Chapter 1
Geoarchives – Why View the Past?

Abstract Comprehensive knowledge of climate and landscape dynamics is essential to obtain a basic understanding of the recent geoecological situation and to assess possible future developments. High mountains and their ecosystems offer an outstanding opportunity for studies on the impact of climate change. The Pirin Mountains in Southeast Europe, situated at the transition between temperate and Mediterranean climate, are considered very sensitive to historical and current global changes. To evaluate the current situation, the existing climate proxy data sets need to be amended by precisely dated and highly time-resolved geoarchives spanning past centuries. Thus, the examination aims to reconstruct climate variability on different time scales, allowing us to improve the regional and sub-regional knowledge of facts and ecosystem services due to trends of global climate change.

Keywords Climate and Landscape development • Geoarchives • Methods • Southwest Bulgaria

1.1 Introduction and Objectives

The anthropogenic change of the natural and cultural landscape increasingly affects ecosystems throughout the world on a regional and global scale. Resulting ecological and economic developments need to be recorded and, if possible, sustainably assessed. Therefore a comprehensive understanding of the structure, function and dynamic nature of these ecosystems is essential.

Our working group carried out such investigations in southeastern Europe for several years (Grunewald and Stoilov 1998; Grunewald et al. 1999, 2007; Grunewald and Scheithauer 2008a). The center of interest is the northern Pirin and its flanking basins and valleys. Due to the biodiversity, this area can be regarded as an important refuge (Griffiths et al. 2004). The highest areas are most affected by the pressure of land use and also by climatic alteration. The ecosystem structures,

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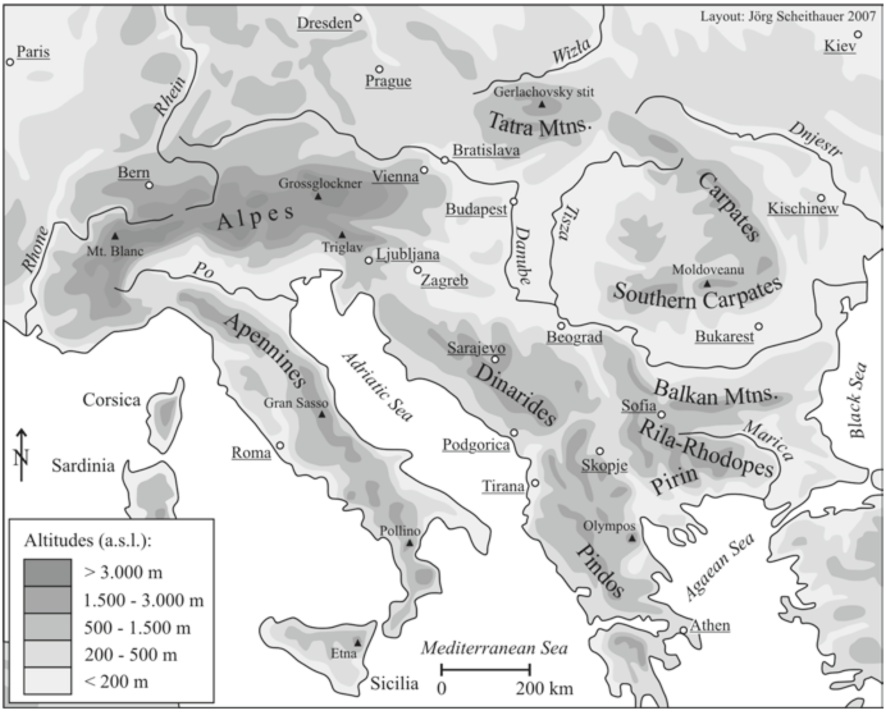

Fig. 1.1 Pirin Mountains as part of the mountain system of southeastern Europe

processes and dynamics of Southwest Bulgaria are representative of the mountain regions of the Balkan Peninsula (Louis 1930; Schönenberger and Neugebauer 1987; Grunewald et al. 1999).

Southeast Europe constitutes a mosaic of several small mountain regions and countries (Fig. 1.1). This strong internal differentiation generates a wide diversity of local physico-geographical and socio-economic situations. On the one hand, high mountain regions such as the Pirin Mountains receive ample precipitation and experience permanently low temperatures. On the other hand, the southern peripheral areas, either highlands or lower areas, are dry and warm (for instance, in northern Greece). Consequently, this strong local geographic diversity offers limited options for extended land use but high potential for nature conservation and recreation areas. However, isolation endured under its eastern bloc political regime, as well as the effects of Balkan historical complexity, have left their mark on the region. Systematic environmental screening is still an exception in this area of Europe (Alitchkov and Kostova 1996; Grunewald and Stoilov 1998; Grunewald et al. 2007). In addition, there is a considerable lack of knowledge regarding the dynamics of weather and climate (time and space), water supply (snow, lakes) and water availability (where and when) at the regional level.

