



# Environmental context and adaptations of prehistoric and early historical occupation in the Southern Altai (SW Siberia–East Kazakhstan)

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## Abstract

The Altai Mountains are well-known for their unique archaeological records, with rich, chronologically sequenced Palaeolithic, Neolithic and the Bronze Age (late fourth–early first millennium BC) sites and, in particular, the Iron Age Scytho-Siberian and early historical monuments represented by burial sites, ritual structures, and rock-art. The Altai prehistoric archaeological localities are distributed across a broad range of topographic and ecological settings, encompassing altitudinal zones from 800 m asl in the lower reaches of glacial river valleys up to 2500/3000 m asl on the high mountain plateaus. The partial spatial overlap of these (often multi-component) geoarchaeological loci over time suggests that similar adaptive strategies were employed by countless generations of hunter and later nomadic communities—their actions constrained by the locally specific forms of (palaeo-)relief and the associated ecosystems. The dynamics of the initial occupation of the boreal and alpine Altai landscapes and subsequent processes of (re-)colonisation during the Final Pleistocene-Holocene transition are directly linked to transformations in the regional hydrological systems after the LGM. The principal settings for early pastoral settlements were the xerothermic grasslands that formed on the flat glacio-lacustrine terraces which rise above the modern fluvial floodplains—the remains of ice-dammed wastage lake basins drained at the end of the Pleistocene (15,000–13,000 year BP). Marked climatic changes, evidenced by regional variations in temperature and humidity across the territory, are well attested in the geological, biotic and archaeological records. The initial Sub-Boreal aridification correlated with the beginnings of the Altai Bronze Age traditions continued until the early Iron Age—causing an expansion of parkland-steppe in the main valleys and a forest retreat in the foothills. Mountain steppes constituted the most essential food-procurement habitat for the Holocene prehistoric and historical settlements of Southern Altai. The current degradation of insular alpine permafrost poses an imminent threat to preservation of the region's most precious archaeological monuments—the frozen burial mounds of the Pazyryk culture (sixth–third century BC) belonging to the UNESCO World cultural heritage.

**Keywords** Altai · Glacial landforms · Human occupation · Geoarchaeology · Permafrost

## Introduction

The Altai is renowned for its unique archaeological heritage—a rich cultural record that charts the long and complex history of this mountainous region. The evolutionary chronostratigraphic sequence encompasses the well-known Middle and Upper Palaeolithic sites (e.g. Derevianko and Markin

1987, 1999; Shun'kov 1990; Chlachula 2001; Zwyns 2014; Markin 2015) as well as little studied Mesolithic and Neolithic settlements based on hunting-fishing economy (e.g. Kuzmin and Orlova 2000; Shmidt 2005; Kiryushin et al. 2006; Kiryushin and Sitnikov 2011; Kiryushin and Kiryushin 2013). From the Bronze Age (late fourth–early first millennia BC) onwards, the evidence for human activity among these high mountains is increasingly abundant. This is especially true of the 'Scythian-Saks' Iron Age (eighth–second centuries BC), the Huno-Sarmatic (second century BC–fourth century AD) and the early Turkic Periods (sixth–ninth centuries AD) (Table 1). These archaeologically fascinating, historical and protohistorical cultures are primarily represented by burial mounds, isolated cultic and ritual structures, and abundant rock-engravings (petroglyphs) (Molodin 1994, 2000;

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Polosmak 2001; Gheyle et al. 2005; Tishkin and Gorbunov 2005; Tishkin 2007; Baumer 2016). During the subsequent Kyrgyz khaganates (tenth–twelfth centuries AD) and Mongol Empire (thirteenth–fourteenth centuries AD), the high plateaus of the Altai seemed to lose their geopolitical centrality, growing into a periphery of these greater nomadic polities.

The multi-millennial history of pastoral economy was influenced by the pristine natural landscapes of the Altai, both by their physical structure and changing local ecology. Prior to formation of the early Iron Age civilizations in the broader Altai region during the first millennium BC introducing horseback pastoralism and iron metallurgy, the preceding prehistoric settlements in the region of the Eneolithic and Bronze Ages (the Afanasievo, Karakol and Andronovo cultures) were based primarily on extensive pasturing (the earliest stockbreeding in the Altai area) on the flat grass-covered terraces in the river valleys and traditional hunting-fishing that imposed relatively little change upon the local landscape. At that time, parkland-steppes and mountain tundra-steppes covered most of the Altai and the adjoining West Sayan territory following climate cooling and landscape drying after ca. 6000 year BP that brought about a decline of coniferous (spruce and fir) taiga (Blyakharchuk et al. 2007; Blyakharchuk 2009; Rudaya et al. 2012, 2016, Rudaya and Li 2013). Opening of mountain valleys allowed for expansion of prehistoric settlements and seasonally based pastoral household mobility still characteristic of modern communities inhabiting this geographic area.

The cultures of the pre-Scythian Iron Age, which predate the famous Pazyryk phenomenon (Molodin 2000; Molodin et al. 1993; 2004), began to impose increasing pressure on the environment by deforestation for new pastures previously limited to flat grass-covered river terraces in the central river valleys as seen clearly in a retreat in the extent of taiga forest in the region. The intensified logging—for firewood and building materials (including massive burial chambers made of larch-wood)—was amplified by broader aridification in climate, evidenced at early nomadic sites across Siberia (Zakh et al. 2010). This trend, climato-stratigraphically corresponding to the sub-boreal period, reached a peak in the mid-first millennium, coinciding with the socio-economic developments that led to the formation of the Scythian civilization. Throughout this period, burials within a characteristic circular stone-built mound were built in various geomorphologic, topographic and environmental settings, including well-irrigated glacial valley grasslands, open parkland-steppes, xerothermic semi-deserts and high mountain plateaus. In the Central and Southern Altai, the most archaeologically visible of these are the rich log-built graves of the Pazyryk culture (sixth–third century BC)—including the famous, mummified ‘royal’ burials sealed in insular mountain permafrost—which are paralleled by the western expressions of regional Scytho-Siberian cultures in the northern Caucasus, Southern Urals and Pontic steppe (Rudenko 1970; Davis-Kimball et al. 1995). However, in comparison to these well-

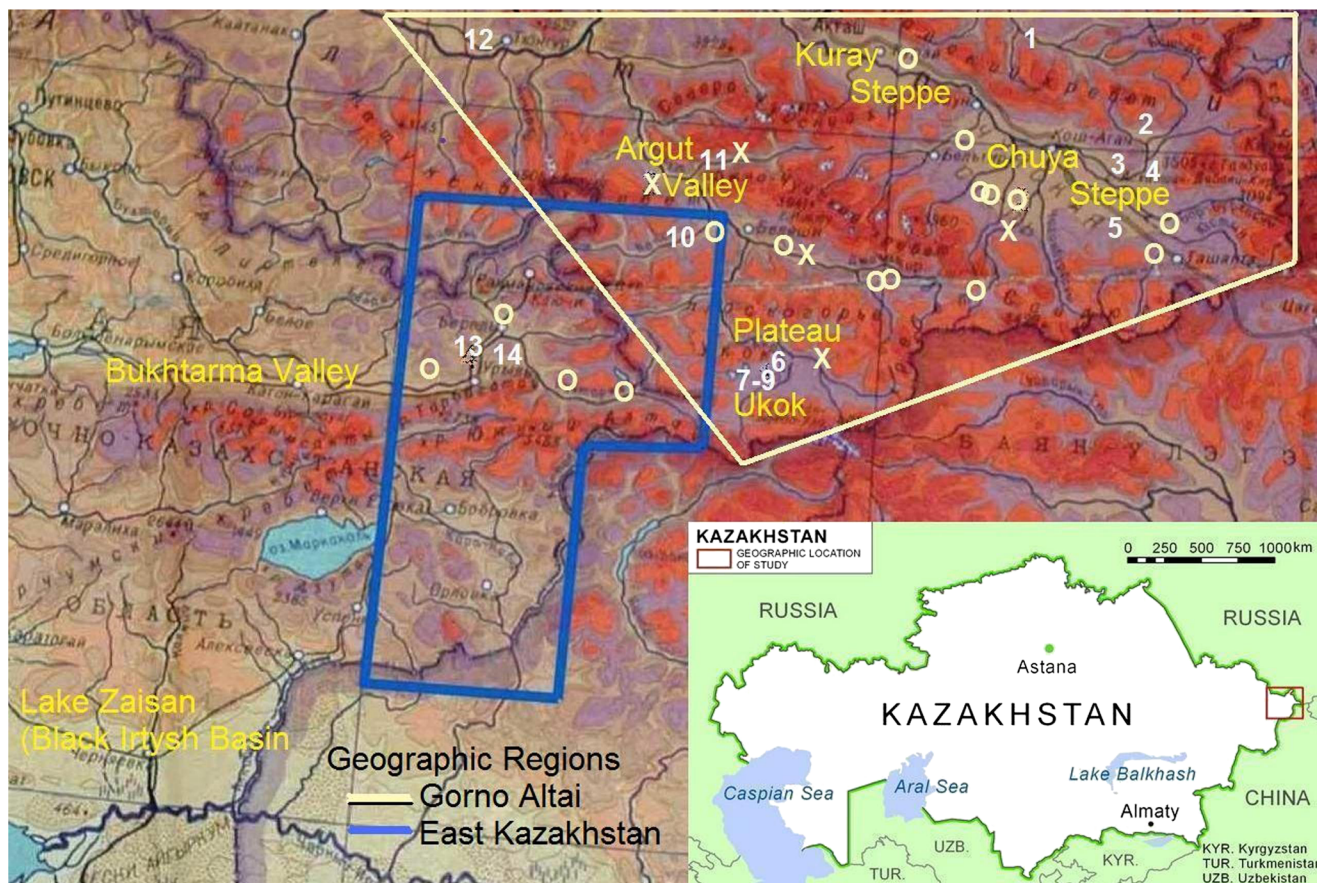
studied areas, this rather unique though geographically marginal region of Inner Asia, spanning the Kazakh, Russian, Chinese and Mongolian border zones, still represents an under-investigated area (Fig. 1).

