Mires and Man

Mire conservation in a Densely Populated Country – the Swiss Experience

WSL FNP

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Mire Conservation in a Densely Populated Country – the Swiss Experience

Excursion Guide and Symposium Proceedings of the 5th Field Symposium of the International Mire Conservation Group (IMCG) to Switzerland 1992

Edited by Andreas Grünig

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Front cover

Autumnal view of a Swiss raised bog of "particular beauty and national importance", but also a testimony to the conflicting relationship between Mires and Man. The effects of peat extraction epitomize the whole problem of mire conservation in a densely populated country.

The peat cutting faces in the middle of the picture remind us that bogs once provided fuel. As a result of subsequent drainage effects, the peat has shrunk in the immediate vicinity of the cutting face. The cut away areas are now used as hay meadows or have been abandoned altogether. In the pit, patches of bottle sedge *(Carex rostrata)* indicate areas of mire regeneration. The remaining bog surface shows the characteristic features of a drained site (with a more unstable water table). Due to a slight lowering of the bog water level, the growth of bog mosses (*Sphagnum* spp.) is restricted and the area in the foreground to the right is dominated instead by the golden-coloured tussocks of deergrass *(Scirpus cespitosus)*. The surface immediately above the peat cutting face is even drier, favouring 'hummock plants' other than Sphagna, such as Bank's hair moss *(Polytrichum strictum)* and dwarf shrubs (*Calluna vulgaris* and *Vaccinium* spp.). Note also the better growth of the existing mountain pine trees *(Pinus mugo)* and the encroachment of young pines and birches *(Betula pubescens)*.
Photo by E. Schneider (taken in a raised bog in the Vallée de la Brévine in the Jura Mountains).

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Foreword

This volume presents an exhaustive view of mire conservation in Switzerland. In 1992 the International Mire Conservation Group held its traditional biannual excursion in Switzerland. Following this, Andreas Grünig and his group intended to publish their voluminous excursion guide. It was also decided to include the contributions to the accompanying symposia. With a sound introduction covering the history of mire conservation in Switzerland, a broad presentation of the country itself and numerous appendices added to the original articles, the volume eventually evolved into a state-of-the-art presentation of mire conservation in a densely populated country.

The reader will quickly recognize that the year 1978 marked the beginning of a dramatic period for mire conservation in Switzerland. In that year the decision was made to undertake an inventory of all peat bogs. We may have reached the culminating point right now. As we have all been busy with conservation related activities over the past fifteen years, we have not always been aware of this. The present volume helps us to see the results of our activities in a broader perspective. Not only does it present the specific situation in Switzerland, but it also outlines the relations to other countries in the Northern hemisphere. Mire conservation has become a global problem. As this book is written in English, we hope that this presentation, which also illuminates the scientific, historical, sociological, political and legal backgrounds, will find an interested readership all over the world.

Otto Wildi

The International Mire Conservation Group: Profile, aims and activities

The International Mire Conservation Group (IMCG) is an international organization of peatland (mire) specialists who have a particular interest in the conservation of peatland habitats.

Peatland soils cover some 5% to 8% of the world's land surface but, because peat formation is generally closely linked to climate, much of the world resource lies in the Northern temperate zone. This concentration of peat in some of the most industrialized countries of the world has meant that, since the 16th century, vast tracts of peat landscape have vanished throughout Europe. In many cases these changes undoubtedly helped to transform the economies of certain regions and even, occasionally, whole nations. However, the environmental cost of this progress now means that some Western nations can point to a date in the near future when, without direct conservation effort, the very last natural peat bog will have vanished forever. For others it is too late; all natural bogs in the Netherlands have already been lost; the raised bogs of Ireland (outside protected areas) may all be gone by 1997; in Switzerland only 500 ha of primary raised bog remain. Even in Canada, with total peat resources of some 130 million hectares, certain regions have already lost more than 90% of their mires.

Peatlands suffer from limited scientific understanding and, perhaps more importantly, a poor public perception of their true natural heritage and functional value. These factors compound and help to explain the scale of the losses. Against this backdrop, the need for an organization such as the International Mire Conservation Group was agreed upon by a number of international peatland specialists at a conference held in Finland in 1983.

The IMCG was subsequently established in 1984 at Klagenfurt, Austria with an initial membership of 10 nations. The Group now holds a field symposium in a different host nation every two years during which the particular problems of peatland conservation in the host country are seen first-hand, while members also have an opportunity to discuss their own, and broader, peatland conservation issues. The venue is usually decided on the basis of a request from a particular country which feels it has a significant mire conservation problem and would benefit from the collective experience of the IMCG.

Membership of the IMCG consists primarily of one or two representatives from each member nation, usually individuals who are responsible for, or most actively engaged with, official peatland conservation issues in their own country. However, the Group welcomes a wider membership. The only requirements are that members should be active in peatland conservation, and that total numbers at field symposia must, for practical reasons, be restricted.

The IMCG aims to:

- highlight the problems facing peatlands on a world-wide basis and to promote and support peatland conservation efforts;
- help policy makers at local, national and international levels to recognize that, where peatlands may be affected by their decisions, it is important to include peatland conservation principles within the decision-making process at all levels and at the earliest opportunity;

- stimulate the international exchange of ideas, information and experience among people working in the area of mire conservation and research;

- act as an expert group available to individuals or organizations requiring information or assistance on the topic of mire conservation;

- collate and maintain a regularly updated global audit of the peatland environment and associated peatland conservation programmes, as far as the data are available.

The IMCG has held a field symposium in a different host country every two years since Austria in 1984. The IMCG has initiated a number of on-going projects. The results of the IMCG Symposia and the various projects underway are outlined below.

Great Britain 1986

The IMCG Symposium to Scotland was stimulated by grave concern amongst IMCG members about the loss of Britain's blanket mires to rapid afforestation, particularly in the Flow Country of northern Scotland. The group visited a range of peatland areas throughout Scotland and was the first body to identify the internationally unique nature of Britain's blanket mires. The Symposium also helped to bring the international issue of the Flow Country to the attention of the public and politicians alike. As a result, the UK Government initiated conservation measures at a scale not previously attempted in Britain, thus partially resolving the problem. The Government has continued to support the development of a land-use strategy for the area. In addition, while they were in Scotland IMCG members identified a new mire type not previously described for Britain.

Sweden 1988

During this meeting the IMCG members were briefed on a range of peatland conservation issues including site evaluation techniques, site management, forestry drainage practices, peat mining and peatland inventory work. The IMCG urged the Swedish government to establish a mire conservation policy based on the results of the national wetland inventory. Additional funding to complete the wetland inventory for the whole country was also recommended. In particular, the IMCG encouraged the government to prevent further damage to mires from forestry protective ditching and from road construction. The Group identified the Blaikfjället area as an internationally important mire system and called for it to be designated as a national park. Blaikfjället is now fully protected, the inventory programme has received additional funding for completion, and ditching practices have been substantially altered where they might affect peatland areas.

Ireland 1990

The 4th formal meeting of the IMCG was held in the Republic of Ireland. The meeting was prompted by the rapid decline in the extent of Irish peatlands due to an intensification in development, and the threat of extinction of all unprotected raised bogs in the central Irish plain by 1997. The IMCG visited a range of mires throughout Ireland and examined problems on both protected and privately owned areas. Based on the experiences of the group members in their own countries, a series of recommendations were made, which, if implemented, will help to ensure the survival of Ireland's peatland resource. The core of these recommendations involved the establishment of a peatland task force to co-ordinate the sustainable development of protected mires and the provision of an adequate annual budget for mire conservation.

Following the mire study tour, a symposium was held in the Royal Irish Academy, Dublin, which aimed to highlight possible solutions to the problems which had been encountered during the Irish excursion (cf. Foss 1991).

Switzerland 1992

The 5th IMCG Field Symposium took place in Switzerland. The meeting was the largest so far and was attended by delegates from 18 countries world-wide, including representatives from Canada, Estonia, Germany (former GDR), Japan, Poland, Russia and USA. Midway through the IMCG field symposium there was a conference in Berne. As at every IMCG meeting, a series of resolutions concerning mire conservation were agreed upon, and these were passed on to the relevant authorities or national governments. The text of these formal IMCG Resolutions is included in Chapter 5 of this volume.

During this field symposium the IMCG members saw not only a range of mires growing at high altitudes (up to 2,300 m), but also the famous bog burst of La Vraconnaz in the Jura Mountains, the Grande Cariçaie Ramsar site along the shores of Lake of Neuchâtel and the large mire landscapes of central Switzerland. During the visit, IMCG saw the problems of mire conservation in a small, densely populated and federalist country which has already lost up to 90% of its natural peatland heritage. The delegates learnt that the conservation of the few remaining mires in Switzerland is making positive progress, but is now poised at a critical stage.

One of the most encouraging aspects of the peatland conservation campaign is that in 1987 the Swiss people voted in favour of an amendment to the Swiss Federal Constitution supporting strict protection of mires and mire landscapes of particular beauty and national importance. This was known as the Rothenthurm Referendum. This new legal basis required three inventories of raised bogs, fenlands and mire landscapes. These were completed between 1978 and 1991. The two mire habitat inventories identified 1,500 ha of raised bogs and 18,000 ha of fenlands of national importance. Following completion of the surveys each site has to be rated for its national importance. The regulations are then applied to the resulting list of sites classed as being of national importance. The legislation for the protection of raised bog sites was enacted in 1991. Subsequent legislation for the fenland sites will be enacted in 1994 only in part; the delay in protecting these sites is due to an increasing opposition by affected land users and some cantons.

The critical part of Swiss mire conservation involves the inventory of mire landscapes. A mire landscape is a larger area that is dominated by bogs and fens, but since the landscape in central Europe is usually created, designed and used by man, it can also include agricultural land, forests, houses, residential areas, roads and so on. The mire landscape survey revealed that 2.2% of the land surface of Switzerland or an area of 92,600 ha contained mire landscapes of national importance. The mires themselves, covering on average less than a quarter of the individual landscape area, are declared nature reserves. The surrounding areas should be strictly managed by the landowners, who will be compensated financially for adhering to the guidelines set out by the conservation agencies. This strict management is the source of most major objections to the proposal. Private landowners feel that they are being restricted too much and some cantons fear interference from the Confederation. There is much debate about the issue and, as a consequence, resistance to a sustainable mire conservation programme is increasing in both the Federal Parliament and the cantons.

Norway 1994

The 6th field symposium of the IMCG will be held in Norway in July 1994 with Trondheim as a starting and ending point for visits to 10 mire locations covering a wide range of mire types.

Organization

From 1992 to 1994 the IMCG has an elected Board of three people:
Chairman: Mr. Richard Lindsay
Secretary: Dr. Gert Michael Steiner
Treasurer: Dr. Gerry Doyle

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Projects being undertaken by the IMCG and project co-ordinators:

European Peatland Map: Dr. Gert Michael Steiner
Peatland Glossary: Mr. Richard Lindsay
Up-date of Council of Europe Peatland Review (Goodwillie 1980): Mr. Michael Löfroth

International Mire Conservation Group

Preface

Through many a dark and dreary vale
They passed, and many a region dolorous,
O'er many a frozen, many a fiery Alp,
Rocks, caves, lakes, fens, bogs, dens, and shades of death –
A universe of death, which God by curse
Created evil, for evil only good;
Where all life dies, death to lives, and Nature breeds,
Perverse, all monstrous, all prodigious things,
Abominable, inutterable, and worse
Than fables yet have feigned or fear conceived,
Gorgons, and Hydras, and Chimaeras dire.

Paradise Lost, II, 618–628; by John MILTON (1608–1674)

With these words, John Milton tells of the journey taken by fallen angels on their return from a satanic meeting. The Alps were inhospitable and in a sense divine. Only herdsmen and holy men dared to approach close to them, and even then with a measure of prudence. Surviving until modern times, this attitude had its reflection in other countries, but in Finland, Ireland or Estonia the "regions dolorous" were fen and bog, rather than fiery Alp. What, therefore, could be worse than a bog or a fen high up in the Alps? However, promoted by explorers, scientists, painters, poets, tourists and sportsmen, Switzerland has become steadily more famous since the 17th century for its natural heritage of dark mountains, green alps, white glaciers and blue lakes, together with its beautiful but cultural landscapes which were created, designed and traditionally used by man. Today, we find that Milton's "Paradise Lost" has become the "Playground of Europe". The "fiery Alp" may now launch a million travel brochures because of this changed perception of Nature, but the same cannot be said for wetlands, and bogs and fens in particular. However, today we try to preserve something of the inhospitality and divinity of the "Paradise Lost" in nature reserves and national parks. We want to understand nature in its pristine state.

Background

Originally Switzerland must have been something of a wetland paradise, with a wide variety of wetland types distributed throughout the country. The bogs and fens, which together covered more than 5% of the land area, first attracted attention in the early 18th century, when peat extraction began. From these early beginnings the rate and scale of change has steadily increased, with the result that Switzerland has lost up to 90% of its original mire area, particularly in the last few decades. This is one of the highest rates of loss in Europe. As a result, intact mire habitats with their natural assemblage of plants and animals have become one of the rarest and most endangered of Switzerland's natural habitats.

Ironically, rarity can be a great stimulus to action, especially as, at the same time, a greater understanding of the need for sustainable nature conservation measures generally was gaining ground among Swiss. Thus, in 1976, when the Swiss League for Nature Conservation (SLNC) had the opportunity to buy a piece of peatland within the mire area of Rothenthurm, the offer was considered seriously. However, obliged to ensure that limited resources were invested as efficiently as possible, those involved in the negotiations tried to establish the scientific and nature conservation value of this area of peatland. In consultation with Dr. Otto Wildi, then mire specialist at the Swiss Federal Institute of Forestry Research (SFIFR) in Birmensdorf, it quickly became evident that no systematic survey of Swiss mires, especially raised bogs, had been carried out since the classic publication by FRÜH and SCHRÖTER in 1904. As the picture had undoubtedly changed considerably since this first survey, a sound evaluation of the present-day nature conservation value of the piece of land under consideration was impossible.

In 1977 it was therefore decided that a budget of Sfr. 50,000 should be raised to cover the cost of an inventory of raised bogs in Switzerland, the work to be co-ordinated by a single individual. This decision became the impetus for what was to become KOSMOS, [Koordinationsstelle für Moorschutz], the Swiss Coordination Centre for Mire Conservation. It was based in Birmensdorf at the SFIFR, but was privately financed by the Swiss League for Nature Conservation (SLNC) and by the World Wide Fund for Nature (WWF) Switzerland which in their turn were partly subsidized for doing so by the Federal Office of Environment, Forests and Landscape, Berne. In autumn 1990, after the Rothenthurm Referendum, the former KOSMOS was fully integrated within the new Federal Institute for Forest, Snow and Landscape Research (WSL/FNP*), with official status and a new name, the Advisory Service for Mire Conservation.

In the early 1980s, "Paradise Lost" was again threatened with losing a part of its last prominent mire landscapes. This time, the Swiss army planned to establish a military training ground at Rothenthurm. The threat gave the impetus to voluntary nature conservation organizations and local opponents to the Rothenthurm army project to launch a "Popular Initiative" about mire conservation. For such an initiative to be successfully brought to a vote it is necessary to obtain the signed support of at least 100,000 voters. Having achieved this, the proposal became known as the Rothenthurm Initiative which then asked the Swiss to express their views in a national referendum (cf. Chapters 1.2.6 and 6.4).

To the considerable surprise of the political and military establishment, on 6 December 1987 the Swiss sovereign (the electorate) voted in favour of an amendment to the Federal Constitution, supporting the integrated conservation of mires and mire landscapes. As a result of that decision, the Swiss legislation now states that: "Mires and mire landscapes of particular beauty and national importance are protected areas ...". In an interim disposition to the Constitution, this protection was made retroactive to 1983 when the referendum was launched. This means that any damage caused to mire systems since 1 June 1983 must be halted and repaired at the developer's expense (cf. Chapter 6.1). Revised legislation for the conservation of Swiss nature in general became effective on 1 February 1988 (cf. Chapter 6.2). Theoretically the mires of Switzerland should now enjoy protection from a set of laws for mire protection which are some of the most advanced in Europe. Is this therefore "Paradise Regained", and if so, what does Paradise look like?

Perhaps not surprisingly, land use pressures on mires and mire landscapes in Switzerland have continued to increase during the last decade despite all this progress. For example, more than half of the 500 raised bog sites designated as being of national importance have been damaged in some way during this period. This picture contradicts the evident legal intention as well as Switzerland's ratification of the Berne Convention. What has gone wrong with this earthly Paradise?

At its 4th Field Symposium in the Republic of Ireland in 1990, the International Mire Conservation Group (IMCG) learned of the considerable legislative progress made in protecting Switzerland's mires, but also of the serious condition of many important sites. As a consequence, the IMCG agreed to hold its 1992 Field Symposium in Switzerland to see for itself the problems, conflicts and solutions associated with the conservation of mires and mire landscapes in a mountainous yet densely populated country. It also hoped to learn about the various threats to mire habitats, and to raise the whole issue of implementation programmes for mire conservation legislation. The Group also sought to understand how land-use conflicts had been resolved by negotiation and agreement, and how positive management arising from such agreements can assist in the process of rehabilitation in the case of damaged peatlands.

* In 1989 the SFIFR became WSL/FNP with a much wider research mandate.

In the course of the 5th IMCG Field Symposium to Switzerland, 40 delegates from 18 countries were struck immediately by both the diversity and beauty of the Swiss mire systems. It was evident that the country has a particularly important part to play in conserving some of Europe's most extreme high-altitude mire systems. IMCG members also learned of the difficulties associated with the implementation of the Rothenthurm amendment to the Constitution, with particular problems linked to the conservation of fenlands and mire landscapes.

By chance, around the time of the IMCG visit and a month before the official end of the consultation phase for the proposed Federal Decree on the protection of mire landscapes, the political debate on the issue reached its climax. Press coverage of the issue throughout the country was such that 300 to 400 newspaper articles were appearing each month. IMCG members were dismayed, because of the implications, to discover that in the last few months the most common objections to the consultation proposals were that, firstly, the sites were too large, and that secondly, the proposals were too restrictive in their interpretation of the Constitutional Amendment. The lesson to be learned was of considerable value to all IMCG members.

Structure of this volume

This volume is divided into various sections. The first includes an introduction to Switzerland, its topographical features, its historical development and a description of the country's main habitats and land uses.

The second section considers the legal details of mire conservation in Switzerland, together with the findings of the various national inventories for mire habitats and mire landscapes. Particular attention is devoted to the programme for the mire landscape inventory. The section ends with three papers about the Swiss Landscape Database and the method of its development and its options to support and promote nature conservation, particularly as a distributed information system.

In the third part, descriptions for each of the sites visited by the IMCG are provided and some of the most valuable mires and mire landscapes for nature conservation in Switzerland introduced. The individual site descriptions include maps at a scale of 1 : 25,000 for each bog or fen, showing the excursion's itinerary across the sites. Notes are also provided on the location and geology, the climate, hydrology, vegetation and fauna, as well as on land use history and conservation measures. Nomenclature follows:

- Flora Europaea (Tutin et al. 1964–1980) for vascular plants and Dony et al. (1986) for English names;
- Daniels and Eddy (1985) for sphagna and Smith (1980) for other bryophytes;
- Peterson et al. (1974) for birds and Grzimek (1967–1972) for other animals.

The fourth section includes the formal papers presented at the IMCG Symposium held in the Natural History Museum, Berne, midway through the field excursion. This one-day symposium was open to a wider audience. The papers provide information about a wide range of peatland topics from around the world, including the problems associated with mire conservation in small, densely populated countries like Denmark and the Netherlands. The texts of some of the evening lectures given during the course of the field symposium are also included. In total, articles are provided by 13 experts from 11 countries. Each author is responsible for any errors or omissions in his/her work. The usage of phytosociological terms is the responsibility of the individual authors.

The fifth part of this volume includes the formal IMCG resolutions agreed upon during the 5th Field Symposium and addressed to a total of 13 countries. These have been forwarded to the relevant government departments responsible for mire conservation in each country. Resolutions for countries with a federalist structure of government were also forwarded to the relevant local authorities. The resolutions target specific problems to do with mire conservation in specific countries and propose or seek action to resolve these issues. The response of each government to these resolutions will be reviewed at the next IMCG Field Symposium to be held in Norway in 1994.

The last sections include: the wording of the Swiss legislation relating to mire conservation and associated topics, an index of insets and technical terms (instead of a glossary), lists of species mentioned in this book, the complete list of references for all contributions to this volume, and the IMCG delegates and external experts who took part in the 1992 Field Symposium.

English usage

As most native English speakers are aware, there are many differences between British and American English. While the majority of contributors to this volume have a British English background, the translation editor has an American English background which has lead to some discrepancies. However, wherever possible the Oxford Dictionary (SYKES 1983, with British usage) and the Oxford Dictionary of Current English (ALLEN 1985) have been used as reference (and referee) guides.

The handling of place-names in a polyglot country where at least two forms for many names exist is not always plain sailing. The fact that the English have their own names for many cities and places does not make it any easier, and choices often had to be made. Basically place-names appear in this book in their British form, and where these do not exist, the French forms tend to be used. This gives us Geneva and Basle (older than the French Genève and Bâle), Berne, Lucerne, St. Gall, Soleure, and Rhône River. However, in some cases the German forms such as Zürich or the Aare River are preferred. A word should be added about the lakes. Some lakes have a name (Lake Leman, like Lake Superior), but where they are named after a town on their shores, the 'of' should not be omitted. Thus Lake Leman (as Byron still called it) is the Lake of Geneva. A special case is the lake on which Lucerne lies. Its real name is the Lake of the Four Forest Cantons, but as it is something of a mouthful, it is normally called the Lake of Lucerne.

At first sight, the attentive reader of this volume may be surprised at the seemingly inconsistent spelling of terms like the Alps, the alp, the pre-Alps, alpine, Alpine, sub-alpine, pre-Alpine, etc. which are spelt either with or without a capital 'A'. When spelt with a capital 'A', the term the Alps refers to the main mountain range of the European continent. To be consistent, the foothills of the Alpine mountain range are called the pre-Alps. However, an alp with a small 'a' is the specific term for summer pasture-land on a Swiss mountain side.

The adjective Alpine with a capital 'A' refers to the Alps as a geographical location. When used without capital 'A' the meaning is broader: alpine can be used, for instance, to describe other high but non-Alpine mountains or a plant suited to mountain regions. Therefore, there are many places other than the Alps, as in Norway or in the Rocky Mountains, where an alpine or sub-alpine vegetation occurs. Thus, there are even alpine or sub-alpine vegetation belts which are spelt with a small 'a' although they are located in the Alps (cf. Fig. 1.6.1). On the other hand, a sub-Alpine bog is a bog which lies in the region of the Alps.

Time is running out for the world's mires. We hope that this volume will provide decision makers in Switzerland, as well as in other nations, with information and case studies which can help to ensure that at least a representative sample of the world's dwindling mire resources can survive. Hopefully, this will enable future generations to continue to experience and enjoy for themselves these last examples of a "Lost Paradise".

Andreas Grünig
Editor

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Last but not least all delegates attending the 1992 IMCG Field Symposium to Switzerland are indebted to two of the most important persons of the whole experience: Margrit von Euw and Fritz Frutig. Margrit not only ensured that all loose ends of the extensive administration always met, but was the very life and soul of the Group always present when help was needed. Fritz, a forest engineer by profession, was more than a professional bus driver mastering all difficulties with ease. Nobody really knows how many hours of his spare time he spent on behalf of the IMCG in reconnoitring the entire 1,908 km of the itinerary, in driving the Group safely up and down the mountains or in repairing and cleaning the coach often late into the night. We warmly thank them both for all their efforts.

1 Introduction to Switzerland

Andreas Grünig

Switzerland – like every state – is built on specific geographical, natural, historical, cultural and economic features. Situated in the heart of Europe, Switzerland displays a fascinating array of scenic grandeur. It is the source of four rivers, Rhine, Rhône, Ticino, and Inn; each has its people, and these four people form a nation.

If one were to try to capture the essence of Switzerland in a single word, that word would surely be 'diversity'. More essentially, one could say that overall it is this diversity which gives Switzerland its spiritual value and very identity. It is rare to find so small a country encompassing such scope, variety and individuality in its national life and above all in its natural features. Situated in southern central Europe, Switzerland is, first and foremost, a land of hills and mountains. This is emphasized by the fact that half of the country's surface

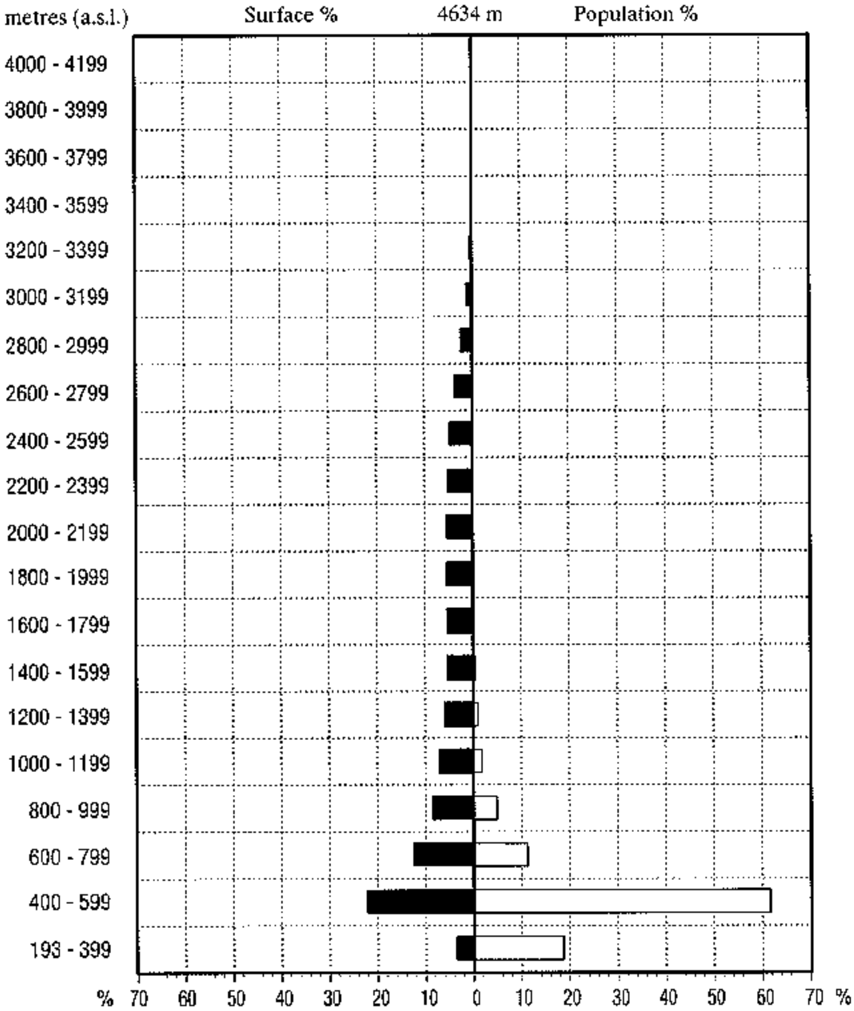


Fig. 1.1. Distribution of land surface area in Switzerland and population as a function of elevation.

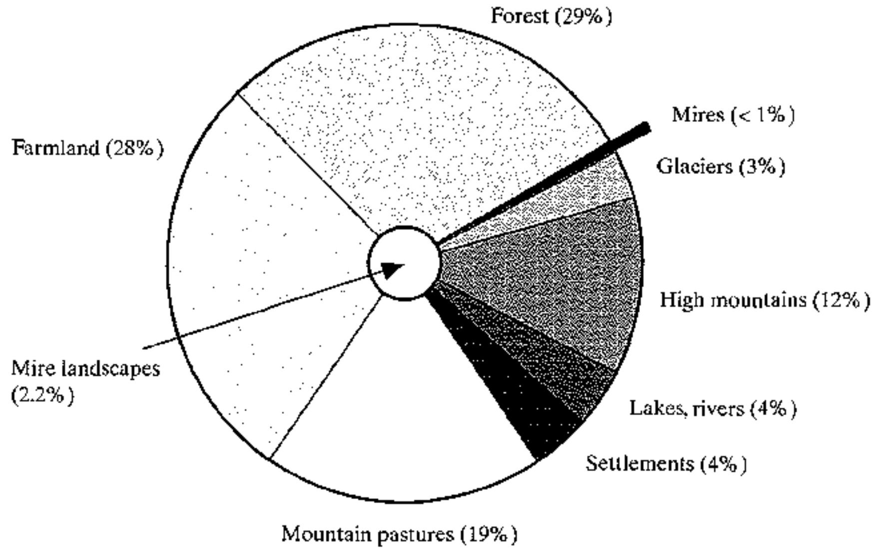


Fig. 1.2. Land use in Switzerland.

exceeds the 1,000 m contour line with an average elevation of about 1,350 m above sea level (a.s.l.; cf. Fig. 1.1). Approximately one-quarter of the country is uncultivated or developed land, one-quarter mountain pastures, one-quarter forest and one-quarter farmland (Fig. 1.2). The total land surface area is 41,293 km².

Throughout history and due to its central position, the country has been an important link in communications and transport between northern and southern Europe.

1.1 Geographical setting

Roughly a fifth of the total range of the Alps, specifically the central part, can be found in Switzerland. This includes the four main passes of Grimsel, Furka, St. Gotthard and Oberalp. Switzerland represents the rooftop of Europe. From

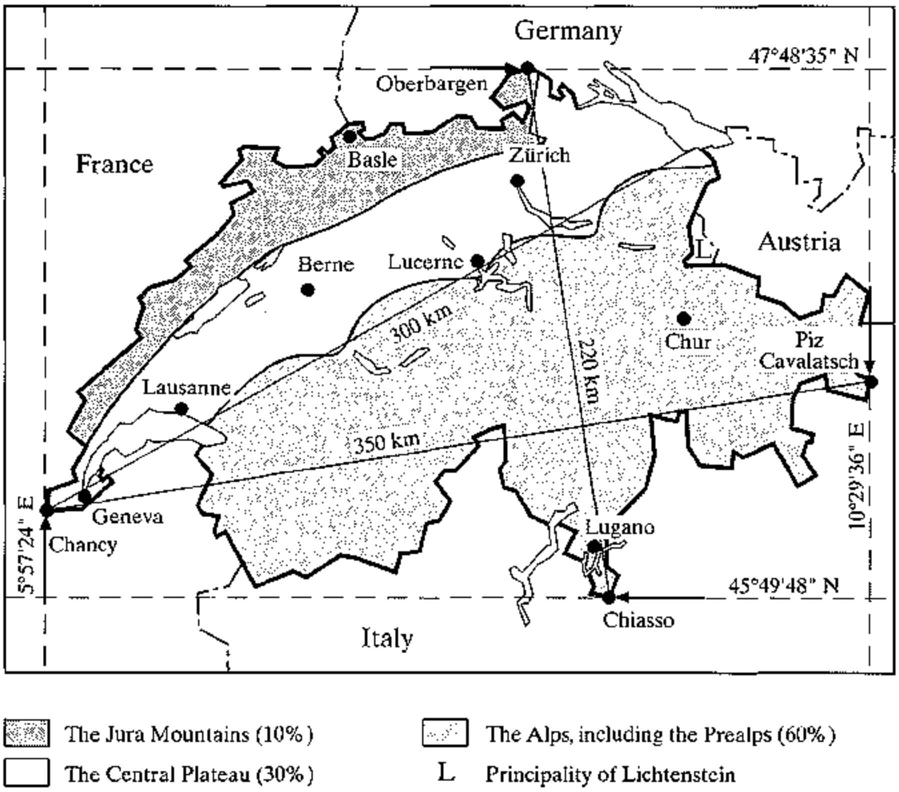


Fig. 1.1.1. The three main geographical regions of Switzerland (modified from BÄR 1979).

here spring the sources of the Rhône and the Rhine, and also the rivers Ticino and Inn, which feed the Po and the Danube respectively, giving rise to the country's popular alternative description as the 'Fountain of Europe' (see Fig. 1.3.5 and Fig. 1.4.3).

The country is situated between 45° and 48° N latitude and 5° and 11° E longitude. Switzerland's maximum distance from north to south is 220 km, and from west to east 350 km (cf. Fig. 1.1.1). It has an area of approximately 41,000 km^2; half that of its eastern neighbour Austria or of the entire island of Ireland.

As a small landlocked state, it has no direct access to the sea. In the north the Lake of Constance and the Rhine form the greater part of the natural border with Germany (346 km). The gently rolling Jura Mountains, which cover much of the north-western area, and the Lake of Geneva mark the border with France (572 km). The southern border with Italy is 734 km. Here, we find the topographical backbone of Switzerland – the southern mountain chain of the Alps with some of the highest mountain peaks of the Alpine arc: The famous Matterhorn, the impressive Piz Bernina and in the Monte Rosa massif, the Dufour peak at 4,634 metres (the highest mountain in the country). In the low-lying area of the canton Ticino, there is sub-Mediterranean climate and flora of the northern Italian lakes region (Lombardy plain; cf. Fig. 1.3.5). From here the frontier travels eastward, one moment following the southern ridge of the Alps, the next cutting across the high valleys and mountain ridges toward Austria. Austria's western end is marked by the ridge of the eastern Alps (cf. Austroalpine nappes in Fig. 1.3.1). Eventually, it is again the Rhine River which marks the borders with both the tiny Principality of Liechtenstein (41 km) and Austria (165 km in all).

Although the country's boundaries stretch as far as the upper Lombardy plain in the south and to the Black Forest beyond the Rhine in the north, the three major regions of Switzerland, geographically speaking, are the Alps, the Central Plateau and the Jura Mountains. The Alps, including the ranges of the pre-Alps, occupy 60% of the land surface; the relatively low-lying Central Plateau which, in geological terms, is known as the Molasse Basin or 'Mittelland' in German and 'le plateau suisse' in French, occupies 30%; this is bound to the north-west by the third region, the Jura Mountains, occupying 10%.

1.2 The roots of Swiss federalism

(development, demography, diversity, (semi-)direct democracy)

(The following description is partly adapted from von Faber-Castell (1984) and Expofederal (1991).)

Little more than a quarter of the total surface area of Switzerland lies in the Central Plateau, yet this plateau presently contains more than two-thirds of the population. It is highly industrialized and intensively farmed. As early as prehistoric times this area appears to have functioned as a melting pot of imported cultures. Therefore, in spite of the country's small size and dependence on others, the Swiss are surprisingly diverse as a people (probably also due to Switzerland's great variety of natural factors, its mountains as obstacles to traffic and its over 700 year old history). However, like most other countries, Switzerland has ideas about what makes it special and different. These ideas are derived from historical tradition, partially self-created and partially assumed, forming (for the present) a sort of national identity even though the state is strongly compartmentalized and federalist.

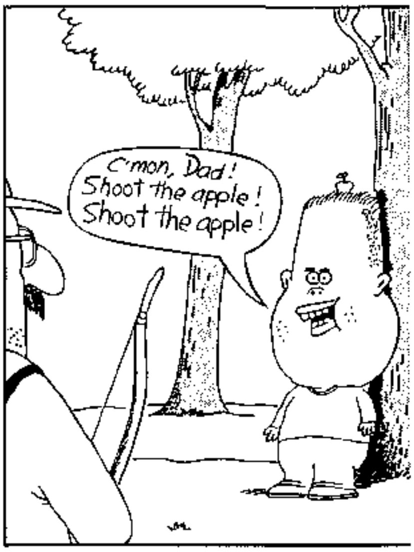


Fig. 1.2.1. Unknown to most historians, William Tell had an older and less fortunate son named Warrren (by Larsen, The Far Side copyright 1986 Farworks, Inc. / Dist. by Universal Press Syndicate. Reprinted with permission. All rights reserved).

1.2.1 Historical development of Switzerland

Roman age

For the Romans Switzerland played an important role as a fortified frontier province acting as a buffer against the German tribes to the north as well as a transit post for their flourishing commercial trade. North-south arteries of trade like the Julier pass, marked by two Roman columns at its summit, or the Great St. Bernhard pass are a throwback to those days.

5th century

After the last of the Roman Legions left at the beginning of the fifth century, Switzerland was infiltrated successively by tribes of Alemanni, Burgundians, Franks and Goths, with the Rhaetians holding out in the eastern Alps. The historical language divisions had already become established: In the Suisse Romande French is spoken, in the Ticino and in the more southerly valleys of the Grisons Italian. In the German-speaking north and north-east, various alemannic dialects prevail (cf. Chapter 1.2.3).

Middle Ages

Switzerland was not created in one day. Following Christianization and the inclusion of the entire territory into the Holy Roman Empire under Charlemagne, it was perhaps the key geopolitical role of the Gotthard pass, even now an important strategic link on the north-south trade routes, which indirectly led to the founding of the Swiss Confederation. However, there is a well-known story relating to its historic foundation: In the year 1291 the people of the three territories, Uri, Schwyz and Unterwalden, concluded the "Treaty of Everlasting Alliance" for their common defence against the royal house of Habsburg. There was a subsequent storming of the fortresses, resulting in the defeat of the Habsburg tyranny in the founding cantons. The bailiffs were driven out and their citadels destroyed (*Remember the legend of William Tell!;* cf. Fig. 1.2.1). However, these tales of the founding of the country are products of later eras. The idea that the Confederation grew out of a resistance movement against the Habsburgs is an ideological invention of the 15th century. It has only been in the past 100 years that 1291 has been named as the founding year of Confederation.

13th century

From recent historical research (Blickle et al. 1990), there is evidence that in the period around 1300, the Central Swiss region of Uri, Schwyz and Unterwalden was economically and culturally underdeveloped, geographically insignificant, and totally devoid of interest to a rising territorial power like the Habsburg dynasty. Although Habsburg-Austria possessed property in the three lands, it made no noteworthy investments there such as founding cities or establishing fortresses. The treaty of 1291 was undertaken by the local ruling families, who were above all eager to consolidate their own power; thus the pact was not primarily directed against the Habsburgs. The Confederation was founded in response to the peripheral nature of its political and economic position. This left self-help measures as the only alternative.

14th and 15th century

In the course of little more than a century, various cities and valley communities became affiliated with the perpetual alliance in the form of cantons (cf. Tab. 1.2.1). Many trials and tribulations were to confront the growing country however. The confederates rapidly earned a reputation as a nation of fierce and daring fighters above all in the various wars against Austria and Burgundy. In a series of battles between 1476 and 1477 the outnumbered confederates' forces destroyed the armies of Duke Charles the Bold; the Confederation became a leading regional military power. As a result, a number of European armies appreciated fighting qualities of the Swiss and engaged them as mercenaries.

Schwyz – the political cradle of Switzerland

(The following description is adapted from ZINGG 1992.)

The town of Schwyz is both the main town of the canton of the same name and the cradle of the Swiss Confederation. It lies in an attractive geographical basin with beautiful scenery whose landmarks are the two Mythen peaks (see Fig. 3.2.1). In contrast to its allies Uri and Unterwalden (divided into the half-cantons Obwalden and Nidwalden), it was geographically less isolated and was, therefore, much more exposed to political conflict. Consequently, it was inevitable that the farming society strove to establish autonomy for the sake of peace. It defended itself energetically and successfully against foreign powers such as the Holy Roman Empire and the Pope.

The battle of Morgarten in 1315 (cf. Chapter 1.2.7) marked the end of a long wrangle with the abbey of Einsiedeln about land rights and was a critical point in the formation of the Swiss Confederation, in which Schwyz played a leading role. The social structure underwent certain changes after the Middle Ages: many of the menfolk left to serve as mercenary soldiers, and what was once a purely peasant society gradually developed an aristocracy. Numerous buildings in and around the town of Schwyz, such as were usually only erected in larger towns, bear witness to this growing wealth and class-consciousness. However, Schwyz remained a borough town – i.e. a country village acting as a political, economic, religious and cultural centre which never attained the status of a town. (The same is true for the major settlements of the other founding cantons: Altdorf in Uri, Stans in Nidwalden, Sarnen in Obwalden).

With the French Revolution and the gradual development of the Swiss Confederation, Schwyz was subject to changes which were energetically resisted by its inhabitants. In the course of history it gradually lost its importance as a leading force. It is possibly because of this insistence upon independence that politics within the canton are preoccupied with local matters and resist influences from outside.

Corporations

The existing corporations of Central Switzerland have developed from medieval groups holding rights to common land. Closely connected in earlier ages to what were then political states, such associations are now bodies ruled by public law. Their property mainly comprises agricultural (mainly pasturage) and forest land. To some extent they also undertake public commissions. However, they are exclusive groups, i.e. they are open only to members of long-established burgher families. Applications for membership are usually rejected. In Central Switzerland the corporations own most of the agricultural and forest land (ZINGG 1992).

16th to 18th century

By 1513, the Confederation consisted of the 13 cantons of Zürich, Berne, Lucerne, Uri, Schwyz, Obwalden, Nidwalden, Glaris, Zug, Fribourg, Solothurn, Basle, Appenzell (cf. Fig. 1.2.2 and Tab. 1.2.1). The Swiss defeat at Marignano in 1515, marked an end to expansionary designs. Internal religious struggles led to a foreign policy of reserve and thus to a decision not to intervene in international conflicts. This was the beginning of Swiss neutrality. However, "in the same way that the world has the UN today, the old Swiss had the Diet where the delegates of their states met. Like the UN, the Diet was no more than an ultimate safety valve. ... The Confederation then remained approximately the same size for nearly 300 years. Driven by the desire to protect the freedom of their own valleys, the Swiss surrounded themselves with a ring of subject territories (for instance parts of the present cantons of Vaud, Argovia, Thurgovia). The Confederation had also gradually managed to break away from the German Empire. ... The peasants had risen in revolt against the cities and the plutocracy's claims to power. All this happened after the Reformation had succeeded in the cities, whereas Central Switzerland had remained loyal to the old faith (see Chapter 1.2.4). Thus, the Swiss were at odds with themselves in a land riven by religious strife on the brink of civil war. The old Confederation had degenerated; it was too rigid and too far removed from any idea of community to be able to muster the strength for self-renewal" (TSCHÄNI 1983).

1789 AD

Thanks to its close ties with powerful neighbouring France, after 1789 the revolutionary ideas of freedom, equality and fraternity soon swept through Switzerland. Domestic upheavals and the military intervention of France resulted in the collapse of the old order and the creation of the Helvetic Republic in the spring of 1798. It was the constitution of the Helvetic Republic that first incorporated the ideas of representative democracy, separation of powers and equality before the law. The rigorous centralism of the Helvetic Period contrasted sharply with historical tradition: the cantons now became mere administrative entities with no independent rights. Such a system could not survive. When Napoleon withdrew his troops, the Helvetic Republic collapsed. In 1803, Napoleon summoned 60 deputies to Paris and presented them with a new constitution, called the Mediation. Under this constitution, Switzerland once again became a league of 19 largely sovereign cantons with a Diet. Citizens' rights were upheld for the moment. But when the French domination of Europe came to an end, Switzerland fell under the influence of the great European conservative powers (mainly Austria and Prussia) which wanted to restore the old order. At the end of 1813, the Mediation was definitively rescinded.

1815 AD

In 1815 at the Congress of Vienna, the present-day national boundaries of the country were fixed (Fig. 1.2.2) and Switzerland's perpetual neutrality guaranteed. After 1830, progressive forces made themselves felt in different regions, and these demanded more democratic rights and constitutional freedom for the people. Their aim was the foundation of a Swiss federal state. In 1847, a short and almost bloodless war pitted the conservative, mainly Catholic and agrarian cantons against the liberal, mainly Protestant and industrialized cantons which were victorious.

1848 AD to 1992 AD

In 1848, a new federal constitution was accepted after a period of intensive negotiations. It contained democratic as well as strong federal characteristics. On the basis of this constitution, revised only once in 1874, the Swiss Confederation has survived – in particular through two world wars – and been transformed into today's quite modern, neutral, highly developed, federated democratic republic.

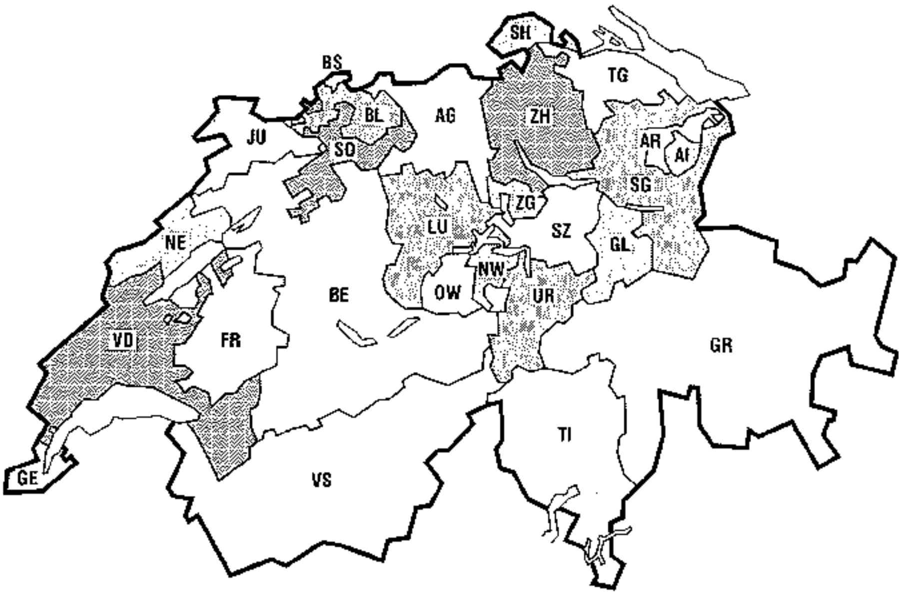


Fig. 1.2.2. Location of the 26 Swiss cantons.
Canton abbreviations:
AG-Argovia; AI-Appenzell Inner-Rhodes; AR-Appenzell Outer-Rhodes; BE-Berne; BL-Basle-Country; BS-Basle-Town; FR-Fribourg; GE-Geneva; GL-Glaris; GR-Grisons; JU-Jura; LU-Lucerne; NE-Neuchâtel; NW-Nidwalden; OW-Obwalden; SG-St. Gall; SH-Schaffhausen; SO-Solothurn; SZ-Schwyz; TG-Thurgovia; TI-Ticino; UR-Uri; VD-Vaud; VS-Valais; ZG-Zug; ZH-Zürich.

In spite of its small size, Switzerland is a strongly compartmentalized, federated country. There are now 26 cantons or half-cantons (23, with three politically subdivided), making up the Confederation (Fig. 1.2.2). They are listed in Table 1.2.1 in official order together with the official Canton abbreviations (according to vehicle number plates) and the year in which they were admitted to the Confederation. This is followed by their area in km², their population in 1990, their percentage of the total population in Switzerland, the number of inhabitants per km², and the capitals of the cantons.

Tab. 1.2.1. Land surface area and population of the cantons and their capitals in 1990.

① *1992 statistics.*
② *CH stands for Confoederatio Helvetica and means Swiss Confederation.*
③ *Half-cantons, Basle divided in 1833, Appenzell divided in 1598 into Appenzell Outer-Rhodes and Appenzell Inner-Rhodes.*

Canton abbrev.	Cantons	Admission to the Confederation	Total area in km² ①	Resident Population in 1990	in %	Inhabitants per km²	Cantonal capital
ZH	Zürich	1351	1728.6	1,150,500	17.0	669	Zürich
BE	Berne	1353	6049.4	945,600	14.0	157	Berne
LU	Lucerne	1332	1492.2	319,500	4.7	215	Lucerne
UR	Uri	1291	1076.5	33,700	0.5	32	Altdorf
SZ	Schwyz	1291	908.2	110,500	1.6	122	Schwyz
OW ③	Obwalden	1291	490.7	28,800	0.4	60	Sarnen
NW ③	Nidwalden	1291	275.8	32,600	0.5	119	Stans
GL	Glaris	1352	684.6	37,600	0.5	55	Glarus
ZG	Zug	1352	238.6	84,900	1.3	358	Zug
FR	Fribourg	1481	1670.0	207,800	3.1	125	Fribourg
SO	Solothurn	1481	790.6	226,700	3.4	286	Solothurn
BS ③	Basle-Town	1501	37.2	191,800	2.8	5182	Basle
BL ③	Basle-Country	1501	428.1	230,100	3.4	539	Liestal
SH	Schaffhausen	1501	298.3	71,700	1.1	241	Schaffhausen
AR ③	Appenzell O.-Rh.	1513	243.2	51,500	0.8	212	Herisau
AI ③	Appenzell I.-Rh.	1513	172.1	13,600	0.2	80	Appenzell
SG	St. Gall	1803	2014.3	420,300	6.2	209	St. Gall
GR	Grisons	1803	7105.9	170,400	2.5	25	Chur
AG	Argovia	1803	1404.6	496,300	7.4	354	Aarau
TG	Thurgovia	1803	1012.7	205,900	3.1	203	Frauenfeld
TI	Ticino	1803	2810.8	286,700	4.2	103	Bellinzona
VD	Vaud	1803	3219.0	583,600	8.6	183	Lausanne
VS	Valais	1815	5225.8	248,300	3.7	49	Sion
NE	Neuchâtel	1815	796.6	160,600	2.4	202	Neuchâtel
GE	Geneva	1815	282.2	376,000	5.6	1346	Geneva
JU	Jura	1979	837.5	65,700	1.0	79	Delémont
CH ②	Switzerland	1291	41293.2	6750,700	100	165	Berne

1.2.2 Demography

Owing to its long-established image of cows, cheese and chocolate, Switzerland is not usually thought of as a densely populated nation. However, by the 1970s the country had become more populous, more urbanized and more service-oriented than ever before. It now has 6,873,000 people (including 1,246,000 foreigners, corresponding to more than 18% of the population) or an average of 181 inhabitants per km² (Fig. 1.2.3). Taking into account the fact that large areas of the country are uninhabited or uninhabitable, this figure can increase to over 380 inhabitants per km². This is exceeded in very few other countries (cf. Fig. 1.2.4).

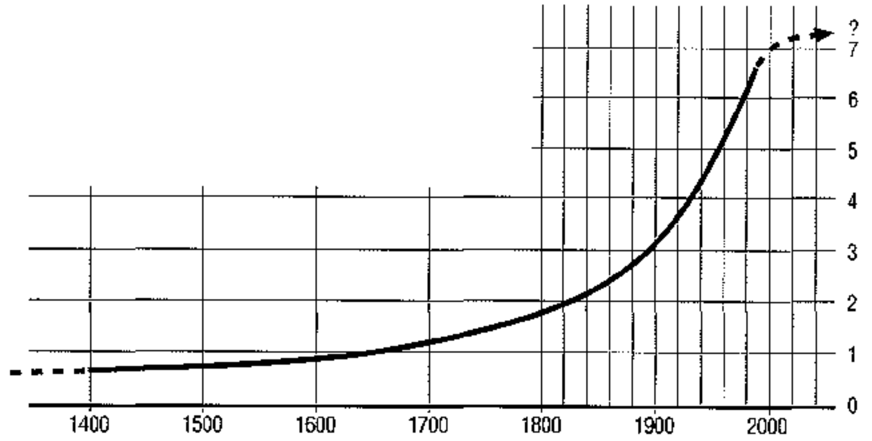


Fig. 1.2.3. The population of Switzerland from the year 1400, based on present international borders (modified from BÄR 1979).

In 1992, more than 5 million people were crowded into the towns of the Central Plateau, with almost 60% living in the major conurbations, notably around Zürich, and less than 4% living above the 1000 m contour line (cf. Fig. 1.1). In comparison, in 1798 only 6.5% of the total population lived in towns with over 10,000 inhabitants. By 1920 this figure had risen to 28%, and by 1970 to 45%.

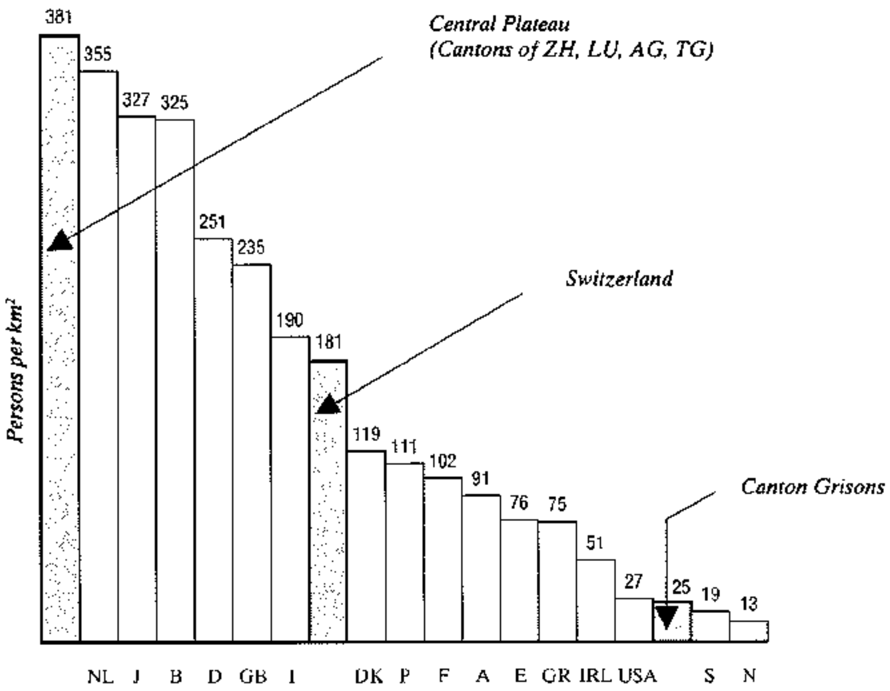


Fig. 1.2.4. The population density in other countries compared to canton Grisons, to the Swiss average (CH), and to four cantons of the Central Plateau (for canton abbreviations, see Fig. 1.2.2). Country abbreviations: A-Austria; B-Belgium; D-Germany; DK-Denmark; E-Spain; F-France; GB-Great Britain; GR-Greece; I-Italy; IRL-Ireland; J-Japan; N-Norway; NL-The Netherlands; P-Portugal; S-Sweden; USA-United States of America.

1.2.3 The four national languages

The existence of several official languages is a characteristic of Switzerland (Fig. 1.2.5). The everyday language of about two-thirds of the population are various guttural German (alemannic) dialects, while High German is used for official and most written communication. A little over 18% of the population speak French as their mother tongue, which is spoken the western part of the country, in the canton of Geneva, Vaud, Neuchâtel, Jura, in major parts of Fribourg and Valais and in minor parts of Berne. Almost 10% speak Italian, the language of the cantons of Ticino and of the southern valleys of Grisons. If we exclude the non-Swiss citizens, the proportions for the three official languages are 74%, 20% and 5% respectively. About 50,000 people in Alpine communities of the Grisons speak the esoteric language called Romansh (or Rhaeto-Romanic), which contains some pre-Roman words and a substratum of Latin elements. Although this comes to less than 1% of the population, Romansh is considered the fourth national language (see Chapter 3.14.6).

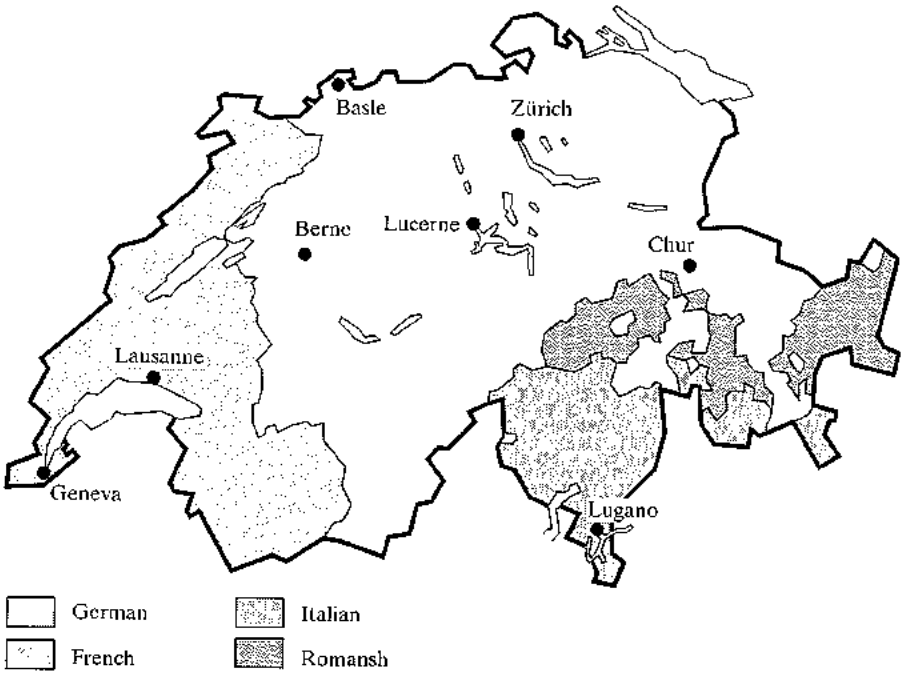


Fig. 1.2.5. The four national languages of Switzerland (modified from IMHOF 1972).

1.2.4 Religion

As in other European countries, the Reformation, led in Switzerland by Ulrich Zwingli in 1519, brought about internal conflicts between Roman Catholic and Protestant cantons. This was spurred on by the arrival in 1536 of Jean Calvin, fleeing France. The spread of Calvinism in Europe led to the coining of the French term Huguenot, a corruption of the Swiss word Eidgenosse (Confederate). After Zwingli's defeat and death in a mire near Kappel (canton Zürich) in a religious war in 1531, a peace treaty gave each territory the right to choose its own faith (Fig. 1.2.6).

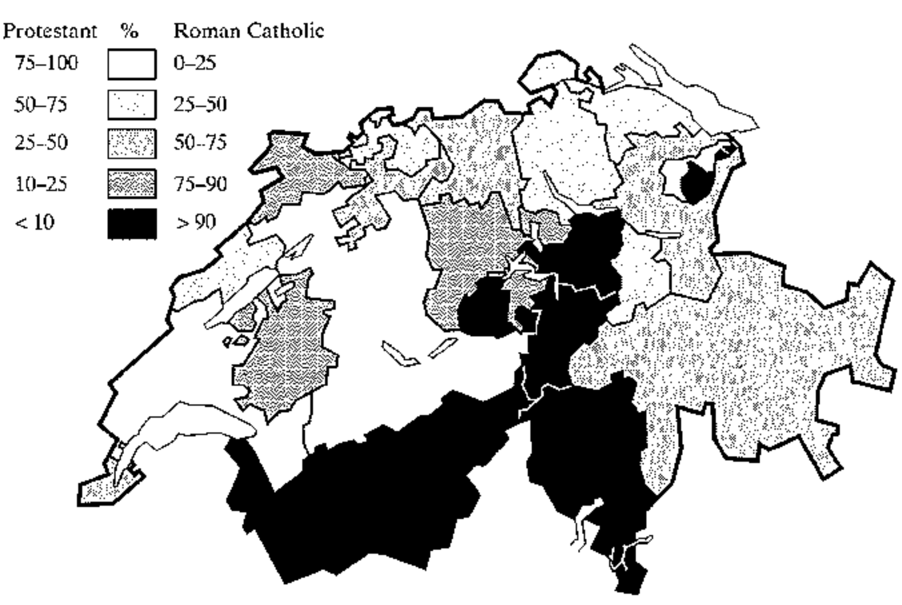


Fig. 1.2.6. The distribution of the two main religions in Switzerland (modified from IMHOF 1972).

Historically speaking, religious divisions were even more important than linguistic diversity. After the foundation of the federal state in 1848, the Protestants, as the victors of the Sonderbund war, continued for many years more or less to constitute the (religious) majority. Now, however, in Switzerland there are over 3 million Catholics (48% of the total population), about 200,000 more than there are Protestants (44%; others 8%). The increase among Catholics after World War Two is attributed to the influx of Italian and Spanish workers, 70% of whom are Catholics. Of Swiss citizens, some 50% are Protestants and 44% Catholics, the latter predominant in the more conservative rural areas of the original Forest Cantons, Appenzell I.Rh., Valais, and Ticino, and the cantons of Jura, Fribourg, Lucerne, and Zug. In recent times, the greatest increase has been in the number of those who claim to have no religious affiliation; religion has become less important in today's life.

1.2.5 Economy

The small state of Switzerland, which as recently as the last century was very poor, has always been economically dependent on foreign countries. With its meagre resources and limited domestic market, the country was forced at an early stage to open its doors to the rest of the world. An indication of its traditional economic weakness was the existence of more than two million Swiss emigrants engaged as mercenaries in various foreign armies (cf. Fig. 1.2.3). This led to Swiss fighting Swiss, a practice which was only abandoned and forbidden by the establishment of the Federal State in 1848. At that time, 60% of the population still worked on the land. However, after 1848 Switzerland's dependence on agriculture diminished. Besides industrialization, this was a result of tourism; the first modern tourists, the British, began to come here 'on holiday' in the 19th century. Other Europeans and some North Americans followed suit, so that soon the small federal state became known as 'a nation of hotelkeepers', presently hosting some 20 million visitors from abroad annually. Today less than 5% of the population work on the land, while 40% are in industry and 55% in the service sector.

In current economic terms, the country is forced to engage in a large-scale exchange of resources and labour with foreign countries. About half of Switzerland's gross national product comes from foreign trade. Nearly 80% of its energy requirement is imported. The high demand for labour has led to considerable immigration. The country has become a centre for international finance. Its most important trading partners are its neighbours, together with the United States and Great Britain. However, Switzerland has a negative trade balance with these countries which is only offset by the income from tourism.

It is, therefore, not surprising that the picture of Switzerland is no longer one of horrible mercenaries, happy yodellers making cheese, and the tinkle of cowbells in peaceful mountain pastures, nor even of (s)watches and precision instruments, but increasingly one of banks and tourism.

The economic structure varies greatly from one part of the country to another. In the Alpine valleys and mountain areas, agriculture and above all tourism dominate the scene. In large centres like Zürich, Basle and Geneva, the most important service institutions can be found, while trade and industry have been pushed more and more towards the periphery of the urban areas. Most of those active in the industrial sector are found in the proximity of the major centres, such as Soleure, Basle-Country and Argovia.

These differences within the economic structure have given rise to considerable regional variations in annual income per capita from the national average. In 1984, this was about 33,000 Swiss francs (Sfr.) which corresponds to approximately 22,000 US$. However, in the poorest cantons or half-cantons (Jura, Uri, Obwalden, Valais) the local average was about Sfr. 25,000 (approximately US$ 16,700), while in the richest (Zug) it was more than double: Sfr. 55,000 (approximately 36,700 US$). This inequality in the economic weight of the cantons leads to other imbalances. Canton Zürich alone is responsible for more than one fifth of the Swiss gross national product. The economic concentration associated with this and the simultaneous depopulation of certain mountain valleys and marginal areas is creating an added strain to Switzerland's federal structure.

Communes - Civil Rights

Today, the commune or borough continues to form the foundation stone of the Swiss Confederation. Each commune governs itself by direct ballot. Swiss citizenship confers franchise rights on three levels: communal, cantonal and federal. The political structure of the communes is extraordinarily diverse; some cantons differentiate between communes of current inhabitants, regardless of birthplace, and communes of burghers stemming from local families. There are many different forms of communal government with varying duties and competence. This diversity is the result of historical development (ZINGG 1992).

1.2.6 A (semi-)direct democracy

Switzerland is a semi-direct democracy. In the years following the foundation of the federal state in 1848, the rights of the people to participate in government were successively developed. In comparison with other methods of government, the most important characteristic of Swiss politics is the unique development of popular rights at the national level.

Apart from questions of national interest (e.g. foreign policy, Post Office services, Federal Railways, military, etc.), each canton governs itself independently, its particular constitution following the pattern of the Federal Constitution. The individual communes and boroughs within each canton also enjoy a considerable degree of autonomy.

Elections

Today, plebiscites are of major importance to the political system of Switzerland. The significance of parliamentary elections, on the other hand, is declining because so many issues are brought directly before the people. Moreover, there is no strong opposition in the Federal Parliament. "New" issues or disapproval of the policies of the governing parties can often find their way into the political system only by way of popular initiatives or referendums.

Parliamentary elections are held every four years. The 200-member National Council is elected according to the principle of proportional representation. The seats are distributed according to the population of the cantons. The Council of States consists of 46 members. Each canton delegates two members, each half-canton one. Both chambers are clearly dominated by the centre-right parties.

Executive

The Swiss Federal Council consists of seven members and is elected by the Federal Parliament. The Federal Council is a collective system; its members assume joint responsibility for decisions and take a common stand. The most important tasks of the Federal Council are to prepare new legislation, issue ordinances and head the Federal Administration.

Popular initiative and compulsory referendum

The signatures of 100,000 eligible voters, collected within 18 months, are needed to launch a popular initiative to amend the Constitution. The same is true of certain other important federal decisions which do not directly involve the Constitution, such as membership of international organizations. Total and partial revisions of the Constitution are subject to compulsory referendum. The institution of the initiative comes into question only for a partial revision. This is usually in the form of a completed project which is put before the people in a referendum, with a recommendation either for acceptance or refusal by the Federal Parliament and Federal Government. (An example is given in Chapter 6.4: Official Information for Voters of the Rothenthurm Popular Initiative "Protection of Mires – Rothenthurm Initiative"). Constitutional Amendment by the means of an initiative needs the approval of both the people and the cantons, since it concerns changes in the Constitution.

Optional referendum

An optional referendum grants the right to bring parliamentary decisions before the people before they go into force. Laws and generally binding federal decrees are subject to optional referendum, requiring the signatures of 50,000 eligible voters or eight cantons. Thus, the referendum constitutes the right of citizens to veto parliamentary decisions. It takes the place of a judicial review of the constitutional validity of laws, as is done in other countries. This would not accord well with popular rights as known in Switzerland. For the acceptance of a law, a popular majority suffices.

The demystification of direct democracy

The rights of initiative and referendum were introduced as popular rights. But over the past decades, the referendum has developed more and more into a powerful instrument, especially in the hands of the trade associations, to influence directly or indirectly the policy of the Swiss Federal Council (executive) and the Federal Parliament. (Similar rights exist on the cantonal level, though details vary from canton to canton).

Of the 1,466 cases subject to optional federal referendum since 1874, only 104 have actually come to a vote. But the main effect of the referendum is indirect: every plebiscite on a referendum delays the legislative process. Hence even before it begins debating a bill, the Federal Parliament does its best to keep the risk of referendum to a minimum.

Consultation Process

During the "Consultation Process", all groups eligible to call a referendum are asked for their positions on a proposed piece of legislation. The mere threat of a referendum tends to have a major impact on parliamentary debates: the demands of organized special interest groups must be taken into account in the legislation.

But the cards of power are not dealt fairly: the short-term, special aims of individual sectors of the economy are easier to organize and achieve than are longer-term general goals – environmental measures for example. The rules of the game are thus heavily weighted toward the "haves", the defenders of the status quo, and against the "correcte form" who are bent on change.

Thus the right of referendum, originally introduced as a popular right, has increasingly developed into a powerful instrument of special interests groups. Different groups do not all have an equal chance of bringing their influence to bear. Collecting signatures and mobilising members takes money and good organization. And that is what, above all, the trade unions and economic organizations have.

If the Federal Parliament does not wish to deal with certain issues, the electorate can launch an initiative. But even the threat of an initiative or a failed initiative can have an effect by at least bringing the issue to the public eye.

1.2.7 The three battles of Rothenthurm

(The following text is partly altered from Zingg 1992.)

Rothenthurm, in the canton of Schwyz, is memorable in history for three "battles" which took place in its vicinity.

15 November 1315

The people of canton Schwyz appropriated lands belonging to the monastery at Einsiedeln, plundered the minster and then set it on fire. The Habsburg dynasty, responsible for the worldly goods of the monastery, set out to punish the "Schwyzer". However, the "Schwyzer", together with their allies from the canton Uri, utterly vanquished the Austrian knights, partly because they employed completely unconventional tactics – guerilla warfare! This first battle helped to cement relations between the three founding cantons of the Swiss Confederation.

2 May 1798:
Battle of Rothenthurm

After the French Revolution, an army of Napoleon's invaded Switzerland and pushed through to the central cantons where it met with massive resistance. Although the "Schwyzer" had one small victory, they were finally defeated by the overwhelming superior number of the French troops. This event marked the end of the rule of the aristocracy in Central Switzerland and was a milestone on the road to modern democracy.

6 December 1987:
Rothenthurm Initiative

On this day what is known as the "Rothenthurm Initiative", a compulsory referendum initiated by Swiss citizens demanding the conservation of mires and mire landscapes, was accepted. More than 57% of the voters and 23 of 26 cantons supported the integrated conservation of mires and mire landscapes of particular beauty and national importance. Of the almost 100 initiatives subject to compulsory referendum since 1874, the vote on the Rothenthurm case was only the 9th which was successful.

The background to this latest "battle" of Rothenthurm is as follows: The Swiss army wanted to establish a military training ground bordering and partly encroaching on the unique mire habitats. This met with enormous resistance from nature and landscape conservation groups and local farmers, who are often at loggerheads with each other but in this case were united in protest. The conflict resulted in a popular initiative which, put to the vote, was rather surprisingly accepted. Considering the circumstances and difficulties, the acceptance of the Rothenthurm Initiative is still remarkable and not yet really accepted by many representatives of the political establishment.

Fig. 1.2.7. The Red Tower [Roter Turm] in the village of Rothenthurm, canton Schwyz, after which the mire site and the Referendum on Protection of Mires were named (Photo by A. Zingg).

1.3 Geological setting

The geological structure of Switzerland is complex. It forms part of the Alpine arc which stretches almost 1,000 km from Nice (French Maritime Alps) to Vienna (Austrian Alps; Fig. 1.3.1). The geological boundary between the Eastern and the Western Alps runs through easternmost Switzerland (see Figs. 1.3.2 and 1.3.5).

The Jura Mountains and the Molasse Basin do not form part of the Alpine mountain chain, but their evolution and present structure have been very much affected by the Alpine orogeny.

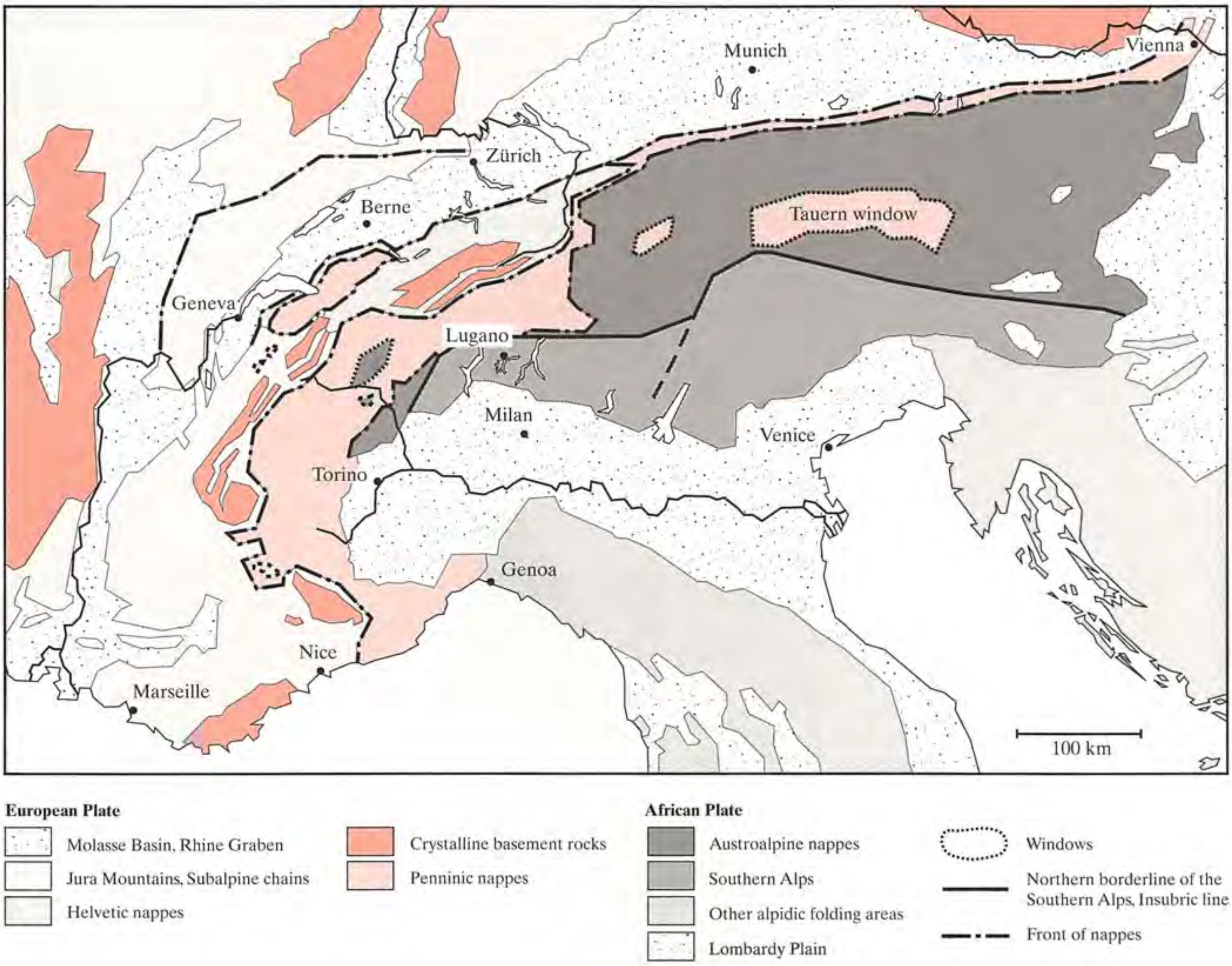


Fig. 1.3.1. Tectonics and geology of the Alps (modified from SCHULZE 1982).

1.3.1 Tectonic units of Switzerland

From north to south the following main tectonic units can be discerned (Fig. 1.3.2):

1 The European Foreland with the southward thickening Molasse Basin and the peripheral Jura Mountains.
2 The External Massifs (Mont Blanc, Aar) as crystalline complexes with their proper Mesozoic cover; tectonically overthrusted by the sedimentary Helvetic nappes. Both units formed part of the ancient southern European continental margin.

> ***Nappe***
>
> *A sheet-like, allochthonous rock unit, which has moved on a predominantly horizontal surface. The mechanism may be thrust faulting, recumbent folding, or both. The term was first used as 'nappe de recouvrement' for the large allochthonous sheets of the Western Alps, and it has been adopted into English. The German equivalent, Decke, is also sometimes used in English (modified from* Bates *and* Jackson *1987).*

3 The Internal Central Alps. This part of the Alps is composed of three regions:
   - The Penninic region as the former European southern continental margin; in part extremely thinned during the Mesozoic extension phase. During Alpine orogenesis it was deformed to a nappe complex more than 15 km thick, characterized by basement nappes which are separated by thin Mesozoic sedimentary zones.
   - The Ophiolite suite, as a dismembered complex, marks the former oceanic region between the two continental parts of the plates.
   - The Austro-Alpine region as a part of the overthrust African plate. Tectonically speaking, the famous Matterhorn does not belong to the former European plate, rather it provides evidence of the overriding African plate.

4 The Southern Alps, also of African origin, which are separated from the Central Alps by the Insubric Line. In this tectonic complex, a Variscian basement is overlain by Mesozoic/Tertiary sediments.

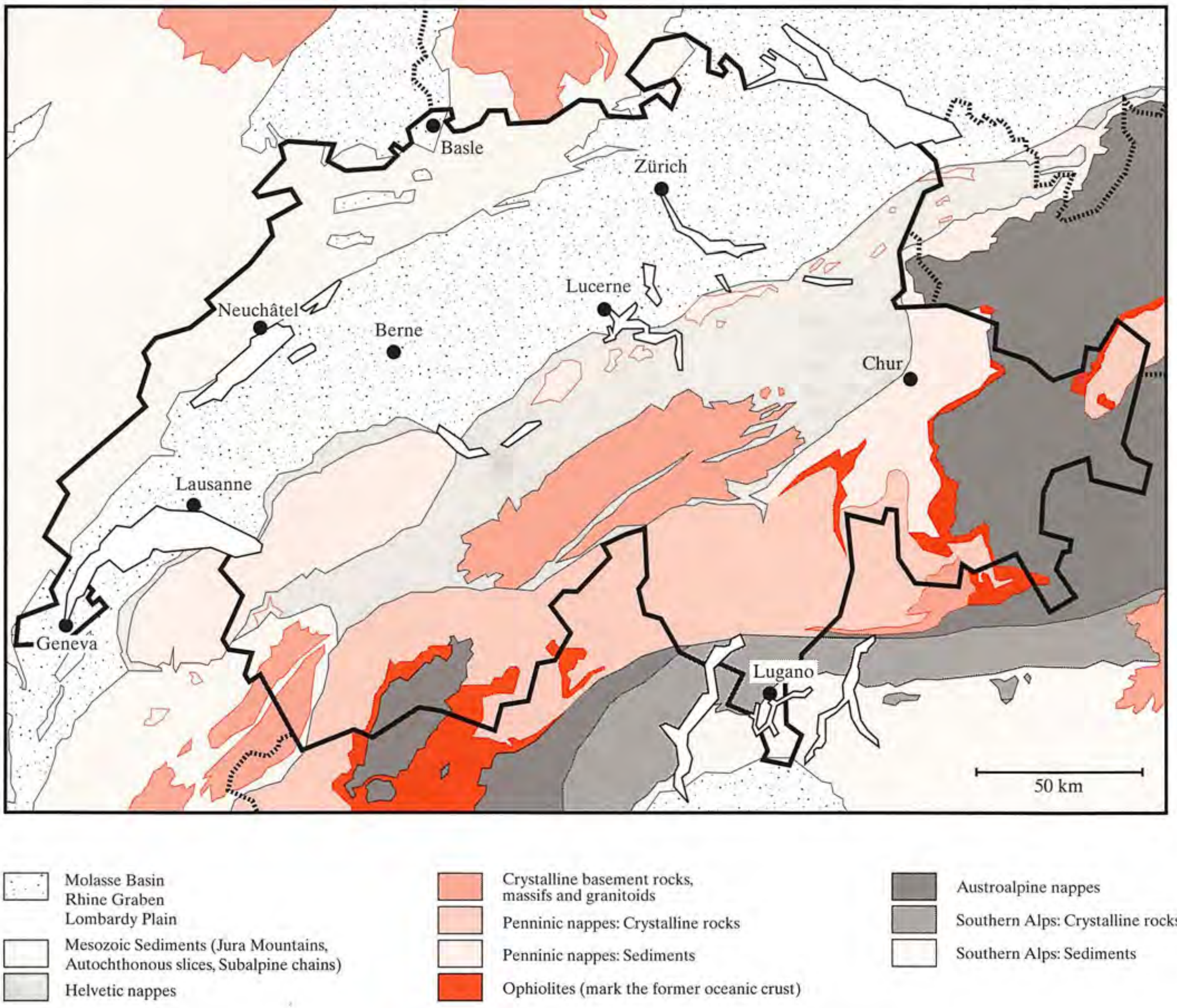
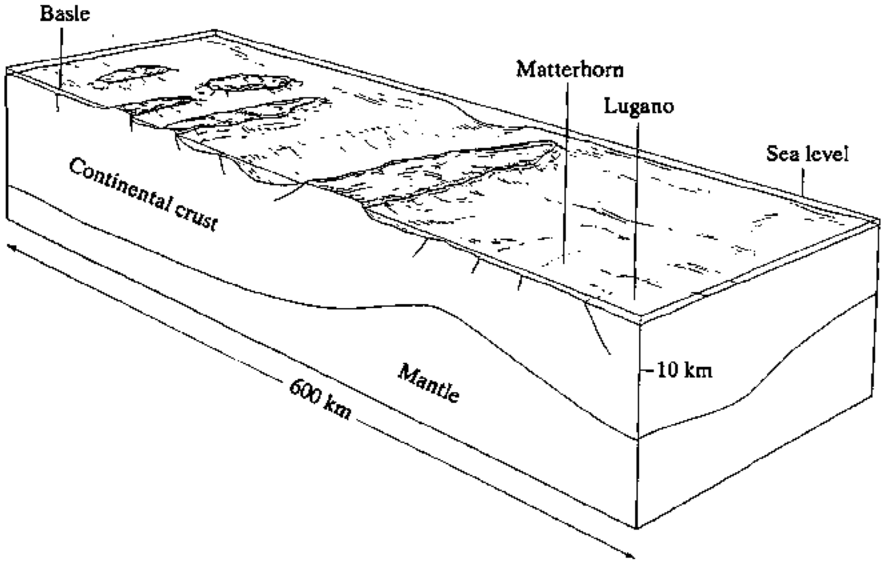


Fig. 1.3.2. Simplified geologic-tectonic sketch map of Switzerland (modified from Trümpy 1980 and Heitzmann 1991).

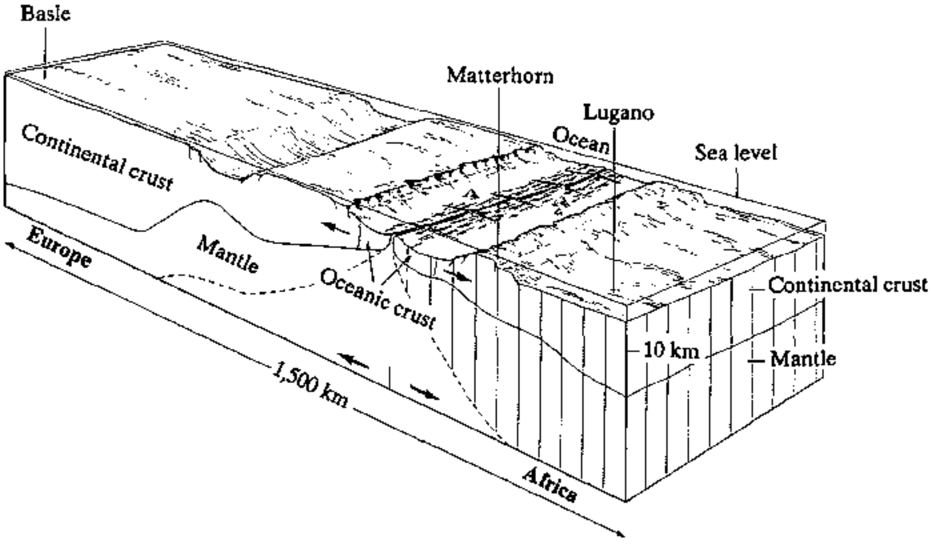
1.3.2 Alpine evolution

The Alpine evolution from the Mesozoic (ca. 200 million years ago) to the present day, encompassing the processes of 1) distension, oceanization and sedimentation; 2) compression, overthrusting and folding and 3) uplift and erosion, is illustrated by Figures 1.3.3 and 1.3.4.