Today, research on long-term past human–environment relationships is of increasing interest. There are efforts to reconstruct prehistoric environmental conditions and their spatiotemporal variability. This information is important, particularly with regard to the expected warming by about 2–4°C by the end of the twenty-first century (IPCC-Report, Solomon et al. 2007).

In historic and prehistoric times of low population density, periods of warm climate have always been advantageous to the population, particularly in mountainous regions such as southeastern Europe (Blümel 2002; Grunewald and Scheithauer 2008b). High mountain regions and their hypsometric zoning are central to the climate change debate because they are sensitive ecosystems and ecological boundaries are exceedingly struck by changes (Pauli et al. 1996, Beniston 1997, 2003; Messerli 2004; Grunewald and Scheithauer 2007; Solomon et al. 2007). Slight temperature variations shift cultivation limits and affect runoff regimes as well as slope stability or other ecosystem services. The mountains, such as Pirin, Rila and Rhodopes, are of extraordinary importance to adjacent semi-humid landscapes such as in North Greece (Grunewald et al. 2007).

The countries in southeastern Europe face challenges from economic and political transition, continuing vulnerability to environmental hazards, and longer term effects of global climate change. The EU-CLAVIER Project aims to help these countries (including Bulgaria) to cope with these challenges (www.clavier-eu.org). For instance, climatic crisis situations can stimulate adaptation strategies and technological innovations, as ancient mass migrations and current efforts to reduce CO_2-emission demonstrate (e.g. Lohmann 2006). Current climate change research in mountains focuses on (cf. Häberli and Beniston 2004):

- The turnover of greenhouse gases
- The expressiveness of long-term instrumental measurements
- The observation of key indicators of environmental change
- Numeric models for analyzing present and future climates in high mountains

The southwestern Bulgarian Pirin Mountains represent an important ecological link between the Mediterranean region and the mid-latitudes. They are the transition between southern European areas where ever taller and thicker trees at the timberline in first line are controlled by the water supply, and the humid high mountains of Europe where the summer temperatures foster tree growing (Grunewald and Scheithauer 2008c). In this transition area, little climate changes have a big effect on environmental conditions and change balances, sometimes, for example, favoring one or the other plant community.

Very different geo-biotopes which are suitable to study the natural landscape and climate dynamics are distributed in the subalpine area of the Pirin Mountains. The altitude of the mountain forest depends on climate-ecological conditions and site characteristics as well as the anthropogenic influences whose examination needs explicit study. Systematic research of the alpine timberline in southeastern Europe's high mountains are not available since Horvat et al. (1974). The endemic tree species *Pinus heldreichii* and *Pinus peuce* show vegetation-historical, climatic, ecological, and local peculiarities (Velchev 1997; Stefanova and Ammann 2003; Grunewald and Scheithauer 2008c).

The main aim of our studies is the reconstruction of climate variability in the high mountains of southeastern Europe, especially in the Pirin Mountains. We analyzed the following temporal dimensions (time scales):

- Scale of millenniums (Holocene, ca. 10,000 years)
- Scale of decades to centuries (modern times, ca. 500 years)
- Scale of days to years (present time)

First, we performed a physico-geographic and environmental mapping of the study area (Grunewald et al. 1999). The main results, which are of fundamental importance for the geoarchives approach, are described in Chapter 2. By characterizing the recent timberline (morphodynamic and soil characteristic, climate parameter, vegetation) we established the basis for analyzing future geodynamic processes.

The research respective to the region's timberline dynamics will be shown. We describe recent timberline ecotones based on selected test plots and sampled sites in the Pirin Mountains. This first implies the analysis and climatical interpretation of the Holocene development of vegetation at higher mountain positions of the Pirin Mountains (Chapter 3). Therefore, we analyzed works of Bulgarian geo-scientists concerning lakes, peats, and vegetation, and we have drawn conclusions based on comparable mountains (the Alps). Drawing on the Pirin Mountains, the southeastern European Holocene climate and landscape development can be well characterized and, through the ups and downs of civilization it can be compared to Southwest Bulgaria (Pirin/Rila Mountains, the valleys of the Struma and Mesta rivers, intra-mountain basins, cf. Chapter 3).