The early royal kurgans excavated at Arzhan (kurgans I & II) and at other sites in the Republic of Tuva, date between the late ninth and early sixth century BC (Chugunov 1994; Chugunov et al. 2003, 2004), may indicate an origin for the westward expansion of early Scythian cultures to the Black Sea area (Akishev 1978; Baumer 2016). The location and geographic extent of the ancient Scythia varied over time, encompassing the Altai-Sayan region and the adjacent parts of Mongolia, North China and Eastern Kazakhstan, across parkland south-western Siberia, the Pontic (Northern Black-Sea) steppes and North Caucasus to the lower Danube area. In some places of the high-mountain Altai, kurgans (burial mounds) with massive larch tombs constructed under stone-slab cairns are of an earlier (Bronze-Age) date and presume a certain continuity in the local prehistoric settlement. The circular burial mounds are analogous to the tomb mounds of the western Scythian civilization in the present Ukraine indicating vital cultural links across the vast (over 6000 km) steppes of Western Eurasia from the Altai to the Carpathians. Apart of the trans-regional cultural affinities, the Gorno Altai archaeological sites display a clear linkage to specific geo-settings not only presuming intention to secure the former occupation subsistence base, raw material supply, but also providing much needed geo-contextual cryolithic conditions for preservation of the deceased elite individuals (‘kings’) of the former society in correspondence with the ancient spiritual belief and cultural customs. This high-relief postglacial landscape is linked to the most recent (Final Pleistocene–Holocene) geological history of this region and mirrors specific economic strategies and natural adaptations among early hunter-pastoral communities. The chronological focus of this study is on the prehistoric (ca. fifth–early first mill. BC) and early historical (sixth–second century BC) time periods, the latter closely associated with the Scytho-Siberian (Pazyryk) settlement (Rudenko 1953, 1960) representing a pre-modern cultural climax in this semi-arid upland region of inner Asia.

This paper reviews present evidence and current insights into the environmental and geoarchaeological context of the post-glacial peopling of the mountain Russian Altai (Gorno Altai) territory of SW Siberia and the adjacent part of East Kazakhstan within a single physio-geographic and geo-ecological zone. Own perceptions relate to the author’s Quaternary geology and geoarchaeology research in this geographically extensive and formerly glaciated/ice-marginal mountain area. These are supplemented by geoscience and bioscience records from field reconnaissance and the exploration expeditions in the Russian-Mongolian-Kazakh border zone (J. Chlachula, 2000–2015) in the Southern Altai (the Kosh-Agach and Katon-Karagay Districts in Gorno Altai and East Kazakhstan, respectively).

**Table 1** Schematic overview of the regional chronology, occupation sites geo-archaeology, geological and geomorphic context, and climate and environmental background of the sequenced Final Pleistocene-Holocene settlement of the Gomo Altai and the Southern Altai region (SW Siberia—East Kazakhstan)

Chronology ( <sup>14</sup> C years BP)	Archaeological cultures and settlement localities	Site geology and relief context	Climate	Vegetation and occupation habitat
18–12 ka	Upper Palaeolithic	Mountain periglacial geo-contexts	Very cold	Tundra forest
	<i>Mixed Lithic Complexes</i> (Tyumechin IV, Ust'-Sema, Tytkesken')	Fluvial gravels	Hyperarid	<i>Betula nana</i>
	(Ust'-Kuyum, Unit 4) (Berel')	Debris colluvia / gravity-flow deposits Aeolian deposits Foothill bedrock elevations	Continental	<i>Salix polaris</i> <i>Artemisia vulgaris</i> Climate warming (15–13 ka BP) <b>Younger Dryas</b> (12.9–11.7 ka BP)
12–10 ka	Final Palaeolithic	Mountain basins	Cool/humid	Boreal forest
	<i>Micro-Blade and Bifacial Stone Tool Complexes</i> (Yustyd I-II, Karaturuk)	Sandy alluvia	Continental	<i>Pinus sibirica</i> , <i>Larix sibirica</i>
	(Barburgazy, Torgun, Boguty)	Fossil brunisols (buried palaeosols) Gravelly wind-deflation surfaces		<i>Betula verrucosa</i> , <i>Salix</i>
10–8 ka	Mesolithic	Slope colluvia	<b>Boreal</b> Cold/arid	Tundra forest
	<i>Fishing-hunting traditions</i> (Ust'-Sema, Zhambul)	River valleys	Continental	<i>Betula nana</i> <i>Pinus sibirica</i>
8–6 ka	Neolithic	Alluvia	Warm humid	Mixed taiga
	<i>Early pastoral traditions</i>	Palaeosols	Continental	<i>Pinus sylvestris</i> , <i>Abies sibirica</i> , <i>Picea</i>
	(Central Katun' River basin) (Tytkesken' 2, Ust'-Kuyum)	Riverine terraces		Deciduous forests <b>Atlantic</b> <i>Populus tremula</i> , <i>Betula</i> sp.
6–4.5 ka	Eneolithic	Alluvia	Moderate	Parklands
	<i>Palaeo-metal traditions</i> (Bertek 56, Kara-Chad)	Riverine terraces Lacustrine basins	Continental	<i>Pinus sylvestris</i> , <i>Betula</i> Cyperaceae, Poaceae
4.5–2.8 ka	Bronze Age	Alluvia, colluvia	Cool/drier	Parkland-steppe
	Afanasiovo C (third–second mill. BC)	Riverine terraces	Continental	<i>Betula</i> , <i>Salix</i>
	<i>Karakol Culture</i> (second mill. BC)	Glacial lake basins		<i>Pinus sibirica</i>
	Andronovo C (seventeenth–ninth century BC)		<b>Sub-boreal</b>	
2.8–2.2 ka	Iron Age	Mountain plateaus	Moderate	Mountain steppe
	<i>Pazyryk Culture</i> (sixth–third century BC)	Periglacial alluvia	Continental	Alpine taiga ( <i>Larix sibirica</i> )
	<i>Sak-Scythian Complex</i>	Permafrost grounds		
	<i>Kara-Koba Culture</i> (Chuya Depression and Plateau Ukok sites)	Riverine terraces Glacial lake basins	<b>Sub-Atlantic</b>	
2.2–1 ka	Early Historical Times	Top soil geo-contexts	Cool	Coniferous taiga ( <i>Picea</i> & <i>Abies sibirica</i> )
	<i>Huns State</i> (second BC–fourth century AD)	River valleys, foothills	Continental	Parklands ( <i>Betula</i> , <i>Populus</i> , <i>Pinus</i> )
	<i>Early Turks State</i> (sixth–ninth century)	Upland plateaus		<i>Pinus sibirica</i> , <i>Larix sibirica</i>
1.0–0 ka	Historical times/present	Top soil geo-contexts	Moderate	Mountain steppe and semi-desert
	<i>Kyrgyz Khaganate</i> (tenth–twelfth century)	River valleys, upland plateaus	Continental	Coniferous taiga ( <i>Picea</i> & <i>Abies sibirica</i> )
	<i>Mongol Empire</i> (thirteenth–fourteenth century)	Parkland-steppe geo-settings	<b>Sub-recent</b>	<i>Betula</i> , <i>Pinus sibirica</i>



**Fig. 1** Geographic location of the study area—Southern Altai (East Kazakhstan and Russian Altai, Siberia). Prehistoric and early historical sites mentioned in the text are marked as follows: X rock art sites (Bronze and Iron Age); O kurgans (only selected sites are illustrated on the map);

the principal Scythian (Pazyryk Culture) burial mound complexes (1 Pazyryk, 2 Uzuntal, 3 Barbugazy, 4 Yustyd, 5 Ulandryk, 6 Kuturguntas, 7 Bertek, 8 Verkh-Kal'dzhin, 9 Ak-Alakha, 10 Samakha, 11 Argut, 12 Katanda, 13 Berel', 14 Uryl')

These mapped within the regional GIS some new geoarchaeological localities (occupation sites/montane refugia, burial complexes, stelae and rock-art/petroglyph sites), alongside the existing published data on the geospatial (geographical, geomorphic and geo-environmental) distribution of the Holocene pastoralist cultures established in this mountain territory. The summary results show various diachronic patterns of change and continuity in the selection of the natural geo-habitats and the spatial placement of archaeological sites, mostly ritual, that are the best-preserved and surface-evident among the mapped Altai's geoarchaeological monuments.

