3 Study area

The study area centres on the site of the Iceman and extends north and south of the watershed, i.e., the main divide of the Alps (Fig. 1-3, see attachment). The region where the Iceman was found is still referred to as Tyrol (Tirol). In 1919, the southern part (South Tyrol, Südtirol) became part of Italy and the northern part (North Tyrol, Nordtirol) remained Austrian. In the past, the area with the main municipalities Schnals and Vent belonged to the county of Tschars (Vinschgau, South Tyrol), but after World War I, Vent was merged with the municipality of Sölden, whereas the whole southern area became Italian. The area played an essential role in the development of alpinism, alpine tourism and the foundation of the continental Alpine Club which was initialised by the famous clergyman Franz Senn (Vent) and his companions. For a comprehensive overview of the local history, especially on the villages Schnals and Vent see Hendricks et al. (1990), Schlosser (2012) and Scharr (2013).

3.1 Geography

The investigated area stretches from southernmost Ötztal (North Tyrol) to the north-western South Tyrol (Haider See), eastwards to about Brixen/Pustertal and southwards to mid Martelltal. The place where the Iceman was found lies at 3,210 m a.s.l., near Hauslabjoch and Tisenjoch (latitude 46°50'N, longitude 10°50'E). For a general view of the studied area and the investigated 1 km² squares see Fig. 1-3 (attachement). The core area with the valleys and mountain ridges (Fig. 1) around the Iceman site is colloquially known as "Ötziland" (Dickson 2011b).

The core area comprises Vinschgau (Naturns village, Castle Juval, Schlanders village), the Schnalstal (the villages of St. Katharinaberg, Karthaus, Vernagt and Unser Frau) up to Kurzras village with the side valleys Pfossental, Klosteralm, Penaudtal, Mastauntal, Finailtal and Tisental leading up to the discovery place of the Iceman. Also the Schlandrauntal/Taschljöchl and the Pfeldderertal until it leads into the Passeiertal were investigated. On the Austrian side, leading down from the Iceman site beside the Niederjochferner (glacier), the study sites comprise Niedertal with Vent, Zwieselstein and Nachtberg/Sölden as well as the Rofental and Tiefenbachtal/Tiefenbach Ferner along the Panorama trail and the way up to the Breslauerhütte. Further 1 km² squares are scattered around the core area such as on the Italian side the Langtaufererertal, the Matschertal, Haidersee, Oris village, Castle Tarantsberg, Partschins village, Martelltal, Oberthalmühle and Marlingerberg as well as more remote sites in the Eisacktal around Brixen with Tils, Kreuztal, Latzfons, Pfunderer mine, Laugen, Cloister Säben, Lajen, Dörf in the Pustertal, Valsertal, Altfasstal and Villnoder. On the Austrian side, detached squares are at Hohe Mut/Obergurgl (Fig. 1).

Apart from cultivated ground around the villages and at the valley bottoms, large parts of the investigated core area lie in the Naturpark Texelgruppe (Italy) and the Naturpark Ötztal (Austria). Within the investigated area there is a considerable altitudinal range from ca. 520 m a.s.l. (Naturns) and ca. 1,360 m a.s.l. (Sölden) to well above 3,000 m a.s.l.

3.2 Geology

Geologically, the investigated area belongs to the Eastern Alps. At a coarse scale, the main bedrocks in the core area are polymetamorphic gneisses and related rock formations belonging to the Ötztal-Stubai-complex (Klebelsberg 1935; Tollmann 1977; Purtscheller 1978; Frank et al. 1987; Hoinkes & Thöni 1993; Schmidt et al. 2004; Krainer 2010). Fig. 3.1 shows a geological map of the investigated area. The leading bedrocks in the surroundings of Brixen/Eisacktal are phyllites (Geitner 2004; Schmidt et al. 2004). The main underlying bedrock types are all siliceous and lead to soil types with an acidic reaction (pH below 6). Exceptions are the Langtauferertal region where outcrops of Mesozoic limestones/dolomites from the "Engadiner Window" prevail and the so-called "Schneebergzug", a special rock formation of metamorphic limestone, often transformed to marble (Frank et al. 1987), at the border between Austria and Italy. Especially at the upperparts of the Pfossental and Pfelderertal this calcareous/marble berock overlays the gneisses. The same holds for the valley bottom of Obergurgl and Vent/Rofen (Konzett et al. 2003; Tropper et al. 2012). In Vinschgau, the Laaser series with the famous white marble forms the boundary (Hoinkes 1980; Krainer 2010). In contrast to siliceous soils, those on the Schneeberg complex have a pH around and above 7.

