description

H. Hurni (1982 : 140-155) distinguishes three main **Holocene morphological processes** chronologically, namely a **morphodynamic**, a **pedogenetic** and an **anthropogenic** generated phase, and describes the environmental conditions favouring these processes. The formation of the **black Ando soils** corresponds to the second phase, which has taken place at any time during the Holocene, from 10'000 BP up to present, but cannot be ranged more closely in the climatic history. This evaluation takes into account the Ando soils under natural conditions. They overlay the whole highland of Simen (above 3000 m) more or less uniformly with 70 cm in depth but are now mainly degraded by erosion in cultivated areas (cf. third phase, soil erosion, sheet nr. 14). Only the restricted area (point at 3535 m) at Gich campsite, where the pedological section was typified is selected as a geomorphosite and will be assessed below (cf. map below).

In fact, a **pedological analysis** of a typical soil profile was carried out at 3535 m and typified as humic andosol (Frei, 1978, In Hurni, 1982, according to FAO, 1914). Thereby the periglacial solifluction deposits on trough-shaped slopes (cf. sheet nr. 8) build the cambic horizon (brown B-horizon) of the soil profile. The humic top soils represent the actual andosol horizon (black A-horizon) consisting of very fine-grained, mouldy black soil with up to 30 % organic material and 60 to 80 % clayey silt, which dries out quickly from the top in the dry season and changes to a brown colour. Many quartz and feldspar corns coming from the supply of volcanic ash are found in both horizons showing that they correspond pedogenetically (cf. ideal profile, annexe 1).

According to H. Hurni and E. Ludi (2000 : 56), "*over whole Simen in areas above 3000 m, andosol is the typical soil type on uncultivated or scarcely cultivated land, whereas in area below 3000 m and on cultivation land above 3000 m, Phaeozem, Vertisol, Luvisol, Regosol and Leptosol are dominant* (cf. map of soil associations in the Simen Mountains)."

Morphogenesis

Detailed researches looked into the question of the depth of the black andosol-A-horizon out of it an important contribution to the genesis can be done. The 30 km^2 large Jinbar valley (3200 m to 4000 m), with its 20 km^2 undisturbed woods and grassland served as major study area. In total 190 samples of the depth of the A-horizons were analysed according to elevation, inclination, slope exposure, slope form and vegetation cover (Hurni, 1975a, 1975b, 1978). Results of the statistical evaluation were summarized by three statements (Hurni, 1978):

1. "*The black soil depth does not vary with **elevation**[1], **exposure**, and **vegetation**, but is 68 cm on the average with little average differences (+/-3 cm).*
2. *The black soil depth slightly diminishes with increasing **slope inclination**: 0-33%: 7l cm, 34-69 %: 6l cm.*
3. *The black soil depth significantly varies with the **form of slope**:*

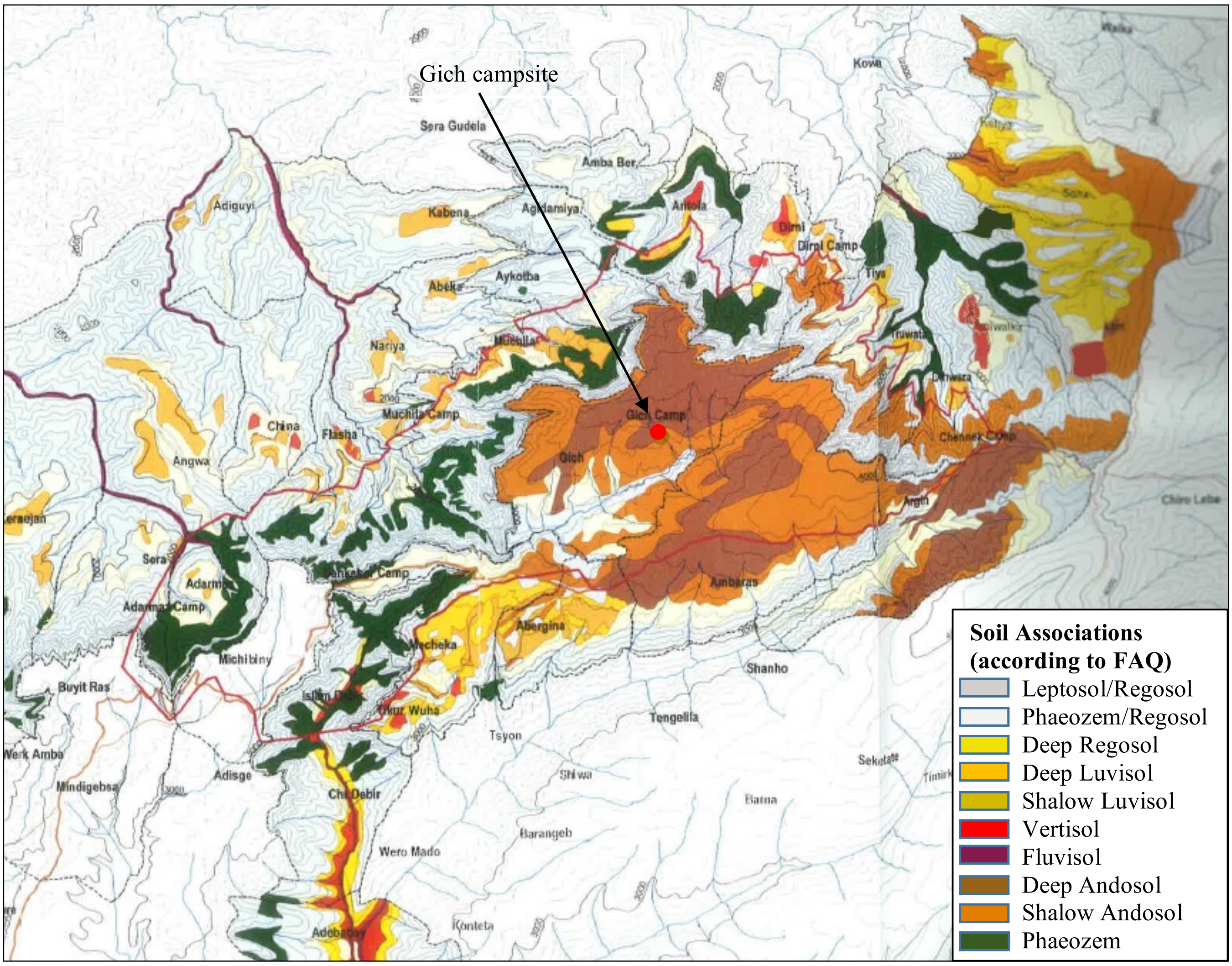
   Strongly convex form: 55.0 cm average
   Convex form: 62.4 cm average
   Straight form: 69.5 cm average
   Concave form: 77.5 cm average
   Strongly concave form: 81.1 cm average"

With the vegetation regrowth on the last cold period periglacial belt after the intensive natural erosion phase (cf. sheet nr. 12), soils started to develop as deep andosol over the whole of Simen in a second, pedogenetic process. The high content of organic matter (of up to 30 %) indicates a long and stable period of soil formation. Interestingly the solifluction accumulations, which are functional as B-horizons of the current soil profile, are only little deep gathered from the later soil formation.

The mineral analyses of a soil profile at Gich campsite (3600 m) showed clearly that both the A-horizon and the B-horizon with higher quartz and plagioclase content differ from the weathered basalt of the geological underground (T. Peters In Hurni, 1975a). For this and other reasons the blowing in of acid **volcanic ashes** (quartz content) must have contributed to the formation of the Ando soils. The principles of soil depth correspond well with this hypothesis: Higher overlays in swales and on flat hillsides, smaller once on ridges, in steep hillsides and around the summit area. Though, the latter regions also have a reduced soil depth due to attenuated climatic and biological factors of the soil formation. The ashes supply might come from the region of the Lake Tana some hundreds km south-east of Simen, where young volcanic necks are observed (cf. sheet nr. 4). The fact that the profile does not show any stratification of the sedimentation is probably due to intensive **bioturbation** with dense rodent population looking for a fast turnover of the mulch up to present time (Hurni, 1982).

[1] Except in summit areas and above 4000m the depth of the A horizons is strongly decreasing.

Since the yearly erosion on grass-steppe accounts in the upper Jinbar valley for less than 2 t per ha, the balance could show a continuous soil formation at least as long as the grass-steppe is not overgrazed by livestock. On the other hand, soil erosion processes on an average slope cultivated with barley, amount about 20 tons per hectare per year and therefore exceeds soil growth in the order of 10-15 times (Hurni, 1982).



Map: Soil Association in the Simen Mountains (Modified from Hurni &Ludi, 2000)

Intrinsic value

Central value		
Integrity	The Ando soils around Gich campsite are intact.	1
Representativeness	This site is exemplary of the formation of the characteristic black Ando soils in Simen.	1
Rareness	Ando soils overlay the whole highland of Simen, thus the site is not rare.	0.25
Paleogeographical interest	The pedological and mineralogical analyses of the soil profile at Gich give important evidence for the investigation of the main Holocene morphological processes and environmental conditions favouring these processes.	0.5
Scientific value	**High**	**0.69**

Additional values	
Ecological value	
Ecological impact	The black Ando soils are very fertile soils (Hurni, 1978, Nievergelt, 1998).
Ecological value	**High**
Aesthetic value	
View points	No viewpoints.
Contrast, vertical development and space structuration	No contrast, no vertical development and no space structuration.
Aesthetic value	**Very low to null**
Cultural value	
Cultural value	**Very low to null**

Use and management characteristics

Protection of the site	
Protection status	The site is located inside the national park boundaries and therefore under protection. Soil erosion is an important issue in Simen and soil and water conservation a high priority for the park management since its establishment in 1969 (Hurni, 1986, FZS – ADC, 2009).
Damages and threats	Even though soils are heavily degraded in some parts of Simen as for example at Gich village there is no damages and threats of the Ando soils at Gich campsite.

Promotion of the site	
Visit conditions	
Accessibility	Gich is accessible from Debark within one day. 2 hours walk from Aynameda camp or 4 hours from Sankabar camp are necessary. The trek follows the Main Gich Plateau Trekking route thus the trail is well visible, average steep for the region and in good condition.
Security	No security issue.
Site context	Soils are covered by the grassland.
Touristic infrastructure	Basic touristic infrastructure is available on-site at Gich camp.
Visit conditions	**The visit conditions are among the better in Simen and access is good.**
Education	
Education interest	The education interest is low as the soil pedon is not visible at Gich without digging up the grass-steppe on purpose, but a specimen of a soil profil could be conserved at Gich for visitors. In this case the education interest would become high as the different horizons can be distinguished fairly easily by non-specialist visitors and amateur analyses on the field would help them to understand the formation of the black andosol layer.
Interpretation facilities	No interpretation facilities.
Educational interest	**Low (High)**

Synthesis

Global intrinsic value

Since the scientific value is high with a high integrity and representativeness and the ecological value is high also the global intrinsic value of this site is quite high.

Use and management

Gich lies on the main trekking road and is easy accessible form Debark. The educational interest of the site could be high if a soil pedon would be prepared and conserved for illustration. Soil and water conservation has a high priority in Simen but no explicit protection is guaranteed to the site.

Management measures and proposals

As proposed above a soil profile could be laid open at Gich and used as a visitor attraction to raise awareness of the great importance and quality of the black Ando soils, how it was formed over time and how it is vulnerable and its degradation irreversible in human minds. Together with visits of other sites a red thread could be developed; the issue of soil erosion could for instance be illustrated and explained at Gich village (cf. sheet nr. 14) and soil and water conservation measures to prevent this process could be demonstrated by using the agriculture terraces built by substantial farmers at the opposite slope of Gich (cf. sheet nr. 15). The information could be presented as a simple leaflet proposing a short autodidactic geo-trail on soil formation and erosion at Gich or trekking guides could be trained to include visits to these sites on special geotouristic visits.

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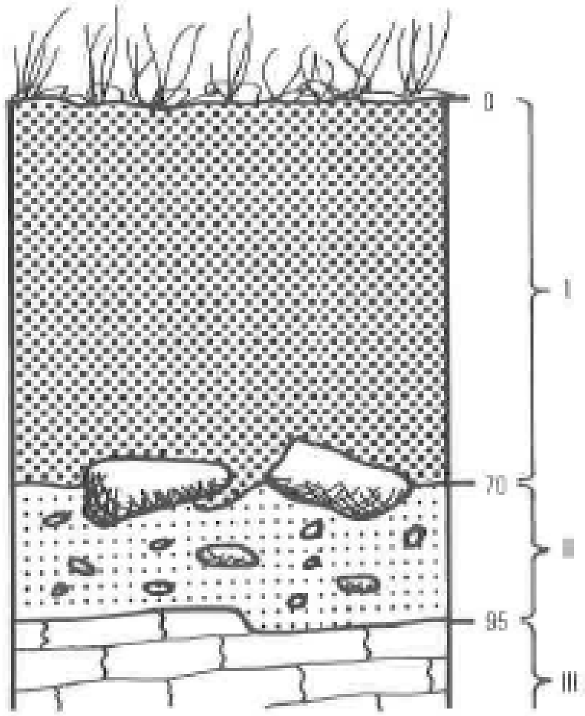
Annexe(s)

1. Ideal soil profile (Hurni, 1978)

Annexe 1: Ideal soil profile (Hurni, 1978)

Figure 2: Ideal Profile



I Black horizon
II Brown horizon
III Basaltic rock

Description:

I Black horizon: Very fine-grained, mouldy black soil, which dries out quickly from the top in the dry season and changes to a brown colour. Many sharp cornered and rounded corns of quartz and feldspar show a secondary supply of volcanic material (ashes). The depth of the black horizon, which varies slightly with the slope form, is about 70 cm on the average.

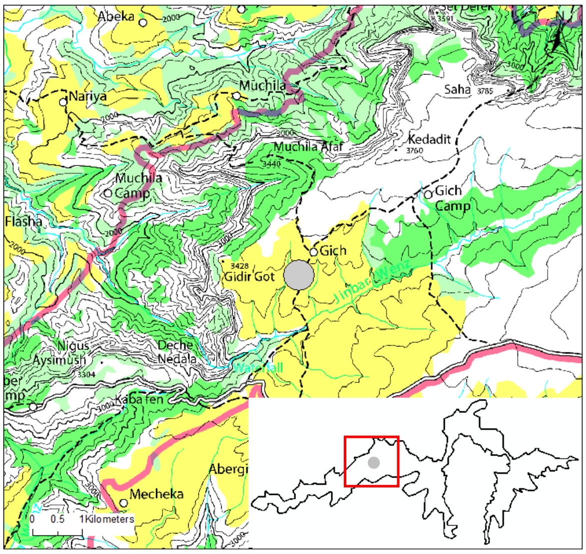
II Brown horizon: It consists of a clayey, silty, yellow-brown matrix with a lot of stones (diameter 1–10 cm). Quartz and feldspar corns show that I and II correspond pedogenetically. The depth of the brown horizon — if existant — varies very much from a few centimeters to meters. On its top, erosion seems to have diminished the brown horizon before the uplay of the black one. Rills and gullies are proof of such an erosion phase. Since it has a lower limit at about 3000 to 3300 m above sea level and becomes deeper with higher elevation, this horizon seems to correlate with the young Pleistocene glaciation on the very tops of some Simien mountains.

III Basaltic rock: The rocky underground is weathered to a high degree, even if the porphyric texture remained. Crystals and the matrix are completely transformed into clay minerals and amorphic substance. Remnants of an old cambisol between II and III are sometimes existant.