Moreover, relative long climate data series, firn and ice layers of glacierets, soils and moraines, as well as rings of trees several centuries old, were analyzed (Chapter 4). The objective was to reconstruct 500 years of climate development for different time scales (from annual to multi-decadal fluctuations). The results of this palaeo-geoecological method cooperation have a novelty value and close a regional research gap.

The regional peculiarities of climate and landscape history on different time scales are summarized in Chapter 5. Information saved in environmental archives was reliably calibrated and accurately transferred into temperature and precipitation estimation. For that, proxy-data such as tree-ring-width, maximum late wood density, firn density, ions or stable isotopes (^{13}C, ^{18}O) were related to direct climate data sets (temperature, precipitation). Climate "proxies" are sources of climate information from natural archives. The relationship between tree-rings and climate parameters, for example, was determined by calculating correlations and the so-called "response functions" (Cook and Kairiukstis 1992; Oberluber et al. 2008). In addition, the statistical values of the mountain tree-ring chronologies show a proxy for the timberline dynamics because growth-limitated climate conditions should be reflected in stronger or weaker population signals.

1.2 Reasons and Scales for Climate Changes

During Quaternary, with its change of warm and cold periods (interglacial/glacial or warm and ice ages), the high mountains were repeatedly glaciated in Southwest Bulgaria. The multiple climate changes have influenced the ecosystem's basic characteristics seen today, from the relief to flora and fauna, to the water balance, to the soil.

The glacial cycles of the Pleistocene, which included in each case about 100,000 years (Veit 2002), are not considered as they were not the focus of our research. Only the last glacial period, the Würm glaciation, is outlined to analyze the initial landscape development (Chapter 3).

Concrete geo-chronological findings of climate and landscape history are available for the Pirin region since the Late-glacial (period between the end of the Würm glacial maximum and the beginning of the Postglacial/Holocene). The stages and their temporal integration are also discussed in Chapter 3. Thus, the recent interglacial, the Holocene, is a focal point of the presentation (Fig. 1.2). Only the shortest and youngest part of this geological time epoch, the time period since medieval times, can be verified by higher resolution and resilient facts on climate and landscape development. Moreover, this period is the easiest for us to understand.

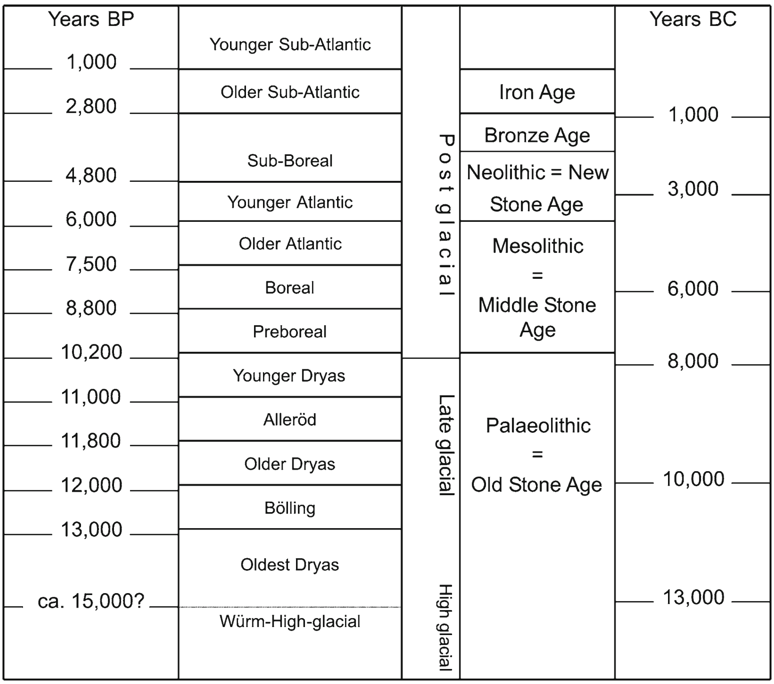

Fig. 1.2 Time-scale and cultural-historic distribution of the Younger Pleistocene (acc. Blümel 2002, modified)