Apart from the specific bedrock, the soil development is further influenced by mineralogical composition and grain size of ground material, (micro)climate (especially temperature and precipitation), weathering (mainly because of physical processes), vegetation, soil fauna and microorganisms, surface structure, water influence and erosion. At high altitudes, the soil development usually starts with virgin soils (Regosol) which further develop to Pararendzina (Rendzic Leptosol). Under undisturbed conditions they may develop to Braunerde (Cambisol) or Podzol. Fluvisols accumulate along the margins of streams and rivers (Alluvium); see also Kuntze et al. (1988) FAO (1998) and Schwienbacher & Koch (2010). Bedrock, soil reaction and chemistry greatly influence the existing moss flora, only a few widespread bryophyte species are indifferent on soil reaction (Dierssen 2001).

3.3 Climate

The investigated area has a temperate climate, which varies not just from the lowland to the higher altitudes, but also from north to south. Because of the high mountain ridges, there is less precipitation south of the main alpine divide. Therefore, most of the Italian part of the investigated area has a drier environment

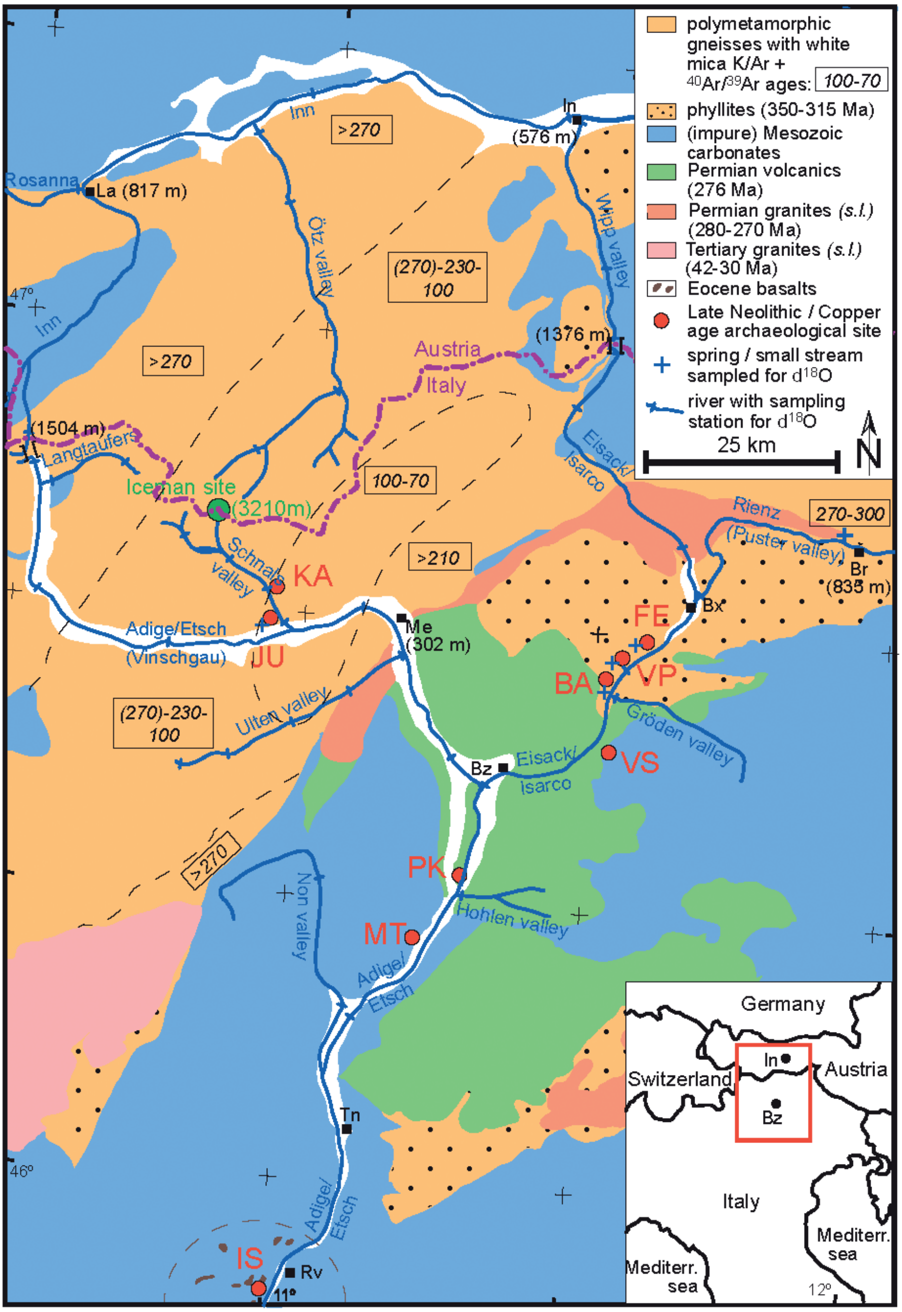

Fig. 3.1: Geological map of Tyrol (Müller et al. 2003b).

than the Austrian part in the north (see also Schiechtl & Stern 1980).

The Austrian part of the study area, north of the central alpine divide shows higher elevation with the lowest altitude near Sölden (1368 m a.s.l.), being wetter (851 mm annual precipitation) and colder with a mean annual temperature of 2.8 °C (Obergurgl 1938 m a.s.l., Fischer 2010). The Italian part, south of the central alpine divide, descends to much lower altitudes, e.g. 518 m a.s.l. at Naturns, being drier (805 mm annual precipitation) and much warmer with a mean annual temperature of 10.3 °C (https://de.climate-data.org, accessed 20th June 2018). In middle Vinschgau, from Naturns to Mals, the climate is quite continental and the lowermost, south-facing slopes are warmer and drier with a submediterranean climate (Schlanders, 720 m a.s.l., annual mean temperature 9.1 °C, annual precipitation 801 mm; https://de.climate-data.org, accessed 20th June 2018). The Vinschgau main valley is somewhat sheltered by mountain ridges and less precipitation is recorded, therefore it is often referred to as an "inner alpine dry valley." Within the study area, temperature and snow cover vary greatly with altitude and aspect; permanent