## Study area

### Geography and geological history

The geographic focus of the study is on the mountain part of the Altai located south of the Pleistocene ice-free, loess-covered Northern Altai Plains (Chlachula 2003; Evans et al. 2003). The Russian Altai (Gorno-Altai) is a major mountain system of southern Siberia (Mt. Belukha, 4506 m). In the

southeast, it adjoins the Mongolian Altai through the Tabyn-Bogdo-Ula massif (Mt. Nairamdal, 4374 m), and in the south, it divides into the ranges of Southern (Kazakh) Altai, which adjoins the northern edge of the Tian Shan mountains through the Tarbagatay Range (2992 m) and Dzhungarskiy Alatau (4464 m) (Chupakhin 1968). The topography of the Altai alpine zone (> 2500 m asl) is built by separate orogenic ridges of the central, eastern and southern part (the Katun', Northern & Southern Chuya, Sailyugen and Chikhacheva Ranges) and high-mountain plateaus (Ukok, Chulyshman) at ca. 2000–2500 m altitude. The lower relief zone (> 1200 m asl) includes more than 50% of the mountain territory, representing relics of old denudation surfaces covered by more recent Pleistocene deposits of past glaciations (Rudskiy 1996; Galakhov and Mukhametov 1999). Major intermontane basins are found in the southern part of the mountain system, the largest of which is the Chuya Depression, an area of ca. 70 × 40 km aligned northeast (1750–2100 m asl) and surrounded by the South and North Chuya Mountains to the west, the Kuray Range to the north, the Chikhachev Range to the east and the Saylugem Range to the South (Fig. 1). The floor of the basin (Fig. 2e), overlying the Proterozoic bedrock, is largely filled by

Neocene clays and capped by the Quaternary alluvial, proluvial and, along its margins, glacial deposits (Deviatkin 1965, 1981). Intensive mass-wasting erosion of the uplifted geological formations led to several periods of complete denudation of the former (pre-Quaternary) topography followed by orogenic stages of renewed relief formation.

The southern Altai shows a complex Quaternary history with environmental transformations reflected in intensive geomorphic processes related to a combination of climate change and regional neotectonic activity. These conditions created the geo-context for prehistoric and early historic human settlement in the region (Chlachula 2001, 2010a, b). The regional relief was repeatedly shaped by glaciations (Fig. 2c) accompanied by intensive fluvial erosion and colluvial processes in the mountain valleys, with the best-preserved landforms dating to the last glacial period (24,000–12,000 yr. BP). Surficial geology (where exposed due to intensive denudation) is formed from Late Pleistocene deposits generated by the last two (MIS 4 and MIS 2) glacial stages. In the southern Altai, these events are documented by two terminal moraines and relict glacio-lacustrine sediments from ice-dammed lake basins, which periodically formed in the Chuya and adjoining Kuray Depressions (Fig. 1). These proglacial lakes would have burst catastrophically during the initial stages of periodic deglaciations. The present evidence indicates the existence of at least 10 large lakes (> 100 km<sup>2</sup>) and several hundred smaller glacial basins in the Gorno Altai during the last glacial stadial (MIS 2) (Rudskiy 1996). The periodic draining of these lakes is manifested in major erosional surfaces at relative elevations of 80–100, 50, 30–40, 4–6 and 1–1.5 m above present floodplain (Rudoy 2001) (Fig. 2a). Large alluvial fans formed by unsorted massive gravely glacial strata, overlying or laterally merging with the highest (110 m) alluvial terraces, attest to dramatic and rather short-term geomorphologic processes.

The retreat of wasting mountain glaciers during the final stages of deglaciation resulted in major floods by ice-dammed lake waters in the main Central Altai basins of the Chuya and Katun' Rivers—the most recent dating to ca. 15,000/13,000 year BP (Rudoy and Baker 1993; Rudoy 1998, 2001; Reuther et al. 2006). A spectacular system of glacio-fluvial terraces developed as a result of the cataclysmic collapse of these proglacial lakes can be seen between 1500 and 2000 m asl in the Chuya and Kuray steppe. The documented water level associated with these events reached a local altitude close to 2100 m asl (Okishev and Borodavko 2001; Herget 2005); this was a vast reservoir of water, totalling several cubic kilometres in volume. The presence of late Pleistocene–Holocene shells in the sediments sealing the lacustrine accumulations (Rusanov 2010) and lateral erosional terraces indicates that a series of smaller lakes were formed in the central part of the Chuya Basin at ca. 1800 m asl after the drainage of the major Final Pleistocene reservoir. This most recent, early Holocene mountain lake is believed to have

drained at ca. 8200 cal/year BP, prior to the Holocene climatic optimum (Agatova et al. 2016; 2017a). The most recent deep-water lacustrine ponds of the former ice-dammed lakes in the intermontane basins of Gorno Altai disappeared sometime after 5000 years ago (Rudoy 2001), leaving behind a sequenced series of down-grading riverine terraces modelling the present landscape. In the Chuya Depression, the residual Holocene lakes of the Last Ice Age are believed to have disappeared at ca. 1500 cal/year BP (Agatova et al. 2014) as a result of increasing territorial aridity during to the early historical nomadic settlement of the Southern Altai. The analogous last glacial basins with the characteristic flat terrace landforms and adjoining proluvial flats became the principal Eneolithic to the early Iron-Age (pre-)Scythian occupation (ninth–third century BC) geo-setting and activity area for the local prehistoric communities. These environments, and their associated cultural monuments, have been mapped in the southern part of the Gorno Altai in the Argut, Koksu, Dzhazator and Tarkhaty Valleys (the Samakha Lake) associated with retreat glaciers in the Katun' Range, and in the Bukhtarma Basin (the Uryl Lake) in East Kazakhstan dammed by the Last Glacial (MIS 2) ice (Fig. 1). The dynamics of the early human settlement and (re)colonisation of these intermontane depressions during the final Pleistocene–early Holocene is directly connected to transformations in the local glacial-hydrological systems after the Last Glacial Maximum (Butvilovskiy 1985, 1993). The large-scale geomorphic processes that shaped the modern relief also created favourable natural conditions for a thriving pastoral economy across the central and southern Altai area. Overall, the present geography of the Gorno Altai and Southern Altai area bears witness of a complex landscape development triggered by past climate change and the regional neo-tectonics (Chlachula 2001, 2010b).

In the principal study area of the SW Altai, the last glaciation (lasting from ca. 23,000 to 13,000 yr. BP) is evidenced by a series of glacio-lacustrine terraces, alluvial fans and terminal moraines distributed along the southern foothills of the Southern Chuya Mountains. Prominent lateral moraine ridges, best preserved at the 1500–3000 m elevation, testify to a massive mountain icecap with glaciers expanding far down into the river valleys. The local Quaternary records attest to existence of a large ice-dammed proglacial basin confined by the surrounding mountains and emptied through the Argut River Valley that is a part of the Katun' River drainage system (Chlachula and Selyanina 2007), corroborating the last glacial history of the broader Altai territory. The Final Pleistocene–early Holocene climatic oscillations are linked with sequenced erosional terrace formation of the Tarkhaty, Dzhazator and Argut Rivers (Figs. 2b, c), analogously found in the adjacent part of Eastern Kazakhstan (the Bukhtarma valley). Fossil periglacial features on the Plateau Ukok (Fig. 3a), including large stony polygons up to 10 m in diameter formed as a result of intense permafrost dynamics, attest to very severe sub-

recent climatic conditions in the extra-glacial zone of the Altai Mountains.

## Present climate

The investigated region encompasses all topographic and vegetation zones of the Altai, with locally specific climatic conditions and ecosystems which have changed little since the mid-/late Holocene formation of the mountain steppe environments of the Russian and Mongolian Altai (Borisova et al. 2005; Rudaya et al. 2012; Rudaya and Li 2013). The present climate in the region is strongly continental with major seasonal temperature variations between the northern lowlands and the southern mountains (Chlachula and Sukhova 2011). In winter, climatic conditions in the mountains are generally less severe than in open steppes, with a microclimate prevailing throughout the year in some protected Altai intermontane locations, such as the Biya, Katun', Chulyshman and lower Chuya Basins. Annual temperatures as well as precipitation rates vary greatly according to topographic settings. Most of precipitation falls on the western and north-western slopes of the mountains, whereas the 'Mongolian' landscapes of the Southern Altai remain very arid. In the Chuya Depression (1750–2100 m asl) (Fig. 1), the most continental region of the Russian Altai, the average temperature in July is +25 °C, dropping to an average of –33 °C in January, with the lowest recorded temperature being –61 °C. Most of the area is characterised by frozen ground with an active (summer) thaw-layer, 30–70 m thick. At present, apart of some isolated corrie glaciers at elevations above 3000 m asl, the major glaciers in the Altai are distributed on the northern exposures of the Northern and Southern Chuya Mountains, and the Katun' Range (Belukha Mt. 4503 m). In spite of very low mean annual temperatures (–9/–10 °C) on the Plateau Ukok (2100–2600 m asl) (Fig. 3a), glaciers (retreating up to 20 m/year) are found only in the Tabon Bogdo Ula Range (4120 m) due to the high aridity of the area (precipitation 150–200 mm/year) (Rudoy et al. 2000). Perennial permafrost underlies most of the Southern Altai mountain zone, including the upland (Kuray-Chuya and Ukok) depressions. Fierce winter winds sculpt the local rock formations (Fig. 2f).

The current climate warming observed in southern Siberia is most evident in the alpine zone of the Altai and Sayan Mountains (Chlachula and Sukhova 2011; Sukhova et al. 2018). This leads to the regional bio-geographic transformations, aridification of the mountain steppes, altitudinal tree-line migration and a mountain biotopes' restructuring (Chlachula 2005). Increased summer temperature as well as MAT causes a progressing glacier ablation and ice retreat, and generates insular permafrost thaw on the uplands (Okishev et al. 2001; Narozhnyy and Nikitin 2003; Surazakov et al. 2007; Shangedanova et al. 2010; Narozhnyy and Zemtsov 2011; Ganyushkin et al. 2017). This trend has a marked

impact to the present-day Altai's ecosystems as well as the geo-environmental contexts of archaeological sites.