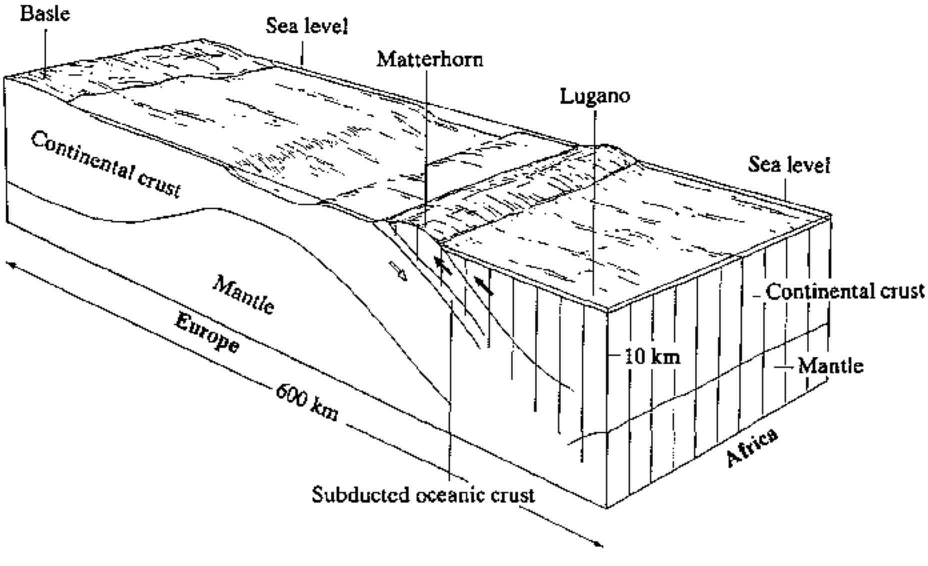
Fig. 1.3.3a-e. Block diagrams showing the Alpine evolution in the central region of present day Switzerland (modified from DECROUEZ and HEITZMANN 1991, unpublished).



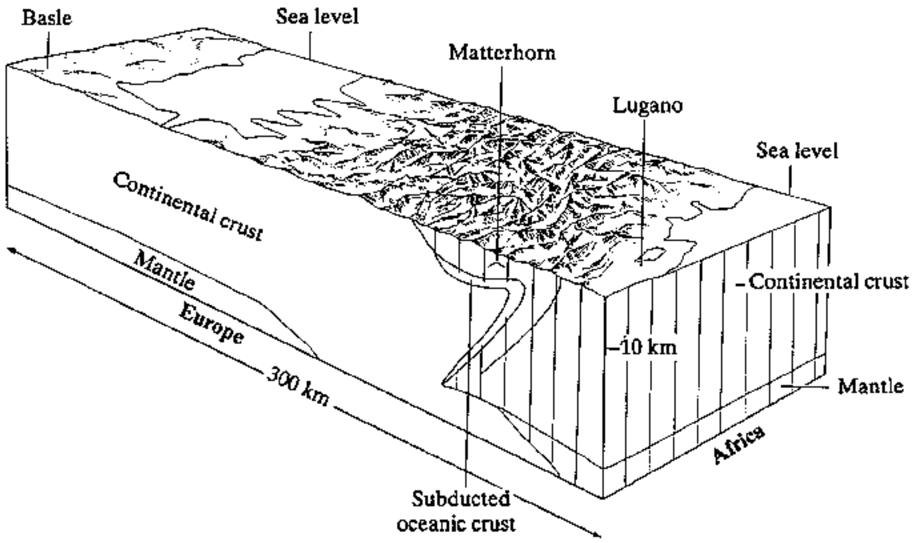
a. Trias (200 million years ago): wide shallow sea. A super-continent consisting of future Europe and future Africa is heavily eroded and almost totally covered by the sea. There is an ocean called Tethys in the east. In the west the Atlantic ocean does not yet exist.



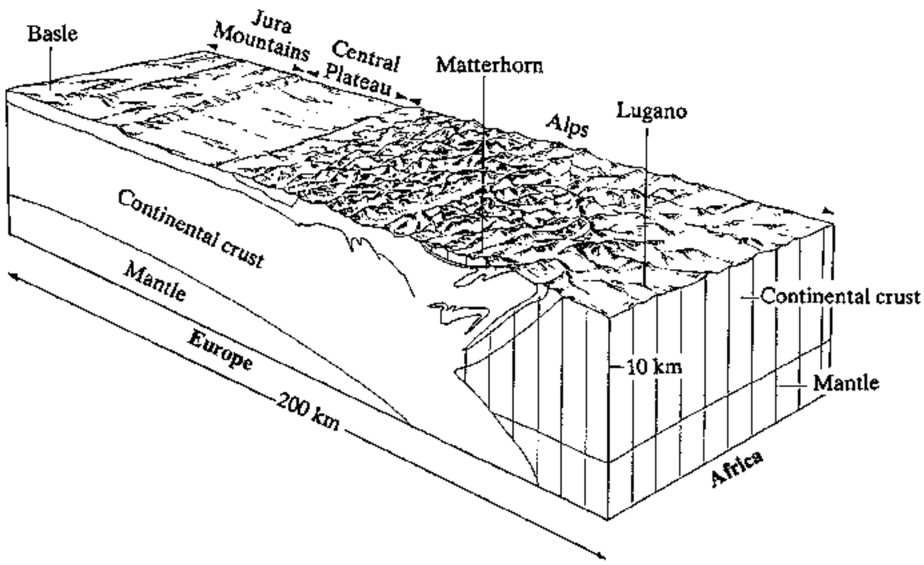
b. Jurassic / Cretaceous (140 million years ago): maximum of oceanization. Extension forces stretch out the super-continent; the subsequent break-up creates different sea basins, partially floored by new oceanic crust. The oceanic ridge marks the limit between the European plate to the north and the African plate to the south. This ocean is the Tethys which widens to the east. It is connected to the west with the Atlantic which started to develop in the Jurassic period.



c. Upper Cretaceous (100 million years ago): beginning of collision. During this phase the plates approach which results in an overriding of the African plate over the European plate and the subducted oceanic crust. Within the African plate, new oceanic crust in the future Mediterranean Sea is created.



d. Aquitanian (20 million years ago): plate indentation / uplift. The former Tethys ocean has completely disappeared. The Alpine mountain chain is uplifted by the African indenter; the future Mediterranean sea is discernible. About 6 million years ago the Jura Mountains were formed.



e. Present time: In this block diagram, the Alpine mountain chain is more compressed, uplifted, and eventually eroded than in the previous sketch (Fig. 1.3.3d). The characteristic shape of the Matterhorn appears as a part of the former African plate.

Distension, oceanization and sedimentation

200 million years ago central Europe was covered extensively by a shallow sea of changing depths. Its bottom was overlain by sediments which were either deposited by rivers near the shore or were precipitated from the sea water in the open sea. Eventually, these sediments formed sandstones, marls, limestones and shales (clays). The subsequent break-up resulted in deep basins where new oceanic crust was created. The maximum of the extension phase in the Alpine Tethys was reached about 140 million years ago.

Compression, overthrusting and folding

The following compression phase due to the approaching plates resulted about 100 million years ago in an overriding of the African plate over the European plate. Subsequently both continental margins and the oceanic realm inbetween were dismembered and overthrusted towards the north forming a nappe complex more than 20 km thick. Synorogenic detrital deposits in deep basins, the Flysch deposits, are incorporated in the Alpine structure.

Uplift and erosion

The last stage of the Alpine evolution began about 30 million years ago. The already structured mountain chain was uplifted – probably by plate indentation – and the eroded material, called Molasse, deposited in the northern and southern foredeeps. About 6 million years ago the Jura Mountains were formed.

Over the last 1 million years the present landscape was formed mainly by the combined action of glacier and water erosion and accumulation processes.

Flysch

In its strictest sense, this term refers to sediments associated with the formation of the Alps. It has been universally used more generally to describe syn-collision orogenic clastic sediments which are subsequently deformed by continuing orogenic movements. Alpine flysch sequences consist of marine, mostly terrigenous, turbidite deposits and are composed of shales, sandstones, conglomerats, marls and limestone. They were laid down during Late Cretaceous or Paleogene times in a variety of generally active structural settings, in relation to Alpine mountain building.

Flysch formations are normally made from soft rocks. Therefore they are easily eroded and form smooth landscapes.

Soils which have developed from Flysch parent rock material may be very impermeable; this makes them suitable to the formation of mires.

1.3.3 Topography: The result of lifting and eroding the landscape

The Alps, a young massif in geological terms, mark the suture of the Late Cretaceous/Tertiary collision between the African and European tectonic plates (Fig. 1.3.3). Thus the old basement complexes of Mont Blanc, Monte Rosa, Bernina and Silveretta were worn down over vast periods of time prior to being covered by sediments. Subsequent movement thrust them into the Alpine nappe complex. In some cases the original sequence has even been reversed (Fig. 1.3.4). Very precise measurements have shown that the Alps continue to uplift by an average of one millimetre a year (Geiger and Gubler 1986; Labhart 1992, p. 65), a figure comparable to the annual average peat accumulation rate within an intact bog. This 'mountain growth' is balanced, however, by erosion (see Fig. 1.3.3e).

1.3.3.1 The Alps

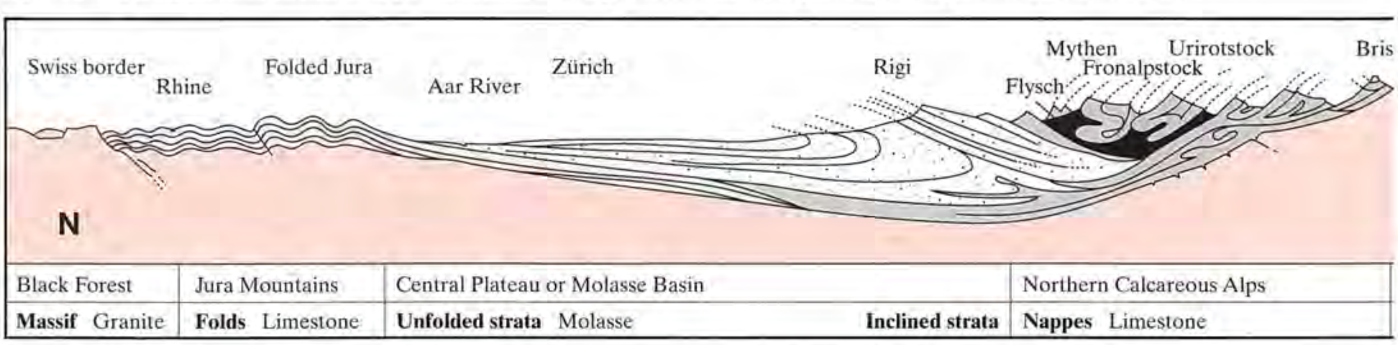
Between Martigny and Chur, the Alps are divided by two large longitudinal valleys, followed by the upper course of the Rhône River and by the Anterior Rhine River, and crosswise by the Reuss and Ticino valleys, their watersheds separated by the St. Gotthard massif (Fig. 1.3.5). The northern mountains comprise a high chain to the south (Finsteraarhorn, 4,274 m) and lower ranges to the north. This division is clear-cut in western Switzerland but becomes indistinct towards the east, where the main range is lower (Tödi 3,620 m) and the front ranges are higher (Glärnisch 2,914 m). Valley bottoms are generally quite low (500 –1,000 m).

South of the Rhône-Rhine furrow, the high Penninic Alps (Monte Rosa, 4,634 m) occupy the southernmost part of western Switzerland. The Lepontine Alps, which mainly form the edge of the Ticino catchment (with the Rheinwaldhorn, 3,402 m, in the north-east), sweep down to the edge of the Lombardy plain. Lake Verbano (Lago Maggiore), at 193 m, is the lowest point in the country.

The Rhaetic Alps in canton Grisons possess a maze of high-altitude valleys; except for the Bernina group (4,049 m), the mountain summits are not as high as in Valais or Berne, but the overall elevation of the land is greater (see Fig. 1.5.1).

The mean altitude of the whole Alpine area of Switzerland is around 1,700 m (see Fig. 1.1). While some 100 summits average around 4,000 m, the highest of them, the Dufour Peak in the Monte Rosa massif, rises to 4,634 m a.s.l.

Fig. 1.3.4. A geological cross-section through Switzerland showing the results of the Alpine evolution (modified from Bär 1979).



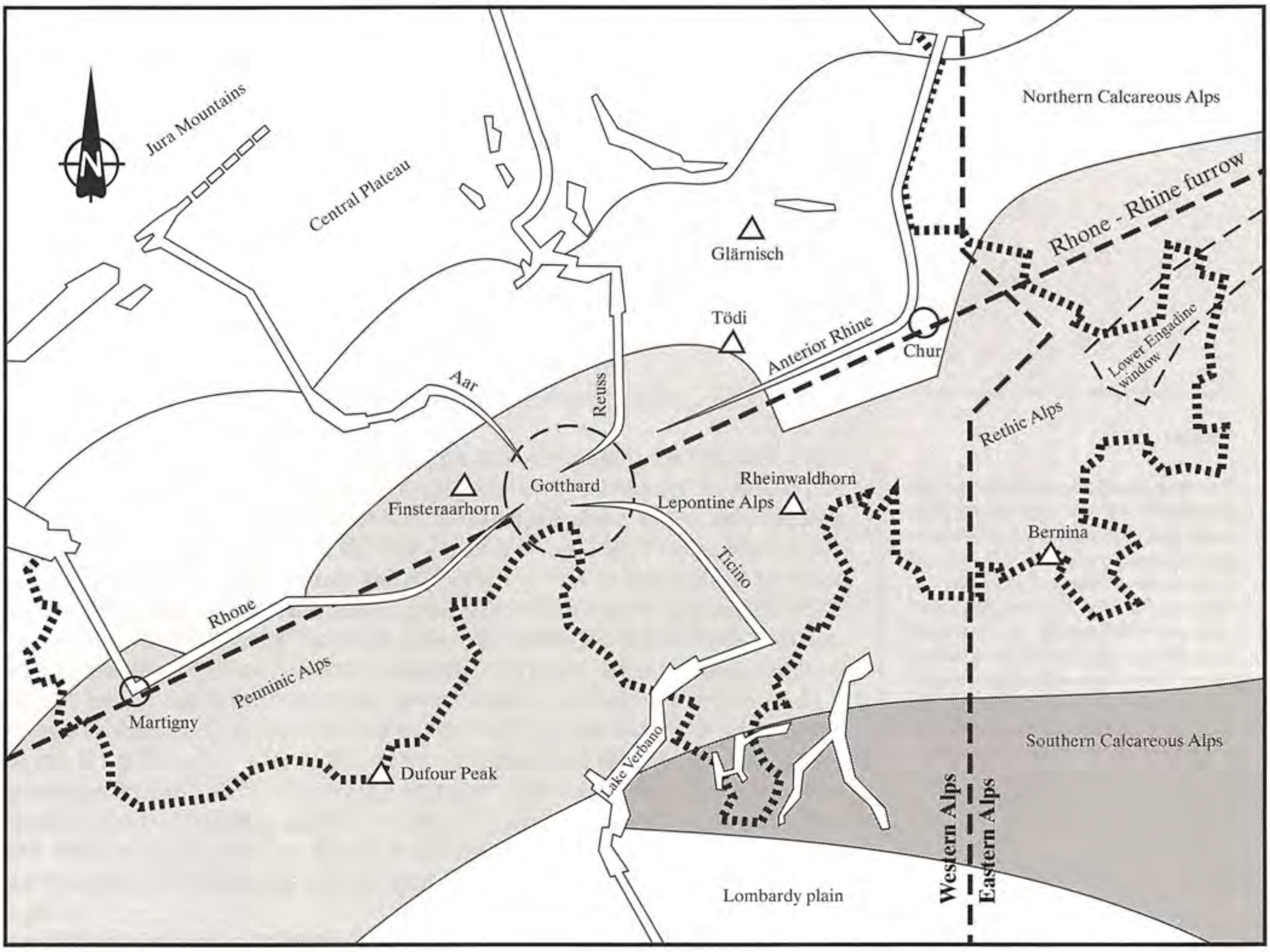
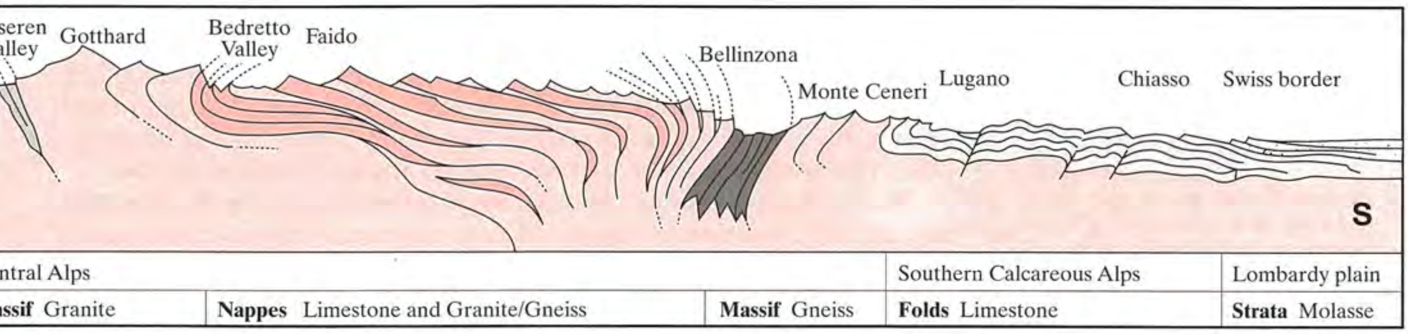


Fig. 1.3.5. Geographic setting of the Swiss Alps (modified from Bär 1979).



1.3.3.2 The pre-Alps

The north-western slopes of the Alps, the pre-Alps, have a complex structure, with peaks averaging around 2,000 m. This is also the realm of the Flysch deposits, which comprise a wide variety of marine sediments ranging from clays and marls to coarse sandstones and conglomerates, deposited during the orogenic period between late Cretaceous and early Tertiary. The soft Flysch bedrock is severely affected by torrents and easily eroded. Impermeable soils are frequently formed on Flysch bedrock. Along with a wet climate this makes it an ideal environment for the formation of mires, even on relatively steep slopes.

Molasse

A term originally used in Switzerland to describe the soft glauconitic sandstones, marls and conglomerates of Miocene age (but younger than the Flysch) found in the lower plains and plateaux surrounding the Alps. It is thought to have been deposited mainly in freshwater lakes, having been derived from materials worn from the recently uplifted mountain ranges. The term is now used to describe all detrital sediments of similar genesis laid down in foredeeps developed during the later stages of a major diastrophism (from WHITTOW 1984).

1.3.3.3 The Central Plateau (or Molasse Basin)

The Molasse Basin was formed during the Alpine uplift phase. Erosion was very active in the Alps, and torrents brought down enormous amounts of sand, gravel and pebbles which gradually consolidated to form new rocks: conglomerates and sandstones of Molasse deposits which in places on the Central Plateau reached thicknesses of nearly 4 km. During the ice ages, which ended some 10,000 years ago, these sediments were almost entirely covered by moraine deposits from Alpine glaciers, forming terminal and lateral moraines and drumlins. Glacial erosion and deposition have created an undulating landscape, a hill country studded with lakes, mires and with few large plains. Valley bottoms lie at 350 to 600 m. The hills in between are a few hundred metres higher, except towards the southern margin, where the morphological transition to the (pre-)Alps is gradual. At a mean altitude of 580 m, this wide plateau, stretching from Lake of Geneva to Lake of Constance, enjoys a milder climate than the Alps and the Jura Mountains. Lying as it does between these two chains, it forms a corridor which provides a natural setting for communications, commercial and cultural activity.

Cluse

A narrow deep gorge, trench, or water gap, cutting transversely through an otherwise continuous ridge; esp. an antecedent valley crossing an anticlinal limestone ridge. In the Jura Mountains, all cluses were formed by rivers which were present before the Jura's folding (modified from BATES and JACKSON 1987).

1.3.3.4 The Jura Mountains

The word "Jura" is Celtic in origin and means the forested mountain area. This is a limestone area which is not very high in elevation. With its delightful landscape of scarps, valleys and plateaux, these ranges have a much less complex structure than the Alps. They form a 300 km long crescent that lines the Molasse Basin in the west and north-west (Figs. 1.3.6 and 1.3.7). Two main rivers cross the Jura Mountains, the Rhône in the west near Geneva and the Aare in the east between Brugg and Koblenz. The Jura is a classic area for Middle Jurassic to Early Cretaceous stratigraphy and is also an interesting example of décollement folding. Its mean altitude of 700 m includes some peaks rising to around 1,600 m (Mont Tendre in the Vaud Jura reaches 1,679 m). Much of the southern Jura lies at about 1,000 m.

Not all parts of the Jura Mountains were folded. For this reason, the Jura can be roughly divided into the following regions (Fig. 1.3.8): the Tabular Jura (Fig. 1.3.9) to the north, and the Folded Jura which includes the Chain Jura (Fig. 1.3.10) to the south-east and the Plateau Jura to the north-west (Fig. 1.3.11). This entire area is related to the formation of the Alps. The Jura folds are relatively weak with regular undulations; they are at their maximum intensity at the south-western end of the Jura chains and diminish in amplitude and breadth toward the north-east. A cross-section shows that the highest folds occur at the edge of the Molasse Basin (Fig. 1.3.7). In the Tabular Jura (Fig. 1.3.9), the sedimentary layer has been uplifted and faulted but not folded.

Combe

A term used in France and Switzerland for a large longitudinal depression or valley along the crest or side of an anticline in the folded Jura Mountains, formed by down-faulting or more generally by differential erosion, often occurring along the line of junction of a hard limestone rock with one that is soft (modified from BATES and JACKSON 1987).

These different types of Jura structures show us that not only the formation but also the duration and efficiency of weathering determine the appearance of a landscape. In the Jura Mountains, the erosive effect of water is less obvious than in the Alps, where untamed waterfalls continuously erode the rocks. Most

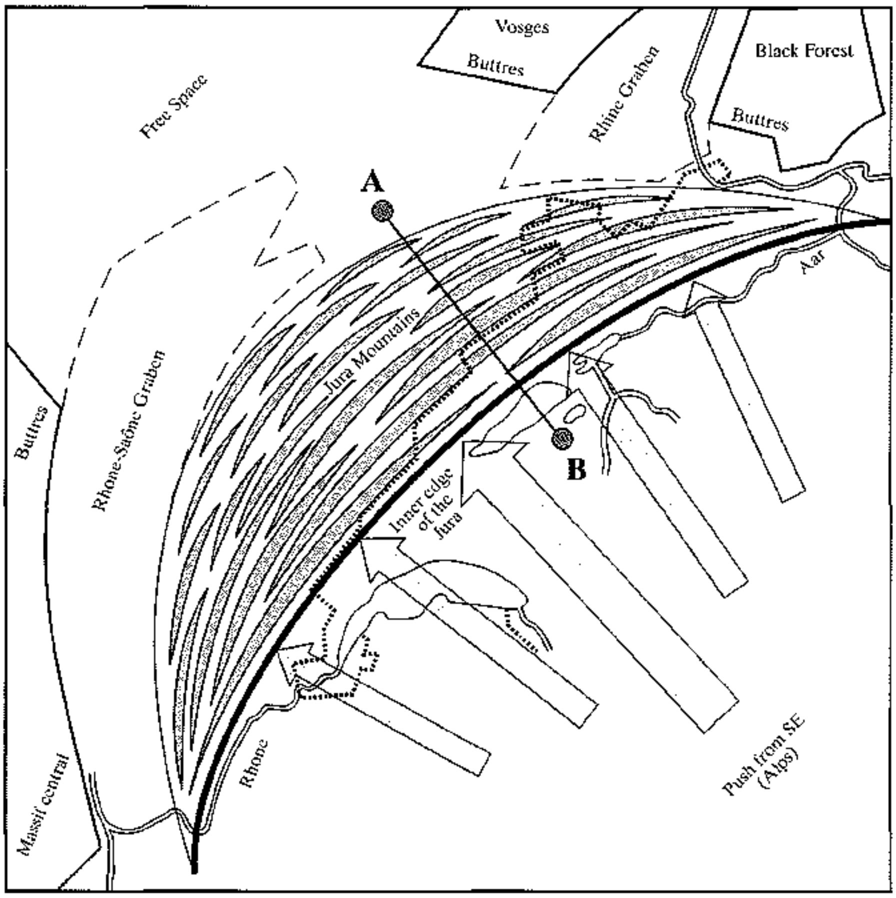


Fig. 1.3.6. The folding of the Jura Mountains (modified from BÄR 1979).

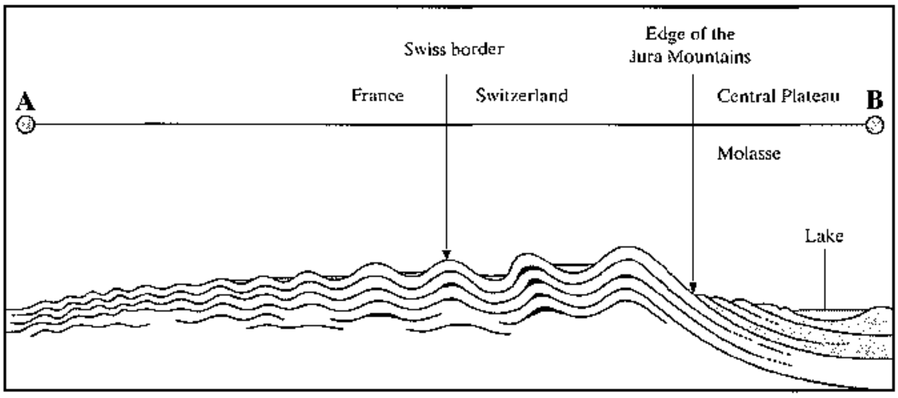


Fig. 1.3.7. Cross-section of folded Jura Mountains (modified from BÄR 1979).

Karst

A German rendering of a Slovenian term referring to the terrain created by limestone solution and characterized by a virtual absence of surface drainage, a series of surface hollows, depressions and fissures, collapse structures, and an extensive subterranean drainage network (modified from WHITTOW 1984).

of the erosion process in the Jura Mountains is hidden because large amounts of water disappear under the soil and flow underground. But the results of weathering and erosion on the surface of the earth over time is seen in cluses, a typical erosion feature in the Jura, or by valleys (combes), which have opened up along the crests of numerous folds (Fig. 1.3.12). From some of these valleys, rivers and streams have cut right through the mountain chains creating deep gorges in order to reach the Molasse Basin. In other places, water has penetrated the permeable limestone to form underground courses. In certain dead-end valleys, these streams disappear abruptly into dolines and swallow-holes, to reappear in a parallel valley or even as a Vauclusian resurgence at the foot of the range (Fig. 1.3.13).

One hundred litres of rain-water can dissolve 1.3 g limestone. Water with carbonic acid from the air or soil, however, can dissolve up to 20 to 30 g per 100 litres. Following limestone dissolution, increasing volumes of infiltration water widen underground rifts and cracks resulting in more and more water being drained under the soil.

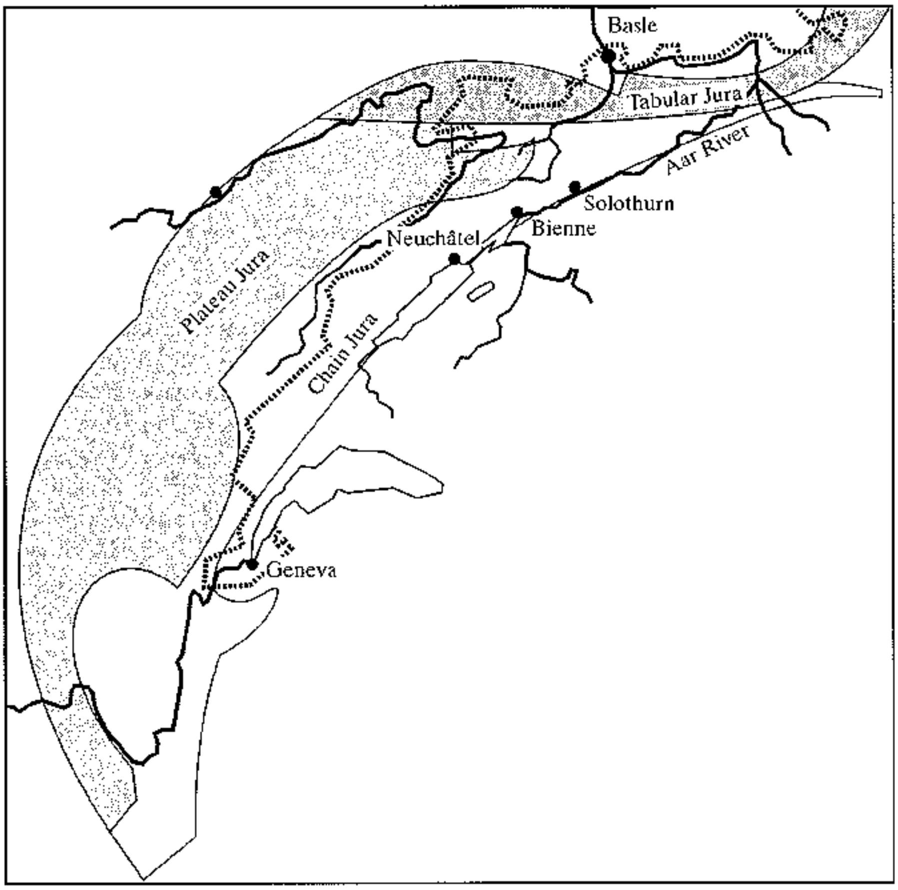
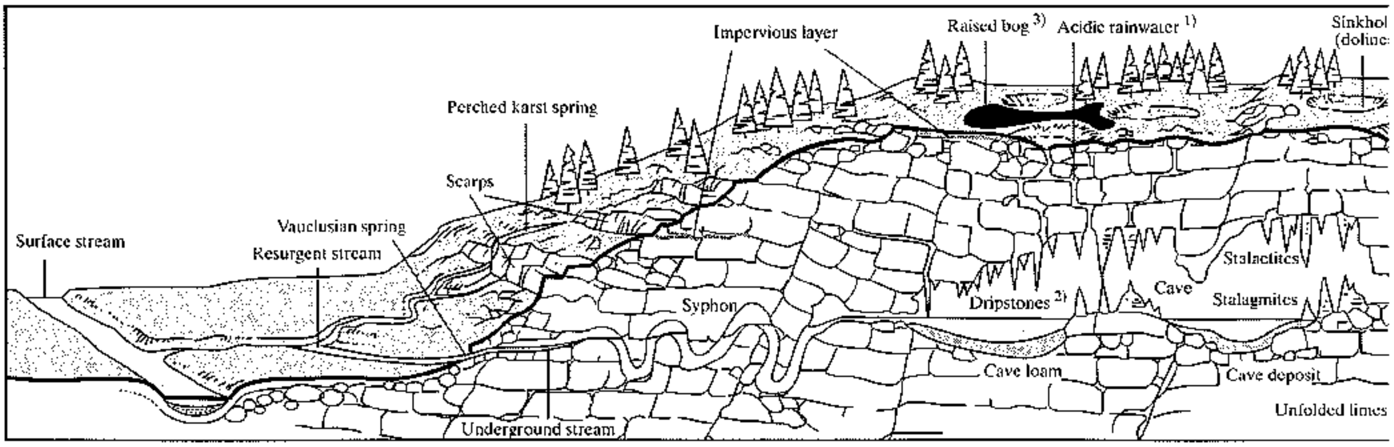


Fig. 1.3.8. The three different types of Jura Mountains (modified from BÄR 1979).

> ***Karren***
>
> *In karst topography, a general term for solution grooves ranging in width from a few millimetres to more than a metre, and commonly separated by knifelike ridges. Karren that originate under a soil cover are rounded and average about 50 cm wide, whereas those that originate at the surface are sharp and typically 1 cm wide. Etymol: German, 'wheel tracks' (modified from BATES and JACKSON 1987).*

All phenomena relating to limestone dissolution and underground drainage are called karstic features (Fig. 1.3.13). The formation of acidic bogs seems at first sight impossible in such a karstic environment rich in limestone and with little surface water. In fact, the bogs have developed in lowland areas on impermeable substrata, underlain either by fluvioglacial clay (for instance in Vallée de Joux, see Chapter 3.8; or in Bellelay, see Chapter 3.10), by marl previously exposed by erosion (for instance Etang de la Gruère, see Chapter 3.9), or by the products of the erosion of Tertiary sediments (for instance La Chaux-des-Breuleux, see Chapter 3.9).

Fig. 1.3.13. Karstic features (modified from BÄR 1979). 1) Acidic rain-water trickles through joints in limestone enlarging them. 2) Dripstones: Stalactites form as drops of water evaporate; stalagmites form as drops of water fall on cave floor. 3) In the Jura Mountains (and in other karstic terrain in Switzerland) raised bogs are only formed when impervious strata or layers appear at the surface. 4) Clints (blocks of rocks) and grikes (solution fissures) form limestone 'pavement'.



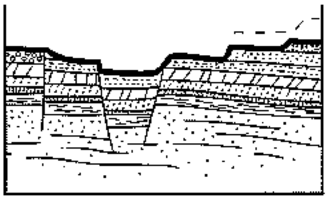


Fig. 1.3.9. The Tabular Jura: Block faulted, non-folded, fissured, scarped, and subsided (modified from BÄR 1979).

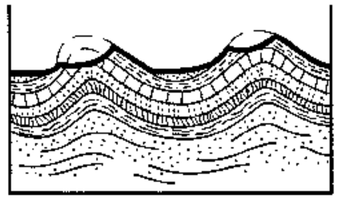


Fig. 1.3.10. The Chain Jura: Late and strongly folded, weakly eroded. Distinct chains with valley and ridge morphology (modified from BÄR 1979).

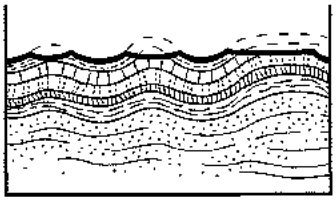


Fig. 1.3.11. The Plateau Jura: Early and weakly folded, strongly eroded. Slightly undulating peneplane surface. More resistant strata appear as small escarpments (modified from BÄR 1979).

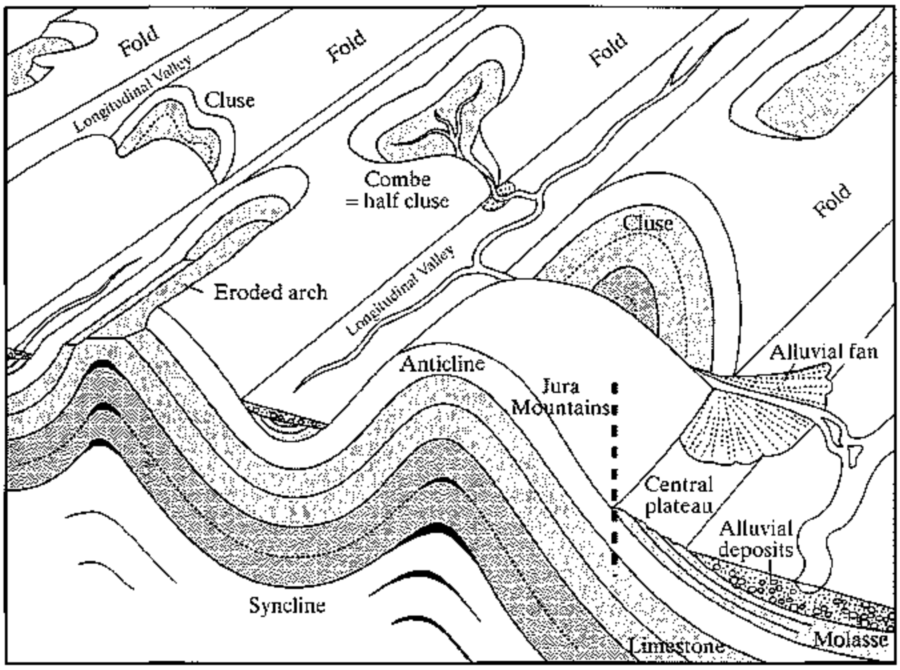
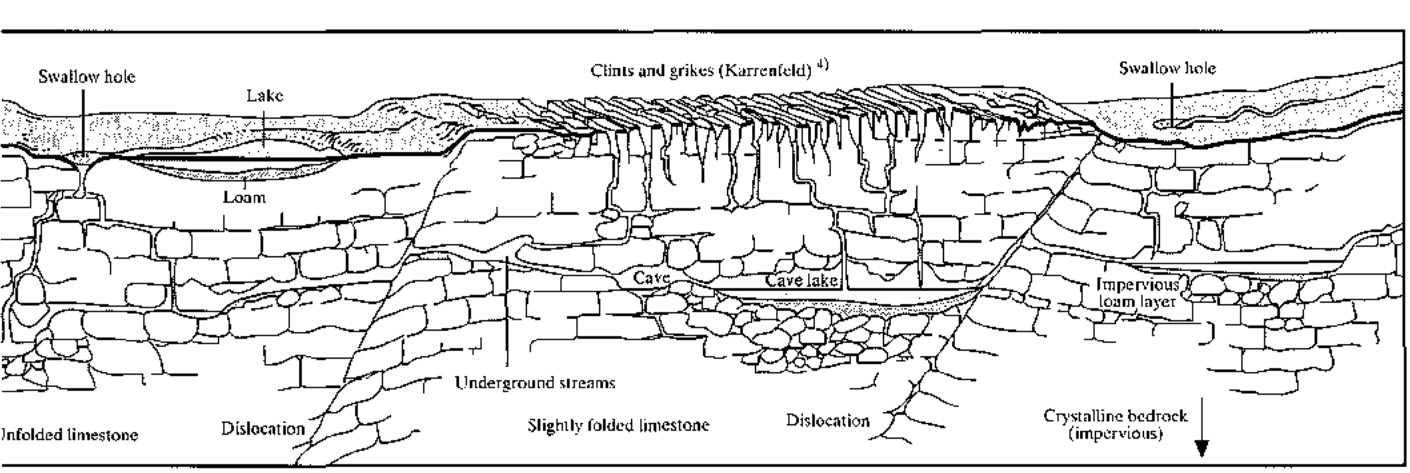


Fig. 1.3.12. The chains, valleys and cluses of Jura Mountains (modified from BÄR 1979).



This situation explains why the bogs in the Jura Mountains constitute an archipelago, in which the growth of each bog is limited by the extent of impermeable underlying deposits. The line between permeable and impermeable basal material is often clearly indicated by the presence of a chain of dolines (cf. Fig. 3.9.3).

1.3.4 Quaternary of Switzerland

(Adapted from TRÜMPY 1980 and SCHLÜCHTER 1986)

The morphology of Switzerland has been shaped to a large extent by the Pleistocene glaciers, and a large part of the country, especially of the Molasse Basin, is covered by Pleistocene moraine deposits, gravels, sands and silts. Despite this, Switzerland is not an ideal region for the analysis of Pleistocene events because strong erosion occurred during and between glaciations; few fairly complete sections have been preserved.

Switzerland lies near the Bavarian plain, where PENCK and BRÜCKNER (1909) established their classical scheme of four Alpine glaciations. Their theory was accepted in Switzerland with the following chronology:

- high-lying, often consolidated plateau gravels (Deckenschotter) corresponding to two earlier glaciations (Günz and Mindel), separated by an interval of slight erosion;
- strong erosion, development of the present river valleys and lake basins;
- Riss glaciation, covering almost all of Switzerland; moraine and gravel terraces lying somewhat above the present valley bottoms (gravels of high-lying terraces or Hochterrassen-Schotter) and also in overdeepened depressions;
- slight erosion;
- Würm glaciation, of much smaller extent than Riss. Well-preserved moraines and sandur gravels (gravels of low-lying terraces, Niederterrassen-Schotter) into which the present rivers have cut only a few metres.

The change from the deposition of plateau gravels to deep erosion by valley glaciers is attributed not simply to the extent of glaciers but rather to crustal movements. This deep erosion, assigned in the Penck/Brückner scheme to the Riss glaciation, was believed to be the most extensive in the sequence. However, the erosion must be older, for in the critical reference section at Thalgut, in the Aare River valley between Thun and Berne, WELTEN (1982) identified two interglacial strata separated by glacial sediments. The younger of the two could be identified palynologically as Eemian (last interglacial) and the older as Holsteinian or older (because of the presence of *Pterocarya* pollen) and thus pre-Riss. The erosional episode must, therefore, be of Mindel age or older. Furthermore, the plateau gravels south of the Black Forest are overlain by the till of this presumed Mindel glaciation.

The Riss glaciation (200,000 to 125,000 BP)

During the Riss glaciation almost the entire country was covered by an ice sheet (Fig. 1.3.14). For example, in the Central Alps, the valleys were filled with ice up to more than 3,000 m a.s.l. In some places it was over 1,500 m thick. In the Jura Mountains, the snow-line dropped to 800 m. The different glaciers can be distinguished by their typical boulder spectra. The Rhône Glacier overran part of the northern Jura and reached south-westward to Lyon (France); its meltwaters eroded some of the canyons of the Plateau Jura. Riss moraines are generally not very thick.

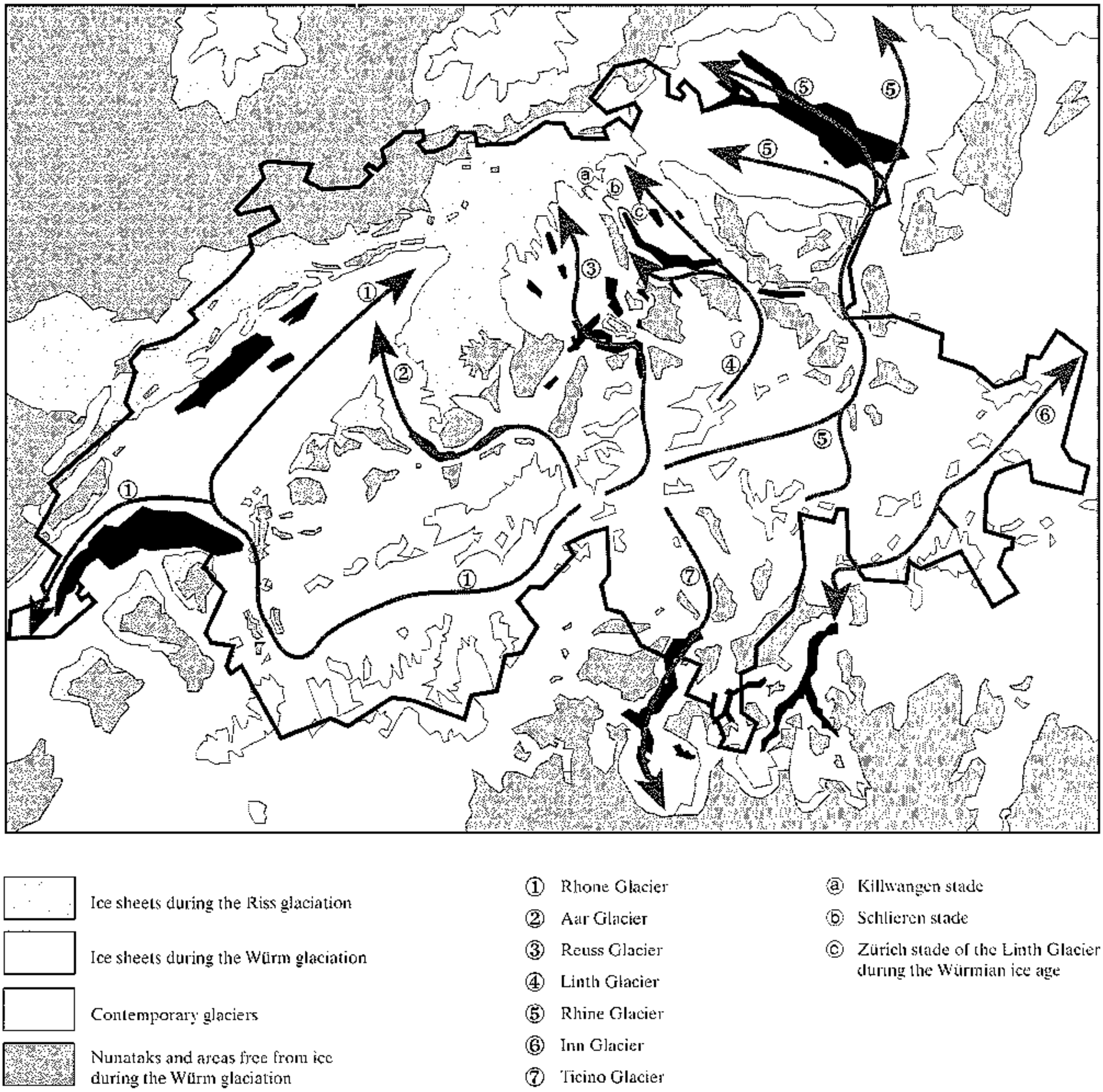


Fig. 1.3.14. Extent of Riss, Würm and contemporary glaciers in Switzerland (modified from IMHOF 1972).

The Würm glaciation (70,000 to 10,000 BP)

The Würm glaciers followed the same valley pattern as the Riss but were less extensive. The different ice streams are shown on Figure 1.3.14. The fluvio-glacial deposits in front of the prominent end moraines locally contain till, so it is possible that the Würm glaciation had more than one phase; in fact this is suggested by the oxygen-isotope stratigraphy of marine sediments. The main maximum moraines (Killwangen stade; cf. Fig. 1.3.14) were probably formed about 18,000–20,000 BP. However, locally, as with the Schlieren and Zürich stades in the Limmat-Linth valley, the retreat stages are marked by more strongly developed frontal and lateral moraines than the maximum or Killwangen stade. The snow-line depression (relative to the present snow-line of 2,500 to 3,200 m) during the Würm maximum was about 1,300 m (100 m less than during the Riss). Before and especially after the maximum extent of the glaciers, very thick clays, silts and sands accumulated in the lake basins. Extensive outwash gravels (gravels of low-lying terraces, Niederterrassen-Schotter) extended beyond the snouts of the glaciers and form important ground-water reservoirs; lakes filled the tongue basins behind the moraine crests.

Late Würmian and Holocene (15,000 BP to present)

The retreat of the glaciers into the Alps after 17,000 BP (leaving, for example, the moraines upon which the city of Zürich is now built) was very rapid. After the Würmian maximum, the ice sheet melted back to small mountain glaciers in only 3,000 years. Deprived of the ice which had acted as a buttress in the valleys, entire mountains collapsed in gigantic landslides (Sierre, Glaris, and Flims). The last of these was visited by the IMCG excursion participants (cf. HANTKE 1980, pp. 232–239; KIRCHEN 1993). A short readvance of the glaciers (Chur stade) covered these landslides locally with a thin veneer of moraine. During the Bölling and Alleröd interstadials that followed, the glaciers retreated far into the higher valleys. The advances of the Older and Younger Dryas periods were relatively modest. Strong postglacial sedimentation filled part of the lake basins (see Chapters 3.18 and 3.19) and separated some of the major lakes into several water bodies (Lakes of Neuchâtel, Bienne and Morat (cf. Chapter 3.6.2); Lakes of Thun and Brienz; Lakes of Zürich and Walen).

Outside of the areas glaciated during the various stages of the Würm and earlier glaciations, the cold periods left loess deposits, polygonal grounds and widespread traces of solifluction.

1.3.5 Substrata

Geological processes produced very varied and rather complex local patterns of substrata, often in close proximity (cf. Fig. 1.3.15).

The Northern Alps consist mainly of calcareous rocks (marl, limestone, calciferous sandstone, calcium-bearing schists etc.). Rocks poor in calcium carbonate are rather infrequent (for instance some schists in the Verrucano; the Flysch of the Glaris Alps east of the Linth and in the St. Gall Oberland; crystalline rocks in the Aar massif). The Central and Southern Alps consist mainly of siliceous rocks; they are mostly poor in calcium and weather to form soils rich in clay. However, calciferous rocks are well-distributed in the Bernese Alps west of the Lötschenpass, in the central and northern Grisons, the Lower Engadine and southern Ticino. Calcareous substrata may also occur in other areas. For instance, the schistes lustrés (Bündnerschiefer) consist of both calcareous and non-calcareous rocks (see Chapter 3.16). The substrata may have a decisive impact on the occurrence and formation of acidic bogs or calcareous fens.

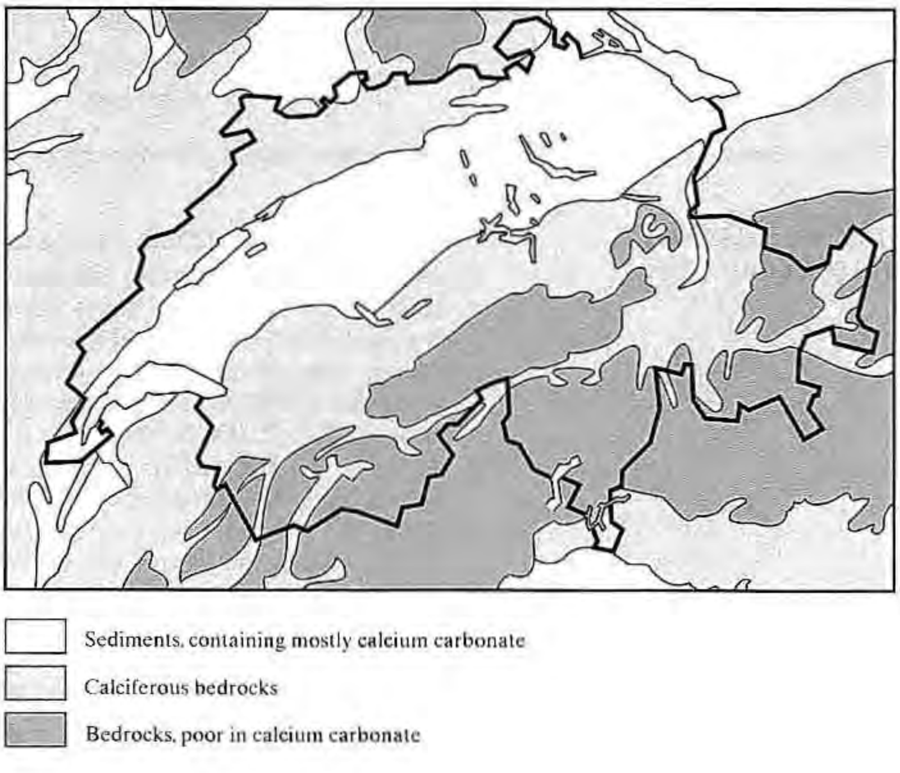


Fig. 1.3.15. Distribution of calcareous and non-calcareous rocks in Switzerland (modified from LANDOLT 1989).

1.4 Hydrological setting

1.4.1 The water balance of Switzerland

The water balance equation is as follows:

$$E = P - R - S,$$

where E is evaporation, P is precipitation, R is runoff, and S is storage. The calculations for Switzerland as a whole over a long-term period (1901–1980) yielded the following annual average values:

- Precipitation, 1,456 mm (compared to the European mean of 770 mm per year), 70% of which has an origin in marine wet air masses and 30% in vegetation;
- Runoff (of Swiss origin only), 978 mm;
- Incremental reduction in storage, due mainly to the melting of glaciers, – 6 mm.

According to the equation above, there are 484 mm left for evaporation.

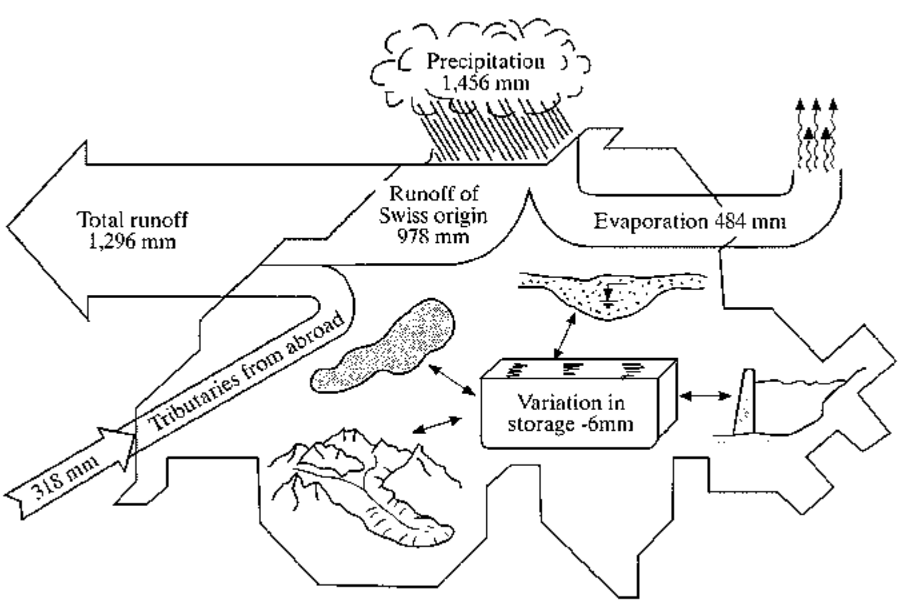
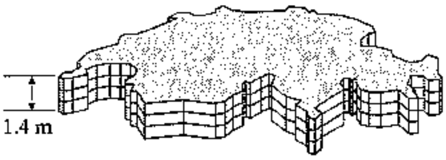
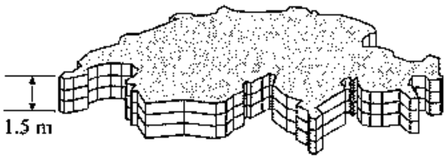


Fig. 1.4.1. The water balance of Switzerland (mean annual averages of the period 1901 to 1980; modified from HANTKE 1991).



a) Annual precipitation evenly distributed over the country



b) Volume of the glaciers evenly distributed over the country

Surface of the glaciers	1,342 km²
Average thickness of the ice	50 m
Volume of the glaciers	67 km³

Fig. 1.4.2. Comparison of the mean annual precipitation and the total volume of the glaciers in Switzerland (modified from BEZINGE and KASSER 1979).

Taking into account 318 mm from tributaries of the surrounding countries, the total runoff across Swiss boundaries increases to 1,296 mm (Fig. 1.4.1).

There are quite distinct differences between the catchment areas of various rivers. For example, precipitation in the hilly Central Plateau amounts to 1,070 mm, while in the outer ranges of the Northern and Southern Alps it is measured at 1,800 mm. Runoff lies between 460 mm in north-western Switzerland (that is, the region around Basle) and 1,450 mm south of the the Alps or within the catchment area of the rivers Limmat and Linth. Evaporation drops to 300 mm in Alpine areas and climbs to 600 mm in the low-lying Basle region.

Since the beginning of this century, the annual amounts of precipitation within all regions have remained virtually unchanged. On the other hand, evaporation in the same period has increased throughout the country to about 13% (equivalent to 60 mm). Correspondingly, the runoff has decreased by about 5%, with the rest compensated for by the melting of the glaciers.

Within the context of Europe, Switzerland has important freshwater resources: 132 km^3 in natural lakes and 4 km^3 in man-made lakes or reservoirs. In addition, the Swiss Alps have more glaciers and névé fields (see Fig. 3.12.5) than the rest of the other Alpine ranges. There are some 1,300 km^2 in all, or 3.25% of the country's surface, holding 67 km^3 of water. In contrast, mires cover only one quarter as much. In 1901, the Swiss glaciers were estimated to contain a volume of about 100 km^3. In comparison, the annual precipitation for all of Switzerland amounts to about 60 km^3 (Fig. 1.4.2).

1.4.2 Rivers and their catchment areas

The Alps' role as the European watershed is most apparent in the central Alpine region of Switzerland. From here the Rhône River flows west, the Rhine River east, the Ticino River south, and the Reuss River north. The fundamental Alpine source, however, is located in the Upper Engadine at Piz Lunghin, from where streams flow toward the North, the Adriatic, and the Black Seas (cf. Fig. 3.13.3). The Rhine drains 68% of the country's water into the North Sea. The Rhône (18%), the Swiss tributaries of the Po (9.3%) and the Adige (0.3%) drain 27.6% of the waters into the Mediterranean. 4.4% flows, via the Inn River, into the Danube and eventually to the Black Sea (Fig. 1.4.3).

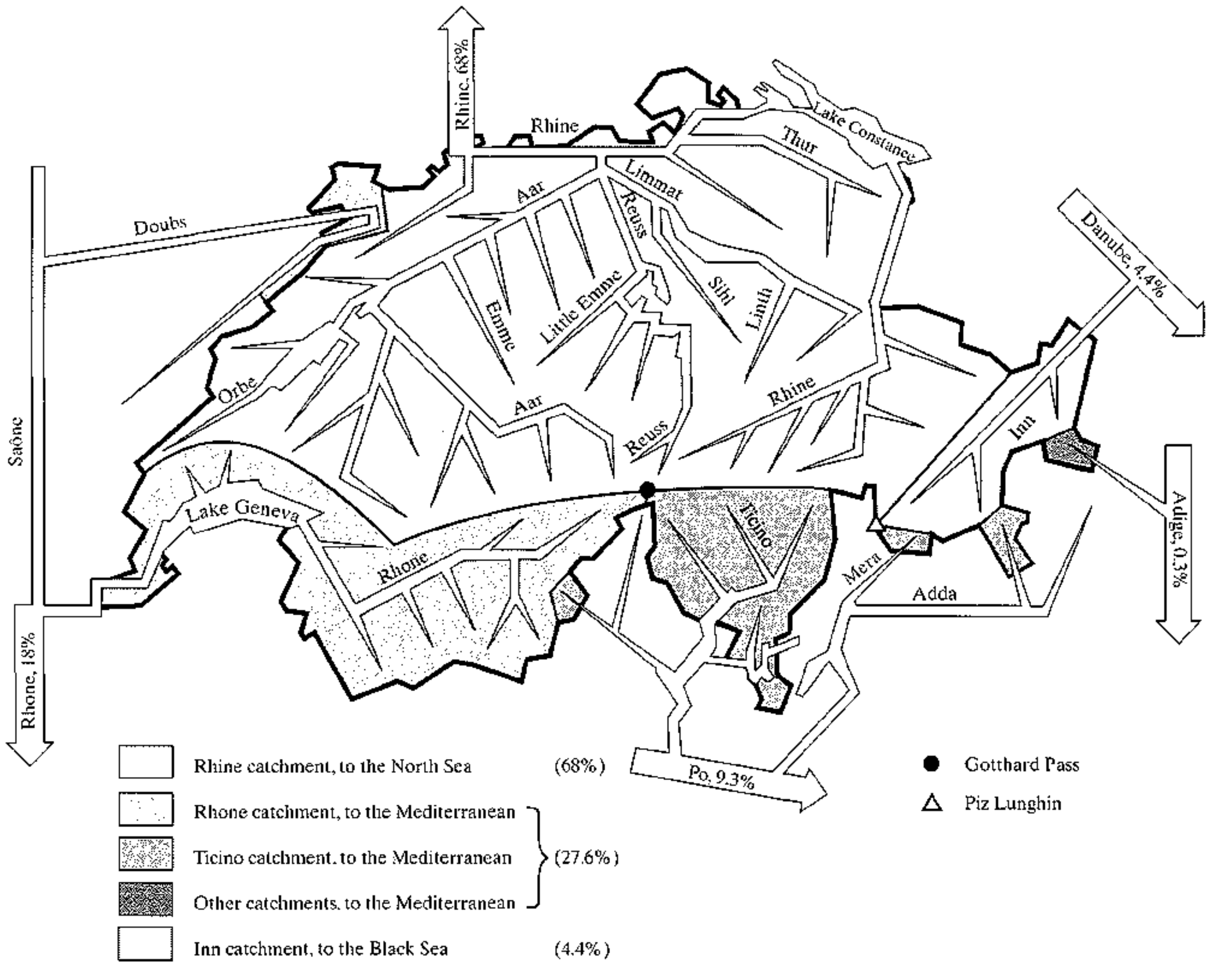


Fig. 1.4.3. Relative importance (as percentage of total land surface area) of catchments in Switzerland (modified from BÄR 1979).

1.5 Climate

Switzerland experiences every possible European climate. The Alps are essentially the dividing line between the differing climates of central Europe, but Switzerland as a whole is influenced by the four main European climatic types:
- in the west by the Atlantic climate, which is affected by the Gulf Stream and the North Atlantic Drift;
- in the east by that of the eastern European continent;
- in the south by the Mediterranean climate;
- and in the north by the middle European cyclonal climate.

These external factors and the varied relief of the country itself, with its sudden changes from mountain to plateau, give rise to many local and regional microclimates which can be both unexpected and quite remarkable. As early as the 18th century, Albrecht von Haller (doctor, Bernese naturalist, and explorer of the Alps, 1707–1777) remarked that "Helvetia has examples of all types of vegetation found in Europe, from the far north of Lapland ... right down to Spain". Details of Switzerland's climate are given in Institut suisse de météorologie 1982–1991.

1.5.1 Temperature

(The following text is mainly adapted from Landolt 1989.)

Air temperature

As altitude increases, the temperature decreases by an annual mean value of 0.55° C per 100 m. This temperature decrease falls to 0.4° C in autumn and winter, but climbs up to 0.7° C in spring and summer. The mean annual temperature in Zürich (425 m) is 9.6° C, in Seewis (953 m) it is 6.6° C, in Davos (1,561 m) 3.1° C, and at the Julier pass (2,237 m) it stays below zero (–0.7° C). Extreme annual mean values of temperature are found in Locarno (11.7° C; 379 m) a town situated in the south of the country, and on the Jungfraujoch in the Bernese Oberland (–8.0° C; 3,579 m). The mean temperature of the coldest month (January) varies between – 10° C (Bever, in the Upper Engadine; 1,712 m), and 2.4° C (Locarno). The corresponding numbers for the warmest month (July) are –1° C (Jungfraujoch) and 21° C (Locarno) respectively. The plant growth rate (and the peat accumulation rate) increases with increasing temperature up to some plant-specific (and peatland) threshold. The growth of plants in high altitudes with low temperatures is thus less vigorous than that of lowland plants. This is also true for plants from which peat can be formed.

Heat emission

Nocturnal heat emission becomes greater with increasing altitude. It increases by 40% between 300 m and 3,000 m. The temperature drop during clear and calm nights may be more than 20° C. Strong nocturnal heat emission in the mountains means frost danger almost throughout the year. Plants must, therefore, be frost-resistant, which is the case of most of Switzerland's mire-dwelling plants.

Large massifs

Large massifs have high mean altitudes above sea level. In Switzerland these are mainly the Central Alps, especially the Valais and the Engadine. During the daytime and in summer, they warm up more than isolated mountain groups such as the Jura Mountains or the Outer Alpine ranges (Fig. 1.5.1). Plants living in the Central Alps must endure more extreme temperatures than species inhabiting the Outer Alpine ranges. On the other hand, the plants are able to grow at higher elevations in the Central Alps because the diurnal temperature increase is stronger there. Warmth-loving (but frost-resistant) species which otherwise occur only in southern areas or steppes are able to grow at rather high altitudes in the central part of the Alpine chain.

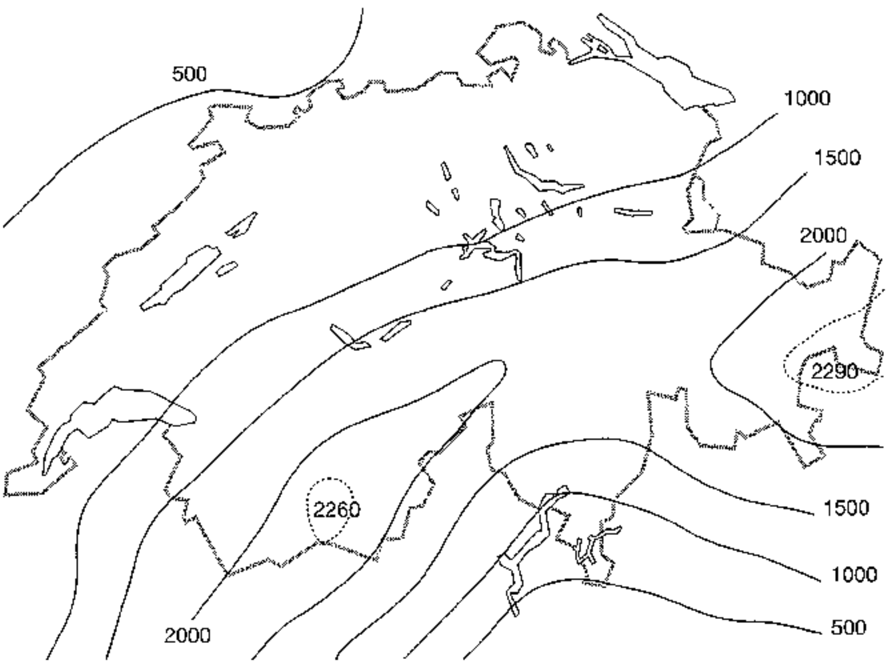


Fig. 1.5.1. Mean elevation above sea level [m] using cells 64 x 64 km (modified from LANDOLT 1989, after CADISCH).

Solar radiation

Direct solar radiation causes the soil to heat up more rapidly and with more intensity than the surrounding air. The soil also retains heat much better than the air. Owing to strong solar radiation at higher altitudes, the soil on the mountains becomes more heated than in the lowlands. Therefore, daytime temperatures in summer may be high but at night may drop drastically. Thus these areas are subject to very large temperature fluctuations. For instance, mean air temperature in July at 1:00 p.m. at 1,500 m is 14° C on the Rigi (an isolated mountain in the Northern Alps) but reaches 19° C in the Engadine, although the mean annual temperatures of these two areas differ from one another only by 0.5° C (Fig. 1.5.2).

The heat of the soil influences the air layers close to the ground; low-growing plants, taking full advantage of the warm air, are therefore common in the Alps. However, these soils dry out rapidly because of greater evaporation.

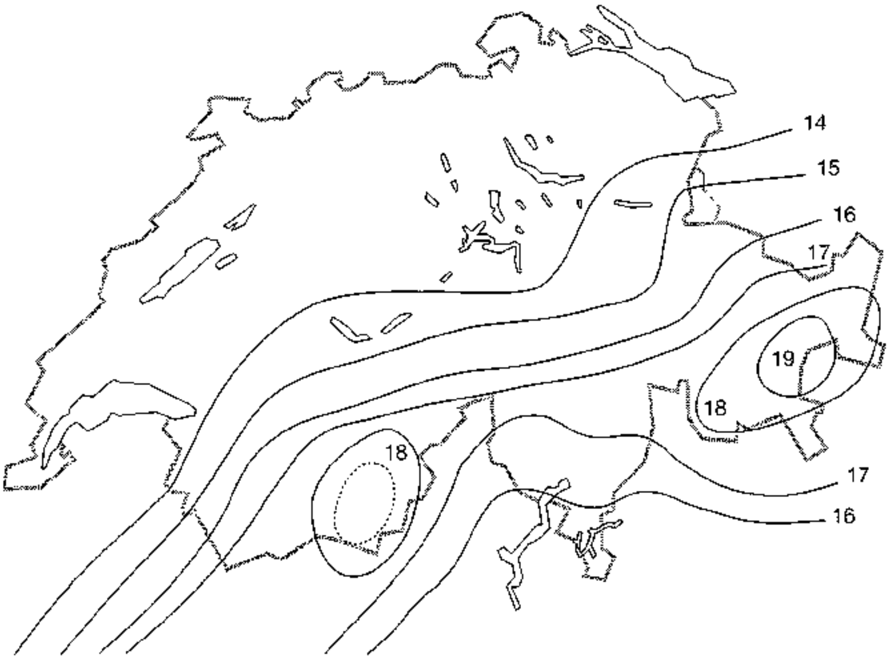
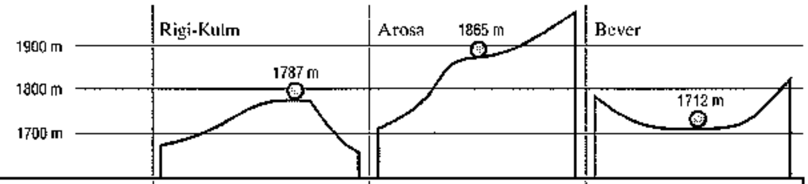


Fig. 1.5.2. Mean July temperatures measured at 1 p.m. and at 1,500 m [°C] (modified from LANDOLT 1989, after DE QUERVAIN).

Topography

Valleys and gullies are colder during the night and in winter than the surrounding slopes and hilltops. Bever (1,712 m) in the Upper Engadine has a mean January temperature of – 9.8° C, the Julier pass (2,237 m) – 8.3° C, whereas the isolated Rigi (1,775 m) has – 4.3° C (cf. Fig. 1.5.3). Frigid air, heavier than warm air, flows into valleys and gullies and becomes trapped there, forming frost hollows. Plants growing in valleys, gullies, and hollows must withstand extreme temperature fluctuations and prolonged periods of frost.



	Rigi-Kulm	Arosa	Bever
Mean January temperature	– 4,3°	– 5,1°	– 10,2°
Mean July temperature	9,8°	10,2°	11,4°
Mean annual range	14,1°	15,3°	21,6°
Climate type	small variation, rather oceanic		extensive variation, rather continental

Fig. 1.5.3. The influence of topography on temperature (modified from Bär 1979).

Light intensity

Light intensity increases with altitude. At 1,600 m, it is twice as strong in summer as at sea level, and in winter even six times as strong. The difference in light intensity between sunny and shady places also increases with altitude. At 3,000 m, light intensity is 6.5 times higher in the sun than in shadow, whereas at 2,000 m it is only twice as high. Increasing light intensity favours sugar synthesis (assimilation) in plants; in spite of low temperatures, plants are able to build up a sufficient amount of sugar. On the other hand, plants have to protect themselves from extreme intense light. They do so through pigmentation (cf. the colours of the *Sphagna*), hair density and cuticle thickness.

1.5.2 Precipitation

Switzerland has more precipitation (annual average of 1,456 mm) than most mire-rich regions in Europe. However, the amount, the forms (rain, snow, dew, deposition from fog) and the distribution of precipitation throughout the year vary greatly from region to region. The average annual precipitation of three-quarters of the country exceeds 1,000 mm. In comparison, 35% of Britain's land surface, 8% of France and 3% of Germany receives a similar amount (cf. Fig. 1.5.4).

Precipitation amount

Since rainfall tends to increase both in direct proportion to altitude (Fig. 1.5.5) and in proximity to the Alps, the precipitation map (Fig. 1.5.6) corresponds very closely to the relief map (cf. Fig. 1.5.1). Because of the marked variation in relief, differences in precipitation within short linear distances are often very great. For example, St. Gall, at 664 m, has an average annual precipitation of 1,329 mm, while that of the Säntis, 2,500 m but only 20 km away, is 2,785 mm (Fig. 1.5.7). At altitudes of 4,000 m precipitation rises to 4,000 mm. For example, the Mönch (4,099 m), in the Jungfrau group, has the highest average annual precipitation (4,141 mm) in Switzerland. It can be accepted as a rule of thumb that between 500 and 2,500 m, precipitation increases by approximately 100 mm per 100 m elevation.

Precipitation is particularly high in the outer ranges of the Southern Alps because they rise very steeply from the Lombardy plain. In contrast to the Northern Alps, precipitation is much greater and more intense. Thus the Southern Alps also experience rather long dry periods and especially strong solar radiation. This may explain why the mires in these regions are infrequent and usually small.

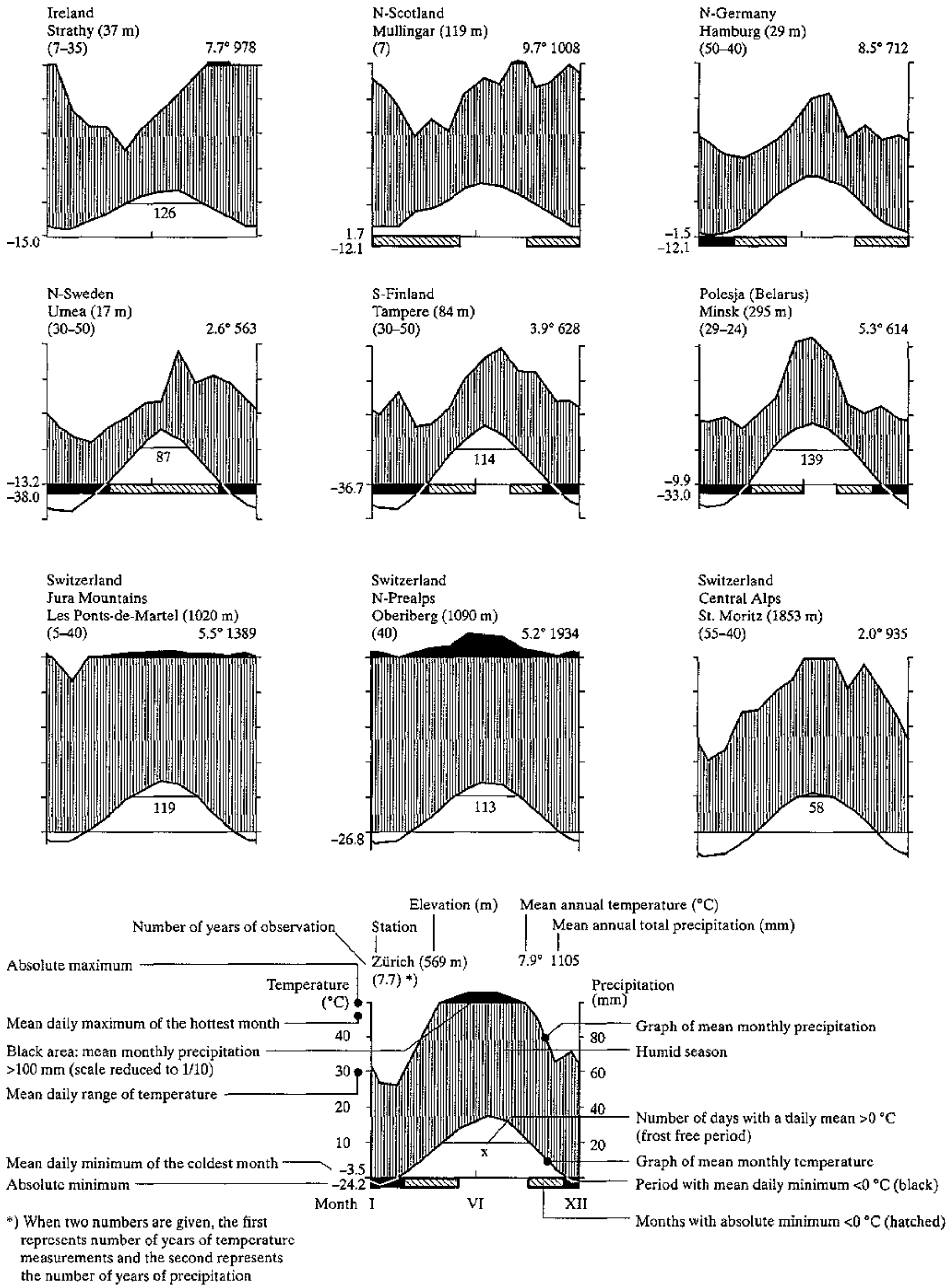


Fig. 1.5.4. Climate diagrams of three typical mire-rich regions of Switzerland in contrast to some mire-rich regions of Europe showing the relative abundance of precipitation in Switzerland (modified from WALTHER and LIETH 1960).

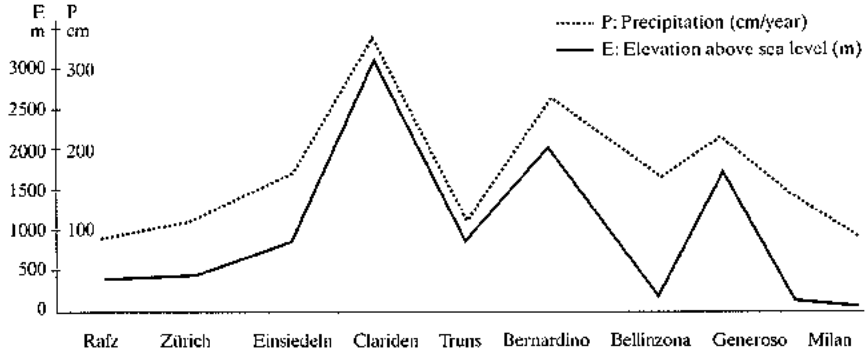


Fig. 1.5.5. Mean annual precipitation in Switzerland along a transect from Zürich to Milan (modified from LANDOLT 1989).

Fig. 1.5.6. Mean annual precipitation in Switzerland (modified from LANDOLT 1989, after IMHOF).

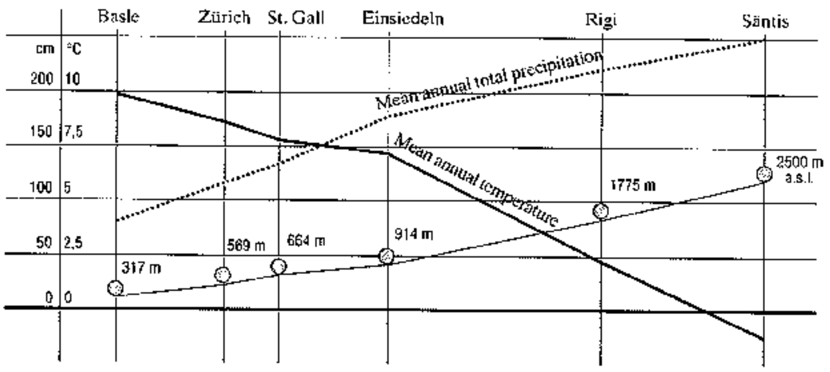


Fig. 1.5.7. The influence of altitude on temperature and precipitation (modified from BÄR 1979).

The rainfall in the enclosed valleys of the Central Alps contrasts sharply with that of the outer ranges. Scuol in the Lower Engadine (canton Grisons) has just 710 mm of rain and snow annually (cf. Fig. 3.13.6). Even less is recorded in canton Valais at Sion (590 mm) and at Staldenried (530 mm), a remarkable fact when you consider that the Matterhorn, just 30 km away, has five to seven times that amount annually. The low rainfall in the Valais plain means that farmers have to rely on an irrigation network to prevent drought.

Precipitation distribution throughout the year

Considering the accentuated relief of Switzerland, it is no wonder that there are also great variations in the distribution of precipitation throughout the year. The number of precipitation days (defined as a day on which 1 mm or more of precipitation is measured) ranges from an annual average of 130 days on the Central Plateau to 150 days in the western Jura Mountains and most parts of the pre-Alps. Up to 170 days are recorded in the (northern) outer ranges of the Alps. Within the enclosed valleys of the Central Alps, the annual average number of precipitation days may drop to 80.

Snow cover and snow-line

The southern town of Lugano (276 m) has a mild climate, with only 5% of the precipitation falling as snow. In Zürich (480 m) 11% is snow and on the Säntis (2,500 m) 72%. At altitudes above 3,500 m, almost all precipitation consists of snow which becomes compacted into perpetual snowfields (névé; see Fig. 3.12.5) and glaciers. The climatic snow-line (that is, the lower limit at which the snow on horizontal surfaces still remains in summer) is about 2,400 to 2,700 m in the Northern Alps, about 2,700 to 3,200 m in the Central Alps, and at about 2,700 to 2,800 m in the Southern Alps. This reflects the fact that the duration of the snow cover increases with altitude and that the snow limit changes with summer temperatures and with varying amounts of precipitation. On the Central Alps which face north, the average snow-free period amounts to nine months at 600 m. At 1,000 m, 1,300 m, 1,800 m, and 2,500 m, the snow-free periods are eight, seven, five, and two months, respectively. Thus, the snow-free period decreases in length by about ten days per 100 m upwards.

Since snow is a poor heat conductor, a thick snow cover protects plants from frost and desiccation during winter. It is also an important water reserve that keeps the soil moist later in the season. On the other hand, snow cover keeps light away from the plants: if the snow cover is 20 cm thick, only 5% of light can reach the plants. However, the plants are still able to synthesize sugar below a shallow snow cover provided the temperature does not fall much below 0° C.

1.5.3 Humidity

Despite high precipitation, the danger of desiccation for plants is generally more serious in the Alps than in the lowlands, because the absolute water content of air decreases with increasing altitude. At 2,000 m, the air on average is only half as moist as of the Central Plateau; it retains less moisture since it is less dense and cooler. During a period of fair weather, the air in the mountains may become exceedingly dry. Pronounced dryness of the 'pure' mountain air and strong desiccating winds cause a higher transpiration in plants growing high in the Alps (thus explaining the raging thirst experienced during trips into the mountains!) than lowland species living in otherwise comparable conditions.

A rapid replacement of the lost water is often hampered at high altitude because the soil is cold. This is especially true in the morning, when the soil is quite often only irrigated by melting snow or possibly even frozen. These phenomena are especially true for wet and cold peat soils.

1.6 Vegetation and mire types

During any excursion in the Swiss Mountains, a quite striking change in vegetation can be noticed with increasing altitude.

1.6.1 Altitudinal belts

Figure 1.6.1 gives a simplified schematic cross-section of the central Alps (from the Swiss Jura as far as the Ticino) showing the altitudinal belts and the natural dominant tree species on average sites. However, the boundaries between particular altitudinal belts are usually not sharp, being obscured by broad transitions or an inherent overlapping of various vegetation types. Human activity has also contributed to the complex situation where, in places, natural vegetation has been worn away. Notwithstanding these difficulties, changes in vegetation with changing altitude are easy to recognize. Temperature differences influence the occurrence and competitive abilities of given species. Lowland plants have their upper elevation limit in the Alps. Alpine species have both an upper and a lower elevation limit. Most plants are able to grow and to remain competitive within several altitudinal belts. Some, however, are confined to particular belts and are a characteristic component there.