Soil erosion forms at Gich village (Jinbar valley)

Debark (Abergina)

Short description: The heavily degraded region around Gich village on the Northern slope of Jinbar River is selected as a representative site of the soil erosion process in Simen. The erosion forms caused by surface runoff are sheet erosion, rill erosion and gully erosion. Soil erosion and degradation mainly occurs on cultivated land; in the Jinbar valley 1000 tons per hectare, or about 15 cm in soil depth have been lost since the human settlement. Current soil erosion processes amount about 20 tons per hectare per year on average whereas the grass-steppe has less than 2 t per ha soil loss.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.

Coordinates: **N 13°15'33.75"/ E38°05'30.24"**	Altitude: **3200 m** to **3600 m**	Type: **AER**	Surface: 2.4 km^2

Ownership: **PUB**

Characteristics: **anthropic, active**

Description

*"**Soil erosion** is caused by man's impact on nature, he disturbs the natural rate of soil formation and soil reduction, and causes an accelerated process of soil movement* (Hurni, 1978 : 94)." Denudation, sheet erosion, rill erosion, gully erosion and accumulation are the forms of soil erosion, caused by water and wind. The erosion forms caused by surface runoff are sheet erosion, rill erosion and gully erosion (cf. scheme erosion forms, annex 2). Wind erosion forms are negligible in Simen.

In a series of publication (1975a; 1975b; 1978), H. Hurni conducted detailed research on soil erosion damage, soil erosion processes and initiated a soil and water conservation program for Simen. The 30 km^2 large Jinbar valley, with 20 km^2 undisturbed woods and grassland served as major study area. For this inventory is only selected and evaluated the restricted area in the heavily degraded region around Gich village on the Northern slope of Jinbar River (cf. area on soil erosion map).

Through the study of 1.) single runoff damage forms as well as 2.) the damage dimension in different area units, and 3.) the depth of the top black horizon, a detailed map of the soil erosion damage was drawn (cf. map below; Hurni Year). 200 samples of soil profiles in undisturbed woods and grassland as well as 300 samples in lightly damaged barley fields, made it possible to present the black horizon depth area wise. The average depth in the woods and grassland is about 70 cm, varying with slope form and inclination, while some barley fields show a diminished depth of 40-60 cm, mainly on convex slope forms.

"Knowing the soil depth in its natural condition (the uncultivated section of the valley), allows to show the effect of sheet erosion in the barley fields (Hurni, 1978, 98) ". As a result the differentiation of the cultivated land into four classes of damage (extremely, heavily, moderately and lightly damaged areas) was mapped. In each unit, it was estimated what percentage of the total of the unit area has destroyed soil horizons.

Damaged spots as results of linear erosion occur in both the woods and grassland as well as in the barley fields. Spots where the soil has been eroded to the rock (rock completely denuded), indicate the final phase of soil erosion. They are mapped in a strong red colour and to scale. Places where soil horizons have been mixed through ploughing are marked with three red dots and indicate important places for initial soil erosion processes. An accumulation of soil removed from the slope above, is frequent in extremely damaged areas. Damage caused by cattle such as eroded paths, river crossings or watering places have been mapped where they might initiate more soil erosion. Gullies were differentiated in their depth and in the form of slope where they exist.

Morphogenesis

In an in-depth study on climate and dynamics of past and present attitudinal belts, Hurni (1982) distinguishes three main Holocene morphological processes chronologically, namely a morphodynamic (cf. **natural erosion**, sheet nr. 12), a pedogenetic (cf. **soil formation**, sheet nr. 13) and an **anthropogenic generated phase**, and describes the environmental conditions favouring these processes. Soil erosion is the third and last phase, which started about 2000 years ago, when the first human settlers began with agriculture of grains and pulse.

"The map shows clearly that man, with his crop and land management, initiates soil erosion. A big concentration of damage occurs in the barley fields of the valley. Cattle produces much less soil erosion in the woods and grassland (Hurni, 1978 ; 99)." Furthermore, clear tendency to damage according to slope aspect, form and inclination has been shown. The barley fields south of the Jinbar River show less soil erosion than the ones north of it. Reasons for such conservation to the South might be less rainfall intensity, or that the cultivation might be more recent than that to the North. In addition, most of the areas damaged more than 20 % are exposed to the South or East. *"The affluents flowing from Gich to the Jinbar River, clearly show this tendency: West-exposed slopes do not show any severe damage, whereas most East exposed slopes are extremely damaged (cf. map). Soil erosion process studies showed a direct relation between the Eastern-exposed slopes and the rainstorm direction from northeast. Steeper slopes are generally more damaged than gentle ones. Ways and paths often initiate extreme damage on slopes by carrying concentrated water flows on them (1978 ; 99)."* A morphogenetic development of soil erosion forms can be presented as follows (Hurni, 1978 : 99):

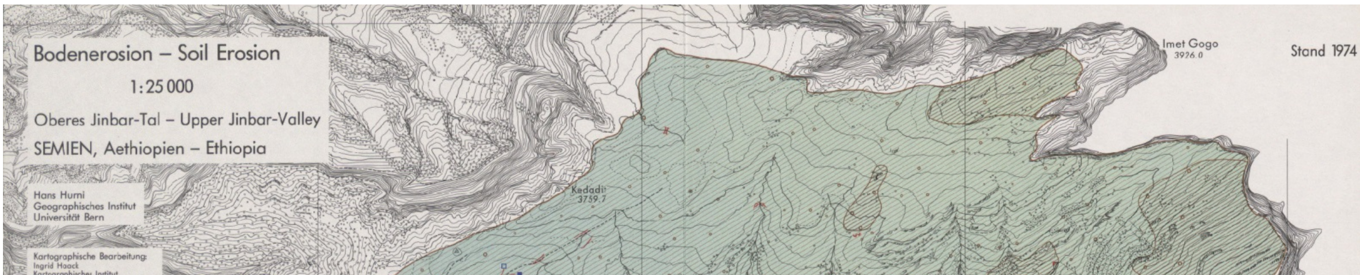
1. "*Mixed soil horizons develop on convex spots by **ploughing** the reduced black horizon together with the brown one. Wind denudation and drying out of the soil are intensified.*
2. ***Rainfall** produces a wash off of the mixed soil to the bare rock, because little soil depth cannot absorb a lot of water and the surface runoff increases proportionally.*
3. *The denuded rock remains without **vegetation** the whole year and soil erosion is effective all year long.*
4. ***Accumulations** arise where slope inclinations decrease on the foot of such destroyed spots.*
5. *When deep enough, **secondary gullies** carve the accumulations again."*

*"Soil **erosion parameters** such as long and intensive rainfalls, steep and long slopes, and fallow areas, especially cumulate in mountain areas* (Hurni, 1978 : 94)." *"Soil erosion not only leads to diminishing soil depth and physical alteration of the soil but also to selective removal of specific nutrients, thereby causing chemical degradation and loss of soil productivity (*Hurni

and Ludi, 2000 ; 58).” “*[Thus,] soil is removed but not replaced, yields diminish, and men are forced to seek for more (and in consequence steeper) cultivated land. […] Basic food for the inhabitants of the upper Jinbar valley is barley. People plough any slope up to 80 % inclination with a pair of oxen, without being aware of the damage caused by soil* erosion (Hurni, 1978 : 94).” Over the whole Simen, age-long, today into steepest slope areas expanding shifting cultivation has reduced the part of high forest from approximately 80 % (1600 km^2) before human settlement to less than 10% (200 km^2). About half of the area (1000 km^2) is used as arable land, further 15% (300 km^2) as grazing land (Hurni 1982).

The soil degradation since the human settlement for the Jinbar valley was recorded quantitatively (Hurni, 1979, In Hurni 1982). It varies between 0 cm and 45 cm mean levelling per slope area, according to exposure. On the average, this loss is about 1000 tons per hectare, or about 15 cm in soil depth. Current soil erosion processes on an average slope of 50 m length and 30% inclination cultivated with barley, amounts about 20 tons per hectare per year, calculated with the Universal Soil Loss Equation (USLE), whereas the grass-steppe has less than 2 t per ha per year soil loss. “*[For whole Simen] average soil loss rates on arable land (including both actually cultivated land as well as fallow land) are estimated at 70 t/ha and year. These figures are 70% higher than the 42 t/ha per year on arable land that have been estimated for the Ethiopian Highland in general* (Hurni, 1988 In Hurni and Ludi, 2000 : 58). ” That the soil loss for the whole area is almost three times as great as the one estimated for the Jinbar valley, must be due to overestimation of the S-factor and due to the very low erodibility factor K of the andosol compared with other soil types occurring in lower areas.

“Soil erosion, therefore, is in the order of 10-15 times too high for an average cultivated slope, so that it will degrade within some 80 years of cultivation, to soil depths of less than 10 cm. This is the case for many slopes in Simen, especially at altitudes between 2500 and 3000 m, which have a very old history of land use, dating back to the first centuries AD but also for most other cultivated areas in Simen (Hurni, 1986 : 38).” “*Historically, highly developed political systems existed around Aksum in the northern part of Ethiopia until the seventh century A.D. Probably due to land degradation, the Aksumite kingdom then declined (Butzer, 1981), while farther south other centres, such as Gonder, Lalibela, and Menz, emerged as centres of cultural activity (Hurni, 1988)*.” *Conservation measures with drainage ditches and graded bench terraces are more frequently used today, but should be carefully improved and implemented much more intensively by planning and campaigns, in order to prevent a total destruction of the agricultural soils of Simen* (Hurni, 1982 : 140).”



Map: Soil erosion – Upper Jinbar valley (Hurni, 1975b)

Intrinsic value

Central value		
Integrity	The active geomorphological process builds and destroys the site by itself. It is suggested that the integrity is high as the forms of soil erosion and its process are well observed.	1
Representativeness	The site represents the soil erosion process and forms of soil erosion, which is highly active respectively are frequently observed on cultivated land in Simen.	1
Rareness	Soil erosion is a common event in Simen thus the site has no character of rareness.	0.25
Paleogeographical interest	Soil erosion of the Jinbar valley and Gich is a reference site for the study of soil erosion processes in Simen. With the understanding of different parameters which influence soil erosion, such as slope aspect, inclination, vegetation, form of slope and gullies the vulnerability of a slope for soil erosion is estimated.	0.75
Scientific value	**High**	**0.75**

Additional values	
Ecological value	
Ecological impact	Soil erosion affects the ecosystem and the biodiversity but is not important for the development of a particular ecosystem or the presence of a particular fauna and vegetation. On the contrary, soil erosion leads to reduced vegetation cover and badlands
Ecological value	**Very low to null**
Aesthetic value	
View points	No special viewpoint for this site
Contrast, vertical development and space structuration	The reddish colour of the spots with eroded soils can be easily distinguished from less eroded or undisturbed ground surface. The vertical development and space structuration are weak or low.
Aesthetic value	**Low**
Cultural value	
Geohistorical	Jinbar including Gich served as a study area of soil erosion for more than 40 years. Important findings for the understanding of soil erosion processes in Ethiopian could be collected by means of this site.
Cultural value	**Average to high**

Use and management characteristics

Protection of the site	
Protection status	The site is located inside the national park boundaries and therefore under protection.
Damages and threats	The active soil erosion process is harmful to soil formation and to the ecoystem but necessary for the creation and maintenance of this site. No damages and threats are noted.

Promotion of the site	
Visit conditions	
Accessibility	Gich village is accessible from Debark via Sankabar including 3-4 hours trekking on the Main Gich Plateau Trekking Road. The trail is frequently used by visitors and in reasonable condition.
Security	No security issues.
Site context	The site is located in the surroundings of Gich village.
Touristic infrastructure	There is very basic infrastructure at Gich campsite.
Visit conditions	**The visit conditions are among the better in Simen and the access is good.**
Education	
Education interest	By means of this site the soil erosion process can be understood by all sorts of visitors.
Interpretation facilities	No interpretation facilities.
Educational interest	**High**

Synthesis

Global intrinsic value

The central value is high as the integrity is high and Gich is an important site for the understanding and representation of the soil erosion process in Simen. Soil erosion has serious economic and ecological consequences with sterilisation of the soils thus the ecological value is very low. The cultural value is rather high as it is a geohistoric site for soil erosion research. Globally the intrinsic value is quite high.

Use and management

The visit conditions are among the better in Simen and the education interest is high but interpretation facilities are lacking and there is no recognition and explicit protection of the geomorphological value.

Management measures and proposals

In combination with visits to other sites in the near vicinity this site should be valorised for trekking tourism. A leaflet for a self-guided geo-trek with at least three attraction points could be proposed with information on soil formation (cf. sheet nr. 13), soil erosion and soil and water conservation (cf. sheet nr. 15). The "historic" measuring station of the University of Bern down at the Jinbar River could be a fourth interest point and thus be valorised for tourism. Visits to this site could also be subject of guided tours on the Main Gich Plateau Trekking Route. An interpretation point explaining the key features and importance of the site could also be installed as it is a location where the environment is disturbed anyway. Such signposts should be used for visitor guidance on the Gich plateau so that the formation of more trails is avoided and dispersing of the impact is minimised.

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Annexe(s)

1. Soil erosion at Gich
2. Soil erosion forms (Hurni, 1978)
3. Eroded paths from cattle trampling (Aynameda to Gich)

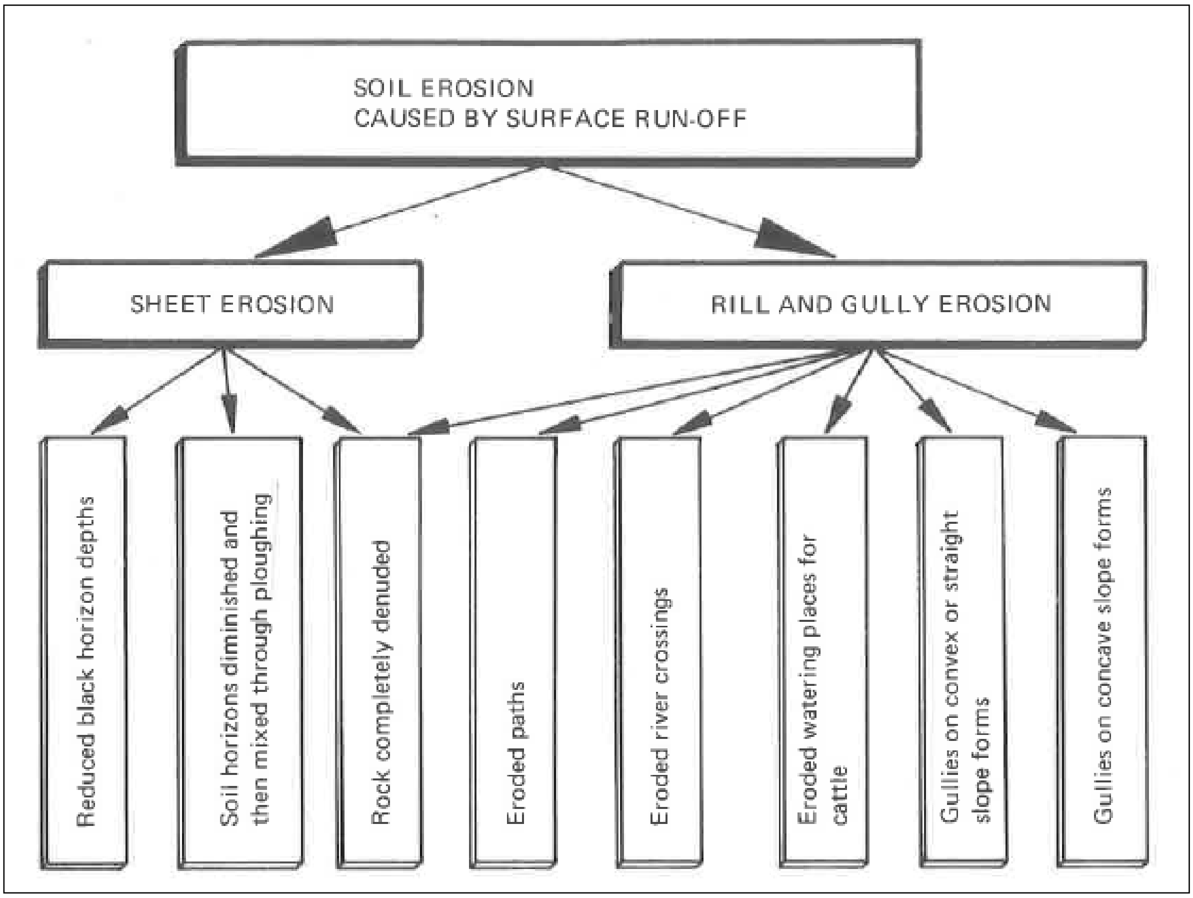
Annexe 1: Soil erosion at Gich

Left: The soil is extremely damaged by soil erosion. In many places the rock is completely denuded. Rills and gullies are washed into the weathered basaltic rock.