snow and glaciers occur above 2500 m a.s.l. and especially above 3000 m a.s.l. (Dickson 2011b). North of the central alpine divide, the glaciated area is still much larger according to the higher precipitation and the lower mean temperatures. However, since more than 150 years the glaciers are more or less drastically retreating (Abermann et al. 2013). For instance, the glaciers around Obergurgl reached their maximum historical expansion around 1850, with the end of the Little Ice Age. Since that time, the glacier area was reduced by about 50 %. Since the beginning of the climate measurements in Obergurgl in 1953 the mean annual temperature increased by 1.2 °C (Fischer 2010).

3.4 Vegetation

In the south, the study area extends from the colline (525 m a.s.l.) to the nival zone (3,242 m a.s.l.), in the north from the montane (ca. 1,450 m a.s.l.) to the nival zone (3,242 m a.s.l.). The potential treeline would be at 2,300 m a.s.l. The actual treeline, however, was lowered by 200 – 400 m (Ellenberg & Leuschner 2010) due to human activities from prehistoric times until present (Jandl et al. 2012). The human impact in high altitudes of the study area dates back to more than 6,000 years (Vorren et al. 1993; Bortenschlager 2000). According to palynological records, the treeline was located more or less at an elevation of 2,250 m a.s.l. ± 200-250 m during the whole Holocene (Bortenschlager 2010). Land use and settlement of the inner Ötztal occurred from the higher altitudes down to the valley, originating from the southern side of the central alpine divide (Bortenschlager 2000).

Even today, large parts of the study area represent a sustainably developed rural landscape, although recently influenced by modern agriculture and tourism. The high number of old wooden farm buildings provides a special charm to Ventertal and Schnalstal, as already stressed by Schiechtl & Stern (1980). Even at present, many of these ancient buildings are in use.

For the distribution pattern of the actual and potential vegetation see Pitschmann et al. (1980) and the "Tirolatlas" (www.tirolatlas.uibk.ac.at), for the northern part of the study area, and Peer (1991, 1995), for the southern part.

In the following, a brief description of the vegetation begins from the lowest site of the investigation area to the highest one and includes also some azonal vegetation types. There is no intention to give a comprehensive overview of the vegetation but some of the most important plant communities will be mentioned.