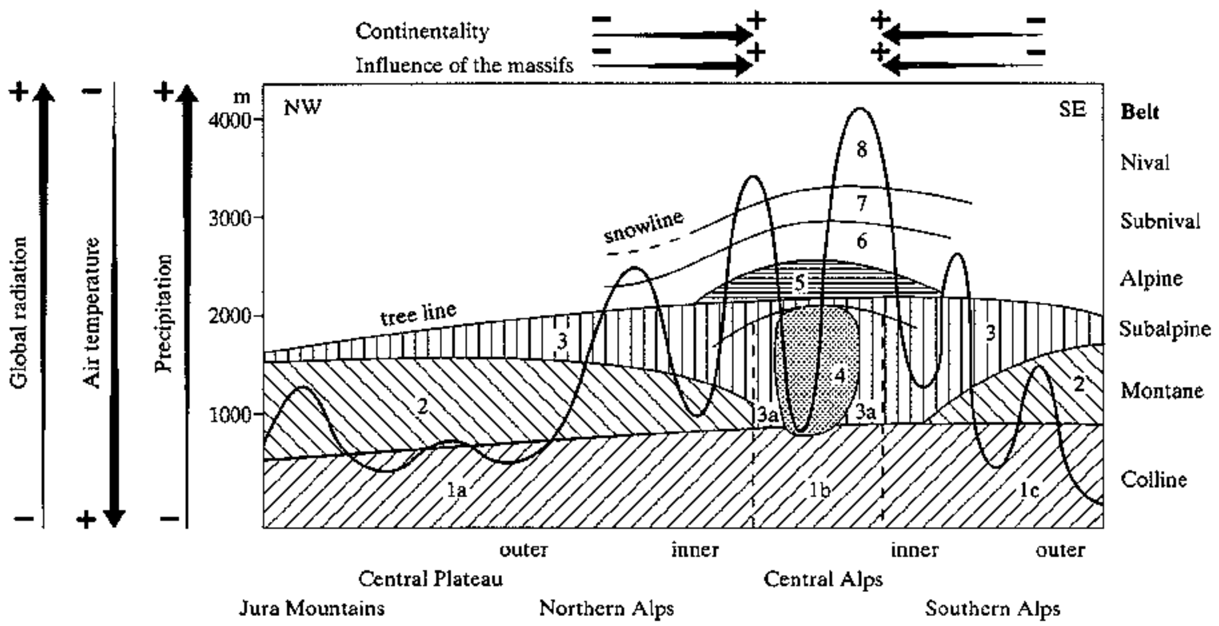


Fig. 1.6.1. Cross-section of the central Alps (from the western Swiss Jura as far as the Ticino) showing the altitudinal belts and the natural dominant tree species on average sites (modified from LANDOLT 1989, after KUOCH).

1 Colline belt (oak-beech belt).
1a The variant occurring in the Northern Alps which includes pedunculate oak *(Quercus robur)*, sessile oak *(Quercus petraea)*, hornbeam *(Carpinus betulus)* and much beech *(Fagus sylvatica)*.
1b The variant occurring in the Central Alps which includes white oak *(Quercus pubescens)* but no beech *(Fagus sylvatica)*.
1c The variant occurring in the Southern Alps which includes white oak *(Quercus pubescens)*, sweet chestnut *(Castanea sativa)* as well as beech *(Fagus sylvatica)*.
2 Montane belt (beech-silver fir belt) including *Fagus sylvatica* and *Abies alba*.
3 Sub-alpine belt of spruce *(Picea abies)*.
3a The variant occurring in the Central Alps which includes spruce *(Picea abies)* and Scots pine *(Pinus sylvestris)*.
4 Continental mountain belt of Scots pine *(Pinus sylvestris)*.
5 Supra-sub-alpine belt of Arolla pine *(Pinus cembra)* and larch *(Larix decidua)*.
6 Alpine belt (belt of low grassland).
7 Sub-nival belt of stabilized scree vegetation (mostly flat cushions).
8 Nival belt (no flowering plants except for local, sheltered places).

The snow-line and timber-line and the boundaries between the sub-montane, montane and alpine belts are higher towards the centre of the Alps. This is a result of the higher land mass and the more continental climate with its increased radiation. In the Central Alps the natural timber-line lies at 2,100 to 2,500 m and in the Outer Alpine ranges from 1,800 to 2,100 m (Fig. 1.6.1). In south-western sites, trees are able to grow at most about 100 m higher than in north-eastern ones. Here the colder winter, late frosts and the dry conditions exclude silver fir *(Abies alba)* and also beech *(Fagus sylvatica)* and other broad-leaved trees. The tree limit in the Central Alps is defined by larch *(Larix decidua)* and Arolla pine *(Pinus cembra)* and in the south by larch alone. In contrast to the conifer-dominated Inner Alps, both the southern and northern Outer Alps are rich in broad-leaved trees. In the north, the tree-line is defined by spruce *(Picea abies)*. In the south, the tree-line is formed by beech *(Fagus sylvatica)*, and this species plays an important part in all the oceanic mountain areas of Europe.

In our country true natural meadows and pastures are confined to areas above the timber-line. Meadow vegetation growing nowadays within the areas formerly occupied by forests relates only marginally and only at higher altitudes to the original Alpine grassland. In sites newly opened to colonization through clearing and thinning of forests, not only are typical grassland species able to compete successfully, but also plants of forests, mires, stream banks, cliffs, and screes. On wetter soils, the (former) widely-used practice of mowing and harvesting straw in the thinned and grazed forests in autumn gave rise to the development and expansion of the very typical litter meadows of the Alpine foothills (see Chapter 2.3). In the floodplains of the Central Plateau, similar management also led to the transformation of the forests and swamps into sedge litter meadows (Chapter 3.17).

1.6.2 Flora and vegetation history since the end of the last ice age

> ***Palynology***
>
> *The study of pollens and spores in an historical context, through observations of peat and sedimentary deposits, to interpret past environments.*

The development of vegetation in Switzerland (steppe, forest, Alpine meadows and cultivated land) since the late Würmian is reconstructed from pollen diagrams (e.g. Rotsee near Lucerne, Fig. 1.6.2). Syntheses over time and altitude are proposed in Figure 1.6.3 for the Northern and Central Alps and in Figure 1.6.4 for the Southern Alps. These diagrams also suggest the general rise of both timber-line and snow-line during the transition from late Würmian to Holocene and oscillations resulting from both climatic and anthropogenic influences. Ambiguity in the detail, particularly of the timber-line and snow-line may result from dating problems. Distant pollen transport may also blur the picture.

With the retreat of the Würmian ice sheet about 17,000 years ago, a heliophilous, treeless steppe vegetation spread in the ice-free areas. This consisted of grasses, *Artemisia*, *Ephedra*, Caryophyllaceae and mosses. At ca. 13,000 BP on favourable sites of the lowland Ericaceae, such as *Empetrum* and *Rhododendron*, willow shrubs and dwarf birch *(Betula nana)* rose above the low vegetation carpet ("Park tundra").

The Bölling Interstadial (13,000 to 12,000 BP) was characterized by the colonization of the lowlands by pioneer trees such as juniper and arborescent birches (*Betula pendula* and *B. pubescens*; as opposed to prostrate birches (*B. nana)*), associated with climatic warming after 13,000 BP. Both the timber-line and the snow-line rose to 1,500 m and 2,300 m a.s.l. respectively. During the Alleröd (12,000 to 11,000 BP), the incidence of *Betula* decreased, partly suppressed by *Pinus* trees (mountain pine and Scots pine) which immigrated and expanded rapidly.

> ***Nunatak***
>
> *An isolated hill, knob, ridge, or peak of bedrock that projects prominently above the surface of a glacier and is completely surrounded by glacier ice. Etymol: Eskimo, 'lonely peak' (modified from* Bates *and* Jackson *1987).*

Alpine plants and numerous northern species followed the retreating ice back into the Alps and were replaced in the lowlands by the immigrating forest species. On the basis of a certain congruence in the distribution of nunatak areas (cf. Fig. 1.3.14) and the present distribution pattern of these alpine-arctic species, it is assumed that outside the high Alps several such species were able

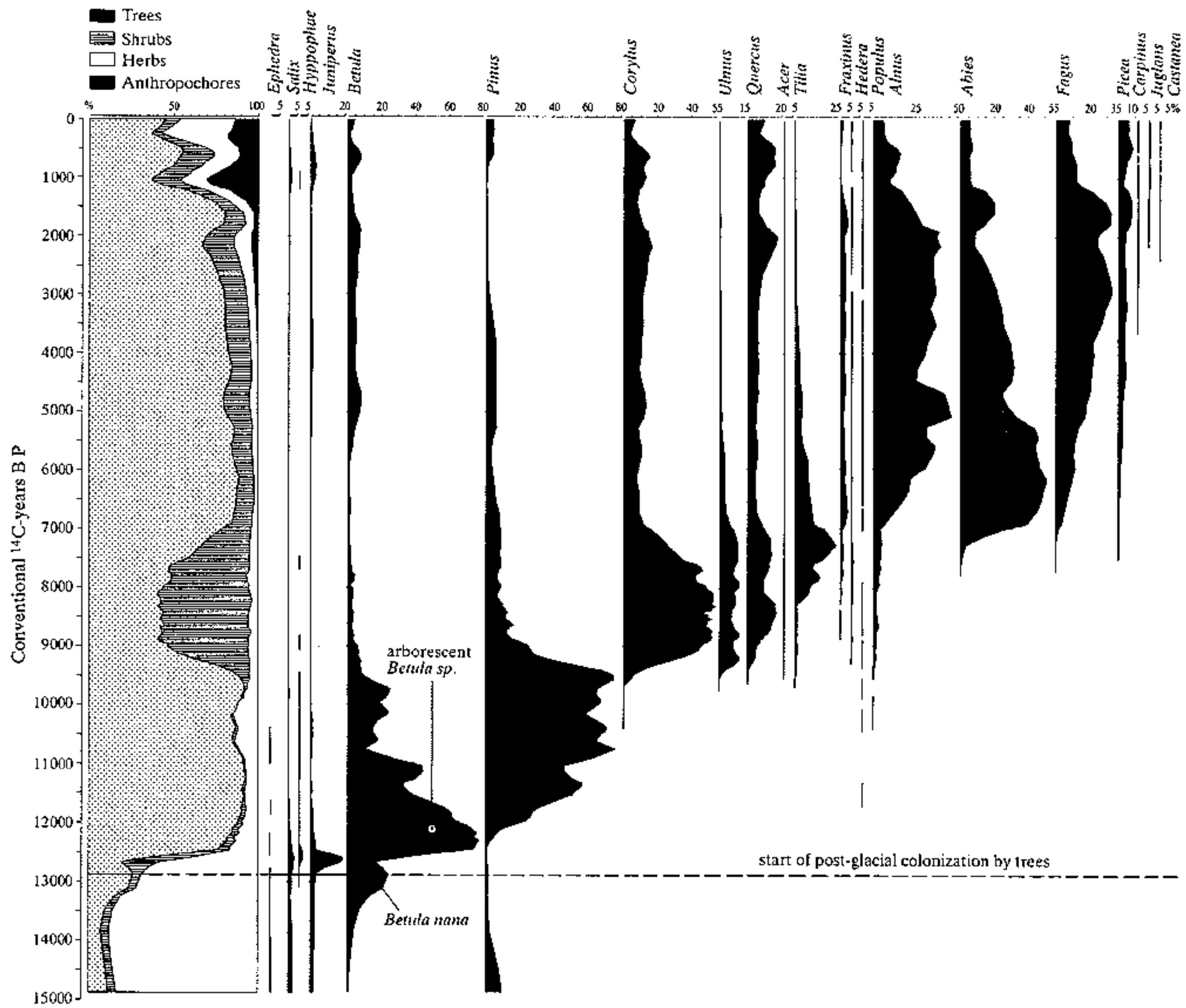


Fig. 1.6.2. Simplified composite (percentage) pollen diagram of deposits from the Rotsee near Lucerne showing the development of the main trees and shrubs in the postglacial period (modified from LOTTER 1990).

to survive in a few favourable sites (e.g. bogs, gullies, and north-facing slopes with scanty woodland). On the Üetliberg near Zürich – a nunatak during the last glaciation – dwarf mountain pine *(Pinus mugo)*, yellow mountain saxifrage *(Saxifraga aizoides)*, small bellflower *(Campanula cochlearifolia)* and paradoxal butterbur *(Petasites paradoxus)* have survived. Some alpine plants such as narcissus-flowered anemone *(Anemona narcissiflora)* or yellow gentian *(Gentiana lutea)* have been able to withstand competition from lowland taxa even outside the glaciated areas (as can be seen, for example, in canton Schaffhausen and in the Hegau).

Not all plants returned to the Alps. The Alpine foreland and Outer Alpine ranges are mostly built of calciferous substrata; a plant that is able to grow solely upon acidic soil which is poor in calcium, therefore, finds few places in these areas where it can grow and remain competitive. At some sites, calcium may be sufficiently leached from the uppermost soil layers, enabling calcifuge plants to grow. However, such soil changes frequently take hundreds of years. Many calcium-avoiding species were therefore unable to immigrate rapidly into the Alps and were either overwhelmed by better adapted plants thriving in a warm climate, or forced back into cold acidic bogs in the Alpine foreland or in the Jura Mountains. For instance, dwarf birch *(Betula nana)* occurs today only in a few bogs within the Alpine foreland (e.g. Einsiedeln) and in the Jura Mountains.

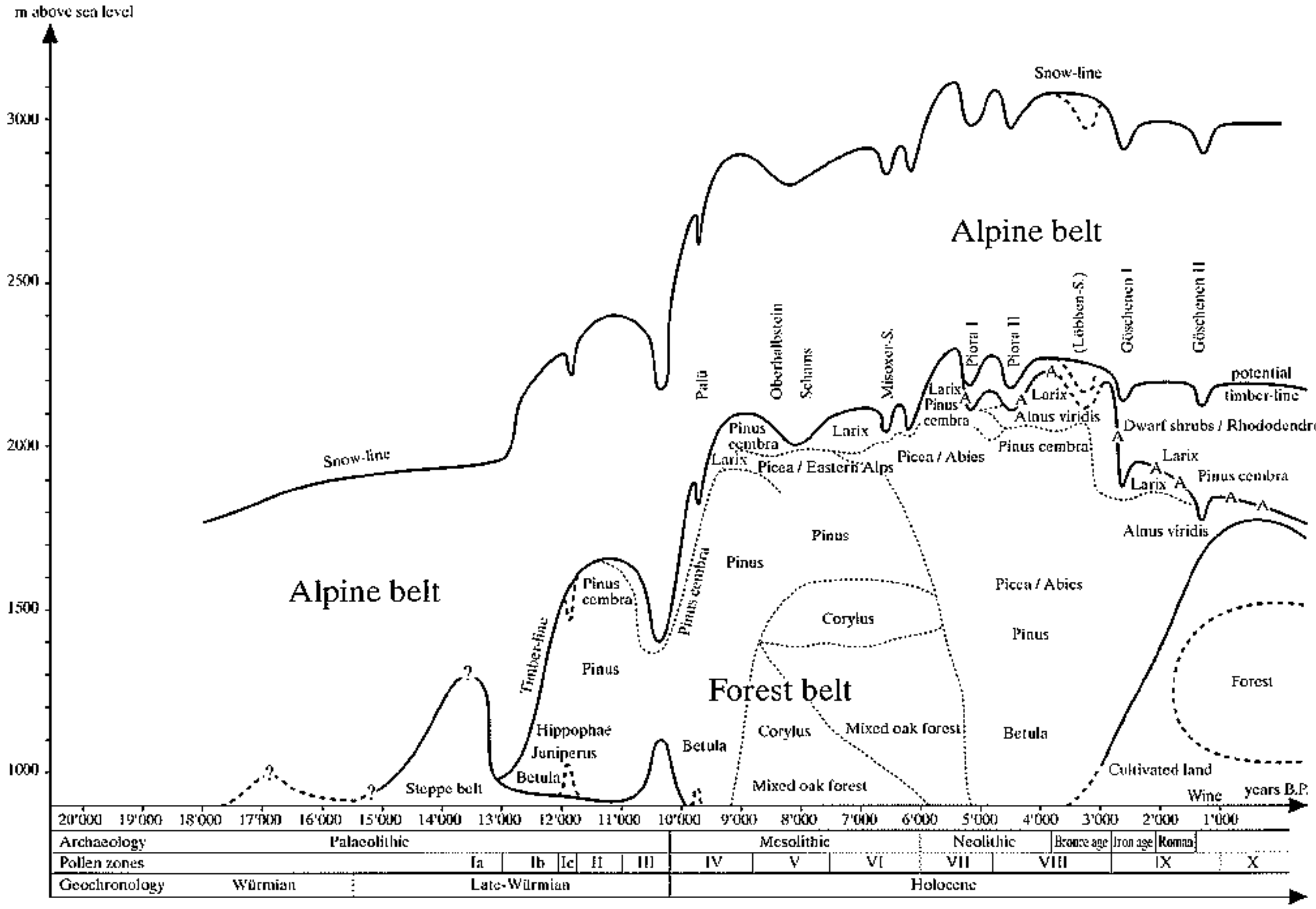


Fig. 1.6.3. Development of the vegetation belts in the northern and central Swiss Alps since the last Würmian ice age (modified from BURGA 1988). A: Timber-line depression due to anthropogenic influence. Palü, Oberhalbstein, ... Göschenen II: glacial readvances.

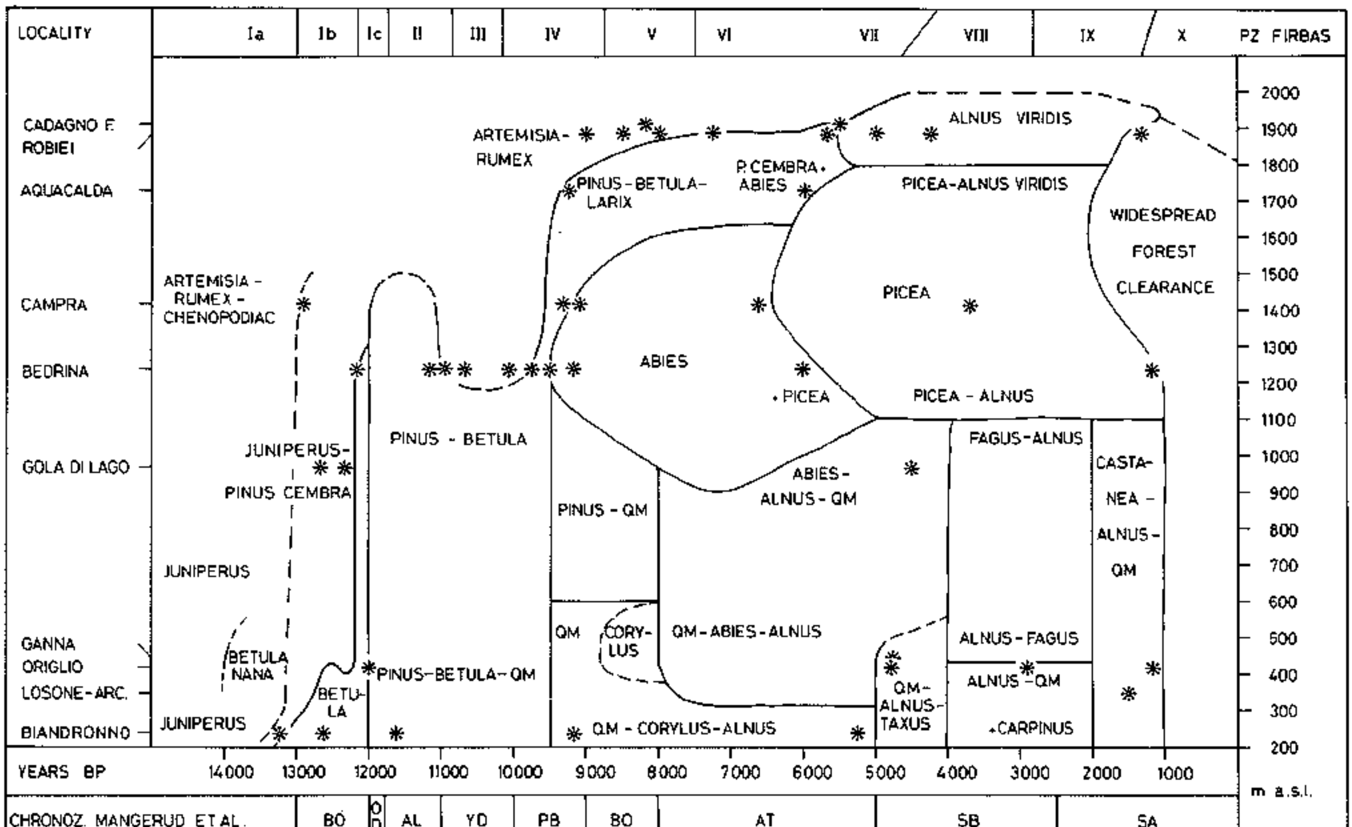


Fig. 1.6.4. Late- and postglacial vegetation development in the Ticino valley in the Southern Alps (modified from SCHNEIDER 1985).
*: 14C-dates; PZ Firbas: Firbas pollen zones (FIRBAS 1949); QM: Quercetum mixtum

The northern species, low birch *(Betula humilis)*, can be seen in Switzerland at present only in the area around St. Gall. Both these dwarf shrubs with small round leaves are, on the other hand, still widely distributed in the Arctic. Chickweed wintergreen *(Trientalis europaea)* which also belongs to this relic group, can be found at present only in very few places in Switzerland (Einsiedeln, Oberhasli near the Grimsel pass, Urseren valley, Morteratsch near St. Moritz, San Bernardino pass). At present, marsh saxifrage *(Saxifraga hirculus)*, another glacial relic, exists only in one mire on the Col du Marchairuz above Vallée de Joux. However, herbarium specimens show that this plant at one time occurred at least at 20 other (mire) sites, mainly in western Switzerland (WELTEN and SUTTER 1982).

The distinct climatic deterioration of the Younger Dryas (11,000 to 10,200 BP) was marked by a timber-line depression of 100 to 300 m in the Central Alps. Numerous steppe plants immigrated from eastern Europe, temporarily revitalizing a steppe vegetation before its final decline in the early Holocene.

The transition to the Holocene was characterized by a marked rise of both the timber-line and the snow-line to 2,100 m and 2,900 m respectively. It was a time when Mediterranean plants appeared from the south in the Ticino and in the valley of the Rhône River (south of Geneva); they proceeded north to the Valais and along the southern foot of the Jura Mountains. Hazel *(Corylus avellana)*, pedunculate oak *(Quercus robur)*, and other deciduous trees also appeared during the Preboreal (10,200 to 8,800 BP). Since the Preboreal, Arolla pine *(Pinus cembra)* and larch *(Larix decidua)* have formed the central-alpine timber-line.

This forest belt has been climatically influenced during the drier phases of the Boreal (8,800 to 7,500 BP). In some areas, it rose above the present timber-line.

In the Central Plateau, large mixed forests of oak appeared. In particularly warm sites, the southern forests of white oak *(Quercus pubescens)* developed which included many Mediterranean plants.

At the beginning of the Older Atlantic (7,500 to 6,000 BP), spruce *(Picea alba)* reached the Central Alps of the Grisons from eastern Europe (cf. Fig. 1.6.5). During the Atlantic, various shade-tolerant but late-appearing plants or so-called 'Atlantic species' arrived in Switzerland from the west. They found conditions suitable particularly in the Ticino and in western parts of the country. Beech *(Fagus sylvatica)* and silver fir (*Abies alba*; cf. Fig. 1.6.6), which colonized the southern side of the Alpine chain much earlier, expanded north of the Alps together with the late-comers. Spruce arrived even later. These trees pushed out oak and pine from middle and high altitudes in the Outer Alpine ranges.

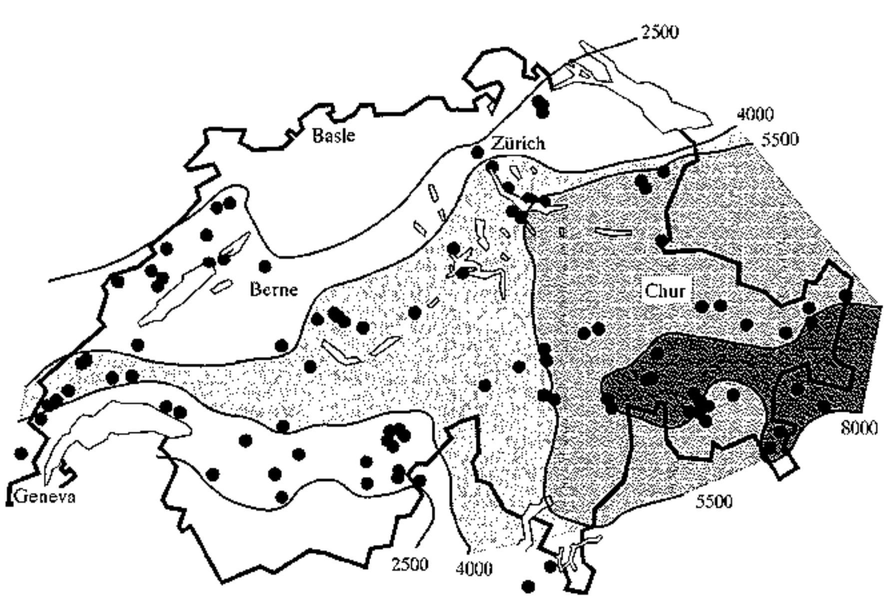


Fig. 1.6.5. The postglacial immigration of spruce *(Picea abies)* from east to west during the period 8,000 BP to present-day (modified from BURGA 1992).

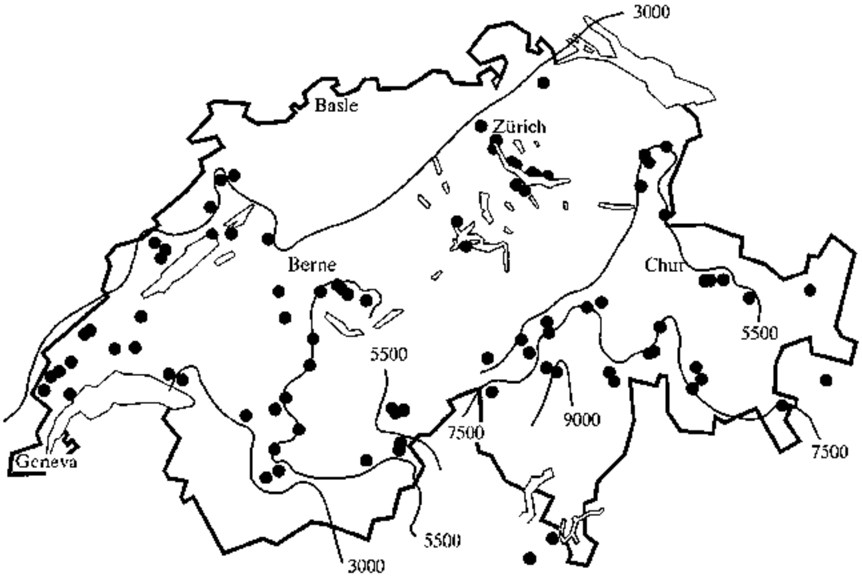


Fig. 1.6.6. The postglacial immigration of silver fir (*Abies alba*) during the period 9,000 BP to present-day (modified from BURGA 1992).

The development of the timber-line, which reached its highest altitude in the period 6,000 to 4,500 BP, provides evidence that the 'Holocene climatic optimum' can be conceived as embracing not only the late Atlantic period but also the early Sub-boreal. The first recognizable human impact on the vegetation in the Neolithic occurred during late Atlantic. It increased stepwise during the Bronze Age and Iron Age (cf. Figs. 1.6.2 and 1.6.3). Sweet chestnut *(Castanea sativa)* and walnut *(Juglans regia)* were introduced during Roman times.

1.6.3 A synopsis of Swiss mire types and their plant communities

Since the beginning of mire cultivation a distinction has been made between fenland and raised bog. Their differences can be seen best in the pre-Alps. The surface of a fen follows the local ground-water-table and is by and large horizontal. In contrast, a raised bog forms a more or less clear dome above the surrounding land, supplied by its own rain-fed water-table. Raised bogs and fenlands, therefore, differ in their nutrient contents and, as a consequence of their different water qualities, in pH. Within the series from fen to raised bog, the pH and the lime content decline, the contents of potassium, magnesium, as well as phosphorus and nitrogen.

1.6.3.1 Main mire types

a) Fenlands

Fenlands are fed by ground-water and can therefore develop even in the driest parts of central Europe. An example of this is (or was) the bottom of Rhône Valley which is situated in the rain shadow of the Alps of canton Valais and the Bernese Oberland, both of which reach altitudes of more than 4,000 m. In Switzerland during the past centuries most of the natural carr (fen woods; American: swamps) have been replaced by treeless communities, such as acidic soil small-sedge fens, calcareous small-sedge fens or tufted sedge swamps (American: freshwater marshes). These communities are prevented from reverting to woodland again (by means of occasional mowing). Apart from this there is very little human impact on these semi-natural sites, which can be regarded as permanent communities (Dauergesellschaften). In mires and swamps which are either too wet for the growth of trees or where no trees exist for other reasons, a large number of plant communities can be found, reflecting the great variety in origin and quality of the water supply (cf. Tab. 1.6.1).

b) Raised bogs

The formation of raised bogs is linked to a local topography suited to maintain a consistently high water-table and to moderately humid climatic conditions, with sufficient precipitation and low evapotranspiration. Intense rainfall and an air humidity that is too high are harmful to the growth of Sphagnum. In particular the hummock mosses (e.g. *Sphagnum magellanicum* and *S. fuscum*) cannot thrive if they are repeatedly submerged or dry out for too long. In Switzerland, raised bogs therefore developed mainly on slightly inclined planes and slopes with sub-oceanic and montane climates in the Jura Mountains, the northern pre-Alps and the montane and high-montane levels of the Outer Alpine chain at altitudes between 850 and 1,450 m a.s.l. (cf. Fig. 2.3.1). Because of the significantly higher radiation in summer (cf. Chapter 1.5.1), bogs can also be found in altitudes between 1,450 m and 2,300 m in the Central Alps (cf. Chapters 3.11 and 3.13). This indicates that a sufficiently high temperature and the length of the growing season are two other important conditions for bog formation. It therefore holds that the colder it is and the shorter the growing period the less growth there is by the mire. Thus under present-day climatic conditions, no true raised bogs can originate above the timber-line in the mountains (cf. Fig. 1.6.1).

c) Transitional mires

Sometimes it is impossible to distinguish between fens and raised bogs because they blend into one another both in space and in time. For this reason, and if one wishes to stress the successional aspect of mires, the term 'transitional mire' ('Übergangsmoor' in German) is useful.

Transitional mires range from extremely oligotrophic to fairly dystrophic (= rich in humic acids). Morphologically they are similar to fens, but ecologically they take an intermediate position in relation to their water supply by groundwater and precipitation. However, they are often found in close association with raised bogs and sometimes they may lead to these genetically. Where the ground is poor in bases, a transitional mire may develop from the outset, i.e. without a previous fen. Classic examples are floating mats surrounding oligotrophic or dystrophic pools or transitional mires which have developed on the extremely acidic and nutrient-poor sandstone outcropping in the Hohgant region in the Bernese Oberland.

1.6.3.2 Hydrologically defined raised bog types

According to their hydromorphology and geomorphological location, five main categories of raised bog can be distinguished in Switzerland:

a) Blanket bog
b) Plateau raised bog (true raised bog)
c) Saddle bog
d) Sloping bog
e) Altitudinal bog (transitional bog in high altitudes)

a) Blanket bog

A very wet climate with cool summers, as in Ireland and north-west England, leads to a bog on which trees cannot grow. Here, conditions are favourable for the formation of a blanket bog growing luxuriantly over everything and covering the whole terrain. There are only suggestions of this type in Switzerland and then only at the montane and sub-alpine levels of the pre-Alpine region (cf. Chapter 3.1 and Klötzli et al. 1973, p. 61).

b) Plateau raised bog

The plateau raised bog may also be called the 'true' raised bog. In central Europe it is naturally the most plentiful, especially in the area where beech *(Fagus sylvatica)* dominates the woodlands. In the Swiss Central Plateau true raised bogs may rise to a number of metres above the very wet zone round the edge, where the water draining from the raised bog collects and joins the water draining from the surrounding mineral soils. These surrounding swamps (called 'lagg' following the Swedish example) consequently show the characteristics of a fen. Raised bogs in the mountains may also have surrounding swamps; they may occur in depressions and on slopes as well as on level ground. Due to the characteristics of the relief most of the raised bogs in the mountains have a very limited extent. Despite their limited extent, most of the true raised bogs in Switzerland were probably free of trees in their natural state. Only the better-drained marginal slopes near the lagg supported a more or less dense stand of trees.

Today, these sites – especially the lagg zones – have been destroyed and are now almost absent in the Central Plateau region. In the mountainous area, many raised bogs are impaired by drainage ditches and are, therefore, largely covered by trees. This is also true for many of the raised bogs in the Jura Mountains (cf. front cover).

c) Saddle bog

Saddle bogs can mainly be found on passes or on similar geomorphologic features. Frequently they are ombro-soligenous and their formation was triggered by local waterlogging, which led by means of paludification to mire-expansion both in upward and downward directions of the hydrological gradient. Due to the permanent influence of the surroundings, saddle bogs quite often remain in the stage of transitional bogs. Intact saddle bogs have become rare in Switzerland. In most cases they have been destroyed by construction of roads and buildings or inundated by hydro-electric plants.

d) Sloping bog

Sloping bogs are widespread in the northern pre-Alps, mainly on Flysch soils. They are the most frequent of all the Swiss raised bog types. Bogs normally form because of an impermeable substrate on a slope which is sufficiently waterlogged. The steeper the hydrological gradient, the more regular seepage is needed to maintain the permanent waterlogging which is crucial to the accumulation of peat. In the upper parts of a sloping bog, the supply by minerals remains relatively high due to a constant influx from mineral soil. Here, the mire still has the characteristics of a fen. As it flows down the slope, the water becomes poorer and poorer in minerals and finally oligotrophic. Deer-grass (*Scirpus cespitosus*; cf. altitudinal bog in the next paragraph) quite often prevails here. The lower part of the bog can become purely ombrotrophic and dominated by *Sphagnum*. Peat mainly accumulates in the lower parts of the bog under these conditions. Sloping bogs, therefore, have a tendency to grow against the hydrological gradient (cf. Chapter 3.16).

e) Altitudinal bog

In the alpine belt, peat can form only in specific places: areas which are free from snow long enough for a noticeable amount of plant material to be produced, and where the ground is saturated or even under water for the entire growing season. Peat is formed very slowly under present-day climatic conditions in the alpine belt. Many of the thicker peat layers were formed during the Postglacial warm period (Atlantic – about 3000 BC) when the climate was warmer than today. At that time, bogs were growing at higher altitudes (and latitudes) than would be possible at present. These sub-Alpine and Alpine (and polar) bogs are no longer actively growing. On the contrary, they are gradually being eroded by cattle trampling, frost-heaving, snow action, heavy rain, drought and wind. In many cases the original contiguous peat has been divided by rills into entirely separate remnants and mounds of peat. Altitudinal bogs must, therefore, be considered as sub-fossil and very sensitive to external disturbance. This is especially true of those formations resembling raised bogs, which now never form above the tree-line.

As a consequence, true raised bog vegetation is limited in altitudinal bogs to isolated peat mounds and smaller elevations. To some extent the vegetation pattern is similar to the northern palsa mires. However, through the influence of snowmelt even the peat mounds are quite minerotrophic (cf. Chapter 3.13.5). The intervening flushes are covered by rather minerotrophic vegetation. Altitudinal bogs, therefore, can be classified as mixed (or transitional or intermediate) mires. These mires are not entirely without *Sphagnum* communities. Nevertheless, they do play only a subordinate role to the deer-grass *(Scirpus cespitosus)* which dominates large stretches of the more or less level mire surface, turning a uniform yellowish-brown colour in the autumn.

For the classification of the minerotrophic fenlands refer to SUCCOW (1988) and STEINER (1992).

1.6.3.3 Description of mire plant communities

As mires are a product of plant communities, it was suggested that they should be characterized by them. In consequence, the IMCG defines a mire as a wetland with vegetation that is usually peat-forming (cf. Chapter 4.2.4). Long before this international definition of a mire, which was accepted during the Field Symposium in 1992, the Swiss mire habitat inventories used vegetation types based mainly on plant sociology to identify mire habitats (cf. Chapter 2.3). This presents difficulties as most of the surveyed sites were covered by a vegetation consisting of a number of plant communities of dissimilar systematic rank growing alongside each other. Thus the following section, based mainly on ELLENBERG (1988), aims to take only a glance at several features of mire vegetation which are characteristic of Switzerland and the Alps (Tab. 1.6.1). For a more comprehensive description of vegetation and plant sociology of pre-Alpine and Alpine mires refer, for instance, to KLÖTZLI (1973), DIERSSEN and DIERSSEN (1984), and STEINER (1992).

In the following paragraphs, some descriptions of mire plant communities, including those replacing the natural ones, are given. The order of these community descriptions follows the plant sociological classification principles which distinguishes between five ecologically different main vegetation types. It aims to represent an ideal vegetation series from eutrophic, base-rich reed bed to oligotrophic and acidic raised bog (cf. Tab. 1.6.1).

a) Reed beds and tall-sedge carr (rich fen; Phragmitetea)

aa) Reed beds
(Scirpo-Phragmitetum typicum)

Reed *(Phragmites australis)* is the most competitive central European wetland plant, comparable to some extent to beech *(Fagus sylvatica)* amongst the land plants. Its ecological and sociological amplitude extends from lime-oligotrophic and acid-oligotrophic to eutrophic water and from shallow water to never or only periodically flooded moist soil. Phragmites requires a certain dormancy period in winter to be able to develop properly. However, the need for warm conditions imposes a clear limit on its distribution in the alpine belt. So far as is known, Lej da Staz (1,800 m a.s.l.) in the Upper Engadine is the highest place in Switzerland where typical reed beds can be found (see Chapter 3.13.5).

Other reed bed types which occur are the sub-associations of *Scirpus lacustris* and of *Typha latifolia*.

Table 1.6.1. A synopsis of the different Swiss mire types and their plant communities. The dominant plant growth-forms and the range of some ecological factors are also shown (modified from ELLENBERG 1988, p. 315). The lower case letters (aa to dd) refer to the corresponding section of this Chapter. For * see insets at foot of page.

		Mire type				
		Fens			Transitional mires	Raised bogs
	Trophic status	eutrophic*	oligotrophic*; lime-rich	oligotrophic; lime-deficient	oligotrophic to dystrophic*	dystrophic* (acid-oligotrophic)
Ecological factors	pH of peat	ca. 4.5–7.5	above 7.0	ca. 3.5–5.0	ca. 3.5–4.5	ca. 3.0–4.2
	Lime content	average to high	very high (lake marl)	low	very low	extremely low
	Content of other minerals	high	low to average	low	very low	extremely low
	Nitrogen availability	good to very good	poor to fair	fair to poor	very poor	extremely poor
	Decomposition degree of the peat	very high to fair	fair (to high)	fair (to high)	low to fair	very low
Dominant plant growth-forms	Trees and bushes	Alder-carr (Alnetum glutinosae); Willow scrub mire (Frangulo-Salicion auritae)		Bog-moss alder-carr (Sphagno squarrosi-Alnetum) (rare)	Birch fen wood (Pino-Betuletum pubescentis)	dd) Wooded raised bog (Pino mugo-Sphagnetum magellanici)
	Dwarf shrubs					Dwarf shrub heath (*Calluna* or *Vaccinium* mires)
	Tall monocotyledons and tall herbs	aa) Reed beds (Scirpo-Phragmitetum typicum) and other reed bed types with reed-mace *(Typha angustifolia)* or bulrush *(T. latifolia)*				
		ba) Meadowsweet fen meadows (Filipendulion)	bb) Purple moor-grass meadows (Molinion; litter meadows) (after clearing)		(after draining)	
	Tall sedges and tall sedge-like plants	ac) Tufted sedge swamp (Caricetum elatae)	ab) Saw sedge swamp (Cladietum marisci)	cca) Bottle sedge swamp (Caricetum rostratae)	ccb) Slender sedge swamp (Caricetum lasiocarpae)	
	Small sedges and small sedge-like plants		ca) Calcareous small-sedge fens caa) Bog-rush fen (Schoenetum nigricantis) cab) Davall's sedge fen (Caricetum davallianae) cac) Deer-grass fen (Caricetum davallianae trichophoretosum)	cb) Acidic small-sedge fens cba) Common sedge fen (Caricetum nigrae) cbb) Alpine cottongrass mires (Eriophoretum scheuchzeri)	cc) Floating mats and transitional mires cca) Bottle sedge swamp (Caricetum rostratae) ccb) Slender sedge swamp (Caricetum lasiocarpae) ccc) White beak-sedge community (Rhyncho-sporetum album)	dc) Deer-grass bog (Trichophoro-Sphagnetum compacti)
	Sward-forming mosses		Brown moss-rich communities (*Drepanocladus*- and *Calliergon*-species or other Hypnaceae)		Bog hollows ccd) Bog-sedge hollow (Caricetum limosae)	Bog hummocks da) Red *Sphagnum* hummocks (Sphagnetum magellanici) db) Brown *Sphagnum* hummocks (Sphagnetum fusci)
		Plant communities				

Dystrophic

A term designating water (or site) qualities that are characterized by a deficiency in nutrient matter and by a particularly high oxygen consumption. The water is brown or yellow and rich in dissolved humic material.

Eutrophic

Of high nutrient regime, with ample or even excess nutrients for plant growth present. By extension, used to describe species characteristic of very nutrient-rich habitats.

Minerotrophic

Nourished by ions in waters previously in contact with mineral sediment or rock.

Oligotrophic

Low in nutrients. By extension, used to describe species characteristic of this habitat.

Ombrotrophic

Ombrotrophic (raised) bogs are nourished only by the ions contained in atmospheric precipitation (for further explanation refer to Chapter 3.13.5).

ab) Saw sedge swamp (Cladietum marisci)

In plant sociology (STEINER 1992), the saw sedge swamp (Cladietum marisci) belongs to the alliance of the Phragmition. It occupies a unique place along the vegetational gradient because it only grows on lime-rich ground, has a low nutrient requirement, and does not tolerate large variations in the water level. In this respect *Cladium mariscus* is much more sensitive than *Phragmites australis* and under eutrophic conditions is a weak competitor against reed. In Switzerland, it often forms quite large stands in old peat pits which have been excavated to the lake marl layer.

ac) Tufted sedge swamp (Caricetum elatae)

The tufted sedge swamp (Caricetum elatae) is very striking with its big columnar tussocks growing up to a height of as much as 1.2 m. Due to these 'stool-like' tussocks, the plants can tolerate large variations in the water level. Today the Caricetum elatae still occupies wide stretches along the lakes of the Central Plateau and large areas of fenland in north-eastern Switzerland. In earlier times (cf. Chapter 2.1) it was valued as a source of litter for housed livestock. On the landward side the tussocks grow closer and closer together until only small water-eroded depressions remain betweeen them. It was at this well-developed stage that farmers preferred to mow the tufted sedge swamp for litter. In doing so they prevented this vegetation type from developing into an alder carr (Alnetum glutinosae), increasingly levelling the tussocks until they eventually achieved a turf-like sedge sward which was easy to mow.

The slender tufted sedge swamp (Caricetum gracilis), widespread and quite common in Scandinavia, is very rare on mires in Switzerland and Austria.

b) Fen meadows and litter meadows (Molinietalia syn. Molionio-Juncetea)

ba) Meadowsweet fen meadow (Filipendulion)

The meadowsweet fen meadow is typically found on moist, nutrient-rich and neutral ground, occurring on a variety of mineral and organic soils which are protected from grazing. This is especially true, for instance, of stream edges or ditches which accumulate nutrients from floods or from the mud and weeds regularly cleaned out of the water course. This tall-herb community is also seen in manured wet-soil meadows (Calthion). Provided it is not mown too often, it is mostly dominated by meadowsweet *(Filipendula ulmaria)*. Physiognomically these stands are reminiscent of the tall-herb communities in the pre-Alps and Alps. The methods of meadow management have been largely responsible for the present-day distribution of the Filipendulion stands. In Switzerland, MAYER (1939) devoted an ecological and phytosociological monograph to them.

In many areas extensive meadowsweet stands can be found where meadows have been abandoned. These never show the characteristic Filipendulion combination of species but they represent intermediate stages in the succession from the wet-soil meadow towards a woodland, although it may take a long time before the first willows and alders become established.

bb) Purple moor-grass meadows (Molinion)

In central Europe there is no other wetland community which is as rich in species and colour as the calcareous purple moor-grass meadow. The acidic soil purple moor-grass meadows (Junco-Molinietum), which can be interpreted as substitute communities of birch carrs (Betuletum pubescentis), appear to be impoverished floristically compared with the calcareous Cirsio tuberosi-Molinietum.

Both the calcareous and the lime-deficient purple moor-grass meadows can be divided into a number of sub-units reflecting the degree of soil moisture. To some extent, the same plants appear on both lime-rich and lime-deficient substrates in the relatively wet sub-communities. As one would expect, the drier sub-units differ most. The 'dry calcareous purple moor-grass meadow' has many species in common with calcareous, slightly arid grassland and is particularly rich in species. On the other hand the Junco-Molinietum on acidic soils shows affinities to mat-grass *(Nardus stricta)* meadows or even *Calluna* heaths, this tendency being stronger the lower the water-table is. For further information about *Molinia* meadows refer to Chapter 1.7.3.

c) Small-sedge fens (poor fen; Scheuchzerio-Caricetea fuscae; syn. Parvocaricion)

Small-sedge fens can be recognized by the dominance of small sedges, rushes, deer-grass or cottongrasses. Comparable to the purple moor-grass communities mentioned above, two main groups can be distinguished: The calcareous (lime-rich) and the acidic soil (lime-deficient) small-sedge fen fens. Due to rapid land use changes during the past few decades, both fen types have become fairly worthless to farmers as they have a low yield and at best can only provide fodder of low quality or litter. They have, therefore, been gradually disappearing through drainage and either being turned into more productive meadows or afforested (cf. Chapter 1.7.3).

ca) Calcareous small-sedge fens (Caricetalia davallianae; syn. Tofieldietalia)

The natural habitat of lime-rich small-sedge fens is the calcareous springs (helocrenes) in the sub-alpine belt. Here they achieve their richest development. Because of the lack of competition from quick-growing plants they have become the refuge of numerous helophytes otherwise rare in the central European flora. This applies not only to the helocrenes but particularly to the lime-rich and floristically exciting semi-natural small-sedge fen communities. At lower altitudes alpine and sub-alpine species are absent from the small-sedge fens which are brought about and maintained by mowing. Instead some meadow plants occur, such as purple moor-grass *(Molinia caerulea)* and devil's-bit scabious *(Succisa pratensis)*. These only achieve dominance where the water level has been lowered and they may eventually lead to a real meadow community (cf. Chapters 1.6.3.b and 1.7.3). Consequently, many different plant associations and sub-associations have been distinguished.

Although the Caricetalia davallianae show a very wide ecological amplitude (Dietl 1975), little scientific work has been done on the ecology of this species-rich plant sociological unit in Switzerland. It is only recently that sound studies have dealt with these mires, mainly in the western part of Switzerland e.g. by Yerly (1970), Bressoud (1986), Buttler (1987) and Giugni (1991).

caa) Bog rush fen (Junco obtusiflori-Schoenetum nigricantis)

In the Central Plateau and the pre-Alps, a special community of the lime-rich small-sedge fens occurs: the black bog-rush fen (Schoenetum nigricantis). Zobrist (1935) devoted a monograph about its occurrence in Switzerland and adjacent regions. In places where the traditional management (mowing and harvesting the litter) has been abandoned, the *Schoenus nigricans* stands are increasingly suppressed either by *Cladium mariscus* or by shrubs such as *Frangula alnus* or willows (*Salix* spp.). Today this association is very rare.

cab) Calcareous small-sedge fen (Caricetum davallianae)

The Davall-sedge fens (Caricetum davallianae) have also become very rare, particularly those directly on the edge of springs actively depositing tufa. Such calcareous small-sedge fens are mostly restricted to small areas in their natural state. Alpine and sub-alpine calcareous spring fens and flushes are the natural habitat of the Caricetum davallianae. They contain several rare species and are easy to characterize. However, in the Outer Alps which have high precipitation many of these species are also found in the swards of Seslerietalia or other communities. Common butterwort *(Pinguicula vulgaris)* and German asphodel *(Tofieldia calyculata)*, for example, are not restricted to fens in the Northern Calcareous (limestone) Alps, but are also to be found on slopes with mineral soil where water periodically trickles down bringing with it a fresh supply of lime. The true Caricetum davallianae needs a sub-oceanic climate. Therefore, it is mainly found in the pre-Alps and Alps. Plants characteristic of this vegetation include Davall's sedge *(Carex davalliana)* broad-leaved cottongrass *(Eriophorum latifolium)*, marsh helleborine *(Epipactis palustris)*, bird's-eye primrose *(Primula farinosa)*, Traunsteiner's orchid *(Dactylorhiza traunsteineri)*, common butterwort *(Pinguicula vulgaris)*, large yellow-sedge *(Carex flava agg.)*, grass-of-Parnassus *(Parnassia palustris)*, German asphodel *(Tofieldia calyculata)*, Alpine rush *(Juncus alpinus)*, marsh valerian *(Valeriana dioica)* and marsh felwort *(Swertia perennis)*. (Dietl 1975).

cac) Anthropogenic deer-grass fen (Drepanoclado intermedi-Scirpetum austriaci; syn. Caricetum davallianae trichophoretosum)

This sub-association of the Caricetum davallianae dominates large mire areas on the Flysch soils in the pre-Alps. It is the classic anthropogenic vegetation which replaces wet spruce forest (Piceetum subalpinum sphagnetosum) after clear-cut followed by a grazing regime. Besides *Scirpus cespitosus* (syn.: *Trichophorum caespitosum*), this vegetation type is characterized by the following species (GRÜNIG 1955): Alpine bartsia *(Bartsia alpina)*, German asphodel *(Tofieldia calyculata)*, bird's-eye primrose *(Primula farinosa)*, broad-leaved cottongrass *(Eriophorum latifolium)*, false aster *(Aster bellidiastrum)*, lesser clubmoss *(Selaginella selaginoides)* and by marsh felwort *(Swertia perennis)*, Davall's sedge *(Carex davalliana)*, common butterwort *(Pinguicula vulgaris)*, flea sedge *(Carex pulicaris)* and purple moor-grass *(Molinia caerulea)*. There is also a more acidic sub-association called Trichophorum caespitosi caricetosum ferrugineae.

cb) Acidic small-sedge fens (Caricetalia nigrae)

Acidic small-sedge fens usually contain fewer species than Caricetalia davallianae communities. They are mainly found in the pre-Alps and Alps, often as a common sedge fen (Caricetum nigrae), sometimes initiating transitional mire development.

cba) Common sedge fen (Caricetum fuscae; syn. Caricetum nigrae)

This association is currently the most important 'peat producer' in the alpine belt. It is the major community of soligenous peats and peaty gleys irrigated by rather base-poor but not excessively oligotrophic waters. The Caricetum nigrae appears in many variations; common sedge *(Carex nigra)*, carnation sedge *(C. panicea)* or other sedges with a similar autecology dominating in different places, together with varying amounts of thread rush *(Juncus filiformis)*, Alpine rush *(Juncus alpinus)*, Scheuchzer's cottongrass *(Eriophorum scheuchzeri)*, common cottongrass *(Eriophorum angustifolium)* or even deer-grass *(Scirpus cespitosus)*. Where the water is less acidic species from calcareous fens may also occur. On the peaty soils, plants from drier habitats only can find a footing when the site has been drained. The Caricetum nigrae in the alpine belt can be viewed as a permanent community (Dauergesellschaft).

cbb) Alpine and sub-Alpine cotton-grass mires (Eriophoretum scheuchzeri)

Since even on limestone the surface layer of fine soil in older moraines has been leached of bases, practically all standing water in the Alpine and sub-Alpine belts is acidic or at least deficient in minerals. Most of the small acidic lakes above the tree-line are fringed with a stand of Scheuchzer's cottongrass *(Eriophorum scheuchzeri)*. The spherical seed hair-tufts of this cottongrass are well-known to all Alpine walkers, the shining white standing out in sharp contrast to the dark waters. The dense stands of cottongrass which begin to shoot up soon after the ice has melted contribute significantly to the peat accumulation when their remains sink to the bottom each year. In some places, brown mosses such as *Drepanocladus exannulatus* contribute to the formation of peat. Apart from Scheuchzer's cottongrass *(Eriophorum scheuchzeri)* itself, the community contains few phanerogams. At most one might come across some individuals of common sedge *(Carex nigra)*, bottle sedge *(Carex rostrata)*, thread rush *(Juncus filiformis)* or common cottongrass *(Eriophorum angustifolium)*, which also are found in acidic fenlands at lower altitudes.

cc) Floating mat (bog pool), hollow and transitional mire communities (Scheuchzerietalia)

From the plant sociological point of view, transitional mires belong to the order of the Scheuchzerietalia, whose centre of distribution in Europe lies in Scandinavia and to a smaller degree in the pre-Alpine region. It embraces not only the classic bog hollows which are included in the alliance of the Rhynchosporion albae, but also the alliance of the Caricion lasiocarpae, which is the transitional mire community par excellence, always present in the lagg of raised bogs.

cca) Bottle sedge swamp (Caricetum rostratae)

In the area liable to flooding around lime-deficient oligotrophic or moderately dystrophic lakes, only less dense and shorter sedge swards can grow. The bottle sedge *(Carex rostrata)* is usually dominant in these swards. Due to the rather wide ecological amplitude of *Carex rostrata*, the bottle sedge swamp is even found around small pools in the centre of some raised bogs, as well as in their laggs where there is no reed *(Phragmites australis)*. It also occurs in wet abandoned peat pits where it seems to be one of the most effective peat-forming plants. The bottle sedge tolerates even more eutrophic conditions which enables the plant to compete successfully with tall-sedge stands. Many authors, therefore, include the Caricetum rostratae within the tall-sedge swamps but, according to DIERSSEN (1982), this plant community is probably best placed in the alliance of the Caricion lasiocarpae (Scheuchzerio-Caricetea fuscae).

ccb) Slender sedge swamp (Caricetum lasiocarpae)

The slender sedge swamp is the most plentiful community among the transitional mires. The Caricetum lasiocarpae is an open turf of uniquely elegant appearance (KOCH 1926, p. 87). Accompanied by just a few other species it occupies not only great parts of the laggs but also oligotrophic shallow pools. Mosses, such as *Sphagnum* and *Drepanocladus* often produce most of the biomass, not only in the swaying slender sedge community, but also in those of other transitional mires.

ccc) White beak-sedge community (Sphagno tenelli-Rhynchosporetum albae)

The natural habitat of this plant community is shallow peat hollows, which are only temporarily filled with water. Melting snow and heavy rain drench these hollows but they dry out during summer and are then susceptible to wind erosion. The Rhynchosporetum albae also grows in places with bare peat, e.g. on peat cuttings or mires where the vegetation has been destroyed by trampling, wind erosion, or occasionally by burning. *Sphagna* are hardly ever present because they cannot tolerate the extreme variations in wetness typical of this community. Such sensitivity is in contrast to the characteristic species of the association such as white beak-sedge *(Rhynchospora alba)*, brown beak-sedge *(R. fusca)*, round-leaved sundew *(Drosera rotundifolia)*, oblong-leaved sundew *(D. intermedia)* and marsh clubmoss *(Lepidotis inundata)*. Other plants typical of the bog hummocks, e.g. hare's-tail cottongrass *(Eriophorum vaginatum)*, can also be found in the white beak-sedge community.

ccd) Mud sedge hollow (Caricetum limosae)

The most abundant species in Caricetum limosae hollows are: feathery bog moss *(Sphagnum cuspidatum)*, *Sphagnum majus*, common cottongrass *(Eriophorum angustifolium)*, bottle sedge *(Carex rostrata)*, bogbean *(Menyanthes trifoliata)*, Rannoch rush *(Scheuchzeria palustris)* and bog sedge *(Carex limosa)*. The last two are the character species of the community because of their sub-arctic – pre-alpine distribution. They are almost completely absent from the plains of north-western Europe. Both species can withstand a high degree of acidity and constant submersion which enables them to compete successfully with other small sedges.

d) Raised bogs (Oxycocco-Sphagnetea)

Plant communities forming the characteristic small-scale mosaic of hummocks and hollows on true raised bogs are confined to small areas within the already small Swiss bogs. They also can be found on wooded raised bogs, but only in patches around the pools and in sites with a rather Atlantic climate where the local topography maintains a consistently high water-table. In the high montane and sub-alpine belts, the characteristic hummock community, Sphagnetum magellanici, is superseded by other communities, e.g. *Sphagnum fuscum* bog or deer-grass bog.

da) Red Sphagnum hummocks (Sphagnetum magellanici)

The most important community of the raised bog is that of Sphagnetum magellanici. It is mainly made up of *Sphagnum magellanicum* and *S. capillifolium* along with vascular plants, e.g. bog rosemary *(Andromeda polifolia)*, round-leaved sundew *(Drosera rotundifolia)*, hare's-tail cottongrass *(Eriophorum vaginatum)*, cranberry *(Vaccinium oxycoccos)*, bog bilberry *(V. uliginosum)*. The occasional drying out of the upper *Sphagnum* layers allows the dwarf shrubs to become dominant and, in some places, *Polytrichum strictum* may also be dominant. Heather *(Calluna vulgaris)* is frequent. The tallest hummocks are taken over by Sphagnetum magellanici vaccinietosum which is completely dominated by dwarf shrubs and often contains mountain pine *(Pinus mugo)*.

The communities of wet cottongrass (Eriophoro-Sphagnetum recurvi) can be regarded as a facies of the Sphagnetum magellanici. They occupy larger areas of cut over bogs. Because of the abundance of *Eriophorum vaginatum* whose tufts of white seed hairs shine far and wide in the summer and whose competitive tussocks remain green into the autumn, they are very obvious even from a distance. The cottongrass-*Sphagnum* bog can change into a cottongrass-pine wood (or a cottongrass-birch wood) while the ground flora remains much the same.

db) Brown Sphagnum hummocks (Empetro-Sphagnetum fusci)

In the raised bogs of the Central Alps, the brown bog moss *(Sphagnum fuscum)* is dominant. This is because it can tolerate long and cold winters and is better adapted to the more continental climate of the region with its large temperature fluctuations and more frequent droughts (cf. Chapter 1.5). The Sphagnetum fusci often forms steep hummocks in which frost-heaving seems to play a part. The ecology of *Sphagnum fuscum* bogs is discussed in more detail in Chapter 3.13.5.

dc) Deer-grass bog (Scirpetum austriaci; syn.: Trichophoro-Sphagnetum compacti)

In altitudinal bogs the Sphagnetum magellanici is replaced by a deer-grass community (Scirpetum austriaci). Besides deer-grass *(Scirpus cespitosus)* and *Sphagnum compactum*, its frequent satellite, this plant community contains for instance few-flowered sedge *(Carex pauciflora)*, purple colt's-foot *(Homogyne alpina)*, mountain arnica *(Arnica montana)* and/or further species typical to raised bogs or to Caricetalia nigrae. Under present-day conditions, the deer-grass bogs rarely accumulate peat, possibly due to climatic effects or because the water economy has been changed artificially. However, the deer-grass community is only indirectly favoured by drainage. It still requires a lot of water and can only succeed in places with frequent precipitation and a moist atmosphere i.e., in oceanic climates. It rapidly disappears from the site whenever it is drained too effectively. *Scirpus cespitosus* and *Sphagnum compactum* thrive best on more or less bare peat which may occasionally dry out, but is constantly being saturated again, and where it can no longer be overrun by quick-growing hummock mosses. This community, intertwined with patches of bare peat and other signs of peat erosion, is also very characteristic of overgrazed mire areas at lower levels.

dd) Wooded raised bogs (Pino mugo-Sphagnetum magellanici)

With the exception of the altitudinal bogs near the timber-line, the bog types, as outlined in Chapter 1.6.3.2a–d (blanket bog, raised bog, saddle bog, sloping bog), in their natural state become progressively less hostile towards the establishment of trees. In more continental regions, trees are able to establish themselves even in the centre of raised bogs, to an extent that the whole mire may eventually become a wooded raised bog. Under the more Atlantic climate of the northern pre-Alps, the less-wet places of the sloping bogs are increasingly occupied by a dwarf shrub-pine wood.

Today, the increased expansion of trees onto the naturally open mire areas is of concern to Swiss mire conservationists, because it is believed that better tree growth on bogs indicates that peat accumulation has come to a standstill.

The reason for the increased growth of trees on Swiss bogs may be a higher input of nutrients by air pollution (cf. Chapter 4.4.6) and/or more persistent and pronounced dry situations. The latter bring about a better aeration of the upper peat layers, thus benefiting the growth of tree roots and their mycorrhiza. These dry periods in the bog are caused by the hydrological gradient and can be promoted by climatic change and changes of water economy (for instance by some drainage carried out in the surroundings of the bogs). These tree-rich bogs can be pictured as the marginal woodlands of true raised bogs which have spread out over the whole mire expanse.

Considering the general influence of man on the water economy in and around the mires, wooded bogs must be regarded as quite characteristic of today's Swiss oligotrophic mires. This is consistent with the views of STEFFEN (1931), LÖTSCHERT (1964) and OVERBECK (1975), who believed that most of the wooded raised bogs in central Europe owe their existence to conscious or unconscious interference by man, some of which dates back a long time.

The surface of wooded bogs is covered with more or less open stands of pine or birch. These grow slowly and rarely form a closed canopy. Nevertheless they give a definite woodland appearance to the mire. In the Central Plateau, Scots pine *(Pinus sylvestris)* is the usual dominant species, accompanied by, and in some places replaced by birch (*Betula pubescens* and *B. pendula*). The upright form of mountain pine *(Pinus mugo)* gives a gloomy appearance to the bogs in the Jura Mountains and in the pre-Alps. The prostrate form of *Pinus mugo*, widely distributed on mineral soil in the high mountains and common to the bogs of Austria and Bavaria, is confined to very few bog sites in eastern Switzerland. However, here they have been planted in several cases (cf. Chapter 3.16).

The relatively sparse tree canopy for its part does not have such a bad effect on the growth of *Sphagnum* as it would have for instance in the British Isles with their oceanic conditions. In fact the light shade could be beneficial for bog *Sphagna* in preventing an extreme lowering of the relative humidity. The seven most reliable raised bog plants, i.e. bog rosemary *(Andromeda polifolia)*, cranberry *(Vaccinium oxycoccos)*, round-leaved sundew *(Drosera rotundifolia)*, hare's-tail cottongrass *(Eriophorum vaginatum)*, red bog moss *(Sphagnum magellanicum)*, *S. capillifolium* and feathery bog moss *(S. cuspidatum)*, are common in these sites. Another positive effect of mountain pine *(Pinus mugo)* stands may be some suppression of peat erosion.

On the other hand, there are *Pinus mugo* bog sites with a steeper hydrological gradient which are suffering from heavier drought, enabling trees to grow taller. Subsequently the tree canopy becomes denser and the site much more shady and even drier. Eventually, the *Pinus mugo* bog develops into a mountain pine forest. The *Pinus mugo* forest is distinguished, mainly in the northern pre-Alps, from the above bog types by the absence of *Andromeda polifolia*, *Vaccinium oxycoccos* and *Drosera rotundifolia*. It is dominated by a dwarf shrub community with some *Eriophorum vaginatum*. Isolated *Sphagnum* hummocks may be present (cf. Tab. 2.3.1). In such stands the hummock and hollow pattern is nowhere to be found.

1.7 Land use

Ever since man began to build settlements he has hacked away at the forests. Findings from pollen analyses, studies of palaeosols and radiocarbon dating suggest that the first farmers appeared in Switzerland between 5,500 and 4,500 BP. After the retreat of the glaciers, man settled not only in the Central Plateau, but also expanded within the Alpine area. The first record of clearings by Neolithic man in the Alps indicates that farming and animal husbandry have been influencing vegetation for several thousands of years, even in these relatively remote areas. Man's impact upon the forests grew with every passing generation, and has particularly intensified since the early Middle Ages. These anthropogenic changes, however, overlap with climatic deteriorations. The deteriorations are frequently referred to in stories originating from the 'Little Ice Age' of 1570 to 1850 AD (telling how a greedy farmer, for example, was punished by finding his alpine meadows covered by snow and ice; cf. GROVE 1988).

1.7.1 Forestry

Today, it is known that in mountainous territory the value of forests for watershed and erosion protection commonly exceeds their value as sources of timber or places of recreation. This is especially true in Switzerland and its Alpine neighbours, where the existence of settlements in the valleys is dependent on the maintenance of a continuous forest cover on the foothills of the great peaks. The guiding principle of management in areas where erosion is a threat is the maintenance of continual cover. Ideally, this is achieved by a forest managed on a selection system; only a few trees are felled at any one point, and the small gap created is soon closed by the outward growth of neighbouring trees.

However, from the 12th to the 14th centuries a large part of the virgin forest was felled by the constantly increasing population, until something close to today's distribution was reached. Now, forests are mainly present on steeper slopes which are difficult to mow and offer poor conditions for grazing or have a protective function against avalanches. However, as soon as a slope becomes less steep, the forest is replaced by pastures, mountain hay meadows, or arable farming.

During the Middle Ages, the forest was felled particularly in those areas where it was most needed, close to villages and towns. In Alpine regions, it was burnt or clear-cut to obtain more alpine pastures for grazing or for mining. Through these activities, the timber-line has often been lowered by some hundreds of metres (on average about 300 m; cf. Fig. 1.6.3). The trees were used as timber for house construction and as firewood in homes, smelters and for making cheese in alpine huts. Regeneration of young trees was prevented by grazing and – before the invention of barbed wire in 1873, saplings were sacrificed in copious numbers for fencing. As a result, natural vegetation became more and more repressed. Numerous Alpine passes (e.g. the Grimsel, the Gotthard, the Furka, the Oberalp, the Bernina, the Simplon) which are treeless nowadays would have been covered by forests. At present, most of these areas are covered by alpine dwarf shrubs, such as rust-leaved alpenrose *(Rhododendron ferrugineum)*, *Rhododendron hirsutum*, bilberry *(Vaccinium myrtillus)*, heather *(Calluna vulgaris)*, and crowberry *(Empetrum nigrum)*, or by green alder *(Alnus viridis)*.

> ***Litter***
>
> *Straw and similar material, for example, bracken, used as bedding for animals or for protecting plants from frost. Straw and dung of a farmyard.*

In the 16th century, Alpine farming gained importance, thus leading to increasing settlement. In the areas where the forest did not disappear completely, it was quite often badly stripped: trimmings were used as fodder, and cattle wandered through the forests in search of pasture, causing severe damage to young plants. They also trampled the topsoil of the forest, making it very difficult for young trees to establish themselves. Dead leaves were often collected and removed so that the forest floor lost important nutrients. A similar effect on the nutrient status and other site factors of wet forests was the widely-used practice of litter mowing and harvesting in autumn. This gave rise to the development and expansion of the very typical sedge litter meadows of the pre-Alpine foothills (see Chapters 1.7.3 and 3.2). The compression of topsoil through heavy trampling by cattle and the decrease of canopy interception due to reduced forest cover may have been the reasons for the formation of new wetlands and the enhanced danger of torrential rains. This is especially true in soft impervious soils such as those developed on Flysch (cf. Chapter 1.3.2).

> ***Litter meadow***
>
> *A litter meadow is cut so late in the season that the growth becomes straw and consists of little more than carbohydrates. As a result, the yield can be maintained without any addition of plant nutrients. This is in contrast with the hay meadows which must be cut once or twice a year, and regularly manured. The number of plant species per unit area, including weeds, is greatest under a less-intensive system where the field is cut for hay or for litter only once in the season and then possibly grazed (cf. Chapters 1.7.3.1 and 2.1.1).*

The early years of industrialization were harbingers of another critical era for Swiss forests; iron smelting, glass making, limekilns, brickworks and many other budding industries used wood in enormous quantities. Before railways were developed making it possible to import large quantities of coal at relatively low prices, wood was the most important fuel and was thought to be inexhaustible. Thus in the 18th and 19th centuries, large intact forests in remote areas fell prey to the woodman's axe. Much of this timber was even exported to the seagoing Netherlands and United Kingdom – always timber-hungry.

Under these conditions, establishment of young trees was nearly impossible. Forests became increasingly sparse and could no longer provide adequate protection against natural disasters such as avalanches, landslides, torrents and floods.

The Federal Constitution of 1848 did not provide the central administration with any powers over forestry management; forestry was under the jurisdication of each individual canton. The disastrous natural catastrophes which occurred in the 1850's were a result of the devastating exploitation of the previous centuries. The increasing number of floods along the rivers Rhine, Rhône, Aare, Emme, Linth and Ticino forced people to rethink, and forestry problems soon took on national significance. As a result of a comprehensive study by LANDOLT (1862) and CULMANN (1864), an amendment about forestry was added to the Federal Constitution in 1872. (However, the real stimulus for change in forest policy was the new possibility of importing raw materials, such as coal, steel and grain by railway. The same was true for agriculture; cf. Chapters 1.7.2 and 2.1). This was followed by the first national Forest Act, which came into force in 1876. Until 1897, however, it was valid only for the Alps and not for the Central Plateau or the Jura Mountains. The Forest Act, which pertains to the whole of Switzerland, dates from 1902. This Forest Act represented a forest policing law stimulated by the widely appreciated fact that a century ago, forests were in such a poor state and exposed to so many dangers that a law was needed to protect and regenerate them again. Thus, the Forest Act aims at preserving the surface area and the distribution of the forest. (In principle, present Swiss mire conservation legislation has similar aims: a sustainable land use. However, the mires' starting point today seems to be even worse than that of the forests over 100 years ago). The Forest Act has been altered and expanded since then, and in 1992 it was replaced by a new law.

Today, one-quarter of the total land area of the country is covered by forests (approximately one million hectares, of which 70% are publicly owned, and 30% privately owned). Of these forests, 80% are coniferous, mostly spruce *(Picea abies)* trees. The other 20% are hardwoods, the main species being beech *(Fagus sylvatica)*. These figures indicate that most of the present forests are not natural; only a few hectares of 'virgin forest' have survived within the whole country. Even in places no longer affected by human intervention (e.g. in the National Park and in nature reserves) nature is barely able to regain its primary balance. The wolf *(Canis lupus)* and bear *(Ursus arctos)* have been eliminated, and lynx *(Lynx lynx)* was reintroduced only a few years ago. Red deer *(Cervus elaphus)*, roe deer *(Capreolus capreolus)*, chamois *(Rupicapra rupicapra)*, ibex *(Capra ibex)*, marmot *(Marmota marmota)*, and other herbivores form populations that in some areas are too large. They graze forests and meadows often as intensively as did (and do) cattle, goats, or sheep. Forests close to their natural state are confined today to less fertile hilltops, steep slopes and/or riverbanks. This tendency is particularly distinct in the mountains.

In the Central Plateau, alien tree species have frequently been planted, with preference given to economically important species. For instance, all forests of spruce and larch which occur in the Central Plateau were planted by man; native spruce forest grows almost exclusively above 1,000 m. On the other hand, forests within the sub-alpine belt were (and still are) often designed to have high light penetration to the forest floor to ensure better grazing. Therefore, most of the pure European larch *(Larix decidua)* forests in the Engadine and in the Valais are not natural but created by man's traditional land use.

1.7.2 Agriculture

Swiss agriculture is characterized, first and foremost, by the different and difficult qualities of its soils. Almost one-quarter of the land is non-arable, another quarter covered by forests, the third quarter is pasture and the last is fields, meadows and good soil where all manner of produce is grown.

Feeding the populace has always been a major preoccupation. A steadily growing population and insufficient agricultural production gave rise to another form of export, namely people, particularly the Swiss mercenary (cf. Chapters 1.2 and 1.2.5). It also gave rise to an early, quite dynamic industrialization which accelerated the exodus of the rural population. In the middle of the 19th century, 60% of the population worked on the land. This figure dropped to 22% before the Second World War and is now only 4.5%. Generally speaking, it is the small and medium-sized farms (less than 15 ha) that have diminished, while the number of large estates (more than 15 ha) in contrast has increased. Parallel to these demographic changes between 1885 and 1940, more than 80,000 ha of the country's wetlands were drained, with the state subsidizing private owners to do so (Département fédéral de l'économie 1947). Drainage reached its peak during the Second World War (cf. Chapter 2.1).

In 1939, Switzerland imported more than 70% of food and fodder cereals. In 1940, Switzerland was isolated by Germany and Italy and faced with the threat of severance of its food imports. As a result, the well-known "Wahlen" nutrition plan was established. Its objective was to change domestic agriculture to growing high-calorie crops (arable produce, in particular potatoes). To guarantee the country's food supplies, a further 80,000 ha of wetlands were drained within a period of only six years (1941 to 1947; Département fédéral de l'économie 1947; cf. Chapter 2.1).

Since the last World War, one square metre of land has disappeared under concrete every second, and the process continues. This means that Switzerland is continually losing farmland to non-agricultural activities. In spite of the great demographic changes, agricultural yield has steadily increased, due to modern techniques and technology, as well as increasing financial and technical support from the federal government.

Today livestock farming (meat and dairy) accounts for nearly four-fifths of the total agricultural income in Switzerland. However, domestic food production covers only 62% of the population's needs, or 57% if the cost of importing animal fodder is reduced. Switzerland is, proportionally, one of the largest per capita importers of foodstuffs.

As in other industrialized countries, Swiss agriculture benefits from government support and protection. Under the Agriculture Act of 1951, the government tries to adjust domestic production to meet the demand and encourages prices which cover the costs of rationally managed farms. For example, it fixes both the prices paid to farmers for milk, grain and sugar beets, and the quota at a guaranteed price for milk for each farm. Agricultural trade policy is also used to encourage the sale of domestic produce: measures include customs and other duties on goods from abroad, import restrictions and a ban on the import of milk. This has meant that up to 80% of a farmer's income is directly or indirectly guaranteed by the state (cf. Fig. 1.7.1), with frequent excesses in food supplies. With great political changes occurring all over the world, this system is being fundamentally questioned.

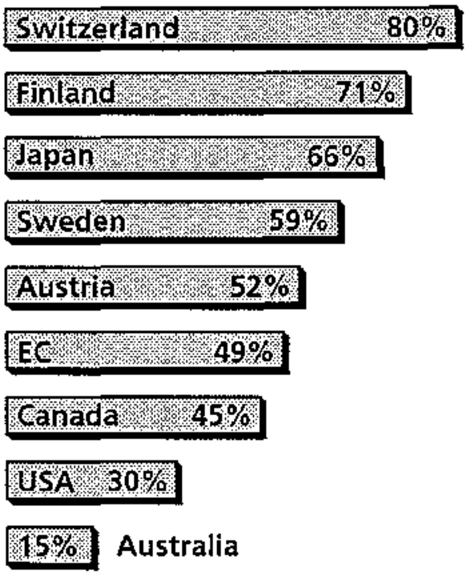


Fig. 1.7.1. Percentage of farmers' income from subsidies and guaranteed prices (modified from BAUMGARTNER 1993).

Taking into account all of these activities, it is not surprising that great changes in agricultural practices have occurred both in the Central Plateau and in the Alps over the last few decades. Farms have become more specialized. Those in the Central Plateau with better climatic and topographical conditions have concentrated on arable farming, fruit farming, viticulture and vegetable production (the latter especially on peat soils; see Chapter 3.6). Those in mountain regions have devoted themselves mostly to livestock. These changes have led to the alteration of the countryside both in the Central Plateau and in the mountain area. In the Central Plateau, for example, more than 90% of the former species-rich habitats, mostly man-made and dependent on sustainable land use of traditional low intensity, have been lost to intensive farming. On the other hand, in the mountains large areas have been abandoned to some extent and forests have begun to reappear in many places.

The familiar scenery of the pre-Alpine and Alpine regions, rich in varied traditional human influences enhancing various habitats (cf. Fig. 1.7.2), is slowly turning into a more monotonous landscape; scenic sites with fine views of valleys and mountains are becoming overgrown by trees. Steep slopes with wild meadows left unmown are even more endangered by erosion (although wild hay plots and litter meadows represent the most colourful and spectacular meadows of the Alps). As a substitute for the original management, very large herds of sheep graze through the summer in the Alps. They do not leave a single flower behind and they expose numerous sites to erosion.

It is difficult today to combine the conservation of a cultivated and traditionally managed landscape attractive to tourists with the conservation of a species-rich and healthy world of plants and animals. To do so requires particular care, understanding, and money.

Fig. 1.7.2. A (coloured) etching by Peter Birmann of the "Kupferstichkabinett" in Basle entitled: "Vue du Lac de Lucerne dit du quatre Cantons prise au dessus de Kusnacht". [View of the Lake of Lucerne, also called the Lake of the Four Forest Cantons, taken to the north of the lake from above Küssnacht (canton Schwyz).] It shows a park-like grazing country, very characteristic scenery of Switzerland about 180 years ago. On the level ground, trees and bushes could survive only where they were protected from grazing by rocks or in wet places.

1.7.3 The origin and future of meadows and pastures

(mainly taken from Ellenberg 1988)

'Without scythe and hay harvest no meadow flora!' This saying of Schlatter made more than a hundred years ago applies to the whole of Europe, with the exception of mires (reed and sedge swamps), salt marshes by the sea and alpine meadows. While grazing of livestock is a very old practice in Europe, meadows requiring tools for cutting the crop are relatively recent. In the Bronze Age sickles were known, but their use was restricted to the harvesting of corn, not for cutting meadows. According to Lüdi (1955), for example, surprisingly little remains of grasses, but a lot of dried shoots of ash (*Fraxinus excelsior**) and other tree twigs were found in excavated settlements in northern Switzerland. Brockmann-Jerosch (1936), in his paper on 'edible deciduous trees of Switzerland' has described how in the past a significant part of the winter fodder for the larger animals was obtained by 'lopping', that is the repeated cutting of leafy shoots.

Cultivation of meadows has arisen in many different localities from extensively grazed pasture-land. By about 1800 there were still such 'wood meadows' in the foothills of the Alps (cf. Fig. 1.7.2). To this day, examples are preserved in many nature conservancy areas. In Sweden and Germany they are called 'Laubwiesen' (meadows with deciduous trees), about which Sjörs (1954) devoted a basic ecological study. In Switzerland a distinction is drawn between 'Studmatten', which are the mown areas between trees, and 'Wytweiden', which are the proper woodland pastures (cf. Chapter 3.9.7). Mowing, that is cutting off practically all the assimilatory organs from all species at the same time, has quite a different effect to the gradual selection by animals. After mowing, all partners have the same start, so to speak; therefore, it favours quick-growing and tall plants provided they are capable of regeneration.

* The scientific name *Fraxinus* is from Latin 'frangere' meaning "to break".

1.7.3.1 Litter meadows

The first meadows were cut only once a year and corresponded to the 'straw meadows or litter meadows' (Ellenberg 1988). For the most part these occupy very wet sites which are avoided by stock. They do not need to be fenced-off if the number of cattle does not exceed the forage supply of the total pasture area. Long after the manured wet-soil meadows have turned lush green and become brilliant with flowers, the stubble on the purple moor-grass meadows is still a pale straw yellow. The purple moor-grass *(Molinia caerulea)*, which is at home in woodlands on more or less damp soils, has become the litter grass par excellence. In the mountains there are often wood anemones *(Anemona nemorosa)* or oxlips *(Primula elatior)* i.e. true woodland plants, which take advantage of this delayed reaction to the coming of spring. When many of the hay meadows have already been mown, *Molinia* starts to send up its shoots with their blue buds, and the accompanying plants also start to flower. By late summer there is a glorious symphony of colour with the dark blue bells of gentians, the yellowish white umbels of pepper saxifrage *(Silaum silaus)*, the carmine heads of sawwort *(Serratula tinctoria)* and many other colourful flowers. When the haulm and leaves of the purple moor-grass finally turn golden yellow and copper, the litter meadow stands out shining from the 'evergreen' hay meadows to compete with the autumn colours of the mixed broad-leaved woodlands.

Sustainable management

The traditional and sustainable management of litter meadows is the mowing and removal of the straw for use as bedding of animals. This is done in the autumn after nearly all the plants have dried and most have already ripened their seeds. In fact they have had time to transfer most of their assimilated material down into storage organs, for example buds, rhizomes or roots on or below the soil surface. There is little advantage in being able to spread vegetatively, and quite often it is the tussock-forming plants like purple moor-grass *(Molinia caerulea)* or Davall's sedge *(Carex davalliana)* which become dominant. These live for only a few years and must be renewed from seed. Although *Molinia caerulea* is late to start growing and is the last of all the grasses to flower, it can collect large reserves of nitrogen, phosphorus and other nutrients in the swollen internodes at the base of its apparently node-free stem ready for the following season. It soon loses its competitiveness if it is cut too soon or if grazing animals damage its storage organs lying close to the ground. On the other hand, harvesting dead parts in autumn removes such a small quantity of essential nutrients that these areas will continue to provide straw year after year without manure, provided there is sufficient water available. The litter which is removed consists mainly of cellulose, other carbohydrates and silica. It contains hardly any protein or other nutrient-rich compounds.

How to maintain litter meadows?

Since the beginning of this century, the litter meadows in central Europe have become fewer and fewer until they have become mainly confined to small remains in a few places in the plains north of the Alps and in some regions of the northern pre-Alps (cf. Chapter 2.3.2 and Fig. 3.17.5). As a result, one of the most pressing problems for nature conservation has become the preservation or rehabilitation of the last remaining unmanured litter-meadow complexes. The easiest and most obvious method would be to continue managing them as they have been farmed up to now. However, this is problematic, since the modern tendency to house cattle without litter has increased in popularity. The simple mowing and removal of the straw has thus lost its economic rationale (cf. Chapter 2.1). Therefore, many litter meadows have been converted into hay meadows. This conversion is easily and rapidly done as litter and hay meadows occur on the same sort of soil. Others have been drained and afforested.

However, even if the litter meadows are not converted but mowing discontinued or cut herbage allowed to lie on the ground, then the species composition will be altered. The rarer species would be particularly susceptible while meadowsweet *(Filipendula ulmaria)* and other tall herbs would spread, or grasses and sedges would form thick layers of dead leaves. Completely left to nature a litter meadow would eventually become thickly wooded. This is especially true for those meadows that have been drained. Even when not fertilized, these will be colonized more rapidly by shrubs and trees than comparable meadows which are no longer cut (BRIEMLE 1980). The mowing can be replaced up to a point by burning. This certainly maintains the dominance of the fire-tolerant purple moor-grass. However, after many years of research carried out in Switzerland, it has been discovered that the only way of maintaining the species combination is to mow the Molinion meadows in the autumn at least every second year and remove the cut material from the meadow. Otherwise the Molinion meadows will soon lose their specific floristic composition (ELLENBERG 1988). The recent problems associated with the appropriate land use of fenlands and litter meadows in Switzerland are revealed by Table 2.5.1 and Figure 2.5.6: one fifth of the fens is allocated to fallow land, more than half is grazed and only 31% is cut for litter which is the preferred management for nature conservation.