Left: Chemical weathering forces the desintegration of the basaltic bedrock similar to detaching of onion skin, process known as exfoliation or desquamation.

Left: Immense gully on one of the barley fields of the Jinbar valley (Hurni, 1978).

Annexe 2 : Soil erosion forms (Hurni, 1978)



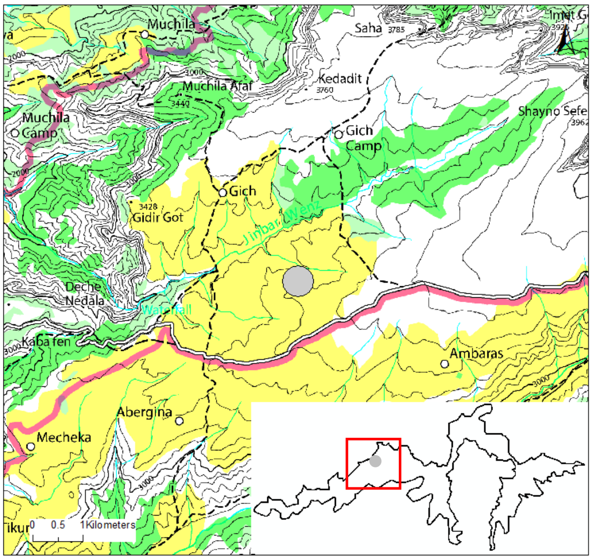
Annexe 3: Eroded paths from cattle trampling (Aynameda to Gich)

Left: Eroded paths from cattle trampling are frequently observed on the Gich plateau on the way to Imet Gogo and like on this picture on the Ambaras plateau.

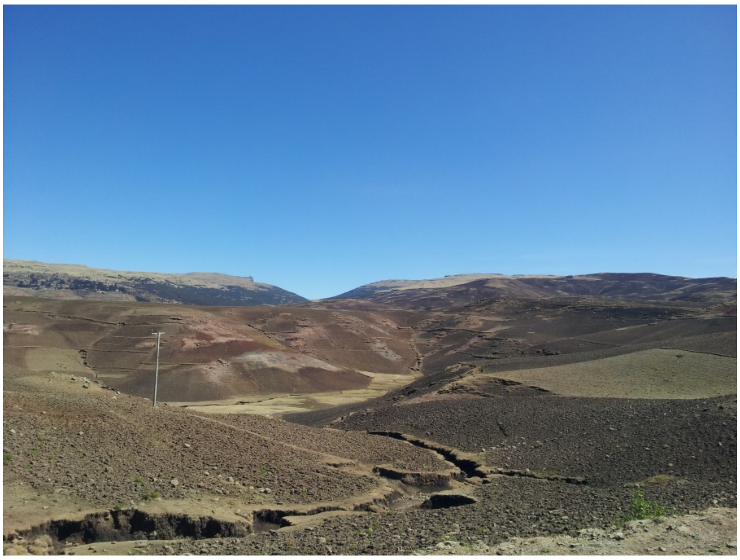
Farmland of Ambaras plateau

Debark (Abergina)

Short description: The Ambaras plateau at about 3600 m on the opposite of Gich represents the largest contiguous area of cultivated land dotted within the park. On the southeastern slope of the Jinbar valley several agriculture terraces built by local farmers spread up to the plateau. Human land use in Simen first started in lower areas but with increasing population and soil degradation on the first cultivated slopes peasants were forced to move up slope. Cultivated land at Ambaras plateau now reaches as high as the climatic limit of barley cultivation at 3700 m.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.



Coordinates: **N 13°14'22.65" / E 38°05'51.72"** Altitude: **3300 m** to **3600 m** Type: **AER** Surface: 6.3 k**m²**

Property status: **PUB** Characteristics: **anthropic, active**

Description

The area on the northern side of the road on the **Ambaras plateau** at ~3600 m with some **agricultural terraces** down to 3300 m on the opposite slope of Gich in the Jinbar valley represents the largest contiguous area of cultivated land dotted within the park (cf. annexes 1, 3). The strongly weathered and eroded plateau surfaces are cultivated by farmers living in villages close to the park border on the southern side of the plateau. Each side of the plateau is ploughed every second year, while the other side lies fallow (Hurni, 1978). Except for the National Park, the entire Simen highlands are very heavily cultivated: almost 50 % of the landscape is used for agriculture (cultivations and fallow land) and the total area under cultivation in the park was recently estimated to be 3126 ha, some 7.6% of the park area (FZS and ADC, 2009).

Morphogenesis

From quotations by European travellers one can deduce that the highlands were quite densely populated 100 to 150 years ago; all larger settlements, such as Argin, Ambaras and Gich already existed (Stähli, 1978). Moreover, the Simen region, being surrounded by old cultural centres like Aksum, Lalibela, and Gonder, has been inhabited by human settlers and cultivators for at least 2000 years (Kirwan, 1972).

Through the cultivation by ox-ploughs (cf. annex 3), **soil erosion** started to destroy the fertile Ando soils (cf. sheet nr. 13). Covering climatically and topographically favourable altitudes around 3000 m first, the peasants had to move up slope – in the course of the centuries – for two reasons : One being the accelerated soil erosion on their fields, destroying the first cultivated soils even on flat slopes, and the other, increasing population. Today, cultivation reaches as far as the **climatic limit** of barley cultivation, at 3700 m (Hurni, 1982).

Why **human settlement** in deeper areas, between 2900 m and 3400 m must have happened previously, can be shown next to the explanation by the much larger soil erosion losses despite significantly shallower relief by the following observations (Hurni, 1982):

1. The two main centres of Beyeda and Janamora, Dilibza and Deresge that lie just above 3000 m, are today surrounded by **badlands** on which cannot grow even grass vegetation.
2. **Agroclimatic** is the altitudinal belt between 3000 m and 3400 m (upper Dega) more favourable than the overlying belt until the barley border at about 3700 m (High Dega), because frost occurs far less frequently.
3. The tendency to shifting upwards in the marginal altitudinal belt in the area of the barley limit continues to this day.

Annex 2 shows the effects of soil erosion for agriculture namely their shifting into the higher marginal areas.

Intrinsic value

Central value		
Integrity	High integrity with risk of overexploitation and soil erosion.	0.75
Representativeness	The site is exemplary of man-made landscapes and land seizure in Simen.	1
Rareness	There are only few areas with agriculture terraces in the SMNP	0.75
Paleogeographical interest	The site indicates well the upper limit of barley cultivation at 3700 m.	0.5
Scientific value	**High**	**0.75**

Additional values	
Ecological value	
Ecological impact	Extensive cultivation has a positive impact on the number of bird species (Nievergelt, 1998). But overall the General Management Plan states that the "*[SMNP's] unique biodiversity and ecological processes simply cannot tolerate extensive human use* (FZS – ADC, 2009)."
Ecological value	**Average to low**
Aesthetic value	
View points	The site is well observed from Gich on the opposite of the Jinbar valley and from the public road climbing up from Gich abyss to the Ambaras plateau.
Contrast, vertical development and space structuration	The colour contrast of the cultivated, arable and fallow land is remarkable during both, the dry and wet season. The vertical development of the anthropic landforms is low and the space structuration insignificant.
Aesthetic value	**Average to high**
Cultural value	
Historical importance	The flat Ambaras plateau has been discovered by farmers for being favourable for agriculture more than 150 years ago. "*Soil erosion damage serves as geomorphic evidence to show that human landuse first started on the gentler slopes of the highland valleys, at altitudes between 2500 m and 3000 m as well as on the flat terrace steps at the foot of the escarpments. With increasing population density in the last centuries and the accelerating destruction of the first cultivated slopes, the peasants were forced to extend onto steeper slopes* (Hurni, 1986)".
Cultural value	**High**

Use and management characteristics

Protection of the site	
Protection status	The site is located inside the national park boundaries and therefore under protection.
Damages and threats	Soil erosion on the Ambaras plateau is not as advanced as at Gich on the opposite of Jinbar River. However, there is a risk for more pronounced soil erosion in this area. Without intensification of soil and water conservation the farmland is likely to become unproductive in the near future and the landscape to be transformed into badlands as observed at Gich.

Promotion of the site	
Visit conditions	
Accessibility	Ambaras plateau is accessible by car within 90 minutes from Debark. The agricultural terraces on the opposite slope of Gich in the Jinbar valley could be approached on a trek from Anyameda or from Gich but the terraces are best observed from distance from Gich or from the road when climbing up to the plateau.
Security	No security issues.
Site context	No remarks.
Touristic infrastructure	The Ambaras plateau is accessible by road and basic touristic infrastructure is available at Gich and at Aynameda campsite.
Visit conditions	**The visit conditions are among the better in Simen with easy access from Debark.**
Education	
Education interest	The landscape showing the influence of man-made activities with arable land and agriculture terraces are well visible for non-specialist visitors.
Interpretation facilities	No interpretation facilities.
Educational interest	**High**

Synthesis

Global intrinsic value

The site combines a high central value as it is representative of the human impact of extensive farming with rather high aesthetic and cultural values thus the global intrinsic value is quite high.

Use and management

Even though the cultivated land and terraces on the Ambaras plateau are situated within the national park the cultural landscape is exposed to the risk of ending up similar to the example at Gich forming a wide almost sterile ground surface. The site presents reasonable visit conditions and a high educational interest but there are no efforts for the enhancement of the geomorphological values.

Management measures and proposals

Together with the soil erosion site at Gich village (cf. sheet nr. 13) and the soil formation site at Gich campsite (cf. sheet nr. 14) this site could be valorised with an information leaflet proposing a geo-trek to these three sites. Moreover, the site should be valorised for the sightseeing tourism as the arable land is well visible from the public road. A sightseeing tour to discover the geoheritage of the Simen Mountains should be proposed with specialised geotourism operators and trained tourist guides (as suggested in other sheets ex. cf. sheet nr. 5). By means of the example of the only slightly damaged cultural land at Ambars in comparison to the heavily eroded land at Gich on the opposite the relationship between human encroachment and soil erosion, increasing population and the importance of soil and water conservation on such slopes for sustainable rural development could be explained. In an illustrative guide book and in a project of geovisulisation on the web of the geoheritage of the Simen Mountains as suggested in other sheets, the three sites regarding soil formation, erosion and conservation should be valorised to raise awareness of the serious consequences which soil erosion has in Simen and what is needed to be done to solve the issue.

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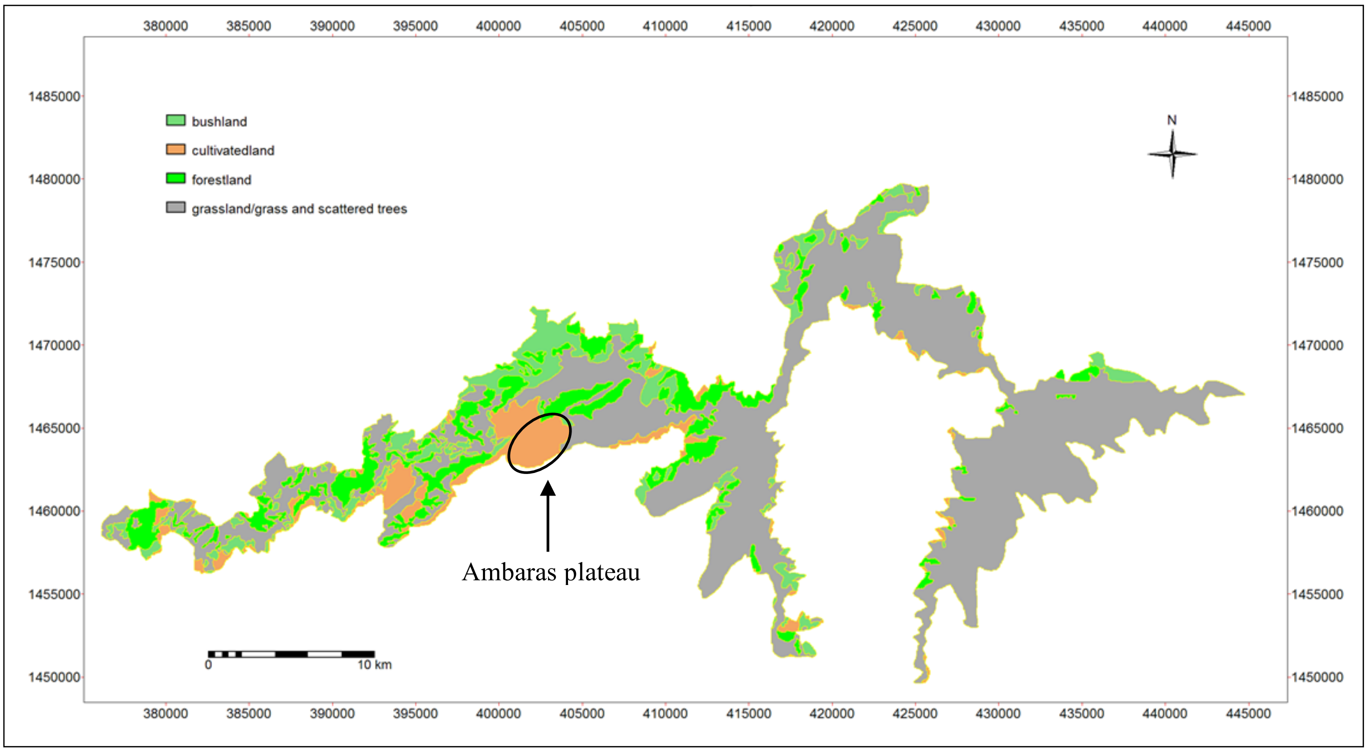
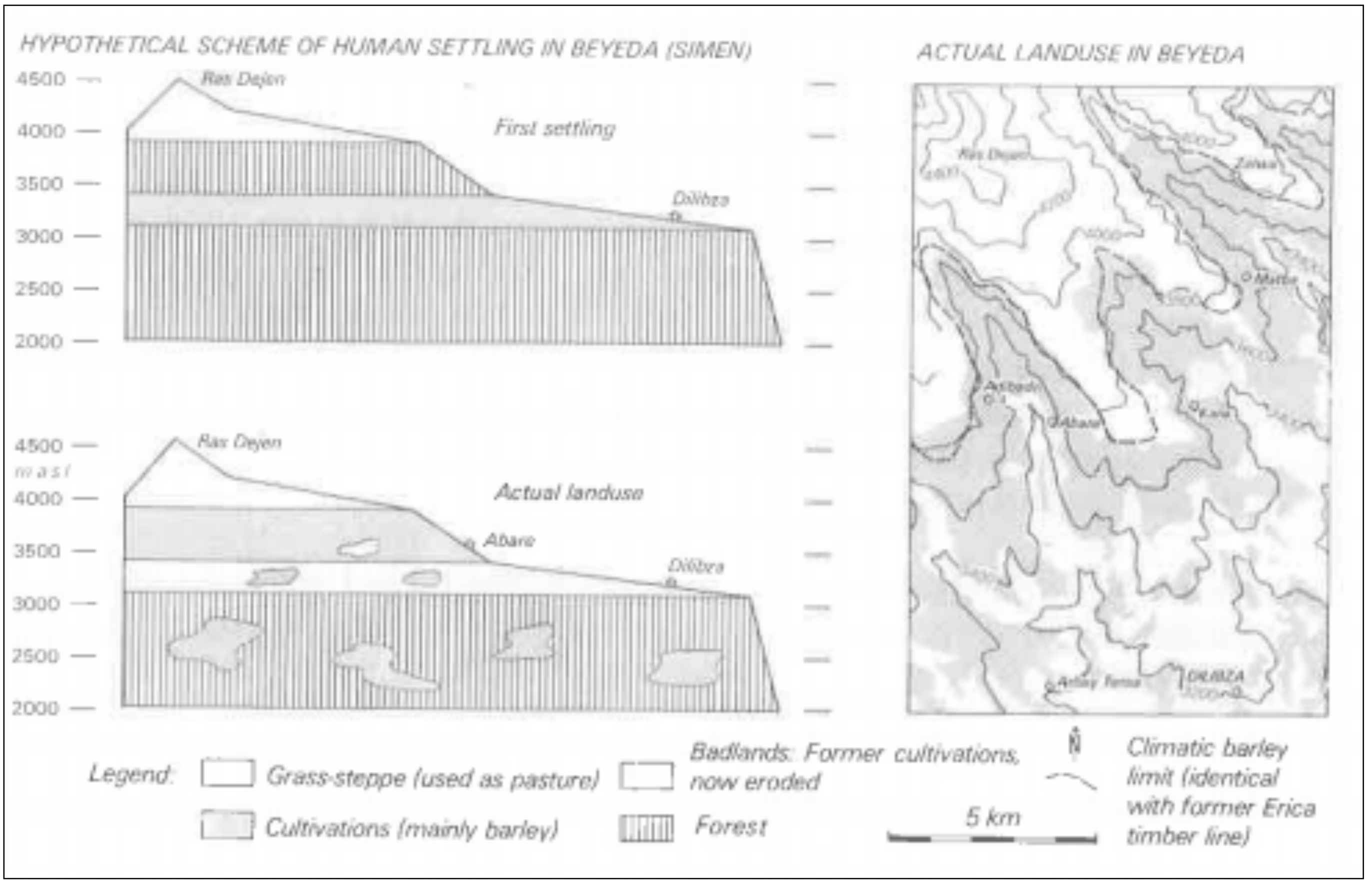
Annexe(s)