Orchards and meadows in the valley bottom and on the lower slopes

Regarding the cultivated land, great differences exist between the Austrian and the Italian part of the study area. Whereas meadows and small vegetable crop fields (e.g. Potato – *Solanum tuberosum*) occur in the flatter parts around Vent, extensive fruit orchards and other intense cultures expand in the Vinschgau lowland. Side valleys such as the Schnalstal, with their very steep slopes, appear to be more similar to the northern areas in respect of cultivation apart from their dry southernmost slopes. There is hardly any potentially natural vegetation left on the valley floor of Vinschgau – now the striking features of that area are the millions of apple trees planted in recent decades (Fig. 3.2). Formerly, cereals and Opium Poppy (*Papaver somniferum*) have been important crops, but now fruit trees are by far the major crop. The dense fruit trees are restricted mainly to the colline belt usually below ca. 500 – 600 m a.s.l. Meadows and pastures are reaching higher altitudes and occur mainly on the steep slopes of the side valleys (Fig. 3.3, 3.4). These meadows are watered, cut two or three times a year and fertilised, the associations belonging to the order Arrhenatheretalia.

Colline to lower montane zone – up to ca. 1,000 m a.s.l. (only in the southern part of the study area)

Steppe heath

A specialised vegetation type adapted to dry conditions can be seen on the lower south facing slopes of Vinschgau (usually below 1,000 m a.s.l., but single steppe elements may reach much higher elevations), Schnalstal and Schlandrauntal. Associations of the Festuco-Brometea class and the orders Festucetalia valesiacae and Brometalia erecti occur. Traditionally grazed, this type of vegetation is home to many rare steppe plants and also the bryoflora is peculiar.

Submediterranean deciduous woodland

The lowest and warmest part of the southern study area is characterized by a submediterranean vegetation. From Bozen north-westwards through the Etschtal-Burggrafenamt to the Vinschgau valley and upwards to middle Schnalstal the climate is mild enough to sup-

Fig. 3.2: Looking down on Castle Juval (square 7). In the valley bottom, in the Vinschgau, the extensive apple orchards and the straightened out river Etsch can be seen.

Fig. 3.3: View of Vent village with green meadows, grey-green pastures and *Pinus cembra* forests (squares 82, 84, 85).

Fig. 3.4: Farm houses between Vent and Zwieselstein surrounded by very steep slopes with meadows, on the opposite side spruce-larch forest (square 91)

port broad-leaved deciduous trees and shrubs such as Hop Hornbeam (*Ostrya carpinifolia*), Downy Oak (*Quercus pubescens*), Manna-ash (*Fraxinus ornus*), Sweet Chestnut (*Castanea sativa*) and Small-leaved Lime (*Tilia cordata*) up to an elevation of ca. 800 m a.s.l. Associations from the order Quercetalia pubescentis with Orno-Ostryetum and Quercetum pubescentis and shrub communities from the Prunetalia order as well as the pioneer shrub community Corylo-Populetum prevail. However, large areas of the originally occurring deciduous woodland were cleared in favour of pastures and in the 19th and 20th centuries large parts of this open grassland were reforested with Black Pine (*Pinus nigra*).

Montane and subalpine zone from ca. 1,000 to 2,300 m a.s.l. (zone of forests north and south of the central alpine divide)

Coniferous forests

Typically, if the trees were not cut down long time ago (Stumböck 2000, 2002), the slopes of the valleys are covered by forest, with a timberline at 2,100 – 2,300 m a.s.l. All communities with tall conifers in the study area belong to the classes Vaccinio-Piccetea, Erico-Pinetea and Pulsatillo-Pinetea (the latter one only in the south). Today, large areas of the forest in the valleys are dominated by Larch (*Larix decidua*; Fig. 3.5). Deliberately encouraged in the past, this kind of open forest (Festuco-Laricetum) allowed a double use as pasture and as source for useful timber. In the areas with enough precipitation (e.g. Vent) we find mixed coniferous forests with Norway spruce (*Picea abies*) and Larch. Peculiar for the Central Alps is the Swiss Stone Pine/Arolla Pine (*Pinus cembra*) woodland, e.g. at Vent village (Fig. 3.6) and at Obergurgl (Mayer & Erschbamer 2012). Synsystematically the Swiss Stone Pine and Larch woodland belongs to Larici-Pinetum cembrae, developed at the timberline of the valleys (e.g. Pfossental, Pfelderertal, Obergurgl and Vent). At many areas, this woodland is now replaced by grasslands (Trisetetum flavescentis) or subalpine pastures (Crepido-Festucetum commutatae, Fig. 3.7, see also Mayer et al. 2012).