1.7.3.2 Fodder meadows

Meadows on drier soils are comparatively young; this is particularly true in the case of the 'fodder meadows'. If a meadow is cut early in the summer when still green to obtain a protein-rich fodder, then the field is soon impoverished by the removal of bioelements. Thus, small slow-growing plants requiring little in the way of food are able to spread. For instance, this is the reason for the species richness of (semi-)arid *Bromus erectus* grasslands. Fodder meadows, therefore, require a dressing of manure to replace the plant nutrients removed with the biomass, even if they are cut only once a year. This is even more necessary if two or three crops are harvested each year. Under such circumstances, species are encouraged which benefit most from the addition of nutrients, especially nitrogen, and grow more quickly than the plants of the litter meadows. A representative characteristic is the false oat-grass *(Arrhenatherum elatius)*, one of the most valuable hay grasses. Like the purple moor-grass *(Molinia caerulea)*, the false oat-grass is a tall tussock-former and relies on occasional regeneration from seed. However, it flowers much earlier, ripens its seeds even more rapidly and stores up fewer reserves, even if the straw is allowed to die naturally on the plant.

Without fertilization fodder meadows can only grow in flood plains where sediment rich in nutrients is deposited. Of course the natural vegetation of such alluvial soils, a well-grown deciduous woodland, must previously have been removed by man and his grazing animals. A further prerequisite is for livestock then to be fenced out of the area, since the true meadow plant community can only develop through regular mowing. The typical fodder meadow, cut twice or more in the season, which became so widespread and popular right up to the middle of this century, is not more than about a thousand years old (SUKOPP 1969). This length of time has been sufficient to allow a plant combination to develop which is distinguished by many good character species, though bearing no resemblance to the natural vegetation. As a result of modern farming methods, especially 'rotational grazing', fodder meadows have become much less frequent and they are now threatened with complete disappearance.

1.7.3.3 Pastures

The universal intensification of farming during the last 100 to 150 years has finally also brought about a fundamental change in the management of pastures. The old grazing rights which had been handed down were abolished, and the commonage was either split up into privately owned plots or managed as a district forest. In the more humid and rainy areas in the pre-Alps and the Alps, the tendency was to graze all grassland with the exception of swampy ground, and to even drain this if at all possible. As a consequence there was an extension of well-manured pasture communities all over the pre-Alpine and Alpine regions of central Europe.

In recent years grassland management has attempted to avoid the disadvantages of permanent grazing by repeated trimming of the pastures, that is, a system of grazing after mowing with raking. The ideal form of this is rotational grazing, in which the total pasture area is divided into 8 to 12 parts. Each paddock is only grazed for a few days but with a large number of livestock at the same time so that it is cropped closely and evenly. As the animals are moved on to the other paddocks in succession, the herbage has many weeks to recover and takes on the appearance of a meadow. In addition the paddocks are mown from time to time for hay. This almost entirely eliminates weeds. Only some grasses and clovers can withstand this kind of treatment resulting in the most boring plant community that any botanist can imagine!

Alpine pastures

In contrast, remote alps and Alpine pastures are now rarely used, and many wild hay and litter meadows are no longer being mown. In the Alpine regions, where human impact is less striking above the tree-line (1,800 to 2,000 m in the outer Alpine ranges, ca. 2,000 to 2,400 m in the Central Alps; cf. Fig.1.6.1), changes in vegetation are rather easily recognizable. This is obvious especially in well-grazed pastures or in meadows where management has changed recently from mowing to grazing. As a substitute for the original management, very large herds of sheep graze through the summer in the alps. Plants which are not sensitive to grazing or trampling, as well as species avoided by grazers (because they are poisonous, bitter-tasting, or prickly), are able to expand at the expense of more sensitive species.

2 Mires and mire landscapes in Switzerland and their need for conservation

200 to 300 years ago, Switzerland must have been a paradise of highly diverse and widespread wetlands. However, the bogs and the fens, which together covered far more than 5% of the land area, were ignored. They first attracted some interest in the early 18th century when peat extraction began and then again at the end of the 19th century when, for a short period, an increased demand for litter meadows existed. Because of ignorance of the value of mires, human activity increased, modifying and drastically altering our traditional landscapes. It is now estimated that densely populated Switzerland has lost up to 90% of its former mire surface. This is one of the highest proportions in Europe, with the result that:

- many of the most beautiful and famous mire landscapes in Switzerland have been damaged or even destroyed by the increasing land use pressure;
- the mire habitats together with their original intact plant and animal communities have become rare and the most endangered of habitats;
- almost half of Switzerland's indigenous plant species that are presently regarded as threatened by extinction depend primarily on these wetlands (Landolt 1991).

By the 1970's, the protection of what was left was a matter of urgency and required the national co-ordination of various measures.

As recently as 6 December 1987, the people of Switzerland, in the Rothenthurm Referendum, voted in favour of an amendment to the Swiss Federal Constitution supporting a set of laws and decrees for the integrated conservation of mire and mire landscapes of national importance. Meanwhile, three major inventories of both the mire habitats and mire landscapes were completed between 1978 and 1991. All three were national surveys, and had, as their primary objective, the identification of sites which were considered to be of national importance. As a result, both the scientific database and the legal basis for effective conservation of mires and mire landscapes now exist. These are among the most advanced in Europe.

Despite this new legislation, unfortunately not yet fully implemented, land use pressure on mires and mire landscapes and objections against integrated mire conservation proposals have continued to increase since the vote in 1987.

2.1 History of land use and mire loss

Andreas Grünig

Whereas raised bogs grow naturally, Swiss fenlands are quite often a result of human land use. Many wet forest areas were cleared, mainly during the last centuries, promoting the development of extensive fenlands on the open surface. For a long time these areas were pastured or managed as litter meadows (cf. Chapter 1.7.3) which was the sustainable agricultural land use of traditional low intensity.

As we have already seen in Chapter 1.7.1, the overexploitation and destruction of large forest areas in the pre-Alpine and Alpine regions, i.e. in the catchments of the main rivers, resulted in increased flooding. Many river plains of the Central Plateau suffered from the increased sediment deposition which brought about a general rise of the water-table. Consequently, in the 19th century, most of the rivers in Switzerland were channeled. The first national enterprise of Switzerland, started in 1807 and finished in 1823, consisted of the hydrological control of the Linth flood plain under the direction of Hans Konrad Escher who was later dignified with the appendix 'von der Linth' to his name. The work consisted mainly of:
- rerouting the Linth River into Lake Walen to improve the sediment transport;
- construction of a straight channel across the Linth flood plain which connects Lake Walen and Lake of Zürich by the shortest route and
- subsequent drainage of the Linth plain.

Further enterprises in the other river systems followed the same principles (cf. Fig. 3.6.3). Embankments and shortening of the river courses prevented the flooding of the river-banks and caused a lowering of the water-table in the surroundings which, up to that time, had supported extensive areas of fen and flood plain forest. The resulting drop in the water-table led to increased pressures from agricultural, residential and industrial land claims, ultimately resulting in extensive loss of these wetland habitats. For instance, between 1885 and 1940, more than 80,000 ha of wetlands, mainly fens, were drained (Département fédéral de l'agriculture 1914; Service fédéral des améliorations foncières 1947; cf. Chapters 1.7.2 and 3.6).

2.1.1 Litter meadows

This trend was interrupted during a relatively short period between 1860 and the beginning of World War I, when a major change in Swiss agriculture occurred which influenced the scenery of the Central Plateau. Because of the new possibility of cheaply importing large quantities of grain by railway, Swiss farmers switched from grain production to dairy farming. As a consequence, the traditonally ploughed, brown Central Plateau soon became more grazed and green (cf. Chapter 4. 8). As a result of this management change in agriculture, the demand for litter increased while the production of straw decreased. Never was the interest in litter meadows (fen meadows) higher than during this period. The price for good litter meadows was even higher than for arable land (Früh and Schröter 1904, p. 329) at this time. Research was even conducted to improve the yield in litter both quantitatively and qualitatively, and to establish new litter meadows artificially (Stebler 1897).

During the First and Second World Wars, wetlands were drained and cultivated to ensure continued food supplies. Within a period of only six years (1941–1947) a further 80,000 ha of mires were drained (Service fédéral des améliorations foncières 1947). After the Second World War, the intensity of agriculture and development increased, further contributing to an additional loss of about 20,000 ha of mires.

2.1.2 Peat exploitation

The exploitation of Swiss mires for peat began during the early 18th century as a result of increased population pressure and rapidly dwindling forestry resources. Based on his experience in the Netherlands (cf. Chapter 4.5), the famous naturalist J.J. Scheuchzer* of Zürich introduced the technique of using peat instead of wood for fuel in 1709. This new knowledge rapidly spread throughout the country. A century later, afraid of the irrational exploitation of the largest Swiss peatlands in the Jura Mountains of canton Neuchâtel, the local

* Linnaeus named the genus *Scheuchzeria* after Johann Jakob Scheuchzer and his botanist brother Johann.

government commissioned the scientist, LESQUEREUX, to examine the problem. In his fundamental report, written in French in 1844 (and translated into German in 1847) he deals with, among other topics of mire research, the problem of regenerating cut-over peatlands. He was probably among the first scientists to do so. Unfortunately his advice was not adhered to. As a result of almost 3 centuries of peat extraction, at least half of the remaining raised bogs in Switzerland show signs of peat cutting.

From these descriptions and comparing the figures to the estimated extent of the mires 300 years ago, it is evident, that up to 90% of the original mire surface of Switzerland has been destroyed by human activity in the last few decades (cf. Chapter 1.7.2). The figure for the Central Plateau is even worse.

2.2 The legal basis for mire conservation in Switzerland and its implementation

Erich Kohli

This section briefly reviews the recent history of mire conservation in Switzerland. The legal basis for protection of both the mire habitats and the mire landscapes is presented. Difficulties in legal enforcement of protection are discussed.

Since the Rothenthurm amendment to the Federal Constitution in 1987, Switzerland is probably the only country in the world where the integrated conservation of mire habitats and mire landscapes is a political maxim. This amendment is very strict in terms of protection and re-creation of the original conditions of the mires, but contains several so-called "undefined legal terms" such as mire, mire landscape, particular beauty, national importance. These terms needed interpretation. Considering that the first three terms were completely new to the Constitution, the immediate need for interpretation, definitions, concepts and examples in that field was even more stringent. Therefore, a set of three national inventories on mire conservation was established.

2.2.1 History

In the late 1970's, Swiss voluntary nature conservation organizations initiated the Inventory of Raised and Transitional Bogs. The Swiss Confederation supported this work financially and it was finished in 1984 (cf. Fig. 2.2.1). This process underlines two characteristics of Swiss nature conservation history:

	Raised Bogs	Fenlands	Mire landscapes	Events
1978	Start of survey			
1979	⇨			
1980	⇨			
1981	⇨			
1982	⇨			
1983	⇨			Submission Rothenturm Initiative on 16/9/83
1984	End of survey (Invent. compl.)			
1985				
1986		Start of survey		
1987		⇨		Amendment to WCNHPA* on 19/6/87
1987		⇨		Rothenturm Initiative accepted on 6/12/87
1988		⇨	Start of survey	Amendment enacted to WCNHPA on 1/2/88
1989	Consultation phase	⇨	⇨	
1990	Negotiations	End of survey	⇨	
1991	Enactment on 1/2/91	Consultation phase	End of survey	
1992		Negotiations	Consultation phase	IMCG Excursion through Switzerland
1993		⇨	Negotiations	
1994		Partially enacted	⇨	
1995		Completely enacted	Enactment 1995?	

Fig. 2.2.1. Synopsis of the development of the three national inventories dealing with mire protection together with their legal implementation.
*Wildlife, Countryside and National Heritage Protection Act

1 The authorities and voluntary nature conservation organizations have always been intertwined, and
2 the government in many cases depends on the initiative and advice from voluntary, non-governmental conservation organizations.

In 1983, the Rothenthurm Initiative for the protection of mires and mire landscapes (cf. Chapter 6.1) was submitted to the Swiss Federal Council. Under the influence of, or perhaps feeling threatened by this explicit text, the Federal Council and the Federal Parliament decreed important changes in the Federal Act on Wildlife, Countryside and National Heritage Protection. Perhaps one of the most important changes was the amendment of 3 articles (Art. 18a, b and c; cf. Chapter 6.2) that authorized the Swiss Confederation to protect, on a national level, all kinds of habitats.

Based on these articles, a decision was made to set up three federal habitat inventories: one on raised and transitional bogs, one on fenlands and a third one on floodplain forests. Since the basic data had already been collected, the work on the raised and transitional bogs consisted mainly of drafting and writing a definitive version of the inventory by the private organizations (cf. Chapter 2.3.1). The inventory of the fenlands started in 1986 and was finished in 1989 (cf. Chapter 2.3.2).

In the meantime, the Rothenthurm Initiative was put to a vote and, surprisingly and quite unexpectedly, was accepted by the Swiss population in December 1987. The Confederation acted immediately and began the third mire inventory in February, 1988: mire landscapes (cf. Chapter 2.4).

After consultation with cantons and various organizations, the first decree concerning a federal habitat inventory (Federal Inventory of the Raised and Transitional Bogs of National Importance) came into force on 1 February 1991. This was followed on 15 November 1992 by the Decree on the Protection of Flood Plains.

The consultation procedure about the second federal mire inventory (on fenlands of national importance) was finished in 1991. Many problems and differences of opinion between cantons and the Confederation have only recently been resolved. Some points to be discussed further include not only the definition of a fen, but a definition of those fens which are nationally important and those which are not. The fenland inventory will hopefully come into force some time in 1994.

The third inventory, mire landscapes, was finished in 1991 and submitted to a consultation process until the end of 1992 (cf. Fig. 2.2.1). The reactions have been quite extreme. There are three main problems:

1 It is difficult for the public to understand the new implications of strict protection of landscapes and not only of habitats.
2 The interim disposition (cf. Chapter 6.1) is much too rigid for many people. It is difficult to accept that legally erected installations should now be demolished at the cost of those responsible for their erection.
3 Preventing construction of any new building or installation is necessary for the protection of the landscape, but seems to stop any activity in these regions. People fear that this includes all human activity which has taken place for hundreds of years.

People want more flexibility and the possibility to weigh their interests against the objectives of mire conservation. In conclusion, to a high proportion of the general public, the priority of landscape protection should be diminished.

To a certain extent, efforts to soften the rigid wording of the Constitution are acceptable. But changes must be made cautiously so that the efficiency of this instrument for landscape protection is not lost.

Opposition to the Rothenthurm article in the Constitution is trying to change the wording. At the very least, an attempt is being made to establish a legal basis to increase the number of possible exceptions.

2.2.2 Legal basis

Before details of the legal basis of Swiss mire protection are described, it is necessary to describe the legal process (Fig. 2.2.2). Every article in the Constitution is focussed by a hierarchy of laws, decrees and ordinances. In Switzerland there are roughly three levels of legislation. The first and most general level is the Constitution. The second level is the federal law. The third level deals with details (e.g. the level of subsidies) which are regulated by both federal and cantonal ordinances or decrees. Using the example of raised and transitional bogs it is possible to demonstrate the legal procedure. At the constitutional level is an article (Art. 24^{sexies} Paragraph 4) that states that the Confederation is able to legislate in the interest of nature conservation. For mires, the Rothenthurm article (Art. 24^{sexies} Paragraph 5) must be taken into consideration (cf. Chapter 6.1).

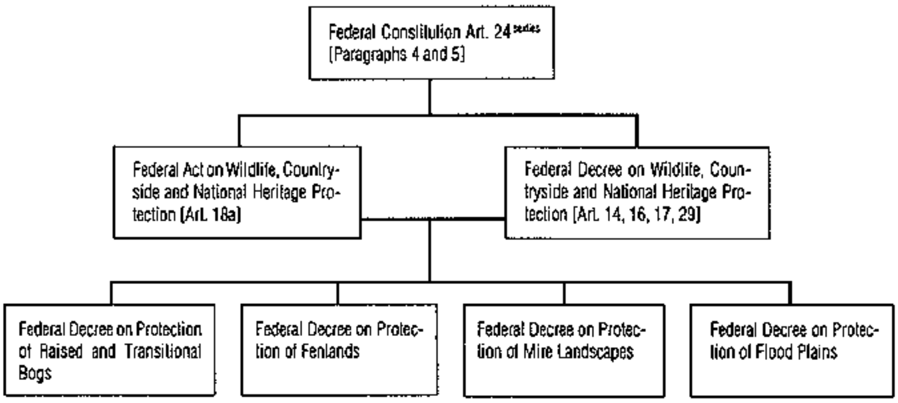


Fig. 2.2.2. The different levels of Swiss legislation (cf. Chapter 6).

The Federal Act on Wildlife, Countryside and National Heritage Protection is the law based on the general statements of the Constitution. Within this act, article 18a states: "[1] The Swiss Federal Council, after the cantonal hearings, designates the habitats of national importance. It determines their locations these habitats and fixes the objectives for their conservation. [2] The cantonal authorities arrange the protection and maintenance of these habitats of national importance. They must take the appropriate measures in the time allotted and ensure that they are implemented." (cf. Chapter 6.2).

In the ordinance to this federal act, articles 14, 16 and 17 describe the objectives and regulate the protection of habitats of national importance. Article 16 states that the designation of habitats of national importance, the definition of objectives for protection, and the deadlines which the cantons are given to organize protection, will be regulated in special ordinances or inventories.

At the time of writing (end of 1992) only one such ordinance (or decree) dealing with a national habitat inventory had been established: the Decree on Protection of Raised and Transitional Bogs. Some brief information about the structure of this decree may be helpful (cf. Chapter 6.3).

Articles 1 to 3 refer to the wording of the Rothenthurm amendment to the Federal Constitution which states that raised and transitional bogs of national importance and particular beauty are protected areas. The articles also specify how these habitats have to be protected through the establishment of a specific bog habitat inventory. A general description of the sites and the demarcation of their boundaries together with ecologically appropriate buffer zones are included. Article 4 describes the general objectives for conservation of the raised bog habitats. The following article outlines the detailed objectives and measures for protection.

The remaining articles 6 to 12 consist of organizational details. One important article states the absolute protection of any site of national importance even if it figures only in a provisional inventory. This article is based on Art. 29 of the Federal Decree on Wildlife, Countryside and National Heritage Protection.

Two appendices complete the decree. One of them contains maps and a short description of each protected habitat. At this stage, the cantons become involved. For each habitat, the cantons must formulate detailed protection measures and arrange management agreements. They must also define the exact boundaries because the federal inventory only depicts the habitats at a scale of 1 : 25,000. The cantons may have to make legislation themselves.

The same procedure, from the Constitutional legislation to the decree, must be undertaken for all further inventories.

Because it is the Swiss Confederation that ultimately carries the responsibility for protection of sites of national importance, the Confederation should also provide the means for efficient protection. This is achieved through consultation, advice and financial support. However, problems do arise.

The Constitution declares that the Confederation is able to legislate in the interest of nature conservation. However, it also states very clearly in paragraph 1 of Art. 24^{sexies}: "The Cantons are responsible for the protection of wildlife, countryside and national heritage".

As a result, after establishing the inventories, the Confederation must only support the detailed protection executed by the cantons. In providing financial support, the Confederation may also set up conditions for their subsidies and guarantee a certain standard for measures of protection. Very rarely is the Confederation able to act directly in the place of a canton that has not fulfilled its duties. Within the very federalist structures of Switzerland, the possibility of intervention may only be used in exceptional cases.

2.2.3 Implementation of the laws

The restriction placed on the Confederation has two consequences:

1 The Confederation is dependent on the opinions and interests of the cantons. It is estimated that only a very small percentage of habitats are listed in an inventory against the will of a canton. There is no alternative but to reach a consensus with the cantonal authorities.

2 Detailed protection is under the guidance of the cantonal administration. The role of the Confederation is limited to consultation and providing financial subsidies of up to 90%.

Thus, the first limitations and problems arise in the application of protection measures at the cantonal level: it depends greatly on the canton how far nature conservation is advanced.

There are more factors which influence whether efficient conservation of bogs or fens and mire landscapes is possible. This ranges from the influence of communities and regional organizations to landowners and groups interested in using or developing the land. These groups must be convinced that conservation of mire landscapes is worthwhile and must be willing to do their part. However, contacts with communities, regions and owners must be through the canton. Any direct contact by the federal government may be viewed by the canton as interference.

It is now possible to judge how delicate and difficult realization of mire protection in Switzerland is on a national level. The responsibilities of the Confederation that set up an inventory are quite removed from the authorities and various groups responsible for the day to day protection in the field.

More problems arise from personal interests and adverse agricultural practices due to the subsidy system that still encourages intensification and increased production. Problems also arise from tourism, an economically important factor in many regions, and from the perceived need to open up all regions with roads. The number of people employed in agriculture, tourism and road construction is at least 10 to 20 times greater than the number of people employed in nature conservation. With respect to financial support of such projects, a similar ratio exists.

How can the last natural areas be conserved?

The outlook is very pessimistic, but there is still hope that the conservation of mires and mire landscapes at a national level may be possible. Despite all the constraints, it must be remembered what the Swiss population has, in principle, already accepted: "Mires and mire landscapes of particular beauty and national importance are protected areas."

2.3 Findings from the two national inventories of mire habitats

Andreas Grünig

After the classic book by Früh and Schröter in 1904, there was no systematic, updated information about the situation of mires in Switzerland until the 1980's. However, there was one exception: a set of about 170 short descriptions of individual mire sites (bogs and fens) from across Switzerland by Lüdi (1943–1951). Lüdi, a professional plant ecologist and palaeobotanist, described the condition and the vegetation of each site and rated, from his expert point of view, their individual value on behalf of the Swiss League for Nature Conservation. Sometimes the descriptions included phytosociological relevés, but vegetation maps or a systematic survey were never provided by Lüdi. Unfortunately, only a few of Lüdi's suggestions were realized.

In 1984 and 1990 respectively, the national bog and fenland habitat inventories were completed. These inventories were initiated in 1978 with the development of the raised bog inventory by the two main voluntary nature conservation organizations. The fenland survey was commissioned in 1986 by the federal authorities (Broggi 1990). The two new inventories of mire habitats give a systematic and quite accurate figure about the (serious) state of our national mire heritage. Therefore, the scientific database for sustainable mire conservation now exists; ignorance can no longer be used as an excuse preventing political and practical action.

The area of Swiss mire habitats identified by the two national inventories of the raised bogs and of the fenlands totals approximately 30,000 ha, which is clearly less than 1% of the country's surface. These inventories include about 4,000 sites, of which approximately 1,500 mires with a total area of 20,000 ha are regarded to be Sites of National Importance.

Co-ordination problems became evident when it was attempted to aggregate the two mire habitat inventories. These are dealt with in Chapter 2.5.2.5.

Table 2.3.1. Dichotomous key used for mapping the vegetation for the raised bog inventory of Switzerland

- At a scale of 1 : 25,000, 1 mm^2 on the map represents a minimum area of circa 600 to 1,000 m^2 in the field. This is the resolution limit of that scale which should be employed both on the map and in the field.
- Only the existing vegetation mosaic is mapped (interpretation of potential or past vegetation should be avoided).
- Cover indication per species or species group is recorded according to the classes of the Braun-Blanquet cover-abundance scale (cf. Mueller-Dombois and Ellenberg 1974, p. 59):
  +: Few plant individuals, with low cover of the recorded area;
  1: Numerous plant individuals, but less than 5% cover, or scattered, with cover up to 5%; 2: Any number, with 5 – 25% cover; 3: Any number, with 25 – 50% cover; 4: Any number, with 50 – 75% cover; 5: Any number, with cover more than 75% of the recorded area.
- An additional characteristic for every mapped bog unit is an indication of its actual state (condition), i.e. the area is labelled as to whether it is in a near natural state (primary bog) or in a damaged state (secondary bog) (cf. inset on facing page).

Question	Decision	Go to question No.	Vegetation units of the raised bog inventory	Unit No.
1. Is the cover of *Sphagna* ≥ 2 ?	Yes No	2 13	 (No bog area)	
2. Is at least one species present out of a group of 4 reliable bog indicators consisting of *Andromeda polifolia, Drosera rotundifolia, Eriophorum vaginatum*, and *Vaccinium oxycoccos* ?	Yes No	4 3		
3. Are at least three species present out of a group of 17 mire species which includes *Betula nana, Calluna vulgaris, Carex limosa, C. magellanica, C. pauciflora, Drosera anglica, D. intermedia, Empetrum nigrum, Lepidotis inundata, Melampyrum pratense, Pinus mugo, Rhynchospora alba, Scheuchzeria palustris, Scirpus cespitosus, Vaccinium myrtillus, V. uliginosum*, and *V. vitis-idea* ?	Yes No	4 13	 (No bog area)	
4. Is the bog area wooded, reaching a cover ≥ 2 ?	Yes No	5 9	 (Area partly cleared)	
5. Is the cover of *Pinus mugo* ≥ 1 ?	Yes No	6 7		
6. Is *Andromeda polifolia, Drosera rotundifolia* or *Vaccinium oxycoccos* present ?	Yes No		*Pinus mugo* bog (Treed bog with *Pinus mugo*) *Pinus mugo* forest	3 7
7. Is the cover of *Betula pubescens* and/or *Picea abies* ≥ 1 ?	Yes No	 8	Wooded bog with birch and/or spruce	5
8. Does the vegetation differ from the above (often composed of patchy, small areas) ?	Yes No	 1	Bog vegetation mixed with other vegetation types	6
9. Is the total cover of *Carex rostrata* and/or *Carex lasiocarpa* ≥ 3 ? (*Potentilla palustris* and/or *Menyanthes trifoliata* are "companions" with the cover of *Sphagna* often ≥ 2)	Yes No	 10	Transitional bog vegetation/ Veg. of bog channels, laggs and seepage zones	4
10. Is the total cover of *Scheuchzeria palustris* and/or *Carex limosa* ≥ 1 (often with open water areas, partially forming floating mats) ?	Yes No	 11	Bog hollow vegetation	2
11. Is the cover of species which are representative for (dried) hummocks and/or heather mires (i.e. dwarf shrubs, *Scirpus cespitosus, Molinia caerulea*) ≥ 3 ? Are there patches of bare peat, often forming fine-structured erosion complexes ?	Yes No	 12	Treeless heath bog/ Bog hummock vegetation	1
12. Does the vegetation differ from the above (often forming a mosaic with fine structures or with larger erosion complexes) ?	Yes No	 1	Bog vegetation mixed with other vegetation types	6
13. If the area appears to form an essential component in the sustainable conservation of the bog site under consideration, it should be surveyed and labelled according to units 7–20 which are stored in the raised bog inventory for both the "non-raised bog" vegetation types and the land use types (e. g. forest, pastured forest, pasture, shrub, fen, open water, peat reclamation area, meadow, arable land, residential area, dump area, area of tall herbs, mixed vegetation on mineral soil, etc.).				

2.3.1 The Federal Inventory of Raised and Transitional Bogs of National Importance

> ***Primary bog – secondary bog***
>
> *These terms are usually used in other countries (e.g. the United Kingdom) to distinguish between an intact dome of peat and a secondary surface from which peat has been removed. However, with respect to the Swiss raised bog inventory the terms primary and secondary also refer to the state of the vegetation (near-natural or damaged).*

The raised bog inventory was commissioned by the Swiss League for Nature Conservation and WWF Switzerland, and was conducted by three scientists between 1978 and 1984 (Grünig et al. 1986). Usually, only sites containing more than ca. 1,000 m² of typical raised bog vegetation were considered to be a potential site of national importance. A vegetation map at a scale of 1 : 25,000 was produced for each individual bog site. Black and white standard air photos by the Federal Office of Topography (scale approximately 1 : 25,000) were used for field work. The map key (cf. Tab. 2.3.1) distinguishes 6 bog vegetation units, each either intact (primary bog) or impaired (secondary bog), and 14 other vegetation types. In the field, both the bog habitat itself has been mapped, and its immediate surroundings which should also be protected. Additional evidence from field investigation and information from literature not accessible to numeric processing were noted in a report on each individual bog site.

Including the surroundings, a total area of 5,100 ha has been mapped and described. The inventory revealed that, in 1984, the remaining area of raised bogs regarded to be of national importance covered only 1,460 ha, or 0.035% of the country's surface. It is estimated that this is barely 15% of the original area, which must have been more than 10,000 ha. Most of the raised bogs have fallen victim to peat cutting, land improvement and agricultural extension, afforestation and construction.

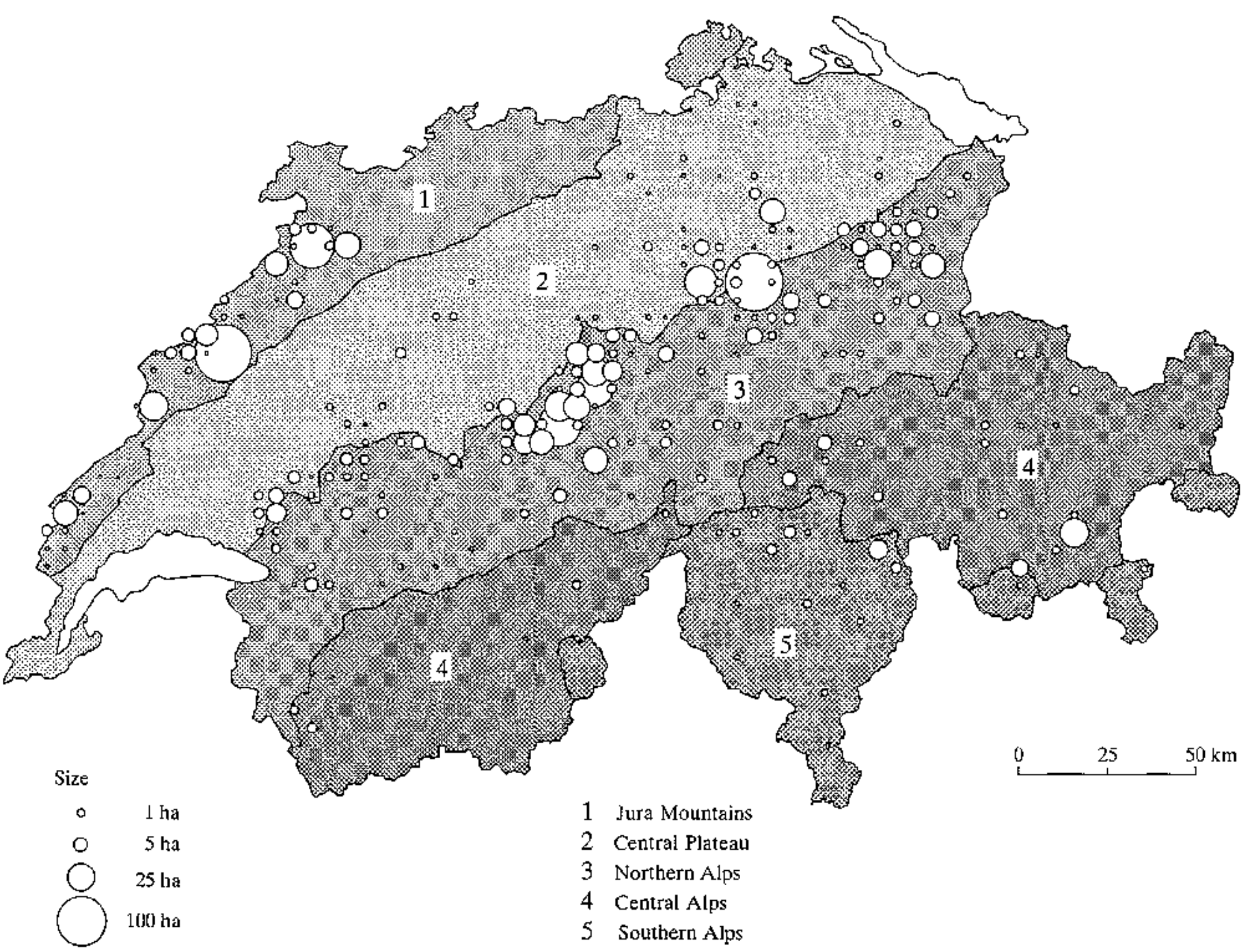


Fig. 2.3.1. Distribution and size of the Raised and Transitional Bogs of National Importance (modified from Grünig et al. 1986).

The total area of the remaining sites with raised bog vegetation is distributed over 500 locations, unevenly scattered over the country (Fig. 2.3.1). With an average area of 3 ha, the individual bog sites are small and are mainly remnants from larger sites. There are only two sites which contain more than 100 ha of raised bog vegetation. More than half of all raised bog sites were concentrated in the Flysch region of the northern pre-Alps (cf. Fig. 2.3.2) where precipitation is high and the soil largely impermeable (cf. Figs. 1.5.6 and 1.3.15; Chapters 3.2, 3.4, 3.5). More than a quarter of the total raised bog surface of Switzerland is found in the calcareous Jura Mountains (cf. Fig. 2.3.1 and Chapters 3.7 to 3.10). In the Central Plateau most of the bogs have been destroyed by man. As a rule these remaining bogs are of no present economic importance.

The raised bog inventory also revealed that approximately 1,000 ha of the total surface area of 1,500 ha of this habitat, considered nationally important, are impaired by human activities such as peat cutting, drainage and overgrazing. The remaining one third of the area, only 500 ha, was considered to be more or less undisturbed and hence in a near-natural state. However, it was evident that continued land use pressure threatened the survival of even these remnants. The main threats were agricultural amelioration and intensification, peat cutting, housing, construction, and pollution. The protection of what has been left as raised bog sites was a matter of urgency and required national co-ordination of various measures.

The Federal Decree on Protection of Raised and Transitional Bogs of National Importance was finally enacted in 1991 by the Swiss Federal Council. With the exception of 5 smaller sites, it includes all 514 bogs of the scientific inventory listed as nationally important (cf. Chapter 6.4). This list is now an integral part of this decree along with the 514 bog maps at a scale of 1 : 25,000.

A more comprehensive presentation of the findings from the Swiss raised bog inventory is provided in the publication by Grünig et al. (1986).

2.3.2 The inventory of the fenlands of national importance

The fenland inventory was commissioned by the Federal Office of Environment, Forests and Landscape to a private project management group. This group started work in 1986 with a preliminary survey to test methodological questions.The major findings of this preliminary project were:

1 to base the whole inventory mainly on vegetation criteria;
2 for reasons of consistency, to adapt the fenland map key to the three main geographical regions of Switzerland (Jura Mountains; Central Plateau; Alps, including the pre-Alps; cf. Fig. 1.1.1 and Broggi 1990, appendix 2); and
3 not to survey fenlands which cover an area less than 1 ha because these sites would probably not have been rated nationally important.

Mapping was done in 1987 and in 1988. The fieldwork consisted of the following:

1 a survey of the fens according to a list of criteria;
2 a demarcation of the area on both the aerial photograph and the map (scale 1 : 25,000); and
3 a short site description.

Finally, the fenland area was surveyed on a sub-site level in more detail using special vegetation keys which distinguished the following wetland vegetation units (usually at the level of phytosociological alliances following BRAUN-BLANQUET; cf. Tab. 1.6.1; MUELLER-DOMBOIS and ELLENBERG 1974, p. 175): Phragmition, Magnocaricion, Scheuchzerietalia, Calthion and Filipendulion, Molinion, Caricion davallianae, Caricion nigrae, and eventually Oxycocco-Sphagnetea. For every sub-site, the total cover of each mire vegetation unit present in the area was estimated in increments of 10%.

In 1990, the criteria for rating sites of national or regional importance were evaluated and fixed (cf. Chapter 2.5.2.7), and corresponding site lists produced. That same year, the inventory was concluded. Creating the fenland inventory has engaged 50 people in total, 33 of them dealing with the field aspects.

This inventory revealed that 3,300 fen sites with a minimum area of 1 ha have been surveyed. They make up a total of 24,300 ha of fenland. Compared with the raised bog inventory, it is evident that more than 90% of the Swiss mire surface consists of fens.

Like the raised bogs, the fens are unevenly scattered over the country (Fig. 2.3.2). At present, they are found mainly on the Flysch soils in the north-alpine region, where more than half of all fens occur. Nearly 25% of the total fenland surface occurs in the north-eastern part of the Central Plateau and in western Switzerland. These fens are found along river-banks and lakes (e.g. Lake of Neuchâtel, cf. Chapter 3.6) resulting from the last glaciation (cf. Fig. 1.3.14). Fens are naturally less common in the central part of the Swiss Central Plateau (where there were no glaciers during the Ice Age), in the Southern Alps (cantons Valais and Ticino), and in the Jura Mountains. The latter is in contradiction to the findings of the raised bog survey (cf. Fig. 2.3.1).

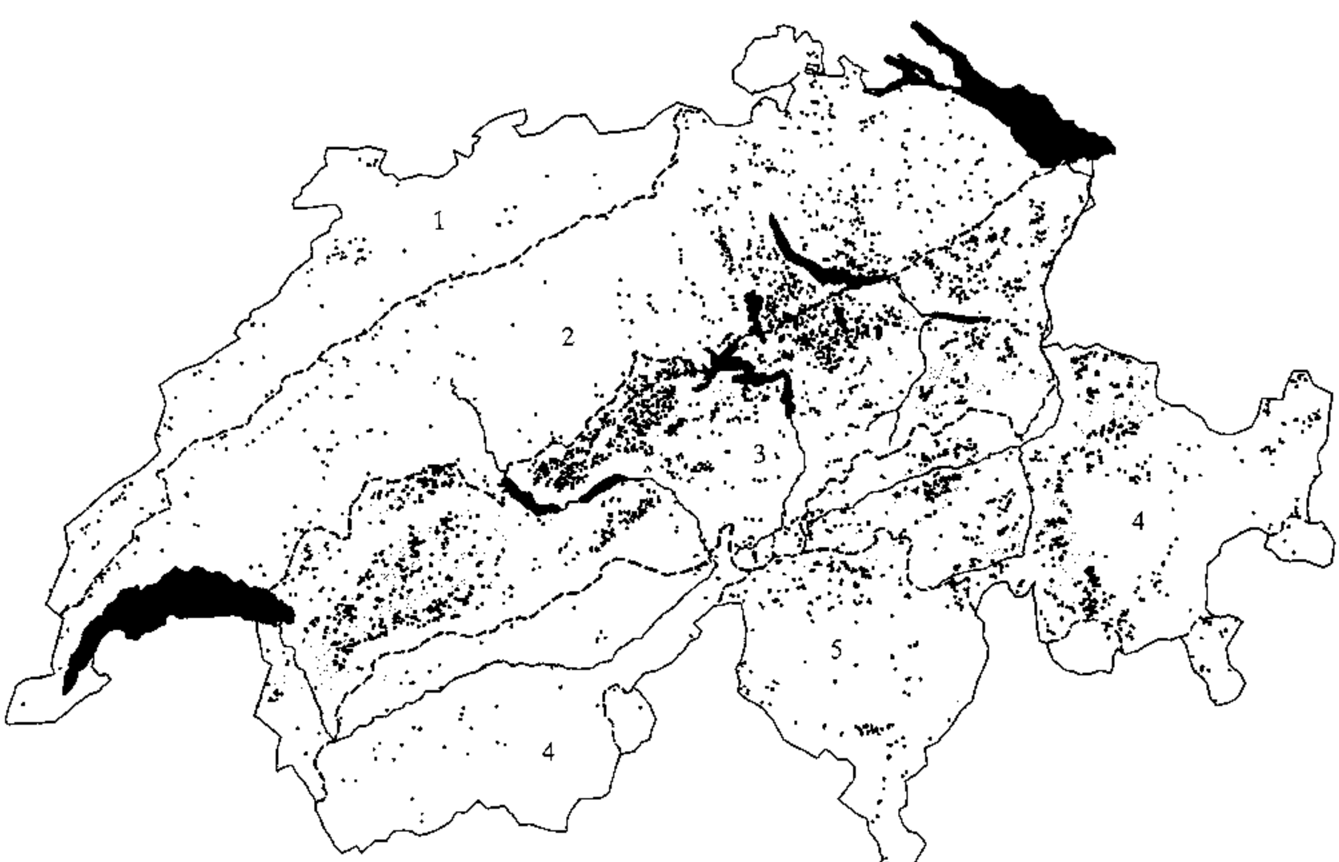


Fig. 2.3.2. Distribution of the fens of national and regional importance (modified from DFI 1990). Numbers: cf. Fig. 2.3.1 (modified from BROGGI 1990). Black dots = fen sites; black areas = lakes; gray shading = impermeable soils of the Flysch zone.

There are various types of fens reflecting the diversity of region, climate, geology, vegetation and of land use. The most common plant alliances of the Swiss fens belong to the base-rich Caricion davallianae and to the acidic Caricion fuscae (Figs. 2.3.3 and 2.3.4). More than one third, or 6,280 ha of the nationally important fenland area totalling 18,500 ha, belong to the Caricion davallianae alliance, stressing the influence of substrata upon the plant cover (cf. Fig. 1.3.15). The figure for Caricion fuscae is less than half or 3,060 ha. Nutrient-rich wetland alliances such as the Calthion and the Filipendulion (Fig. 2.3.5) occur all over the country but especially in the north-Alpine region, as a result of the increased use of fertilizers and continued drainage. They cover an area of 3,680 ha. The 500 ha of species-rich Molinion fen meadow which is the typical litter meadow alliance, are concentrated in the north-eastern part of the Central Plateau. In western Switzerland, almost all Molinion-bearing sites have been destroyed by drainage and land use pressure whereas in the central part of the Central Plateau this alliance is rare mainly because of natural influences (e.g. no glaciation).

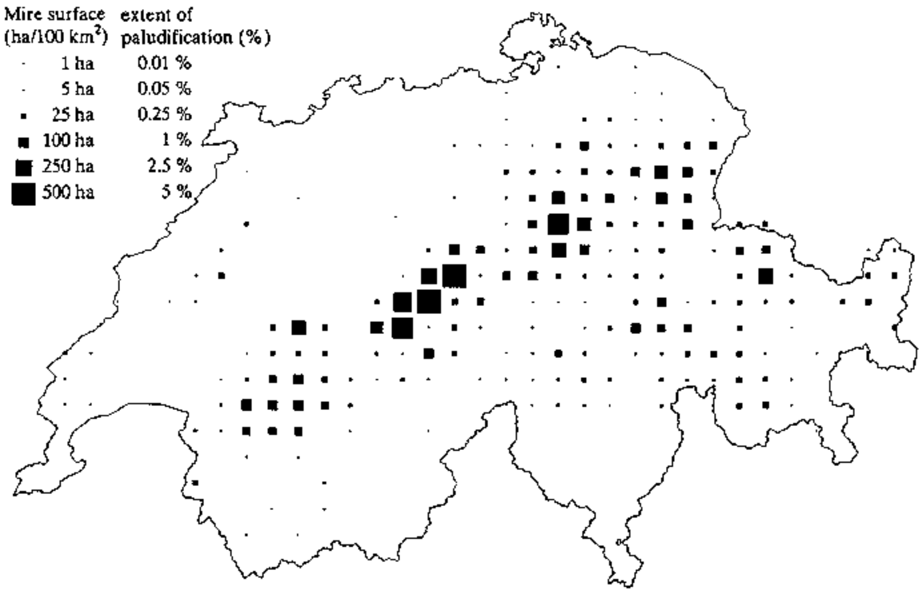


Fig. 2.3.3. Distribution of the Caricion davallianae alliance. The size of the squares is proportional to the surface of the fenlands (modified from BROGGI 1990).

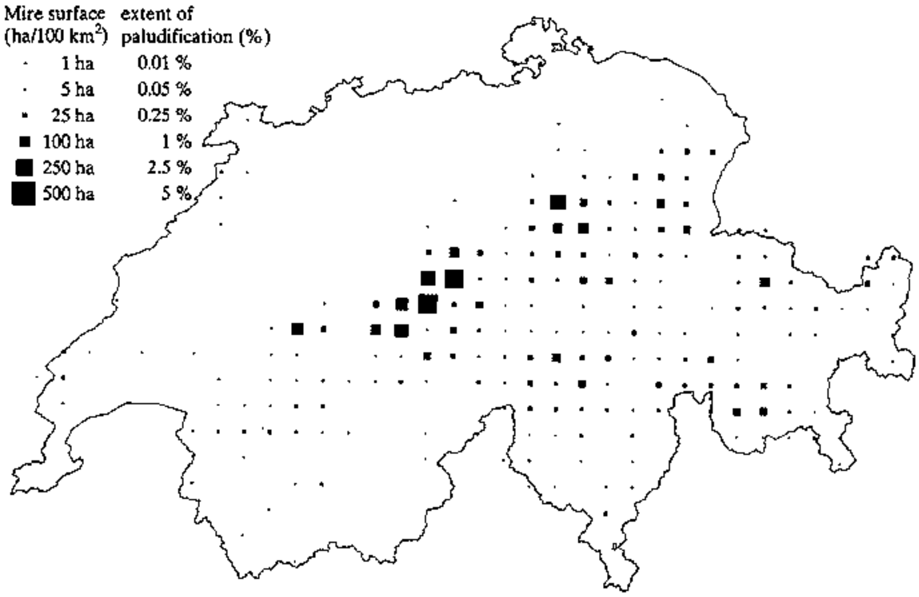


Fig. 2.3.4. Distribution of the Caricion fuscae alliance. The size of the squares is proportional to the surface of the fenlands (modified from BROGGI 1990).

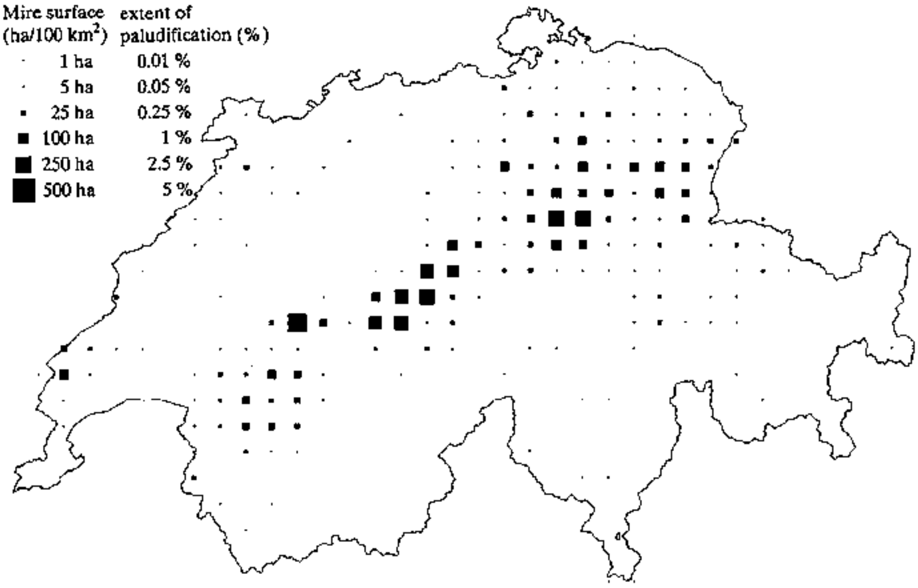


Fig. 2.3.5. Distribution of plant communities belonging either to the Calthion alliance or to the Filipendulion alliance. The size of the squares is proportional to the surface of the fenlands (modified from BROGGI 1990).

The list of the fenlands of national importance consists of 1,084 sites representing 18,500 ha. This is 32% of all surveyed fen sites greater than 1 ha. The average size is approximately 17 ha. The smallest fenland surveyed and rated to be of national importance is 1.2 ha, whereas the largest one extends to 213 ha.

With regard to agricultural management, about half of the fen sites considered to be nationally important are still exclusively used as traditional litter meadow with the grass cut once a year in autumn. A third of the sites are grazed completely, whereas another 253, mostly larger sites, are partly grazed and partly cut for litter. Overgrazing of fenlands is a problem especially in the Swiss pre-Alpine region. However, at almost half of the sites traditional land use has become irregular (cf. Chapter 2.5.2.6). The fallow areas are increasing. Hence on many sites, mire vegetation is being threatened by overgrowth of bushes, trees and woods. In summary, these results demonstrate that in regions where fens cover extensive areas of agricultural land, they either were, are, or could once again be of economic importance for local farmers.

Further information on the Swiss fenland inventory is provided in the publication by BROGGI (1990) and in Chapters 2.5.2.6 and 2.5.2.7 of this volume.

2.4 The inventory of the Swiss mire landscapes of particular beauty and national importance

Urs Hintermann

Article 24^sexies^ Paragraph 5 of the Federal Constitution aims at protecting not only particular mire habitats, i.e. bogs and fens, but also entire mire landscapes which must be regarded as protected areas when designated to be of particular beauty and national importance (cf. Chapter 6.1). This Paragraph 5 is very clear and rigorous in terms of protection and re-creation of the original conditions. However, interpretation is required of "undefined legal terms" such as mire, mire landscape, particular beauty, and national importance. Whereas the two inventories of the raised bogs and of the fenlands provide a clear idea about essence, number and distribution of the nationally important "mires" (cf. Chapter 2.3), it was a basic goal of this third mire inventory to find out how to identify mire landscapes and what they must look like to qualify for national importance and particular beauty.

The first part of this section is devoted to the consideration and definition of the term landscape, especially mire landscape. There is also the question of how to deal with the terms "national importance" and "particular beauty". In the second part, results of the inventory are presented, while the third is devoted to the purposes and problems concerning the implementation of mire landscape conservation. Finally, conclusions are drawn.

2.4.1 Why was there a need for an inventory of Swiss mire landscapes?

A mire landscape contains, as defined by the Swiss Constitution, not only bogs and fens, but also contiguous areas of other land use which also have to be regarded as protected areas. Only this definition legally ensures a sustainable conservation of the unique landscape and their habitats. Considering both the rigour of the new legislation and the problem of the undefined legal terms, it was obvious that some legal uncertainty existed among those affected by the Rothenthurm amendment. This was true as long as the location, perimeter and permissable land use of the mire landscapes regarded to be of potential national importance remained undefined.

Defining these factors was, therefore, an important goal of the mire landscape inventory, commissioned by the Federal Office of Environment, Forests and Landscape to a firm of environmental consultants (Hintermann and Weber AG). They had to develop a method to survey, demarcate, rate and select mire landscapes and to establish an inventory listing those landscapes considered to be "of particular beauty and of national importance". This would provide a basis for further discussion and action. Surveying for the inventory started in 1988 and both the survey and list were completed in 1990 (Hintermann 1992). The surveying team consisted of 6 consultants.

2.4.2 How is a mire landscape defined?

Mires as phenomena of natural processes, well-known in principle, are comparatively easy to define (for instance by an institution like the IMCG) using scientific criteria. The use of the word "landscape" does not cause any problems in our colloquial language. However, if it is used in the Constitution or in an act, then it makes a significant difference whether a home or a property lies inside or outside a particular landscape. Inevitably, the questions "What is a mire landscape? Where does it begin and end?" become very relevant. Therefore, the word has to be defined very carefully.

After much discussion (for further reading see Hintermann 1992), it became evident that:

- A landscape (or at least the German notion of Landschaft) is not perceived in the same way as a habitat. A landscape is not an entity, it is a concept, a model we develop in our mind. Therefore, it is not possible to find the true and correct definition of the term landscape.
- It was essential to develop a useful, obvious, understandable concept of a mire landscape, stressing the context of the Rothenthurm amendment to the Federal Constitution.

In this inventory, a mire landscape is defined as a large area that is dominated by bogs and/or fens. It can cover several square kilometres. Normally, Swiss mire landscapes are not natural landscapes. They are created, designed and used by man, so they can include agricultural land, forests, houses, roads, railroads and so on. For instance, characteristic mire landscapes may include

- an entire valley (as in the case of the mire landscape of Rothenthurm; cf. Fig. 2.4.1 and Chapter 3.1);
- an entire slope (as in the case of the mire landscape Faninpass; cf. Chapter 3.15);
- several smaller compartments of a landscape (as in the case of the mire landscapes Habkern and Sörenberg; cf. Chapter 3.5).

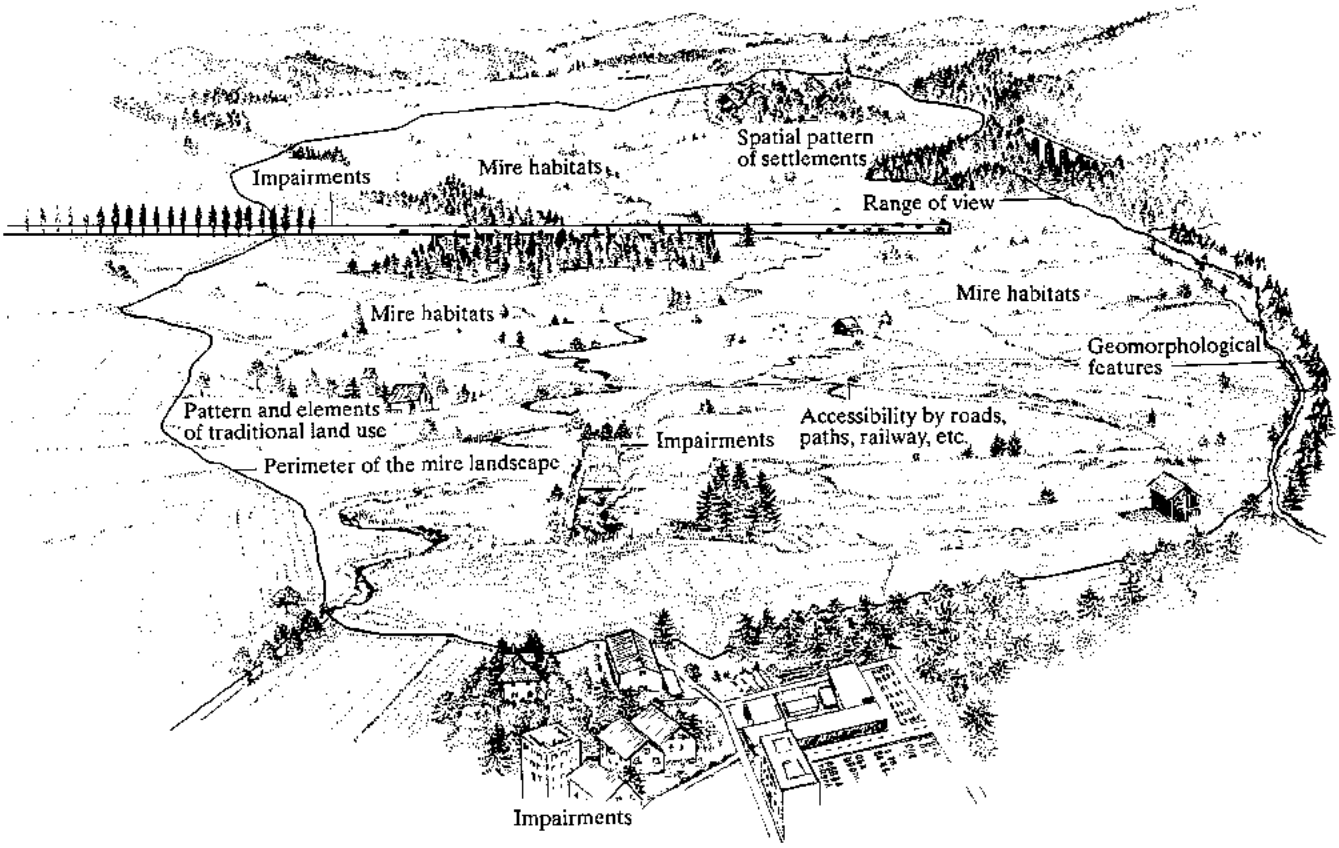


Fig. 2.4.1. Demarcation of a conceptual mire landscape showing important terms and rating criteria used in the mire landscape survey. For further explanation cf. Table 2.4.1 (modified from KIENAST et al. 1992; line drawings by Verena Fataar, WSL/FNP).

2.4.3 Demarcation of mire landscapes

Having an idea of what a mire landscape consists of does not necessarily imply knowledge of how to demarcate a mire landscape. Where does it begin and where does it end? Mapping mire habitats often involves the use of a vegetation-map key which provides a simple means to precisely delimit the target sites. In contrast, mapping mire landscapes is much more difficult because there is no true rule of how to define a mire landscape. Therefore, a whole set of demarcating rules was established and tested to reach the goal of Art. 24^{sexies} Paragraph 5 of the Federal Constitution: to protect and preserve mire landscapes of particular beauty and national importance.

Whenever possible, natural topographic features were used to demarcate a mire landscape, like crests, ridges, forest edges, stream and river courses, etc. (Fig. 2.4.1). For situations which were either more ambiguous and questionable or more complex, sets of rules were developed. They were mainly based on case studies and on experience. In this way the survey team were able to achieve consistent results.

2.4.4 Rating of mire landscapes: the difference between 'value' and 'national importance'

Rating is often presumed to be a scientific matter. This is not the case! Rating is always based on political considerations. However, rating can be supported by scientific experts and should be based on sound data which are processed according to scientific rules (Hintermann 1993).

Experts and consultants have the competence and knowledge to decide whether mire landscape A is better or more valuable than mire landscape B, or whether mire landscape C is of greater value for nature conservation than mire landscape D. However, the crucial question usually is: how many sites are to be protected at all? Only the best, three, ten or hundred with the highest ratings? This decision is mainly political.

As scientists we can demonstrate how threatened mire habitats or landscapes are. As consultants we have to present this information to decision makers and illustrate the consequences of further destruction of habitats and landscapes. (In a sense, the International Mire Conservation Group is doing the same thing, but on an international scale). Nevertheless, the final decision is a political one. It must be recognized that the interpretation of the undefined legal term "national importance" is strongly influenced by the decision makers' judgement of public opinion.

The eventual selection of mire landscapes which were recommended to be considered sites of national importance, resulted from an evaluation procedure based on several levels (cf. Tab. 2.4.1). A mire landscape is regarded to be of national importance

- if it is either unique to Switzerland, or
- if it belongs to the very best of a group of similar, comparable mire landscapes in the same region.

Thus, the loss of one of these mire landscapes must be considered as a loss to the whole country. The conservation of any particular mire landscape in this selection is a national duty.

Table 2.4.1. Evaluation procedure for mire landscapes considered to be of national importance

Evaluation principle
– unique site – best representative of a group
Rating approaches
– numerical approach using 9 criteria (cf. Tab. 2.4.2) – descriptive approach for each site
Eventual selection as an iterative process entailing
– discussions with the employer, the Federal Office of Environment, Forests and Landscape – comparisons between similar mire landscapes – discussions within the team

The rating, grouping and ranking of the mire landscapes was mainly based on two different approaches:

- A numerical-statistical approach using 9 different criteria which were determined for each mire landscape considered nationally important (cf. Tab. 2.4.2).
- A structured and detailed description of each mire landscape to include attributes not accessible to numeric processing.

As stated above, these two approaches were fundamental in assessing mire landscapes, but they were not sufficient to decide on the national importance of an individual site.

Table 2.4.2. List of the 9 criteria surveyed in each mire landscape for the numerical-statistical approach of mire landscape assessment

Quality and diversity of
– the mire habitats (raised bogs and fenlands) – geomorphological features – biotopes (other than mire habitats) – elements and pattern of traditional land use (e.g. peat cutting pits, sheds (cf. Fig. 3.1.7), litter meadows, orchards, hedgerows, streams, etc.). – quality of settlements (traditional, historical or new buildings) – impairments of the mire landscape by industry, dumps, agriculture, traffic, tourism, military, etc. – degree of access by highways, roads, paths, railways, etc. – surface of the mire landscape – ratio of surface area of mire habitats to mire landscape

Consequently, the eventual selection of these mire landscapes evolved in an iterative procedure comprising:

- Extensive discussions with the Federal Office of Environment, Forests and Landscapes as employer. This included several field excursions in potential mire landscapes of national importance. They often took place in mire landscapes of questionable quality: the target was to discover what would be the minimum requirements for a mire landscape to qualify for national importance;
- Comparisons between similar mire landscapes;
- Extensive discussions within the team.

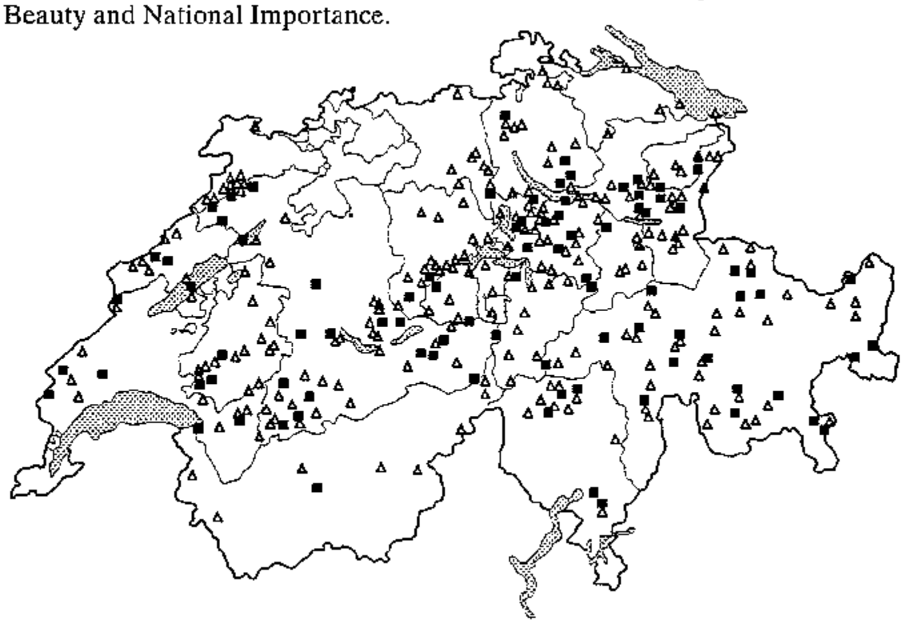
It cannot be overemphasized that defining the level of national importance is a political and not a scientific process. It is important that we at least realize this even if we cannot accept it.

2.4.5 Particular beauty

The rigorous protection guaranteed by the new article in the Swiss Constitution demands sites to be nationally important and also of particular beauty. Therefore, it was necessary to determine and define "particular beauty". As much as the assessment of beauty can be based on measurable and describable criteria, the criteria remain essentially the same as those used to assess national importance (Hintermann 1992). In general, therefore, a mire landscape of national importance is also one of particular beauty. There are exceptions of course, for example cases where the mire landscapes have been so greatly damaged that the criteria of particular beauty are no longer fulfilled.

2.4.6 Results of the mire landscape inventory

Within a period of two years, a total of 329 mire sites of potential national importance was surveyed. From these, only 91 successfully passed the very restrictive assessment procedure (cf. Fig. 2.4.2). These 91 sites were regarded by consultants and experts to fulfil the criteria demanded by the Rothenthurm amendment to the Constitution. As a result, they were embodied in the scientific national mire landscape inventory. It is recommended that all 91 sites be included in the Federal Inventory of the Mire Landscapes of Particular Beauty and National Importance.



△ Mire landscapes surveyed (before the rating process)

■ Mire landscapes (after the rating process) proposed to be of particular beauty and of national importance

— National or cantonal border (for the cantonal names refer to Fig. 1.2.2)

Fig. 2.4.2. Of the 329 mire landscapes surveyed only 91 passed the rating procedure.

The inventory survey revealed that these 91 sites contained an area of 92,600 ha or 2.2% of the land surface of the country (cf. Fig. 2.4.3). As in the case of the mire habitats, the mire landscapes are mainly concentrated in the northern pre-Alpine region; in the densely populated Central Plateau they are very few and relatively small. Nevertheless it is assumed that the inventory contains the full range of mire landscape types to be found in Switzerland. This was supported by an examination of the evaluation methodology (KIENAST et al. 1992) which found that the 91 selected mire landscapes did not form distinctive clusters when statistically analysed. This meant that every individual mire landscape proved to be unique to a certain degree. Hence, the number of sites could not be reduced to a few typical examples if a further loss of the country's natural heritage is to be avoided (cf. Chapter 2.4.4 and Tab. 2.4.1).

The inventory also revealed that during the survey at least 1,600 interferences were recorded. These are possibly in contradiction to the interim disposition of Article 24^sexies Paragraph 5 of the Constitution and must be examined (cf. Chapter 6.1). However, this is only an indicator and precursor of the many serious problems to be resolved in implementing the third mire inventory in Switzerland.

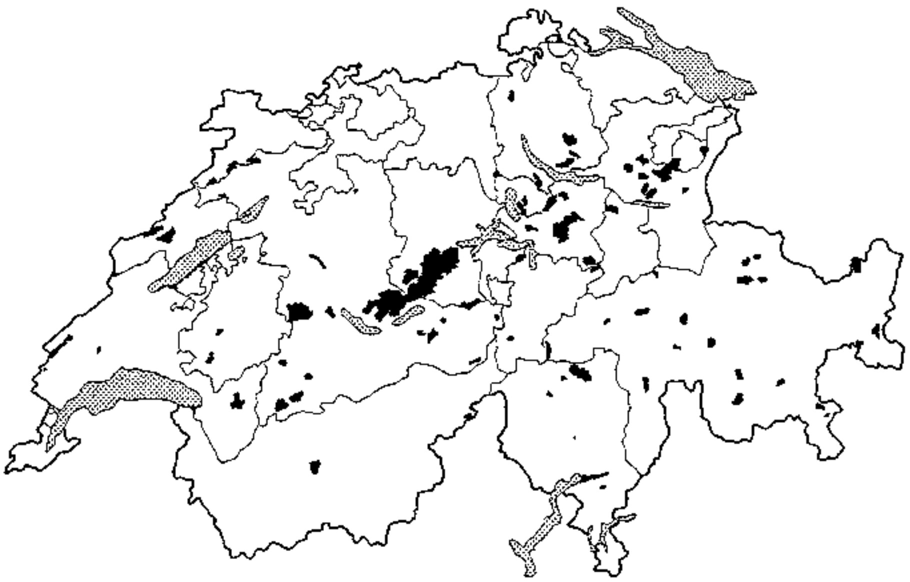


Fig. 2.4.3. Distribution and size of the proposed 91 mire landscapes of particular beauty and national importance: 926 km^2, a remainder (approximately 2%) of the original landscape.
— National or cantonal border (for the cantonal names refer to Fig. 1.2.2).

2.4.7 Implementing mire landscape conservation

The inventory provided the basis for the consultation procedure which was terminated officially at the end of 1992 (cf. Chapter 2.2). Cantonal governments, federal authorities, many voluntary conservation groups and non-governmental organizations, farmers' associations, chambers of commerce, tourist and trade unions and other interested parties were invited to offer their point of view on the mire landscape inventory and on the proposal of a federal decree.

The opinions and suggestions, ranging from enthusiasm and demands for more and larger mire landscapes to complete rejection of the proposal, need to be carefully examined. Some of the suggestions can be taken into consideration without changing the present concept of mire landscapes. However, most of the response was aimed at changing the concept and having fewer and smaller mire landscapes. This attitude reflects the enormous opposition against the mire landscape inventory in affected communities as well as in the Federal Parliament.

2.4.8 Conclusions and summary

What are the conclusions to be drawn so far from this experience? Is the approach to protect whole mire landscapes a valuable tool to improve the conservation of nature? To answer these questions it must be noted that in contrast to the inventories of the mire habitats, the mire landscape inventory does not deal with individual mire habitats or other biologically valuable elements of the landscape.

So far, the following conclusions can be drawn from the experience:

1 The landscape approach

The landscape approach always aims to look at an entity, an entire landscape which is generally a natural unit ideally dominated by raised bogs and fenlands. In the long run, only this broader view of larger units will make it possible – at least in theory – to gain control over the real causes of continued destruction of habitats. These continue to be:
- land improvement programmes;
- intensification of land use;
- increased access of the landscape by roads;
- promotion of tourism;
- insufficient regional planning;
- etc.

2 The mire landscape approach

The mire landscape approach also offers opportunities to take important measures to improve the quality of protected areas, for instance by:
- designing buffer zones which are ecologically appropriate and designed according to the needs of the site to be conserved (cf. Chapter 6.3, Art. 3);
- interlinking valuable areas by wildlife corridors;
- offering optimal habitat conservation for sensitive animal species requiring a full range of different habitats.

In conclusion the mire landscape concept presented here is probably the only promising approach to conserve the target sites in a densely populated country (cf. Chapter 4.5).

3 Criticism of the methodology

The methodology, planning and implementation procedures have come under heavy attack. However, in most cases the criticism is unwarranted. It serves only as an attempt to either eliminate the mire landscape inventory or to eliminate from the inventory list single mire landscapes provisionally designated to be nationally important (cf. point (1) of this enumeration).

4 Landscape protection as a fight against symptoms

The visual aspect of most landscapes, i.e. the scenery, is the result of the land use activities taking place in that landscape. Too often landscape conservation is considered only to be protection of the scenery. But this is mainly a fight against the symptoms. In the long run, we need to fight the disease. This means that we have to gain control over land use practice, either directly or by changing the economic and political framework, in such a manner that land use practice results in a landscape that not only pleases the eye but is also ecologically sound.

5 National interests

With respect to habitat and landscape conservation, both the establishment of national inventories and the identification of national targets for these inventories are essential. From experience, it is evident that national conservation interests have never been voluntarily and sufficiently respected at a regional or local level. Ultimately, national interests and federalism (or basic democracy) are incompatible.

6 Mire landscapes and developing countries

Tensions exist between Swiss regions concerned with mire landscapes and major urban areas. The conflicts are in principle comparable to the relationship between developing countries and the wealthy first world. People interested in better nature conservation usually live and earn money in wealthier regions of Switzerland where, ironically, most of the mires have already been destroyed. People in less developed regions are asked to lower their expectations to protect, for instance, a mire landscape instead. Why should they agree?

People of developed countries recognize and value the beauty and ecological significance of the less developed regions; conservation is a natural and justifiable goal. However, citizens of these poorer countries mainly see our high standard of living and refuse to compromise their chance at attaining a similar level of wealth.

Reviewing these facts it is clear that there will be no progress in nature and mire conservation unless there is a major change in attitude towards nature and natural resources. This may mean asking people to lower their aspirations and standard of living. However, it is doubtful if this change will occur in time and on a broad, voluntary basis. There is no easy way that mire landscape conservation will be accepted by a majority. Therefore, it will be simply a matter of political power who will succeed. In the long run, hopefully, it will be both: mires and man!

2.5 The contribution of the "Landscape Database Switzerland" to nature conservation

Thomas Dalang

2.5.1 Introduction

"Landscape Database Switzerland" is a research group of the Swiss Federal Institute of Forest, Snow and Landscape Research. This group consists of four scientists and manages a conglomerate of habitat and landscape inventories which are used for nature and landscape conservation. The main task of the Landscape Database Group is to process these inventories, especially to combine and compare them. It also includes the support of the database, the scientific handling of the data and their transfer from the government and scientific institutions to the users. The technical tools used are the graphical overlay utilities of a Geographical Information System (ESRI 1991) and some database software (Oracle Corporation 1990).

The aim of this section is to present seven examples of different ways of evaluating inventories on a computer system with the tools of a Geographical Information System. The examples also illustrate the contribution of Landscape Database Switzerland to the management of nature conservation in a country where much of the natural beauty could be lost for ever. The examples show the potential and limitations of some important habitat and landscape inventories.

Chapter 2.5.2.1 deals with the interpretation of the differences between the boundaries of several inventories. These differences could be due to insufficient precision of the digitalization, different intentions during the creation of the inventories, different mapping scales, or differences in the definitions of the mapped units.

The analysis of the development in time (Chapter 2.5.2.2) is important for planning nature conservation strategies of pioneer habitats.

In Chapter 2.5.2.3, an example is shown with differences in the data sets concerning the same type of habitat. The interpretation of these differences helps to improve and complete the data.

In Chapter 2.5.2.4, the use of habitat inventories for landscape evaluation is discussed.

The aggregation of two or more inventories into one single inventory simplifies the political utilization of the data. The questions around this task are discussed in Chapter 2.5.2.5. Data extracts of Landscape Database Switzerland are used to answer questions of special interest, such as the agricultural land use of wetlands in Switzerland (Chapter 2.5.2.6).

Rating habitats should be based on statistical analysis and an evaluation of different rating methods. Chapter 2.5.2.7 shows how the fenlands were rated to distinguish between sites of national importance and other sites.

Whereas in the present context the practical aspects of applications are considered, two other sections in this volume deal with the support of the database (see Chapter 2.6) and the data transfer to the users (see Chapter 2.7). Figure 2.5.1 shows the locations of the data used in the following examples.

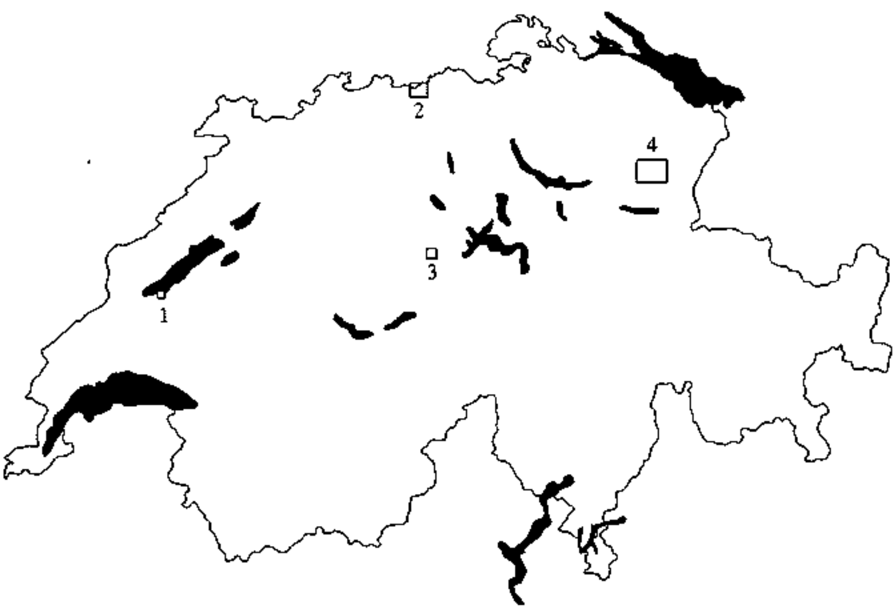


Fig. 2.5.1. Locations of the different examples discussed in this section. 1 South shore of the Lake of Neuchâtel (2.5.2.1); 2 Kaisten (2.5.2.2); 3 Entlebuch (2.5.2.5); 4 Schwägalp (2.5.2.6).

2.5.2 Examples

2.5.2.1 South shore of the Lake of Neuchâtel

Figure 2.5.2 is a map showing 4 km of the south shore of the Lake of Neuchâtel (cf. Chapter 3.6). There are sites of five different inventories. Three of them are landscape inventories, one is a habitat inventory, and one is a mixed type.

The boundaries of the landscape sites in the so-called KLN inventory were proposed in 1967 and in 1979 by three non-governmental organizations. The latest of a number of subsequent revisions took place in 1988 (SBN et al. 1988). During political discussions, these boundaries were – as expressed by the government – "carefully revised" (DFI 1977/1983). In fact, the revision resulted in a reduction of the average size of the landscape sites. In the case shown in Figure 2.5.2., villages and their neighbourhoods were excluded (Fig. 2.5.2, No. 1). As a result of this revision process a new inventory was created, called the BLN inventory which stands for Bundesinventar der Landschaften und Naturdenkmäler von nationaler Bedeutung [Federal Inventory of Landscapes, Sites and Natural Monuments of National Importance] (DFI 1983). In cases of conflicts, the BLN inventory is a legal basis to defend the position of landscape conservation.

The difference between the KLN and BLN inventories is the result of a democratic discussion. The interests of nature conservation are better represented in the KLN inventory than in the BLN inventory. Consideration of other interests (economy, tourism, agriculture etc.) have led to a greater political importance for the BLN inventory.

In 1987 Swiss people voted for a stronger "mire landscape conservation", forcing the federal government to make another effort to define landscapes of national importance (DFI 1991c), ten years after the first edition of the BLN inventory (DFI 1977). Today the mire landscape inventory has a status similar to that of the KLN inventory because the political forces, apart from mire conservation interests, have not yet been considered. To date, of the 91 proposed mire landscapes, only 27 have found a shape which is also acceptable to the most important political forces (NZZ 1992).

On the mapped site (Fig. 2.5.2), the boundaries of the mire landscape and the BLN inventory are quite similar. The two differences are the result of different methods of defining the boundaries: No. 2 points to the boundary of the mire landscape which now follows a little stream. The BLN inventory instead considered the distribution of sub-soil water. No. 4 points to the mire landscape boundary which is located on the outer border of the forest. The boundaries of the KLN and BLN sites, on the other hand, follow the main road and the railway (Fig. 2.5.2, No. 3).

The focus of both the BLN and KLN inventories is the landscape in general. The restrictions applied to the BLN sites are weaker than those of the mire landscapes. The methodological approach of the mire landscape inventory is, therefore, more convincing. In summary, in regions where mire landscapes have been defined, the KLN and BLN inventories help to complete the landscape approach because they consider other aspects such as historical monuments and other artifacts. In the case illustrated by Figure 2.5.2 the KLN inventory shows that villages (No. 1) at the lakeside are important components of a cultural

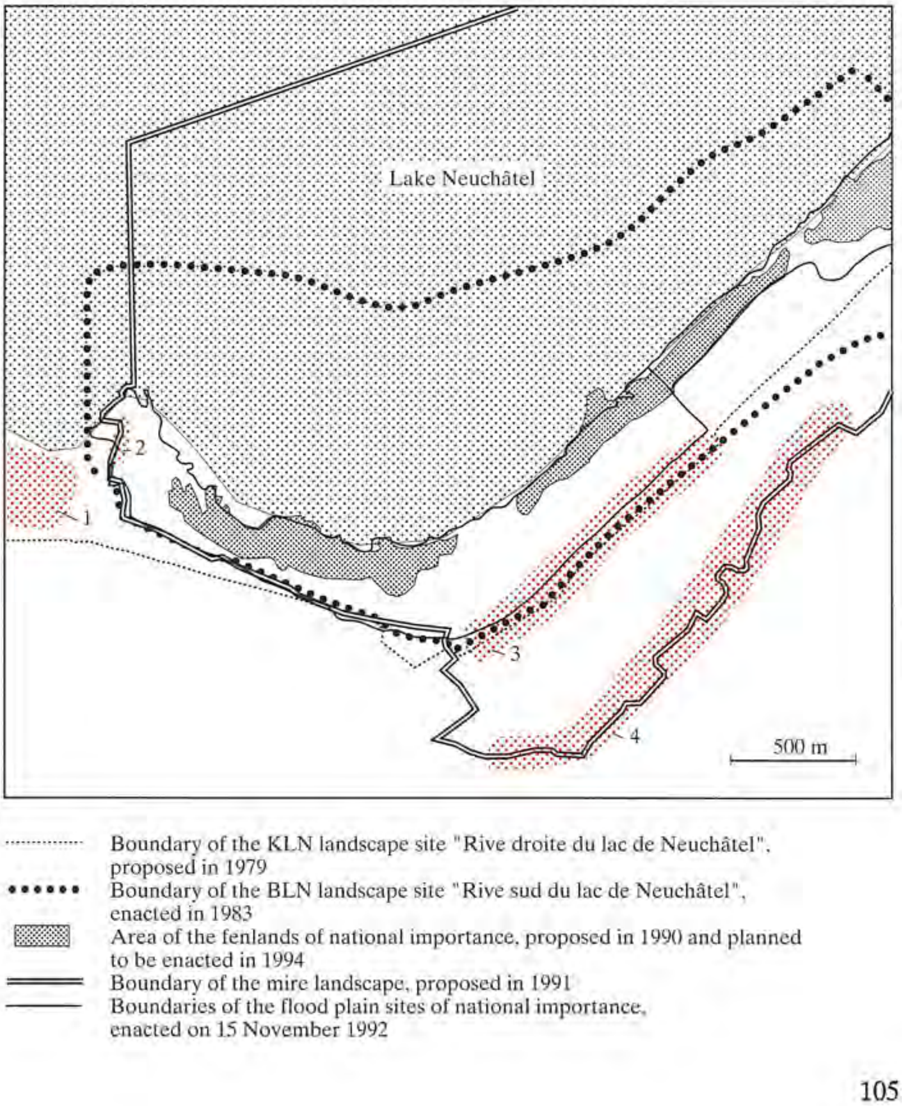


Fig. 2.5.2. Boundaries of five different inventories on the south shore of the Lake of Neuchâtel near Yvonand (canton Vaud). The areas marked with red and parts of the boundaries marked by numbers are discussed in the text.

landscape influenced by man. The mire landscape inventory shows that the neighbourhood of a wetland, even if it is only in visual contact, also belongs to the landscape (see for instance Fig. 2.5.2: the area between No. 3 and No. 4).

Along with the landscape inventories, the boundaries of the fenland inventory are shown (DFI 1990). These sites were defined by the vegetation. The conservation objectives are not the same in every part of a landscape: in some parts the agricultural goals have priority, in others the aesthetics of the countryside or the village are more important. The fenland inventory points to areas where habitat conservation has priority. In the case shown in Figure 2.5.2, the fenlands are endangered by the wave erosion. Since the Jura Water Correction which took place in the 1870's, 200 m of the southern lakeside have been eroded (Huber 1989; cf. Fig. 3.6.2 and Fig. 3.6.3).

The flood plain inventory (DFI 1991a) occupies an intermediate position between landscape and habitat inventories. In the case shown in Figure 2.5.2, this inventory supports the other inventories. In other situations, for example along rivers, it provides additional information about wetlands.

These five inventories all aim to protect nature, but they were produced at different times under different circumstances and with different methods. It is therefore no surprise that different boundaries were established. These differences create practical problems for the implementation of these inventories because the citizen may believe that the government had contradictory opinions. However, the combination of different inventories is a very good base for nature conservation: the problems have been analysed from many different viewpoints and have involved the local authorities on many occasions. As discussions about the mire landscape inventory show, it may still be possible to find a satisfactory solution for this region (NZZ 1992).