1. Simen Mountains National Park landuse map (PaDPA, 2007)
2. Actual landuse and human settlements in historical times, reconstructed with the soil erosion damage (Hurni, 1982)
3. Farmland of Ambaras plateau

Annexe 1: Simen Mountains National Park landuse map (adapted from PaDPA, 2007 In FZS – ADC, 2009).



Annexe 2: Actual landuse and human settlements in historical times, reconstructed with the soil erosion damage (Hurni, 1982)



Annexe 3: Farmland of Ambaras plateau

Above: Terraces on the Ambaras plateau; view from the main road.

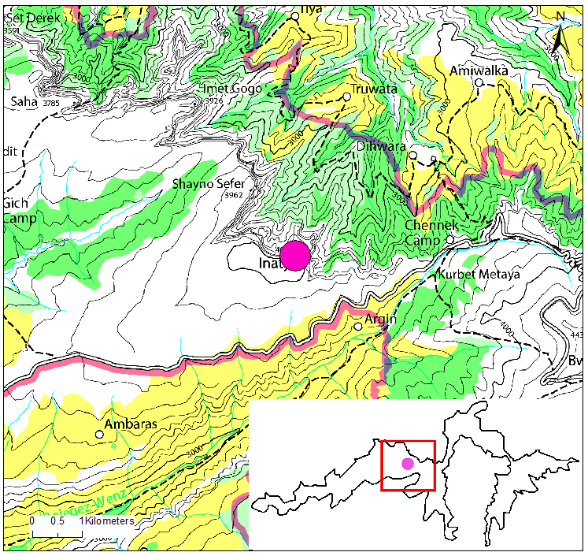
Above: Cultivated land on the northern side of the Ambaras plateau; view from Gich camp

Above: Poughing by oxen

Turf exfoliation on the Inatye high plateau

SMNP

Short description: On the Intaye high plateau circular turf exfoliations are found in abundance. This active miniature cryogenic phenomenon dominates in Simen as bounded solifluction form in a small strip right blow the present day periglacial limit at 4225 m on the average. Needle ice (pipkrake) action in the diurnal freeze-thaw cycles leads to the destruction of the vegetation cover through the removal of soil and possible influence of root-eating Gelada baboons.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.

Coordinates: **N 13°15'39.52" / E38° 9'24.64"**	Altitude: **4000 m** to **4070 m**	Type: **AER**	Surface: **78ha**

Property status: **PUB**

Characteristics: **natural, active**

Description

Vegetation terracettes respectively circular **turf exfoliations** on a plain are the most frequent solifluction form below the present day lower periglacial or **frost detrital limit** (at 4225 m on the average), defined and mapped as a sharp onset of the upper limit of the afro-alpine vegetation with over 50% ground cover. Although observed as lowest laying **frost action** at 3700 m (Hastenrath, 1974) and at 3600 m (Werdecker, 1955), they dominate as **bounded solifluction** form in a strip at 100-150 m below the vegetation limit vs. periglacial limit (Hurni, 1982).

We found this active miniature **cryogenic phenomenon** for example on Bwahit plateau (2270 m) and on the northern aspect of Mesarerya (4200 m) but it is best observed on the Inatye high plateau at 4050 m (+/- 10 m) along the trekking route from Gich to Chennek campsite where turf exfoliation occur in abundance (cf. annex 2). The circular form is 40 to 60 cm in diameter; the terracettes have typical dimensions of tens of cm (distance and height).

Morphogenesis

*"[**Turf exfoliation**] is a denudation process that is particularly prevalent in periglacial areas and leads to the destruction of a continuous vegetation cover through the removal of soil exposed along small terrace fronts. Among the processes that lead, possibly synergistically, to this phenomenon are needle-ice (pipkrake) action, desiccation, rain wash erosion, zoogeomorphic activities and aeolian deflation* (Goudie, 2004 : 1075)." Thus, in Simen, influence of **root-eating baboons** cannot be excluded for an interpretation.

Needle ice (cf. annex 2) is the accumulation of ice crystal growths in the direction of heat loss at, or directly beneath, the ground surface and is common to areas of diurnal freeze–thaw, ranging from tropical alpine to subarctic environments (Goudie, 2004). "*Zwar sind in Semien Tage mit Bodenfrost schon oberhalb etwa 2200 m möglich, und mittlere tägliche Minimal-Temperaturen mit Null Grad an der Bodenoberfläche sind in 3600 m zu beobachten, wenigstens ausserhalb der Regenzeit. Rauhreiferscheinungen und gelegentliche Kammeisbildungen [needle ice] sind oberhalb 3600 m besonders in den Randzeiten zur Regenzeit die Regel* (Hurni, 1982 : 160)."

A **topographic analysis** of all active solifluction forms shows that the present day periglacial frost detritus limit (resp. the lower solifluction limit, demarcating downwards micro-terracettes and turf exfoliation in dense occurrence) is weakly dependent on **exposure** and **slope gradient** (cf. annex 1). Moreover, it is climatologic interpretable, most likely as a temperature-dependent limit although soil moisture, sun, cloudiness and winds are also responsible for its differences of relief with a special influence of winter snow. *"The **North-South contrast** in glacial (asymmetric distribution of relict moraines, cf. sheet nr. 7) and periglacial morphology caused by radiation is peculiar to the outer tropics [including the Simen Mountains], and does not occur in equatorial East Africa. The **West-East asymmetry** results from the powerful diurnal control of circulation systems in low-latitude mountain massifs. This is characterized by a maximum of cloudiness and precipitation in the afternoon, thus reducing the daily totals of insolation on slopes of westerly aspect* (Hastenrath, 1974)."

Since the last glacial period the altitudinal belts have risen quite exactly one step, so that the **last cold period periglacial belt** is covered of the present afro-alpine grasslands steppe and the **last cold period glacial belt** of the present day periglacial frost detrital belt. The **snowline**, in the cold period at 4250 m, would today lie around 700 m higher at around 5000 m well above the highest peaks (Hurni, 1981).

Intrinsic value

Central value		
Integrity	The site is undamaged.	1
Representativeness	This site is representative of the active periglacial process of bounded solifluction forms which dominant a narrow altitudinal strip below the vegetation limit of Simen.	1
Rareness	Circular turf exfoliation occurs in abundance on the Inatye high plateau but on the reference scale of Simen they are a rather rare phenomenon restricted to some peak areas.	0.75
Paleogeographical interest	The turf exfoliation at Inatye was used as a reference site to define and map the present day lower periglacial limit.	0.5
Scientific value	**High**	**0.81**

Additional values	
Ecological value	
Ecological impact	Turf exfoliation leads to the destruction of the vegetation cover.
Ecological value	**Very low to null**
Aesthetic value	
View points	The landforms are too small to be seen from distance respectively from a viewpoint.
Contrast, vertical development and space structuration	Contrast, vertical development and space structuration are weak.
Aesthetic value	**Very low to null**
Cultural value	
Cultural value	**Very low to null**

Use and management characteristics

Protection of the site	
Protection status	The site is located inside the national park boundaries and therefore under protection.
Damages and threats	No damages but ignorant trekking tourism could threaten the integrity of the vulnerable turf exfoliation.

Promotion of the site	
Visit conditions	
Accessibility	The site lies on the Main Gich Plateau Trekking Route between Gich and Chennek. Chennek camp is reached from Debark in 2-3 hours. About 90 minutes trekking should be calculated to reach Inatye from Chennek or about 3-4 hours from Gich. The trail might be slippery at some locations and relatively steep but in general the walking difficulty is not at the highest level.
Security	There are some locations where the path from Gich to Chennek is only a few meters away of the escarpment.
Site context	Inatye offers a very calm and natural environment with great sceneries.
Touristic infrastructure	There is very basic touristic infrastructure at Chennek camp and at Gich camp.
Visit conditions	**The visit conditions are among the better in Simen with good access, great sceneries and a natural environment.**
Education	
Education interest	Non-specialist visitors can easily recognize the circular landforms, they may wonder how these landforms are formed and they could understand that frost action in the diurnal free-thaw cycles resulted in the destruction of the vegetation cover through removal of soil and perhaps influence of root-eating baboon.
Interpretation facilities	No interpretation facilities.
Educational interest	**High**

Synthesis

Global intrinsic value

The site has a high scientific value characterised by the high integrity, representativeness and rareness. The additional values are very poor, thus the global intrinsic value is average to high.

Use and management

The site is well accessible and shows a high educational interest but ignorance from trekking tourism presents a risk to the vulnerable landforms.

Management measures and proposals

Geo-trekking on the Gich plateau should also enhance the geomorphological value of this site whether in a booklet for self-guided tours (cf. sheet nr. 8) or by tourist guides offering an exclusive geoheritage product. Scholars or specialists undertaking an excursion on geomorphosites of Simen should also visit this site as they could learn from the insight of fossil periglacial deposits visited in prior several hundred meters downslope in the upper Jinbar valley (cf.sheet nr. 8) and the active solifluction forms observed on Intaye that attitudinal belts in Simen since the last cold period have shifted upwards.

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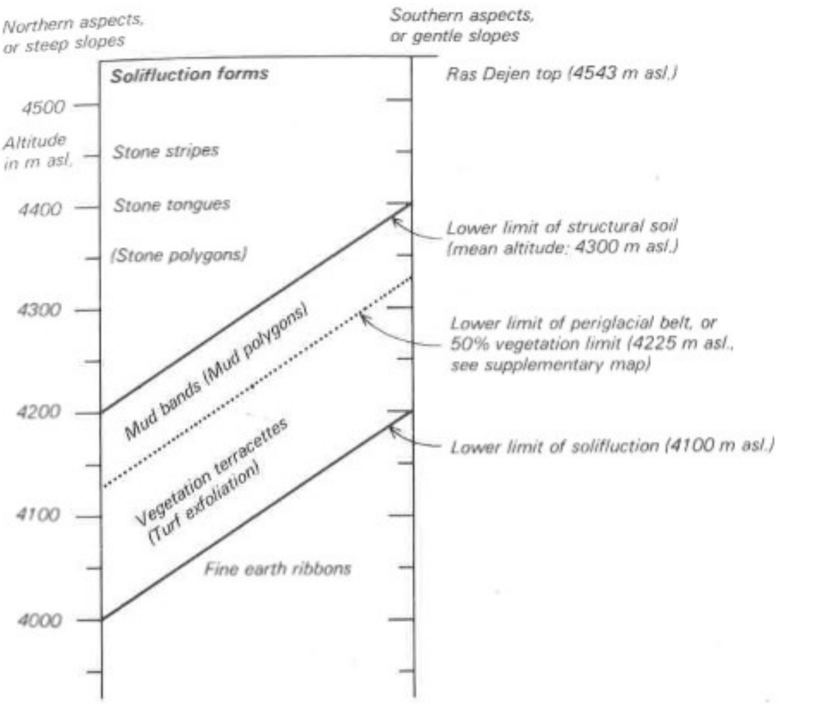
Annexe(s)

1. Topographic analysis of the periglacial belt and other attitudinal belts (Hurni, 1982)
2. Circular turf exfoliation on Inatye high plateau at 4050 m
3. Needle ice (pipkrake) not in Simen (B. Shields)

Annexe 1: Topographic analysis of the periglacial belt and other attitudinal belts (Hurni, 1982)



Figur 50 Klassifikation der beobachteten Solifluktionsformen in Semien, geordnet nach der Höhenstufe ihres dominanten Vorkommens. In Klammern die analoge Ausbildung einer Form bei flacher Hangneigung. Zusätzlich sind die Höhen von drei Höhengrenzen der Gipfelbereiche angegeben.

Observed actual soilfluction forms in Simen classified into altitudinal belts of their dominant occurrence, with limits dependent on slope aspect and gradient (see Figure 54). In parantheses, related forms on a plain. Additionally, mean altitudes of the limits for all mountains.