Over millenniums, the climate change is above all determinated by the fluctuation of the earth's orbit parameters (so-called Milankovitch-forcing) as well as changes of the planetary albedo and the composition of the atmosphere (greenhouse gases, aerosols) (Rahmstorf and Schellnhuber 2007; Wanner et al. 2008). Occurrences such as volcanic eruptions, meteorite impacts and self-enforcement effects (positive feedback) considerably influence the effects of the changes. Wanner (2007) compared the correlation of these natural climate-driving factors of the earth's energy balance with the two most important modes of the internal variability system: ENSO – El Niño Southern Oscillation, and NAO – Northern Atlantic Oscillation. He proved that the radiation supply on the northern and southern hemisphere inverted about 5,000 years before present (BP, before AD). Therefore, the summer solarization maximum translocated, which led to a shifting of the circulation and climate belts. Southeastern Europe, our area of study, became moister during the mid Holocene period (circa 6,000 BP). Such a change is singular for the Holocene and is an example of long-term dynamics.

From decades to centuries, the reconstructed data series show quasi-periodicities which, however, are rarely temporal and regionally synchronous (Wanner 2007). Archives have to be examined as precisely as possible with new methods for better understanding, comparing and interpreting the reasons, strengths, regional effectiveness and temporal courses of natural climate changes (Bubenzer and Radtke 2007). Accordingly, a principal aim of our work in the Pirin Mountains was to select and produce data to close regional research gaps.

Since the Stone Age, anthropogenic activities have drawn attention to the climate system (greenhouse gases, land use, aerosols). However, the anthropogenic signal only became clearly visible since the industrial-energetic revolution and its significant increase to the CO_2-concentration of the atmosphere. Hence it is presumed that climate and nature will not remain within the relatively close boundaries of the Holocene in the foreseeable future. The instrumental climate measurements started in the 1930s in the southeastern European mountain areas (Sharov et al. 2000). Thus, only the past 80 years can be verified by direct, well-defined climate data. Data of regional climate stations were investigated, statistically tested, analyzed and interpreted. On this basis, trends, extremes and threshold values of the regional mountain climate were characterized (see Chapter 4).

1.3 Archives and Methods

The application of specific indicators and methods is necessary to value long-term climate and environmental events and dynamics. Soils, lake sediments, trees and geoarchives such as moraines, timberline ecotones and glaciers, are available in high mountains for reconstruction purposes. They are analyzed by means of geoecological fieldwork techniques as well as by biological, physical and chemical laboratory methods (Geyh 2005). In particular, analysis concerns age determination of different temporal resolution samples.

First, research in dendroclimatology, palynology, lichenometry, palaeozoology, sedimentology, loess stratigraphy, tephrochronology, isotope analysis and the analyses of historical documents are established (Röthlisberger 1987). It is important to examine different indicators in different (geo-) archives of one area so that the results supplement, correct and confirm each other, as reconstruction always contains elements of uncertainty. The measured climate data help to verify the examined landscape archives, especially tree-ring widths and the area variance of the glacierets.

The climate signals, which are saved in different geoarchives, do not produce immediate values for temperature or precipitation, but only produce indirect indicators, the so-called proxy data. All data show different accuracies, temporal resolutions and regional significance of former climate and landscape conditions. In the case of climate reconstruction, several methods should be used for validation, i.e. morphogenetic phases known in the cirques should be checked against historical sources and independent physical records such as lichenometry, dendroclimatology and historical climatology. Table 1.1 shows the available geoarchives of the Pirin region, including indications as to whether the archives have already been examined.

The climate archives relevant in the research area are numerous but they supply incomplete and proxy data that do not reach far back in time. Relatively complete climate archives on their own solely represent the polar ice mass and marine or limnic sediments. However, we will attempt to correlate the fragmentary facts with complete and more precise marine and glacier data sets, including regional comparisons with well-examined mountains such as the Alps. Absolute dating methods will be used for the temporal classification of former climate changes (Bradley 1999; Geyh 2005), whereas in the Pirin Mountains, the ^{14}C-radiocarbon method has almost always been applied.