Some bryophytes form a consistent part of the understorey in these woodlands; a good example is *Hylocomium splendens*. However, the bryodiversity is more concentrated on specialised synusia such as bolder scree, shaded cliffs, crevices and rotten wood or bark.

Dwarf shrub heath

Just above the timberline or replacing felled woodland dwarf shrub heaths extend at ca. 1,600 – 2,400 m a.s.l. in the upper montane-subalpine-lower alpine belt, usually dominated by the True Alpine Rose (*Rhododendron ferrugineum*) on soil with acid reaction or Fringed Alpine Rose (*Rhododendron hirsutum*) on base-rich soil. These dwarf shrub communities belong to the class Loiseleurio-Vaccinietea with associations such as Rhododendretum ferruginei, Rhododendretum hirsutae or Rhododendro-Vaccinietum. There are also the low-growing conifers, such as the Dwarf Mountain Pine (*Pinus mugo*, Fig. 3.7) forming the alliance Erico-Pinion mugi, locally in large stands on the hillsides. Especially when relatively base-rich bedrock prevails, Common Juniper (*Juniperus communis* ssp.*nana*) occurs, forming the association Junipero-Arctostaphyletum. Also Savin (*Juniperus sabina*) may occur in this community.

Formerly, the dwarf shrub heath was regularly cut and burnt (in German called “schwenden”). Nowadays, this management practice is not allowed anymore.

On acidic, steep and moist slopes such as avalanche paths Green Alder (*Alnus alnobetula*) prevails. Usually many different bryophytes are present in this vegetation type (Alnetum viride). Here, widespread bryophytes are various species of *Barbilophozia* and *Pleurozium schreberi*, which are by no means only restricted to the dwarf shrub zone, they occur also in woodland below.

Pastures occur from well below the timberline to some hundred metres above the treelines (e.g. Crepido-Festucetum commutatae, Sieversio-Nardetum strictae). Today, these areas are grazed by sheep, goats, cattle and horses from below 2,000 to 2,500 m a.s.l.

Alpine and subnival zone from ca. 2,300 to 3,000 m a.s.l.

Alpine grasslands

In the alpine zone, dense alpine grasslands formed by sedges (*Carex curvula* - acidic soil; *Carex sempervirens* – lime-rich soil) as well as by grasses (*Nardus stricta* – acidic soil, *Sesleria caerulea* – lime-rich soil) occur depending on soil reaction. Corresponding vegetation types are from the class Caricetea curvulae with Caricetum curvulae and Sieversio-Nardetum strictae and from the class Seslerietea albicantis with Seslerio-Caricetum sempervirentis and Caricetum ferruginei. Apart from the soil reaction, the vegetation is often patchy according to soil depth and duration of snow cover. Wind edges with *Loiseleuria procumbens* (Loiseleurio-Vaccinion: Loiseleurietum procumbentis) and snow beds (e.g. with *Salix herbacea* or *Salix retusa*, *Salix reticulata*; Salicetum herbaceae on siliceous rock and Salicetum retusae-reticulatae on lime-rich rock) represent the extremes in respect of snow cover. Whereas the former is exposed at the crests without snow in winter, the latter may be covered with snow until mid-summer. If the ground is unstable due to permafrost

Fig. 3.5: Schnalstal, view down to lower Schnalstal with typical larch woodland on the steep slopes, in the background snow covered mountains (squares 10 to 16).

Fig. 3.6: *Pinus cembra* (Swiss Stone Pine) woodland on the slopes of Mutsbichl near Vent (square 84)

Fig. 3.7: Niedertal near the timberline with extensive *Pinus mugo* stands from behind a big erratic block called "Hohler Stein" (hollow stone), a place of prehistoric excavations (square 82).

such as in the subnival zone, the vegetation is very patchy and mainly characterized by snow bed vegetation and cryptogams. All in all the alpine and subnival zones represent classical cryptogam (co)dominated vegetation types with many different species of bryophytes and lichens forming miniature forests (Goffinet et al. 2012; Rozzi et al. 2012).

Fig. 3.8 – 3.13 give some further impressions of the landscape and vegetation in the alpine and nival zone.