## The Holocene climate evolution

Climate played a decisive role in the post-glacial geoenvironmental development of the Southern Altai. Marked climate shifts around the Pleistocene–Holocene transition and the following stages are seen in the regional variations in temperature and humidity evident in geological, palaeobotanical and archaeological proxy data. A close regional palaeoclimate trend is delivered by high-resolution loess-palaeosol sequences topping the massive Last Glacial formations on the Northern Altai Plains and the East Kazakhstan foothills (Chlachula 2003, 2010b; Evans et al. 2003) and showing the progressing early Holocene warming and pedogenic alteration of the aeolian substrate recorded by diagnostic magnetic susceptibility variations with formation of brunisolic taiga forest soils. Following the Holocene climatic optimum (6500–5900 year BP). The Gorno Altai as well as the adjoining Mongolian Altai climates experienced increased continentality and aridity (Rudaya and Li 2013; Rudaya et al. 2016), which promoted the establishment of the current ecological zoning with forest-steppe in the foothills, and semi-desert on the mountain plateaus and continental depressions. The fine sedimentary (sand/loess) deposits over most of the Central and Southern Altai basins are rather thin because of the intensive aeolian deflation that continues until the present time. Changes in the unconsolidated sediment cover have apparently been active throughout most of the Holocene, resulting in massive sediment transfer and accumulations of aeolian sands in some areas, such as in the lower Bukhtarma Basin and the spectacular barchan dune fields in the Zaisan Basin (Fig. 1) potentially burying and re-exposing the Iron-Age and earlier sites.

Within the close study area, a most detailed mid- to late Holocene palynological climate change signal from two loci above the present forest line (2330 m asl) in the Kuray Range adjoining the Chuya Depression indicates a pronounced mid-Atlantic temperature drop within the Holocene (Atlantic) climatic optimum. The subsequent Sub-boreal cooling initiated a coniferous forest (taiga) expansion in southern Altai/Siberia dominated by *Picea obovata* with a recession around 5300 year BP due to a marked early Sub-boreal cooling (Table 1). Partial restoration of taiga forest ended at ca. 3400 year BP followed by the Sub-Atlantic warming. Subsequent climatic declines are mapped from the nearby Tarkhata Valley (2210 m asl) from the open semi-arid *Larix sibirica* zone for the last two millennia—with a cold and wet phase around fifth century AD, a cold and dry phase at ca. AD 1200 and the Little Ice Age (seventeenth–eighteenth century) (Schlütz and Lehmkuhl 2006). These climate shifts are clearly



**Fig. 2** **a** Sequenced 50–170 m-high terraces (780–900 m asl) formed by repeated drainages of an ice-dammed lake at the present confluence of the Chuya and Katun’ Rivers (Gorno Altai). **b** Steppe-like terraced valley (2065–2080 m asl) resulting from ice-dammed lake regression and drainage from the Chuya Basin downstream into the Tarkhaty River valley. Numerous archaeological sites are found on these glacio-lacustrine landforms. **c** Argut Valley (Gorno Altai) with the central 20–50 m deep river-cut canyon boarded by discontinuous terraced platforms

geoarchaeologically associated with prehistoric monuments (burial steles and kurgans). **d** Kokorya Valley irrigated by a glacier-stream opening into the Chuya Basin. **e** The Chuya Depression (a former glacial lake basin, 2000 m asl) with the ‘Mongolian’ arid rocky steppe. **f** Wind-eroded coarse-grained granites of the Chokpartas Range (2350–2500 m asl) sculpted over the millennia by extreme continental/periglacial conditions. Photographs by the author

linked with the main settlement stages in Gorno Altai as well as extensive ethnic migrations in north-central Asia.

The palynologically based mid- and late Holocene climate history corroborates the reconstructed glacial dynamics in Southern Altai over the past 3000 years, with stages of mountain ice re-advance at 2300–1700 cal/year BP and during the thirteenth–nineteenth century AD (Agatova et al. 2014). The advanced territorial aridity and cooling promoted expansion of mountain grasslands that constituted the primary subsistence base of the early Iron Age (Scythian) nomadic settlements. Pastoralism as the traditional economy of the Altai region is closely associated to the mosaic mountain habitats across the N–S (lowland–alpine zone) latitudinal gradient and thus principally directly dependent of the present climate change. This brings present weather pattern shifts in the high-mountain areas, with increased continentality, progressing frozen ground thaw as well as seasonal environmental changes due to earlier springs that altogether contribute to activated erosion, landslides, soil cover degradation and pristine biotopes' instability.

### Vegetation and soil cover

The regional zonal vegetation distribution is predetermined by the physiographic configuration and climate. The main biotic components of the southern Altai landscape are taiga, alpine grasslands and shrubs, mountain tundra, steppes, and secondary mesophytic meadows. In the intermountain depressions, the modern vegetation cover is characterised by open grassy steppe-parklands dominated by birch and pine, with some poplar along streams. Mixed taiga (with larch, spruce, pine, the Siberian pine, fir and birch) covers most of the lower mountains replaced by the alpine vegetation with pine, larch and dwarf birch above 2000 m asl elevation. Semi-desert communities including taxa characteristic of the Mongolian semi-desert steppes are found on the uplands and the mountain basins (Fig. 2e). The floral composition of these communities consists of native species. Very few introduced species (except for those directly planted by people) were found, and no spreading of invasive taxa has been recorded (Chlachula 2005). The principal environmental factors that affect the regional vegetation cover are altitude, topography (especially inclination and orientation of slopes), but also intensity of human activity. The Kazakh part of the Altai along the Bukhtarma River is also more densely inhabited than the Russian (Gorno Altai) area, so the landscape structure and biodiversity are more anthropogenically effected. There, mesophytic meadows are very common with floristic communities associated with human activities such as animal grazing, haymaking and deforestation (Fig. 4a). Presumably, this was also the case in the past due to the generally more favourable natural conditions and milder climates.

Grasslands that constituted the principal pastoral economy-based ecosystem for the Altai prehistoric as well as historical occupation appear in several forms depending on the local geo-environmental background, plant ecology and the species compositions. In the specific biotic (regional geobotany) structure, the mountain grasslands include floristic elements of the original Eurasian steppes, the alpine zone and wetter high-grass meadow fields depending on the atmospheric and relief factors (humidity, altitude, slope steepness) of the particular area. In the Southern Altai, the steppes are represented by the following:

1. The Eurasian semi-arid steppes (stretching from Pannonia to Manchuria), including:
  - (a) Typical steppes found on the flat basin floors and river terraces (Figs. 2a and 3c, d)
  - (b) Rocky steppes established in extreme geomorphic settings—sunny slopes and cool windy bedrock exposures (taxonomically rich, mainly dicotyledons) (Fig. 2b)
2. The Mongolian steppes (arid sparse low-grass vegetation) (Figs. 2e and 3e)
3. Secondary mesophytic meadows located below the present forest line (Fig. 4a)
4. Low-grass alpine meadows (> 1800 m asl with a rich herbaceous flora, including *Gentiana* sp., *Pedicularis* sp., *Bistorta*, *Polygonum alpinum*, etc.) (Figs. 2f and 3a)

Floristically, the typical steppes of the explored Argut and Bukhtarma River basins are very similar in the species compositions to the vast continental steppes at low altitudes of East Kazakhstan. The dominant herbs include *Festuca*, *Stipa*, *Koeleria* and *Elymus* accompanied by the arid-settings species (*Carex*, *Artemisia*, *Dracocephalum*, *Potentilla*, *Alyssum*, *Iris*, *Phlomis*, etc.) and taxa growing on barren rocky grounds (*Orostachys spinosa*). Rocky steppes developed on hard-to-reach steep slopes, usually with a shallow bedrock base. In the pristine form, they are usually richer in sedges and tall plant species in the predominance of dicotyledons (*Fragaria viridis*, *Achillea* spp., *Campanula sibirica*, *Aster* cf. *alpinus*, *Bupleurum aureum*, *Carex humilis*, *Ligularia glauca*, *Lathyrus gmelinii*, *Polygonum alpinum*, *Thalictrum* spp., etc.). In places of intensive grazing (primarily by sheep and goats), the rocky steppes became mesophilic.

The alpine meadows are located above the forest boundaries 2100–2900 m asl. They are very rich in floral species, with a number of expressively flowering dicots such as *Pedicularis*, *Gentiana*, *Oxytropis*, *Saxifraga*, *Rhodiola*, further *Bistorta vivipara*, *Schulzia crinita*, *Viola altaica*, *Callianthemum angustifolium*, *Hedysarum* sp., *Patrinia sibirica*, *Anemone narcissiflora*, *Allium altaicum*, *Papaver* sp. and many others. In the sub-alpine settings, the lush meadows are bordered by creeping shrubs of



willows (*Salix*), dwarf birch (*Betula rotundifolia*), *Vaccinium myrtillus* and *Juniperus sabina*. In the alpine zone, specific small-sized plant biotopes are established near humid creeks (*Primula nivalis*, *Trollius altaicus*, *Geranium pseudosibiricum*, etc.), mountain springs and marshes. In wetter places, fields of moisture-loving high-grown (up to 2 m) grasses of *Aconitum*, *Delphinium*, *Saussurea*, *Geranium*, *Allium*, *Cirsium helenoides*, *Polemonium caeruleum*, *Trollius altaicus*, *Ligularia altaica*, *Pleurospermum* cf. *uralense* and *Veratrum lobelianum* are widely distributed (Koutecký et al. 2007) (Fig. 3a).