The analyses of the cirque lake sediments and peats constitute an important basis for reconstruction, especially for vegetation historical analyses, because they often show ideal deposit and preservation conditions (Geitner and Becht 2001; Stefanova et al. 2006). Lithology, pollen analysis, macrofossils and radiocarbon

Table 1.1 Geoarchives for the reconstruction of environmental and climate change in Southwest Bulgaria (time period acc. Bradley 1999; Bubenzer and Radtke 2007)

Archive	Minimum ascertainable period of time (years)	Maximum ascertainable period of time (years) (in brackets: analyzed in Pirin Mountains)
Ice/glacier (glacieret)	1	10^6 (10^2)
Limnic sediment (cirque lake)	<1	10^5 (10^4)
Moraine	10^2	10^6 (10^3)
Soils (fossil)	10^2	10^6 (10^4)
Sinter (stalactite)	10^2	10^5 (–)
Fluvial deposits	10^2	10^5 (–)
Tree-rings	<1	10^4 ($10^{2\text{ bis }3}$)
Pollen, Macrofossils	1	10^5 (10^4)
Peat bogs	10^2	10^5 (10^4)

dating of these archives supply good information on vegetation history, climate phases, morphological activity as well as anthropogenic impacts. The spectrum of methods was already developed in northern Europe and the Alps at the beginning of the twentieth century (cf. Gams 1963) and has been further improved and completed since then (e.g. Faegri and Iversen 1989; Beug 2004).

Our working group has already examined a number of soils, which helps solidify our understanding of landscape history since the Mid-Holocene (Chapters 3 and 4). Unfortunately, only one moraine in the "Kasan cirque" could be included in modern geochronological research. Around 70 findings from different laboratories on the radiocarbon dating of pollen, macrofossils, humus sediments and charcoal are available for the Pirin region. The oldest radiocarbon age comes from the sediment of the Kremensko Lake in northeastern Pirin and dates back to 13,526 years BP (15,872–16,285 cal BP, cf. Stefanova et al. 2006).

The concrete research as to the archives of timberline ecotones, glacierets and dendroecology of *Pinus heldreichii*, as well as the applied methods, is considered in Sections 4.2–4.4.

References

Alitchkov DK, Kostova IS (1996) Possibilities for water conservation in Bulgaria. GeoJournal 40(4):421–429

Beniston M (1997) Variation of snow depth and duration in the Swiss Alps over the last 50 years: links to changes in large-scale climatic forcings. Clim Change 36(3–4):281–300

Beniston M (2003) Climatic change in mountain regions: a review of possible impacts. Clim Change 59:5–31

Beug H-J (2004) Leitfaden der Pollenbestimmung für Mitteleuropa und angrenzende Gebiete. Verlag Dr. Friedrich Pfeil, München

Blümel WD (2002) 20000 Jahre Klimawandel und Kulturgeschichte – von der Eiszeit in die Gegenwart. In: Wechselwirkungen – Jahrbuch aus Lehre und Forschung der Universität Stuttgart

Bradley RS (1999) Paleoclimatology. Reconstructing climates of the quarternary, vol 68, 2nd edn. Academic Press, London

Bubenzer O, Radtke U (2007) Natürliche Klimaänderungen im Laufe der Erdgeschichte. In: Endlicher W, Gerstengarbe F-W (Hrsg.): Der Klimawandel – Einblicke, Rückblicke und Ausblicke. Potsdam, pp 17–26

Cook ER, Kairiukstis LA (1992) Methods of dendrochronology – applications in the environmental sciences. Kluwer Academic, Dordrecht, Boston, London

Faegri K, Iversen J (1989) Textbook of pollen analysis, 4th edn. Wiley, Chichester

Gams I (1963) Logarcek Cave. Acta Carsologica 3:7–84, Ljubljana

Geitner C, Becht M (2001) Fluviale Sedimente der subalpin-alpinen Höhenstufe in den Zentralalpen als Archive für landschaftsgeschichtliche Untersuchungen. In: Innsbrucker Jahresbericht 1999/2000 der Innsbr. Geogr. Ges., pp 140–147

Geyh MA (2005) Handbuch der physikalischen und chemischen Altersbestimmung. Wiss. Buchgesell, Darmstadt

Griffiths HI, Krystufek B, Reed JM (2004) Balkan biodiversity: pattern and process in the European hotspot. Springer, Kluwer, Netherlands, Dordrecht

Grunewald K, Scheithauer J (2008a) Klima- und Landschaftsgeschichte Südosteuropas. Rekonstruktion anhand von Geoarchiven im Piringebirge (Bulgarien). BzL Band 6. RHOMBOS-Verlag, Berlin

Grunewald K, Scheithauer J (2008b) Holocene climate and landscape history of the Pirin Mountains (Southwestern Bulgaria). Managing alpine future. In: Borsdorf A, Stötter J, Veulliet E (eds) Proceedings of the Innsbruck Conference, IGF-Forschungsberichte, Band 2, Verlag der Österreichischen Akademie der Wissenschaften, Oct. 15–17, 2007, pp 305–312