Fig. 3.8: A frozen spring on a summer morning in the alpine zone (square 73)

Fig. 3.10: Gorge above the Martin-Busch-Hütte (square 69)

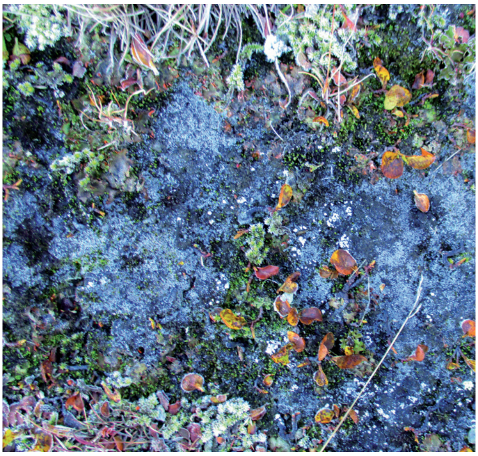

Fig. 3.9: Typical snowpatch with *Anthelia*, *Racomitrium elongatum* and autumn coloured leaves of *Salix herbacea* (square 73)

Fig. 3.11: Water irrigated scree in the alpine zone – a typical locality for *Grimmia mollis* (green cushions; square 70)

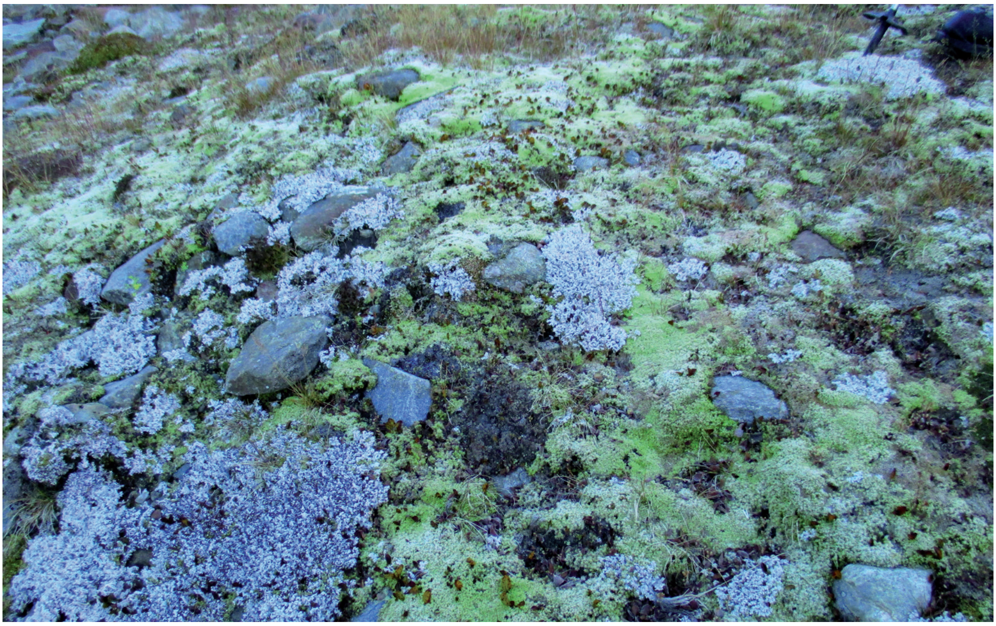
Fig. 3.12: Exposed wind edge in the alpine zone covered in bryophytes and lichens (square 68)


Fig. 3.13: Finailspitz (3,514 m a.s.l.) in summer (above square 66)

Glacier forelands (Fig. 3.14)
Due to the continuous retreat of the alpine glaciers, abundant new areas for colonization appear year by year. As an example, Nagl & Erschbamer (2010) give a comprehensive survey of primary succession in the glacier foreland of the Rotmoosferner near Obergurgl.

Nival zone, above 3,000 m a.s.l.

Above 3,000 m a.s.l., the nival zone with very restricted plant life occurs (Figs. 3.15, 3.16). Phanerogams survive on protected sites, while cryptogams become more important. Growing on permanent snow or ice only special snow algae are able to survive.
Due to the discovery of the Iceman in the nival zone, this belt was regarded as the crucial zone for the assessment of the actual distribution of bryophytes. At the altitude of the Iceman site, at 3,210 m a.s.l., only a few vascular plant species are present (e.g. *Ranunculus glacialis* and *Poa laxa*). In contrast, a high diversity of lichens, mosses and liverworts, the latter being very diminutive, was found among rock outcrops, cracked stone and permanent ice. Typical moss species of the nival zone are *Paraleucobryum enerve*, *Polytrichum piliferum* and *Polytrichastrum sexangulare*.