2.5.2.2 Amphibian spawning places in the community of Kaisten

Traditional nature conservation focuses on species. To protect a species, we have to preserve its habitat. Since the procedure of habitat conservation is well-established, the government is using this approach in an attempt to protect amphibians. The first step towards the development of such a habitat inventory

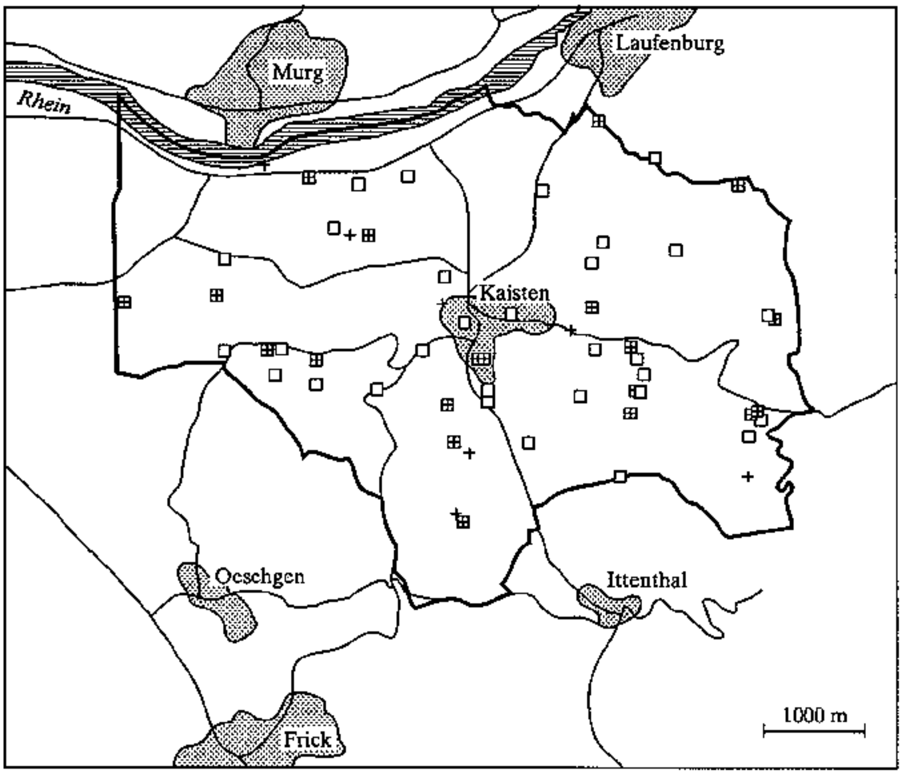


Fig. 2.5.3. Amphibian spawning places in the community of Kaisten (canton Argovia); data from 1979 (+) and 1988 (□).

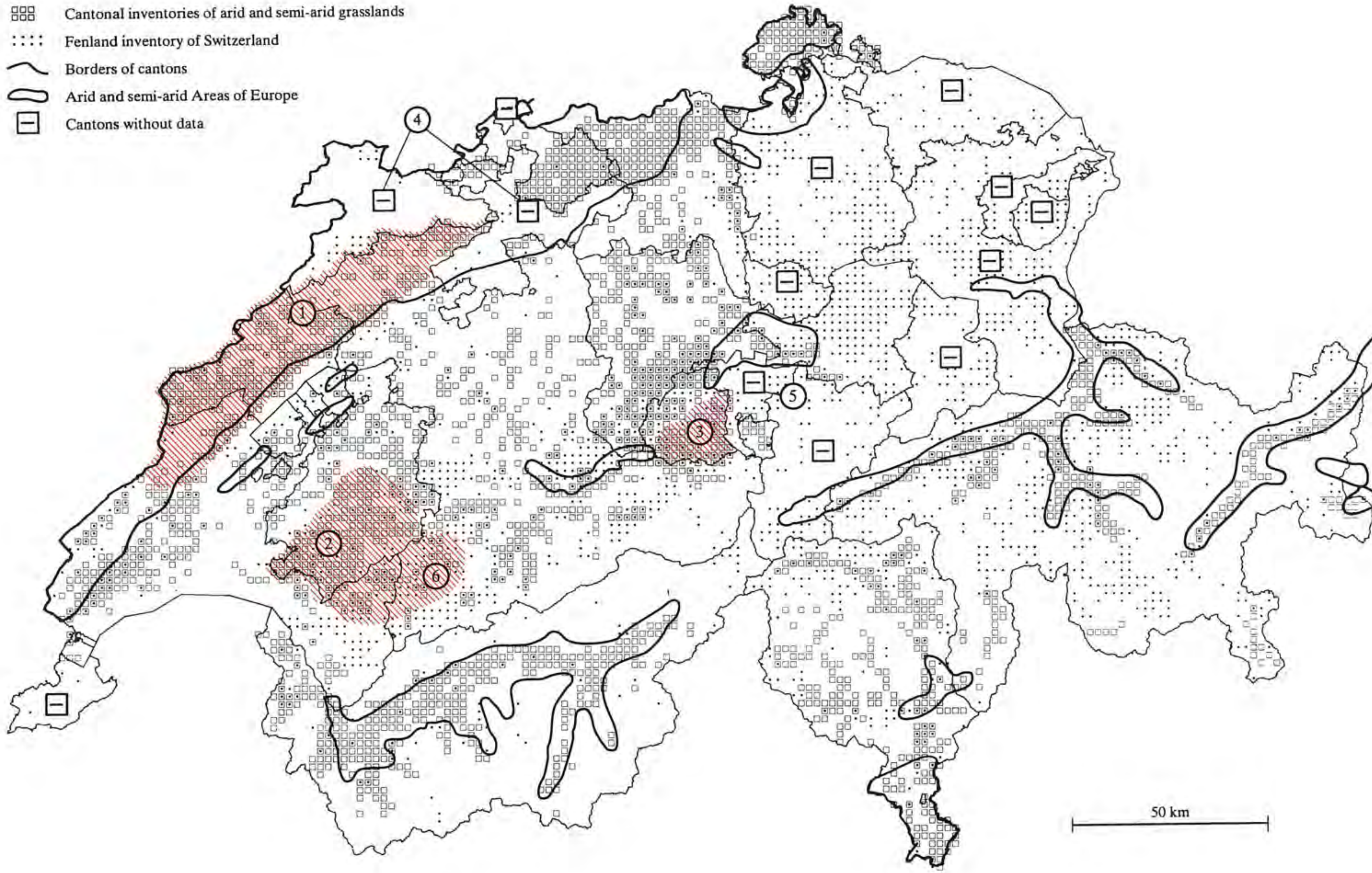


Fig. 2.5.4. Sites of (semi-)arid grassland and of fenlands according to the data of the "Landscape Database Switzerland", combined with a European study (Wolkinger and Plank 1981) about important regions of arid grassland. For areas shaded in red and/or numbered 1–6 refer to Chapters 2.5.2.3 and 2.5.2.4.

is an atlas of distribution (Grossenbacher 1988). For some regions, there are data from two different surveys. Figure 2.5.3 shows the amphibian spawning places in both 1979 and 1988 in a community in the north of the Central Plateau near the German border (ANL 1991; Tester 1992). The number of mapped sites has increased due to a more systematic investigation and the creation of new ponds. The more abundant species have profited from these new spawning places, but rare species have decreased in number.

The example demonstrates the dynamics of amphibian spawning places. It is difficult to manage the amphibian conservation programme using only a habitat protection instrument designed for spatially fixed sites. It would be better to conserve the entire range of the populations.

2.5.2.3 Combination of the (semi-)arid site inventories with data of a European council study

Most cantons of Switzerland have established an arid grassland inventory. The cantons where data are not available or have not been integrated in the database are marked with a "minus-box" in Figure 2.5.4 The Swiss government has promised financial support and proposed a standard for inventory methodology (Klein 1986). An assessment of the inventories in relation to the whole country is not possible on this basis because of insufficient homogeneity of the data. This inhomogeneity is apparent when the data are compared with a general European survey of arid grasslands (Wolkinger and Plank 1981).

The differences in density of the arid sites in the Jura Mountains (Fig. 2.5.4, No. 1), as shown by the inventories of the cantons, are questionable. In two regions in the Northern Alps, the inventories seem to have too many sites (Fig. 2.5.4, No. 2 and No. 3). Important data gaps are in the Jura Mountains (No. 4) and in the Northern Alps (No. 5).

If the federal administration intends to produce an inventory of the same quality as the mire habitat inventories, it will have to repeat the process with a uniform and supervised method.

2.5.2.4 Rating of landscapes

Based on the data given in the inventories, it is possible to develop indicators to estimate the value of a region for nature conservation by combining the data from different types of inventories. For example, we could say that regions with both arid sites and wet sites have a high diversity and are, therefore, important for nature conservation. Such regions are, for example, the Bernese Oberland and the Pays-d'Enhaut in canton Vaud (Fig. 2.5.4, No. 6).

There is no widely accepted precise definition of the German expression "Landschaft" (landscape; cf. Chapter 2.4.2), but the concept of landscape and of landscape conservation is very popular. The consequence is that there are many different approaches to rate landscapes. The approach which views the landscape as a complete entity is now very popular (Kuhn et al. 1992; Hintermann 1992; Chapter 2.4.2).

In the context of nature conservation, habitats are considered very important elements of a landscape. So, the analytical approach is an important complement to the holistic approach. The combination of arid and fenland sites is shown here as an example.

We have also tested this approach with other data: a test with land use data from the governmental statistical department showed that with only five categories of this database, the diversity index of Shannon and Weaver (1949) could be used to distinguish regions of different natural conditions (Fischbacher 1991). The new land use statistics, which distinguish 69 categories, will produce much more detailed results (BfS 1992). Another example demonstrated that some types of traditional cultural landscapes can be identified if we assume that fenlands and settled areas are located close together in such a landscape (Dalang 1992a).

2.5.2.5 Aggregation of two wetland inventories

The raised bog inventory (Grünig et al. 1986, see Chapter 2.3.1) was produced over a period of seven years and described, including the immediate surroundings, a total area of 51 km². The fenland inventory (Broggi 1990, see Chapter 2.3.2) was produced in three years and described sites with a total area of 243 km². These figures indicate that the fenland inventory was produced in a hurry, driven by rapidly developing political pressures (cf. Chapter 2.2). At the same time, Geographical Information Systems became widely used. Consequently, computer input of the data was carried out with different methods. It is therefore not surprising that co-ordination problems between the two inventories have occurred.

The area shown in Figure 2.5.5 covers only a few square kilometres. It shows different areas of the raised bog inventory and the fenland perimeter. Because the two inventories were developed independently of each other, boundaries which are identical in the field may differ on the map. However, the difference between corresponding boundaries is only 10 to 20 m and is sufficiently exact for practical purposes.

One of the ideas presently being discussed is to combine these two inventories into a single inventory. To realize this task, the differences in the boundaries have to be assessed. Most of the differences seem to be of a technical nature and should be easily corrected with a suitable Geographical Information System.

Another problem is that the two inventories use different definitions of a wetland. In the raised bog inventory, fenlands are considered buffer zones. In the fenland inventory, this mire type is the focus with no other defined buffer zone. One way of combining the two inventories is to take the core zones from both and to redefine a common buffer zone. Another possibility would be to take the core and the buffer zone of the raised bog inventory and to complete the buffer zone around the fenlands.

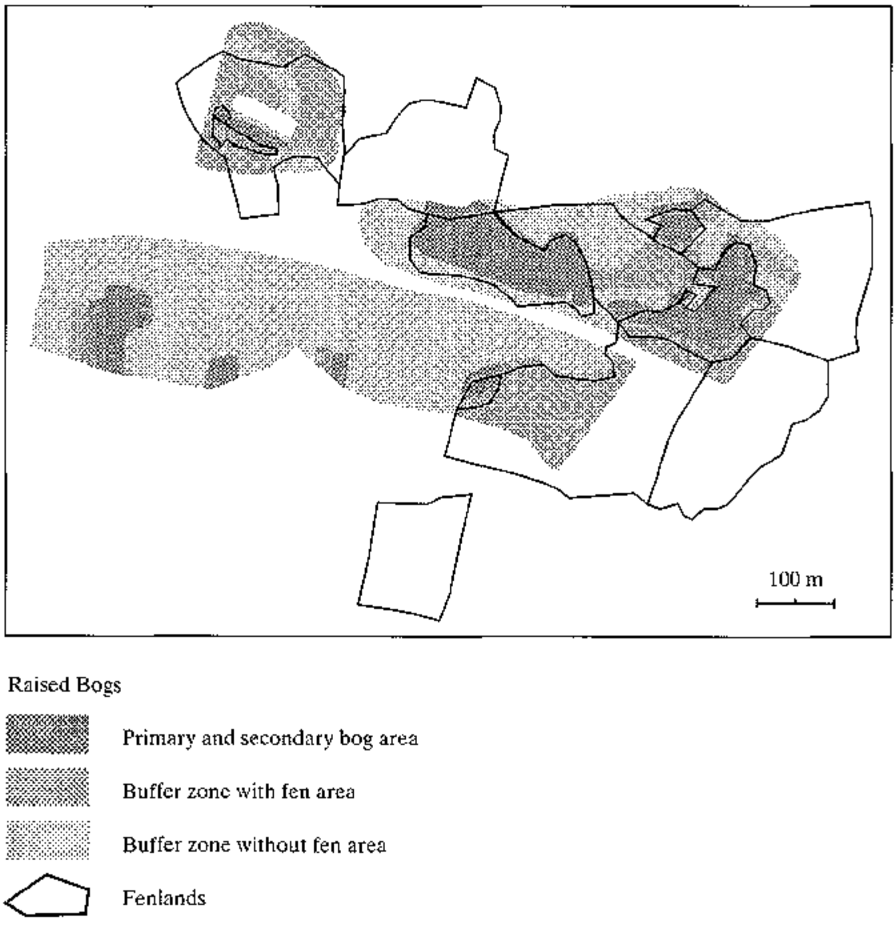


Fig. 2.5.5. Overlaying raised bog inventory and fenland inventory in the community of Entlebuch (canton Lucerne).

This example demonstrates how problems of definition and mapping become evident when we attempt to combine two inventories, even when basically similar.

2.5.2.6 Land use in fenlands

Other applications require the processing of selected data. In the mire landscapes, only agricultural land use as it has been practised until now is permitted (cf. Chapter 6.1). This democratic decision for "zero-growth" in certain areas is in contrast to the fundamental paradigm of growth in our society. For that reason, this formulation has become a key issue in the debate between the representatives of agriculture and nature conservation. To provide the necessary information for these discussions, it is important to know the type of agricultural land use currently practised in different regions.

Figure 2.5.6 offers an example from the mire landscape "Schwägalp" (DFI 1991c) in the north-eastern Alps. For part of the site, the data for pasture and fallow areas are also shown. The relevant figures are given in Table 2.5.1 and they indicate that in this area, grass cutting is preferred to pasture and the percentage of fallow area is quite high (Dalang 1992b).

The landscape database can produce visualization of special data. For instance, this will make it possible to compare it with any future data to monitor the changes in land use.

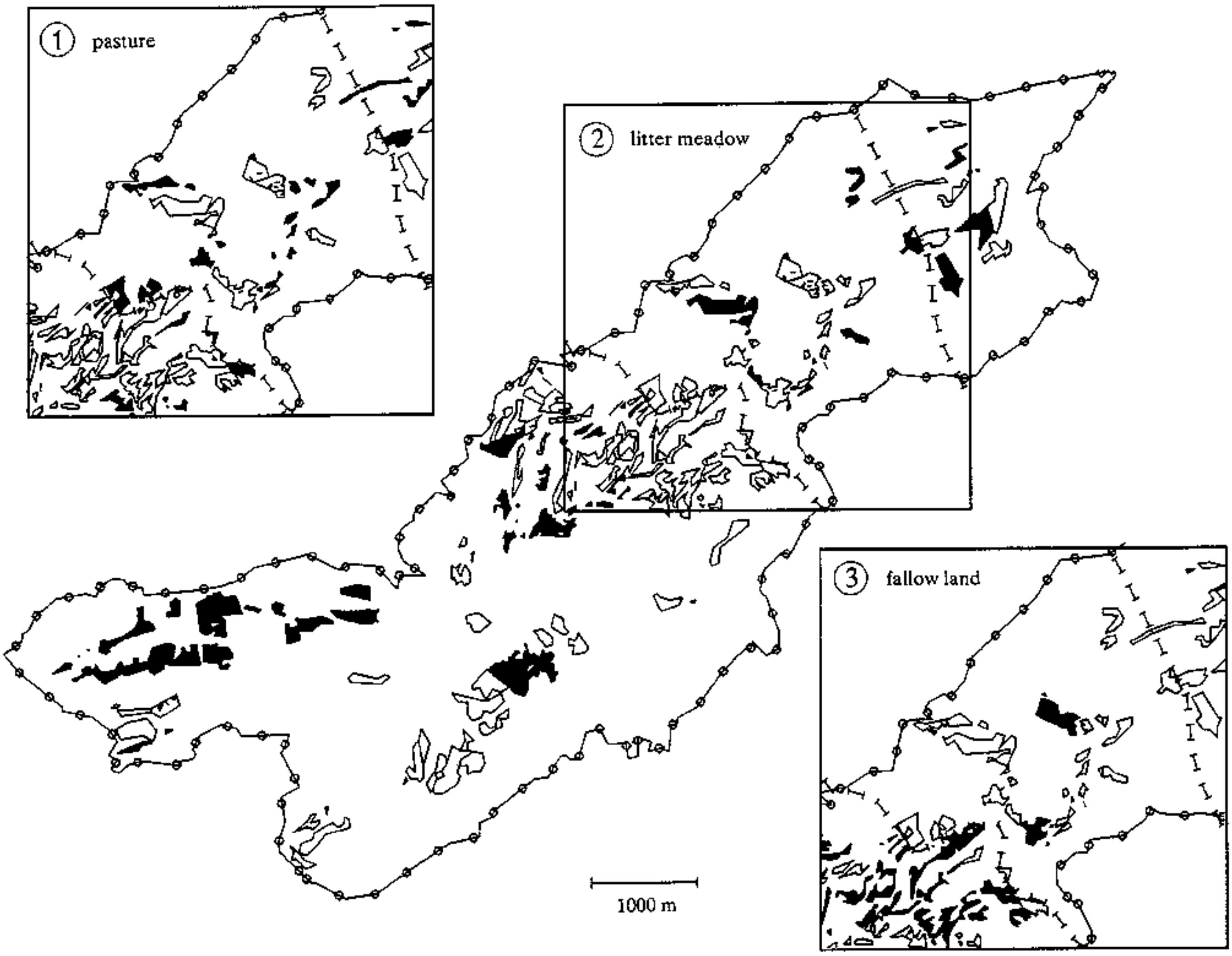


Fig. 2.5.6. Land use in the fens of the mire landscape "Schwägalp". The pasture areas are marked in box 1. In box 2, the litter meadows are marked black, the other fens are outlined. The fallow land is marked in box 3.

Table 2.5.1. Land use in fens at three spatial levels in 1987 to 1988

Land use	Fens within the mire landscape Schwägalp		Fens within the mire landscapes of the Northern Alps		All fens in Switzerland	
	ha	%	ha	%	ha	%
Litter meadows	136	41	2170	22	7538	31
Pasture	118	36	6590	67	12366	50
Fallow	76	23	1083	11	4554	19
Total	330	100	9843	100	24458	100

2.5.2.7 Fenland rating

The government pays higher subsidies for sites of national importance than for sites of regional or local importance (Chapter 6.2, Art. 18d). Therefore, during the preparation of the fenland inventory, an important task was to establish the principles for assessing the sites. The project management developed quite a simple method which essentially uses only the size of a site and the vegetation diversity as the basis for assessment (OFEFP 1991; Broggi 1992):

Only seven plant alliances are distinguished. For an assessment, the number of plant alliances is counted. On the basis of common occurrence, groups of plant alliances are defined. These groups are counted and the figure doubled. The size of the site is converted to a number between 1 and 12. If the total of these three numbers exceeds a certain limit, the site is rated "of national importance" (Tab. 2.5.2). This system of assessment allows both small sites with high diversity

Table 2.5.2. Assessment of fenlands

The following formula determines whether or not a fenland site qualifies for "national importance", as defined in the Federal Act on Wildlife, Countryside and National Heritage Protection [Natur- und Heimatschutzgesetz]:

$$\mathbf{N + 2 \cdot D + F \geq W}$$

where

N represents	the number of vegetation units of the surveyed site according to a set list of seven units.
D (R) represents	the number of groups of vegetation units. This was calculated for each geographical region (R) (Jura Mountains, Central Plateau, Northern Alps, Central Alps and Southern Alps) according to the coinciding occurrence of the units.
F (R) represents	the category of surface size. This was also calculated separately for each geographical region (R).
W (E, R) represents	the limit for "national importance": 15 in the case of a good state of conservation (E), 17 or more in the case of a poor state. In the Northern Alps this criterion is more strictly applied.
Additional criteria:	1 Fenland sites that border directly on a raised bog of national importance automatically qualify for national importance. 2 In special cases (e.g. an extraordinary richness in species on the Red Lists), a fenland site with few points can be rated "of national importance".

and large sites with less diversity to qualify equally for the status of "national importance". The additional criteria of Table 2.5.2 were developed to make these rather undifferentiated rules more flexible in relation to special local conditions.

2.5.3 Conclusions

The examples show that a combination of different data can be easily made with a Geographical Information System. The interpretation of the resulting combination patterns is, however, quite difficult in most cases. Some hypotheses about the relationships between the data sets must be established. It is one of the tasks of our database group to test the possibilities of data combination and to evaluate resulting patterns in order to provide answers to questions about nature conservation and land use management.

The most important problems that can be dealt with using the tools of a landscape database are:

- Data quality improvement by different consistency checks across the database. This is particularly important if data collection in a mapping project requires a great deal of time and no special co-ordinating effort is made; the inventory method can change over time depending on the political situation and the special circumstances of the region.
- Rating of habitats and, with the help of models, rating of landscapes. This is used to set priorities for nature conservation policy.
- Answering special questions, for example, about land use patterns. It is then possible to intervene in the political decision-making process.
- Cartographic visualization (MacEachren and Ganter 1990). As more data become available, communication becomes increasingly more important. A special task is to produce good mapping tools for computer graphics.
- Analysis of development over time. This helps to monitor the success of environmental policies and it is also important for the management of pioneer habitats, such as amphibian spawning places.

The fenland, raised bog and mire landscape database provides a good instrument for establishing environmental policy in Switzerland. The (semi-) arid site and the amphibian inventories must be revised before they can be of use to the national nature conservation programme.

2.6 Managing landscape and mire habitat data

Peter Schönenberger

There are two basic types of information in a Geographical Information System (GIS):

- Spatial or landscape data
- Descriptive or habitat data.

Spatial information describes the coordinates and perimeters of landscape data such as points, lines and areas. These are, for example, the shape and location of a raised bog, the perimeter of a lake or the shape of a street.

Spatial data are represented as different layers of a topographical map. These layers can be overlaid to compose different topographical maps.

Descriptive information about features is stored by a relational database with different tables. This relational database contains detailed site information such as the name of a site, the importance of a site, a list of *Sphagnum* mosses and so on (Fig. 2.6.1).

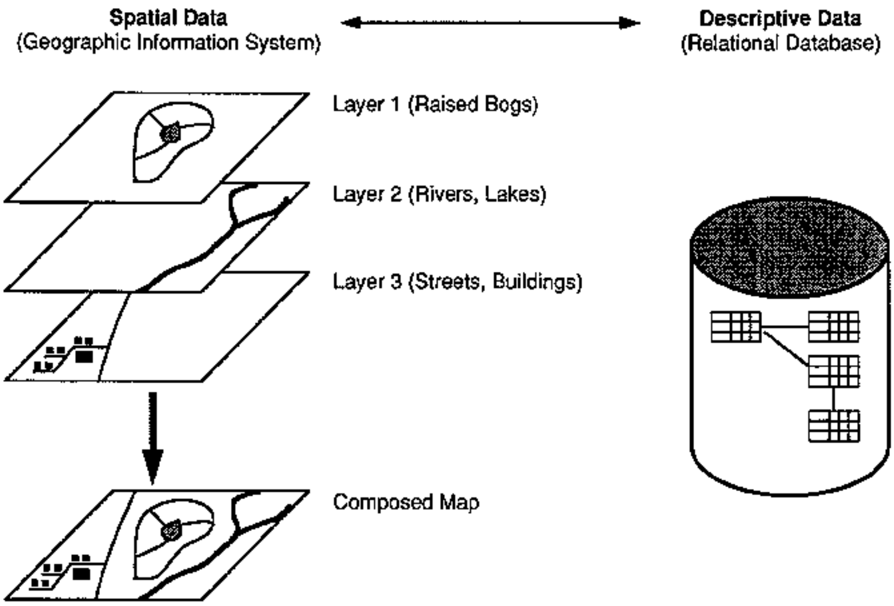


Fig. 2.6.1. Spatial and descriptive data.

2.6.1 Spatial data concepts

The spatial information contained within a map is described graphically as a set of points, lines and areas. A point defines a location on a map such as a centre of a city or a mountain peak. A line represents the shapes of geographic objects that are too narrow to depict as an area (e.g. streets, streams) or linear features that have a length but no area (e.g. elevation contours). An area is a closed figure that represents the shape and location of homogeneous features such as states, counties or land use zones. In this way we can define an area as a polygon that is represented topologically as the lines (or arcs) defining the polygon. A list of the arcs that make up each polygon is stored in a table and is used to construct the polygon. Each arc may appear in the list of arcs for each polygon. The arc coordinates are stored in a separate table and need to be stored only once. Storing each arc only once reduces the amount of data and also ensures that the boundaries of adjacent polygons don't overlap.

2.6.2 Descriptive data concepts

To describe the data structure of the descriptive data of the mire landscape database, a model called the entity relationship diagram (ERD) has been used (ZEHNDER 1989). Three terms are important to understand the ERD:
- The entity
- The entity set or the relation
- The relationship between two relations

An entity is an individual item of elements of the real or the imaginary world. An example of an entity is the mire landscape site number 23. Each entity has attributes such as an area, name, canton and so on. All the entities with the same or similar attributes build an entity set or a relation. Thus, all the mire landscape sites build the relation "mire landscape site". One or many attributes build a unique identification called the primary key of the relation. In the above example, the site number is the primary key of the relation "mire landscape site".

Two relations can build a relationship. There are several types of relationships:

- Simple association (represented by '1'):.There is exactly one entity which corresponds to the other entity.
- Conditional association (represented by 'c'): There is exactly one or no entity which corresponds to the other entity.
- Multiple conditional association (represented by 'mc'): There are no, one or many entities which correspond with other entities.
- Multiple association (represented by 'm'): There are many (but at least one) entities which correspond with other entities.

In Figure 2.6.2 the relation "mire landscape site" has a 'c-to-mc' relationship to the relation "fen site". Thus a mire landscape site may contain none, one or many fen sites and (read the other way around) one fen site may belong to exactly one or to no mire landscape site.

This relationship is realized by repeating the primary key of the relation "mire landscape site" in the relation "fen site". This repeated key is named the secondary key to the relation "mire landscape site". For example, to determine which fen sites are located inside the mire landscape site number one, the fen sites are selected with secondary key "ML-ID" equal to 1. Or the other way around: which mire landscape site does the fen site number 645 belong to? The answer is in the secondary key of the relation "fen site": It is the mire landscape site number 416. Because it is a conditional relationship, the secondary key can be 'NULL' which means that this fen site doesn't belong to a mire landscape site.

The simplified entity relationship diagram (ERD) in Figure 2.6.3 represents the database of the mire habitat data. At the top there is the relation "mire landscape sites" which have no, one or many raised bog sites. These raised bog sites are composed of one or many raised bog sub-sites. Such a sub-site is itself composed of one or no near-natural areas, one or no damaged areas and one or no surrounding areas and each raised bog sub-site has exactly one record of habitat data. This ERD can be read the other way around. In this case it would

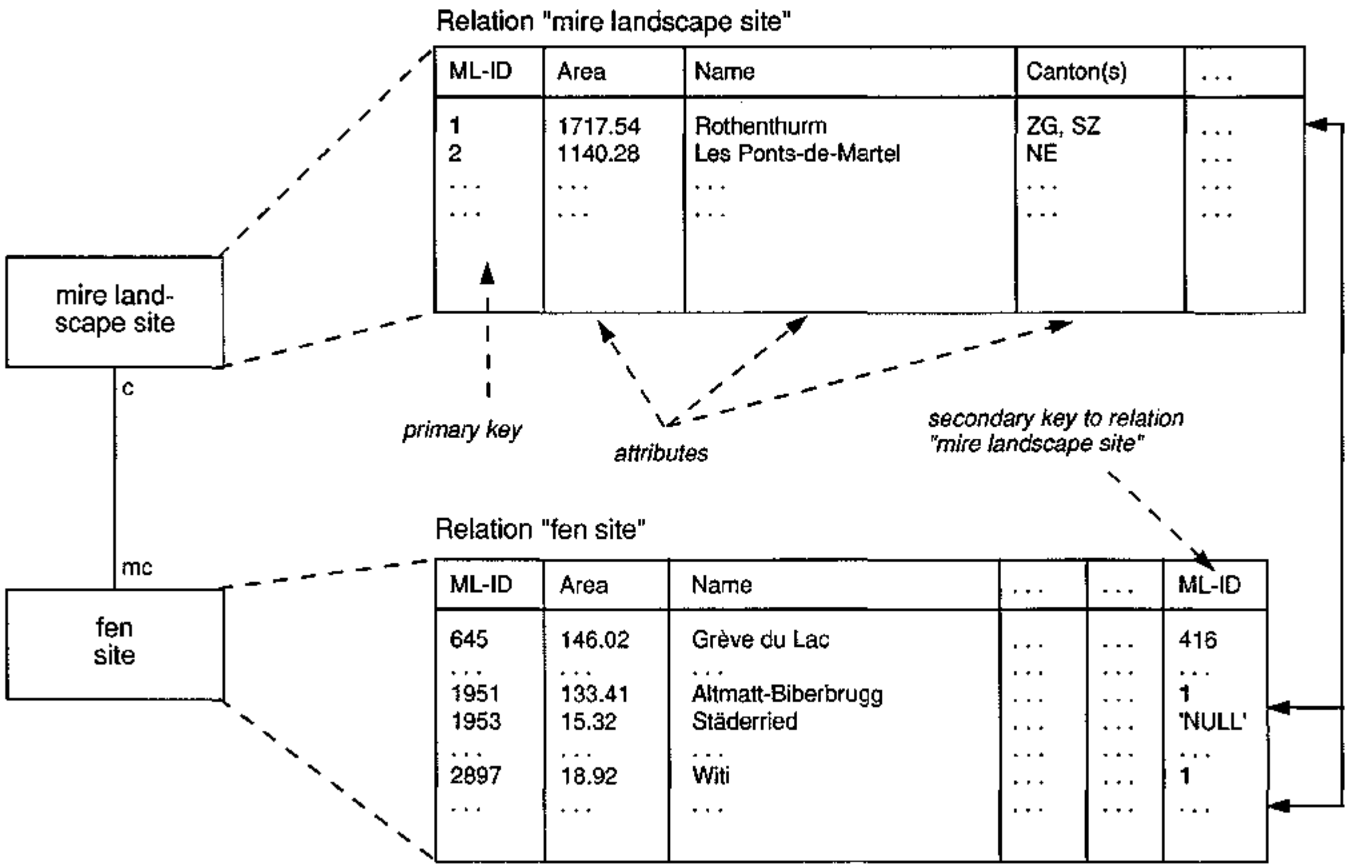


Fig. 2.6.2. Relational database – the one-to-many relationship.

read: Each raised bog near-natural area belongs to exactly one raised bog sub-site which belongs to exactly one raised bog site and each raised bog site belongs to one or no mire landscape sites.

There are some additional relations in the complete ERD of the database (e.g. aerial photos, references) which we exclude when trying to understand the fundamental structure of the database.

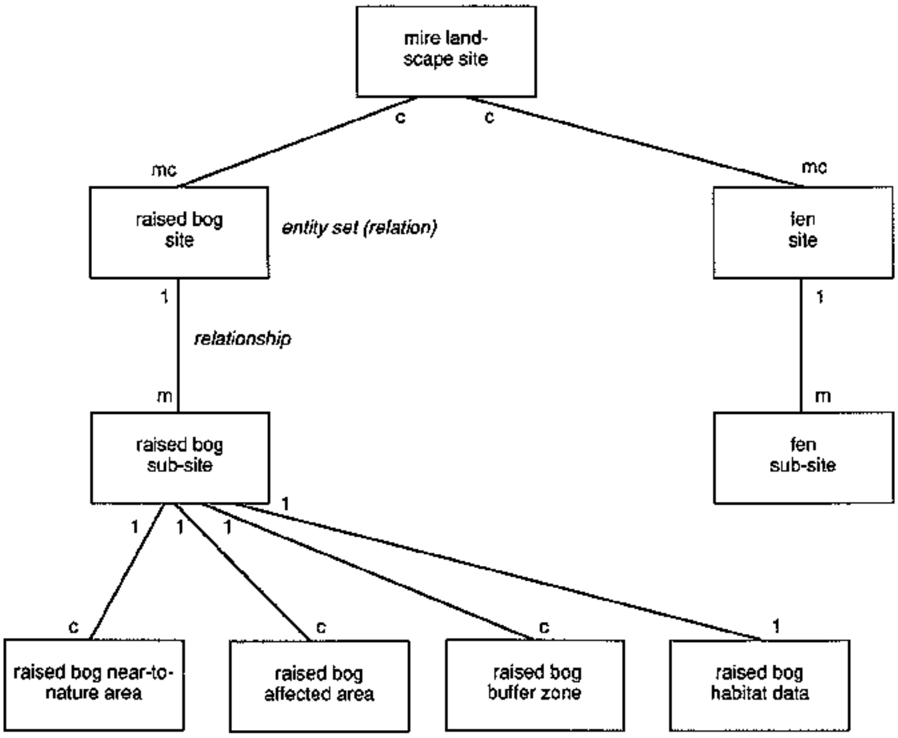


Fig. 2.6.3. The entity relationship diagram (ERD) of the mire habitat database.

2.6.3 Linking attributes to features – the georelational model

Spatial data are represented by coordinates and topology. Descriptive data are organized as records in the tables of a relational database.

The next concept to understand is how a link is created between the features and their corresponding attribute records (Fig. 2.6.4). A feature number associates the attributes with the polygons through a one-to-one correspondence between the spatial and descriptive records. This connection is established through the polygon attribute table (PAT). In other words, the PAT is a relation whose attributes are the polygon numbers and the feature numbers. The feature number serves as a foreign key to a relation in the descriptive database.

Once this connection is established, the map can be queried to display attribute information, or descriptive data can be used to compose a special map of selected objects. For example, a selection of raised bogs with a special species (stored in the relation "habitat data") can be used to compose a distribution map of this species.

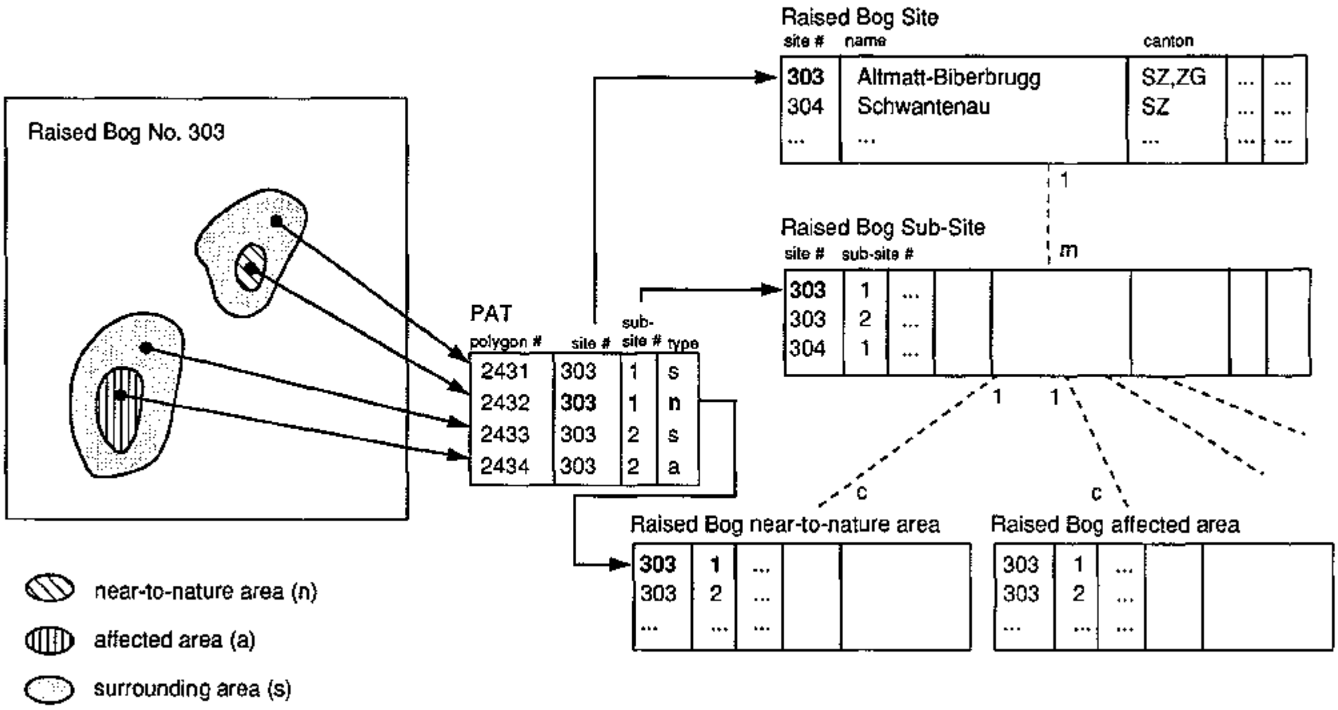


Fig. 2.6.4. Spatial and descriptive data linkage.

2.6.4 Managing time

Another important aspect of a georelational database is storing the history of the data (Fig. 2.6.5).

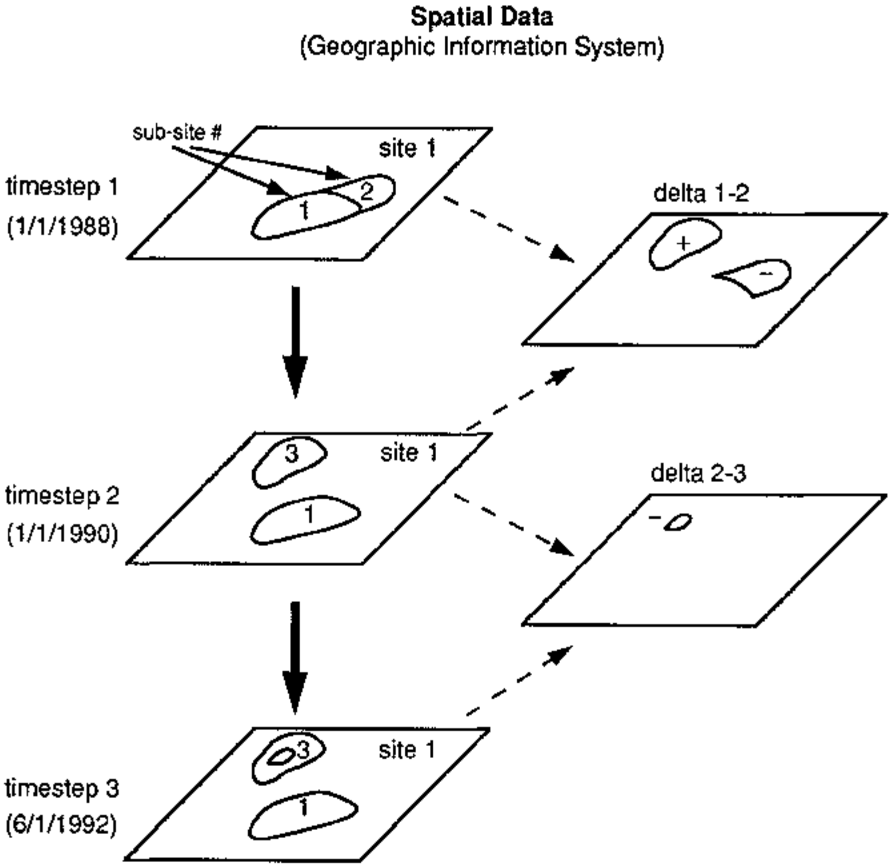
In the case of spatial data, at timestep 1 (e.g. '1/1/1988') the inventory is completely digitized. With time, several areas change. For example, a new site is found or a site disappears. Thus, at timestep 2 the inventory is copied and modified. At timestep 3, the inventory of timestep 2 is copied and modified again. The changes from timestep 1 to timestep 2 are calculated by overlaying the two layers and selecting the differences. This is done automatically by the GIS-Software (Kienast et al. 1991).

In the case of descriptive data, two new attributes are added to the primary key of each relation (Kinzinger 1983). These additional attributes are "valid from" and "valid to". With this new primary key, each entity can be identified at a specified time. The actual data are marked by setting the attribute "valid to" to '1/1/3999'. For example, the valid data at '5/7/1991' are selected by generating a view with "valid from" earlier or equal to '5/7/1991' and "valid to" later than '5/7/1991'. The actual data are simply selected by generating a view of the relation with all the records which have "valid to" equal to '1/1/3999'.

2.6.5 Technical information

The mire landscape and habitat database described above is implemented on a SUN Sparc2 Workstation (32 MB RAM, 1.6 GB Disk, 19" Colour Desktop) using the following software:

- Geographic Information System: ARC/INFO, Version 6.0
- Relational database: ORACLE, Version 6.0



Descriptive Data
(Relational Database)

site	sub-site	valid from	valid to	..
1	1	1/1/1988	1/1/3999	..
1	2	1/1/1988	1/1/1990	..
1	3	1/1/1990	6/1/1992	..
1	3	6/1/1992	1/1/3999	..

Fig. 2.6.5. Managing time.

2.7 Making habitat and landscape inventories available to Macintosh users

Peter Longatti and Urs Fischbacher

Managing the national habitat inventories also includes the task of distributing the data of these inventories. Up to now, each inventory has been published separately in a set of folders with the data of each site assembled on one sheet and the boundary of the site marked on a map. When required to work with the data of several sites of different inventories, one is faced with reams of paper.

2.7.1 Easy Access

To provide a more efficient access to all the inventory data, an application for displaying them on a Macintosh has been created. This application is called Toposkop and consists of two programs: the Toposkop graphic viewer and the Dataskop database. It has been designed to present the inventory data in a way that is most convenient for the user. However, you can do more than just locate the site and look up the information:

- You create your own map of any area at any scale with whatever inventories you choose.
- You can export this map to any other program to add further elements to it (a scanned topographical map, for example).
- You can even analyse the data to a certain extent (depending on the type of the Dataskop database).

For the time being the Toposkop programs and the inventory data are distributed on a removable hard disk cartridge.

2.7.2 Data available

At the moment, the Toposkop is distributed together with the following inventories:

Raised bogs
Fenlands
Mire landscapes
Flood plains
Bird sanctuaries
Amphibian spawning places
Refuges (no hunting)
Landscapes, Sites and Natural Monuments (BLN)

Communities, cantons and the boundaries of the topographical maps are represented in the same way as the inventory objects.

Some further extensions are planned for the future:

on-line assistance (Help, Glossary)
a bibliography database

2.7.3 Contents of the inventories

In general an inventory consists of three parts: the site location, the site description and the inventory information. The site location is the geographical information. It contains the exact boundaries of the site. The site description always contains:

- ID: the site number
- site name: if there is one
- classification: is the site of national importance?
- communities, cantons: the community(ies) and canton(s) it belongs to
- area: the size of the site

Depending on the type of inventory there is additional information. The fenland inventory, for instance, contains information on the plant communities found and the agricultural use of the site. In the raised bog inventory, individual plants found at the site are listed.

The inventory information consists of general information, such as the number of sites in the inventory, the total area covered by the inventory, the legal base, the legal state and the exact criteria for including a site in the inventory.

2.7.4 Separation of spatial and descriptive data

There are two types of data: geographical and descriptive. The treatment of the two types has been completely separated (cf. Figs. 2.7.1 and 2.7.3).

"Dataskop" is an application used for showing the descriptive data of the inventories. In the first version, a HyperCard Dataskop will be provided. This means that the database is implemented in HyperCard. The advantage of this is that the basic software (HyperCard) is available on every Macintosh. A disadvantage is that the database functionality of HyperCard is rather limited; there is no easy way to make selections and lists. As it was intended to provide an instrument for viewing the data rather than analysing them, this does not really matter.

The geographical data are presented with an application called "Toposkop". Its main function is to create maps.

Dataskop and Toposkop are linked by an AppleEvent interface. It is therefore possible to get geographical information based on a descriptive key (showing the site that is described on a map) and vice versa (obtaining all the descriptive information about a site shown on a map).

An important point is that Dataskop and Toposkop can be replaced by other applications. As soon as a program satisfies the requirements for the interface for the Dataskop or Toposkop, it can be used as a Dataskop or a Toposkop respectively. For instance, we can provide the descriptive data in a relational database. The interface between Toposkop and the relational database is all that needs to be built. The implementation of the data in 4th Dimension (a relational database program) is planned.

2.7.5 Dataskop in HyperCard

With the Dataskop the user can scan through the descriptive information.

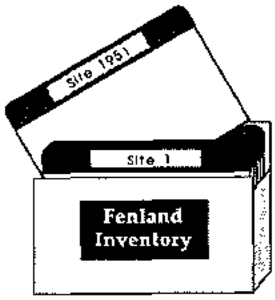
In an overview, the user can choose from the different inventories, the inventory information and the site information. Preferences can also be selected. The most important of them is the language; all information will be available in four languages (German, French, Italian and English).

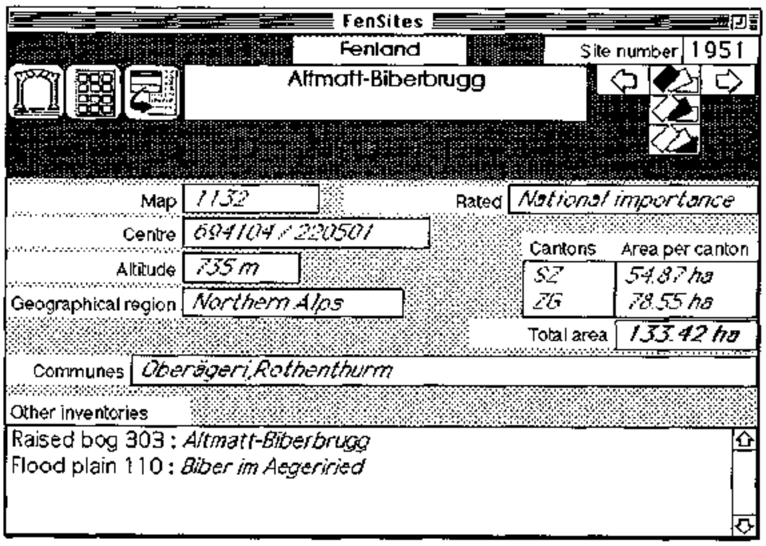
From a site description, the corresponding inventory description can be accessed and vice versa. Sites of different inventories are linked, so it is possible to jump from the information of a fenland site to the information about the raised bog that lies within it.

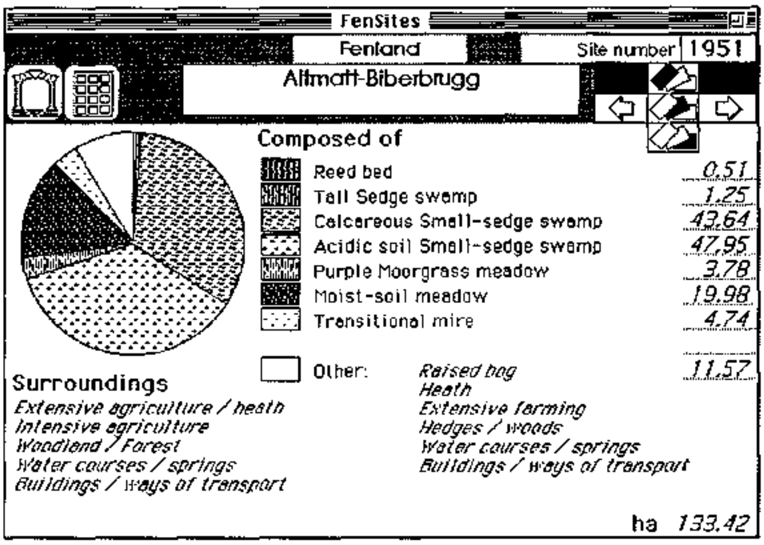
In order to keep all information completely visible even on smaller screens, the information about one site is distributed on several cards. There are for example three cards for each site in the fenland inventory: the first card with the general information (site name, canton(s), area, ...), the second with biological information (plant communities) and the third card with further information such as land use, damage and dangers. The user can always choose the information that is most interesting to him/her (Fig. 2.7.1).

It is also possible to enter one's own data. A note card can be linked to each site of every inventory and lists of different sites of different inventories can also be created.

The search possibilities are rather limited. Only the search functionality that is implemented in HyperCard is provided (Fig. 2.7.2). This is a simple full text search that can be restricted to certain fields. It is difficult to search for sites that







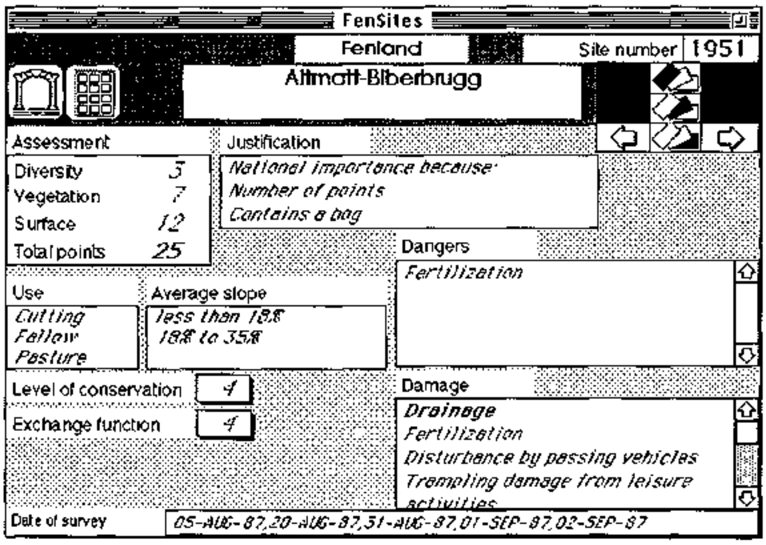
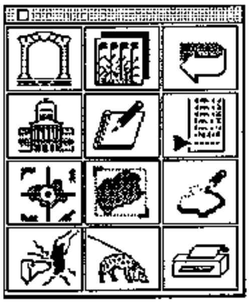


Fig. 2.7.1. The figure shows all the information about fenland site 1951. The first part with the general site information (in the top window) is similar for all inventories. The other parts with the specific information differ in number and content according to the inventory.



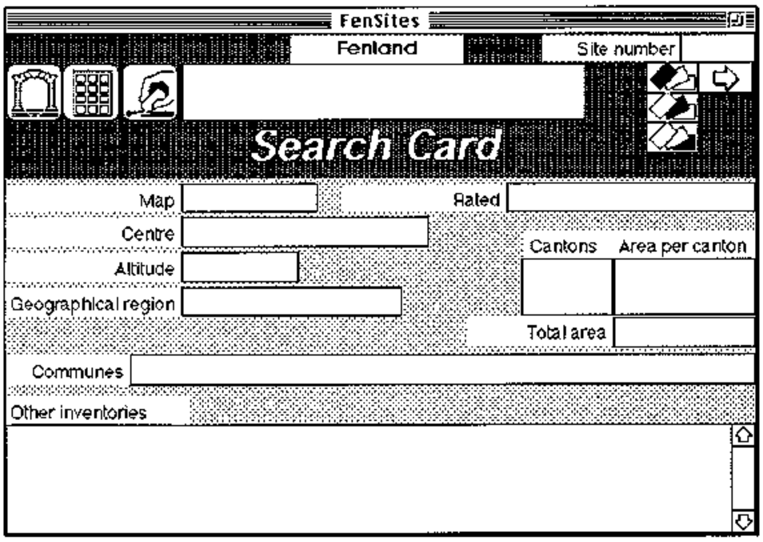


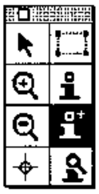
Fig. 2.7.2. The search card is used to get the site information. For instance once the site number has been entered into the appropriate field click on the track icon of the palette.

satisfy complex conditions. It is even harder to find, for instance, sites that have an area that is bigger than a specified amount. Such functionality will be provided in a relational database version.

2.7.6 Toposkop

Toposkop allows a composition of maps of several layers, each layer containing one inventory. In such a map, a specific region can be chosen and sites can be identified (Fig. 2.7.3). For this purpose, there are three tools available:

- With the zoom tool a specific region can be targeted and viewed at maximum size. By clicking (together with keys), the scale can be doubled, halved and the map can be moved. Centre and scale can also be entered numerically.
- With the info tool a site is identified. If the connection to Dataskop is established, the user can click with the info tool on a site, and he receives the descriptive information about the site. If the user wants the information about more than one site, lists can be made by marking the sites with a selection rectangle and by adding sites to an existing list.
- With the mark tool a set of sites is marked. Subsets of inventories can be built.



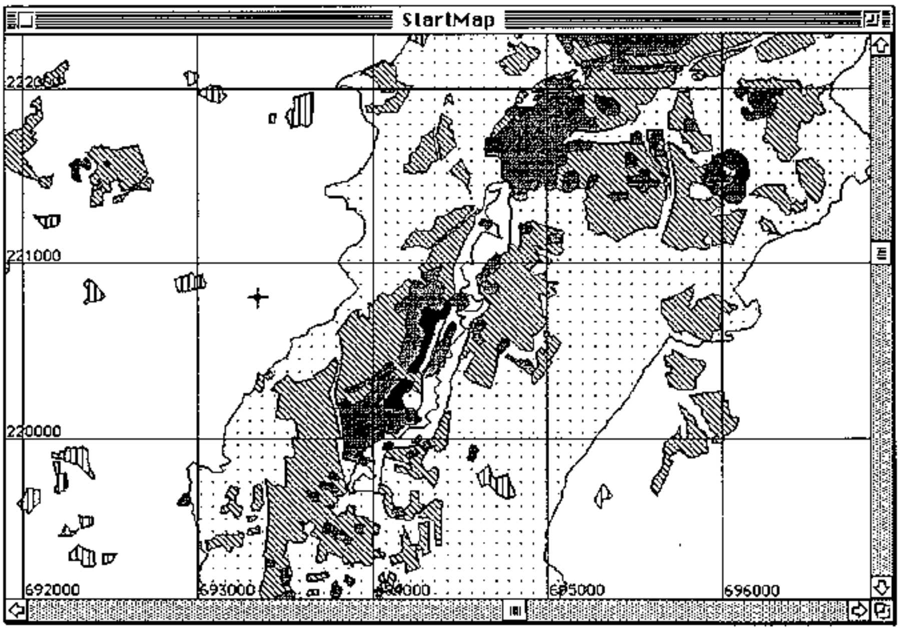


Fig. 2.7.3. A map is made up of layers. The layers are covers that must be selected and placed in a suitable order.

2.7.7 Link between Dataskop and Toposkop

The user can get the descriptive information about a site by clicking the site on a map in Toposkop. Sites may also be chosen in Dataskop and marked in Toposkop.

This is accomplished with an AppleEvent interface. When the user clicks on a site on the map in Toposkop, the command to show the object and the ID of the site are transmitted to Dataskop.

The ID of a site is composed of the ID of the inventory and the number of the site. The ID of the inventory is a four byte string. IDs of national inventories start with CH, those of cantonal inventories with the official two letter abbreviation. If others want to define inventories, they can register their IDs in order to keep them unique.

2.7.8 Data exchange

Dataskop and Toposkop can both be replaced by other applications that fulfill the interface requirements. It is also possible to import data: Toposkop allows importing Arc/Info-Covers (point, arc and poly covers) and data in a special format similar to the Arc/Info-Generate format. In the HyperCard Dataskop, additional inventories can be integrated. A stack must be made that contains the data and must satisfy a minimal set of rules. It must for instance provide a method for showing the site with a given ID.

2.7.9 Conclusion

The goal of the project is to provide information relevant to nature conservation, together with a product to view this data. It must be cheap, simple to distribute and easy to use even for a casual user. It need not provide methods for editing the data or for complex analysis, but the data must be presented and made accessible in an intuitive way.

3 Field excursions and site descriptions

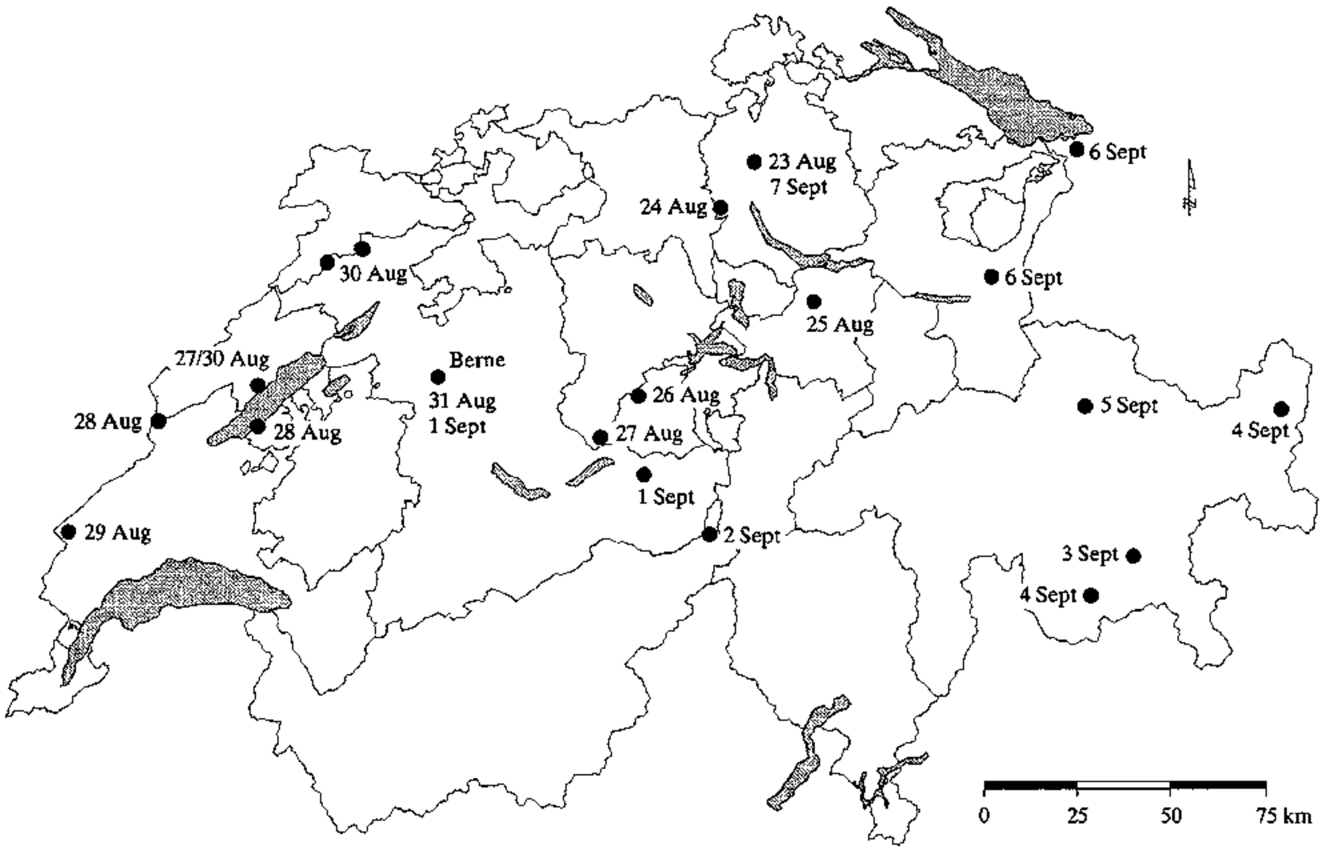


Fig. 3.1. The excursion route of the 1992 International Mire Conservation Group visit to Switzerland.

Dates:	24 August to 6 September 1992
Theme:	**Mires and Man** Mire conservation in a densely populated country – the Swiss experience. Five years after the vote on the Rothenthurm Popular Initiative.
24 August	Official welcome and initial information at the Swiss Federal Institute of Forestry, Snow and Landscape Research, Birmensdorf near Zürich. Presentation of the activities and the infrastructure of the Landscape Ecology Department.

Introduction papers:

Mires and mire landscapes in Switzerland and their need of conservation (cf. Chapter 2). Papers given by

- Erich Kohli: The legal basis for mire conservation in Switzerland and its implementation.
- Urs Hintermann: The inventory of the mire landscapes of particular beauty and national importance.
- Thomas Dalang: The contribution of the "Landscape Database Switzerland" to nature conservation.
- Peter Schönenberger: Managing landscape and mire habitat data.
- Urs Fischbacher: Making habitat and landscape inventories available to Macintosh users.

Travel to Central Switzerland:
Mires of the northern pre-Alps.
Visit to the mire landscape of Rothenthurm (canton Schwyz, SZ; Chapter 3.1).
Presentation of the mire habitats and the history of the Rothenthurm Popular Initiative (Referendum). Issue: What is a mire landscape?

25 August Excursions to discuss problems associated with conservation and management of fens.
Visit to Alpthal (canton Schwyz, SZ; Chapter 3.2). Issues: What could be the role of bogs and fens in flood desynchronization? Effects of different land use and drainage schemes on the runoff of small catchment areas. Fundamental requirements for sustained management of fens and forests. Habitat conservation for black grouse *(Lyrurus tetrix)* and capercaillie *(Tetrao urogallus)*.
Visit to Schwantenau mires (canton Schwyz, SZ; Chapter 3.3). Issues: Evaluation of the fauna and proposals for their conservation. Travel to Glaubenberg (canton Obwalden, OW).

26 August Introduction to the most important mire landscape of Switzerland.
Excursion to examine Upper Schliere valley (canton Obwalden, OW; Chapter 3.4).
Issues: Traditional land use and paludification. Bog erosion due to overgrazing. Breaking up of forest pasture in boggy areas. Effects of clear-cutting and mire drainage on the hydrology of a catchment area in the Flysch region. State afforestation vs. peatland conservation.
Visit to Giswiler Laui. Issues: Torrent control and forest protection policy: presentation of construction works.
Excursion to Sörenberg (canton Lucerne, LU; Chapter 3.5). Visit to Stächelegg bog: Interaction between Schrattenkalk (fissured limestone) and acidic peatlands. Issues: What is an optimal management for wet pastures and fenlands in theory and reality?
Visit to Wagliseichnubel mires. Issues: Military exercise ground vs. mire conservation.

27 August Walk to several mires west of Sörenberg. Implications of different land use models for mire systems and the living conditions for local farmers. Implementation of the new mire conservation legislation by canton Lucerne. Presentation of results of negotiations with farmers on sustainable management of fenlands (including contracts and subsidies). Issues: Impact of forestry on bogs (logging operations). Tourism vs. conservation of mire habitats and mire landscapes. Travel to western Switzerland via Emmental-Seeland (crossing Grosses Moos, "The big mire").

28 August Travel to Yverdon
Mires of the Central Plateau.
Excursion to Château Champ Pittet, south shore of Lake of Neuchâtel
Visit to la Grande Cariçaie (cantons Vaud, VD and Fribourg, FR; Chapter 3.6). History of formation and conservation of the largest contiguous fen area of Switzerland. Hydrological control of the three Jura lakes and its implications on the management of the fenlands; Ornithological studies; decline of reed beds due to erosion.
Travel to Ste. Croix

Mires of the Jura Mountains.
Introduction to the geology of the Jura Mountains.
Visit to La Vraconnaz bog near Ste. Croix (canton Vaud, VD; Chapter 3.7). Presentation of bog burst features. Monitoring of botanical and zoological successions after the event, mapping of the bog by photogrammetry.

29 August — Travel to Vallée de Joux.
Visit to la Burtignière bog (canton Vaud, VD; Chapter 3.8). Presentation of flora and vegetation of intact bogs and mires of the Jura Mountains, at the edge of the Mount Risoux forest, the largest forest complex of Switzerland. Historical development and conservation aspects. Issues: Impact of cattle, construction activities, water consumption and pollution of the Orbe River on the mire landscape.

30 August — Travel to Franches-Montagnes.
Visit to the bog of la Chaux-des-Breuleux (cantons Jura, JU, and Berne, BE; Chapter 3.9). Geology: Effect of karst features on the distribution and limitation of mires. Vegetation development after peat extraction. Presentation of management planning. Issues: Filling in of drains, demarcation of pasture from bog area.
Visit to Bellelay bog (canton Berne, BE; Chapter 3.10). Presentation of exploitation history, management and 'natural' rehabilitation of exploited peat pits.

31 August — Day off in and around Berne, capital of Switzerland.

1 September — IMCG Symposium at the Natural History Museum in Berne: **Mire conservation in theory and reality: local issues and global implications** (cf. Chapter 4).
Travel to Meiringen.
Mires of the northern pre-Alps (continued).
Walk to Chaltenbrunnen mire (canton Berne, BE; Chapter 3.11), the largest near-natural altitudinal bog area in Switzerland. Issues: Impact of cattle and tourists, demarcation of pasture from bog area.

2 September — Travel to St. Moritz via the 4 passes Grimsel, Furka, Oberalp and Julier.
Mires of the Central Alps.
On the way:
Stop at Rhône glacier (canton Valais, VS; Chapter 3.12), the movements of which have been measured more accurately than any other glacier in the world. Classical site of vegetation succession studies. Presentation of young developing mires. Stop at the spectacular postglacial Flims landslide (canton Grisons, GR). It has a volume of about 12 km^3, by far the largest landslide of the Alps. At present, its debris still covers an area of 50 km^2.

3 September — Visit to the mire landscape Stazerwald (canton Grisons, GR; Chapter 3.13). Presentation of the bogs Mauntschas and Lej da Staz with *Sphagnum fuscum* growing in a more or less continental climate. Effects of tourism - especially cross-country skiing; impacts of past peat exploitation.
Walk along an altitudinal gradient (1,800 m to 2,300 m a.s.l. Muottas da Schlarigna) to study the growing conditions of peatlands at their climatic limit.

4 September Visit to Maloja pass (canton Grisons, GR; Chapter 3.13.9). Glaciation features (moraines, roches moutonnées, glacier mills). Examination of conflicts between land use and bog conservation. (Cancelled due to lack of time.)
Excursion to Lower Engadine (canton Grisons, GR; Chapter 3.14). Geology: Lower Engadine window. Presentation of the old terrace landscape of Ramosch, probably dating back to the Neolithic period (5,000 BP) with beautiful species-rich hay meadows. Mires at the drought limit of their existence. Issue: Conservation of the traditional landscape.

5 September **Mires and their Future.**
Excursion to Fideriser Heuberge / Faninpass (canton Grisons, GR; Chapter 3.15). Typical fen landscape from 1,600 m up to 2,000 m a.s.l., still traditionally managed by cutting of the litter. Implementation of appropriate measures for the preservation of mires by canton Grisons.
The consequences for the agricultural land use by the conservation of the mire landscape.
What are the implications of the new mire conservation measures for agriculture? (Cancelled due to bad weather conditions, snow!)
Travel to Voralp/Grabs.
Excursion to examine the Gamperfin bog (canton St. Gall, SG; Chapter 3.16). Presentation of hydrology and dynamics in the development of a peat bog. Case study of potential of an exploited sloping bog. Issue: Rehabilitation measures.

6 September Excursion to the wetlands of the Rhine valley (Land Vorarlberg, Austria; Chapter 3.17).
Travel to Zürich.

Fig. 3.1.1. Autumn in the Biber valley, viewed from the south. The vegetation of the peatlands generally still shows the traditional land use pattern (Photo by the Rothenthurm Referendum Committee).

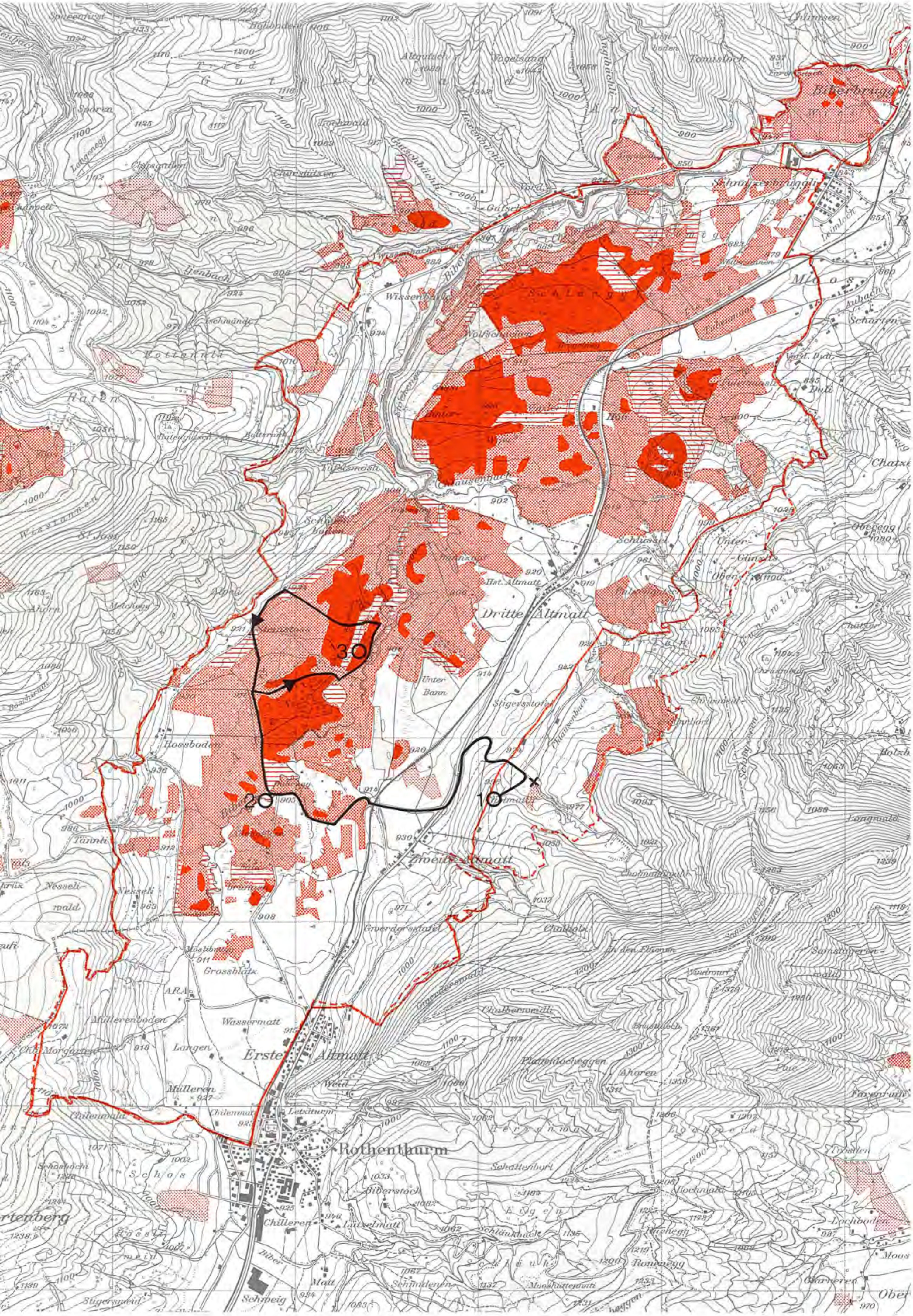
3.1 The cradle of Swiss mire landscape conservation – Rothenthurm

Roland Haab

Communities: Rothenthurm, Einsiedeln and Feusisberg (canton Schwyz); Oberägeri (canton Zug)
Locality: Biber valley (between Rothenthurm and Biberbrugg)
Coordinates: 693-697 / 218-224
Elevation of the mires: 900 m
Area of the raised bogs: 105 ha
Area of the fenlands: 310 ha
Area of the mire landscape Rothenthurm: 1,200 ha

3.1.1 Highlight of the visit

According to the Inventory of the Raised and Transitional Bogs of National Importance, the mire landscape of Rothenthurm is Switzerland's largest surface of contiguous raised bog and fen vegetation (Grünig et al. 1984). Because of its huge extent, diversity of wetland habitats and still largely traditional land use patterns, the mire landscape of Rothenthurm is probably unique in pre-Alpine Europe. Apart from their function as a habitat for relic species from glacial times, the mires of Rothenthurm serve as one of the last staging grounds for waders and other migratory birds flying south over the Alps.


Biberbrugg
Rothenthurm
Erste Altmatt
Zweite Altmatt
Dritte Altmatt
Hst. Altmatt
Rossboden
Nesseli
Tanni
Wassermatt
Müllerenboden
Langen
Mülleren
Chilenmatt
Letziturm
Grossblätz
Chilleren
Biberstock
Lutzelmatt
Schattenbort
Unter Bann
Stigerstofe
Tomisstock
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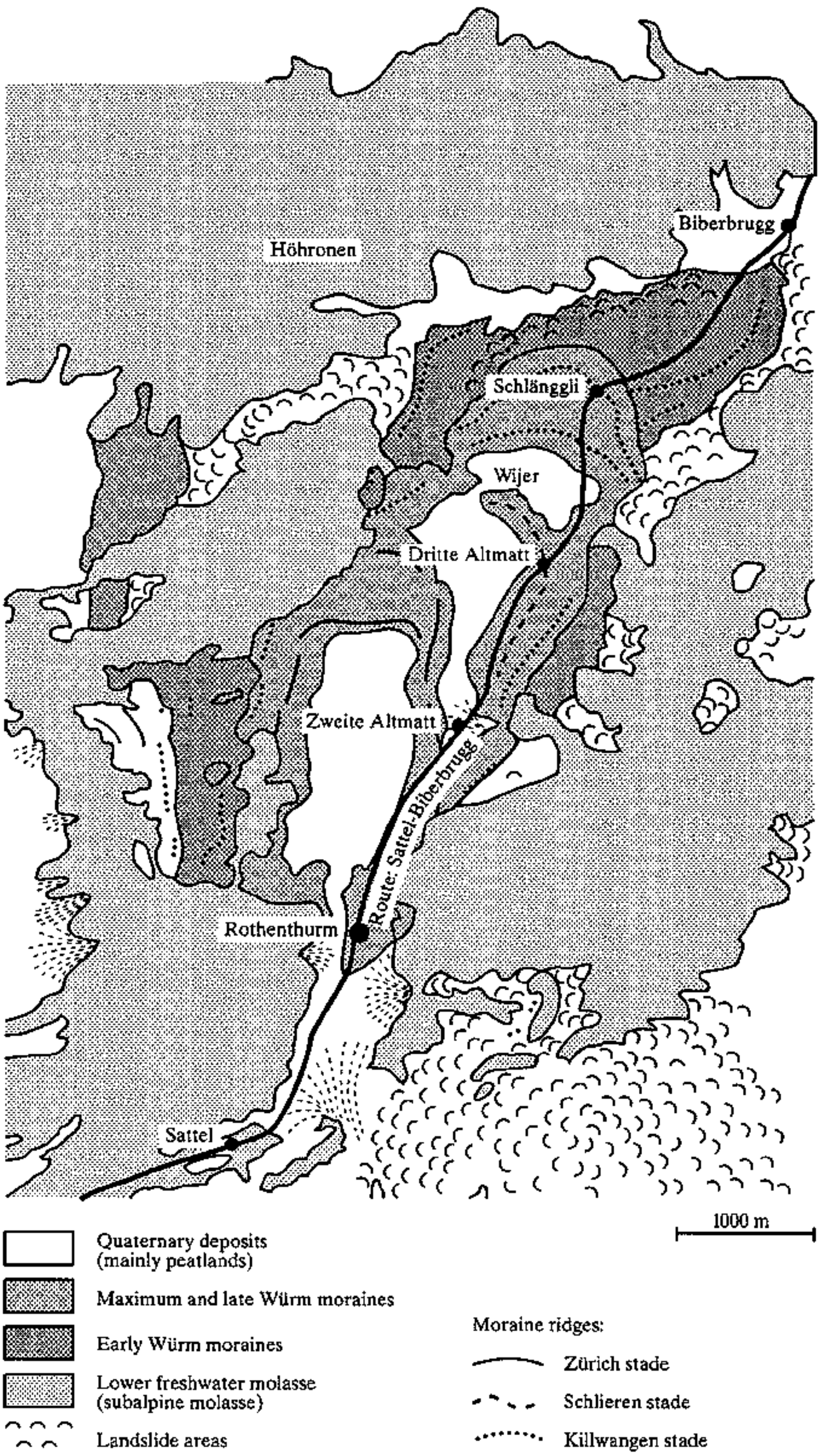


Fig. 3.1.3. Geological sketch map of the Biber valley and surroundings (modified from Hantke et al. 1967).

Fig. 3.1.2. Location of the mires and the mire landscape of national importance in the area of the Biber valley (modified from DFI 1990, 1991b, 1991c).
1 Vantage point; 2 Biber River; 3 Ägeriried. Scale of the map: 1 : 25,000; for key, see end-cover. Reproduced by courtesy of the Federal Office of Topography, Berne, 9 June 1992.

3.1.2 Location and geology

The mires of the Rothenthurm area are located in a broad, glacial valley through which the Biber River winds (Figs. 3.1.1 and 3.1.2). The valley bottom is quite flat and varies across an altitude of 900 and 920 m a.s.l. within the most paludified area between Erste Altmatt and Schlänggli, a distance of more than 4 km.

From a geological point of view, the Biber valley lies almost entirely in the area of the sub-Alpine Molasse and, therefore, may be viewed as a part of the Central Plateau (Fig. 3.1.3). In contrast to the geologically younger Molasse layers that form the surface of the northern Central Plateau, the sub-Alpine Molasse was gently folded or erected by the sliver of Middle Miocene (Helvetian) rocks. At Rothenthurm, the outcrops on the mountainsides consist mainly of carbonate-rich Nagelfluh, sandstone and marl.

Long before the glaciers of the ice ages formed the present shape of the Biber valley, Alpine rivers must have carved the channels along which the glaciers pushed forward. The morphology of the Biber valley was largely shaped by the last glaciation. During this, the Würm glaciation, ice of the Muota/Reuss glacier passed Sattel and moved north-west (Hantke 1980). Near Wijer-Schlänggli, at Dritte Altmatt and close to Zweite Altmatt, the receding glacier left behind a series of moraines which are contemporaneous with the Killwangen, Schlieren and Zürich stades (cf. Fig. 1.3.14) of the Linth/Rhine glacier (Hantke et al. 1967). The valley ground was covered by low permeability ground moraines that, together with a cold, humid climate and shallow sloped relief, gave rise to the formation of one of Switzerland's most impressive mire landscapes.

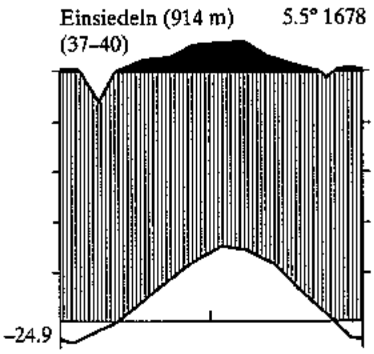


Fig. 3.1.4. Climate diagram for Einsiedeln which is climatically similar to the Biber valley (modified from Walter and Lieth 1960). For explanation see Fig. 1.5.4.

3.1.3 Climate

With frequent summer rainfall, the Biber valley belongs to a zone of high precipitation characteristic of the Swiss pre-Alpine region (Fig. 3.1.4). In contrast to Einsiedeln, where the annual amount of precipitation is around 1,700 mm, annual precipitation at Rothenthurm amounts to 1,850 mm a year. Cold north winds that enter the valley at Biberbrugg give rise to harsh climatic conditions. Warm south winds are obstructed by mountain ranges so that frost in early summer and snow coverage from October to the end of March are both quite common.

3.1.4 Pedology and hydrology

In the past, scientists have suggested that after deglaciation the Biber valley was covered by a huge lake. This theory has now been rejected by most geologists and pedologists because soil and peat profiles have never revealed evidence of lake sediments. The Biber River must have broken through the moraines quite early after deglaciation.

The catchment area of the Biber River today measures around 15 km² (Grubinger et al. 1967). While the river and its tributaries must have had torrential characteristics after deglaciation, the catchment area today is consolidated by an unbroken vegetation cover. Between Zweite Altmatt and Dritte Altmatt, the incline of the Biber River is on average 0.3%. In spite of the low incline, the river during the last millennia lowered its base several metres and, therefore, enhanced the draining effect on the adjacent mires.

The formation of peatlands started 10,000 years ago. Calcareous fen communities were created inside shallow pans between the moraines and on gently sloping hills and hilltops. Where peat formation was either rarely flooded or unaffected by the meandering river or its tributaries, the growing peat bodies gradually lost contact with the calcareous ground-water and/or runoff. Bog formation began in such places and resulted over thousands of years in peat accumulations up to 8 m thick. Near Wijer, a peat profile taken in 1928 showed 50 cm of Trifarium peat (from *Calliergon trifarium*) overlain by 60 cm of *Carex* peat and more than 3 m of *Eriophorum* and *Sphagnum* peat (KELLER 1928).

3.1.5 Vegetation and fauna

The vegetation of the Biber valley consists of a rich mosaic that reflects not only the varying natural habitat conditions, but also the recent impact of peat cutting and agriculture. The valley bottom includes a mosaic of more than 250 ha of fens and 105 ha of bogs (Fig. 3.1.2).

Along the river-banks, prevalent nutrient-rich flood-meadows and flood plain forests are considered to be of national importance. Beyond the influence of high water, peat has accumulated and in general the supply of nutrients is declining. The better drained slopes between the river and, at higher elevations, the adjacent areas of Arrhenatherion, Calthion and Molinion lead up to a plateau with bog vegetation. With the exception of small areas the bog vegetation shows the impact of earlier exploitation. At Ägeriried, there are remnants of the Pino-Sphagnetum which earlier may have covered most of the bogs. Because of the drainage by ditches and peat cutting, today the trees there grow bigger and in greater density. Birch *(Betula pubescens)* together with spruce *(Picea abies)*, alder buckthorn *(Frangula alnus)* and rowan *(Sorbus aucuparia)* occur in the remaining *Pinus mugo* wood. The treeless surroundings of the *Pinus* site are covered by bog vegetation, heather and litter meadows with purple moor-grass *(Molinia caerulea)* predominating.