The present soil cover corresponds to the mapped zonal vegetation distribution. In the protected riverine valleys (Koksu, Dzhazator, Bukhtarma) and on the plains at 1800–800 m asl steppe, chernozems form the principal pedogenic surfaces with leached luvisolic soils in more humid floodplain locations. Kashtanozems and podzolic forest soils prevail in the lower mountain taiga zone; thin brunisols and tundra regosols are found in the (sub)-alpine zone and semi-deserts. Brown calcareous soils and saline soils (solonets) appear in the high-mountain basins and on the upland plateaus (Ukok).

## Geomorphic context of Holocene peopling of southern Altai

Based on present evidence, the archaeologically most significant post-glacial Holocene occupation loci include the former glacial lake basins—Chuya (1750–2100 m), Kuray (1480–1600 m) and Samakha (1500–1600 m asl); the interconnecting/lateral river valleys—Yustyd (2030–2050 m), Chuya (1600–1750 m), Tarkhaty (2050–2200 m), Dzhazator–Koksu (1570–1900 m), Bukhtarma–Chindagatuy (1000–1750 m); and the upland plateaus—Ukok (2150–2600 m asl) (Fig. 1), corresponding to an altitude range of ca. 1500 m (1000–2500 m asl). The majority of habitation sites from the early Holocene until the present time are positioned on the former glacial basin floors and flat erosional glacio-fluvial terraces formed during the periodic lakes' drainage cycles at the end of Pleistocene (Deviatkin 1965, 1981; Rudoy 1998) (Figs. 2a–e and 3b–e) (Table 1).

Most of the cultural sites are exposed on the modern surface in open mountain-steppe landscapes, more rarely on slope settings. The topographic range of burial complexes and isolated petroglyphs/rock art which adorns exposed bedrock walls (Fig. 3e–f) encompasses loci around 800/1000 m asl (Bukhtarma River Basin) up to 2000–2500 m asl (Kosh-Agach Basin, Plateau Ukok). These boundaries define the approximate limits of the former main settlement areas for the Bronze and early Iron Age pastoralist communities across the Southern Altai. The relatively high frequency and diachronic diversity in the structural composition of burials provide evidence of a multi-cultural landscape of occupation

during the prehistoric and early historic periods. The sites mapped in most marginal geographic and environmental loci, away from the main river corridors, further attest to the spatial extension of occupation into the overall very dry mountain area, including alpine meadow and tundra habitats and indicate greater adaptation to the local mosaic of mountain and steppe settings.

The most intensively were occupied geomorphological and ecological niches in the major intermountain basins of the southern Gorno Altai (Chuya, Kuray and Samakha steppes) at ca. 1750–2200 m altitude as well as the glacial-fluvial terraces and alluvial fans of the main drainage river systems (Katun', Chuya, Argut and Bukhtarma) at 1000–1900 m altitude, which offered the necessary water supplies and grassland biomass to raise cattle. Terminal alluvial fans overlying terrace formations are best-observed in the upper Katun' Valley (1500–1800 m asl), while rocky ramparts representing erosional fragments of the granitic/gneiss bedrock can be found along the margins of the river valleys, and the high Altai plateaus such as Ukok (2150–2600 m asl) which provided locally specific occupation habitats. Some elevated places hidden among rocks may have served as temporal refugia (e.g. Malyy Yeloman). Although the early Palaeo-metal (Eneolithic and Bronze Age) records remain fragmentary, the Iron Age (the Scythians as well as more recent pastoral ethnics) and historical occupants of the region clearly inhabited all topographic settings of the investigated central and southern Altai area.

The early Iron Age is closely associated with the Pazyryk culture (sixth–third century BC) that represents the peak of the prehistoric development in the Altai. Archaeologically, this is represented by spectacular burial mounds (kurgans) contextually sealed in compact, massive to inter-stratified sandy-gravel deposits of the exposed cataclysmic glacial lake floors (e.g. Yustyd, Issyk, Kuderge, Elangash, Saliyugem, Ak-Alakha, Bertek, Verkh Kaldzhyn) (Figs. 1 and 3b, e) on top of the erosional glacio-fluvial terraced platforms at 80–100-, 50- and 30–40-, and 5–10-m elevations above the present floodplains (Tarkhaty, Koksu, Argut, Karagem and Chuya–Kuray burial complexes) (Fig. 3c, d), and in massive loessic/loamy valley deposits (Berel') (Fig. 4a, b). Today, > 500 burial mounds are recorded in Gorno Altai alone (Molodin 2011).

Lone burial mounds are known, but they are more frequently found in groups across the studied area. Except for those found in wide open steppe settings (Fig. 3b), they are routinely positioned in small tributary valleys and at their confluences adjoining the main river basins (Fig. 3d). Large unexcavated burial mounds recorded on top of the highest terrace near Uryl' in East Kazakhstan (around 200 m above the modern floodplain of the Bukhtarma River) are likely to be the burials of particularly significant individuals in these societies (Chlachula, unpublished data). Less ostentatious Iron Age burials, with shallow grave pits and poorly furnished



**Fig. 3** **a** Northern slopes (3000–2600 m asl) of the Plateau Ukok with ice-eroded bedrock exposures and small alpine post-glacial lakes. **b** The central part of the Plateau Ukok (2300–2150 m asl) with the Tabyn Bogdo Ula Mountains (in the background) and an excavated mound of the Ak-Alakha (‘White waters’) Scythian ‘royal’ burial complex (2165 m asl). **c** An Iron Age cemetery in the upper Argut valley with aligned stone steles and several (formerly looted) kurgans. **d** A preserved (Scythian) burial mound complex on a raised floodplain at the confluence of the

Argut and Karagem Rivers (1290 m asl) constructed from granitic glacial boulders from the nearby river channel banks. **e** A prehistoric (Bronze Age?) cultic site with a kurgan cemetery in the Chuya steppe (2005 m asl) positioned at the surface-exposed mass-wasted erratic gneiss bedrock block. **f** Rock engravings (3E) depicting lifestyles and hunter-pastoralist economy of the late Bronze/early Iron-Age in southern Altai. Photographs by the author

tombs scattered across the landscape and simple rocky burial *stelae* (Fig. 3c), stand in opposition to the richest and most spectacular royal kurgans with burial chambers dug 3–5 m into the permafrost in the most arid and inaccessible upland environments in the region (e.g. the Ukok and upper Bukhtarma River burial mound complexes) (Fig. 4b). These burials often warranted or required the ‘eternal’ preservation of the mummified bodies and accompanying materials (funeral offerings). For archaeologists, the discovery of these graves, replete with preserved organic materials provided, together with zoomorphic and anthropomorphic rock art, unprecedented information about the lives and lifestyles of these ancient peoples (Polosmak 2001).

The geological structure of the post-glacial landforms largely consisting of unsorted massive gravelly deposits exposed on the land surface provided an abundance of material for the kurgans’ stone cairns, which sealed the wooden log chambers in which the dead, particularly of the elite social status, were buried. Granitic glacial boulders and large cobbles exposed by the Final Pleistocene fluvial erosion as well as angular gneiss and flat schist blocks from local rocky exposures were used for construction of these mounds and the burial steles (Figs. 3c, e and 4a). The richest Scythian burials with larch wood-lined chambers are placed in stratified (glacio-)fluvial gravels in the high Altai plateaus (Ukok, Kalguty) and the wind-deflated intermountain depressions (Kuray–Chuya, Samakha, Argut) with little top fine sediment cover (Fig. 2b and 3b–d). In the lower reaches of the river valleys, easy-to-excavate massive to partly stratified loessic sediments form a sealing geo-context of the ancient Scythian entombment sites (e.g. the Berel’ burial complex) (Fig. 4b). Use of remote sensing techniques for spatial locating of pre-historic and early historical burial sites defined by a specific geomorphology (kurgan complexes and other ritual sites) facilitates the new geoarchaeology field data assembling and their preliminary/approximate culture-chronological assessment, particularly in the distant and difficult-to-access mountain places (Bourgeois et al. 2000, 2014; Gheyle et al. 2005).

## Biotic context and the Altai Mountain steppes

The vast steppes of SW Siberia, being a part of the Great Steppes of the mid-latitude Eurasia, played a major role in the prehistoric and historical socio-economic development of the Altai (both the lowland and upland regions). The open landscapes north of the southern Siberian mountain ranges provided the main migration routes across the territory since the earliest times facilitating (due to the absence of major physiographic barriers) sequenced ethnic movements, gene flows and speeded up a civilisation progress in the north-central Asia with dissemination of cultural innovations and technological knowledge, including stone-working, and

bronze and iron-melting (Derevianko and Markin 1999; Weber 1995; Legrand 2006; Matveeva et al. 2014; Agatova et al. 2017a, b). The archaeological significance of the Altai grasslands is put into linkage with the Bronze Age and primarily the Scythian horse-riding pastoral nomads.

The continental short-grass semi-desert Mongolian steppes are absent in East Kazakhstan due to the significantly higher MAP rates (500–1000 mm) unlike the neighbouring Gorno-Altai (the Chuya Basin) (Fig. 1). The primary (biotically pristine) Eurasian steppes occur in the more arid parts of the region where the dry climate does not promote growth of trees. In the close study area, these are found on the flat glacio-fluvial terraces in the Argut and Bukhtarma River basins and their tributary valleys (Dzhazator, Kalguty, Koksu, Karagem, Berel’) as well as on rocky talus slopes (mostly southerly orientated), where a high solar radiation is combined with a shallow regosolic soil cover and a low surficial water retention. Some partially confined steppe patches climb up to the upper forest boundaries up to 2400 m asl. In the upper reaches of the Bukhtarma valley in East Kazakhstan, a slightly wider distribution of primary grasslands is found on the loess-covered foothills (the former glacial relief forms) and permeable gravel terraces in a close distance from the famous Pazyryk mound complex at Berel’ (Fig. 4a). A separate category represents the relic periglacial steppes (2000–2400 m asl) characterising the smoothly undulating relief of Plateau Ukok drained by the Ak-Alakha and Karalacha Rivers (Fig. 3b). Regardless of the major concentration of the mapped Iron Age archaeological sites, this upland part of the Southern Altai is just marginally affected by human activities due to a speedy seasonal natural grassland regeneration promoted by ground humidity, higher precipitation and the broader geographical extent.