Fig. 3.14: View down Tisental, a typical glacial trough valley and glacier forefield, in the distance the reservoir at Vernagt (squares 60, 61, 63, 64)

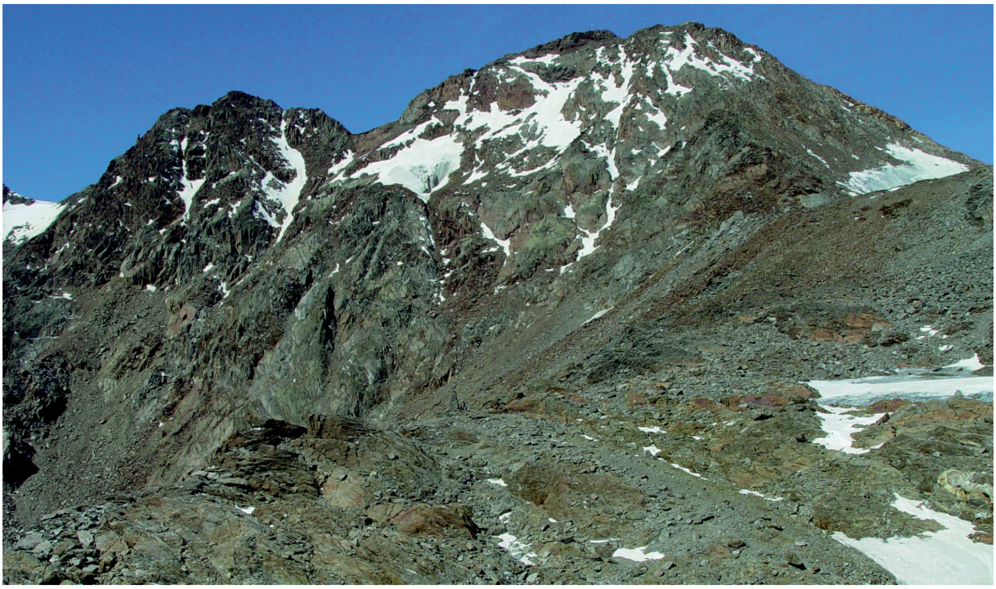

Fig. 3.15: Nival zone near the discovery place of the Iceman; bolder screes and rock cliffs (square 66), small patches of pioneer vegetation, September 2000 (square 66)

Fig. 3.16: Nival landscape between the Similaunhütte and the discovery place of the Iceman (mostly squares 65 and 66) with snow patches and rocky outcrops

Azonal vegetation

Cliffs and block screes

Not bound to particular altitudes, these habitats can be found throughout the investigated area. With increasing elevation, phanerogams get scarcer and cryptogams (bryophytes and lichens) take over. Important associations from the Asplenietea trichomanis class on more or less stable rock are the Androsacetum alpinae (siliceous rock), the Androsacetum helveticae (lime-rich rock) and several associations from the Thlaspietea rotundifolii class on scree. Typical components of the bryophyte cover on such rocky sites are different *Grimmias* (*Grimmia*, *Schistidium*).

Wetlands

Within living memory, the valley bottom of Vinschgau was much wetter, but nowadays almost all sites are drained and cultivated. Scattered patches of reed fens with various remnants of vegetation belonging to the Phragmiti-Magnocaricetea class can be seen. The only low ground in Vinschgau where *Sphagnum* spp. (Bog mosses) occurs, lies at the south end of Haider See at 1,500 m a.s.l. At much higher elevations there is more or less acidic peat-forming vegetation with different *Sphagnum* spp. and other bryophytes of wetlands such as *Warnstorfia* spp. Examples are the bogs at Martin-Busch-Hütte (2,500 m a.s.l. and slightly above), Penaudtal (2,075 m a.s.l.) and Kurzras (ca. 2,000 m a.s.l.).

Riverine woodland

Since the straightening of the main river Etsch in Vinschgau, the riverine woodlands nearly disappeared. There are, however, some remnant areas such as the Schludernser Au with the typical riverine vegetation still present, harbering communities of Salicetum albae, Salicetum purpureae and Alnion glutinosae-incanae. Along the rivers of the side valleys, riverine woodlands are more or less lacking. Thus, coniferous forests extend down to the river (Fig. 3.17).

Fig. 3.17: Venterbach, downstream of Vent (square 87) with coniferous trees along the river