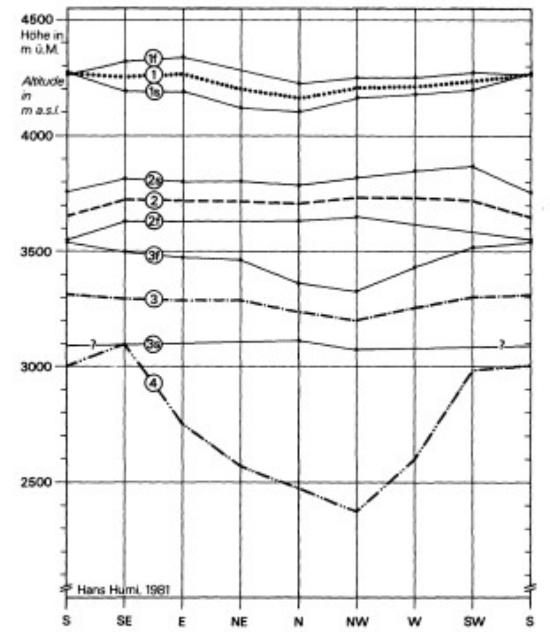
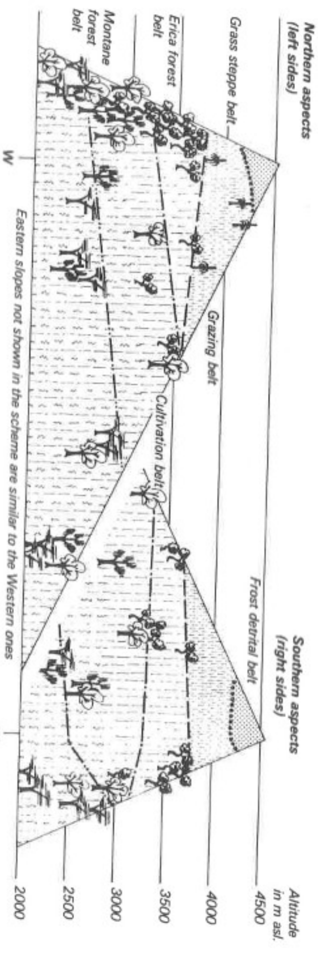


Abb. 3: Topographische Analyse der kartierten gegenwärtigen Höhengrenzen: Korrelationen mit Höhe, Exposition und Hangneigung. Die linear interpolierten Punkte repräsentieren die Durchschnittswerte von mindestens 4, im Mittel 11 kartierten Grenzteilstücken von 0,5 km Länge. 1 Frostschuttgrenze; 2 Erika-Waldgrenze; 3 Hagenia-Juniperus-Olea-Grenze; 4 Akaziengrenze. Nur steile Hänge über 15°: 1s, 2s, 3s; nur flache Hänge unter 15°: 1f, 2f, 3f

Topographic analysis of the mapped altitudinal limits: Correlations with altitude, slope aspect, and slope gradient. The linearly interpolated points represent average values of mapped sections of 0.5 km lengths (minimum 4, on the average 11 sections per point). Averages of all values: 1, 2, 3, 4 (symbols see supplement IV); only steep slopes over 15°: index s, only gentle slopes: index f



Figur 55 Schema der gegenwärtigen Höhenstufen im Semien-Gebirge in Abhängigkeit von der Exposition und der Hangneigung. Die gewählte Darstellungsform ermöglicht es, die N- und S-Expositionen nach Neigung zu differenzieren. Für die Definition von Höhenstufen und -grenzen siehe Text.

Scheme of present day altitudinal limits and belts dependent on slope aspect and gradient. The drawing is selected specifically to mark the differences between steep and gentle slopes of the same – Northern or Southern – aspects.

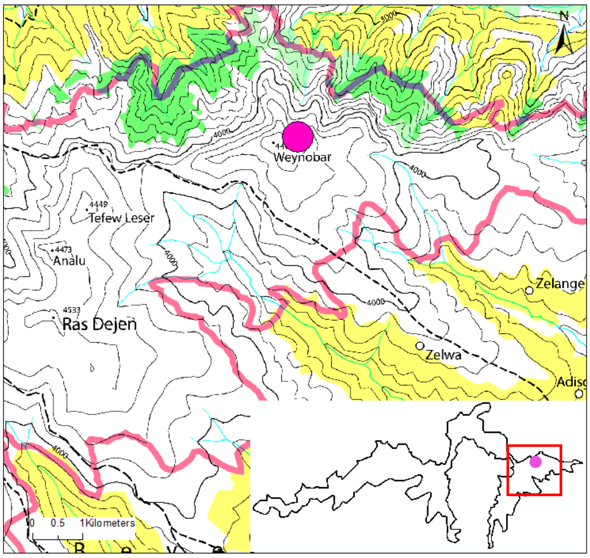
Annexe 2: Circular turf exfoliation on Inatye high plateau at 4050 m

Annexe 3: Needle ice not in Simen (B. Shields)

Patterned grounds on Weynobar

Beyeda (Meleb, Segenet, Medebay, Selewa)

Short description: Heavily weathered bedrock and frost debris accumulations, arranged in random to ordered patterns form the characteristic micro-relief on Weynobar also visible on the other high summits of Simen rising above the present day frost detritus belt vs. periglacial belt. In this cold and humid area freeze-thaw cycle days are the norm during most time of the year with cryogenic weathering the principle process responsible for the creation of the free solifluction and patterned grounds.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.

Coordinates**: N 13°16'5.72" / E 38°24'43.75"** Altitude: **4225 m** to **4465 m** Type: **AER** Surface: **2.4 km^2**

Property status: **PUB** Characteristics: **natural, active**

Description

Heavily weathered **bedrock** and **frost debris accumulations**, arranged in random to ordered patterns such as observed on Weynobar (4464 m) constitute the **micro-relief** close to the highest peaks. The attitudinal belt of extensive **active** natural processes is the present day frost detritus belt, with **free solifluction** (lacking vegetation cover) above the lower frost detritus limit of 4225 m and bound solifluction in a strip underneath (cf. sheet nr. 16). According to H. Hurni (1982) s**tone stripes** and **stone tongues** with dimension ranging around 5 to 20 cm (up to 1 m for the tongues) and only a few cm deep are the typical ground cover down the lower limit of **patterned grounds** (or *structural soil limit* following Hurni, 1982) (at ~ 4300 m). The genetically related form of **stone polygons** could be observed only rarely, because flat terrain features in this altitude is largely missing (Hurni, 1982). **Mud polygons** and **mud bands** dominate the high range immediately above the vegetation limit (vs. periglacial limit). In contrast to the stone polygons and stripes, these patterns consist predominantly of fine material and contain very few larger pebbles. A gradual transition can be observed in the field form near-symmetric polygon nets on horizontal terrain to elongated polygons and bands on slopes (cf. annex 2).

Morphogenesis

In the cold and humid environment above the periglacial or frost detrital limit, correlating approximately with the altitude position of 180 **freeze-thaw** cycle days per year **cryogenic weathering** is highly efficient (Hurni, 1982). *"Experimental work has shown that numerous mechanisms are involved in frost weathering, not only volumetric expansion of water; the most significant include adsorptive suction, as pore water moves toward the freezing front, and expansion (0.6 per cent from +4 °C to -10 °C) of absorbed water [called* ***cryosuction*** *to form* ***segregation ice]****. Many experimental studies have shown the importance of rapid freezing rates (at least 0.1 °C per minute), low minimum temperatures (< -5 °C) and high rock moisture content in determining the efficiency of frost weathering in causing* ***shattering*** *of rock samples* (McGreevy and Whalley, 1985 In Goudie, 2004 : 658)." "***Frost heave*** *[one effect of solifluction (cf. sheet nr. 8)] is an important process in formation of* ***patterned ground****, where stones and boulders are heaved in particular directions to give rise to conspicuously ordered surface arrangements* (2004 : 415)." In the case of stone stripes and polygons *"a variety of sorting arrangements and dimensions occur apparently in response to grain size distribution and depth of penetration of the freeze-thaw cycle. Large particle size and deeper-reaching freezing and thawing seem to contribute towards larger overall dimensions of the pattern* (Hastenrath, 1984 : 27)."

Frost action (as explained above) is one component of cryogenic weathering, i.e. the combination of weathering processes, both physical and chemical that operate in cold environments either independently or in combination. Many aspects of cryogenic weathering are not fully understood, but the processes other than frost may be efficient decay agents. The weathering of bare bedrock on Weynobar (or on Ras Dejen) for instance indicates the interference of **chemical reactions** such as hydrolysis, hydration or solution (dissolution) transforming rocks and minerals into new chemical combinations that are stable under conditions at or near the Earth's surface (cf. annex 1). On the other hand, **physical weathering** which involves the breakdown of rock material into smaller pieces without any change in the chemistry or mineralogy of the rock acts in the formation of mud polygons and bands. Needle ice (cf. sheet nr. 16) has apparently not been observed under this pattern but the processes active in **gilgai-phenomena** namely **drying and wetting** and a conventional frost mechanism may overlap in the mountains of the tropics and subtropics (Hastenrath, 1984).

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Intrinsic value

Central value		
Integrity	Good conservation.	1
Representativeness	Bounded solifluction and frost shattering is one of the principle processes in the region of the highest peaks and thus not negligible in Simen. The patterned ground and weather bedrock on Weynobar is quite illustrative for this process.	1
Rareness	Patterned gournds are observed on all high peaks, which rise above the present day frost detritus limit, but they are not that much pronounced as on Weynobar and it would be wrong to say that this from-type is found in abundance in Simen.	0.5
Paleogeographical interest	The site is as a reference for the study and fixation of the present day periglacial belt.	0.75
Scientific value	**High**	**0.81**

Additional values	
Ecological value	
Ecological impact	No ecological impact.
Ecological value	**Very low to null**
Aesthetic value	
View points	The forms are too small to be observed from distance.
Contrast, vertical development and space structuration	There is a certain contrast due to the soil patterns but their structuration does by far not meet the importance of space structuration.
Aesthetic value	**Low**
Cultural value	
Cultural value	**Very low to null**

Use and management characteristics

Protection of the site	
Protection status	The site is located inside the national park boundaries and therefore under protection.
Damages and threats	None.

Promotion of the site	
Visit conditions	
Accessibility	Weynobar is one of the most remote summit areas in Simen. It is probably most easily accessible via Ras Dejen pass. A car drive from Debark to Ras Dejen takes about half a day thus it is advisable to camp somewhere in the Mesheha valley or on the pass and to hike several hours to Weynobar the next day. There are some trails but the path has to be searched well if not to lose it. We achieved Weynobar from Metelal pass so we never used this path over the Beyeda high plateau, on the Google earth image it seems very safe with some light up and down.
Security	No risk.
Site context	Very natural and calm environment with amazing sceneries to the Tekeze River basin.
Touristic infrastructure	No touristic infrastructure in theses region except for the road access to Ras Dejen.
Visit conditions	**The visit conditions are some of the hardest in Simen. The visit of this site is only advisable for very fit and experienced trekkers but the view and the environment of Weynobar are worthwhile the efforts.**
Education	
Education interest	Cryogenic weathering as an important active process on this altitude in Simen can be well observed by non-specialist visitors on Weynobar. They could identify heavily weathered bare bedrocks and the miniature landforms of patterned ground.
Interpretation facilities	No interpretation facilities.
Educational interest	**High**

Synthesis

Global intrinsic value

The strengths of this site are the perfect integrity and high representativeness as well as the quite significant paleogeographical interest. The additional values are very poor, however. This combination gives a rather average global intrinsic value.

Use and management

There is no risk, which could threat the integrity of the site. Visits are only recommended for experienced trekkers and the educational interest is quite high.

Management measures and proposals

It is not recommended to promote this site for trekking and geotourism *in situ*. There are many other trekking possibilities in Simen, the Weynobar is a unique wilderness area which should be maintained in its natural state without tourism. In *ex situ* publications the site could be promoted as high priority conservation site.

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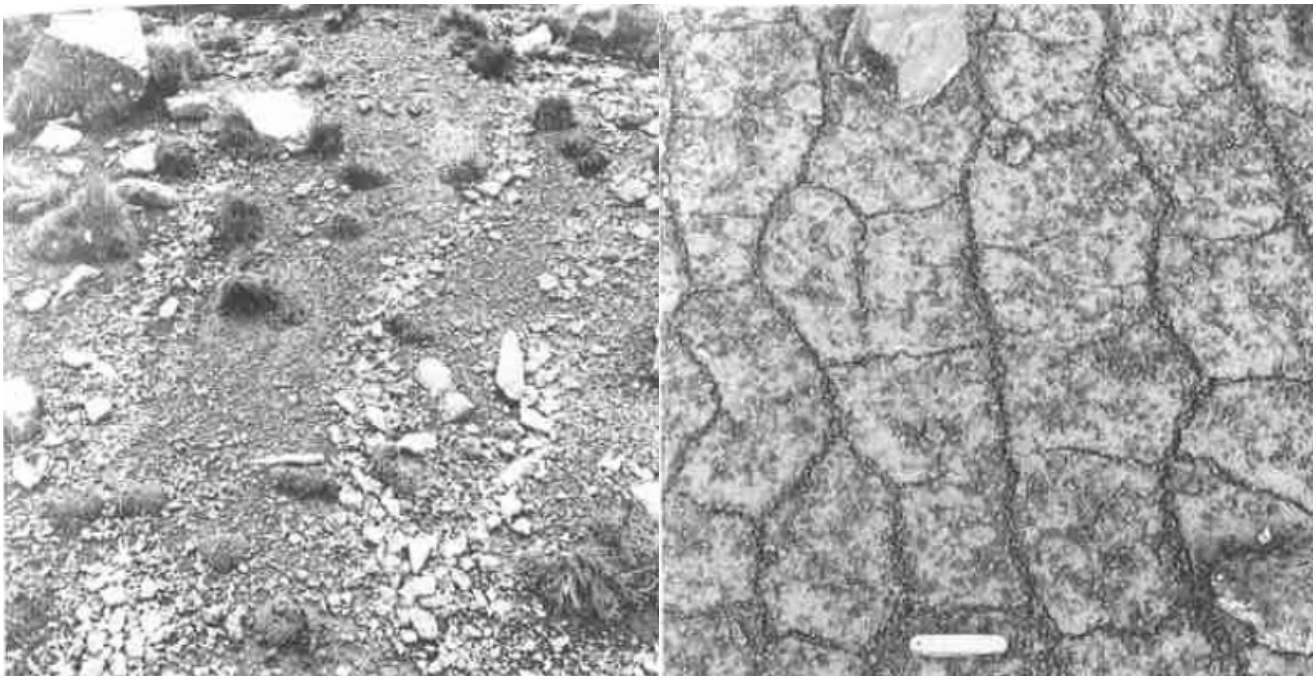
L. Mauerhofer (2016)

Annexe(s)

1. Frost shattering and chemical weathering of the bedrock close to the top of Weynobar (4464 m)
2. Stone stripes and mudbands (polygons) on Weynobar (Hurni, 1982)

Annexe 1: Frost shattering and chemical weathering of the bedrock close to the top of Weynobar (4464 m)

Annexe 2: Stone stripes and mudbands (polygons) on Weynobar (Hurni, 1982)

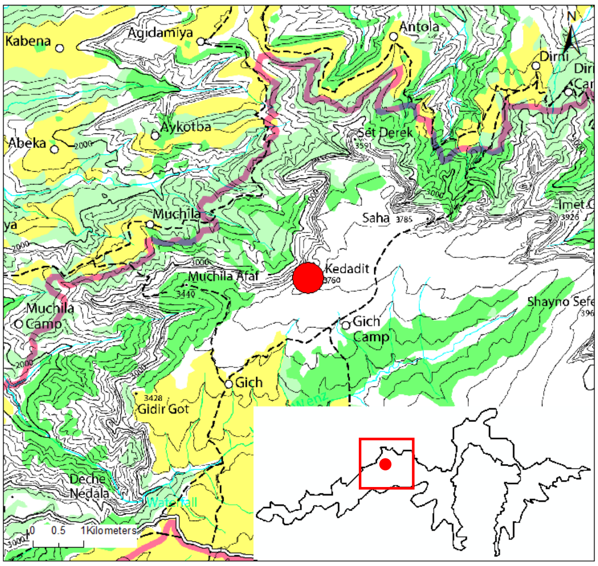


Left: Stone stripes on the SW aspect of Weynobar at 4350 m / **Right:** Transition downslope from mud polygons in the foreground (with knife) to mud bands in the background on steeper slopes. Southern aspect of Weynobar at 4400 m

Natural arches, Kedadit

SMNP

Short description: Two very similar looking natural arches are found in Simen, one called Kedadit next to Gich and a second one hidden below to the public route at the Bwahit southern slope. They are formed through the natural, selective removal of rock, the principle force involved in carving the arches is frost weathering. They remain stable provided the load is transmitted into the abutments; however, they are short-lived landforms on geological time scales and continuous erosion may provoke their collapse in a rather near or distant future.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.