Secondary steppes that arose as a result of past human activity (deforestation and cattle breeding) are common. At present, it is impossible to determine exactly their age, but most likely their natural origin goes back to the time of the initial introduction of pastoralism into the Altai area about 6000–5000 years ago (Kuzmin and Orlova 2000). Based on field investigations (Chlachula 2005; Koutecký et al. 2007), the secondary steppes seem to be predominant in the study area in spite of their relative remoteness from the present settlements. This fact suggests a certain antiquity of the present anthropogenic mesophytic grasslands in the main basins and well-accessible mountain valleys of the Southern Altai (Fig. 4a). Dominance of taxonomically uniform short grasses at these places is primarily due to long-term overgrazing. A physiographic combination of the primary steppes on the south-facing mountain slopes and foothills with the opposite (northern) slopes covered by coniferous (spruce and larch) taiga is apparent. This physiographic zonal vegetation distribution pattern characteristic of the Altai-Sayan Region may have played a major role in the economic base of the ancient

cultures by providing an easy resource access for pastures as well as wood used for the dwelling construction and fuel in the nearest proximity of occupation loci. The viability of the timely sequences ancient settlements throughout the past millennia was also supported by sufficient, year-round sources of running water, including the most arid Kosh-Agach basin (Fig. 2e) irrigated by glacial streams of the surrounding Southern Chuya, Sailyugen and Chikhacheva Mountains (Fig. 2d) as well as seasonally activated permafrost lakes with lush summer pastures in their close surroundings.

## Permafrost background of the iron age settlement

The high mountain plateaus are largely underlain by discontinuous permafrost, though as a result of current warming trends, this is now progressively degrading. Frozen mounds, which preserve organic remains (wood, wool, horn, leather, bark and human bodies/soft tissue) because of cryolithic conditions, provide an exceptional source of information about historical and cultural processes in the Early Iron Age (Rudenko 1960; Polosmak 2001; Cheremisin 2006; Samashev 2014). The Southern Altai permafrost-enclosed tombs deliver direct insights on the past burial practices and ancient cultural adaptations, lifestyles and social structure (Fig. 4c, d). There is an intriguing question if the regular natural polygons up to 10 m in diameter representing natural periglacial features formed by periodic freeze and thaw within this alpine environment, particularly well-developed on the Plateau Ukok, may have inspired the circular stone-cover arrangements on top of the burial barrows. Superficially, at least, they often have the appearance of kurgans. It is also interesting to wonder whether the Scytho-Siberian and other preceding cultural groups who inhabited the Southern Altai were influenced in their choice of burial practices and spiritual beliefs by the harsh cryogenic environment of the region, which persisted after the Last Glacial Maximum and allowed for preservation of buried mummified human and animal bodies (mainly horses) (Molodin 2000; Samashev and Zhumatayev 2015). Finally, to what degree the plateau was regularly occupied by prehistoric and early historic populations/tribes (was it used for year-round pastures, with its limited snow cover, which allowed for winter grazing) or was the place frequented mainly because of its importance as a site of burial and other ritual activities by taking advantage of the icy grounds.

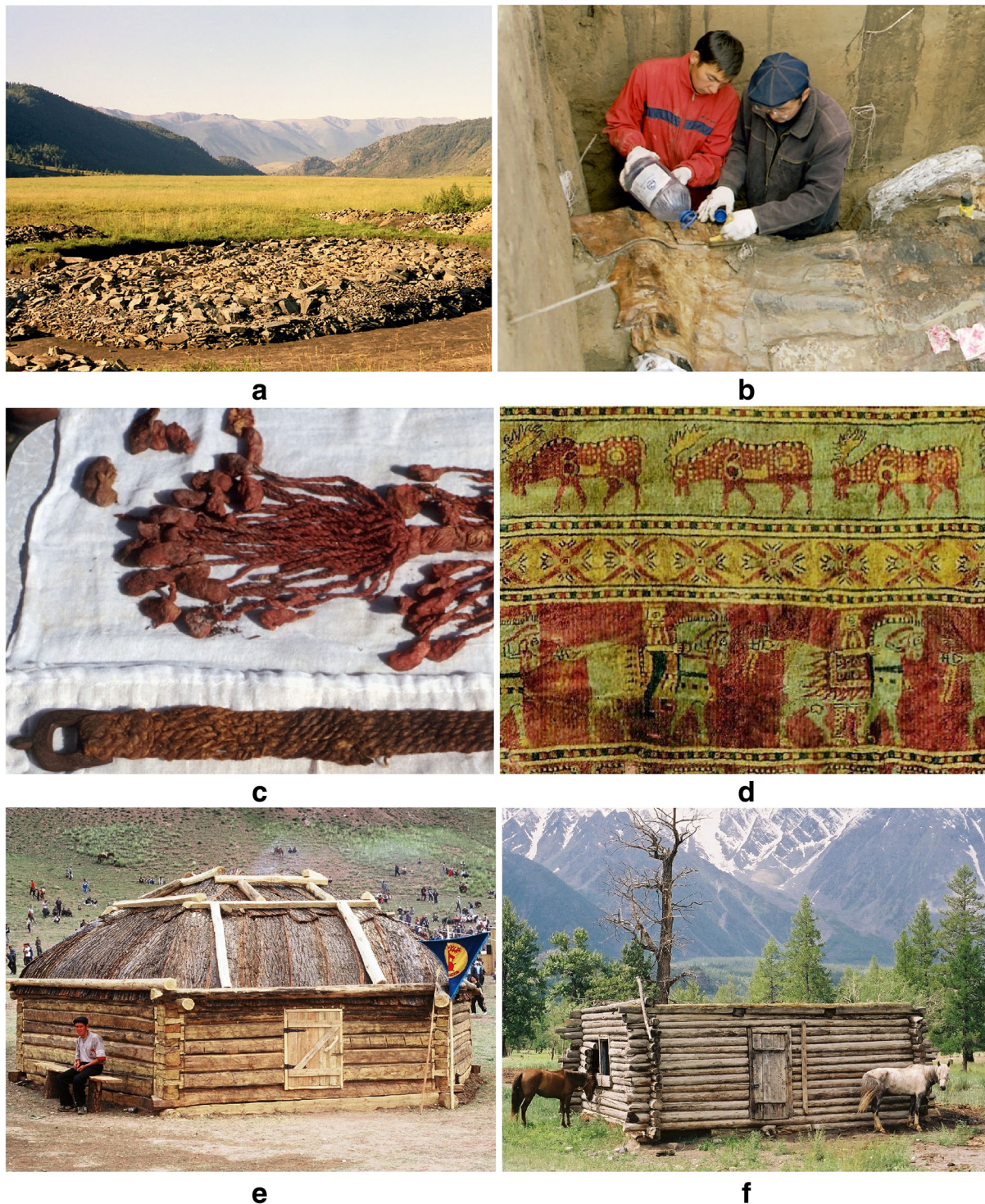
Aside for taking advantage of the natural permafrost (above 2000 m asl), the same icy conditions were artificially created at the lower elevations (1100–1300 m asl). This is best-seen in the ‘Valley of Kings’ in the upper Bukhtarma River Basin near Berel’ (East Kazakhstan) (Fig. 4a, b). There, the main burial complexes are placed in the shadow of the surrounding mountains with funeral chambers sealed in soft fine-grained silty

sediments 4–5 m below the modern surface, and intentionally water-filled so as to form permafrost lenses in this otherwise unfrozen geomorphological setting (Samashev 2011). This technique of the artificial cryolithic funeral conservation is also encountered in the Xing-Jiang Province (Turpan Basin) and in the Mongolian Scythian burial complexes (Törbat et al. 2009). The Kazakhstan sites indicate that permafrost in the Altai can exist under favourable conditions in places up to 1000 m lower than normally believed (Gorbunov and Gorbunova 1994) due to deep ground winter freezing. The larch logs used for the tomb interior point to forest clearance and, in the case of the Ukok Plateau burials, to a longer-distance transport of massive larch logs through the rough mountain terrain to the treeless uplands covered by open grasslands. Alongside the contextualising geoarchaeological information, the burial constructions themselves also serve as records for the study of forest exploitation in this period represented by people of the Pazyryk culture (Bykov et al. 2005). Under the presently progressing temperature rise in the alpine settings of Gorno Altai, the long-term conservation of the cultural monuments located in the degrading mountain permafrost is problematic (Hahn 2006). Geoarchaeology field mapping and rescue excavations of the most endangered frozen burial mound entombments are therefore of utmost importance (e.g. Epov 2003; Epov et al. 2012; Gheyle et al. 2011). Use of cryolithic grounds for the funeral (and food storage) purposes during the earlier occupation periods of Southern Altai is archaeologically not well documented but is likely particularly for the mountain Bronze Age settlements.

## The Pazyryk culture phenomenon

The major pre-modern civilization progress in the broader Altai area is associated with the Iron Age Scytho-Siberian occupation. The early Scythians, belonging to the Iranian ethno-linguistic group (Kuz'mina 2007), are known from the Antic Greek and Persian sources as nomadic horse-mounted warriors and referred to as Saka–*Sacae* (Herodotus Book VII) or *Sai* in the Chinese records (Szemerényi 1980). Their cultural links within the Altai region relate to the pastoral Pazyryk culture with its presumed genetic and cultural formation roots dating into the late Bronze Age (Rudenko 1960, 1970; Pilipenko et al. 2016).