The best preserved areas of raised bog vegetation are found around Schlänggli (Swiss German dialect, meaning bog hollow in English; Fig. 3.1.5). The vegetation is dominated by hummock communities (Fig. 3.1.6) of red bog moss *(Sphagnum rubellum)*, brown bog moss *(Sphagnum fuscum)* and burgundy red bog moss *(Sphagnum magellanicum)*, joined by cranberry *(Vaccinium oxycoccos)*, hare's-tail cottongrass or bog cotton *(Eriophorum vaginatum)*, round-leaved sundew *(Drosera rotundifolia)*, bog rosemary *(Andromeda polifolia)*, heather *(Calluna vulgaris)* and other Ericaceae (VOSER 1978). Between the hummocks, feathery bog moss *(Sphagnum cuspidatum)* together with rare species such as Rannoch rush *(Scheuchzeria palustris)*, great sundew *(Drosera anglica)* or marsh clubmoss *(Lepidotis inundata)*, colonize the small hollows.

Fig. 3.1.5. Open bog vegetation at Schlänggli, viewed from the west. The bog of this area shows few signs of peat cutting but some drainage ditches. The vegetation consists of mainly hummock plant communities interspersed with small hollows (Photo by R. Haab).

Fig. 3.1.6. Close-up of the hummock vegetation at Schlänggli with typical bog rosemary *(Andromeda polifolia)*, cranberry *(Vaccinium oxycoccos)* and heather *(Calluna vulgaris)*. (Photo by R. Haab).

As a result of the extent and diversity of the landscape structures and habitats, the mires of the Biber valley play an important role as a refuge for many rare and endangered animal species, e.g. ermine *(Mustela erminea)*, polecat *(Mustela putorius)*, adder *(Vipera berus)*, midwife toad *(Alytes obstetricans)*, yellow-bellied toad *(Bombina variegata)*, cranberry fritillary *(Boloria aquilonaris)* and clouded yellow (*Colias palaeno europome;* Schuler and Meile 1978; de Marmels 1978). The birdlife is of outstanding importance. Of Switzerland's 196 species of breeding birds, more than 60 species have bred in the past 25 years in the area of Altmatt-Ägeriried (Schuler and Meile 1978). Out of these 60, 11 belong to a group of 35 of Switzerland's most endangered bird species (Zbinden 1989). Apart from their function as a breeding habitat, the mires of the Biber valley serve as important feeding and resting areas for more than 50 other bird species.

3.1.6 Land use history

The Biber valley was first populated after 1000 AD. In a document from 1018 AD the wooded area around Einsiedeln was described as rough and hostile. The mires of Rothenthurm at this time must have been covered by open forests dominated by mountain pine *(Pinus mugo)*, spruce *(Picea abies)*, alder *(Alnus glutinosa)*, birch *(Betula pubescens)*, willow (*Salix* spp.) and alder buckthorn *(Frangula alnus)*.

Between the 13th and 15th centuries, clearing was initiated and accelerated by the monastery of Einsiedeln (cf. Chapter 1.2.7). Over the centuries, the cleared area as well as the remaining woods served as pasture. The increase in clearing and pasture led to shortages of (fire)wood and to problems of erosion. The shortage of fuel was partly solved when, in the 18th century, peat cutting began. Until the end of World War Two, vast areas of bog vegetation in the Biber valley were affected by exploitation.

Until the present the fens of the Biber valley, and to a certain extent also the bogs, were used as litter meadows or even for agriculture (Fig. 3.1.7). Cultivation of vegetables (e.g. potatoes) reached its peak during World War Two. Today it is restricted to a few small areas. However, Switzerland's farming policy in pre-Alpine regions is sustaining livestock and pasture. Because of the decrease in the need for litter over the past few decades (cf. Chapters 1.7.2, 2.1 and 3.2.6; straw is often easier and cheaper to get on the market), many litter meadows have been either abandoned, or drained and "improved" by fertilizers.

Fig. 3.1.7. Cultural and historical evidence of peat cutting and the traditional management of litter meadows, viewed from the northwest. The straw piles to the right of the shed are called "Tristen": a trunk with partially cut-off branches used to pile the straw of litter meadows. The sheds served to store peat briquettes and implements (Photo by R. Haab).

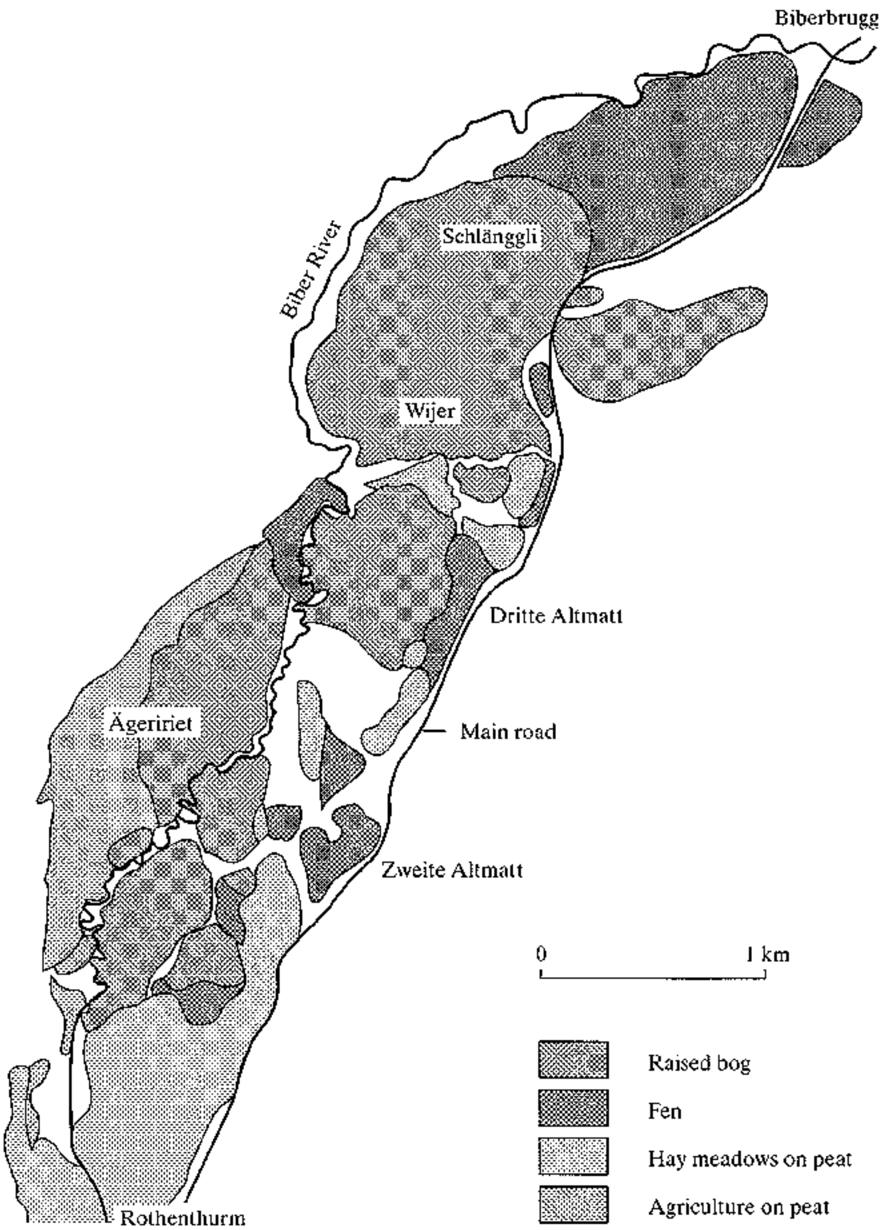


Fig. 3.1.8. Vegetation and land use of the peatlands of the Biber valley at the turn of the century (modified from FRÜH and SCHRÖTER 1904).

After the initiation of the Rothenthurm Initiative, canton Schwyz imposed a ban forbidding any further changes to the mires of the Biber valley. Today, most of the mires are protected as Sites of National Importance and new cantonal legislation has been prepared to allow the canton to help the farmers maintain these sites through financial subsidies.

3.1.7 Changes in vegetation and fauna since the turn of the century

Although vegetation maps made by different authors must be interpreted with caution, they can show general trends in vegetation change. Comparison of vegetation maps of the mires in the Biber valley published in 1904 (FRÜH and SCHRÖTER 1904) and 1991 (DFI 1991b) show a decrease in the amount of raised bog vegetation from almost 280 ha to 105 ha (cf. Fig. 3.1.8 and Fig. 3.1.2). Further investigations have indicated that the decrease in mire surface was neither restricted to the period before World War Two nor just to bog vegetation. It was only between 1975 and 1982 in the Rothenthurm-Altmatt-Biberbrugg area that 15% of the total surface of bogs, fens and litter meadows were intensified or afforested (SBN 1983).

In relation to changes in the fauna, only a little information concerning birds is available. While corncrake *(Crex crex)* must have disappeared in the first half of this century, snipe *(Gallinago gallinago)*, curlew *(Numenius arquata)* and great grey shrike *(Lanius excubitor)* disappeared in the Biber valley between 1950 and 1980 (HESS 1990).

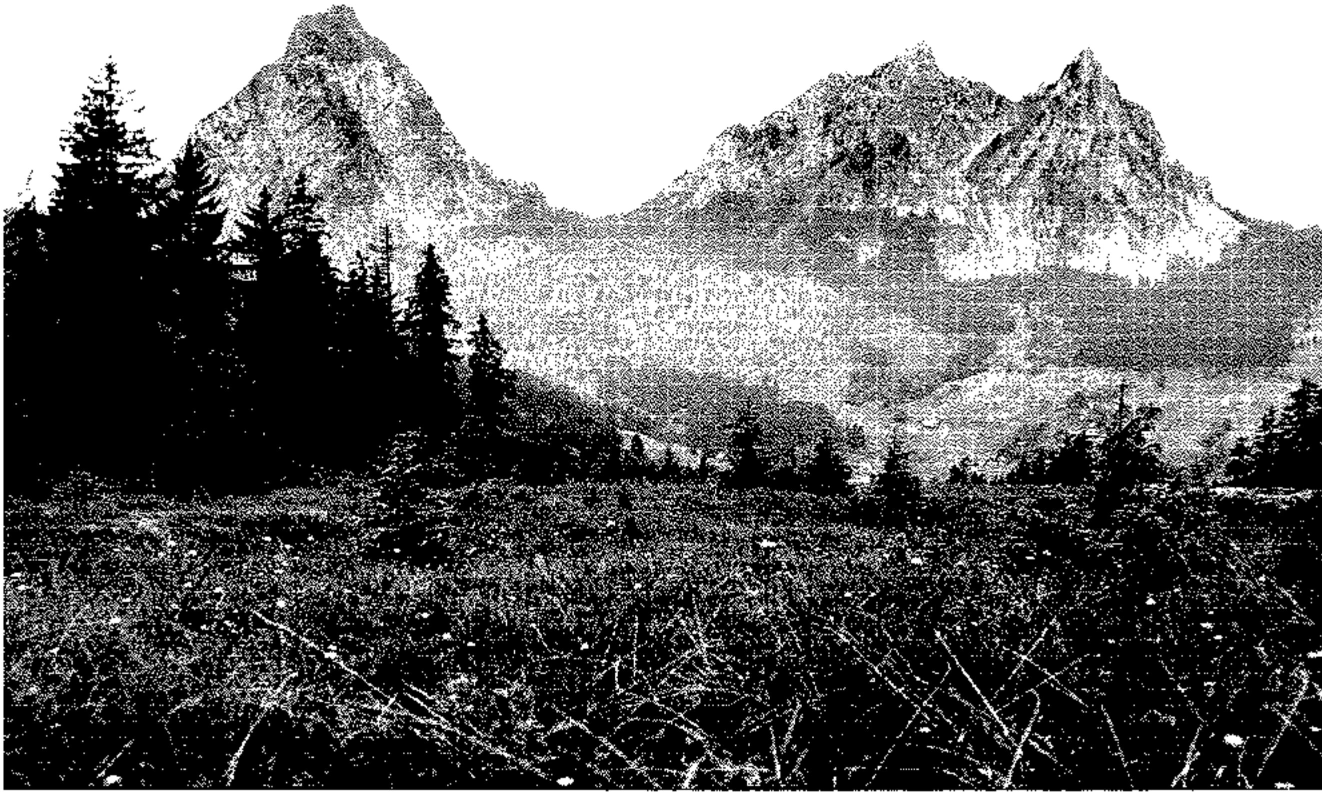


Fig. 3.2.1. Intense mixture of established forest with encroaching forest typical of many mires of the Alp valley, viewed from the east. The background is dominated by the mountain peaks of Grosser and Kleiner Mythen, a famous example of a klippe (Photo by R. Haab).

3.2 Hydrology, forestry and the capercaillie – the sloping fens of Erlentobel and Zwäckentobel

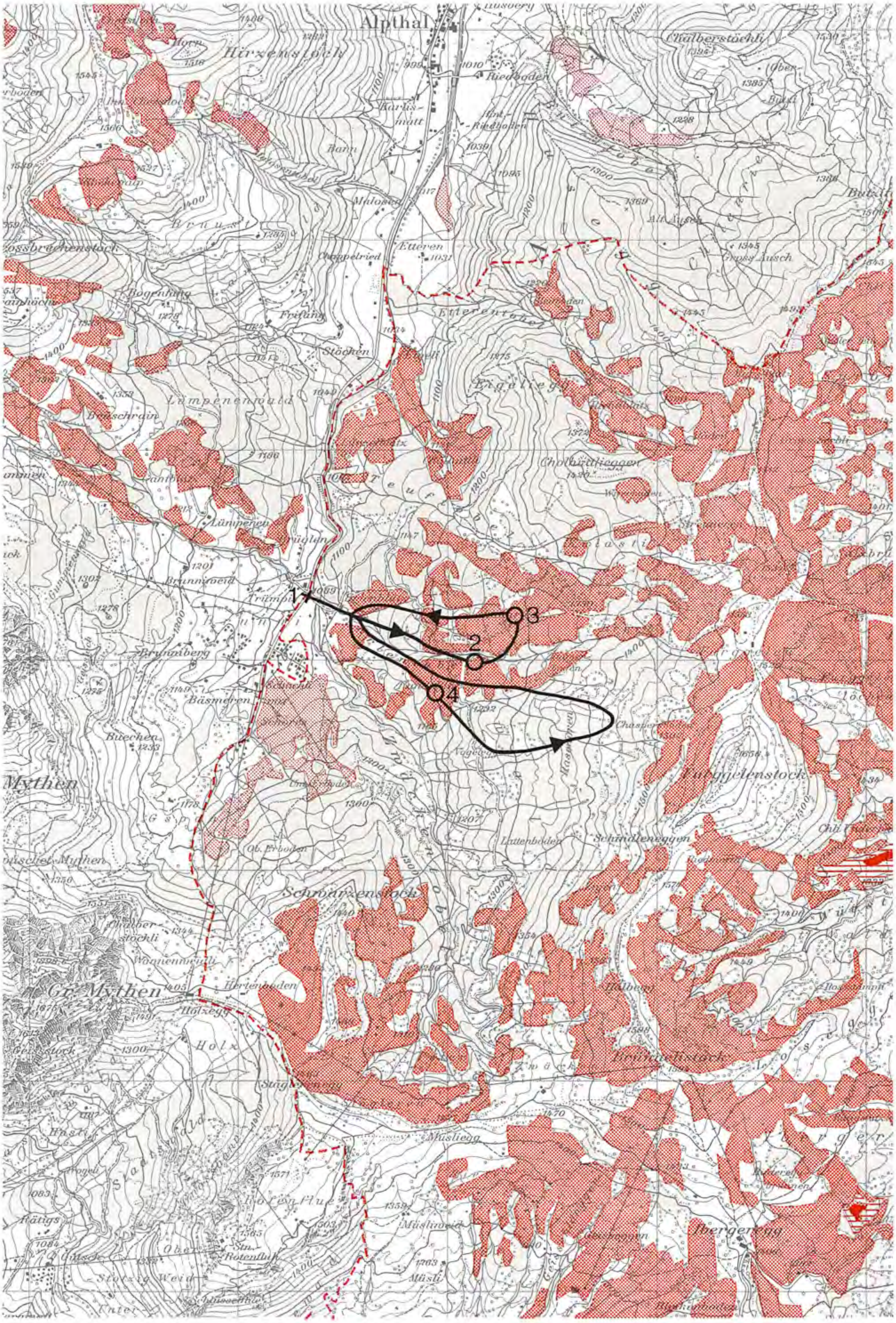
Roland Haab, Hans M. Keller (†) and Ruedi Hess

Community: Alpthal (canton Schwyz)
Locality: Erlentobel and Zwäckentobel
Coordinates: 696-698 / 209-212
Elevation of the mires: 1,200 m
Area of the fenlands: 120 ha
Area of the mire landscape Ibergeregg: 4,200 ha

3.2.1 Highlight of the visit

> ***Klippe***
>
> *An isolated rock unit that is an erosional remnant or outlier of a nappe. The original sense of the term was merely descriptive, i.e. it included any isolated rock mass such as an erosional remnant (modified from* Bates *and* Jackson *1987) (cf. Fig. 3.14.3).*

As with other Flysch areas the importance of the individual mire is absorbed within its more general function as part of the whole peatland landscape. The mires of Erlentobel and Zwäckentobel are part of the mire landscape of Ibergeregg which, with a mire density of 25%, is one of the highest in Switzerland (DFI 1991c; see Fig. 3.2.2). Because of their size, their isolation from settlements and their intense interlacing with patchy sub-alpine forests, the mires of Erlentobel and Zwäckentobel are considered to be of national importance. This is not only because of their vegetation but also because they provide a habitat for the capercaillie *(Tetrao urogallus)*, whose population of males diminished in Switzerland between 1970 and 1985 from approximately 1,100 to about 650 (Marti 1986).


Alpthal
Hirzenstock
Chalberstöchli
Riedboden
Karlismatt
Etteren
Stöcken
Lümpenenwald
Lümpenen
Brunniweid
Brunniberg
Bäsmeren
Büechen
Mythen
Gr. Mythen
Holzegg
Schwarzenstock
Vogelegg
Luttenboden
Schindleneggen
Fuggelenstock
Brünnelistock
Müsliegg
Müsli
Iberger Egg
1
2
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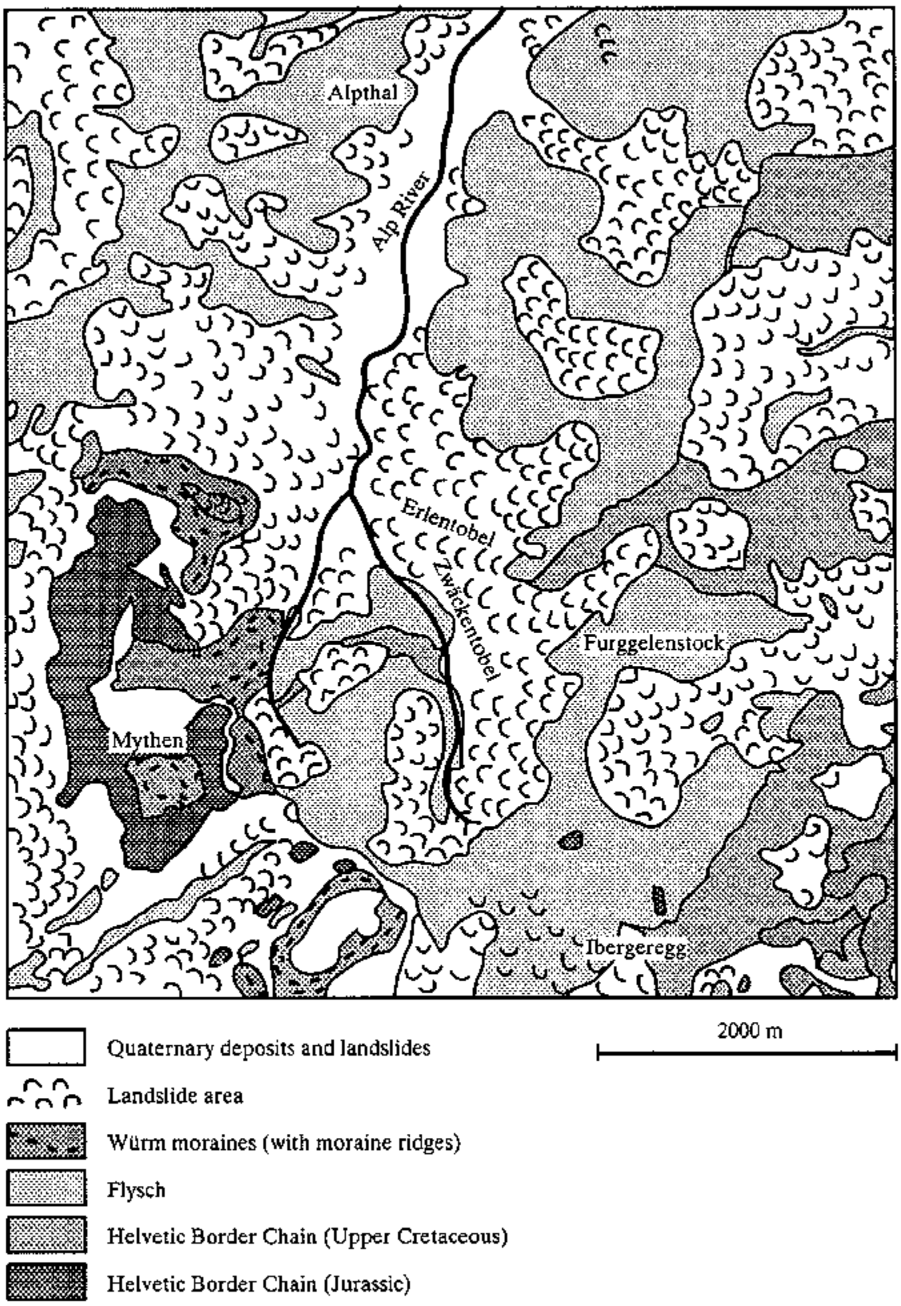


Fig. 3.2.3. Geological sketch map of the southern Alp valley and surroundings (modified from HANTKE et al. 1967).

◀ Fig. 3.2.2. Location of the mires of the southern Alp valley (modified from DFI 1990, 1991c).
1 Runoff research station Erlenbach;
2 Climate research station Erlenbach;
3 Langried fen (Erlentobel);
4 Rund Blätz fen (Erlentobel).
Scale of the map: 1 : 25,000; for key, see endcover.
Reproduced by courtesy of the Federal Office of Topography, Berne, 9 June 1992.

3.2.2 Location and geology

The mires of Erlentobel and Zwäckentobel are located within small basins to the south-east of the Alp valley. The area belongs to the northern pre-Alps of central Switzerland. The geological parent material consists of Flysch, a Tertiary sediment (cf. Fig. 3.2.3 and Chapter 1.3.2). Calcareous sandstones alternate with clayey schists dominated by argillite and bentonite. Due to weatherability and unconsolidated bedrock, the landscape is characterized by smoothly shaped hilltops and hillsides. It has been compartmentalized into different small catchments by the strongly erosive tributary streams. Soil creep and landslides are frequent (KELLER 1990).

During the Würm glaciation, glaciers originating in the areas of Mythen and Zwäckentobel united at Brunni. Supplied by different tributaries, the glacier moved northward as far as Trachslau (south-south-west of Einsiedeln) where today parts of a side moraine indicate the maximum extent of the glacier. During the Hurden stade of the Linth/Rhine glacier, the Alp glacier retreated and

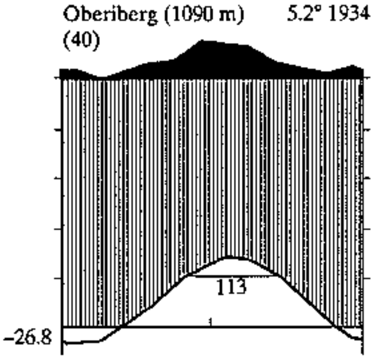


Fig. 3.2.4. Climate diagram for Oberiberg which is climatically similar to the Alp valley (modified from WALTER and LIETH 1960). For explanation see Fig. 1.5.4.

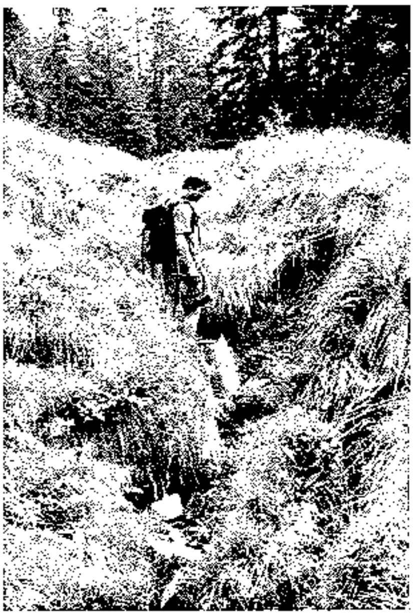


Fig. 3.2.5. Deeply eroded drainage channel at Erlentobel. The drainage ditches were dug to allow natural forest development and artificial afforestation (Photo by R. Haab).

separated back into its original branches around Mythen and Zwäckentobel (HANTKE 1980). Over the past thousands of years, the moraine deposits have suffered from strong postglacial erosion and landslides and have been almost completely destroyed.

3.2.3 Climate

The climate of the Alp valley demonstrates the typical characteristics of the northern pre-Alps region (Fig. 3.2.4). A high annual precipitation of between 2,000 and 2,300 mm combines with relatively low mean annual air temperatures of about 4.5° C. In winter, up to 35% of the precipitation can fall as snow. Winter snowpack is extremely variable. Maximum snowpack ranges from 200 to 800 mm water equivalent on open land and hence results in very variable snowmelt runoff in spring. In summer (mainly July), intense thunderstorms often result in flooding and massive erosion (KELLER 1990).

3.2.4 Pedology

The weathering of the Flysch bedrock results in primarily fine but also blocky material. The soils, due to their high clay content, are heavy and of low permeability. Large areas along the hillsides of the Alp valley are therefore covered by organic soils. Local open drainage ditches have been dug in the hope of improving the stability of the slopes and obtaining better growth from the shallow-rooted vegetation (Fig. 3.2.5).

The mires of Erlentobel and Zwäckentobel are located along the valley slopes, the mean gradient generally varying between 25 and 40%. The vegetation cover of the mires, predominantly consisting of fen, is supplied by calcareous runoff. During periods of low precipitation, the steep slopes combined with drainage systems result in enhanced drying of the upper peat layers.

3.2.5 Hydrology

As a result of extensive research by the Swiss Federal Institute for Forest, Snow and Landscape Research, the hydrology of several different catchments within the Alp valley is well understood today. One of the catchments studied encloses the basin of Erlentobel. The catchments differ in their forest area, extent of paludification, land use and other characteristics. The data collected, therefore, provide important information for landscape management and mire conservation.

The hydrologic research basins in the Alp valley

Objectives

Hydrological research has been carried out in several small catchments of the Alp valley since 1968. The objective has been to study the water balance and nutrient budgets and their variation in time and space. Differences in vegetation cover, land use, soil condition and other basin parameters should be evaluated quantitatively in a small region of similar climatic conditions. Six basins with surface areas between 0.5 and 1.5 km² have been included, three are now operational on a long-term basis.

A second and no less important objective is to investigate the processes which are of primary importance to the hydrological response of a catchment. Of the many processes to be studied, only a few investigations have been carried out. They include accumulation and melt of snowcover, rain and snow interception, wet deposition above and below the forest canopy and suspended and bedload transport in torrent channels.

The sites

The basins are located 10 km south of Einsiedeln in central Switzerland at an elevation of between 1,100 and 1,600 m a.s.l. Climate and pedology of the region are described in Chapters 3.2.2 and 3.2.3. The two catchments subsequently compared differ in various aspects (Tab. 3.2.1).

Table 3.2.1. Main characteristics of the two catchments Vogelbach and Erlenbach.

Catchment	Size	Mean slope	Forest cover	Wetland area	Alpine pasture
Vogelbach (3)	155 ha	41 %	63 %	25 %	12 %
Erlenbach (10)	64 ha	30 %	39 %	61 %	-

Some results

The basins with the greatest contrast in vegetation cover and soils are No. 3 (Vogelbach) and No. 10 (Erlenbach). A comparison shows some quantitative differences in hydrological behaviour, related to the fate of both water and nutrients.

The mean monthly water balances of the two basins are shown in Figure 3.2.6. The annual water balance (precipitation minus streamflow) is about 450 mm in Basin 3 and about 300 mm in Basin 10. Most of this difference can be explained by the difference in forest cover and by the abundant shallow peat soils in Basin 10. It is interesting to note that peak flows during intensive rain events differ considerably in the two basins. Long-term measurements have shown that the smaller Basin 10, which has shallow soil but higher drainage density, yields an average peak discharge rate which is about 30% higher than in the larger Basin 3, for similar events (Fig. 3.2.7).

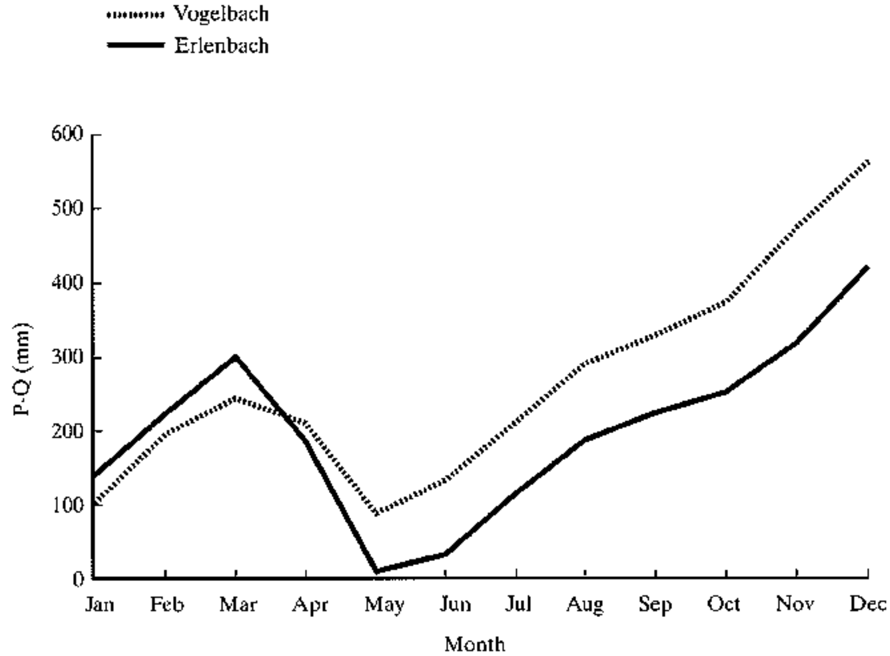


Fig. 3.2.6. Monthly cumulative water balance (P-Q) of the Vogelbach (3) and Erlenbach (10) basins; means of a 10-year period.
P= precipitation, Q= streamflow.

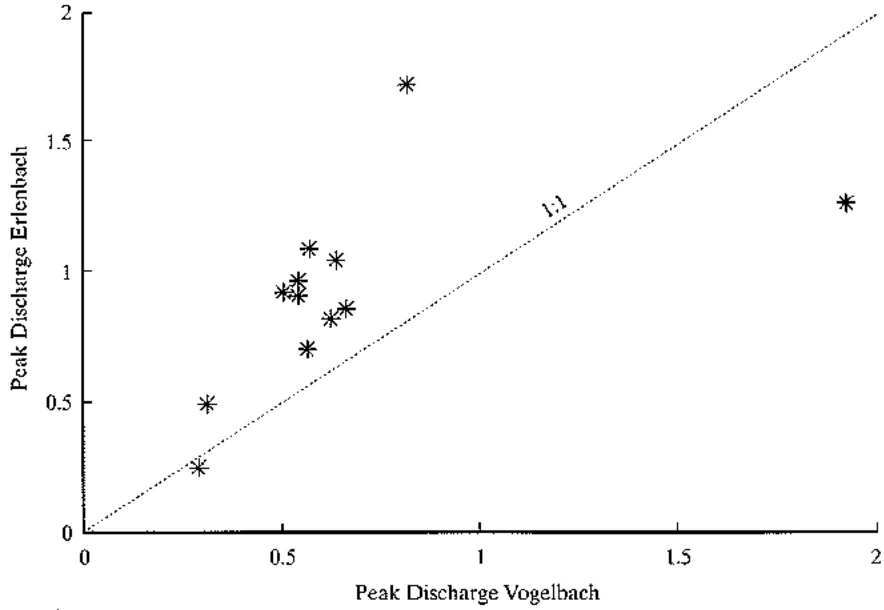


Fig. 3.2.7. Comparison of peak discharge rates [mm/10 min] between the Vogelbach (3) and Erlenbach (10) basins.

Figure 3.2.8 shows the differences of nitrate concentrations in streamflow. In both basins, relatively high concentrations are observed during late winter (snowmelt season) when large quantities of water pass through the upper soil layers and the vegetation is dormant. During the other seasons, the nitrate concentrations in Basin 10 remain lower than in Basin 3. However, a higher mean and variability of nitrate concentrations occurs in Basin 3. No clear explanation can be offered at present, but further research is in progress. The mean monthly inorganic nitrogen budget at Erlenbach (Basin 10) is shown in Figure 3.2.9. The continuous cumulative budget for the period of 1986 through 1989 in Figure 3.2.10 shows that in winter the input of inorganic nitrogen in precipitation almost equals its output in streamflow. In the summer, however, the accumulated amounts are considerable. The corresponding data for Basin 3 are not available. However, with respect to long-term variations, data from Basin 3 show a clear trend of increasing nitrate concentrations during the last 23 years of observation (Fig. 3.2.11). It remains difficult to explain the variations and the trend. No comparison can be made with Basin 10 because research there only began in 1982.

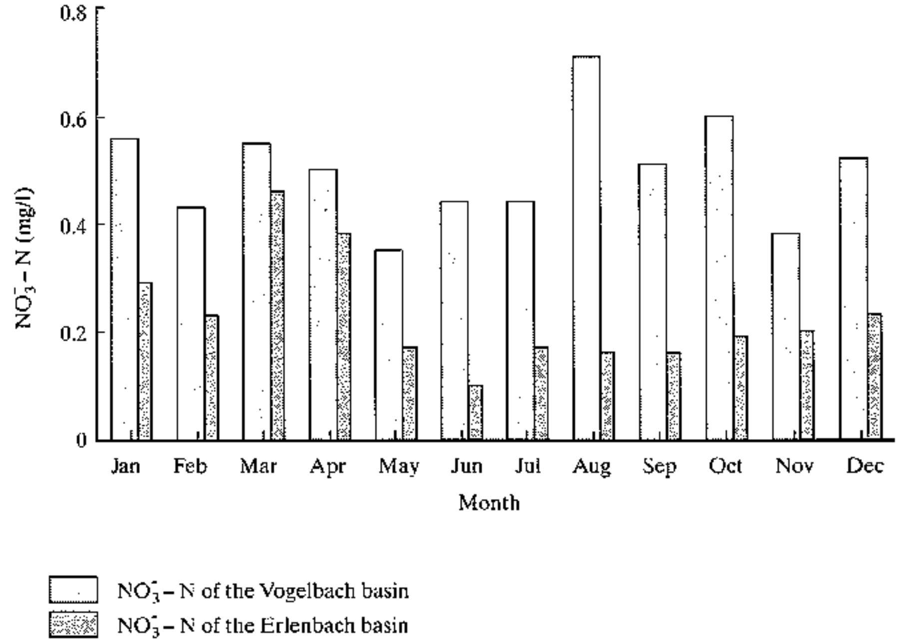


Fig. 3.2.8. Monthly nitrate concentrations in the streamflow of the Vogelbach (3) and Erlenbach (10) basins; mean from 1985 to 1990.

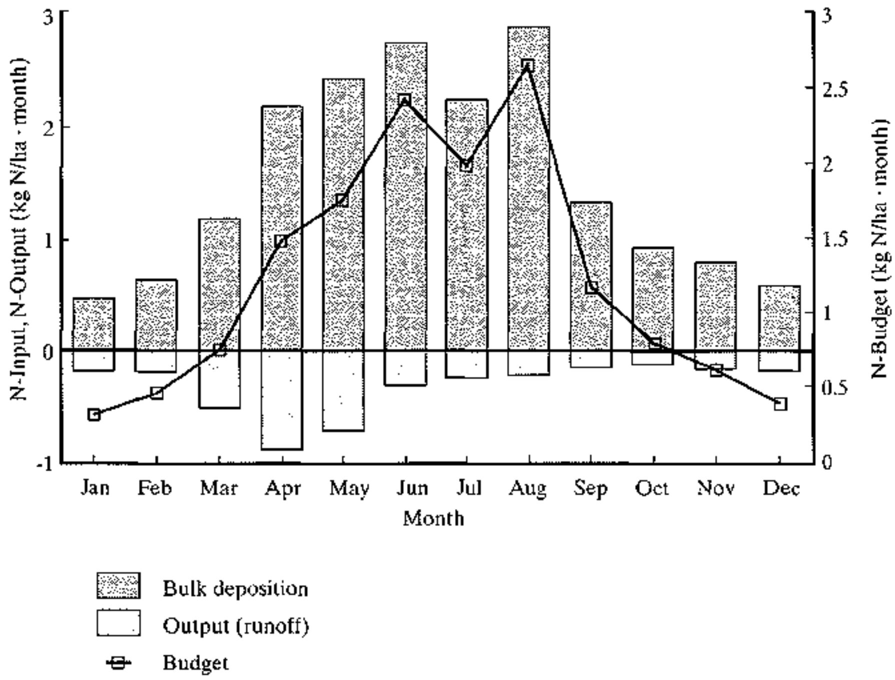


Fig. 3.2.9. Monthly inorganic nitrogen budgets of the Erlenbach basin (10); means from 1983 to 1991.

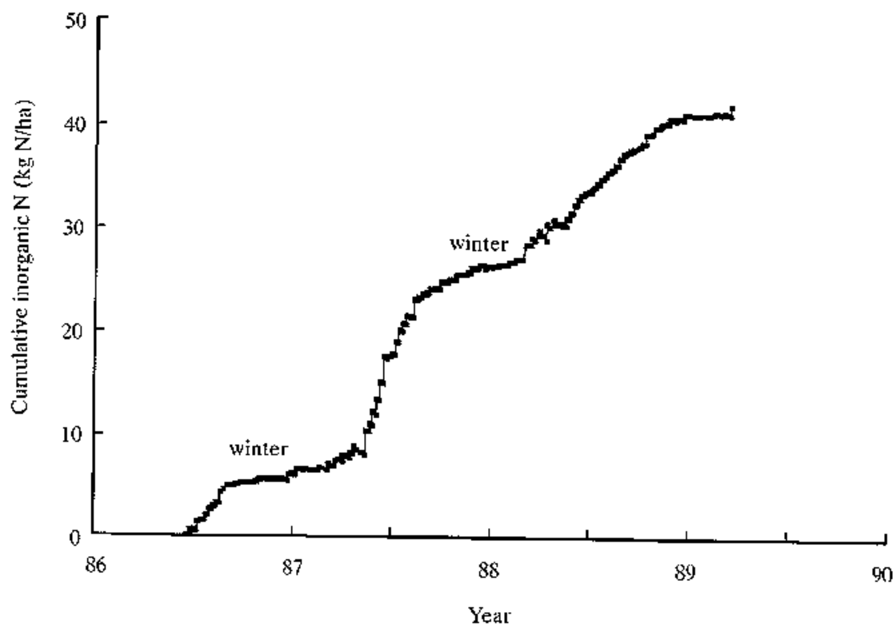


Fig. 3.2.10. Cumulative inorganic nitrogen budget of the Erlenbach basin (10); from 1986 to 1989.

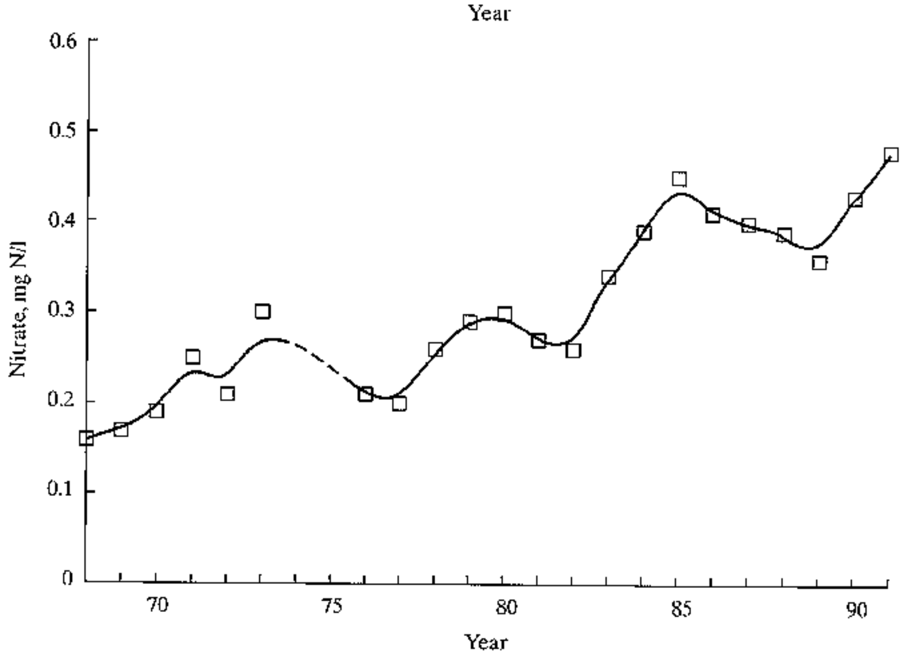


Fig. 3.2.11. Annual nitrate concentrations in the streamflow of the Vogelbach basin (3); means from 1968 to 1991.

In summary, the water balance comparison of Basins 3 and 10 shows that Basin 10 responds more rapidly with less intermediate water storage. The nitrate concentrations in streamflow in the more peaty and shallow soils of Basin 10 seem to be generally lower than in Basin 3 with deeper mineral soils. Further research is necessary to fully explain the observed trends.

3.2.6 Vegetation and fauna

The vegetation of the south-eastern parts of the Alp valley consists of a complex web of forests and fens (see Fig. 3.2.1). Above an altitude of 1,400 m, large fens with solitary trees or small open forests dominate the landscape pattern. These areas are traditionally used for mountain pasture. Along the hillsides below 1,400 m, fens alternate with larger forests. Here a striking difference between dense spruce *(Picea abies)* forests and open fens creates a well-stuctured diversity in habitats. To a large extent, these forests are still free of infrastructural impacts. The vegetation of the valley floor is dominated by partly improved hay meadows.

The mires of Erlentobel and Zwäckentobel consist of about 120 ha of fen (Fig. 3.2.2). Among the different plant communities found here, the Caricion davallianae alliance is predominant. Eutrophic plant communities such as Calthion or Filipendulion occupy up to 10% of the total fen surface at Erlentobel and 25% at Zwäckentobel. According to the inventory of the fenlands of national importance, the fens of Erlentobel and Zwäckentobel show local signs of peat erosion caused by cattle (DFI 1990). Because of economic changes in agriculture over the past few decades, the fenland area used for straw has steadily diminished. Drainage ditches are enhancing the drying of the surface peat layers, leading to colonization by trees. In general, the tendency for colonization declines with increasing altitude and wetness of the topsoil. It is dependent on features such as land use, drainage, density and height of the vegetation cover, extent of erosion, etc.

Besides their contribution to the preservation of endangered plant species and communities, the fens of Erlentobel and Zwäckentobel together with their surroundings are of special importance in the conservation of the capercaillie *(Tetrao urogallus)*.

Status and significance of the population of capercaillie *(Tetrao urogallus)* in the area of Alpthal (Alp valley), canton Schwyz

Capercaillie in Switzerland

Between 1970 and 1985, the number of male capercaillies (in spring) decreased from at least 1,100 to only 550 to 650. Moreover, the distribution range diminished greatly (MARTI 1986). The species is listed in the Red Data List, indicating that it is an endangered species (ZBINDEN 1989).

The main causes of this drastic decline include cold and wet weather during rearing and reduction of habitats due to modern forestry. Another reason for the decline is disturbance by tourism. As a consequence, suitable habitats have become more and more isolated.

Capercaillie in canton Schwyz

The pre-Alpine region of canton Schwyz has one of the largest and most dense populations of capercaillies in all of Switzerland (SCHIFFERLI et al. 1980; MARTI 1986). More specifically, three areas with dense populations are found here:

1 On the eastern side of the Alp valley, the area between Ibergeregg, Oberiberg, Gschwändstock and Alpthal, otherwise known as Furggelen.
2 On the western side of the Alp valley, the area of Tändliwald, Vogelwald, Hirzenstock and Hundschottental, called Tändli.
3 Between Lake Sihl and Lake Wägital, the area of Wisstannen, Chrummfluewald, Rosenhöchi, Salzläckiwald and Gross Allmeindwald, known as Rosenhöchi (HESS and MEILE 1978/1982).

It has been shown that in the northern part of its range the capercaillie in the pre-Alpine area of canton Schwyz declined sharply between 1950 and 1980 (Nievergelt and Hess 1984). Meile, a collaborator in the Capercaillie Conservation Project of the Swiss Ornithological Institute in Sempach, noted a decrease of 50% of the population in canton Schwyz from 1978 to 1989. Therefore, the situation of capercaillie in canton Schwyz has become extremely critical.

Capercaillie in the Zwäckentobel area

Zwäckentobel belongs to the area of Furggelen, the region with the largest and most dense population of capercaillie in canton Schwyz. Nevertheless, the present population of Zwäckentobel is small. A census in November to December 1991 resulted in two to three males. When the neighbouring areas of Schwarzenstock, Cholhüttlieggen and Husegg were included, six to seven males were found.

The high proportion of fens, typical for this Flysch landscape, is very important to the capercaillie. Fens surrounded by forests make up a structural diversity which is an essential requirement for the capercaillie. One factor of this diversity in habitat structure is the relative abundance of forest edge. This results in potential cover from predators and the presence of food sources such as bilberry *(Vaccinium myrtillus)* or ants.

The construction of forest roads and the artificial afforestation or natural forest (re-)establishment of many mires are the main threats to the capercaillie in the Zwäckentobel area.

Endangering capercaillie through the opening up of forests and alpine pastures.

The construction of new roads in capercaillie habitats normally results in a common sequence of events:

1 More roads attract more people. This results in more frequent disturbance of these shy birds. However, if the area already has heavy tourist traffic, new roads help to channel people and limit their access.
2 Despite traffic prohibitions and barriers, the roads are only very rarely closed. There is generally little control; often too many people are allowed to drive on the roads and barriers are frequently open or damaged.
3 The actions of the forestry industry following the opening of a new road are often needlessly damaging even in areas of known capercaillie habitats. The use of large machinery, the intense utilization of old forests and afforestation often destroy the habitat of capercaillie.
4 After construction of a new road, sewage sludge or artificial fertilizers are introduced to the worked land resulting in an intensification of agriculture on alpine pastures and even on fens of national importance. The little used transitional zone between forest and alpine pasture or fen is an important part of the capercaillie habitat.

Protective measures

The population of capercaillie in canton Schwyz has been halved within the last ten years. This coincides with a period when many openings in undisturbed capercaillie habitats were built. Openings should not be generally prevented, but in the three previously discussed areas of Furggelen, Tändli and Rosenhöchi further openings must be prevented if protective measures for the capercaillie are to have a chance of success. Probably because of their mainly undisturbed state, these areas contain not only the largest populations of capercaillie in canton Schwyz, but also many mires of national importance.

It should be determined (in an overall plan) whether and where in the canton forest reserves could be created. Such reserves would be of great benefit to the capercaillie. Under no circumstances should forest openings be considered until such time as an overall conservation plan has been drawn up and agreed upon.

The decline in the number of capercaillie is a very complex phenomenon. Thus, a simple recipe for the conservation of the capercaillie cannot be given. If the impressive capercaillie is worth saving, human activity must be restricted; forestry must be managed with a view to the preservation of the capercaillie. Preservation of the capercaillie will not exclude forestry, but it will require consideration. What is needed is the maintenance and preservation of stable mountain forests from natural regeneration, with a rich structure that represents the ideal habitat. It is fortunate for the capercaillie that in the area of Furggelen, many mires have been proposed for classification as nationally important. Financial compensation for the maintenance of the litter meadows is probably the only guarantee of preserving the mires and, to some extent, also the capercaillie (cf. Chapter 3.2.8).

3.2.7 Land use history

Before successive deforestation from the 14th century to the beginning of the 19th century, the Alp valley was covered by sub-alpine spruce *(Picea abies)* forests. Although sites with shallow soils or north-facing forests were left untouched on steep slopes, large parts of the landscape up until the end of the 19th century were converted to agricultural use (Keller and Strobel 1982). The areas close to the hilltops were used for mountain pasture. Over time, less and less food was produced for local consumption. Cultivation of vegetables and grain competed with the growth of animal fodder. Consequently, most of the livestock had to be sold annually. However, because of increased trade, livestock gained importance. The remaining fields in the valley were turned into hay meadows to provide more fodder for the winter season. Due to both the increase of livestock and the decrease of grain-growing (providing straw), the hillside fens gained importance as litter meadows.

Since the turn of the century, forest policy and economic changes in agriculture (straw imported from the grain fields of the lowlands or abroad; liquid fertilizer; cf. Chapter 1.7.2) have resulted in different land use patterns. On the hillsides, the total area of forests has increased. The pasture fields are fenced and the fens are only occasionally used to cut straw. Today, sustained by drainage and afforestation, forest is redeveloping over large parts of the abandoned litter meadows (Figs. 3.2.12 and 3.2.13).

Fig. 3.2.12. Despite good accessibility, many fens of the Alp valley have not been used for years and today are being reduced in area by encroaching forest (Photo by R. Haab).

Fig. 3.2.13. Afforestation of the Gross Blätz fen sustained by drainage ditches (not visible), viewed from the west (Photo by R. Haab).

The preservation of the fens endangered by afforestation and natural forest (re-)establishment requires the resumption of traditional land use management strategies such as straw production or combining pasture with regular mowing. These activities must be planned and executed in accordance with the requirements for the preservation of the capercaillie *(Tetrao urogallus)*. Under the prevailing agricultural conditions, the farmers need to be compensated for their additional expenditure (cf. Chapter 3.2.8). Although canton Schwyz was one of Switzerland's first to pay contributions for conservation management, the payments of Sfr. 350 to 700 per ha have generally been insufficient. Furthermore, for most sites of national importance, the legal requirement to obtain these contributions (demanding a cantonal inventory of these sites) has not been provided.

3.2.8 Profit and loss account for the management of litter meadows: a case study

The farmland at Unterägeri in canton Zug consists of 22 ha of fodder meadows and 6 ha of litter meadows. The straw from the litter meadows is used as floor covering for the stable and contributes almost a third of my farm's total need for straw. Due to limited drying capacity during the autumn months, it is impossible to maintain larger surfaces of litter meadows.

Table 3.2.2 outlines the financial aspect of the management of three parcels of litter meadows. The prices are adjusted to the autumn of 1991. Machine costs were taken from official reports. Wages were calculated at Sfr. 20 an hour and straw at Sfr. 10 per 100 kg. Financial compensation connected with nature conservation management was not received for any of these parcels of land.

The balance of the profit and loss account for the management of litter meadows is dependent on many different factors.

On the income side, the amount of agricultural subsidies is mainly dependent on the steepness of the slope and the location (altitude) of the maintained area. Where the incline of the slopes is less than 18%, no subsidies are paid. For parcels with an incline of more than 35%, higher subsidies are disbursed. The value of the straw is highly dependent on the operational structures of the farm. For farms operating with liquid manure or farms with little livestock and/or large fields of corn or litter meadows, straw may offer little economic value.

Table 3.2.2. Financial aspects of the management of three different parcels of litter meadows. All of these areas are maintained by Ruedi Hess, Unterägeri (canton Zug).

Parcel name	Elsisried	Hürital	Hinterwald
State	considered a fen of national importance	considered a fen of national importance	considered a fen of local importance
Vegetation	Caricion davallianae	Caricion davallianae	Calthion
Area	1.24 ha	1.06 ha	1.25 ha
Altitude	850 m	830 m	880 m
Slope	0.7 ha with 18–35%	18–35%	more than 35%
Agriculture Zone	Mountain Zone I	Mountain Zone II	Mountain Zone I
Distance from farm	4.5 km	5.5 km	0.5 km
Value of the straw	Sfr. 320 per ha	Sfr. 190 per ha	Sfr. 320 per ha
Agricultural subsidies	Sfr. 260 per ha	Sfr. 530 per ha	Sfr. 590 per ha
Total Receipts	Sfr. 580 per ha	Sfr. 720 per ha	Sfr. 910 per ha
Labour costs	Sfr. 580 per ha	Sfr. 650 per ha	Sfr. 620 per ha
Machine costs	Sfr. 540 per ha	Sfr. 370 per ha	Sfr. 470 per ha
Rent for land	Sfr. 100 per ha	–	Sfr. 100 per ha
Total Expenses	Sfr. 1220 per ha	Sfr. 1020 per ha	Sfr. 1190 per ha
Loss	Sfr. 640 per ha	Sfr. 300 per ha	Sfr. 280 per ha

On the expense side, the costs for machines vary according to the degree of their utilization (hours per year). In the present case highly utilized machines from a farmers' cooperative organization, called a machine ring, were used. Therefore, machine costs are relatively low. The rent for land of the three parcels mentioned above must be regarded as low. Although the cost of labour cannot be reduced drastically, it generally decreases with diminishing wetness of the soils, decreasing incline of the slope and various other factors. The costs exclude cutting by hand (for instance on very steep or wet surfaces) and management of surrounding or interspersed forests. This work need not be done annually, but is nevertheless time-consuming.

Over the past decades, the management of litter meadows for many farmers has resulted in a financial loss of up to several hundred Swiss francs per hectare. As a consequence, most litter meadows up to the 1980's were subject to (subsidized) drainage and fertilization or were abandoned. Under prevailing agricultural policy, these tendencies (especially for litter meadows with inclines less than 18% and litter meadows of the Central Plateau) will only be prevented by the disbursal of contributions bound to nature conservation management.

Today, several cantons offer this kind of contribution. Canton Zug offers the prospect of up to Sfr. 2,000 per hectare per year for the maintenance of litter meadows. The general minimum is approximately Sfr. 800 with another Sfr. 800 to be paid to compensate for difficulties in management due to steepness or wetness. An additional Sfr. 400 will be paid if the area has a high degree of species diversity or rare species. The federal government subsidizes the canton with contributions of up to Sfr. 1,500 per ha. In comparison with other cantons, the contributions of canton Zug are distinctly higher than average. With these contributions, many farmers may feel the traditional maintenance of litter meadows could be a source of income rather than an expense.

Fig. 3.3.1. Mire landscape of Schwantenau, viewed from the north. In the foreground peat cutting faces and peat huts of the central basin provide a reminder of the earlier use of bogs for fuel. In the background, the moraine ridge of Altberg is covered by fens and fertilized hay meadows (Photo by R. Haab).

3.3 The fauna of a cut over peat bog – the mires of Schwantenau

Roland Haab and Thomas Walter

Community: Einsiedeln (canton Schwyz)
Locality: Schwantenau
Coordinates: 698-700 / 223-225
Elevation of the mires: 900 m
Area of the raised bogs: 20 ha
Area of the fenlands: 90 ha
Area of the mire landscape Schwantenau: 480 ha

3.3.1 Highlight of the visit

According to the Inventory of Raised and Transitional Bogs of National Importance, the bog of Schwantenau, with a surface of 20 ha, is one of the largest in Switzerland (GRÜNIG et al. 1984). The surrounding fens which cover a surface of almost 90 ha are among the fifty largest fens of this country (DFI 1990; Fig. 3.3.2).

The bog and fens of Schwantenau are not only important because of their size and biodiversity, but also as a record of traditional peat exploitation. Nowhere else in Switzerland have the remnants and surface structures of traditional peat cutting been preserved to such an extent.

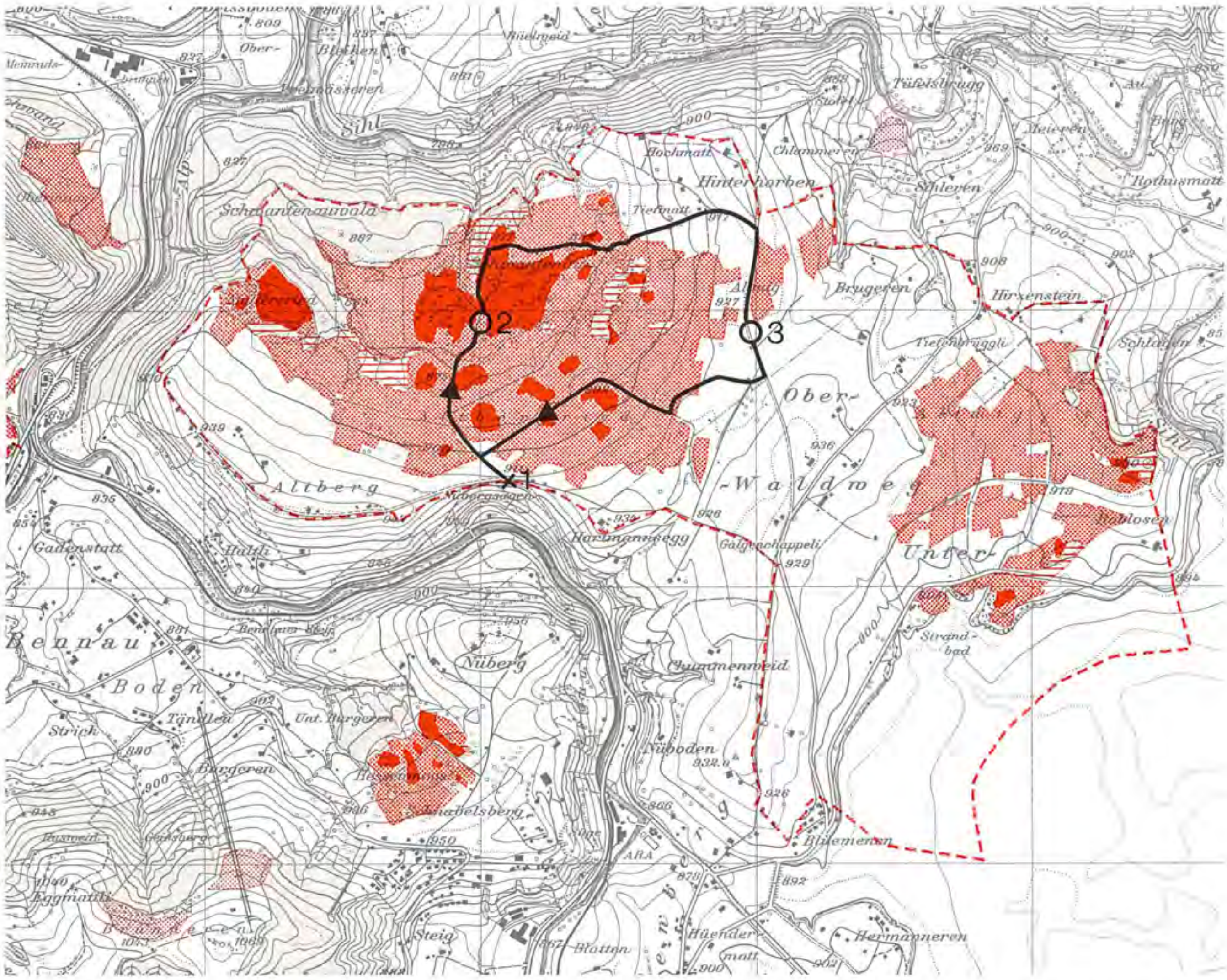


Fig. 3.3.2. Location of the mires and the mire landscape of national importance in the area of Schwantenau (modified from DFI 1990, 1991b, 1991c). 1 Vantage Point; 2 Central basin and bog of Schwantenau; 3 Fens of the moraine ridge of Schwantenau.
Scale of the map: 1 : 25,000; for key, see end-cover. Reproduced by courtesy of the Federal Office of Topography, Berne, 9 June 1992.

3.3.2 Location and geology

The mires of Schwantenau are located in a broad glacially formed basin between 870 and 930 m a.s.l. To the east and the west rise mountainous ranges belonging to the Lower Freshwater Molasse (Fig. 3.3.3). This saddle was covered during the last period of the Ice Age by a branch of the Linth/Rhine glacier as well as by the Sihl/Alp glacier. During the early Würm, the valley which subsequently became Lake of Zürich was not entirely filled by ice when the Sihl/Alp glacier passed the saddle near Biberbrugg and reached the side of the Linth/Rhine glacier at Samstagern (Hantke 1980). With its increasing size, the ice of the Linth/Rhine glacier pushed back the Sihl/Alp glacier.

At its greatest extent, a branch of the Linth/Rhine glacier passed the saddle mentioned above in the opposite direction. Between Hinterhorben and Altberg (near Biberbrugg), the Linth/Rhine glacier left a large semicircular end moraine contemporaneous with the Killwangen stade of the main branch of the same glacier (cf. Fig. 1.3.14). This end moraine today delimits the south end of the mires of Schwantenau.

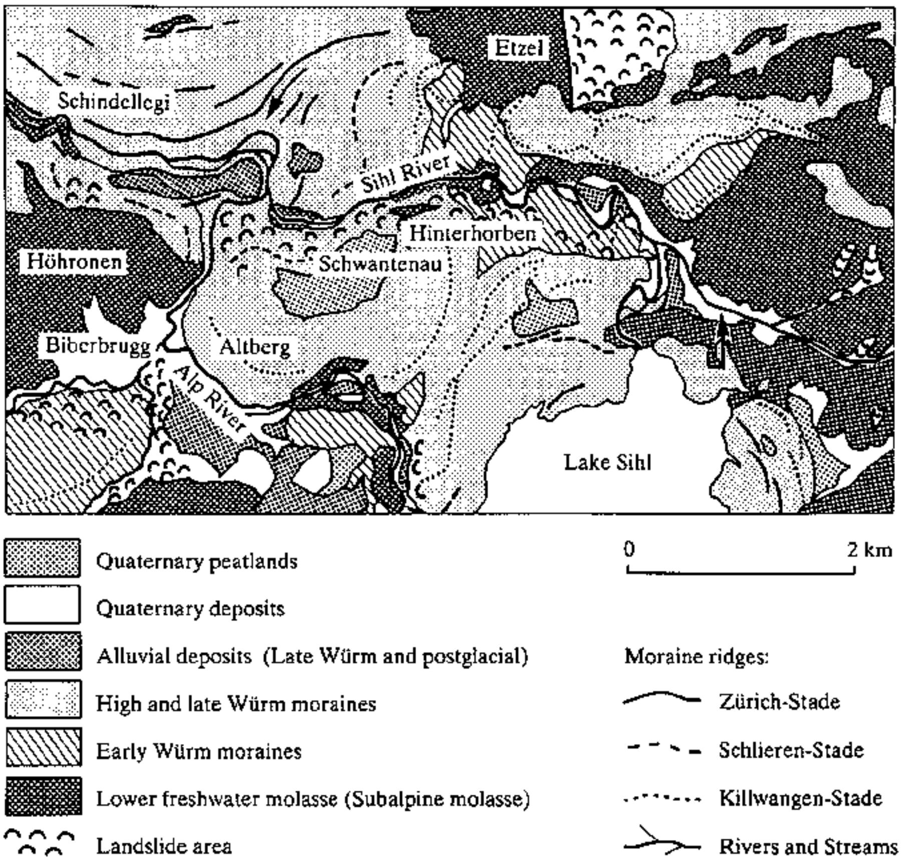


Fig. 3.3.3. Geological sketch map of Schwantenau and surroundings (modified from HANTKE et al. 1967).

About 1 km northward, the retreating glacier left a second but smaller moraine rampart which is associated with the Schlieren stade (HANTKE et al. 1967). To the south, the north and west, the landscape of Schwantenau is shaped by the rivers Sihl and Alp like an amphitheatre. During deglaciation these rivers served as drainage channels for the retreating Sihl and Alp glaciers. Due to their erosional power, the rivers lowered (and continue to do so) their base by many metres. As a result, to the north of Schwantenau, the moraine is becoming increasingly unstable because of under-cutting by the Sihl River.

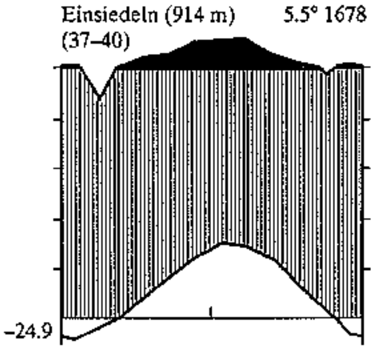


Fig. 3.3.4. Climate diagram for Einsiedeln which is climatically similar to Schwantenau (modified from WALTER and LIETH 1960). For explanation see Fig. 1.5.4.

3.3.3 Climate

The climate of Schwantenau is similar to that of the Biber valley at Rothenthurm (Fig. 3.3.4; see also Chapter 3.1.3). The basin of Schwantenau opens towards the north and lies near the valley of Lake of Zürich. The climate therefore shows a little more influence from the Central Plateau.

3.3.4 Pedology and hydrology

Because of its location at the edge of the glacier's tongue, deglaciation in the Schwantenau basin occurred earlier than in the Biber valley. After the retreat of the glacier, clay particles were washed off the hillsides and deposited in the centre of the basin. As a result, a thick and almost impermeable soil layer developed. Above this layer, about 11,000 years ago, peat formation began.

During the following millennia, peat layers of up to 6 m in thickness accumulated. The peat profiles taken from Schwantenau revealed no evidence of lake sediments. The peat in the centre of the basin mainly consists of *Eriophorum* peat underlain by layers of Cariceto-Hypnetum peat with *Phragmites* and *Betula* (FRÜH and SCHRÖTER 1904). Towards the foothills surrounding the basin, patches of *Scheuchzeria* and *Carex* peat indicate the increasing influence of runoff from the hillsides.

The catchment area of the mires of Schwantenau is divided by a small creek through which the bog at the basin centre is hydrologically cut off from the southern hillsides. Today the basin centre is, therefore, predominantly supplied by rain-water. Runoff only enters the basin centre from a small area to the east. In contrast to the once well-developed and typically raised bog of the basin centre, other patches of bog vegetation also became established on the surrounding hillsides. In these places, oligotrophic conditions are caused either by small topographic elevations or by the progressive filtering of soil water by peat.

3.3.5 Vegetation and fauna

The mires of Schwantenau consist of 20 ha of raised bog vegetation and 90 ha of fenlands (Fig. 3.3.2). As a result of peat cutting, agriculture and the varying influence of calcareous runoff, a rich pattern of mire habitats, including heaths, transitional mires, spring fens and wet meadows, has become established. Altogether, the flora of the wetland habitats at Schwantenau consists of more than 200 species of phanerogams.

The flora of the bog vegetation in the centre of the basin is dominated by deer-grass *(Scirpus cespitosus)* and heather *(Calluna vulgaris)*. Because of the different levels left after peat exploitation, a close-knit mosaic of wet, relatively dry, wooded and open areas gave rise to a range of bog communities. Although the surfaces of isolated peat bodies caused by peat cutting bear a heath vegetation rich in lichens, just a few metres away large hollows show signs of bog regeneration (Fig. 3.3.5). Along the edges of the central basin, spruce *(Picea abies)*, rowan *(Sorbus aucuparia)* and downy birch *(Betula pubescens)* indicate the influence of runoff water supply.

Fig. 3.3.5. Shrunken but still impressive peat cutting faces of the central bog, viewed from the west. In the foreground, masses of feathery bog moss *(Sphagnum cuspidatum)* indicate areas of bog regeneration (Photo by R. Haab).

The morainic hillsides in the south and east of the central basin are predominantly covered by communities of the Caricion fuscae. It is replaced where calcareous spring and soil water or nutrient-rich runoff water from fertilized meadows may influence the upper layers of peat penetrated by roots. These areas are concentrated on the upper part of the semicircular end moraine. Due to the higher permeability of the soils close to the hilltop, these areas are better drained and therefore used as (fertilized) hay meadows. At 915 m, calcareous vegetation occurs along a spring line (Früh and Schröter 1904). Spring water at this elevation contributes to the water supply of the adjacent fens. The chemical composition of the water changes as it passes through the peat layers. With increasing distance from the spring, the water becomes increasingly poor in minerals and nutrients as a result of ion-exchange. Consequently, plant communities of the Caricion fuscae cover a major part of the moraines beyond the spring zone.

As a result of its diversity of habitats and its wide amplitude in water content, the mires of Schwantenau serve as important zoological refuges. Species sensitive to disturbance such as the meadow pipit *(Anthus pratensis)*, as well as species typical of fens and bogs, populate the mires. Scientific investigations over the past decades have been carried out mainly on birds and butterflies. These investigations and Switzerland's most recent Red Data Lists note that the mires of Schwantenau support 12 endangered species of butterflies. One of them, the cranberry fritillary *(Boloria aquilonaris)*, belongs to a group of 12 species threatened with extinction (JUTZELER 1990).

Ornithological studies from 1984 to 1989 in an investigation area of 25 ha has found 32 bird species breeding – among them seven species on the Red Data List of endangered birds (e.g. common quail *(Coturnix coturnix)*, red-backed shrike *(Lanius collurio)*). With almost 5 pairs in 10 ha, the Red Data List species, tree pipit *(Anthus trivialis)*, has reached an astonishing breeding density (SCHOENENBERGER 1990).

For additional information on the fauna of Schwantenau and its surroundings, as well as its preservation through conservation management, see Chapter 3.3.8.

3.3.6 Land use history

The land use history of the mires of Schwantenau proceeded in a similar pattern to that of the mires within the Biber valley. Before 1000 AD, the surrounding area as well as most parts of the mire must have been covered by forests. The wettest areas in the centre of the basin were sparsely wooded. In peat profiles of the basin centre, woody remains of birch (*Betula* spp.), spruce *(Picea abies)* and pine (*Pinus* spp.) were found and indicate the temporary existence of open forest (FRÜH and SCHRÖTER 1904).

Whereas it is known that after 1000 AD the surroundings of Einsiedeln were gradually cleared and settled, there is no record of when this happened in the Schwantenau area. What is certain is that at the turn of the century, the hillsides and the basin centre of Schwantenau had already been used for agriculture or peat exploitation. The upper parts of the end moraine to the south and the east of the basin were used as dunged hay meadows or potato fields. Beyond a zone of spring-fed vegetation, litter meadows with purple moor-grass *(Molinia caerulea)*, carnation sedge *(Carex panicea)* and deer-grass *(Scirpus cespitosus)* show transitional stages towards raised bog vegetation. FRÜH and SCHRÖTER (1904), the pioneers of Swiss mire research, therefore concluded that the bog of the central basin was once linked with the bogs of Hartmannsegg and Chlammeren (cf. Fig. 3.3.2).

According to FRÜH and SCHRÖTER (1904), peat exploitation at Schwantenau started after 1870. At the turn of the century, 168 storage sheds and two houses had been established on the bog of the central basin. To the west and south-west of the central basin, the bog had already been exploited almost to the underlying mineral soil. Around 1940, the subsidized settlement of farmers along the rim of Altberg increased the land use pressure. These farmers had been made homeless by the flooding of the Sihl valley for the construction of a hydroelectric power-station. Today a few isolated and shrunken cutting-faces give an impression of the original extent of the peatland. Peat cutting is now forbidden by law, but the drier parts of the central bog are still used as litter meadows. Because of the use of heavy harvesting machines, there is a tendency either to reopen old drainage ditches or to give up the maintenance of the litter meadows. In contrast to the traditional ditches, today's channels are dug mechanically and, therefore, are larger and deeper.

3.3.7 Changes in vegetation and fauna since the turn of the century

Früh and Schröter (1904) described the area of the central bog to be 45 ha. Due to peat cutting and also to continued drainage and fertilization, only 20 ha of bog vegetation remain today (Conseil fédéral suisse 1991). There are no data available for the decrease in the surface area of the fens. Because of the higher agricultural potential of the fens, it may be assumed that the area of these plant communities has also been greatly decreasing.

Data on the changes in fauna have only been published for birds. A survey carried out in 1952 was repeated in the same area between 1984 and 1989 (Schoenenberger 1990). The results of the survey show that between 1952 and 1989 the number of bird species inhabiting woods had increased. The disappearance of the endangered species great grey shrike *(Lanius excubitor)* and probably also whitethroat *(Sylvia communis)* contrasts with the appearance of black redstart *(Phoenicurus ochruros)* and common quail *(Coturnix coturnix)*. The author of the survey concludes that any future hopes of encountering species like snipe *(Gallinago gallinago)*, curlew *(Numenius arquata)* or great grey shrike *(Lanius excubitor)* is unlikely. It can only be hoped that species such as common quail *(Coturnix coturnix)*, meadow pipit *(Anthus pratensis)* and red-backed shrike *(Lanius collurio)* will continue breeding.

3.3.8 Evaluation of the fauna in the mire areas of Schwantenau, Roblosen, Breitried and Schützenried (canton Schwyz) and proposals for their conservation

Introduction

Until now, the usual emphasis in the planning of mire conservation has been placed on the vegetation. Fauna has been mentioned only in passing. Consideration of fauna provides an essential supplement to the vegetation, but, conservation measures for fauna could conflict with any conservation measures established for flora. Priorities for conservation will have to be defined for each individual case.

Another problem is the time and expense required to examine a selection of animals. Because of this, in the study described here, only a small group of animals was investigated. The following animal groups were recorded in the mire areas of Schwantenau, Roblosen, Breitried and Schützenried: birds, reptiles, amphibians, grasshoppers, dragonflies and butterflies.

These animal groups represent approximately 3% of the total number of animal species that probably exists in these areas. The criteria for selection included the following:

1. The species had to be easily observed in the field.
2. Their habitats and distribution had to be known (this made it possible to evaluate their importance and establish the appropriate protection measures).
3. The animal species chosen had to be complementary to each other in their habitat demands (this minimized the danger of losing a species to extinction with a high conservation value).

Of course it would have been reasonable to include other categories of animals in such a study, but this would have substantially increased the expense. The research was completed by Büro für Ökologie (BfÖ) in Zürich for the Nature Conservation Agency for canton Schwyz (Walter et al. 1992).

Importance for nature conservation

The mire areas around Lake Sihl (an artificial lake covering once famous peat bog areas in Switzerland) are of international interest for conservation because of their butterflies. For detailed information about species and their occurrence, refer to Walter et al. (1992). Table 3.3.1 gives a general overview of the importance of protecting these mire areas in relation to specific animal species.

Table 3.3.1. Number of observed species in the mire areas around Lake Sihl and their status of protection (field work done by Büro für Ökologie 1991).

Animal groups	Total number of species	Species of the Swiss Red Data List	Nationally protected species
Birds	67	13	63
Reptiles	2	—	2
Amphibious animals	4	2	4
Grasshoppers	20	8	—
Dragonflies	19	5	19
Butterflies	45	7	10
Total	157	35	98

Measures for the conservation of the endangered species of animals

The observed fauna indicated that first priority should be given to the conservation of butterflies. The next priority is to maintain and improve the habitats of birds, grasshoppers, dragonflies and amphibians (especially in the areas of Breitried and Schützenried, both situated at the southern end of Lake Sihl). In combining the following measures of management and maintenance, the endangered species can be conserved and their population strengthened. The measures that are suggestive for the single parcels and sub-parcels form part of the comprehensive management plan and are stored in a database.

Traditional use of litter meadows

Target group: butterflies, grasshoppers, birds
Litter meadows should be maintained. Cutting should be done as late as possible in the year (after the middle of September) and with very light machines or by hand. The litter straw should remain on the meadow to dry and later be collected. It would be best if Tristen (traditional hay piles; see Fig. 3.1.7) could be maintained.

Cutting of the mire vegetation

Target group: butterflies, grasshoppers
Mire habitats with endangered species which hibernate in vegetation, should be cut alternately every 2 to 5 years. This prevents forest encroachment.

Adjusted grazing

Target group: butterflies, grasshoppers
The mire habitats, with a few exceptions, should not be grazed. If the slopes leading to the mires are steep and traditional mowing impossible, a cursory trimming is appropriate. This prevents the onset of forest growth.

Adjusted fertilization surrounding the mires

Target group: butterflies, dragonflies
If there is a probability that nutrients could be carried into mire habitats, an unfertilized buffer zone should be established. The width of each buffer zone would vary from case to case. In steep areas, a buffer zone should be established around the distribution range of specific species (e.g. the grasshopper *Chorthippus montanus*). With specific dragonfly species, nutrients in the water should definitely be limited.

Conservation of connected mire habitats

Target group: butterflies, grasshoppers, birds
Further isolation of mire habitats by fields and pastures should be prevented. Where possible, they should be restored to litter meadows. These areas in the mires mentioned above have already been identified.

Regulation of the water-table

Target group: butterflies, grasshoppers, birds, amphibians
Drying out large areas of mire habitats should be avoided by damming ditches and eliminating drainage (cf. Chapters 3.10 and 3.16). However, some dry habitats are needed for species such as the mottled grasshopper *(Myrmeleotettix maculatus)*. Some species characteristic of wetlands are also dependent on dry areas for their hibernation.

Management of ditches	Target group: dragonflies, amphibians, butterflies, grasshoppers Ditches should be kept free from overgrowth and banked. This procedure, preventing the growth of shrubs on the edges of the banks, should occur in cycles of 2 to 5 years. This should be done in areas with both free-flowing and dammed drains.
Control of bushes and shrubs	Target group: butterflies, grasshoppers, birds Partial cutting of shrubs should be carried out. However, there are also advantages in allowing parts of the undergrowth to develop. It provides the shade, shelter and cover which are needed by some species. Whether shrubs are required or not varies from case to case.
Peat cutting	Target group: butterflies, dragonflies, grasshoppers Management of existing peat cut faces and pits are desirable for this group. In doing so, early stages of succession are stimulated.
Adjusted recreation use	Target group: birds Pedestrian traffic through mire habitats must be minimized, especially during the breeding season of birds. This is also true for the use of the implement sheds formerly used for peat cutting now being used as weekend homes. A compromise must be found between recreational activity and the continued existence of some endangered species. Successful conservation of these mire habitats will only improve if man relates more sensitively to them. For example, the highly artificial lawns of the sheds could be replaced by flower meadows or even sparsely covered (vegetated) peat surfaces. The latter, in Schwantenau, would be favorable to animals such as the mottled grasshopper *(Myrmeleotettix maculatus)*.

Fig. 3.4.1. Mire landscape of the upper Gross Schliere valley, viewed from the south-west. The slopes to the north-west of the Gross Schliere River (left side of the picture) face the sun. They are drained and fertilized and serve as mountain pasture. In contrast, bogs and fens with scattered trees prevail on the opposite slope. They are used for litter cutting and mountain pasture at lower intensity (Photo by R. Haab).

3.4 Managing forests, pastures and tourism – the mires of the upper Gross Schliere valley

Roland Haab

Community: Sarnen (canton Obwalden)
Locality: Oberes Schlieretal
Coordinates: 652-654 / 193-196
Elevation of the mires: 1,420 m
Area of the raised bogs: 45 ha
Area of the fen lands: 120 ha
Area of the mire landscape Glaubenberg: 12,500 ha

3.4.1 Highlight of the visit

The mires of the upper Gross Schliere valley lie in the heart of Switzerland's main centre of mire distribution. According to the inventory of the mire landscapes of particular beauty and national importance, this centre consists of five adjacent mire landscapes with a total surface of 30,300 ha (DFI 1991c; cf. Fig. 3.5.2). This area represents more than a fourth (385 ha) of Switzerland's bog vegetation and contributes more than a fifth (5,045 ha) of the total fen surface of this country. The importance of a single mire area is its function as part of a larger contiguous genetic reservoir of many rare and endangered mire species. However, a few single mires are especially important. The most prominent among these is the bog of Seeliwald (see Fig. 3.4.2). It contains a large diversity of raised bog structures and large areas of mainly unaffected primary habitat conditions. Among the bogs of Switzerland only two are larger in terms of their area of primary bog vegetation.