Coordinates:		
Altitude: **4150 m** and **3710 m**	Type: **PCT**	Diameter: **~ 1 m (both)**

Property status: **PUB**

Characteristics: **natural, active**

Description

"*A **natural arch** is a rock exposure that has a hole completely through it formed by the natural, selective removal of rock, leaving a relatively intact frame* (NABS, 2015)." In Simen two surprisingly similar example of this structural landform are found, one frequently visited by tourists north of Gich camp, called *Kedadit* (Amharic name assigned by local people to the Satan who has broken to the hole) extremely exposed in a wall on the ridge of the Northern Escarpment at 3710 m, offering spectacular views towards the Northern Lowlands, and another only known by few local people in a 15 meter high rock wall on the Southern side of Bwhait at 4150 m (cf. annexe 1-3). Both almost circled rock holes have a maximal diameter of approximately 1 m. The term ***"natural window"***, which refers to *"a natural arch that reminds an observer of a window"*, would be more appropriate for these geological features. However, the Natural Arch and Bridge Society (NABS, 2015) does not recommend the use of this term in any serious description or classification of natural arches due to the lack of its definition.

Morphogenesis

None of the natural arches of Simen has been mentioned in literature so far. As stated in the definition, a natural arch is formed by the natural, **selective removal** of rock from a rock exposure. "*There are many different processes of erosion that can contribute to the natural, selective removal of rock but **water**, **gravity**, and **temperature fluctuation** are the principle forces involved in carving natural arches out of rock* (NABS, 2015)." Morphogenesis through **fluvial** or **marine erosion**, where a current of water, such as a stream, clearly was a major agent in the formation of the opening (hole), specific to the formation of ***"natural bridges"*** as one type of natural arches, can be ruled out here. As several study has shown that "***wind** never has more than a polishing effect after a natural arch has formed* (NABS, 2015)" the formation of both of these arches seems most likely related to the in situ mechanical breakdonwn of the rock through gelifraction. The basaltic underground in Simen, has sufficient permeability to provide the seepage that promotes weathering, yet it has the necessary cohesion for an arch to develop (Goudie, 2004). Frequent diurnal frost thaw conditions occur in Simen above the altitude of 3600 m (Kedadit is at 3710 m), at least outside the rainy season (cf. sheet nr. 16). And above 4250 m intense frost weathering with approx. 180 duirnal freeze-thaw cylces per years can be expected (cf. sheet nr. 17) (the arch at Bwahit is at 4150 m).

"*Natural arches may take various forms, but will remain **stable** provided the load is transmitted into the abutments. This condition is met so long as the thrust line of the load remains within the arch. Arches are therefore very stable features. However, continued erosion may result in an unstable form, and the arch may then **collapse** by folding in on itself at several hinge points.* […] *Erosional weakening of the abutments into which the load is transmitted can also cause an arch to collapse* (NABS, 2015)."

"*Except for the handful of natural arches whose formation has been observed and recorded, there is currently no way to determine the **age** of a specific arch. However, it is also clear that all of these features are very **short-lived** on geologic time scales, and are quite recent phenomena. Therefore, it is safe to say that no natural arch is older than about 30 thousand years. Most are probably between 5 and 15 thousand years old, i.e., not incomparable to the span of recorded history. Certain types of natural arch, however, are much younger than this on average. These are either relatively weak structurally (e.g., caprock natural arches) or are subject to much higher rates of erosion (e.g., sea natural arches)* (NABS, 2015)."

Intrinsic value

Central value		
Integrity	Intact.	1
Representativeness	Natural arches are untypical landforms in Simen but it is interesting to note that there are no just one but two examples of it. Both specimens show illustrative example of natural arches.	0.5
Rareness	The rareness characteristic is very high as these two specimens are the two only natural arches in Simen.	1
Paleogeographical interest	Low paleogeographical interest but not null as the form and process shaping them seems to be interesting for future research.	0.25
Scientific value	**High**	**0.69**

Additional values	
Ecological value	
Ecological impact	No ecological impact.
Ecological value	**Very low to null**
Aesthetic value	
View points	The viewpoint on the hill called Kedadit offers an impressive insight of the natural arch with the kilometric cliff wall of the Northern escarpment instantly below.
Contrast, vertical development and space structuration	Regarding the specimen next to Gich, the contrast is high especially during the sunset; it could even happen that the sun at some point could shine right through the window though, we have no proof for that event to chance. The vertical development of the entire edifice is metric and space structuration is weak
Aesthetic value	**High (the natural arch below Bwahit is less aesthetic)**
Cultural value	
Religious importance	In the indigenes' culture the natural arches are interpreted as a sign of the Satan who has broken to the hole, thus the hill north of Gich camp is named "Kedadit" by the Amharic term corresponding to this event.
Cultural value	**Very high**

Use and management characteristics

Protection of the site	
Protection status	The site is located inside the national park boundaries and therefore under protection.
Damages and threats	None.

Promotion of the site	
Visit conditions	
Accessibility	The car-drive up to Bwahit takes about 3 to 4 hours from Debark. The specimen next to Bwahit is accessible by foot within 10 minutes from the public road. There is no path; it is necessary to walk in the high grass of the afro-alpine meadow. Gich is approached by car until Anyameda camp or Jinbar waterfall from where it has to be continued by 2-4 hours trekking on a safe and frequently used trail. From Gich camp Kedadit can be visited within 15 minutes, no path is visible; the grass however is short as the land is used for grazing.
Security	No risk.
Site context	Kedadit is a place of natural beauty offering great calm and spectacular scenery. The natural arch at Bwahit is a hidden and silent place.
Touristic infrastructure	Very basic touristic infrastructure is available at Gich camp and at Chennek but not in proximity of Bwahit.
Visit conditions	**Kedadit offers reasonable visit conditions with a campsite in proximity, good access and outstanding site context. The specimen at Bwahit is less attractive for tourism in all sense except that it is accessible directly from the road without trekking.**
Education	
Education interest	The site (both specimens) is fascinating but does not particularly well illustrate a specific geomorphological process.
Interpretation facilities	No interpretation facilities.
Educational interest	**Low**

Synthesis

Global intrinsic value

The scientific value is high. The strong points are the great rarity and the high integrity. On the other hand the paleogeographical interest is rather low. The aesthetic and cultural values are also quite high so that the global intrinsic value is high.

Use and management

The conservation of the site is guaranteed even if explicit protection of the site is lacking. The visit conditions are quite attractive but the educational interest of the site to illustrate geomorphological processes for the broad public is rather low.

Management measures and proposals

Natural arches are vulnerable sites, which could be easily destroyed if not appropriately protected. It is not recommended to organise visits to the specimen at Bwahit; it should remain unknown and its high integrity conserved. Even if Kedadit is visited frequently no direct human contact will risk damaging the site as it is too exposed in the wall of the escarpment. The site is visited by most trekking tourists and a special geo-trekking should also not miss the obligatory evening walk to Kedadit to experience the "magical" power of this geoheritage. Scientific knowledge could be added but it is this spiritual experience that we think should be paramount to enhance and diversify the visitor experience of this location. In a guide book on the geoheritage the religious and scientific explanation of the morphogenesis could face one other.

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Hurni, H (1982). *Klimatische und geomorphologische Studien im Hochgebirge von Semien - Aethiopien* (Ph.D. thesis). Bern: Geographica Bernensia, G13.

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Author

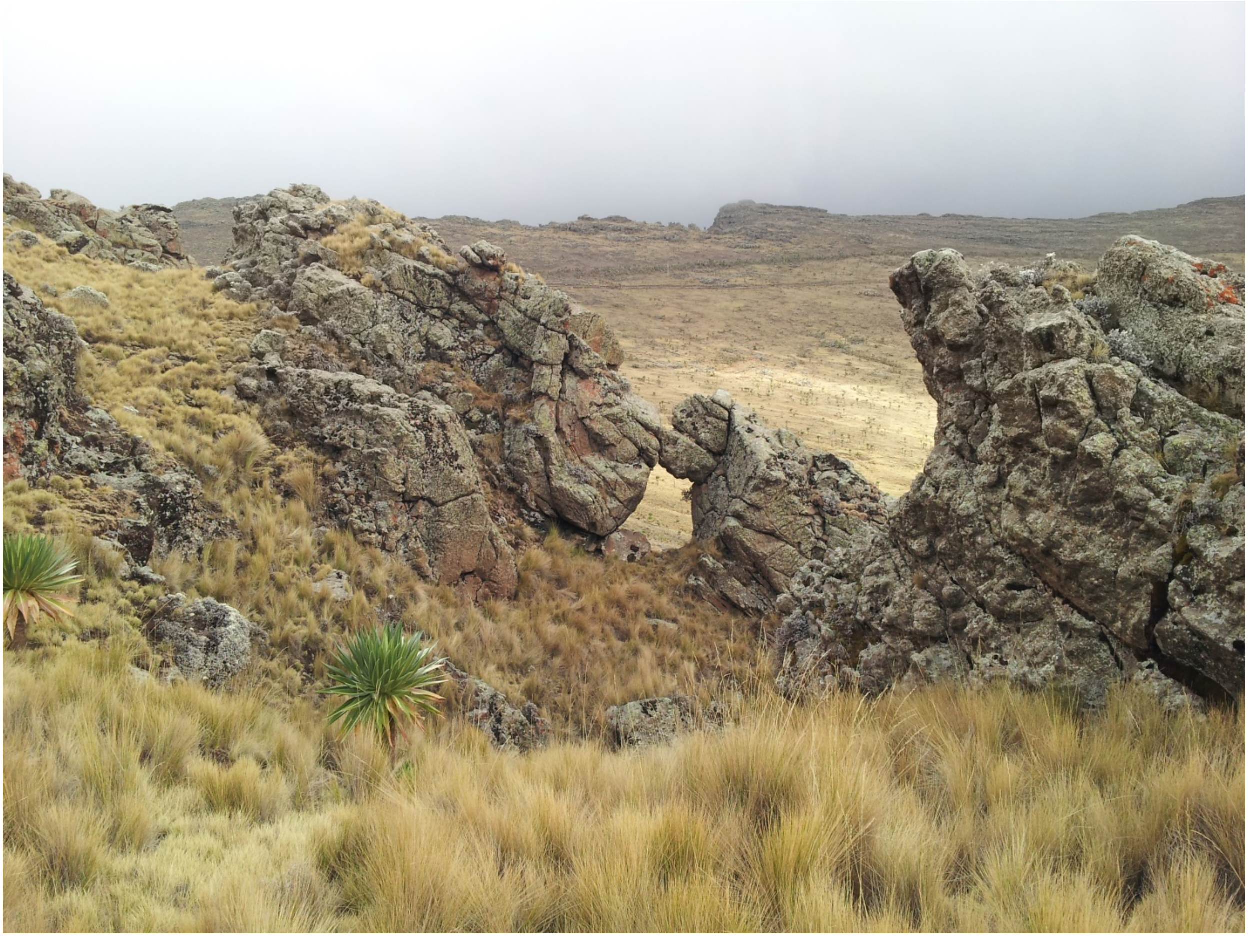
L. Mauerhofer (2016)

Annexe(s)

1. Natural arch on the southern side of Bwahit (4150 m), view from below the hole
2. Natural arch on the southern side of Bwahit (4150 m), view from above the hole
3. Natural arch at Kedadit (3710 m), view from Kedadit viewpoint

Annexe 1: Natural arch on the southern side of Bwahit (4150 m), view from below the hole

Annexe 2: Natural arch on the southern side of Bwahit (4150 m), view from above the hole

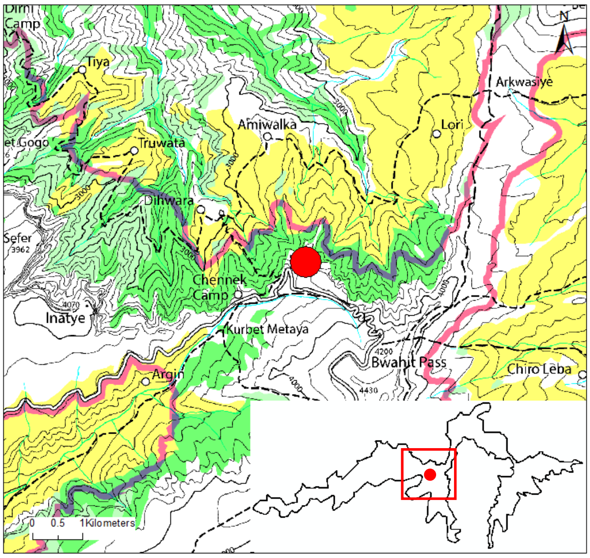


Annexe 3: Natural arch at Kedadit (3710 m), view from Kedadit viewpoint

Chennek Medhanealem cave (Church)

SMNP

Short description: The Chennek Medhanealem cave is a sacred site next to the escarpment below Bwahit. The entrance hall has a pool with still fresh water covered with algae. The cave is scientifically unexplored, its total extension is not known but it appears to prolong as a very long tunnel corridor (or network). In Simen, on volcanic underground such cavities could be lava tubes, which are formed below crusted surfaces when the supply of lava at the vent has ceased and the last slug of lava may have drained downslope leaving an empty conduit.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.

Coordinates: **N 13°16'3.28"/ E 38°12'12.23"**	Altitude: **3810 m**	Type: **PCT**	Volume: **unknown**

Property status: **PUB** Characteristics: **natural, active**

Description

When walking from Chennek camp 20 min uphill following the main road to Bwahit there is only several meters before the 1000 meters deep scarp of the Northern Escarpment the entrance to the **Chennek Medhanealem cave** or Church. The sacred place is inhabited by Ethiopian Orthodox priests and only accessible for people of the same religion. According to the park expert who entered the cave for us while we were waiting outside, the entrance hall is at least 40 m deep, 20 m wide and about 3 m high. However, behind the door where the priests actually live there must be a longer narrower corridor whose total length is unexplored and it seems that even the clergies never reached the end of the aisle. Numerous religious people were waiting the cave to enter, which is allowed only for one person at the time (cf. annex 1). The place is known as the *"holly water"* because of a pool with more or less stagnant, very pure and cold water covered by algae. Here someone can wash his body with fresh water to recover from a bad sickness. It is also possible to undergo a longer more difficult process to get rid of all the sins and therefore achieving that the body after death will actually stay fresh forever (won't decompose). However, the latter religious procedure is only possible for *"real Orthodox people"* who practise their religion every day by praying to God, going to Church and respecting strict fasting rules.