Present archaeological evidence points to least two coeval entities in Gorno Altai during the sixth–third century BC: the Pazyryk culture and the Kara-Koba culture (Surazakov 1988) (Table 1). Craniofacial studies of the investigated cemeteries show that the preceding Eneolithic and Bronze Age population (Afanasiev culture) was ethnically rather heterogeneous and included the typical Caucasoid as well as the Mongoloid anthropological features with the latter prevalent in the Lake Baikal area and inner Mongolia, thus implying active regional



**Fig. 4** **a** The ‘Valley of the Kings’—an excavated burial mound at Berel’ (1100 m asl), East Kazakhstan, located on the flat Bukhtarma Valley floor, with a stony circular kurgan alignment of green gneiss plates extracted from nearby bedrock outcrops. **b** Excavation (Z. Samashev, 2005) of the Berel’ kurgan—exposure of birch-bark layer covering the burial chamber, contextually sealed in fine deposits (silts and clays) after creation of artificial insular permafrost ca. 2500 years ago. **c** A wool-woven belt and a red-dye coloured horse saddle decoration from the Verkh

Kal’dzhyn (2170 m asl) Pazyryk burial complex (excavation N. Polosmak, 1994). **d** A segment of the wool-made carpet from the ‘royal’ kurgan at Pazyryk, with zoomorphic and anthropomorphic decorations (The Ermitage, St. Petersburg). **e** A hexagonal Scythian woodhouse made of larch logs and a larch-bark roof used as a summer shelter of the Gorno Altai people (Kokorya, Eloin 2000). **f** A rectangular larch-wood log house with a flat grass-covered roof for year-round pastoral occupation (the Argut Valley, 1500 m asl). Photographs **a–c**, **e–f** by the author

E–W migrations (Tumen 2008). Certain ethnic diversity is also apparent in the early Iron Age among the Pazyryk bearers and the later Sibero-Scythian groups (Chikisheva 1997; Molodin 2011). The high-social-hierarchy permafrost burials in the southern Altai area, however, include exclusively the blond-hair Caucasoid race (Polosmak 2001). This shows an affinity to anthropological types of the antecedent Bronze Age proto-Caucasoid Eurasian steppe populations. The Mongoloid variant was clearly of autochthonous origin and presumably genetically linked with the bearers of the Gorno Altai Karakol culture (Chikisheva 1997).

The Pazyryk culture represents the climax of the prehistoric evolution in south-western Siberia. Its primary pastoral economy was based on horse, cattle and sheep/goat breeding adjusted to the local mountain steppe habitats. Horse represented the principal means of mobility as well as the military expansion and trade from the presumed heartland of the Sibero-Scythian tribes in the Altai-Sayan region south into the Tarim Basin (the present southern Xing-Jian Province), south-west along the Tian-Shan foothills of Kazakhstan and Kyrgyzstan into the central Asian steppes, and across the vast Euro-Asian parkland-steppes westwards into the Pontic (North Black Sea) region and the Near and Middle East (Di Cosimo 1999; Mallory 2000; Mallory and Mair 2000; Samashev 2001; Beckwith 2009). The historical process of the Scythian expansion eventually encompassing during the seventh–third century BC the territory delimited by the Carpathians in the West to the Ordos Plateau and Lake Baikal in the East (with the local pre-state organisation entities archaeologically manifested by the Ordos and Tagar cultures, respectively) is beyond the scope of this study (Legedynsky 2007). Yet, the broad physiographic diversity of the occupied lands illustrates the high geo-environmental capability of the ancient peoples to adjust to various habitats, primarily of grasslands, both uplands and lowlands. This is partly true about the Eastern Scythians (*Saka/Sacae*) living in Inner Asia and centred in the Altai Mountains. The opulent burial mounds, up to 25 m high and 20–70 m in diameter (with the largest 110 m kurgan at the Arzhan I burial complex in Tuva) (Gryaznov 1980; Chugunov et al. 2004), with larch-log tombs covered over by stone cairns sealing unique fine art items made on precious metals provide witness of active trade links with the early historical civilizations of the Hellenistic Greece, Egypt, Assyria, Iran (Parthia), the Pamir-Hindukush area (Bactria), India and west-central China. The uncovered archaeological records deliver unprecedented insights on lifestyles of the Altai occupants of that time.

## The iron age feedback to the Altai landscape

The Altai landscape experienced major environmental transformations since the Last Glacial. With the onset of the late

Holocene (4000 year BP), characterised by cooler and drier conditions leading to a gradual replacement of taiga forest by open grassland, herding began to supplement the traditional subsistence activities (hunting, fishing and wild-plants gathering). Husbandry became the principal economy during the Bronze Age (since the late third mill. BC). The following early Iron Age Altai subsistence was largely based on extensive agriculture (herding and marginal crop production) as well as forestry. Nomadic pastoralism in the broader Altai area lasting over the past five millennia since the introduction of extensive cattle breeding in mid-Holocene undoubtedly significantly affected the original post-glacial landscape with mosaic boreal taiga-steppe biotopes. This became particularly evident since the Bronze Age due to the rising population as seen by the increased number of multi-layered archaeological sites of the Afanasievo, Karakol and early Scythian traditions, and expansion of occupation habitat into the sub-alpine zone as well as the higher-altitude steppes (Figs. 2e and 3b).

At that time of the early Iron Age Pazyryk culture formation and afterwards, the most intensively occupied pristine mountain settings became transformed in a certain degree into a ‘cultural landscape’. Based on the present-day analogues from the same geographic area inhabited by the modern Altai/Kazakh/Mongol communities practicing the traditional seasonally based semi-sedentary pastoral economy with presumably the same adaptive patterns and shelters (Fig. 4f), these anthropogenically induced environmental shifts are believed to have been most pronounced on the open glacio-fluvial (riverine) terraces in the main as well as subsidiary valleys of the Katun’–Chuya –Argut Basins that represented the principal prehistoric as well as historical settlement concentration loci. Especially cattle (cows and sheep) kept in a nearby proximity of the settlements generates a certain species dominancy and uniformity by selective grass feeding, well-represented on the semi-arid Southern Altai steppes by *Artemisia*, *Fusca*, and in better-watered places along the streams of the Chuya Basin by dense, stiff grasses (Fig. 2d). Secondary and nutrient poorer mesophytic meadows comparing to alpine meadows are currently dominant in the more humid Bukhtarma Valley (Fig. 4a) and are frequently encountered in Gorno Altai as well (Fig. 1).

On the contrary, the alpine meadows and upland plateaus over 2000 m asl such as Ukok were less effected by overgrazing and have largely retained, until today, the original vegetation characteristics and floristic species structure of the Last Ice Age tundra-steppe (Chlachula 2017). This is also due to the large extent of the local open grasslands irrigated by pro-glacial streams and seasonal permafrost lakes (alases) with a greater natural regeneration potential (Fig. 3a, b). Similarly as at modern times, these upland plateaus are likely to have been used as winter pastures particularly for semi-domesticated horses kept in herds (*tabuns*) at open air due to a thinner (10–20 cm) snow cover and a better accessibility to

nutrient-rich grasses exposed on solidly frozen grounds comparing to the closed intermountain valleys with higher snow-fall rates (Rudoy et al. 2000). Very low winter temperature (presently going down to  $-40/-50$  °C) with increased windiness does not seem to have been a limiting factor for the prehistoric people as well as animals in respect to high mountain atmospheric aridity strengthened by the Siberian High. Massive larch-wood houses, wool-made temporary yurts and clothes provided some comfort in the high mountain zone even during the winter time.

Rock art has a long tradition in the Altai region possibly dating back to early Holocene. A wealth of illustrative rock-engravings' expressions of the Bronze Age in the Russian and Mongolian Altai showing wild game (elk, deer, aurochs) and herding animals explicitly documents the habitats and human activities in the upland parkland-steppe landscapes (Molodin 1994; Jakobson-Tepfer 2008). The Southern Altai mid- and late Holocene rock art with the depicted fauna—both hunted animals (mouflon, chamois, deer) living in the Altai Mountains today, as well as breded ones (such as camel, horse, cow, goat and ram)—found engraved on gneissic and granitic bedrock exposures (Fig. 3f) and decorated in the form of tattoos on the buried Scythian people's bodies provides eloquent testimony on the Iron Age adaptations and economies. Separate zoomorphic categories represent birds—golden eagle (*berkut*) or its mystic entity (gryph) and snow leopard encountered on the burial-mound votive objects. Snow leopard (*Irbis*) presently occupies the Southern Altai high-mountain habitats at  $>2000$  m asl (Chlachula 2007). Except for ritual meaning and/or a social status attribute, these zoomorphic records best-known from funeral goods (wool carpets, wooden sculptures, gold ornaments) from the famous Scythian burial complexes at Pazyryk in Gorno Altai (the Ulagan District), Ak-Alakha on Plateau Ukok and Berel' in East Kazakhstan (Fig. 4d) testify to the wide topographic range of prehistoric activities and the variety of ancient lifestyles (Rudenko 1970; Polosmak 2001; Polidovich 2008; Marsalodov 2013).