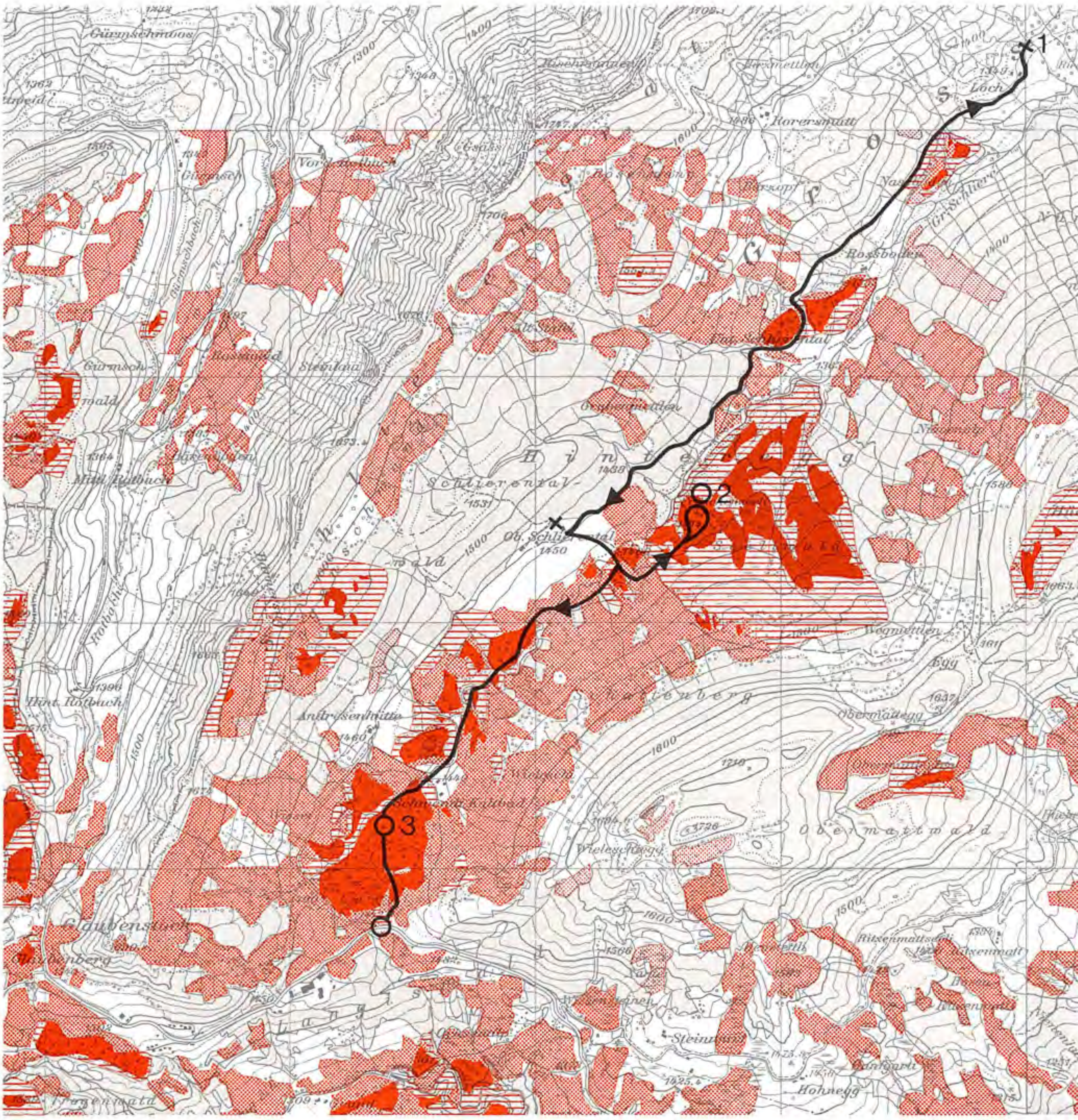
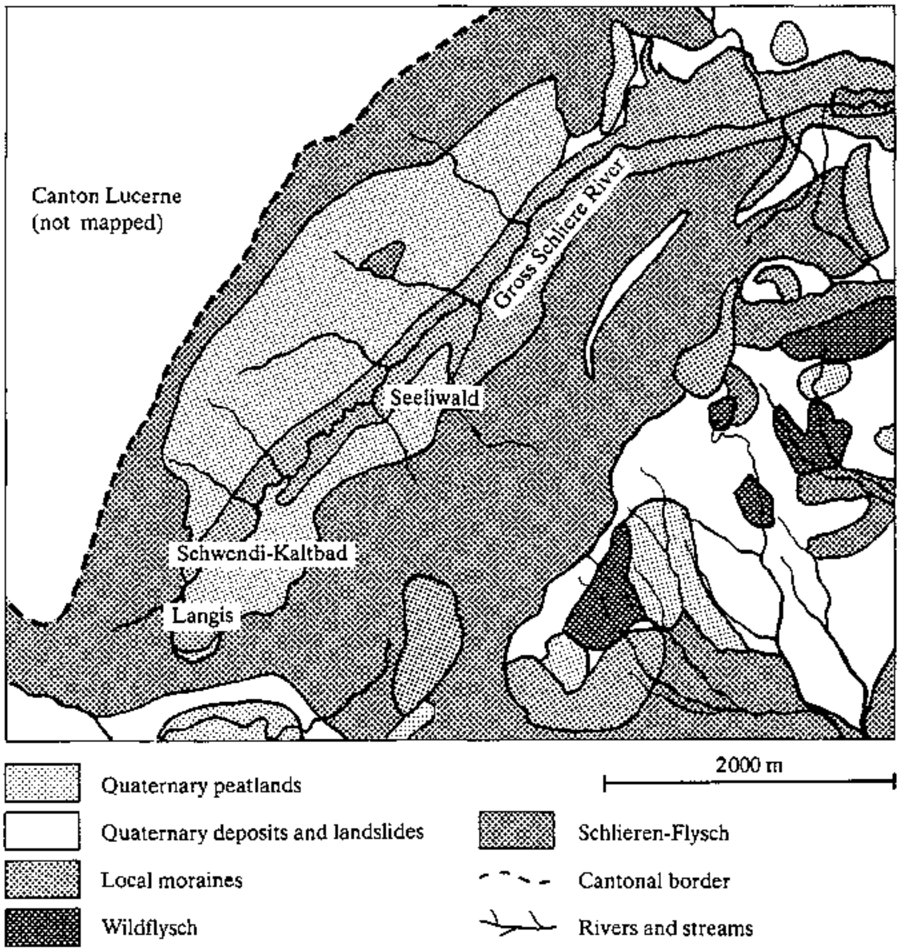


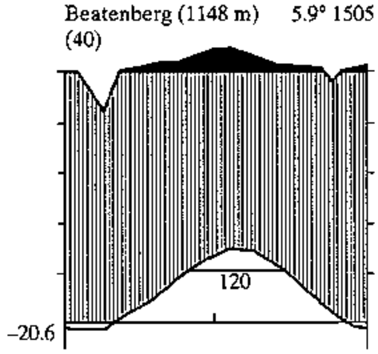
Fig. 3.4.2. Location of the bogs and fens of the upper Gross Schliere valley (modified from DFI 1990, 1991b).
1 Loch Alp; 2 Fröschenseeli within the Seeliwald bog complex; 3 Bog complex of Schwendi-Kaltbad.
Scale of the map: 1 : 25,000; for key, see end-cover. Reproduced by courtesy of the Federal Office of Topography, Berne, 9 June 1992.

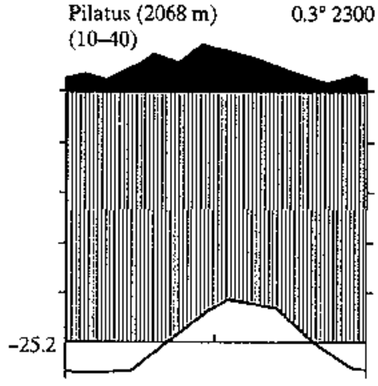
3.4.2 Location and geology

The mires of Gross Schliere valley are located within the zone of Ultrahelvetic Schlieren Flysch in between the Helvetic folds (Fig. 3.4.3). Lithologically, the Schlieren Flysch predominantly consists of turbidic sandstones and marl deposited in marine basins between the folding Alps (cf. Fig. 1.3.4). The uppermost part of the Gross Schliere valley consists of a broad saddle shaped by local glaciers during the Würmian ice age. Towards the north-east, the Gross Schliere valley stretches out – first as a broad, shallow valley with little signs of erosion, but with increasing distance, becoming more narrow and the valley bottom more affected by erosion.

Fig. 3.4.3. Geological sketch map of the upper Gross Schliere valley and surroundings (modified from Kantonales Oberforstamt Obwalden 1981).







Figs. 3.4.4a and 3.4.4b. Climate diagrams of Beatenberg (located 30 km south-west of Schliere valley) and Pilatus (modified from WALTER and LIETH 1960).
The climate research station of Pilatus is located on a mountain peak, 13 km north-east of the upper Gross Schliere valley. Both diagrams, therefore, provide an approximate representation of the climate of Gross Schliere valley. For explanation see Fig. 1.5.4.

The bogs of Schwendi-Kaltbad and Seeliwald are located in the upper part of the Gross Schliere valley. The valley bottom beyond the peatlands consists mainly of moraines from local glaciers mixed with eroded material from the hillslopes.

3.4.3 Climate

The climate of the Gross Schliere valley is characteristic of the northern pre-Alpine region. In the upper parts of the valley, the annual precipitation normally varies between 1,800 and 2,400 mm, with most of the precipitation falling during summer thunderstorms. The annual average temperature is around 4° C. During the plant growth period, the average temperature increases to 12° C. In the Gross Schliere valley, fog is also an important climatic factor that, most notably during the months of August and September, lowers the evapotranspiration rate. In summary, the climate of the upper Gross Schliere valley may be described as humid and cool with oceanic characteristics in summer (Figs. 3.4.4a and 3.4.4b).

3.4.4 Pedology and hydrology

The hillsides and parts of the bottom of the Gross Schliere valley are covered by Schlieren Flysch. This material weathers easily and results in loamy and unstable topsoils. Because of the abundance of marly clay, the soils are relatively impermeable. During an extended or heavy rainfall, most of the water ends up as runoff. Summer thunderstorms may result in torrential flooding which is known to be the worst in Switzerland. In the more steeply sloping areas of the Gross Schliere River, these torrential floods have strongly eroded the underlying Flysch. Rapid and progressive lowering of the river bed results in unstable river-banks and the mires along the banks of the Gross Schliere River are often strongly affected by landslides.

The bogs of Schwendi-Kaltbad and Seeliwald are located in the upper course of the Gross Schliere River. Its closeness to the saddle (Schwendi-Kaltbad) and its location on a smoothly sloping river-bank (Seeliwald) give these bogs significant shelter from strong erosional impacts. Whereas the better drained topsoils of the hillsides consist of Gley-Podsols, the smooth slopes and basins of the valley bottom after deglaciation gave rise to peat layers of up to 3 m in thickness. In spite of the lack of strong eroding forces, these peatlands (due to the meandering upper course of the Grosse Schliere River or to regressional erosion of small tributaries) were hydrologically separated into different smaller units. Although the influence of long-term climatic changes, clearing, pasture and drainage on the water balance of a catchment area are not fully understood, it may be presumed that during the last few centuries human impact in the upper Gross Schliere valley resulted in enforced stream erosion. Due to the lowering of the river and tributary beds, resulting in the division of the bog into smaller sections, its vegetation today is subject to increased drainage.

3.4.5 Vegetation and fauna

The mires of the upper Gross Schliere valley between Langis and Seeliwald consist of 45 ha of bog and 120 ha of fen vegetation (Fig. 3.4.2). According to the inventory of the fenlands of national importance, the fens of this area show little diversity (DFI 1990). Almost two thirds of the total fen surface are covered by communities of the Caricion fuscae. The remaining third consists of variations of the Caricion davallianae and occurs because of the influence of calcareous runoff from the hill sides.

Despite their proximity, the bogs of Schwendi-Kaltbad and Seeliwald differ in various aspects. The most obvious difference between these bogs, which were at one time connected, is their state of preservation; they have experienced human influences over the centuries to differing extents. Whereas the bog of Schwendi-Kaltbad was affected by peat exploitation, drainage, pasture and military training, the bog of Seeliwald shows few signs of human impact and is rich in original habitat.

Fig. 3.4.5. Characteristic problem of the Schwendi-Kaltbad bog viewed from the west. The vegetation is strongly affected by cattle trampling that results in deep erosional gullies (up to 2 m; Photo by R. Haab).

The bog of Schwendi-Kaltbad is separated into several hydrologically independent units. This is due to the erosion by the Gross Schliere River and its tributaries as well as to peat cutting. The largest section of the bog is located around the saddle of Langis. This part of the Schwendi-Kaltbad bog has suffered heavy erosion because of grazing (Fig. 3.4.5). The vegetation, therefore, consists mainly of a complex of dried-out bog and secondary fen communities dominated by deer-grass *(Scirpus cespitosus)*, common sedge *(Carex nigra)* and star sedge *(Carex echinata)*. Mountain pine *(Pinus mugo)*, which was once part of an open wood covering the whole area between Schwendi-Kaltbad and Seeliwald, today covers only small areas. Here and there relatively well-preserved but dry hummocks with dwarf shrubs occur. Deeply eroded gullies support bottle sedge *(Carex rostrata)*.

Fig. 3.4.6. Bog pool and floating mats of the Fröschenseeli, viewed from the east (Photo by R. Haab).

Fig. 3.4.7. Treeless seepage zone to the north-east of Fröschenseeli; viewed from the west. The vegetation of this zone is dominated by bottle sedge *(Carex rostrata)* (Photo by R. Haab).

In contrast to the bog of Schwendi-Kaltbad, the Seeliwald bog, because of its location, is better protected against erosion by the river as well as against peat exploitation. Grazing and forestry stopped twenty years ago. Gradually the vegetation has recovered. Today, human impact is mainly restricted to the south-western part where an old drainage system still affects the bog's water balance. Furthermore, tracks for cross-country skiing traverse the most sensitive area of the bog. At certain places these tracks were cut into the mineral subsoil and have caused erosion. Apart from that, the bog of Seeliwald is well-preserved and exeptionally rich in characteristic bog features (EDI 1988). Fröschenseeli, to the west of the bog, is considered to be one of the largest and best preserved bog pools in Switzerland (Fig. 3.4.6). It has extraordinary floating mats rich in Rannoch rush *(Scheuchzeria palustris)*. With increasing distance from the open water the vegetation changes from treeless to wooded bog vegetation. A few metres to the east of the bog pool, a large and almost treeless rill with predominant bottle sedge *(Carex rostrata)* drains the adjacent area (Fig. 3.4.7). In contrast to the treeless bog structures mentioned above, wooded bog vegetation covers large parts of the total bog surface. The open forests of the bog are dominated by mountain pine *(Pinus mugo)*. The vegetation beyond these forests alters with slope and thickness of the peat layer. Whereas locations with shallow slope and thicker peat layers consist both of hummocks and hollows, the plant cover of better drained areas only permits the growth of plants characteristic of hummocks such as hare's-tail cottongrass *(Eriophorum vaginatum)*, bilberry *(Vaccinium myrtillus)*, bog bilberry *(Vaccinium uliginosum)*, cowberry *(Vaccinium vitis-idaea)*. Towards the steeper hillsides and the channels of the river and its tributaries, mountain pine *(Pinus mugo)* is gradually replaced by spruce *(Picea abies)*.

As with most of Switzerland's pre-Alpine mires, there is little information about the fauna of the mires between Schwendi-Kaltbad and Seeliwald (LANG et al. 1983). All three of the observed amphibian species – Alpine newt *(Triturus alpestris)*, grass frog *(Rana temporaria)*, common toad *(Bufo bufo)* – are protected by federal law. The following bird species are particularly rare or belong to a group of bird species for whose preservation Switzerland and other central European countries have a special responsibility: capercaillie *(Tetrao urogallus)*, black grouse *(Lyrurus tetrix)*, three-toed woodpecker *(Picoides tridactylus)*, pygmy owl *(Glaucidium passerinum)*, ptarmigan *(Lagopus mutus)* and hazel hen *(Tetrastes bonasia)*.

3.4.6 Land use and vegetation history

The land use and vegetation history of the mires of the Gross Schliere valley and its surroundings may be surmised from pollen analysis and from the interpretation of place-names. On the basis of different exploratory drillings at Schwendi-Kaltbad, peat has accumulated since 7,000 to 8,000 BP (LANG et al. 1983). At that time, the mires were covered with minerotrophic fen communities still influenced by hillside runoff. A peat profile taken in the centre of the Schwendi-Kaltbad bog revealed 1 m of fen peat under 1.5 m of transitional mire and raised bog peat. Large areas of the valley bottom between Schwendi-Kaltbad and Seeliwald seem to have been covered by fen for thousands of years.

With increasing thickness of the peat layer, the topsoil gradually lost contact with minerotrophic ground and runoff water and gave rise to vegetation of transitional mires and bogs. When the mires between Schwendi-Kaltbad and Seeliwald were visited by Jakob Früh at the end of the last century, bog vegetation in the valley covered an area more than 2 km long and up to 750 m wide (FRÜH and SCHRÖTER 1904). The landscape was dominated by open forests of mountain pine *(Pinus montana)*. At that time parts of the bog had already been affected by peat exploitation and pasture. In their standard work on the bogs of Switzerland, FRÜH and SCHRÖTER (1904) described the bog of Schwendi-Kaltbad as "strongly affected by pasture, dug up, half peat-desert, half wooded bog".

Around Schwendi-Kaltbad, change in land use had begun long before Früh visited that area. Place-names indicate that after 800 AD in canton Obwalden, alpine pasture had already been created. Between 1000 and 1300 AD and between 1500 and 1800 AD, large areas were cleared for alpine pasture (FÄH 1984). Historic research on place-names conclude that the first clearings and pasture were already present at Schwendi-Kaltbad between 1000 and 1300 AD. Branches and trunks found 30 to 50 cm under the surface of today's fens indicate that the hills of the Gross Schliere valley were once covered by forests. This finding suggests that as a result of forest clearing the hydrology was altered which in turn caused paludification of the forests.

From the 18th to the 20th centuries, the area of Schwendi-Kaltbad was developed as a health resort. Large parts of the Schwendi-Kaltbad bog suffered peat exploitation to supply the necessary ingredients for medicinal baths.

In the 20th century, large areas of the mires between Langis and Seeliwald were affected or destroyed by agricultural land-claim or were afforested. Today the strongest impacts on the mires around Schwendi-Kaltbad are caused by grazing (see Fig. 3.4.5) and increasing tourist activities. A proposed development project to build a tourist resort with dozens of vacation homes plus a ski-lift may be prevented due to the Rothenthurm legislation.

Fig. 3.5.1. The mire of Stächelegg-Ghack with the Schrattenfluh in the background (Photo by T. Held).

3.5 The area richest in mires – the community of Flühli-Sörenberg

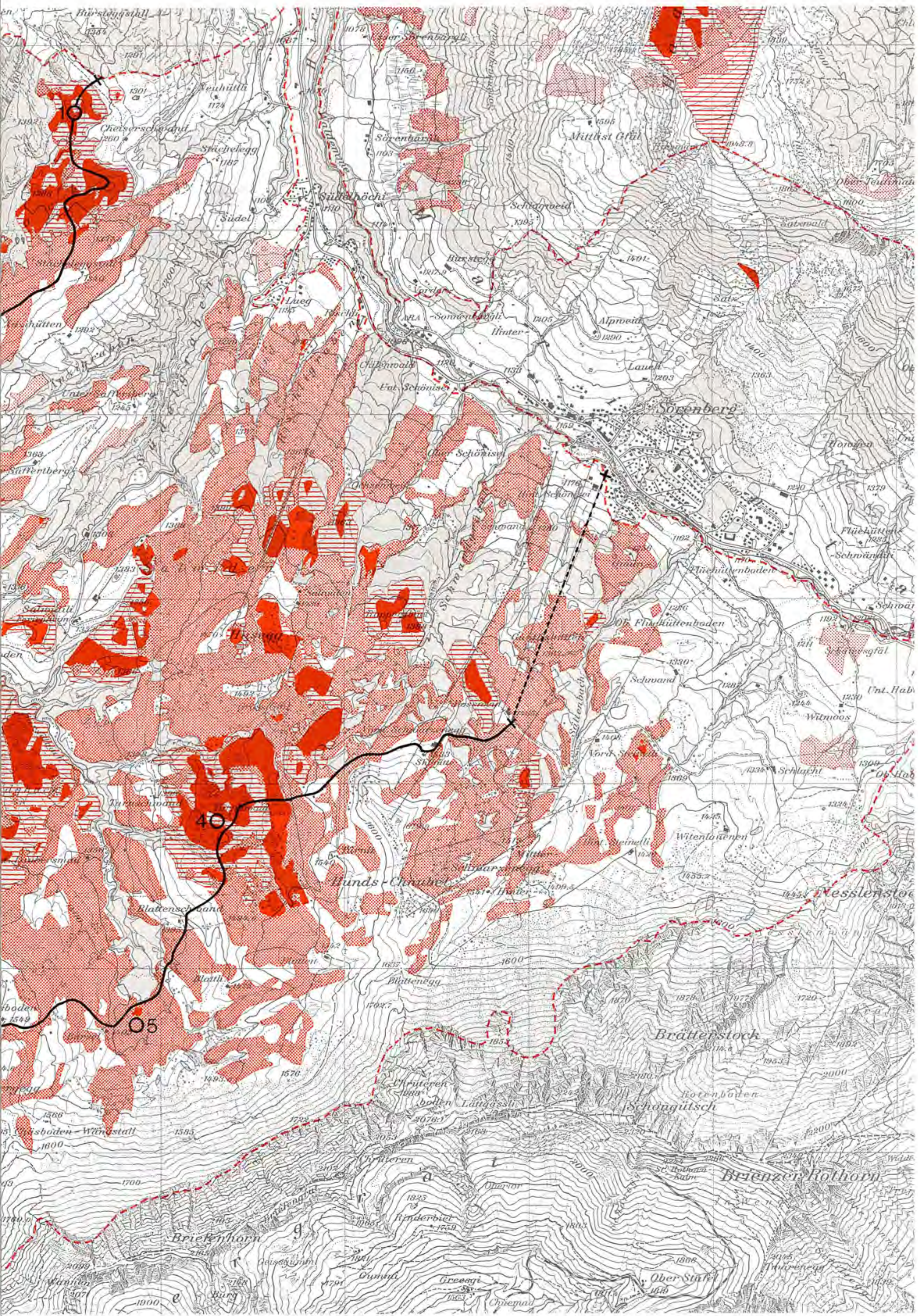
Thomas Held and Beat von Gunten

Community: Flühli (canton Lucerne)
Locality: Area of the village of Sörenberg
Coordinates: 639-648 / 180-190
Elevation of the mires: 1,100 to 1,400 m
Area of the raised bogs: 129 ha
Area of the fen lands: 1,237 ha
Area of the mire landscape Habkern-Sörenberg: 9,300 ha

3.5.1 Highlight of the visit

The centre of the Swiss mire distribution almost coincides with the geographical centre of Switzerland (cf. Figs. 3.5.2 and 1.2.2). Mires are a prominent feature of two large communities there, Flühli (in canton Lucerne) and Habkern (in canton Berne). Compared with the rest of Switzerland, the density and extent of these bogs, fens and other mire landscapes is extraordinary. For example, 20% of the more or less intact raised bog area of Switzerland is located in the community of Flühli (101 ha; Grünig et al. 1986; see Fig. 3.5.3).

The aim of a one and a half day excursion in the village of Sörenberg, a part of the community of Flühli, is to see and understand one of the most important pre-Alpine mire areas. Conflicts between mire preservation and other existing land uses or planned projects, can also be examined.



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Stächelegg
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Südel
Schlagweid
Satzwald
Bürstegg
Lueg
Alpweid
Hinter
Lauch
Chilchwald
Unt. Schönisei
Ober Schönisei
Unter Saffertberg
Saffertberg
Homiken
Flüehütten
Flüehüttenboden
Ob. Flüehüttenboden
Schwand
Witmoos
Schlacht
Witenlonenen
Hunds-Chnubel
Blattenegg
Blattenschwand
Brattenstock
Schöngütsch
Brienzer Rothorn
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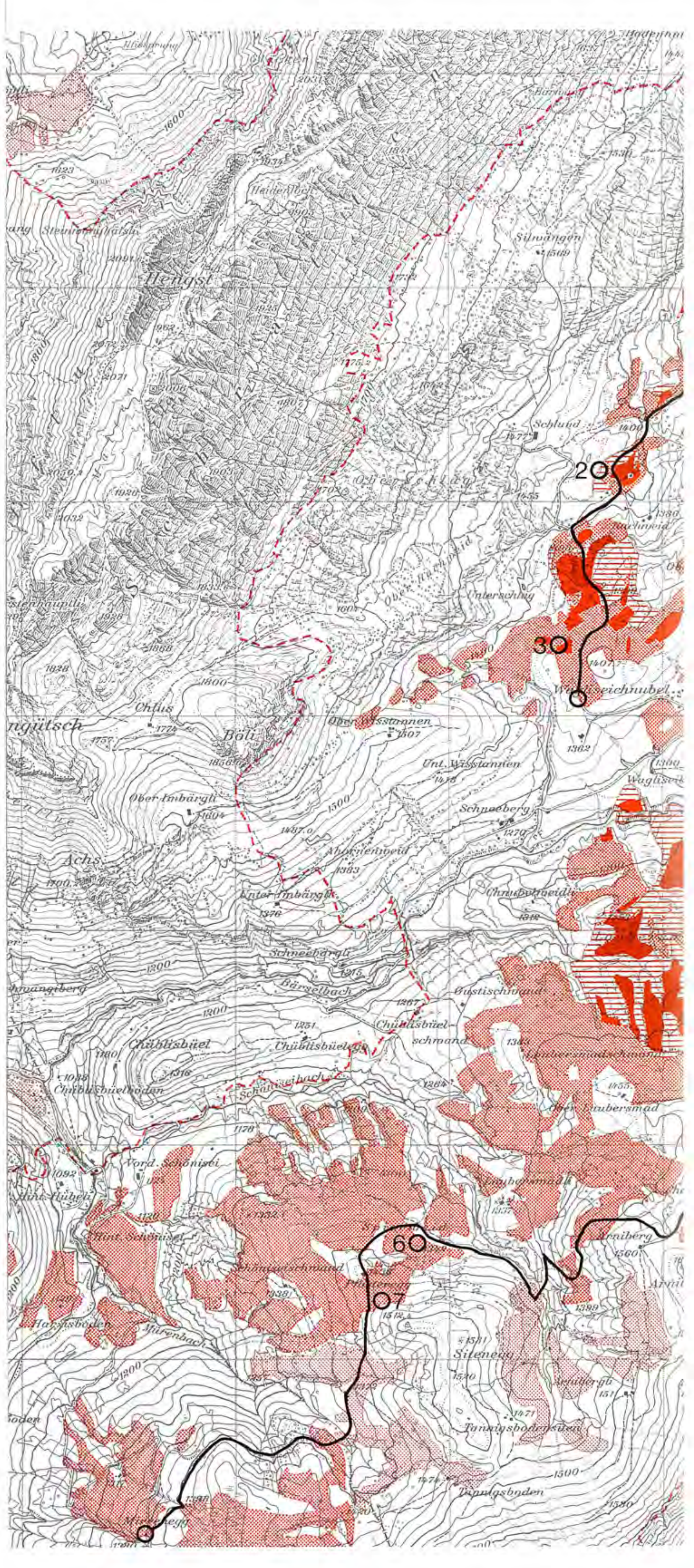
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Unter Imbärgli
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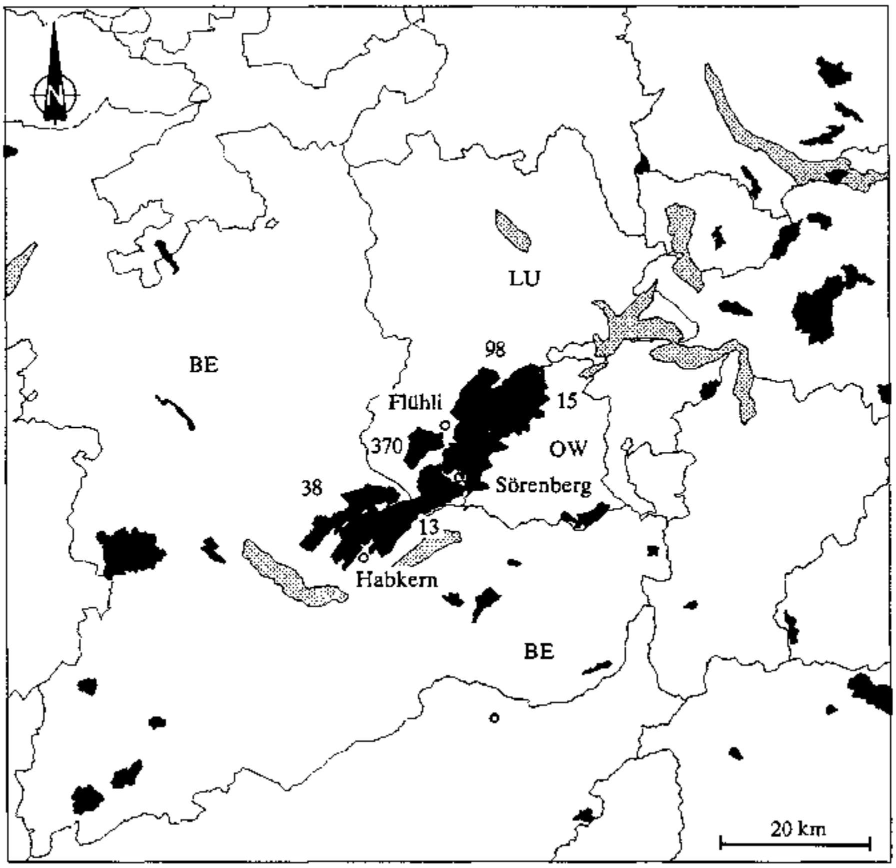


Fig. 3.5.2. Map of central Switzerland showing the location and extent of the mire landscapes. Glaubenberg (15) and Habkern-Sörenberg (13) are the two largest mire landscapes of the country. Also shown are the communities of Flühli and Habkern and the village of Sörenberg.

—— Cantonal borders.
BE = canton Berne; LU = canton Lucerne; OW = canton Obwalden.
(13) Mire landscape of Habkern-Sörenberg;
(15) Mire landscape of Glaubenberg;
(38) Mire landscape of Rotmoos-Eriz;
(98) Mire landscape of Klein Entlen;
(370) Mire landscape of Hilferenpass.

3.5.2 Location and geology

The highest point of the "Panorama-Road" still lies inside the boundaries of the largest mire landscape of Switzerland (Glaubenberg, 12,600 ha; see Chapter 3.4). After crossing this point, we enter the valley of the Little Emme River (see Fig. 3.5.7). In the west, close to Glaubenberg, the second largest mire landscape of Habkern-Sörenberg can be found (9,300 ha; DFI 1991c; cf. Figs. 3.5.2 and 3.5.3).

The entire mire landscape of Habkern-Sörenberg lies within the Flysch zone. In the north this borders on the Helvetic Border Chain and in the south, on the Helvetic Wildhorn-nappe (Brienz Ridge; see Figs. 3.5.4 and 3.5.5). These three geological formations give strong character and unity to the whole range of the landscape, also known as the depression of Habkern.

The Helvetic Border Chain, also called the nappe of Niederhorn-Pilatus, and the Helvetic Wildhorn-nappe consist of calcareous sediments from the Cretaceous and Tertiary. These sediments come from the northern and southern ranges of the Helvetic shelf. The Schrattenfluh is the type locality for the classic limestone Schrattenkalk.

The soft zone of Flysch contrasts with the sharp edges of the bordering mountain chains. The watershed of the Emme and Little Emme Rivers which is formed by the anticline of Salwiden-Sattelegg lies in this Flysch zone. The Flysch zone is divided into the Habkern Flysch and Schlieren Flysch. The Schlieren Flysch consists mainly of compact, partially consolidated sandstone, which may or may not be non-calcareous. The beds of sandstone alternate with very fine sand and marly clay, which generally contains high levels of calcium carbonate. The Habkern Flysch consists of large formations of Leimera layers, Globigerina shales and Wildflysch. The Leimera layers consist of limestone, marlstone and marly shales. The Globigerina shales are made up of limey shales, torn sandstone beds and dense limestone. The Wildflysch consists mainly of

◀ Fig. 3.5.3. Location of the mires and the mire landscape of national importance in the area of Habkern - Sörenberg, with only part of Sörenberg shown (modified from DFI 1990, 1991b, 1991c).
1 Stächelegg-Ghack; 2 Ruchweid;
3 Wagliseichnubel; 4 Türnliwald; 5 Bärsel;
6 Spierweid; 7 Pfosteregg.
Scale of the map: 1 : 25,000; for key, see endcover. Reproduced by courtesy of the Federal Office of Topography, Berne, 9 June 1992.

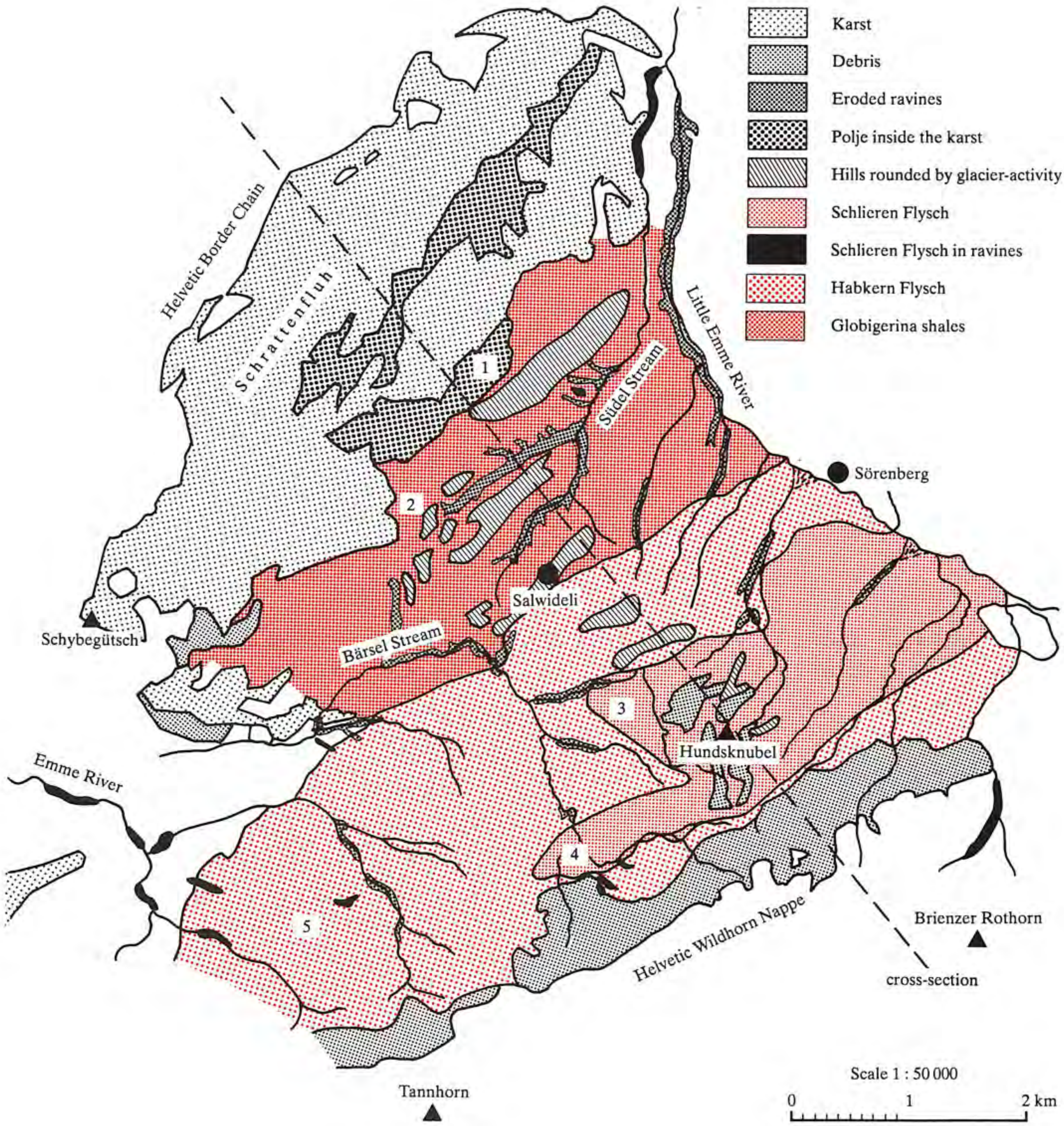


Fig. 3.5.4. Geological sketch map of the area between the Schrattenfluh and the Brienz Ridge (modified from SODER 1949). 1 Stächelegg-Ghack; 2 Ruchweid/Wagliseichnubel; 3 Türnliwald; 4 Bärsel; 5 Spierweid/Pfosteregg.

limestone and marlstone alternating with sandstone. The layers are partly folded, kinked and torn. A number of scale-like rocky intercalations (Leimera layers, Habkern granite, Schlieren Flysch and limestones from Helvetic upper Cretaceous and old Tertiary) are particularly interesting.

During the Quaternary, glaciers formed the depression of Habkern. The excursion area was influenced by the glaciers of the Little Emme and the Emme. The former extended from the Rothorn of Brienz to Flühli. The latter ranged from the area of the Bärsel stream to Kemmeriboden. Presumably it was blocked off by the large Aare glacier during the Riss and Würm glaciation, forcing most of its ice to flow into the glacier of the Little Emme. Evidence of

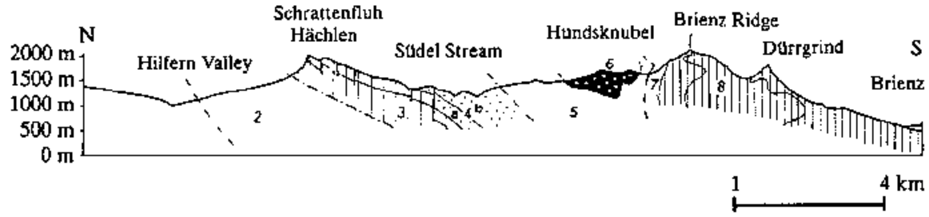


Fig. 3.5.5. Geological cross-section from the Schrattenfluh to the Brienz Ridge (modified from Soder 1949)
- Sub-Alpine zone: 1 Sub-Alpine Molasse; 2 Sub-Alpine Flysch;
- Helvetic Border Chain (Niederhorn-Pilatus nappe): 3 Cretaceous; 4a Eocene; 4b Südel stream Series (Globigerina shales);
- Depression of Habkern: 5 Habkern Flysch; 6 Schlieren Flysch;
- Helvetic Wildhorn nappe (Brienz Ridge): 7 Eocene; 8 Cretaceous.

glacial activity includes moraines, long, rounded, south-west to north-east oriented hills and elongated mires, reflecting the terrace steps of the ground (cf. Figs. 3.5.3 and 3.5.4).

Newer geological formations include the frequent landslides - the village of Sörenberg was built on one - and deeply eroded ravines of the Bärsel and Südel streams. These are often drastic consequences of the intensive deforestation which occurred during the 18th and 19th centuries (see Chapter 3.5.7).

The formation of the mires has resulted from the following geological features (Fischer and Loser 1987):

- Rocks of Flysch, Globigerina shales and most moraine materials experience argillaceous weathering. They have a tendency to form impermeable soils on which the extensive mire areas developed after the retreat of the glaciers.
- In the Flysch, easily weathered sandstones dominate the soils. They are not only impermeable but also acidic and contain few nutrients. This leads to the formation of oligotrophic-acidic wooded mires which we will see in great numbers and covering large areas.
- Since most rock formations have variable calcium carbonate contents, a mixed vegetation of bog and fen prevails, influenced by waters from the slopes. Plant species of the calcareous fens extend a long way into the bog centres.

***Polje** (or interior valley)*

A large flat-floored closed depression in a karst area. Its drainage is subsurface, its size is measured in kilometres, and its floor is commonly covered by alluvium. Interior valleys may become intermittent lakes during periods of heavy rainfall, when the sinking streams that drain them cannot manage the runoff (modified from Bates and Jackson 1987)

3.5.3 Climate

The climate is humid and relatively cool. Precipitation occurs mainly in summer, usually as strong and frequent thunderstorms. In Flühli, the average annual precipitation over a 40 year period (1901–1940) was 1,680 mm (Uttinger 1949). The mires of Sörenberg probably receive at least 1,800 mm, but fluctuations can be fairly large. In 1989, the amount of precipitation at Salwideli (1,350 m a.s.l.) was only 1,310 mm. In summer, there is frequent fog and the average temperature is just above 10° C. During the growth period of almost four months, an oceanic climate prevails between 1,200 and 1,650 m a.s.l. During the cold winter, a thick coat of snow covers the herbaceous and dwarf shrub vegetation. Mountain pine *(Pinus mugo)* and spruce *(Picea abies)* dominate and are cold-tolerant.

The humid climate and impermeable soils gave the village Sörenberg its name, meaning sour (acidic), wet and spongy mountain (Früh and Schröter 1904).

3.5.4 Vegetation and vegetation history

(Mainly summarized from Fischer and Loser 1987, 1990; and from Lüdi 1962)

In the southern Alps of the Entlebuch (see Fig. 3.5.7), the montane belt (up to 1,000 m a.s.l.) belongs to the *Fagus sylvatica - Abies alba* climax area (cf. Fig. 1.6.1). Above it is a *Picea abies* sub-alpine belt, which extends to the timber-line (approximately 1,850 m a.s.l.). At high elevations from the middle of the *Picea* belt, *Pinus mugo* ssp. *uncinata* is present in increasing numbers and forms the timber-line above the spruce line. This belt of mountain pine is a characteristic of the northern Alpine Border Chain between Lake of Lucerne and Lake of Thun. It is regarded as the pre-Alpine equivalent of the Arolla pine *(Pinus cembra)* belt of the Central Alps (Lüdi 1962; cf. Fig. 1.6.1).

The mires of lower elevations that were originally widespread in the Entlebuch valley bottom have been destroyed or damaged, mainly by peat exploitation and drainage. The remote sub-alpine areas such as those in the south-west of Sörenberg still display a very high rate of paludification (cf. Fig. 3.5.3). In the community of Flühli, bogs and transitional mires of national importance cover 129 ha (or 9% of the Swiss total). Fens of national importance extend over 1,237 ha (or 7% of the Swiss total). In addition, fens of regional importance cover 169 ha.

Palynology

Palynological investigations by LÜDI (1962) in the complex mire of Hagleren, north of Sörenberg (see Fig. 3.5.8), revealed that as the result of an increasingly humid and cool climate, the hazel shrub *(Corylus avellana)* and mixed oak forest was replaced by silver fir *(Abies alba)* simultaneously with an expansion of fen. At the end of the *Abies* period, during the transition from the Sub-boreal to Sub-atlantic (around 800 to 500 BC), the development of the forests suddenly changed. During a relatively short period, the climate became more oceanic. This led to wet eluviated soils and to increased air humidity. The timber-line moved lower, allowing increasing paludification and even an extension of mires onto slopes. Open wet areas and characteristicly waterlogged woods and wooded mires with rapidly expanding mountain pine and a few spruce became established. According to Lüdi, this paludification is not recent; the bogs of the area may be 2,500 to 2,800 years old. Investigations by FISCHER and LOSER (1990) suggest that the present extension of the small-sedge beds resulted from secondary paludification after forest clearing, pasturing and grass cutting.

Raised bogs

Raised bogs developed only on gentle slopes. In Sörenberg, they are mainly found on slope terraces, anticlines, synclines, and flat hilltops. Generally, the peat is not very thick, but in topographically favourable situations such as in a basin, considerable peat accumulation has occurred (for instance 6.5 m at Husegg). At present no further bog growth is expected because of, among other things, widespread pasturing. Moribund areas with no growth ("standstill complex") or erosion of peat soils now predominate.

Bog vegetation is not dependent on the thickness of the peat. It also grows on eluviated and paludified gley soils (Fahlgley in German). The almost constant presence of mineral soil water indicators (DU RIETZ 1954) like common sedge *(Carex nigra)*, star sedge *(Carex echinata)* and purple moor-grass *(Molinia caerulea)* are characteristic of the area (see Chapter 3.5.2). Pure ombrotrophic bogs never exceed several hundred square metres. On the other hand, classic bog species like hare's-tail cottongrass *(Eriophorum vaginatum)* and few-flowered sedge *(Carex pauciflora)* have a large ecological amplitude. They also occur in common sedge swamps (Caricion nigrae) and even in the rather calcareous-rich Davall's sedge swamps (Caricon davallianae; cf. Chapter 1.6.3.3). The main part of the raised bogs is covered by mountain pine (Pino mugo-Sphagnetum). Open hummock-hollow complexes are mostly limited in extent.

Four bog sites (Hagleren, Laubersmadghack, Stächelegg-Ghack and Türnliwald) in the community of Flühli number among the eighth largest, reasonably intact bogs of Switzerland. They are complex mires with intertwined areas of fen, transitional mires and bogs surrounded by wet forests of mountain pine and spruce. Gradual transitions between these units are common.

Fenlands

Fens are much more numerous than bogs. They dominate the landscape more than the bogs, as the latter are mostly hidden in forests. Stands from the phytosociological alliances of Caricon davallianae, Caricion nigrae, and Calthion characterize the vegetation of the open slopes. In 1987, the fenland inventory revealed that these stands cover 43%, 33% and 23% respectively of the total fenland area of the community. The extinction of Caricetum nigrae in the area is mostly due to human activity. Forest clearings forced the enlargement of the originally isolated and small areas. Pasturing and drainage caused a shift from bog associations to those of common sedge fens. These can deteriorate yet further to wet rush meadows (*Juncus* spp. meadows) through more intensive pasturing. The typical oligotrophic Davall's sedge communities occurring in spring fens are rare in this area. Only the units mixed with species from Calthion and/or Nardo-Callunetea are common. This is also a result of human activity. Parts of the Calthion communities have been substantially increased by the transition to more intensive pasturing and application of manure and fertilizers.

Special floristic features also occur in the area. Sheathed sedge *(Carex vaginata)*, a rare glacial relic species, is found here. Furthermore, three neighbouring transitional bogs are the only locations for the eurosibiric species, bog rush (*Juncus stygius;* Fig. 3.5.6), in Switzerland.

Fig. 3.5.6. Bog rush *(Juncus stygius)* (from Hess et al. 1967).

3.5.5 No future for the primary, ombrotrophic raised bogs?

The special vegetation of raised bogs is (primarily) a result of the low nutrient supply. The only source of nutrients is the atmosphere (wet and dry deposition). The natural nitrogen input from the atmosphere was estimated at 1 to 2 kg/ha·a (Mohr 1987). In all industrialized countries over the past few decades, atmospheric conditions have deteriorated significantly because of increasing air pollution. Increased emissions of nitrogen-oxides (NO_x) and ammonia (NH_3) have led to increased deposition of nitrogen compounds. In Switzerland, the deposition of these pollutants has more than doubled over the last 40 years. Nutrient-poor ecosystems, especially raised bogs, have become increasingly endangered.

In 1989, an investigation was made of 13 remote and unwooded sites of raised bog and transitional mires along a transect in the Swiss pre-Alps between 850 and 1,330 m a.s.l. (Dussex and Held 1990; Held et al. 1992). They found that gravitational deposition of nitrogen (NH_4^+ plus NO_3^-) into collectors was 11.6 to 17.8 kg N/ha/a. Together with dry and gaseous deposition, which are difficult to measure, the total nitrogen input was estimated to be between 25 to 30 kg N/ha/a. Between 65 and 83% of the annual deposition was received during the vegetative period and the ratio of nitrate to ammonium was 1 to 2.

Although the 13 investigated sites were the most pristine sites found along the pre-Alpine transect, because of other human activities (drainage at the edges, litter mowing, bordering, manuring, etc.), most of them did not have a natural nitrogen budget. Thus, a causal connection between the differences in the vegetation and the corresponding deposition rate was impossible.

Critical load

As the rate of atmospheric nitrogen deposition increases, the relative importance of nitrate to the total N supply increases. This results in a drastic change in the nitrogen budget of the bogs. An expert international commission regarded a critical level of nitrogen for ombrotrophic bogs to be 3 to 5 kg N/ha/a (Nilsson and Grennfelt 1988). More recent estimates now range from 5 to 10 kg N/ha/a (Bobbink et al. 1992).

What are the effects of such an unbalanced nitrogen budget on the bog itself? Peat mosses, which are adapted to very low ammonium concentrations, rapidly assimilate dissolved nitrate and ammonium from the atmosphere directly into the leaves (Woodin et al. 1987). As a result of the high nitrogen contents in tissue, sphagna become physiologically stressed. Woodin et al. (1987) discovered that with *Sphagnum recurvum* and *Sphagnum cuspidatum*, the nitrate reductase activity (NRA) is uncoupled and general growth is inhibited. Rudolf and Voigt (1985) came to a similar conclusion: *Sphagnum magellanicum* reacts similarly to ammonium. The capacity of nitrogen immobilization which, under natural conditions is managed largely by *Sphagnum*, is diminished by the increasing disruption of nitrogen metabolism in *Sphagnum*. Under natural conditions, the peat microbial communities and the 'accompanying' flora are sub-optimally supplied by nutrients (Malmer and Sjörs 1955; Müller 1968, 1973) and dominated by the *Sphagnum* species. These other communities can profit from both the weakened competitive status of the sphagna and the increase in available nitrate and ammonium.

Field observations and a comparison of 15 year-old plots (surveyed by WILDI in 1977) with the present situation at some of the pre-Alpine bog sites were made. The leaf mosses, bank hair moss *(Polytrichum strictum)*, bog thread moss *(Aulacomnium palustre)*, wavy spike moss *(Dicranum undulatum)*, Schreber's feather moss *(Pleurozium schreberi)* and red feather moss *(Hylocomium splendens)* had become more extensive at the expense of sphagna. This is especially true when the supra-optimal nitrogen supply is combined with additional factors such as drainage or manuring. With increasing growth of the formerly suppressed leaf mosses, the site conditions will change still further. It will become drier, less acidic and, through stimulated mineralization, still richer in nutrients. The grasses, herbs and dwarf shrubs rooted below the surface of the moss carpet would then become increasingly important.

There seems to be a very real danger that over-supply of nitrogen will lead or has already led in parts to the loss of the oligotrophic character of the raised bogs. The consequence would be an unwelcome succession to an atypical, more trivialized bog vegetation. A drastic reduction of the emissions of ammonia from agriculture and of nitrogen-oxides from traffic and industry is necessary at a national as well as at an international level if this trend is to be halted or reversed.

3.5.6 Fauna

A section of the excursion area is a national hunting reserve. It is characterized by the occurrence of rare black grouse *(Lyrurus tetrix)* and capercaillie (*Tetrao urogallus*; cf. Chapter 3.3.5). These birds, attracted by the bright and diverse mire forest complexes, are protected.

3.5.7 History of land use and its consequences for the mires

Early in the Middle Ages, the valley of Entlebuch was occupied by few people and almost entirely wooded. Population increases in the 17th and 18th centuries required more and more space. Trade and industry (for example, the expansion of the city of Lucerne, the iron industry and its blast-furnace, the production of milk sugar in Marbach and glass production in Flühli) required a large fuel source which could only be found in the forests. The ruinous exploitation of the forests began with the production of glass. As a result, Flühli became the

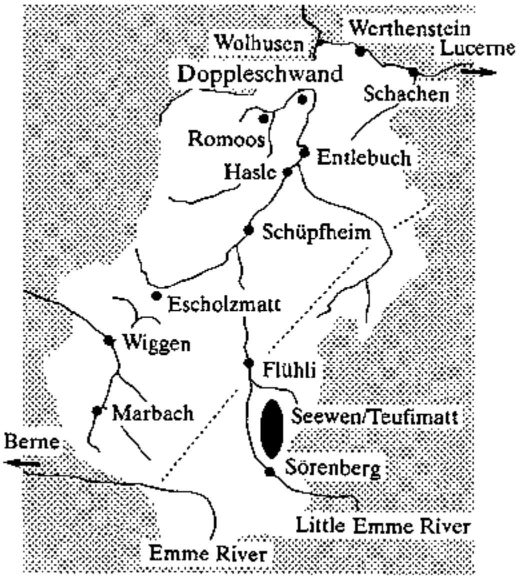


Fig. 3.5.7. The Entlebuch valley showing the location of the alps Teufimatt and Seewen between Flühli and Sörenberg (modified from HOFSTETTER et al. 1991).

community in canton Lucerne with the smallest percentage (18%) of forest area (HOFSTETTER et al. 1991). This resulted in a steady increase in the number of disastrous floods, directly attributable to the loss of forests which had acted as a buffer against heavy precipitation. Testimonies to this ruinous exploitation can still be seen (see Chapter 3.5.2). Finally at the end of the 19th century, opposition to the overexploitation of the forests led to the area being drained and reafforested, at enormous cost (cf. Figs. 3.5.7 and 3.5.8).

From the 9th to the 16th centuries, the bogs were untouched by forest clearance. At most, they were pastured extensively. From the beginning of the 16th century, alp management became more intensive. Its activities extended into paludified forests and involved clear felling. Sheep, cattle and horses passed the summer on wet alp areas. Large litter meadows yielded straw. Subsequently, the fen areas increased even more. From the 19th century on, attempts were made to transform the fens into more productive pastures and meadows. From the beginning of this century, litter management has been abandoned in favour of pasturing (cf. Chapter 3.5.8). Another alternative use has been natural forest regeneration. Because of pasturing and the large number of grazing animals, damage to bog vegetation and impoverishment of fens has steadily increased. Vegetation has either deteriorated due to excess supply of nutrients or has been destroyed by additional manure, fertilizers, or sludge. This tendency toward changes in vegetation due to pasturing, manuring and fertilizing continues. In some places, the fen vegetation has already changed from the conditions described by the 1987 inventory survey.

Crossing over the border west into canton Berne, a conspicuous and immediate change in alp management can be seen. Bernese agriculture is largely more traditional and sustainable compared to the areas around Sörenberg. The difference can be seen in the quality of the fens and landscape. Furthermore, the Lucerne area of the mire landscape is much more affected by tourism and military activities.

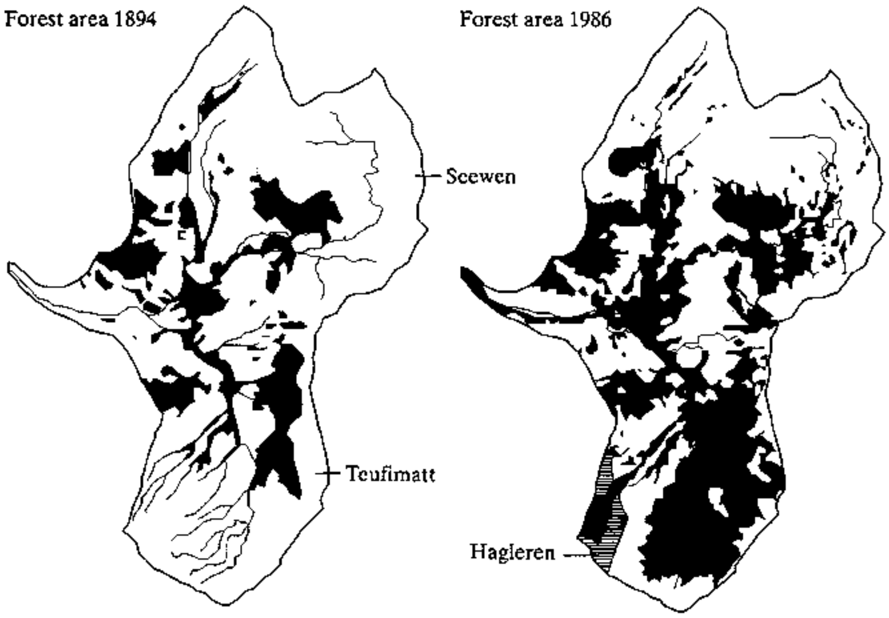


Fig. 3.5.8. Reafforestation of the alps Teufimatt and Seewen. Between 1884 and 1986, 71 km of ditches were installed and 1.5 million young trees planted, enlarging the forest area from 124 ha to 301 ha. The location of the bog complex of national importance called Hagleren is also shown (modified from HOFSTETTER et al. 1991).

3.5.8 Alpine pasture and mire conservation

Mires (bogs and fens) are mostly very poor in both forage quality and quantity. This means that, generally, mires should not be pastured at all, mainly because of animal protection, pasture hygiene and forage production. To improve the pastures the farmer may be tempted to fertilize the wet areas. In most cases, more tall herbaceous perennials will result in a patchy vegetation on marshy soil, and cattle will rarely venture onto such ground.

Cattle can seriously damage the bogs and fens associated with the pasture, especially when the population density is too high or when they are kept too early or too long on the same pasture area. Cattle also lose weight in mires because it is hard for them to walk and they thus expend a great deal of unnecessary energy. Furthermore, there are various cattle parasites in the puddles and pools, so the farmer must inoculate the animals before they go to the alp. Even then, the cattle often require veterinary treatmant. Without sufficient attention, the cattle suffer terribly and may subsequently die.

Solution of the problem

The solution to these problems can be outlined as follows:
The density of cattle on a particular alp should be calculated on the basis of forage potential of dry parts and parts with variable water regime that are of relatively good quality. The general rule is two heifers per hectare on the good parts of the alp. The density, pasture duration and the pasture partition have to be adapted to the local situation. If these points are respected, it is also possible to prevent shrubs and trees from becoming overabundant (modified from STADLER 1991).

A case study

The Stächelegg-Ghack bog, considered very special with its distinct contact zones between calcareous karst and acidophilic *Sphagnum* mosses, offers an example of the impact of alpine pasturing on mires and vice versa.

In 1947, the Swiss League for Nature Conservation (SLNC) bought a parcel of land in Stächelegg-Ghack with a large bog hollow area surrounded by a *Pinus mugo* bog. The extensive fen and forest areas of Stächelegg had been pastured for a long time, and the cattle had entered the bog freely. In most cases they only trampled the bog when escaping from the summer heat seeking shade under the *Pinus mugo* and water in bog pools. Consequently, there had been some undesirable trampling in the sensitive bog area which was noticed when making the contract of purchase. It took almost 40 years until the SLNC succeeded in fencing the southern part of the bog.

Since 1985, the neighbouring farmer has been paid annually for the loss of yield from the forest pasture (mostly transitional mires or small-sedge fen fens within the forest area) and for loss of income from reducing the number of young cattle on the alp: Sfr. 1,500. Another Sfr. 500 is paid annually for the maintenance of a new fence (about 1,500 m long); in spring the fence is erected and in autumn it is taken down to protect it from heavy, sliding snow. Only with this investment was it possible to keep the cattle away from the bog, even though it was evident that the cattle have little interest in grazing the bog.

Further development

The changes in Alpine agriculture in the past few decades from a diverse subsistence economy to mostly livestock farming subsidized to a large amount by the government, has encouraged the farmers to rely on such subsidies (cf. Chapter 1.7.2). Farmers are hostile to the preservation of the remaining mires and mire landscapes because it involves additional intervention by the federal state. This may result in the need to reduce farming intensity and/or reactivation of former utilization methods. If they have to return to less intense agriculture, they will have to be indemnified for all loss of income. For example, the loss of income for one less cow on the alp (over 100 days) is about Sfr. 1,000. For one heifer, it amounts to about Sfr. 250 during the same period. Unfortunately, these numbers are not directly comparable with the financial compensation of mowing litter meadows (cf. Chapter 3.2.7). Most farms have to be considered on an individual basis.

Despite the relatively high costs of reducing land use intensity, and conflicting land use interests emerging at the meetings between farmers and conservationists, extensive mire conservation is urgently required and must continue.

3.5.9 Implementation of the Federal Decree on Protection of Raised and Transitional Bogs (and of the fenlands) of National Importance

General information

Swiss federal law states that each individual canton is responsible for the implementation of national legal requirements with respect to the protection of mires and mire landscapes of particular beauty and national importance. "After hearings of the landowners and land managers, the cantonal authorities will implement appropriate measures for the protection and conservation of the national areas concerned" (see Chapter 6.3). In implementing these measures, the cantons are supported financially by the federal authorities (subsidies of 60 to 90% for areas of national importance) and by expert advice. The detailed proceedings depend on the judgement of the cantonal Authority of Nature Conservation because the federal authorities only offer recommendations. Thus, there are numerous different protection schemes.

How can mires actually be preserved?

Properly protected bogs and fens should consist of true habitats and their ecologically appropriate buffer zones (cf. Chapter 6.3). Inventories were made of mire (especially fen) habitats of national importance at a scale of 1:25,000 excluding buffer zones. To implement the recommendations, the boundaries of the habitats and buffer zones must be identified more accurately at a larger scale. In many cases this involves the creation of a map at a scale of at least 1:5,000. The federal authorities have recommended that the responsible cantonal experts should map the vegetation as well as the present damage and potential threats. This will help to define land use and maintenance affecting the various mire systems. Parcel by parcel, measures for upkeep and restrictions in utilization will be recorded in agreement with land managers and landowners. Their work and the decrease in yield will be financially compensated. In addition, the requirements recorded in the contracts, including the mapped boundaries, will be laid down as public law by the cantonal authorities.

As of 1 February 1991, cantonal authorities have either 3 or 6 years to protect raised and transitional bogs of national importance. Until proposed fens are definitely designated as fens of national importance by the Swiss Federal Council, the cantonal authorities must ensure that the condition of the fens does not deteriorate.

An example: canton Lucerne, in particular the village of Sörenberg

Because of the urgency in canton Lucerne, maps of the proposed land uses were drawn up rather hastily. The vegetation was not mapped, but assessed using the definition of management categories. The boundaries of the bog and fen areas of national and regional importance and the surrounding buffer zones were fixed on land register plans at a scale of 1 : 5,000. This was mainly done by private consultants mandated by the canton. These areas with defined boundaries were assigned to four proposed management units: no management, meadow cutting, pasturing without manuring and cutting or pasturing with minimal manuring. With these proposals, individual land managers and landowners were contacted in order to discuss the contract. Permissible future management was definitively defined, and general conditions and specific arrangements were fixed in a ten year contract. In areas that are more difficult to work, the compensation paid is higher (hand-work receiving up to more than Sfr. 1,500 per ha).

There is less and less traditional low-intensity land use in Sörenberg (see Chapter 3.5.7). The main problems in the course of implementation are the use of too much manure and fertilizers and too intensive pasturing. Sometimes, compensation for maintenance and reduction in yields cannot balance the losses caused by decreasing fertilization, manuring and pasturing. If a financial loss occurs, then it is very difficult to get farmers to accept an arrangement for mire conservation.

There are also conflicts between the conservation of mire habitats and forestry, tourism and the military. In the process of implementation, the Federal Inventory of Mire Landscapes of Particular Beauty and National Importance was completed. Because most of the tourist facilities of Sörenberg lie inside the mire landscape of Habkern-Sörenberg, the opposition against the proposed perimeter of the landscape is great: "We will fight for our hunting-grounds like the American Indians".

Mire preservation within a mire landscape with a far lower land use intensity (Faninpass, Fideriser Heuberge) is discussed in Chapter 3.15.

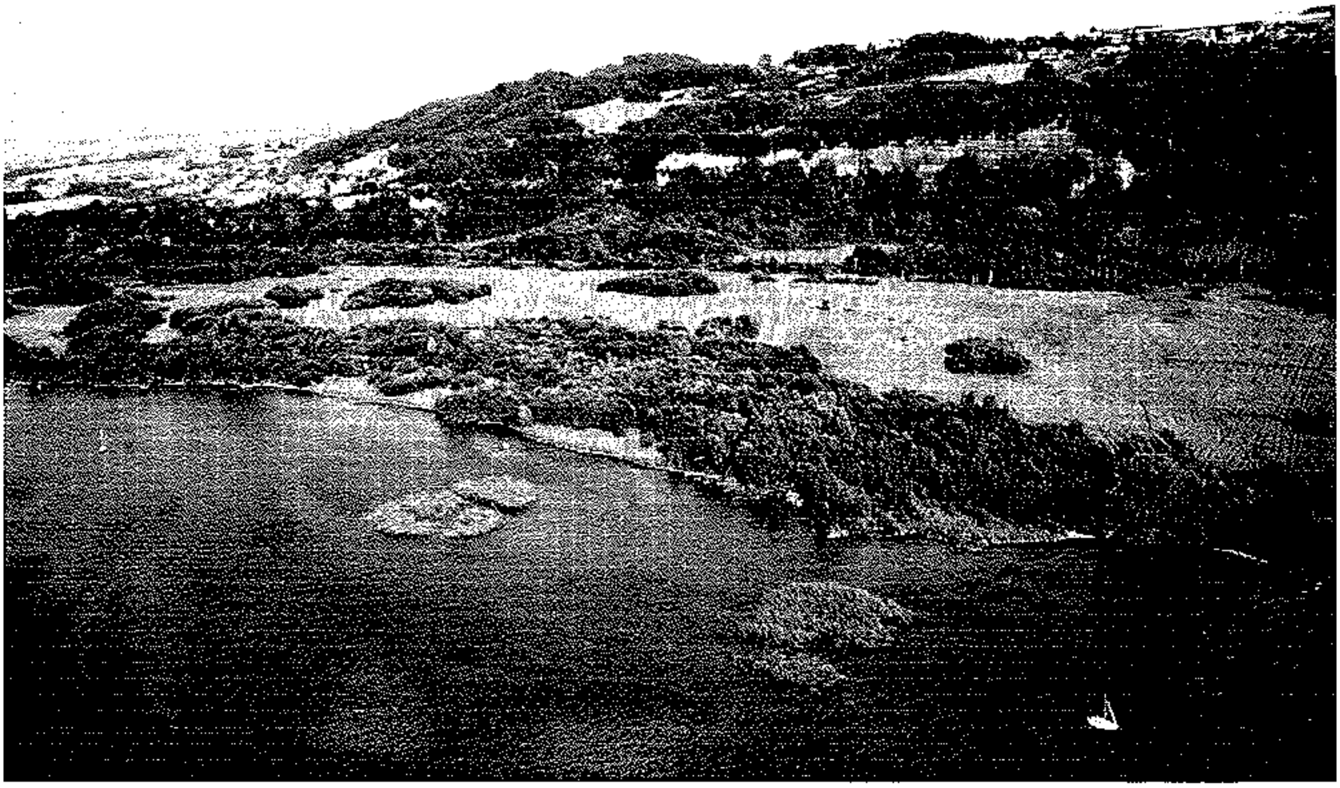


Fig. 3.6.1. Oblique aerial photograph of la Grande Cariçaie, showing the eroding littoral (in the foreground), the wetlands on the littoral and on the bank (in the middle), and the forests on the molasse cliffs (in the background) (Photo by B. Renevey).

3.6 The result of a century of hydrological control – the fenlands of La Grande Cariçaie

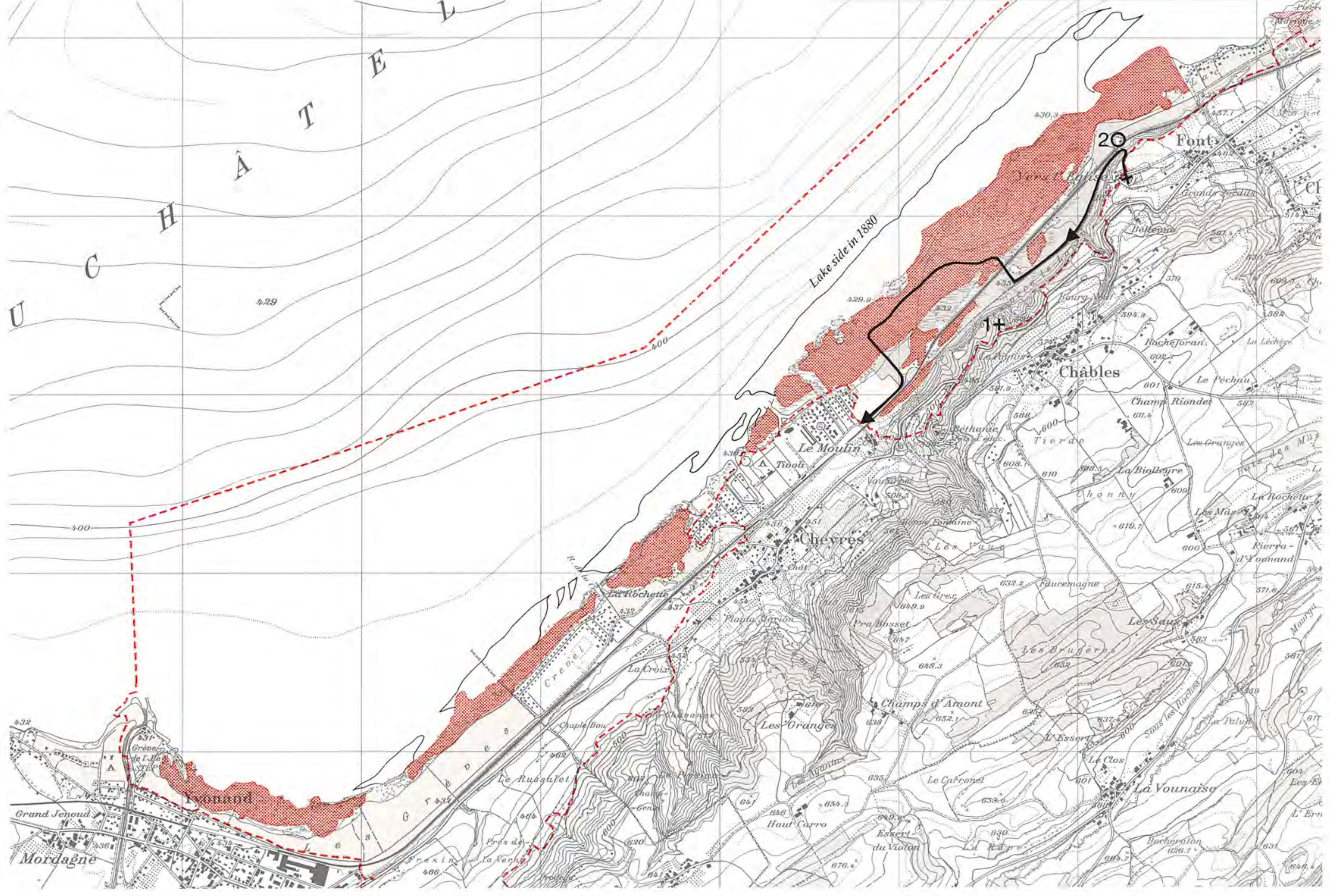
Alexandre Buttler and Gilles Mulhauser

Communities: Châbles, Cheyres, Font (canton Fribourg); Yvonand (canton Vaud)
Locality: Grèves du lac
Coordinates: 547-553 / 183-188
Elevation of the mires: 430 m
Area of the fenlands: 108 ha
Area of the mire landscape La Grande Cariçaie: 2,060 ha

3.6.1 Highlight of the visit

The south shore of the Lake of Neuchâtel is of great importance for nature conservation. In Switzerland, it is the largest and the most diverse littoral wetland ecosystem, linked to a less extensively used countryside. Therefore, it has been registered in several federal inventories (see also Chapter 2.5.2):

1 Federal Inventory of Landscapes, Sites and Natural Monuments of National Importance (DFI 1977/1983);
2 Federal Inventory of the Flood Plains of National Importance (DFI 1991a);
3 Inventory of the fenlands of national importance (DFI 1990; cf. Fig. 3.6.2); as well as in the
4 Inventory of mire landscapes of particular beauty and national importance (DFI 1991c).


U C H Â T E L
Lake side in 1880
400
429
2
1
Font
Châbles
Rochejoran
Le Péchau
Champ Riondet
Bellevue
Bourg Neuf
Grands Cordus
Béthanie
Le Moulin
Tivoli
Tierde
La Biolleyre
Les Granges
La Rochette
Les Mas
Chevres
Bonne Fontaine
Faucemagne
Les Grez
Pra Bosset
Planta Marion
Les Saux
Les Brugères
La Croix
Champs d'Amont
Les Granges
L'Essert
Le Clos
La Vounaise
Sous les Roches
La Palud
Le Carronet
Le Russalet
Haut Carro
Essert du Violon
Yvonand
Grand Jenoud
Mordagne
Les Grèves
Crenel
Frexin
Prés de la Verna
Bocheraton

This ecosystem is also recognized as being of international importance, and the area is listed since 1976 in the Ramsar Convention (Ramsar Convention 1971).

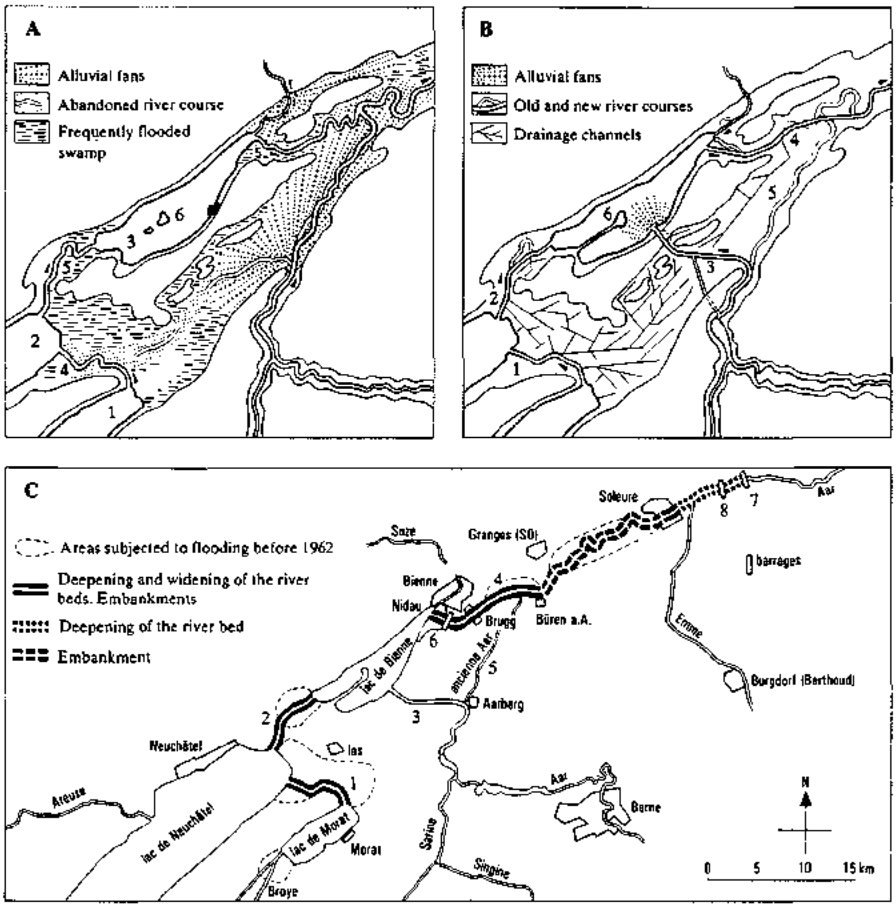


Fig. 3.6.3. Hydrological control of the Lakes of Neuchâtel, Bienne and Morat (modified from Bär 1979). The area in between is called Grosses Moos (the "Big Mire").

A Situation before modern hydrological control.
1 Lake of Morat
2 Lake of Neuchâtel
3 Lake of Bienne
4 Broye River
5 Zihl River
6 St. Peter Island

B Situation after the first modern hydrological control in 1878.
1 Broye Channel
2 Zihl Channel
3 Hagneck Channel
4 Nidau-Büren Channel
5 Former Aare River bed
6 St. Peter Peninsula

C Situation after the second modern hydrological control in 1962.
1 Broye Channel
2 Zihl Channel
3 Hagneck Channel
4 Nidau-Büren Channel
5 Former Aare River bed
6 Port dam
7 Hofuhren dam
8 Flumenthal power-plant
9 Excursion site

3.6.2 General information

The Grande Cariçaie wetland extends along the 42 kilometre-long south shore of the Lake of Neuchâtel (cantons Vaud, Fribourg, Berne and Neuchâtel). It is situated on the south fringe of the Jura Mountains, in the sub-Jurassic glacier depression and belongs to the Rhine catchment area (cf. Fig. 1.4.3). The wetland lies at a mean altitude of 430 m.

One of the features of this fenland is that it is only about one hundred years old, having appeared after hydrological control was gained of the so-called Jura Waters. This lowered the level of the three connected Jura lakes by approximately 2.7 m (cf. Fig. 3.6.3). In doing so, Switzerland's largest wetland area (40,000 ha), situated between the three lakes, was transformed into the country's largest market gardening area, known as Seeland. On the southern shore of the Lake of Neuchâtel, the newly-created wetlands of 2,000 ha were able to offer a habitat compensation for the natural and semi-natural communities lost by agricultural land-claim.

The Jura Water Correction is one of the main impacts man has made on wetlands in Switzerland. Carried out in two steps (Fig. 3.6.3) the work resulted in rerouting the Aare River into the Lake of Bienne. (Before this, the Aare sometimes flowed to the east, joining the Zihl River near Büren, or sometimes to the west, flowing into the Lake of Neuchâtel.) The hydrological control also involved the enlargement of the streams between the three lakes and further down to Soleure, by building channels. A network of ditches was also established and the peat soils drained. The water input and output was regulated by a few electrical power-stations along the rivers Aare and Sarine, as well as on the outlet channel near Bienne.

◀ Fig. 3.6.2. Location of the fenlands and the mire landscape of national importance of La Grande Cariçaie between Cheyres and Font (modified from DFI 1990 and 1991c). The lake side in 1880 is also shown (modified from Huber 1989) which gives evidence of the rapid erosion of the littoral (150 m to 400 m) since the Jura Water Correction in the 1870's (cf. Chapter 3.6.2).
1 Vantage point; 2 Vers l'Eglise (molasse cliffs); 3 Littoral transect.
— Lake side in 1880
Scale of the map: 1 : 25,000; for key, see end-cover. Reproduced by courtesy of the Federal Office of Topography, Berne, 9 June 1992.

A second hydrological control project was undertaken because the first one was unable to prevent some areas from being flooded in spring. At this time, the water flow of the Aare River is usually drastically increased by the snowmelt from the Alps. The main goal of this second intervention was to reduce the fluctuation of the three lakes from about 3 m to 1.8 m. (from 1.5 to 1 m on an annual mean fluctuations basis). In the young wetland communities of the south shore, this has promoted, to some extent, deposition of sediments, forest encroachment and also littoral erosion.

The wetland ecosystem is now mainly endangered by wave erosion (cf. to the lake side in 1880 in Fig. 3.6.2). Since the first Jura Water Correction, the southern lake side has been eroded (Huber 1989) by 150 m to as much as 400 m (with an average of 200 m). Furthermore, the fenlands and the mire landscape are now threatened by lake eutrophication, developing residential areas, as well as by tourism, since the beauty of the site attracts many people. All of these factors acting together have dramatically increased the pressures on this ecosystem.

3.6.3 Geology, pedology and hydrology

Most of the shore is cut from the molassic sandstone, bedded by Aquitanian (Oligocene) or Burdigalian (Miocene) rocks, possibly covered with loose sediments originating from the molasse and a patchwork of moraines. At many places, the sandstone cliff, eroded by the lake before the Jura Water Correction was undertaken, dominates the wetland (see Fig. 3.6.1). Nevertheless, near Cudrefin, Yvonand and Yverdon, the geomorphology is quite different, and the wetlands are connected with alluvial flats.

The soils have developed either directly on an impermeable sandstone substratum, especially on the foothills fed by runoff, or on more or less deep loose sediments. In the first case, the ground-water is transient and the soils are mainly pseudogleys. In the second case, the ground-water is permanent, more or less connected with the lake waters, and gleys or peat soils have developed. With the present lake regulation, not all the wetlands are flooded by the lake.

Depending on the permeability of the sub-soil, the ground-water may behave quite differently and the soils may vary in respect to oxidation and other chemical properties. Where the ground-water table is relatively high and stable, peat forms (up to 40 cm in 100 years!), whereas gley soils occur where the ground-water fluctuates. Depending on its dynamics, the gleys are either reduced, forming anmor humus, or oxidized with hydromull or mull humus (Fig. 3.6.5). On the lake front, wave action creates sand bars.

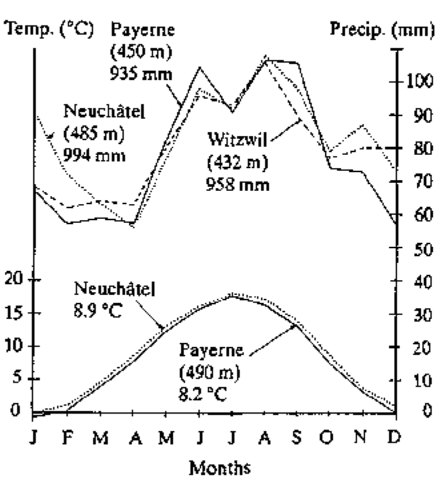


Fig. 3.6.4. Precipitation diagram of Witzwil and ombrothermic diagrams of Neuchâtel and Payerne which are climatically similar to the southern side of Lake of Neuchâtel (modified from Buttler 1990).

3.6.4 Climate

The area experiences a wet sub-oceanic climate alternating between oceanic and continental conditions regulated to some extent by the influence of the lake. In Payerne, the mean annual temperature is 8.2° C and mean annual precipitation 935 mm. The climate diagrams (Fig. 3.6.4) show that it is somewhat colder and drier on the south shore compared to the north shore where the influence of the Jura Mountains is perceptible.

3.6.5 Vegetation

The vegetation shows the typical succession of littoral ecosystems (Fig. 3.6.5 and Tab. 3.6.1). As part of the infra-aquatic succession series, the following communities can be found: Lemnion minoris, Sphagno-Utricularion, Potamogetonion pectinati, Nymphaeion albae, Scirpo-Phragmitetum, Typhetum angustifoliae and latifoliae, Phalaridetum, Caricetum elatae, Caricetum ripariae and Cladietum marisci. In the supra-aquatic series, we can see: Orchio-Schoenetum nigricantis, Ranunculo-Caricetum hostianae and Molinietum coeruleae. Brushwood and woodland are characterized by Salici-Viburnetum, Frangulo-Salicetum cinereae, Alnetum incanae, Fraxino-Alnetum glutinosae, Salicion albae and Molinio-Pinetum. On bare ground, communities of Nanocyperion and Eleocharition acicularis occur.

It is worth noting that among the 264 species recorded in the entire wetland, 82 are listed in the Red Data List of endangered plants in Switzerland (Landolt 1991). Fen orchid *(Liparis loeselii)*, summer lady's-tresses *(Spiranthes aestivalis)* and lady's slipper *(Cypripedium calceolus)* are about to disappear in our country.