Morphogenesis

"The standard definition of a ***cave*** *is 'an underground opening large enough for human entry' (Oxford English Dictionary and others). As such, natural caves occur in most consolidated rocks or compacted sediments and in most geomorphic settings, created by a variety of processes* (Goudie, 2004 : 124). *"*As the cave at Chennek is scientifically completely unexplored, it is impossible to make clear statement of its morphogenesis but it is possible by process of elimination to make a suggestion of the dominant formation process.

It is possible to distinguish two types of caves, **karst caves** (where dissolution of comparatively soluble rocks, ex. limestone is the predominant trigger process) and **pseudokarst caves**. The volcanic lithology is not favourable for dissolution. Thus, the Chennek Medhanealem cave appears a pseudokarst cave created by **mechanical processes (**such as thermokarst collapse, frost riving, wave action, etc.) (Goudie, 2004 : 124).

"*The lengthiest pseudokarst caves are* ***lava tubes****, formed by channelled discharge of still-molten lava within consolidating flows; single tubes, dendritic networks and anastomosing mazes are known, some extending for 10km or more* (Goudie, 2004 : 611)." This formation process should be investigated in the volcanic morphology of Simen as the description above seems to be quite suitable for the occurrence of single or a network of lava tubes. "*[At the beginning of their morphogenesis], active lava flows radiate prodigious quantities of heat near the vent such that they rapidly form a surface crust. This can thicken sufficiently to insulate the core of the flow from thermal losses, lowering the rate of viscosity increase, and thereby promoting longer travel distance. Mafic flows quite often crust over completely, with lava continuing to flow in tunnels, which can grow in cross section by thermal erosion of the walls. When the supply of lava at the vent ceases, the last slug of lava may drain downslope leaving an empty conduit or lava tube* (Goudie, 2004 : 611)."

Intrinsic value

Central value		
Integrity	The cave is totally conserved.	1
Representativeness	Caves are not known as characteristic landforms of Simen but this exemplary is well illustrative of what is understood as a cave.	0.25
Rareness	There are some small cavities below rocky overhangs but without tunnel corridors. To our knowledge it is the only cave of this magnitude.	1
Paleogeographical interest	If the site could be confirmed to be a lava tube the paleogeographical value would rise to its highest level. As the site is unexplored much uncertainty exists regarding the scientific value of this site. As a precaution it is attributed a rather high value as the site might incorporate significant information about the history of earth.	0.75
Scientific value	**High**	**0.75**

Additional values	
Ecological value	
Ecological impact	Inside the cave there is only very sparse vegetation, especially algae in the pool.
Ecological value	**Very low to null**
Aesthetic value	
View points	Regarding the problematic of the evaluation of the sub-criteria "*view points*" in underground contexts, A. Perret and E. Reynard (2011) suggest to attribute high scores to cavities *« présentant de vastes volumes (salles, puits, galeries) et des possibilités de points de vues multiples (carrefours, lucarnes) ».* From this point of view the volume of the Chennek Medhanealem cave offers several possibilities for observation.
Contrast, vertical development and space structuration	The power of the green and clear colours of the water in contrast to the dark wall of the cave is quite impressive and the apparently long tunnel complex implicates a certain structuration of the underground.
Aesthetic value	**Average to high.**
Cultural value	
Religious importance	The cave is an important spiritual location of the local community.
Cultural value	**Very high**

Use and management characteristics

Protection of the site	
Protection status	The site is located inside the national park boundaries and therefore under protection. Moreover it is a religious site, which is protected by local people and clergy against impact from tourism.
Damages and threats	None.

Promotion of the site	
Visit conditions	
Accessibility	Chennek is accessible from Debark within 2-3 hours by car. From the campsite it takes a 30-minute walk on trails or along the road to reach the cave. There is no particular walking difficulty. It is not allowed to enter the cave for non-Ethiopian orthodox people.
Security	No risk.
Site context	The location is reserved for local orthodox people.
Touristic infrastructure	Very basic touristic infrastructure at Chennek camp.
Visit conditions	**As it is a local spiritual site, it is not favourable for touristic visits.**
Education	
Education interest	For the moment more scientific knowledge about the formation of the cave is needed before this site could be used for educational purpose.
Interpretation facilities	No interpretation facilities.
Educational interest	**Low**

Synthesis

Global intrinsic value

The central value is characterised by a high integrity and great rareness of the feature even though the site is not very representative of the region's geomorphology. Moreover, it is the spiritual importance value of the site thus the cultural value which has to be highlighted. Overall the intrinsic value is quite high.

Use and management

The Chennek Medhanealem is used by orthodox clerics as their home and it is a religious site for local people. The site is in good conservation condition but touristic visits are not allowed and the educational interest is low.

Management measures and proposals

The local spiritual meaning should be respected, thus it is not recommended to use this site for touristic visits nor promote it for geotourism *in situ*, as this would unnecessary arouse interest. Perhaps Ethiopian orthodox visitor could lead to this site if the clerics welcome this. But it could be interesting to make research on the extent and origin of the cave if the clerics agree. Enhancing protection is not necessary if the use of the site is not going to change.

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Annexe(s)

1. Pictures of Chennek Medhanealem cave (Church)

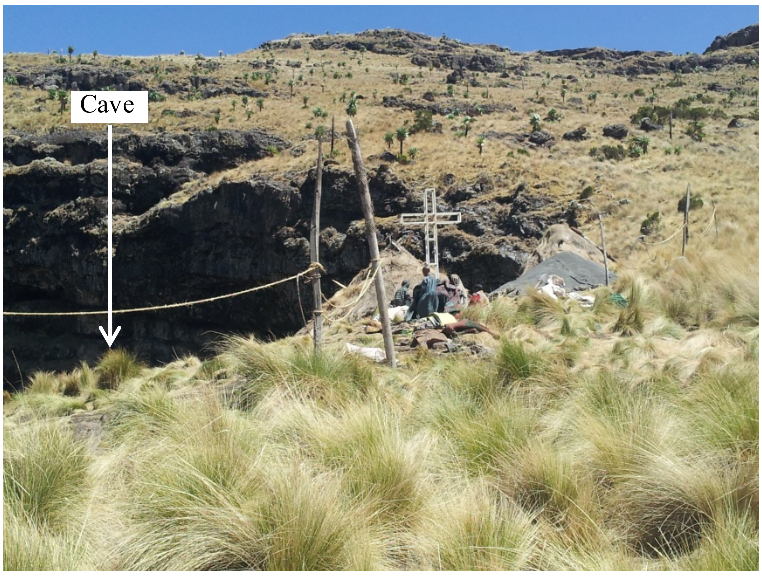
Annexe 1: Pictures of Chennek Medhanealem cave (Church)

Left: Entrance with religious tools hanging on a cordon (photo taken by Belayneh Abebe)

Left: "Holly water", pure, cool water covered by algae (photo taken by Belayneh Abebe)

Left: Entrance seen from inside the cave (photo taken by Belayneh Abebe)

Left: Path close to the escarpment leading to the cave (photo taken by Belayneh Abebe)



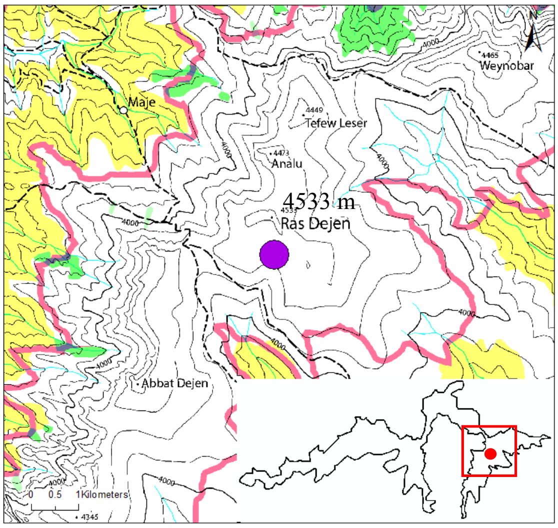
Left: Religious people visiting the sacred place

DEJgla020

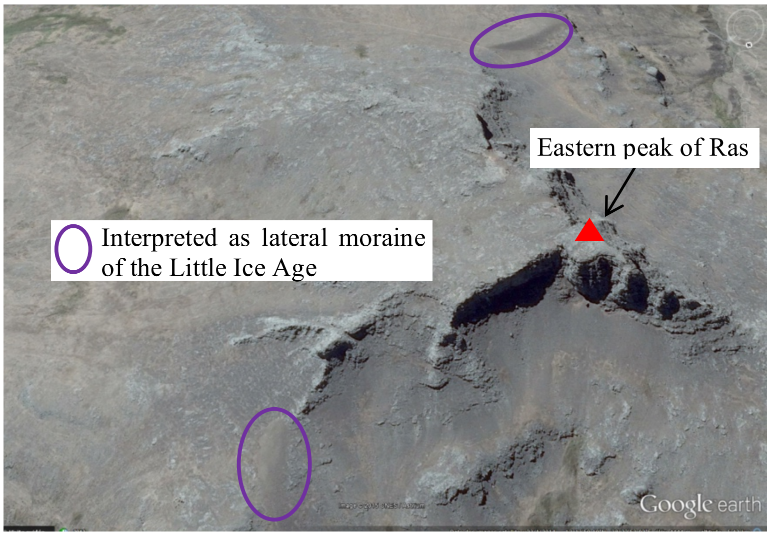
Moraines of the Little Ice Age at Ras Dejen

Beyeda (Abare and Beyeda Matriba)

Short description: On the Ras Dejen NE and SE flank two small debris accumulations may be interpreted as moraine of the Little Ice Age (LIA) (Grab, 2001). The LIA corresponds to a colder climatic phase between 14th and the middle of the 19th century with progressing glaciers in some northern mountain areas such as the Alps. The author of this inventory does not see clear evidence of glacial deposits of the LIA from his study. But the possibility of permanent snow caps during the LIA especially on Ras Dejen should be possible.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.



Coordinates: **N 13°13'27.19" / E 38°22'36.53"**	Altitude: **4355 to 4365 m**	Type: **LIN**	Surface: **180 m**

Property status: **PUB**

Characteristics: **natural, inherited**

Description

At ~ 4360 m on the NE of Ras Dejen accumulations of relatively fresh and unvegetated ~5 m high debris has been interpreted as moraine of the **Little Ice Age** (Grab, 2001 : 72) (annex 1 and 2). The author of this inventory could not visit the site himself (we found the article of Grab (2001) after the fieldwork). But Grab's cartography remains very unclear to us as he seems to indicate unvegetated moraine also on the NE slope of Analu instead on Ras Dejen. Thus, we wonder whether he did not a mix-up this with Last Cold Period moraine (cf. sheet nr. 21). In fact, two prominent frontal moraine crests are found on that slope. They are lithely overgrown with vegetation and in the middle there is a moor, which in this case would not match the descriptions. But we also found two debris accumulations (annex 1) which correspond well to the description by Grab (2001) of relatively fresh, unvegetated debris, situated at the altitude of approximatively 4360 m. At least one of these accumulations is also located on the NE flank of Ras Dejen. H. Hurni who crossed the site that we located on the SE flank of Ras Dejen considers "*it is very unlikely that this has some thing to do with a LIA moraine accumulation, although there might have been perennial snow on Ras Dejen. The area is too low; there is no accumulation crest above, and there are no other similar signs at this altitude (email exchange).* He actually thinks that for both accumulations indicated on the image below (annex 2).

Morphogenesis

Generally, it is known that "*the climate became colder from about 3,000 BP, starting the increase of glaciers in high mountain areas of the world (NEOGLACIATION), with a culmination in the period between the thirteenth century and about 1750 in Europe (e.g. Nesje et al. 2000), or about a hundred years later [(ex. 1850 in the Alps)] in some regions of the world. This period is known as the Little Ice Age. Since then deglaciation has prevailed until recent times in most glacial environments of the world* (Goudie, 2004 : 234)." Even though H. Hurni clearly negates the possibility of fluctuation of the **snowline** below the highest summit of Simen in historical times, S. Grab (2001 : 1) states that "g*iven the glacial advances elsewhere in east Africa during the Little Ice Age (e.g. Hamilton, 1982; Mahaney, 1989), it is possible that small pockets of glacial ice last occurred on such Simen Mountain slopes during this time. Several historical reports dating to 1624–1627 mention* ***permanent snow caps*** *on the Dashen Range, with the last perennial snow patches apparently dis-appearing by the early 1900s (Miehe and Miehe, 1994).*" "*[Nowadays,] although the Simen Mountains experience occasional snowfalls above 4000 m ASL, the snow usually thaws within two days* (Grab, 2001 : 1)."

Intrinsic value

Central value		
Integrity	Good conservation.	1
Representativeness	These are very small glacial deposits compared to the up to 50 meters high moraines of the last cold period in Simen.	0.25
Rareness	They are the only glacial deposits in Simen, which may date from the Little Ice Age	1
Paleogeographical interest	Their paleogeographical interest is little explored; if other researchers with scientific methods can confirm their occurrence this score should be upgraded at the highest level.	0.75
Scientific value	**High**	**0.75**

Additional values	
Ecological value	
Ecological impact	No ecological impact.
Ecological value	**Very low to null**
Aesthetic value	
View points	The forms are too small to be observed from distance.
Contrast, vertical development and space structuration	The contrast is very weak that is also why the forms are rather difficult to identify; their vertical development is not more than 5 meters.
Aesthetic value	**Low**
Cultural value	
Cultural value	**Very low to null**

Use and management characteristics

Protection of the site	
Protection status	The site is located inside the national park boundaries and therefore under protection.
Damages and threats	No damages but the Dejen area could receive more visitors in the nearer future and with that the small and unremarkable site might be at risk.

Promotion of the site	
Visit conditions	
Accessibility	Best accessible from Ras Dejen pass, which is reached from Debark within half a day car-drive. From the pass the moraines can be reached within 20 to 40 min walk on a relatively flat trail below the summit leading to the eastern site of Dejen.
Security	No risk.
Site context	Quite unspoiled area with calm.
Touristic infrastructure	No touristic infrastructure in this region except for the road access to Ras Dejen.
Visit conditions	**There are no touristic infrastructures in proximity but except for that the visit conditions are all right with access from Debark within half a day.**
Education	
Education interest	This site has to be researched in detail before it could be used for education.
Interpretation facilities	No interpretation facilities.
Educational interest	**Low**

Synthesis

Global intrinsic value

The strengths of this site are the perfect integrity and high rareness as well as the quite significant paleogeographical interest. The additional values are very poor, however. This combination gives a rather average global intrinsic value.

Use and management

The site is quite easy accessible but the educational interest is low. There is no immediate need for protection measures as the site is in a rather unspoiled area situated inside the national park.

Management measures and proposals

The hypothesis that small permanent snow patches really occurred on Ras Dejen during the Little Ice Age has to be better researched before it could be used for geoheritage popularisation. No protection measures are advised for the moment but more attention should be given to the site in general.

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Miehe S, Miehe G. 1994. *Ericaceous Forests and Heathlands in the Bale Mountains of South Ethiopia*. Stiftung Walderhaltung in Afrika: Hamburg.