Grunewald K, Scheithauer J (2008c) Untersuchungen an der alpinen Waldgrenze im Piringebirge (Bulgarien). Geo-Öko 29:1–32

Grunewald K, Stoilov D (1998) Natur- und Kulturlandschaften Bulgariens. Landschaftsökologische Bestandsaufnahme, Entwicklungs- und Schutzpotenzial. Bulgarische Bibliothek, Neue Folge, Band 3, Biblion Verlag, Marburg

Grunewald K, Haubold F, Gebel M (1999) Ökosystemforschung Südwest-Bulgarien. Untersuchungen zur Struktur, Funktion und Dynamik der Landschaften im nördlichen Pirin und im Becken von Razlog. Dresdener Geographische Beiträge, Heft 5, Im Selbstverlag der TU Dresden, Institut für Geographie, Dresden

Grunewald K, Scheithauer J, Monget J-M, Nikolova N (2007) Mountain water tower and ecological risk estimation of the Mesta-Nestos transboundary river basin (Bulgaria-Greece). J Mountain Sci 4(3):209–220

Häberli W, Beniston M (2004) Klimawandel und Gebirge. In: Gamerith W et al (eds) Alpenwelt – Gebirgswelten. Tagungsbericht und wissenschaftliche Abhandlungen. 54. Deutscher Geographentag, Heidelberg und Bern, pp 113–114

Horvat I, Glavač V, Ellenberg H (1974) Vegetation Südosteuropas. G. Fischer Verlag, Jena

Lohmann L (ed) (2006) Carbon trading. A critical conversation on climate change, privatisation and power. Dag Hammerskjöld Foundation, Uppsala

Louis H (1930) Morphologische Studien in Südwest-Bulgarien. Geographische Abhandlungen. J. Engelhorns Nachf, Stuttgart

Messerli B (2004) Von Rio 1992 zum Jahr der Berge 2002 und wie weiter? Die Verantwortung der Wissenschaft und der Geographie. In: Gamerith W et al (eds) Alpenwelt – Gebirgswelten. Tagungsbericht und wissenschaftliche Abhandlungen. 54. Deutscher Geographentag, Heidelberg und Bern, pp 21–42

Oberluber W, Kofler W, Pfeifer K, Seeber A, Gruber A, Wieser G (2008) Long-term changes in tree-ring–climate relationships at Mt. Patscherkofel (Tyrol, Austria) since the mid 1980s. Trees 22:31–40

Pauli H, Gottfried M, Grabherr G (1996) Effects of climate change on mountain ecosystems – upward shifting of alpine plants. World Resour Rev 8(3):382–390

Rahmstorf S, Schellnhuber HJ (2007) Der Klimawandel. Diagnose, Prognose, Therapie. Beck Verlag, München

Röthlisberger F (1987) 10.000 Jahre Gletschergeschichte der Erde. Verlag Sauerländer, Aarau, Frankfurt a.M, Salzburg

Schönenberger R, Neugebauer J (1987) Einführung in die Geologie Europas. Rombach, Freiburg

Sharov V, Koleva E, Alexandrov V (2000) Climate variability and change. In: Hristov T et al (eds) Global change and Bulgaria. Bulgarian Academy of Science, Sofia, pp 55–65

Solomon S, 7 others (eds) (2007) Climate change 2007: the physical science basis. Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge

Stefanova I, Ammann B (2003) Late-glacial and Holocene vegetation belts in the Pirin Mountains (southwestern Bulgaria). Holocene 13(1):97–107

Stefanova I, Atanassova J, Delcheva M, Wright HE (2006) Chronological framework for the Lateglacial pollen and macrofossil sequence in the Pirin Mountains, Bulgaria: Lake Besbog and Lake Kremensko-5. Holocene 16(6):877–892

Veit H (2002) Die Alpen – Geoökologie und Landschaftsentwicklung. UTB Band 2327. Ulmer, Stuttgart

Velchev V (1997) Types of Vegetation. In: Yordanova M, Donchev D (eds) Geography of Bulgaria (in Bulgarian). Bulgarian Academy of Science, Sofia, pp 269–283

Wanner H (2007) Der Klimawandel in historischer Zeit. In: Endlicher W, Gerstengarbe FW (Hrsg.): Der Klimawandel – Einblicke, Rückblicke und Ausblicke. Potsdam, pp 27–33

Wanner H, Beer J, Bütikofer J et al (2008) Mid- to Late Holocene climate change: an overview. Quatern Sci Rev 27(19–20):1791–1828