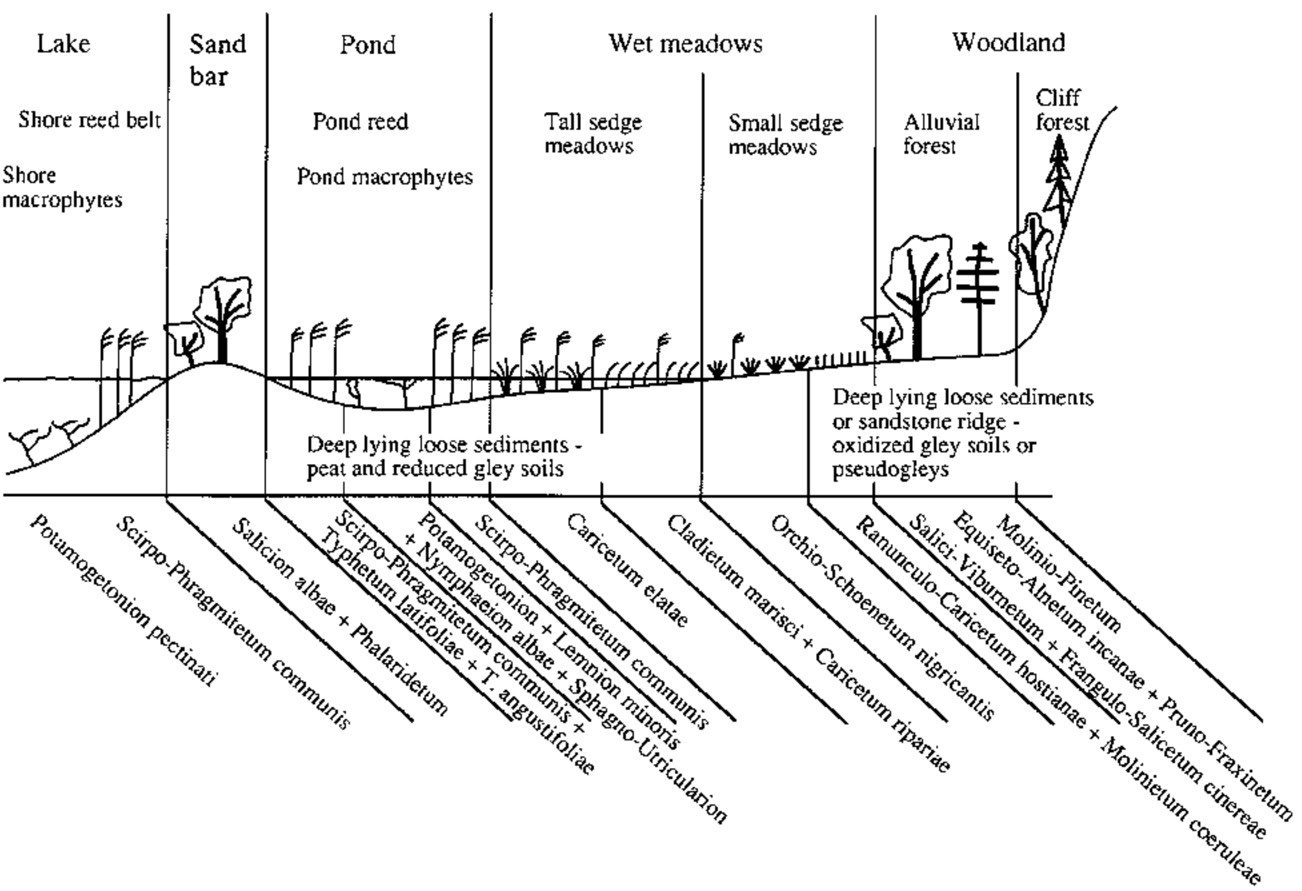


Fig. 3.6.5. Cross-section of the lake shore of la Grande Cariçaie showing site characteristics and vegetation types (modified from Buttler and Gallandat 1989).

Table 3.6.1. Vegetation of la Grande Cariçaie. The chart displays species composition along the vegetation gradient of the south shore of Lake of Neuchâtel.

● = typical or dominant species
☆ = frequent species

	Pond vegetation	Scirpo-Phragmitetum communis	Cladietum marisci	Caricetum elatae	Orchio-Schoenetum nigricantis	Small sedge meadows and Molinietum caeruleae	Alluvial forest	Molinio-Pinetum
Utricularia vulgaris	●	☆		☆				
Nymphaea alba	●	☆		☆				
Lemna minor + trisulca	●	☆						
Potamogeton gramineus + coloratus	●	☆		☆				
Scirpus lacustris		●						
Phragmites australis	☆	●	☆	●	☆	☆	☆	
Cladium mariscus			●		●	☆		
Hippuris vulgaris	☆							
Typha angustifolia + latifolia		☆						
Berula erecta		☆						
Utricularia minor + intermedia		☆		●				
Carex elata		☆	☆	●		☆		
Scutellaria galericulata		☆		●		☆		
Peucedanum palustre				●	☆	☆		
Stachys palustris		☆	☆	●	☆	☆		
Senecio paludosus			☆	●		☆		
Rorippa amphibia		☆						
Schoenus nigricans			☆		●			
Orchis laxiflora palustris					●	●		
Spiranthes aestivalis					●			
Carex panicea + hostiana			☆		☆	●		
Mentha aquatica		☆	☆	☆	☆	☆	☆	
Galium palustre		☆	☆	●	☆	☆	☆	
Lythrum salicaria		☆	●	●	●	☆		
Eupatorium cannabinum cannabinum			☆	☆	☆	☆	☆	
Lysimachia vulgaris			☆	☆	☆	●	☆	
Hydrocotyle vulgaris			☆	☆	☆	●		
Frangula alnus			☆		☆	☆		
Thalictrum flavum				☆	☆	☆		
Euphorbia palustris				☆	☆	☆		
Eriophorum angustifolium + latifolium				☆	☆	☆		
Cirsium palustre					☆	☆		
Eleocharis uniglumis					☆	☆		
Lathyrus palustris						☆		
Molinia caerulea caerul. + caerul. arundinacea					●	●	●	●
Epipactis palustris					●	☆		
Juncus alpinus					☆	●		
Carex flava					☆	●		
Dactylorhiza majalis maj.+ incarnata incarn.					☆	☆		
Iris pseudacorus				☆			☆	
Alnus incana + glutinosa					☆	☆	●	
Fraxinus excelsior							●	
Populus alba + nigra						☆	●	
Prunus padus padus							●	
Ranunculus ficaria bulbifer							●	
Ribes rubrum							●	
Lamium maculatum + galeobdolon							●	
Salix alba alba							●	
Carex acutiformis							●	
Humulus lupulus							●	
Epilobium hirsutum							☆	
Equisetum hiemale							☆	
Brachypodium sylvaticum syl.+ pinnatum pin.							☆	☆
Pinus sylvestris					☆			●
Calamagrostis varia varia								●
Berberis vulgaris								☆
Juniperus communis								☆

3.6.6 Ornithological study

The entire complex of fens on the south-eastern side of Lake of Neuchâtel is a very important place for many animal species, particularly birds. As a result, it has been included in the Ramsar Convention (1971). One aim of the management is to preserve characteristic and rare species linked to the open marshy areas.

One of the most important surveys is the study of the effect of mowing on bird populations. Modifications in distribution and abundance have been investigated using and comparing two methods (line transect and square census). This study was begun in 1985 (ANTONIAZZA 1988).

The first findings indicated that no species had either disappeared or appeared because of mowing. In fact, the breeding habitats were not modified in their structure. Birds such as little grebe *(Podiceps ruficollis)*, reed bunting *(Emberiza schoeniclus)*, water rail *(Rallus aquaticus)*, great reed warbler *(Acrocephalus arundinaceus)* and Savi's warbler *(Locustella luscinioides)* are the most easily documented species. Herons, ducks, crakes, waders and other marsh warblers were too scarce to show any significant changes linked with mowing. In contrast, the great crested grebe *(Podiceps cristatus)*, bearded tit *(Panurus biarmicus)* and reed warbler *(Acrocephalus scirpaceus)* were too densely concentrated to be followed easily.

The local distribution of each species was, however, clearly affected by mowing. The one year-old parcels were nearly devoid of breeding birds. The two year-old parcels recovered between 50 to 80% of the "normal" density, depending on the species. The three year-old parcels displayed a "normal" density compared to control data (previous data in the same habitat or unmowed parcels). For some species, the density has even increased. A tendency toward concentration seems to emerge from the results but is difficult to demonstrate locally with statistical significance. In a global view (regional state of the populations), no significant modification has appeared in any population of any species (ANTONIAZZA 1991).

Other monitoring studies on fauna have also been carried out, including the regional state of amphibian populations, a census of butterflies and dragonflies, the control of the effect of hedgerow, bush and edge management on spiders and butterflies and a survey of colonization of newly cleared or created ponds by aquatic invertebrates.

3.6.7 Present land use

In a joint effort dating back more than 10 years, two nature conservation associations (the Swiss League for Nature Conservation and the World Wide Fund for Nature) and two cantons concerned with the littoral zone (Fribourg and Vaud) have worked together to conserve this ecosystem. The objectives were to conserve in its entirety a near-natural environment with complex internal dynamics, and to maintain the diversity of the wetlands, giving priority to the wettest communities. A master plan was prepared for the development

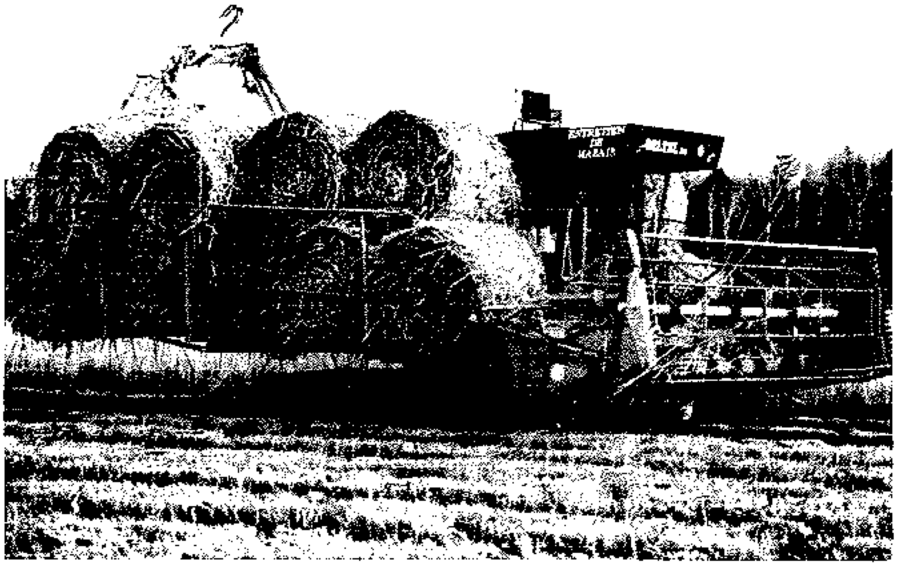


Fig. 3.6.6. Litter harvesting.

of the area specifying, among other things, that all natural and semi-natural areas had to be given protected status. Under an agreement, with the assistance of the Swiss government, the four partners undertook to provide the funds required to manage the wetlands. Under the authority of a joint commission, a study and management group was formed to carry out maintenance, scientific monitoring and information gathering.

The main example of active management is the mowing of more than 100 ha of wet meadows on an annually rotating basis (see Fig. 3.6.6). This includes the removal of the resulting 1,000 t of litter, digging out of ponds that have been filled in, cutting of shrubs, and protecting the shore against erosion. In addition to these activities, scientific monitoring is carried out. Systematic monitoring of bird, plant and insect species is used to determine and if necessary improve the effectiveness of the maintenance programme in achieving the objectives.

3.6.8 Special topic

Since hydrodynamics is the main factor influencing the wetland ecosystem, a better understanding of the relationship between ground-water and the lake is needed. Some scientific projects are therefore attempting to establish the quantitative relationship between lake fluctuation, topography, sediment permeability, climate and ground-water. The ultimate question is how to regulate the lake in order to bring about the best hydrodynamic conditions in the wetland, taking into account the different ecological tolerances of the plant communities. It is quite clear that this problem has to be solved with consideration given to opposing interests like electricity production at the power-stations, agriculture in the Seeland area, fishing and protection of other diverse interests (residential areas, industry, etc.) along the shore.

Fig. 3.7.1a. Near infra-red false-colour aerial photograph of the bog of la Vraconnaz on 31 July 1984.

Fig. 3.7.1b. Near infra-red false-colour aerial photograph on 20 October 1987, taken ca. one month after the bog burst. (Photos taken by the Coordination Centre for Aerial Photographs, Dübendorf).

3.7 A moving mire – the burst bog of la Vraconnaz

Elizabeth Feldmeyer-Christe and Gilles Mulhauser

Community: Sainte-Croix (canton Vaud)
Locality: La Vraconnaz
Coordinates: 525-527 / 187-189
Elevation of the mires: 1,100 m
Area of the raised bog: 31 ha
Area of the fenlands: 25 ha
Area of the mire landscape La Vraconne: 200 ha

3.7.1 Highlight of the visit

This site is worth seeing because it was affected by a bog burst in 1987. Such an event, which occurs comparatively frequently in Scotland and Ireland, is very unusual in Switzerland.

3.7.2 General information

The bog of la Vraconnaz is located in the Jura Mountains (canton Vaud), to the north of Sainte-Croix and near the French border.

Situated in a large depression on a gentle slope north-west to south-west at a mean altitude of 1,090 m, the raised bog has a surface of about 30 ha surrounded by 25 ha of fen (Fig. 3.7.2). Most of the bog belongs to the Swiss League for Nature Conservation (SLNC).

Like most of the Jura bogs, the bog of la Vraconnaz was being cut for fuel by the 18th century; the peat was used for a smelting furnace near Mouille-Mougnon (1.5 km south-east of the bog's centre). The peat cutting stopped at the end of World War Two. In 1987 the bog suffered a bog burst (cf. Chapter 3.7.6).

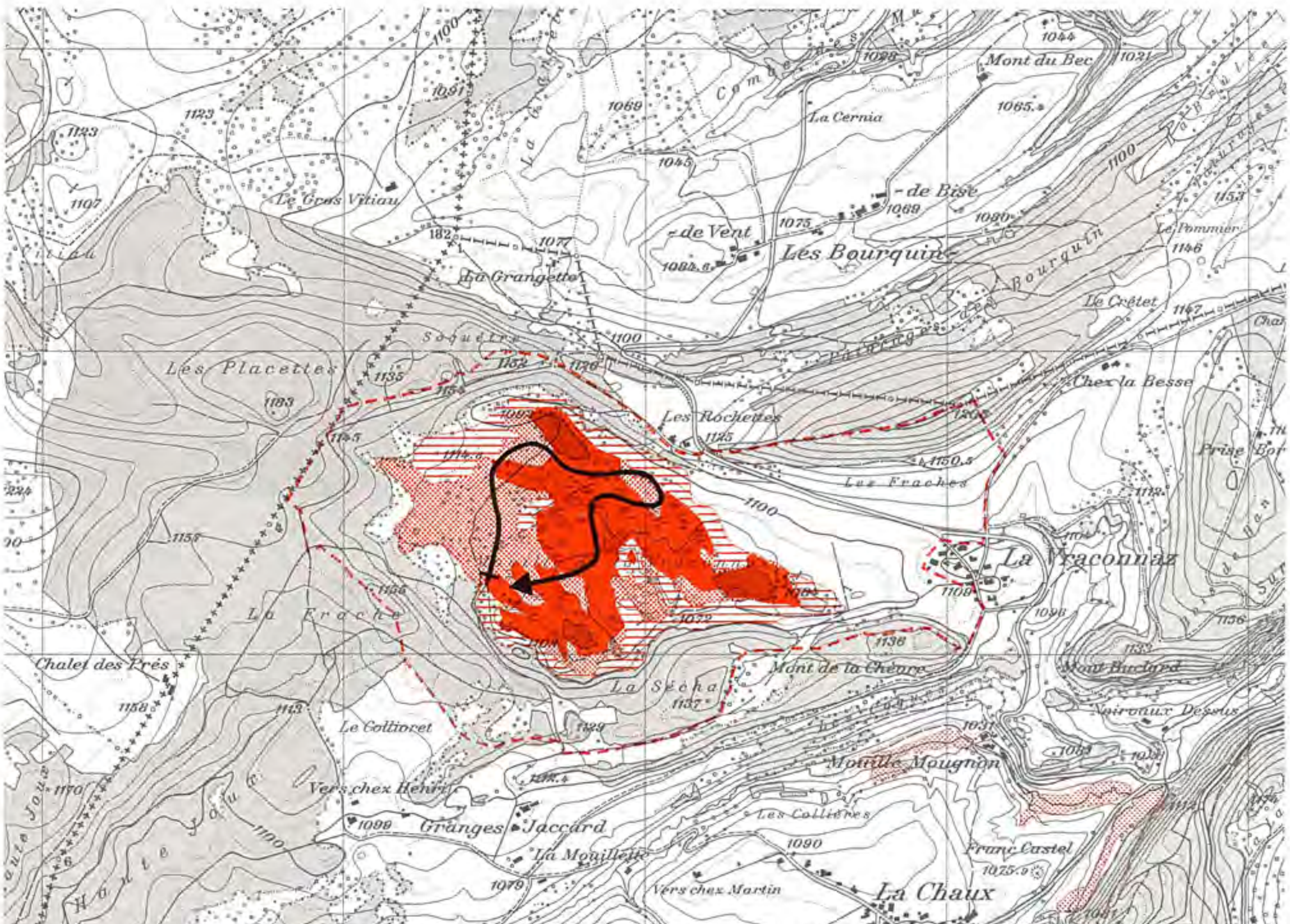


Fig. 3.7.2. Location of the mires and the mire landscape of national importance in the area of La Vraconnaz (modified from DFI 1990, 1991b, 1991c). 1 Vantage point; 2 Bog burst area; 3 "Intact" bog area.
Scale of the map: 1 : 25,000; for key, see end-cover. Reproduced by courtesy of the Federal Office of Topography, Berne, 9 June 1992.

3.7.3 Geology and hydrology

Geologically, the bog is located in the Chain Jura (cf. Fig. 1.3.8). Most of the Jura in canton Vaud lies between two large, complex sinistral faults: the Vallorbe-Pontarlier running to the east and the Morez-les-Rousses running to the south-west. Dextral east-west to east-south-east to west-north-west conjugate faults are associated with both fracture zones. The kinematic relations between folding, thrusting and strike-slip movements are very intricate. Large, broad box-folds constitute the Vaud Jura, while the synclines show more complex structures. The bog lies on a large anticline. The bedrock is probably made up of impermeable marly rocks of the Cretaceous. The outcrops at the north and west edges are limestone of the Sequanian that forms the centre of the fold. The soils of the anticline in the east part consist of calcareous clay of the Callovian (mainly summarized from Trümpy 1980).

The water supply comes from rainfall and seeping water, which appears from several spring outflows. Because of its situation in a quite closed basin, the runoff water from the bog is unable to escape except into a range of dolines on the southern edge.

3.7.4 Climate

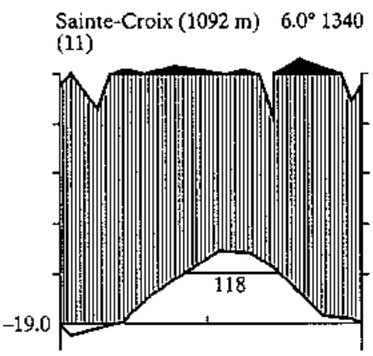


Fig. 3.7.3. Climate diagram for Sainte-Croix (modified from Walter and Lieth 1960). For explanation see Fig. 1.5.4.

The climate data are supplied by the station located in Sainte-Croix - L'Auberson, 2 km to the south of the bog's centre (Fig. 3.7.3). The mean annual level of precipitation is between 1,320 and 1,480 mm with large variations. The mean annual temperature is between 4° and 5° C. Frost is possible in almost any month of the year.

3.7.5 Peatland types and vegetation

The bog at la Vraconnaz is a sloping bog. The undisturbed north-eastern part of the bog supports vegetation groups of Sphagnion magellanici (with a small and rare liverwort *Lophozia laxa*), as well as mud sedge *(Carex limosa)*, Rannoch rush *(Scheuchzeria palustris)*, feathery bog moss *(Sphagnum cuspidatum)*, and slender sedge *(Carex lasiocarpa)* in depressions. Most notable of all is the presence of string sedge *(Carex chordorrhiza)*. The north-western part has vegetation groups of alkaline fens of the Caricion davallianae association. The parts which were exploited during the two world wars now present many regeneration complexes with a mixture of Sphagnion magellanici groups, *Calluna* heath and acidic fens of the Caricion nigrae group.

The bog is almost completely enclosed with pastures of the Cynosurion alliance, meadows of Polygono-Trisetion and woods with spruce *(Picea abies)*. In the north, the depression is lined by an Abieti-Fagetum forest.

3.7.6 The bog burst of la Vraconnaz

An exceptional climatic event caused the bog slide in September 1987. After three weeks of drought, heavy rainfall followed on 25 and 26 September; almost 180 mm of rain fell within one night. This has been the most extreme event ever recorded since the start of systematic climate measurements in the region 80 years ago (Röthlisberger et al. 1991). It was so extraordinary that even the well-developed natural drainage system in the surroundings of the bog (Karst situation) may have been full to overflowing. Such a large amount of water could not be soaked up by the peat. A spring at the upper edge of the bog swelled so much that the peat body was torn away from the mineral sub-soil and slid downwards. The aerial photograph demonstrates that the mechanism of the peat slide was similar to the movements of a glacier (cf. Figs. 3.7.4 and 3.12.5).

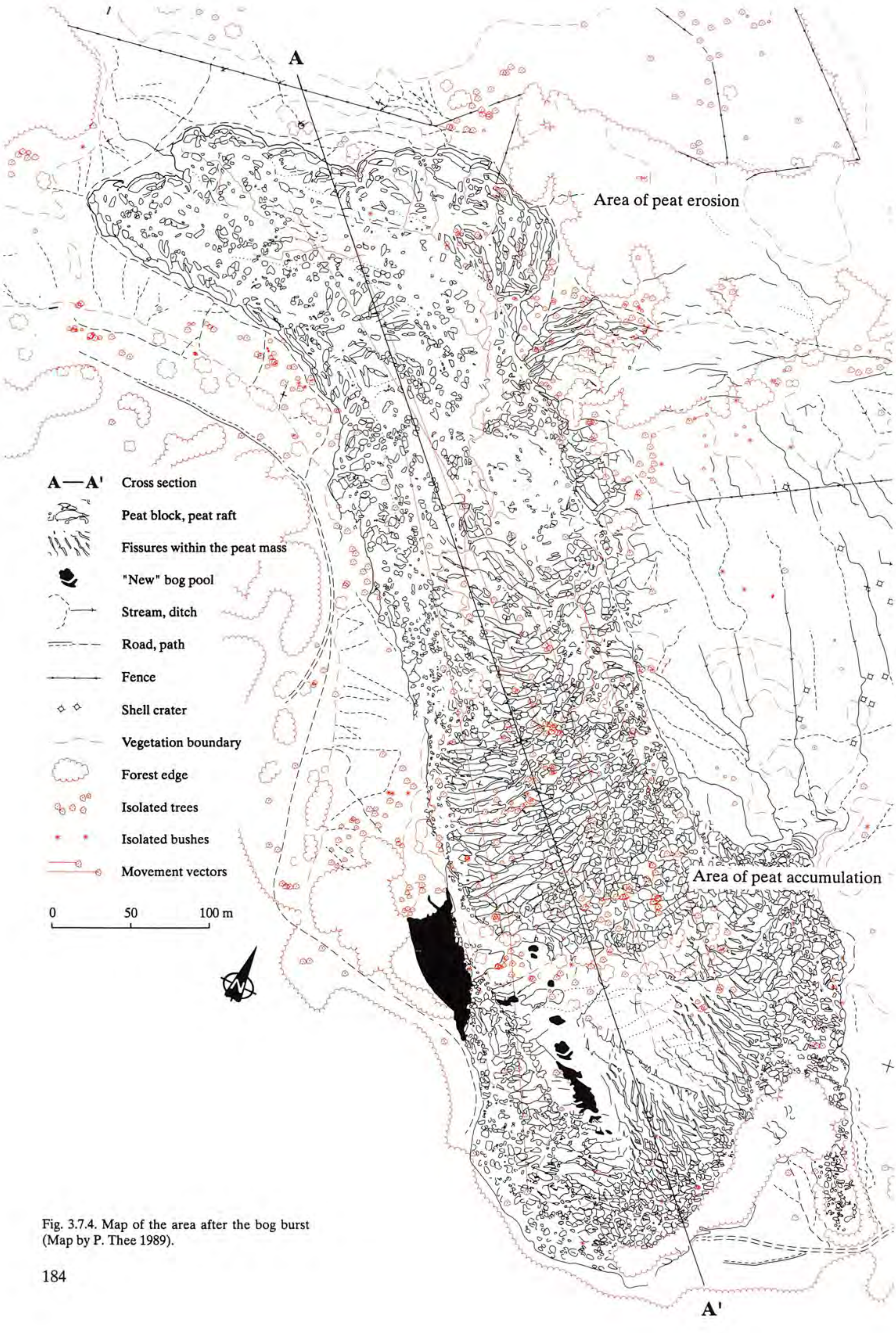


Fig. 3.7.4. Map of the area after the bog burst (Map by P. Thee 1989).

About 15 ha on the western part of the bog was affected by the slide. This area had been cut for fuel and still showed many scars. It was also well-known that this was an area of ground-water recharge during snowmelt. During the night, about 150,000 m^3 of peat slid along the gentle slope for a distance of at least 300 m (Figs. 3.7.4 and 3.7.5). Many trees were carried with the peat-rafts and remained standing. The peat at the burst was eroded in places, until the grey mineral sub-soil was exposed. The two biggest dolines in the south were completely filled up with peat. A small pine forest (mainly *Pinus montana*) in the same area was entirely crushed. Because the residual water did not completely escape into the dolines, several new ponds were formed in the south-west and south-east corners.

This uncommon event immediately triggered a multidisciplinary programme of research in geophysics, vegetation science, pollen analysis, entomology, pedology and mapping (Feldmeyer-Christe 1990a).

A photogrammetric map of the situation, at a scale of 1 : 1,000 (Fig. 3.7.4), was established after the bog slide by means of near infra-red false-colour aerial photographs (scale of 1:9,000 and 1:5,000) taken 3 years before and immediately after the bog burst (cf. Figs. 3.7.1a and 3.7.1b). This map helped to provide an overview of the drastically disrupted landscape. Other maps were then produced, such as maps of drainage ditches, contour lines and longitudinal profiles (Fig. 3.7.5).

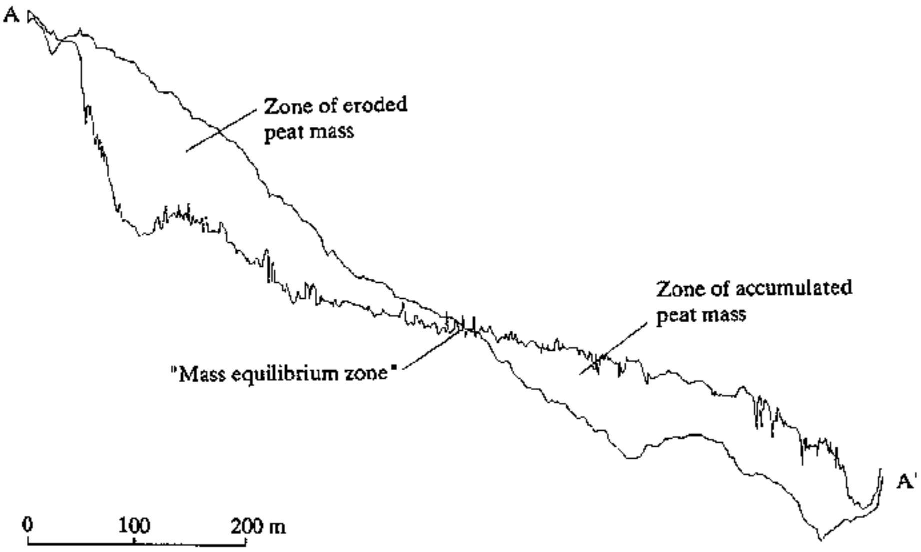


Fig. 3.7.5. Cross-section A–A'of the bog burst of la Vraconnaz (cf. Fig. 3.7.4). The vertical scale is exaggerated 20 x. (Diagram by P. Thee 1989).

3.7.7 Present land use

Despite the SLNC owning a good part of the bog, it is still partially used for grazing. There has also been an increase of trampling by people attracted to the spectacular effect of the bog slide.

3.7.8 Research

After the bog burst in 1987, the bog became an interesting research area for development and regeneration studies.

Botanical succession

The bog slide in the autumn of 1987 caused a complete change in the hydrological and soil conditions in the western part of the bog. Simultaneously, it offered an exceptional opportunity to study the development of the vegetation in such a disturbed environment.

One hundred permanent plots were selected in 1988 to represent the greatest environmental diversity. Some of the plots are situated in representative plant groups (Sphagnion magellanici, Caricion nigrae, Caricion davallianae or *Pinus mugo* forest) that seem at first sight little modified by the slide. The other plots are situated in different kinds of pioneer habitats like bare peat, new hollows, new pond banks or mineral soil.

Vegetation relevés are made at different time intervals (every year, every two or five years) according to the speed of change in vegetation. The objectives of this survey are to study the different phases of plant settlement as well as plant successions. The behaviour and resistance of sphagna and other bryophytes to hydrological changes and eutrophication are also closely observed, as well as their sensitivity compared to phanerogams.

In a 3 year comparative study, the first results show a drying out in the groups of Sphagnion magellanici with an increase of heather *(Calluna vulgaris)*. The groups of alkaline Caricion davallianae and acidic Caricion nigrae exhibit a decline in characteristic species and the appearance of damp meadows species.

The changes in the pioneer permanent plots occurred more quickly. Out of 11 plots without vegetation in 1988, only 2 were still bare in 1990. The 11 plots in question all have a soil of very dry peat, strongly compressed and mineralized. There is random settlement by pioneer plants in damp areas with competition beginning only after a lag period of some years.

Zoological successions

For zoologists, the bog burst represented a special and profitable occasion to study the colonization of new habitats from the very beginning. The aquatic system was the most modified, so that numerous and varied aquatic habitats were created: ponds, streamlets, hollows and rivulets (Mulhauser 1990). Terrestrial parts were also carried down in the landslide, but with their original fauna. Thus, the problem of colonization does not really exist in this case (it is more a problem of reorganization linked to the evolution of vegetation).

Only some of the hundreds of aquatic species have been chosen, described and classified into 8 different types (Mulhauser 1990). In three elements of each type, aquatic fauna (according to a standardized method) was captured every two years (1988, 1990, 1992), three times a year (June, July, September). Data are presently being analysed; precise results are not yet available.

This landslide has brought a significant enrichment to the fauna. Compared with previous data, this is especially the case for beetles (Coleoptera), bugs (Heteroptera) and dragonflies (Odonata) whose number of species increased significantly. Beetles and bugs have shown a faster response, as have some Diptera families. Dragonflies seem to colonize more slowly; new populations of characteristic species (that were absent before the slide) are establishing themselves (Mulhauser 1991).

The main goal of such a survey and analysis is to provide a description of the communities' succession of aquatic invertebrates in a specific habitat. This will allow biologists to know in advance which kind of fauna would colonize a new man-made pond. This information is also helpful in designing a specific environment to promote certain taxa.

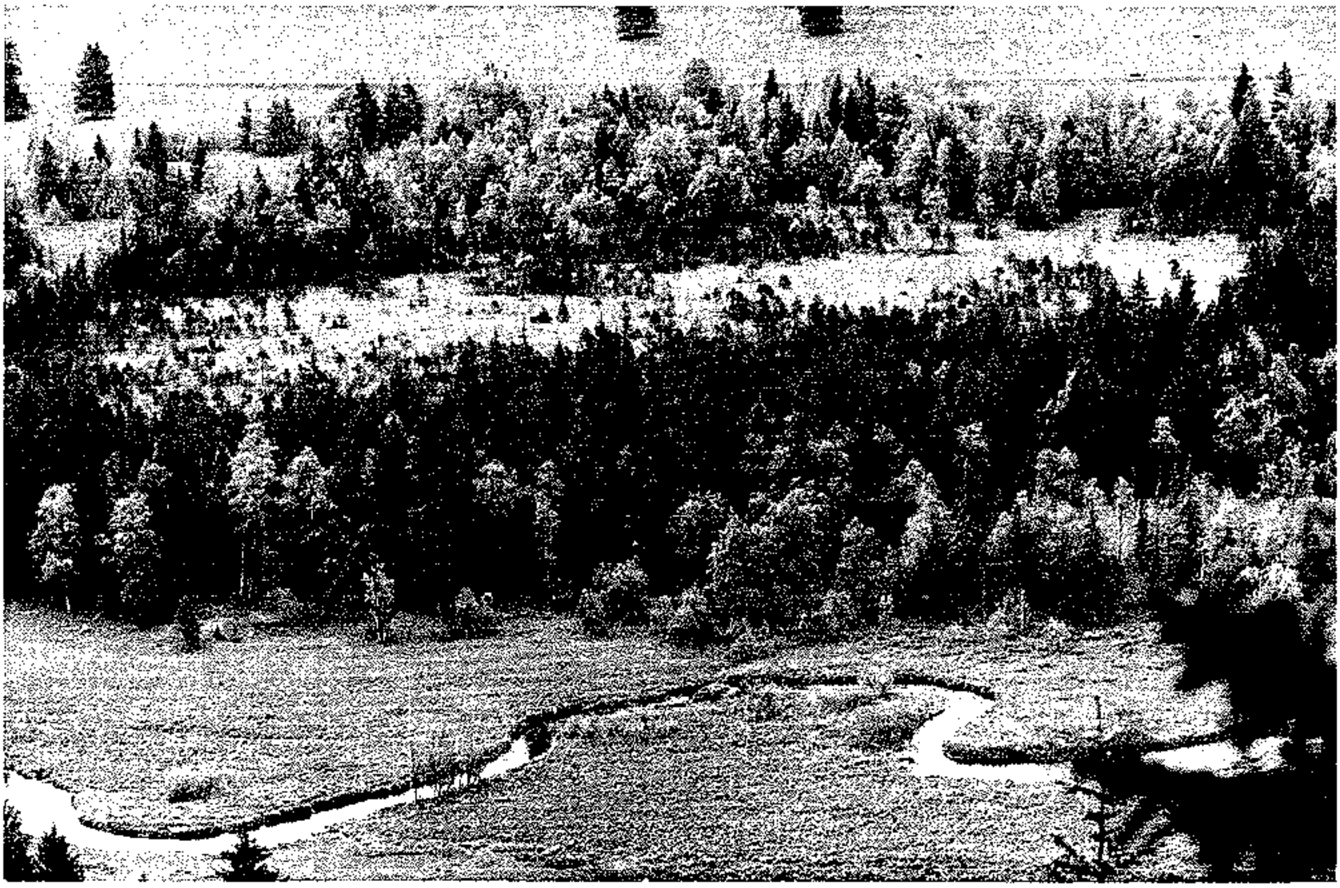


Fig. 3.8.1. View of la Burtignière raised bog showing the different vegetation zones from the treeless bog centre to the inundation area of the meandering Orbe River in the foreground (Photo by M. Broggi).

3.8 A classic bog – la Burtignière in the Vallée de Joux

Alexandre Buttler, Gilles Mulhauser
and Catherine Vaucher-von Ballmoos

Community: Le Chenit (canton Vaud)
Locality: Sagnes de la Burtignière
Coordinates: 501-503 / 156-158
Elevation of the mires: 1,040 m
Area of the raised bog: 11 ha
Area of the fenlands: 11 ha
Area of the mire landscape Vallée de Joux: 1,090 ha

3.8.1 Highlight of the visit

Among the high-altitude valleys of the Jura Mountains, Vallée de Joux is unique because of its extraordinary mire density. In the surroundings of the highly industrialized watch-making villages of le Sentier and le Brassus, most of the raised bogs were cut over and transformed to fenlands or to hay meadows and pastures. The more remote raised bog of la Burtignière and its neighbours are among the few bogs both in Vallée de Joux and in the Jura Mountains which are quite intact. They still show large patches of primary raised bog vegetation and well-developed buffer zones (Fig. 3.8.2).

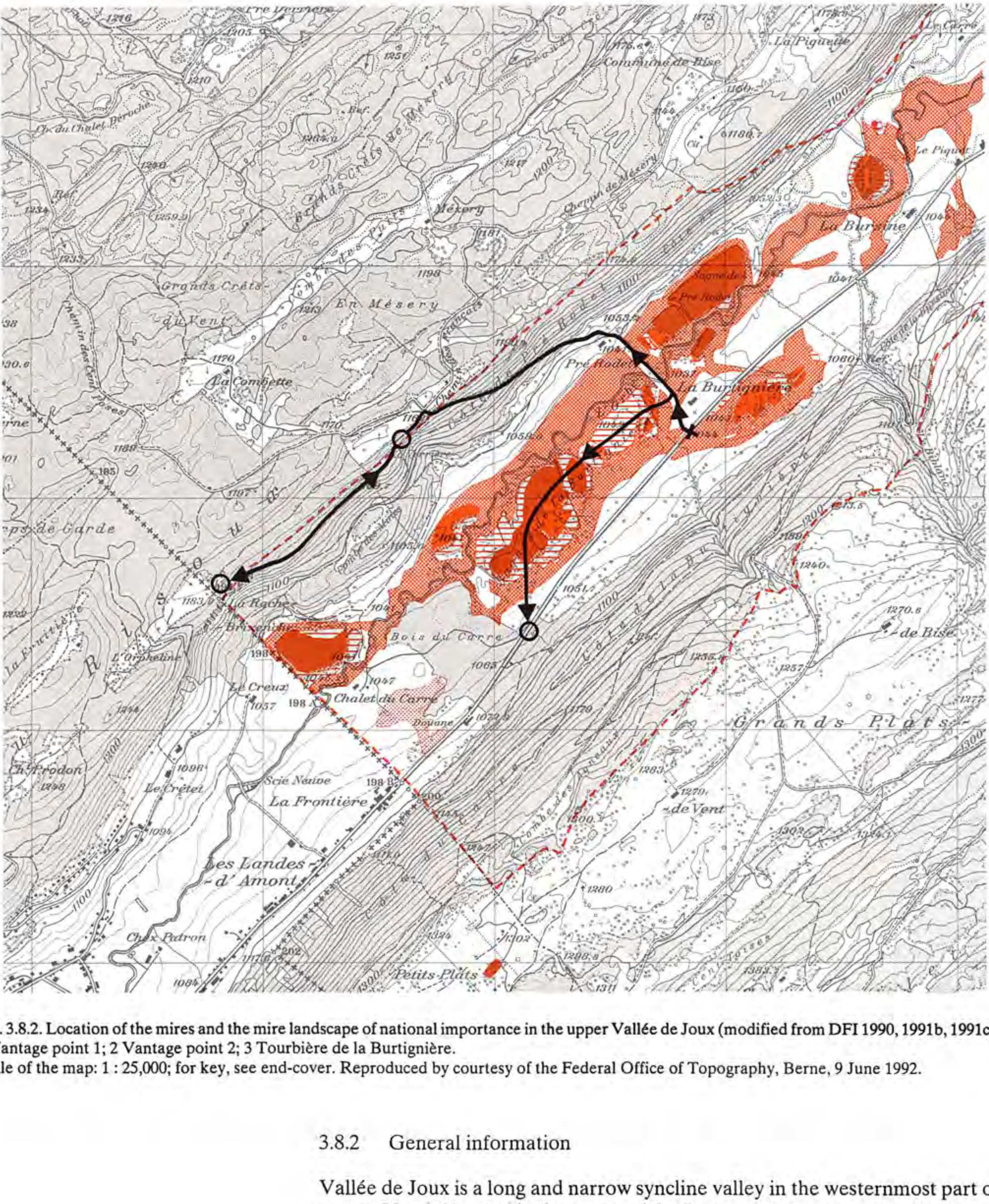


Fig. 3.8.2. Location of the mires and the mire landscape of national importance in the upper Vallée de Joux (modified from DFI 1990, 1991b, 1991c). 1 Vantage point 1; 2 Vantage point 2; 3 Tourbière de la Burtignière.
Scale of the map: 1 : 25,000; for key, see end-cover. Reproduced by courtesy of the Federal Office of Topography, Berne, 9 June 1992.

3.8.2 General information

Vallée de Joux is a long and narrow syncline valley in the westernmost part of canton Vaud. Situated in the centre of the Jura arch, it is oriented south-west to north-east. The Orbe River meanders from Lac des Rousses (which lies in France) over the talweg of 30 km into Lac de Joux. The valley bottom, lying at approximately 1,000 m, is dominated in the south-west by Mont Tendre (1,679 m) and in the north-east by Mont Risoux (1,419 m) where the largest contiguous woodland of Switzerland exists. This is appropriate because the appellation "la joux" means "tall forest" in Celtic. The thrust fault of Dent de Vaulion blocks the east end of the valley making it a closed basin and giving rise to the formation of Lac de Joux which covers an area of about 10 km^2.

The pastoral economy near the still well-preserved bogs along the French border has destroyed or altered many wetland habitats, especially the sloping fens which were drained and manured. In comparison, in the next valley to the north situated in France (Chapelle-des-Bois) some similar wetland features occur. There, agriculture was conducted in a less intensive way and the vegetation is much more diverse (GALLANDAT 1982).

3.8.3 Geology, hydrology and pedology

The variety of landscape and vegetation cover arises from the karst morphology, which is clearly expressed in this part of the Jura Mountains as a consequence of the stratigraphy. Hard limestone (Kimmeridgian, Portlandian), marl-limestone (Valanginian, Hauterivian, Sequanian) and impermeable marl (Oxfordian, Argovian) alternate. However, the existence of the wetlands in the Vallée de Joux is mostly attributable to fluvio-glacial deposits rather than marl (Fig. 3.8.3). In the Würmian ice age, the Rhône glacier did not transgress the first anticline southward, which lies at about 1,600 m. Instead, the Vallée de Joux syncline (Fig. 1.3.14) was covered by a local glacier (Fig. 3.8.4). At different places, the retreating glacier formed a (semi-)amphitheatrical arrangement of moraine ramparts. This peculiar feature of ridges promoted bog formation by both collecting runoff water and protecting the basin from regular flooding by the Orbe River (Fig. 3.8.5).

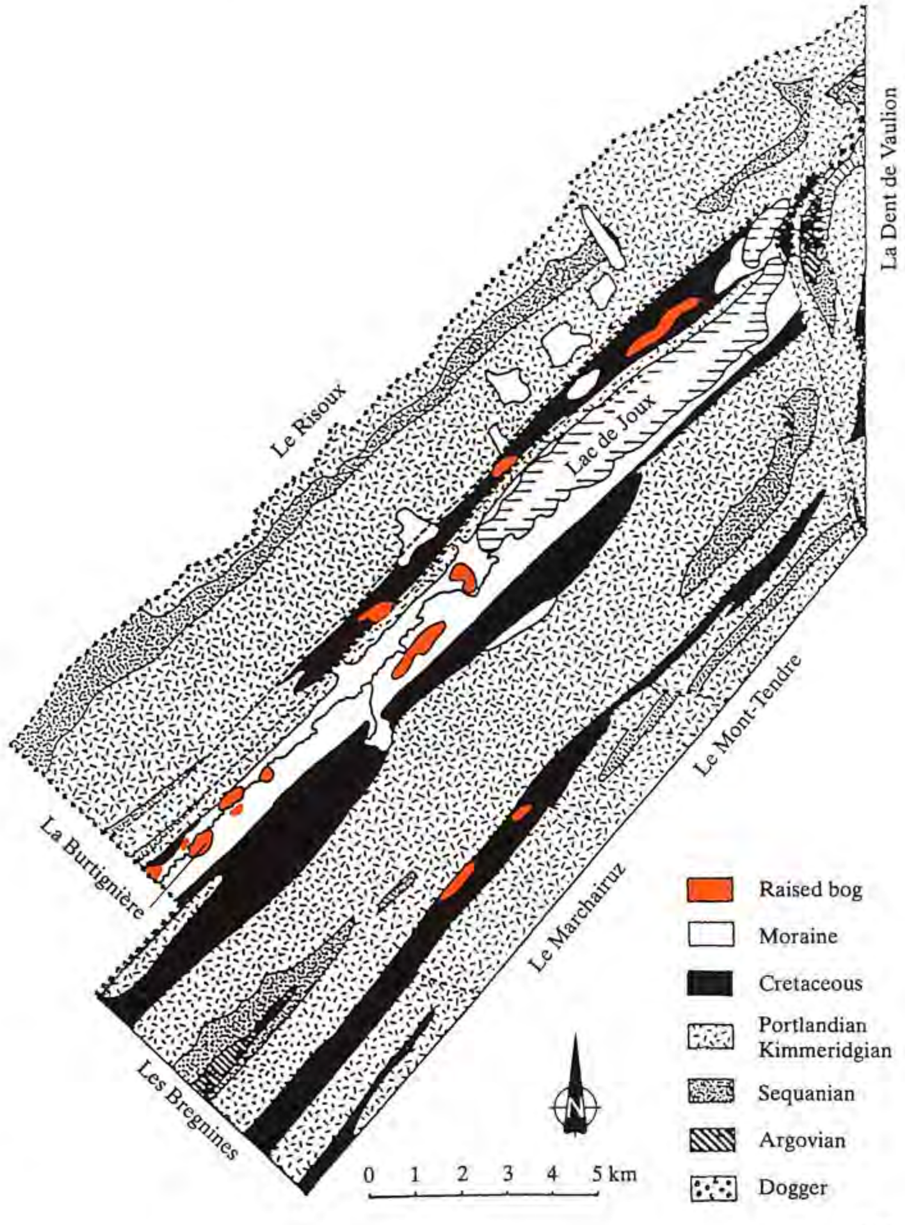


Fig. 3.8.3. Geological sketch of the Vallée de Joux (modified from AUBERT 1943).

A main feature of the hydrology of this area is the scarcity of rivers and streams; most rain-water sinks directly into the fissured limestone. The only river in the valley is the Orbe. Between Lac des Rousses and Lac de Joux, this river meanders in a mostly unaltered state for 30 km. Eventually the river disappears in the karstic system (cf. Fig. 1.3.13) of Dent de Vaulion to feed the Vauclusian spring of Vallorbe 220 m further down (CHAUVE 1975; GALLANDAT 1982).

The soil formation is diverse depending on the geology, the geomorphology, the vegetation and also human impact (Fig. 3.8.8).

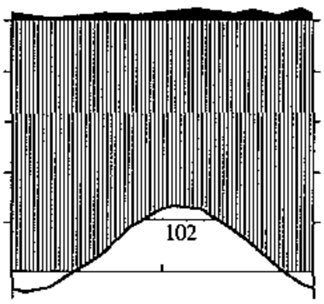


Fig. 3.8.6. Climate diagram for Le Sentier (modified from WALTER and LIETH 1960). For explanation see Fig. 1.5.4.

3.8.4 Climate

The extreme climate of this region (Fig. 3.8.6) is well-known. Due to its orientation, the valley is exposed to a cold north wind. Because of its confined basin between the mountain chains, cold air settles at the bottom of the valley. The mean annual level of precipitation is about 1,500 mm in the valley and 1,800 mm on the neighbouring mountains. The mean annual temperature is 5.9° C. Frost can occur at any time of the year.

3.8.5 Vegetation

The vegetation along a transect through the valley is illustrated in Figure 3.8.8 and on the vegetation map (Fig. 3.8.7). The main plant communities in the bog include the Sphagnetum magellanici, the Rhynchosporion (not seen on the excursion), the Pino-Mugo Sphagnetum and the Sphagno-Piceetum. On the

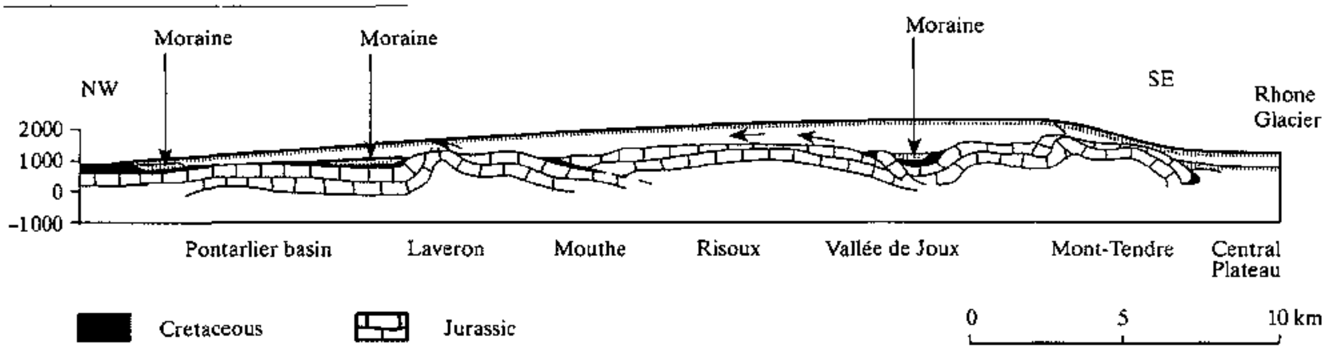


Fig. 3.8.4. Cross-section of the Vallée de Joux and area showing the extension of the local ice sheet to the Rhône glacier during the Würmian ice age (modified from AUBERT 1965).

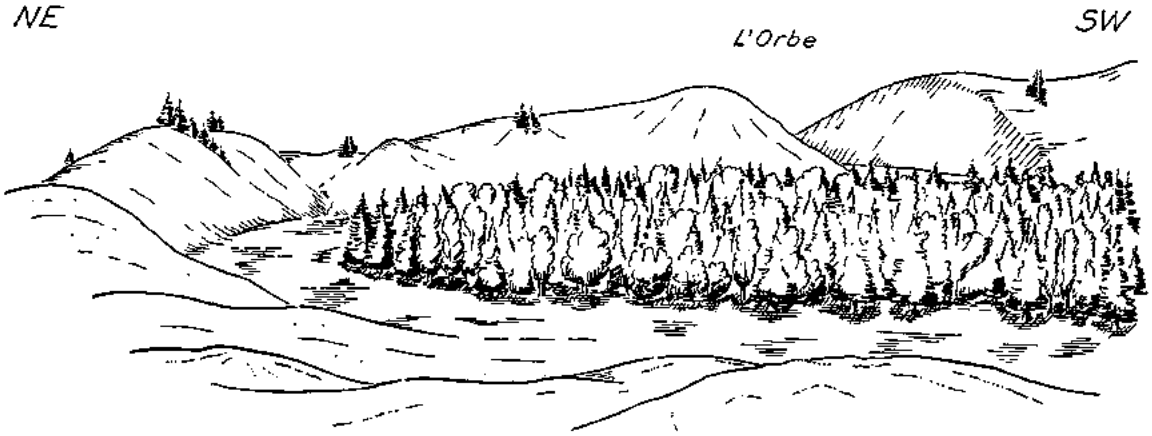


Fig. 3.8.5. Morainic arc surrounding the raised bog of Pré Rodet in the Vallée de Joux (from AUBERT 1943).

fringe of the bog, the fen communities include: Caricetum davallianae, Caricetum nigrae, Caricion lasiocarpae with lesser tussock sedge *(Carex diandra)*, as well as some communities dominated by deer-grass *(Scirpus cespitosus)* and purple moor-grass *(Molinia caerulea)*. Along the Orbe River, the Sparganio-Glycerion, the Magnocaricion with slender tufted sedge *(Carex acuta)* and bottle sedge *(Carex rostrata)*, the Filipendulion (Aconito-Filipenduletum and Aconito-Chaerophylletum) and the Salicion pentandrae (Salicetum triandrae and Daphno-Salicetum pentendrae) can be found. The wet meadows surrounding the bog include the Calthion (Trollio-Cirsietum and Cirsio-Juncetum) while the pasture land includes the Festuco-Cynosuretum.

3.8.6 Present land use

One of the major features of this bog is its relationship with the Orbe River. There are constant threats of polluted water from agricultural activities and a drop in water flow because of water diversions. Penetration of cattle into the bog or buffer zones is also an unresolved problem.

3.8.7 Special topic: peat-bridge

Because the bog has evolved with streams running across the valley slope, some natural erosion channels have developed. One of them was covered as the bog expanded and today has left a kind of peat-bridge (cf. Fig. 3.8.7).

3.8.8 Rand and buffer zones

Swiss federal law requires that every peat bog should possess an ecologically appropriate buffer zone (cf. Chapter 6.3). The goal is to permit the development of an ecotone with its own particular species diversity and biological value.

In many cases, these transitional zones do not exist and have to be created because "aggressive" agriculture is bordering or encroaching onto the bog (directly or through drainage and fertilizers). In the bog of la Vallée de Joux, the presence of well-developed transitional zones offer biologists an opportunity to study some of the rare reference cases of the Swiss Jura. Studies of the relationship between soil, water and vegetation have been carried out. The relationship between invertebrate communities (Diptera and Oribatid mites) from the different vegetation belts (from agriculture into bog) is presently being researched to understand the competition or segregation existing in the inner soil fauna. Similar investigations are also being carried out on epigeous spiders, but in other areas. Utilization (eating, breeding, foraging) of such habitats by butterflies and birds are also documented.

In fact, these transition areas play a multifunctional role, especially for the fauna: not only does it serve to regulate water and fertilizers flowing between eutrophic and oligotrophic systems, but it protects the systems from mechanical damage (see Fig. 3.8.9). Considering all of these criteria, the aim is now to propose a system to determine the best width adapted to local factors: topographic profile, kind of soil and peat, water circulation, etc. In the newly created buffer zone, a less intensive land use will be promoted (limited pasture or single and late mowing) with no drainage and no fertilizers.

3.8.9 Buffer zones around raised bogs in the Swiss Jura Mountains: a zoological viewpoint

The near-natural and anthropogenic contact zones between peat bogs and the surrounding ecosystems are actively studied in the Jura Montains from botanical and pedological perspectives. Their study from the point of view of soil zoology appears equally important for many reasons:

1 the contact zones host original communities, some constituent species of which could be specific to these habitats: some species are likely to be new to either the regional or Swiss fauna, or to science generally;
2 unlike plants, which are blocked by the agricultural use of adjacent areas, the animal communities of the soil are able to expand into the meadows. This provides a means of estimating the extension of the peat bog ecocomplex (sensu Blandin and Lamotte 1988); and
3 if this is true, the animal communities of the soil could be used as global bioindicators of the limits of that ecocomplex. This will help to determine the buffer zones that will protect the bogs against the most immediate damage due to human activity;
4 when the central ponds of the raised bogs dry out, some species survive in the external, secondary ponds. In general, the variety of existing situations triggers the diversity of the ecological niches in the Jura Mountains, thus raising the intrinsic interest of these contact zones.

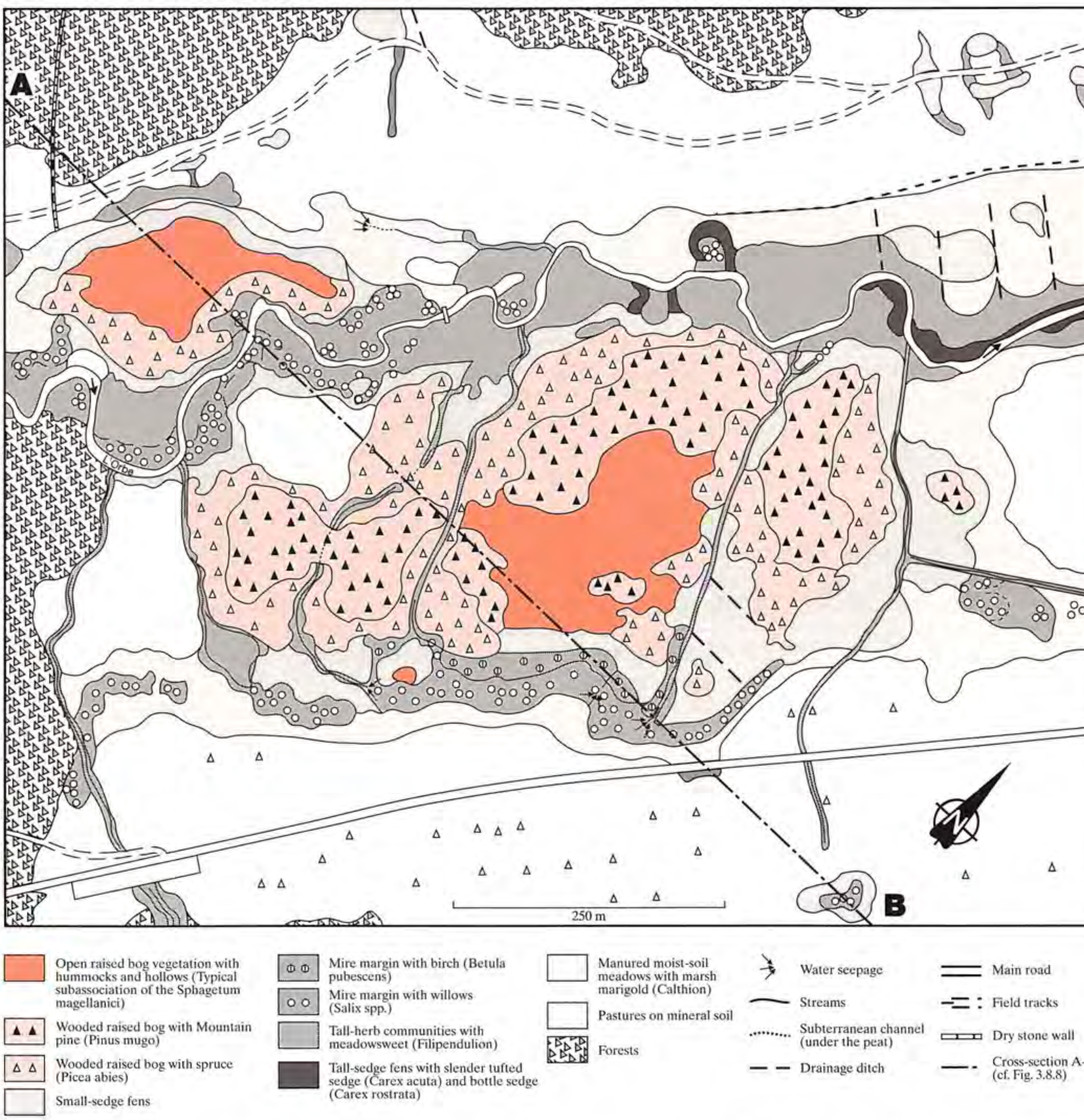


Fig. 3.8.7. Vegetation map of la Burtignière raised bog and area (mapped in 1977; modified from Gallandat 1982).

Field-oriented studies are being conducted of the ecology of Oribatid mites and Diptera with soil-dwelling and lower vegetation-dwelling larvae of the transition zones between bogs and meadows in the Jura Mountains. These taxa have been selected based on the following criteria:

1 both groups are plentiful and varied, thus more likely to form distinct species assemblages in response to the various constraints of their habitats;
2 mobility. Oribatid mites are almost immobile (at a scale of some metres) both in their adult and immature stages. When facing environmental changes, the local species assemblages have to cope with their available resources to adapt themselves, within some years of environmental modification. Diptera with edaphic larvae are mobile as adults, but their larvae are not. Thus they are strictly dependent upon local conditions. An environmental modification can therefore result in rather quick species replacement. Organisms that are mobile in both adult and immature stages (i.e. Carabidae, Spiders) are being studied by other teams (Mulhauser and Pearson 1994).

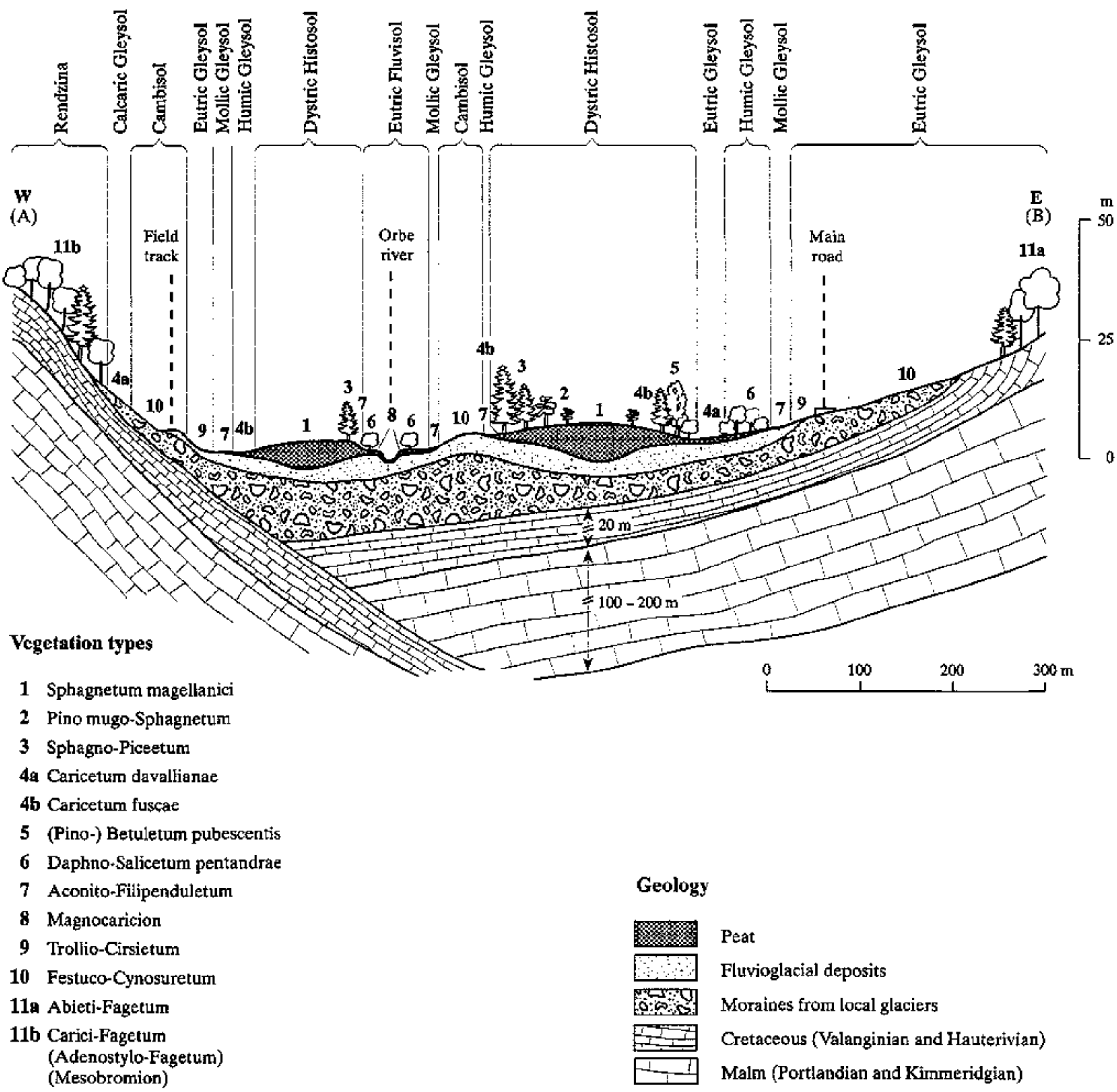


Fig. 3.8.8. Cross-section A-B (cf. Fig. 3.8.7) of the Vallée de Joux with the bog of la Burtignière displaying geology, soil and vegetation (modified from Gallandat 1982). In the legend, the order of the vegetation units is the same as in Fig. 3.8.7.

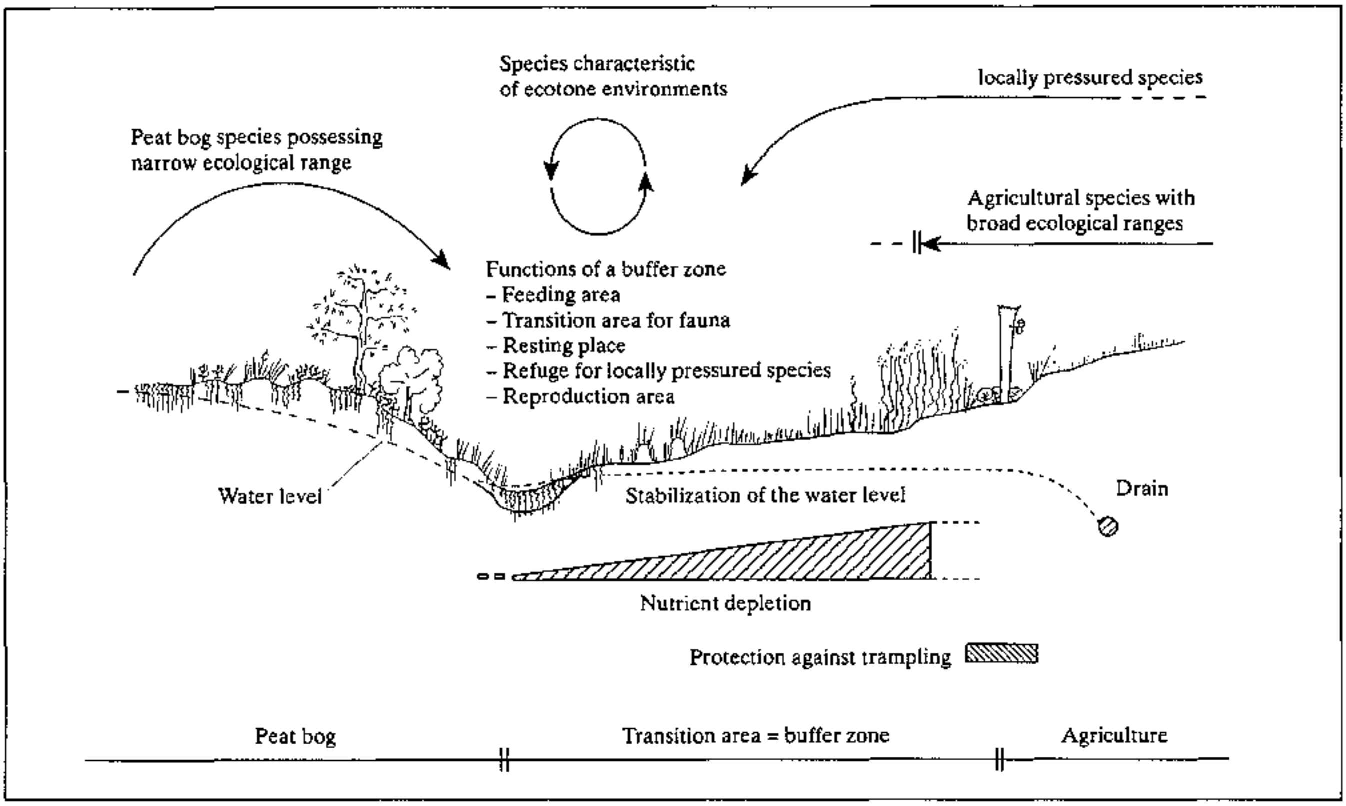


Fig. 3.8.9. Cross-section through an ideal buffer zone, showing niches and functions for both the peat bog site and the species requiring different ranges.

These various animal groups give complementary pictures in that they display different occupation strategies. Whereas some species spend their whole life cycle rather statically in the same narrow ecological and structural conditions, others need to exploit dynamically elements of the whole transition zone during their development, including raised bog and meadow (or forest). A clear definition of the functional limit of the bog ecocomplex is thus not so obvious as might be supposed from the botanical situation.

The research is structured in 3 steps: description, confirmation and experimentation.

Description

Two near-natural (La Burtignière and Praz Rodet, both in Vallée de Joux) and one anthropogenic (Le Cachot in Vallée de la Brévine) transition zones were studied in 1991. Their communities are presently being described: density, diversity, species richness, spatial structure. Their main features are being interpreted by means of a set of ecological characteristics.

Confirmation

The first-year results will be confirmed at the same sites, as well as at a set of other bog-meadow contact zones in the Jura Mountains. This will help estimate the constancy of the features that were observed in the first year's studies. A general typology of the communities will be established and correlated with their environmental features.

The two basic research steps above will be framed by a series of hypotheses dealing with the spatial autocorrelation of the data, their relationship with environmental factors, and the presence of discontinuities along a bog-meadow transect.

Experimentation

Starting in 1992, Oribatid mite and Diptera communities will be studied after a manipulation of their environment: in a situation where fertilized water streams down into a transition zone, a wall of marl will be raised, preventing contamination. The soil communities will be checked for medium-term structural modifications after this change.

Fig. 3.9.1. View from the unexploited centre of the bog of la Chaux-des-Breuleux to the north-east (Photo by E. Feldmeyer-Christe).

3.9 An acidic archipelago in a calcareous landscape – the bog of la Chaux-des-Breuleux in the Franches-Montagnes

Elizabeth Feldmeyer-Christe

Communities: Saignelégier, La Chaux-des-Breuleux (canton Jura); Tramelan (canton Berne)
Locality: La Tourbière
Coordinates: 569-572 / 229-231
Elevation of the mire: 1,000 m
Area of the raised bog: 38 ha
Area of the mire landscape La Chaux-des-Breuleux: 310 ha

3.9.1 Highlight of the visit

What are the decisive ecological conditions which led to the development of quite large raised bogs within a terrain of strong karstic character? A characteristic but endangered landscape element of the Franches-Montagnes, les pâturages boisés (wooded pastures), grazed by horses and cattle will be seen. Large peat cuttings, which in 1984 led to the first substantial rehabilitation attempts on a Swiss peatland, will be presented.

3.9.2 General information

Between Saint-Imier valley in the south and the Doubs, a river that forms part of the border with France in the north, the mountains have been reduced by denudation to an undulating plateau, or peneplain. This Plateau Jura, which extends into France (cf. Fig. 1.3.8), is known geographically as Franches-Montagnes (Free Mountains in French), a name acquired in 1384 when the Bishop of Basle freed the inhabitants from taxation to encourage settlement of the remote and climatically unfriendly area.

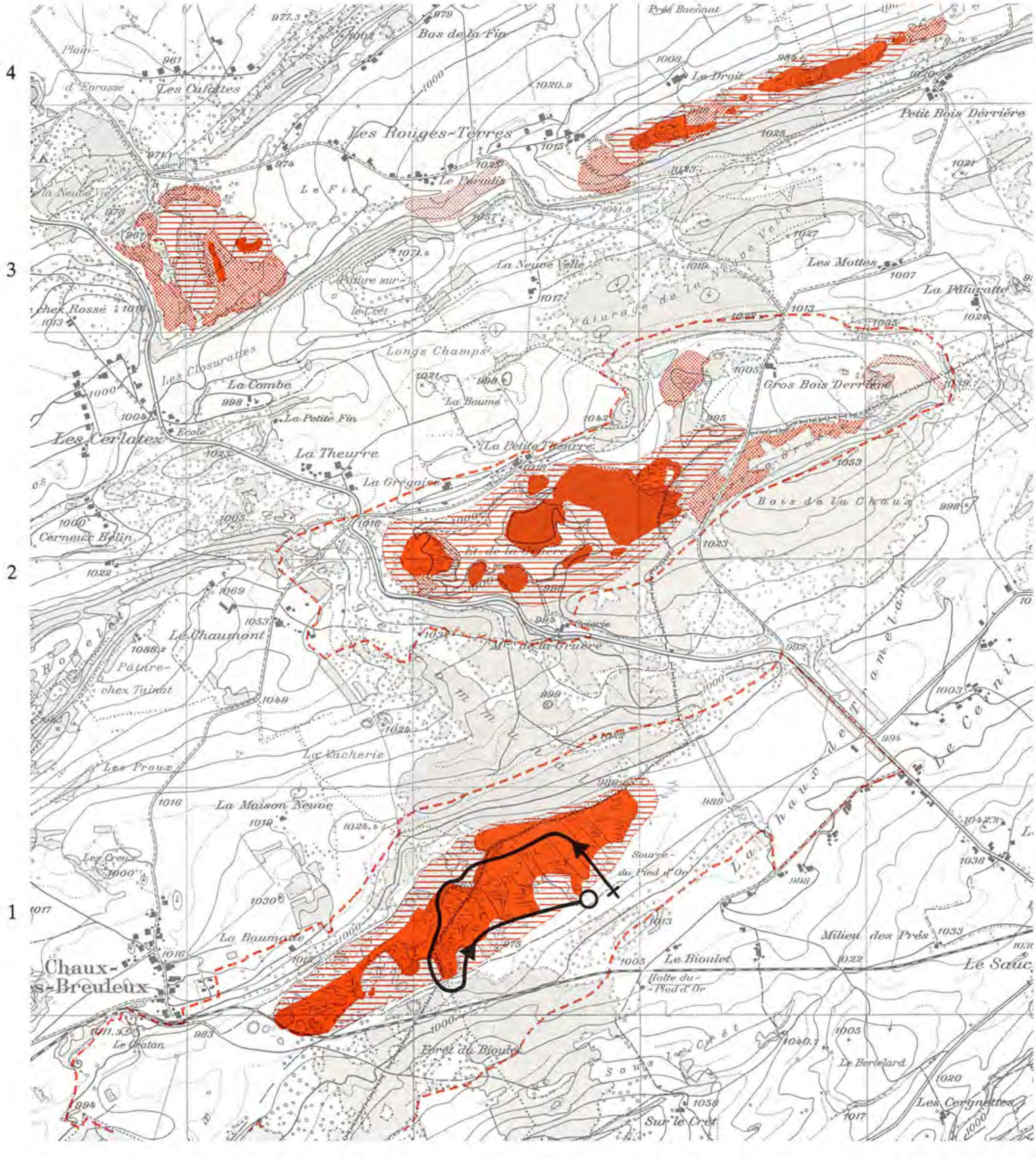


Fig. 3.9.2. Location of the mires and the mire landscapes of national importance in the area of the Franches-Montagnes (modified from DFI 1990, 1991b, 1991c). 1 The bog of la Chaux-des-Breuleux; 2 Etang de la Gruère; 3 Les Royes; 4 Les Rouges terres.
Scale of the map: 1 : 25,000; for key, see end-cover. Reproduced by courtesy of the Federal Office of Topography, Berne, 9 June 1992.

3.9.3 Geology and hydrology

Geologically, the bog occupies the bottom of a synclinal valley with an impervious Tertiary stratum. Two chains of dolines to the south and to the north of the bog define a sharp border between permeable (Dalle nacrée) and impermeable bedrock (Cretaceous). These dolines are particular karstic formations that are very common on the Plateau of the Franches-Montagnes. As a result of these dolines, there is no mire margin or lagg. It is easy to imagine that these sinkholes have played an important role in the growth of several bogs in this region. They effectively surround the impervious, flat surfaces suitable for acidic bog development and protect them from infiltration by alkaline runoff (see Fig. 3.9.3).

When considering the general hydrology of the Franches-Montagnes, one must remember that mature karstic systems are without surface streams or rivers. Resurgences can occur, like the source of the Pied d'Or to the south of the bog which flows inside a doline just a few metres after its outflow. All the ponds in this area of the Franches-Montagnes are man-made. In a region without rivers men realized the hydrological potential of the bogs. Through a drainage system, water was collected from the bog into a pond which was then channelled to a water-mill or a sawmill, before it disappeared into the karstic system (Feldmeyer-Christe 1990c). This was also true for the mill at Etang de la Combe which was built in 1782 in the largest sinkhole to the north of Tourbière de la Chaux-des-Breuleux (Leu 1955; cf. dammed up pond in Fig. 3.9.3). The sawmill at Etang de la Gruère (cf. Fig. 3.9.2, No. 2) was the last to be used in this way, and was electrified in the 1950's.

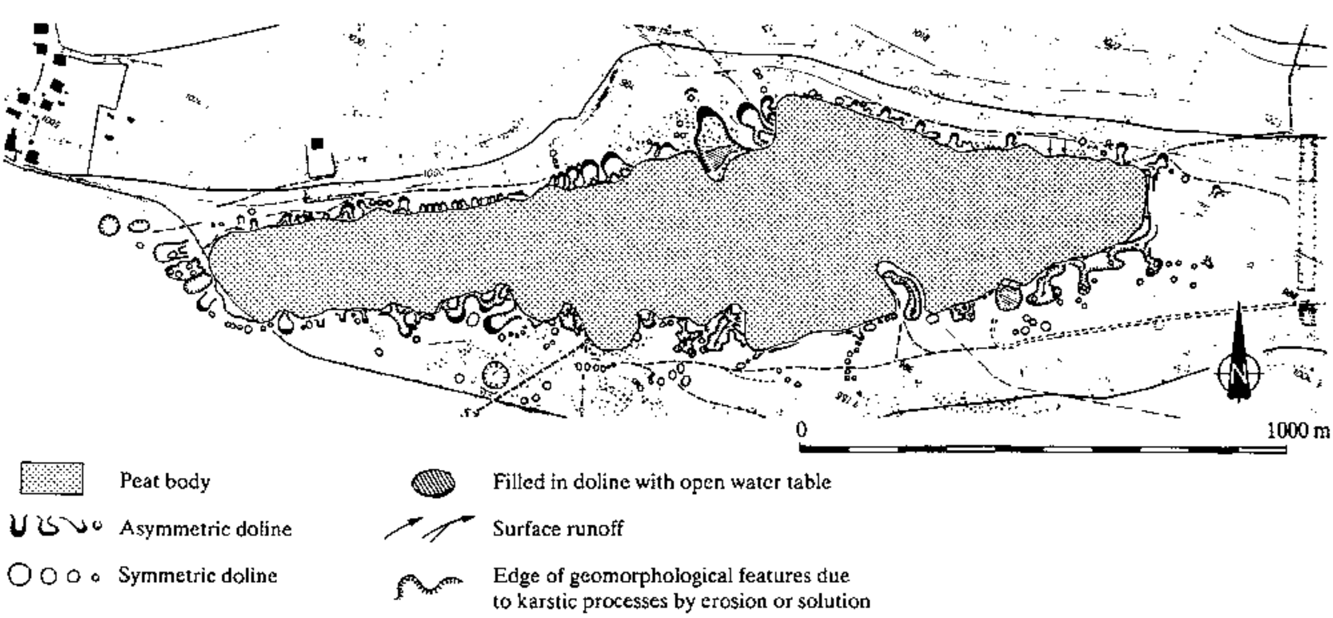


Fig. 3.9.3. Geomorphological sketch map of the raised bog of La Chaux-des-Breuleux showing the natural control of lateral mire expansion by karstic features (dolines). The bog developed in a syncline over an impervious Tertiary sediment layer (modified from Gerber 1989).

3.9.4 Climate

The climate in the Franches-Montagnes is determined by its topographical situation in central Europe, 650 km from the Atlantic and 550 km from the Channel at an elevation of 1,000 m. The climate is rather continental in its temperature (the mean annual is 5.4° C) and rather oceanic in the amount of rain which falls (mean annual is between 1,250 to 1,300 mm). However, it is a dry region, suffering frequent drought periods during summer because of the high permeability of the karst. People were even forced to build farm houses with huge roofs to collect as much rain-water as possible. The water was stored in a cistern and used for watering the animals or for drinking water during dry periods. Generally, the climate is recognized as one of the harshest of all European stations, with an elevation of approximately 1,000 m.

3.9.5 Specifications of the bog

The bog, situated at an altitude of 1,000 m, is 2 km long and up to 300 m wide. It covers the valley floor running north-east to south-west and overlaps the territory of cantons Jura and Berne. It is typical of raised, ombrotrophic peat bogs which have been cut over. An unexploited mound of peat (with a thickness of 3.5 m) in the centre of the bog still gives an idea of the original shape (Fig. 3.9.1). However, as a result of intensive peat exploitation, the whole bog area is criss-crossed by about 190 km of ditches of different depths and widths. These contribute to lowering the water-table within the bog.

Despite intense human impact, la Tourbière de la Chaux-des-Breuleux is one of the most important raised bogs of this region; its surface of about 40 ha of ombrotrophic peat is the third largest in all Switzerland. Parts of the bog have been a nature reserve since 1974. The bog area is surrounded by pastures or by pastured woodland which is a very typical landscape element of the Franches-Montagnes area.

3.9.6 Vegetation

As a result of extensive drainage, the actual vegetation consists mostly of heather *(Calluna vulgaris)* and dry stands of hare's-tail cottongrass *(Eriophorum vaginatum)*. Patches of *Sphagnum magellanicum* are still growing on the non-exploited peat mound which has remained in the bog's centre. Figure 3.9.4 shows the zonation of vegetation at the edge of this mound where peat cutting has modified the hydrological conditions. On the eastern side of the mound, a big peat cutting pit is now entirely invaded with bottle sedge (*Carex rostrata;*

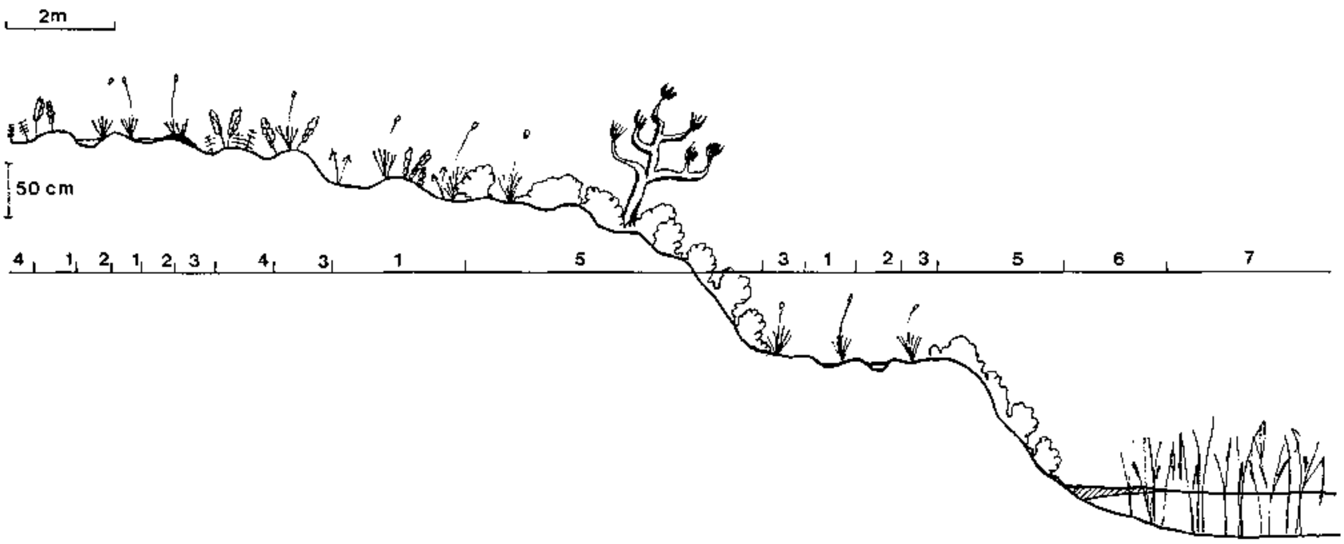


Fig. 3.9.4. Cross-section showing micro-relief and vegetation through the partially exploited bog of La Chaux-des-Breuleux (from Feldmeyer-Christe 1990c).

1 Typical sub-association of the Sphagnetum magellanici (red hummocks);
2 *Sphagnum tenellum* variant of the Sphagnetum magellanici sub-association with *Cladonia arbuscula;*
3 *Sphagnum fuscum* variant of the Sphagnetum magellanici sub-association (brown hummocks);
4 *Cladonia arbuscula* and *Polytrichum alpestre* variant of the Sphagnetum magellanici sub-association;
5 *Vaccinium uliginosum* stage partly invaded by *Pinus mugo;*
6 *Sphagnum angustifolium* variant of the Caricetum rostratae sub-association;
7 Typical sub-association of the Caricetum rostratae.