Nesje, A., Dahl, S.O., Andersson, C. & Matthews, J.A. (2000) The lacustrine sedimentary sequence in Sygneskardvatnet, western Norway: a continuous, high-resolution record of the Jostedalsbreen ice cap during the Holocene, *Quaternary Science Reviews* 19, 1,047–1,065.

Author

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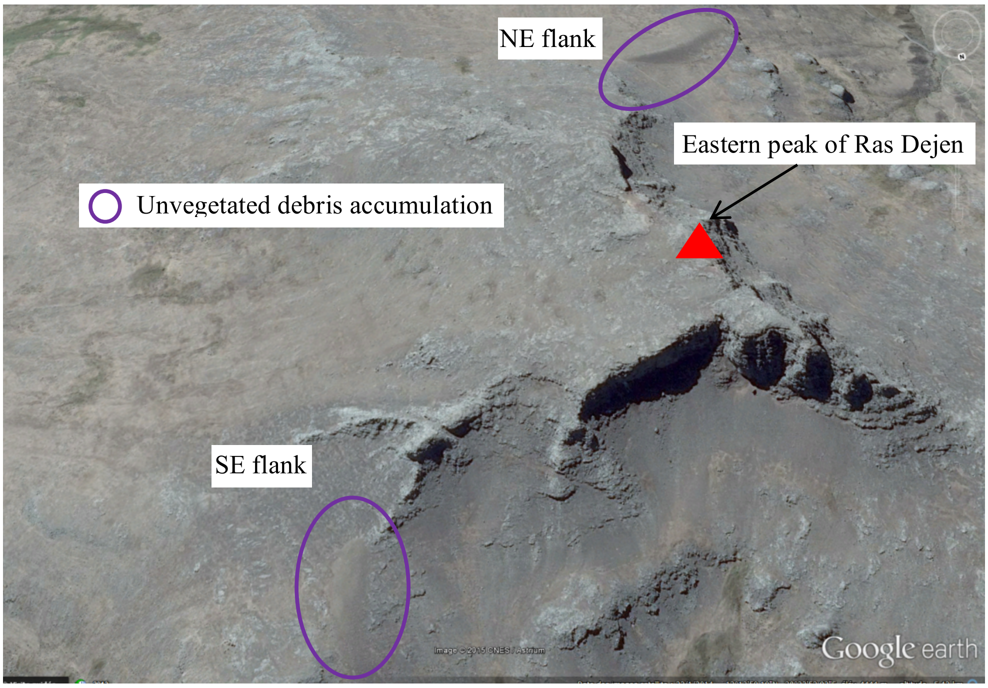
Annexe(s)

1. Small unvegetated debris accumulations at 4360 below the Eastern Ras Dejen peak corresponding to the description of Little Ice Age moraine by Grab (2001)
2. Mapping of two unvegetated debris accumulations interpreted by Grab (2001) as LIA moraine

Annex 1: Small unvegetated debris accumulations at 4455-4475 m below the Eastern Ras Dejen peak corresponding to the description of Little Ice Age moraine by Grab (2001)



Comment: Hurni (email exchange) crossed the site in the lower part *on* the photography (SE flank) in April 2013. We are rather convinced by his consideration that the two debris accumulations look more like lateral moraines of the Last Cold Period than that this had something to do with LIA moraines.

Annex 2: Mapping of two unvegetated debris accumulations interpreted by Grab (2001) as LIA moraine

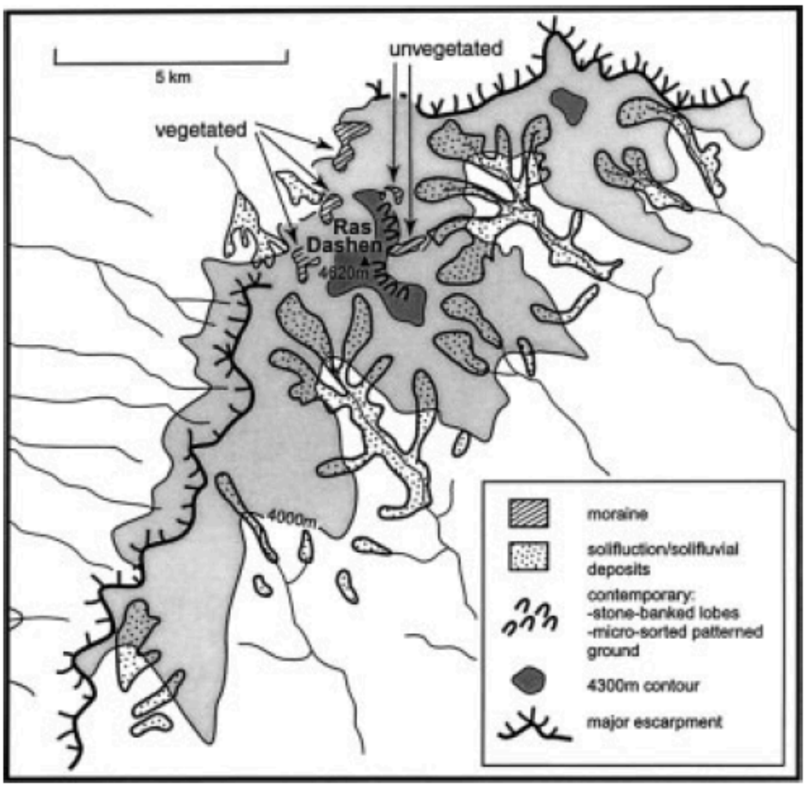


Figure 5 Distribution of periglacial features in the Simen Mountains—Ras Dashen Range (modified after Hurni, 1982, with permission).

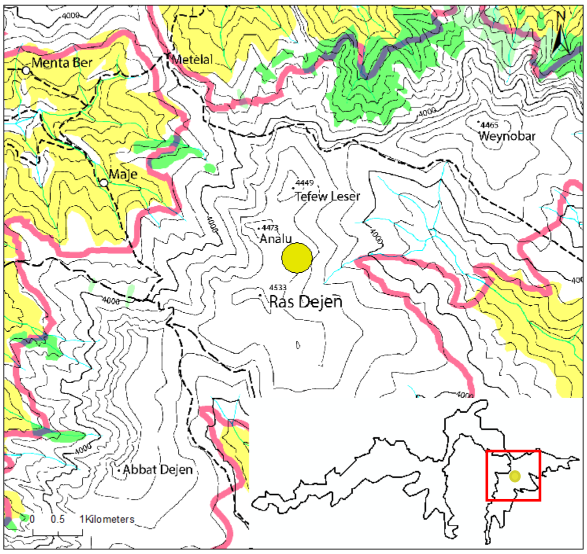
"Given the glacial advances elsewhere in east Africa during the Little Ice Age (e.g. Hamilton, 1982; Mahaney, 1989), it is possible that small pockets of glacial ice last occurred [on specific Simen Mountains slopes] during this time. Several historical reports dating to 1624–1627 mention permanent snow caps on the Dashen Range, with the last perennial snow patches apparently disappearing by the early 1900s (Miehe and Miehe, 1994 In Grab, 2001).

Comment: wrong transliteration of Ras Dejen

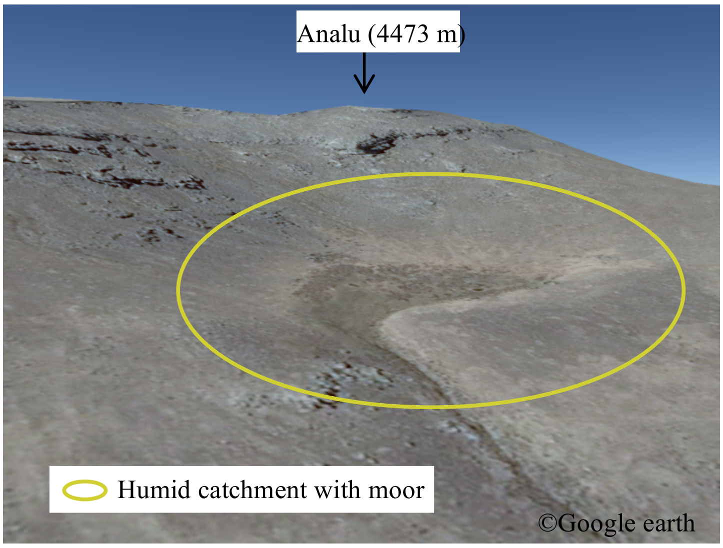
Vegetation-derived accumulation on Weynobar and Analu

Beyeda (Beyeda Matriba, Selewa)

Short description: A well represented moor and mounds of organic material resembling to small-shaped hummocks (or thufurs) are observed on Weynobar and Analu. These landforms are preconditioned by the humid and cold climate with regular freeze-thaw cycles. Cryoturbation as well as cryogenic swelling seem to play a major role in the formation of the mounds whereas the moor is triggered by a humid catchment covered with last cold period glacial deposits.



Lukas Mauerhofer, 2015. Base map: Centre for Development and Environment, Universitiy of Bern, 2010.



Coordinates**: N 13°15'26.06" / E 38°24'47.22"**	Altitude: **4250 m** to **4330 m**	Type: **AER**	Surface: **20 ha**

Property status: **PUB**

Characteristics: **natural, active**

Description

Mounds of organic material (peat) resembling to small-shaped **hummocks** (thufur, Islandic name) with dimensions of tens of cm, covered with moos occur at Weynobar on the SW slope at ~ 4300 m. Whereas below Analu at 4300 m on the NE slope is observed one of the largest **moors** triggered by the humid catchments dammed by relict frontal moraine (cf. annex 3), for instance also found on Bwahit (Hurni, 1982) (cf. sheet nr. 7).

Morphogenesis

Hummocks are known from subpolar regions although similar forms have been observed in the mountains of Southern Africa (Hastenrath, 1984). Their formation is caused by movements of **cryoturbation** (corresponding to soil circulation within each feature, driven by moisture redistribution during freezing and thawing) and cryogenic swelling in organic materials (peat) and silt (Goudie, 2004). In the cold and humid environment of Simen similar processes leading to the same phenomenon on the highest peaks would be possible. Mainly organic processes are also at the origin of moors found in humid catchments of relict moraines such as on Analu. Unfortunately, our camera was without battery the day we visited Weynobar thus annex 1 presents a wetland found on the terrace-plateau at 3800 m on the northern site below Silki along the old Eastern Trade Route with rhizomes of the Giant Lobelia maybe affected by cryoturbation also forming small mounds. However, unlike the forms at Weynobar, these mounds do much less resemble to hummocks.

Intrinsic value

Central value		
Integrity	Good conservation.	1
Representativeness	Moors and wetlands are rather untypical geomorphological features though the organic process is observed in the high regions on all three mountain ranges of Simen. The specimen on Weynobar respectively Analu is probably the most illustrative example of these landforms.	0.5
Rareness	Mounds like hummocks were not found elsewhere and the moor at Analu is quite unique in size and exemplarity.	1
Paleogeographical interest	In February 1976 a pit was dug into the moor down to its base, and an organic sample for 14C analysis taken from the base of the pit. The results showed a too low age of 2946 BP of the oldest organic horizon in the moor, thus the last cold period could not be dated with absolute methods but the evidence shows that no glaciation took place in historical time (Hurni, 1982).	0.5
Scientific value	**High**	**0.81**

Additional values	
Ecological value	
Ecological impact	Highland swamps, a key feature of the Afroalpine grasslands support a number of resident and migratory water bird populations (FZS – ADC, 2009).
Ecological value	**Very high**
Aesthetic value	
View points	The mounds are too small to be observed from distance. The moor could be observed from the top of Analu.
Contrast, vertical development and space structuration	Because of the stronger vegetation growth in relation with the geomorphological context the contrast of this site is rather high. The vertical development is very low and there is no significance of space structuration.
Aesthetic value	**Average to low**
Cultural value	
Cultural value	**Very low to null**

Use and management characteristics

Protection of the site	
Protection status	The site is located inside the national park boundaries and therefore under protection.
Damages and threats	None.

Promotion of the site	
Visit conditions	
Accessibility	Weynobar is one of the most remote summit areas in Simen. It is probably most easily accessible via Ras Dejen pass. A car drive from Debark to Ras Dejen takes about half a day thus it is advisable to camp somewhere in the Mesheha valley or on the pass and to hike several hours to Weynobar the next day. There are some trails but the path has to be searched well if not to lose it. We achieved Weynobar from Metelal pass so we never used this path over the Beyeda high plateau, on the Google earth image it seems safe with some light up and down. The moor below Analu lays half way on the path to Weynobar.
Security	No risk.
Site context	Very natural and calm environment.
Touristic infrastructure	No touristic infrastructure in this region except for the road access to Ras Dejen.
Visit conditions	**Difficult visit conditions as the site is in a remote area without accommodation and infrastructure.**
Education	
Education interest	The site is illustrative enough to show non-specialist visitor the relation between the glacial deposits and the formation of the moor. The mounds like hummocks could be interesting for scholars in the domain of geomorphology and to experts.
Interpretation facilities	No interpretation facilities.
Educational interest	**Rather high**

Synthesis

Global intrinsic value

The high central value is characterised by the perfect integrity and great rareness. Moreover the site has a high ecological value. Globally the intrinsic value is rather high.

Use and management

There is currently no pressure on this site. The visit conditions are difficult but the educational value of the site is rather high.

Management measures and proposals

As the area is remote and difficult to access, it is not recommended to promote this site for trekking and geotourism *in situ* except perhaps for special excursion with geomorphology scholars. The Weynobar-Analu region should remain in its unspoiled natural state and more research on the hummocks would be needed before popularisation. Good photographs or a video of the moor at Analu would help for the establishment of *ex situ* interpretation facilities.

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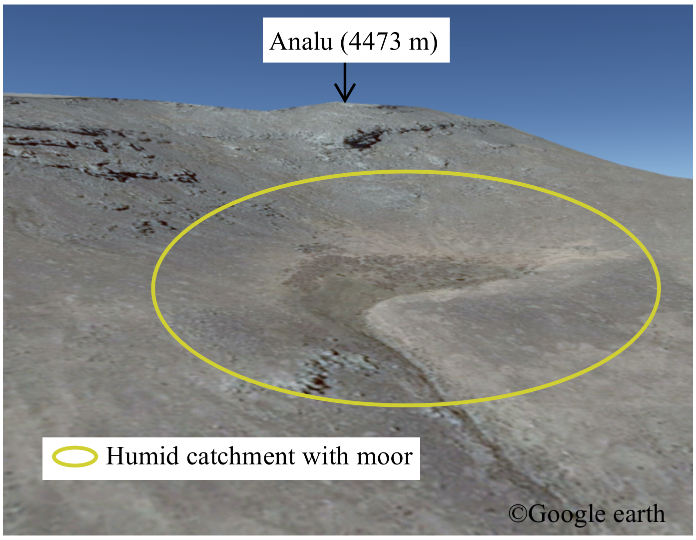
Annexe(s)

1. Mounds of Giant Lobelia rhizomes maybe affected by cryoturbation
2. Moor on Analu

Annexe 1: Mounds of Giant Lobelia rhizomes maybe affected by cryoturbation

Left: Wetland along the old Eastern Trade Route on a terrace-plateau at 3800 m below Silki with rhizomes of the Giant Lobelia probably affected by cryoturbation forming small mounds.

Annexe 2: Moor on Analu



Left: Moor in a humid catchment of relict frontal moraine on the Analu NE aspect at 4300 m.