The century-long intensive grazing on the semi-arid xerotheric mountain grasslands geomorphically associated with the glacio-fluvial terraces and rocky piedmont settings, spatially confined to the main riverine valleys of the Katun', Chuya, Argut and Bukhtarma River, was likely posing a biotic stress to the short-grass dominated ecosystems and promoted distribution of nutrient-poor and taxonomically uniform plant species. This trend may have triggered an incipient emergence of semi-sedentary animal herding and horse breeding with seasonal homesteads analogous to the historical ones used in the area until today, eventually supplemented by extensive agriculture. Climatic and environmental conditions under increased atmospheric humidity over the Altai territory during the early first mill. BC (Sub-Atlantic) (Table 1) undoubtedly effected timing of spread of domestic plant cultivation in

north-central Asia. In SW Siberia, millet and barley were grown since the mid-second mill. BC although some grain recorded at the Altai's archaeological sites may have been imported (Ryabogina and Ivanov 2011). Palaeobotanical investigations suggest initial cultivation of cereals (wheat, broomcorn millet and naked barley) introduced from Central Asia into Eastern Kazakhstan and the Russian Gorno Altai during the late Bronze Age (Spengler et al. 2016). The better naturally irrigated mosaic mountain steppes and semi-humid river valley settings (the latter with fertile chernozemic soils) may have provided reasonable yields supplementing the principal pastoral economy at the time of the Scythian occupation. The regional geo-environmental food-production conditions allowed for a relatively high demographic concentration of the prehistoric semi-nomadic communities in congruence with the mapped burial sites found in most of the Altai valleys and uplands. Fortified settlements recorded in the East European and West Siberian steppes (e.g. Melyukova 1995; Becker and Fassbinder 1999) are absent in the Altai region. This may be due to the high mountain relief with natural physiographic barriers, deep ravines and swift rivers hampering accessibility into the area.

The Altai Scythian permafrost tombs revealed remains of various plants used in ritual practices or daily life as medical plants or hallucinogens with specific geographic or altitudinal provenance connotation. Use of *Canabis* sp. by the Pazyryk people is well documented (Rudenko 1953). While this plant is absent on the arid plateaus of Gorno Altai such as Ukok, it is (and most likely used to be) widely distributed in the adjoining Bukhtarma Valley of East Kazakhstan with milder and more humid settings. The unique botanical diversity of the Southern Altai steppes and especially the alpine meadows (Koutecký et al. 2007) allows to assume a broad application of the local flora for healing practices and teas (e.g. *Rhodiola*, *Bergenia*, *Rhaponticum carthamoides*) and for the bodies' mummification using floral balsams. Arboreal and non-arboreal plants are also frequently found as motives in the Scythian artwork showing close ties of the ancient people to the natural Worlds/their occupation environment. Neither mummification nor a particular season of burial seems to have played any role in the final burial preservation (Polosmak 2001).

Wood used for the kurgans' interior structure points to forest clearance and, in the case of the Ukok Plateau burials, to a longer-distance transport of massive larch logs through the rough mountain terrain (Fig. 3a) to the treeless upland tundra covered by open grasslands (Fig. 3b). Alongside the contextualising geoarchaeological information, the burial constructions themselves serve as records for the study of forest exploitation in this period represented by people of the Pazyryk culture (Bykov et al. 2005). The active Iron Age deforestation of the Southern Altai pilot-studied in the eastern part of the Chuya Basin (Agatova et al. 2014) undoubtedly

strengthened, together with overgrazing, the negative anthropogenic impact to the early Late Holocene landscape and promoted regional aridity. The radiocarbon and dendrochronology cross-dating of well-preserved larch (*Larix sibirica*) wood logs from the permafrost-sealed Scythian mounds demonstrates persistence of the Paryzyk culture in Gorno Altai during the period of 720–240 year BC. The following stage of the early historical forestry with intensified wood cutting during the Hun-Sarmatian and early Turkic period (AD 470–830) indicates a major anthropogenic feedback to the Altai landscapes (Panushkina et al. 2007). Except for fuel, larch wood use for house construction is best-evidenced by polygonal log structures found dissembled at the Ak-Alacha I burial complex (kurgan 1) (Myl'nikov 1999; Polosmak 2001) and reminding the historical Altai household dwellings (*ails*) used for food preparation and as a family summer shelter (Fig. 4e). Wooden instruments of daily use, such as ladders, waggons, chariots, and wooden objects for ritual purposes have also been found (Rudenko 1953).

All these activities and ancient adaptation strategies left permanent imprint on the present Altai landscapes with a continuation of the traditional economies passed from generation to generation throughout millennia. The past–present cultural continuity is also apparent in the historical Kazakh artwork exemplified by wool-made carpets with the original Scythian style ornaments and production technique recorded in the permafrost tombs and on jewellery motifs (Polosmak 2001, 2013; Samashev 2014).

## Prehistoric people and environment interactions

The diversity of the relief and natural environments in the Southern Altai played a major role in the process of prehistoric and early historical occupation of this mountain territory. By mapping the geographical distribution and the geomorphic context of the cultural remains human adaptation to the shifting climate of the Holocene in this locally varied, but highly continental setting can be explored. The topographically prominent Altai Mountains, situated at the southern margin of Siberia, are seen as a gateway for the initial peopling of north-central Asia since the Palaeolithic times and a major passage way for ethnical and cultural interaction and exchange in later periods, as is evident from its rich archaeological landscapes. The sequenced Holocene nomadic migrations are explicitly evidenced by numerous cultural sites and isolated monuments. The physiogeographic regularities of occupation loci in transitional (former periglacial) mountain zones corroborate the evolution of relief in the particular areas documented since the Late Pleistocene (Baryshnikov 1992; Baryshnikov and Maloletko 1999).

Past climate change and associated geo-environmental transformations across the Altai's intermontane basins and upland plateaus are evident in geological, biotic and early cultural records. The well-preserved glacial topography and the derived glacial deposits attest to multiple mountain glaciations sculpturing the former ice-marginal periglacial landscapes and forming favourable environments for human habitation in later, post-glacial times. Because of the pronounced climatic continentality of the territory, even minor variations in atmospheric humidity and heat balance led to major changes in local ecosystems, particularly in the open intermontane basins (Chuya, Kuray, Samakha) and the alpine plateaus (Ukok), this is easily observed today (Chlachula and Sukhova 2011). Relatively stable and more balanced conditions persisted in the protected lower-reaches of the Katun' and Chulyshman River Valleys in the central and northern areas, respectively, due to increased annual precipitation and the tempering effect of the mountains. In the southern Altai region (the Chuya and southern Kuray Basins), however, very dry conditions characteristic of the Mongolian steppes and semi-deserts prevailed throughout the history of human interaction with these mountain territories. This is due to the major orogenic barriers (3000–4500 m asl) which inhibit the influx of the westerly/north-westerly atmospheric streams, though it has been accentuated by a marked territorial aridisation after the Holocene (Atlantic) climatic optimum (ca. 8000–6000 year BP). Only the connecting river valleys, which follow a more progressively sloping (1800–1300 m asl) topographic gradient (Dzhazator, Koksus, Argut, Karagem, Bukhtarma) (Fig. 1), host vital year-round ecosystems with lush meadows and patches of trees on the raised terraces and floodplains near the glacier-fed channels emanating from the Southern Chuya and Katun' Ranges. Unsurprisingly, these valleys are associated with more permanent and substantial evidence of prehistoric and early historic activity. This is seen most clearly in the numerous Bronze and early Iron Age sites, mostly associated with ritual or ceremonial activities (rock-engravings, burial grounds). The occupation sites of this region are basically unknown. This can be explained by simple wooden structures and semi-mobile yurt-style households similar to these used by the historical including modern Altai and Kazakh inhabitants of the area.

The prehistoric colonisation of these mountain territories is archaeologically visible from the late Last Glacial. However, bearing in mind the dramatic large-scale geomorphologic processes during the Last Glacial period, with cataclysmic flooding from the glacial lakes, an earlier (Upper/Middle Palaeolithic) occupation documented in the non-glaciated valleys of NW Altai (Derevianko and Markin 1999) cannot be excluded. Indices of this might be difficult to find in the distorted geo-environmental context (Chlachula 2010b). Existence of pre-Last Glacial sites, however, is quite plausible. A solid evidence for occupation of the Southern Altai and the



West Sayan mountain basins following the last deglaciations relates to Final Palaeolithic/Mesolithic (Chlachula 2001; Zwyns 2014). The subsequent Neolithic settlement (Table 1), based on early pastoral economy in addition to traditional hunting and fishing, principally concentrated – according to the present evidence – in the Central Altai mountain valleys and tributary streams rich of fish which provided the most environmentally favourable natural conditions (Kiryushin et al. 2006).

A territorial expansion in the mountain (alpine) regions and upland plateaus is securely dated into the Eneolithic and the Bronze Age (the Palaeo-Metal traditions) in linkage with search and exploitation of the rich local mineral resources (Bertek 56 and Kara-Chad burial sites on the Plateau Ukok, cooper mines in the Kalguty area (Ukok), etc. (Molodin et al. 2004; Pilipenko et al. 2016). At that time, southern Siberia experienced a major expansion of newly occupied lands in both lowlands (the steppe Altai) and the mountain areas. A more arid and cold climate in comparison with the first half of the Holocene brought an economic prosperity of the Altai nomadic cultures. Semi-sedentary lifestyle documented across south-western Siberia presumably generated a demographic rise comparing to the previous cultural stages relying on the traditional and more mobile hunting-gathering food-procurement (Zakh 2013). Regionally, the most significant cultural findings are, however, associated with the Iron Age period, showing a more permanent establishment in high-mountain tundra-steppe (Polosmak 2001). This climate-triggered civilization trend eventually led to introduction of knowledge of iron smelting in the southern Altai area during the following centuries (Agatova et al. 2017a, b).

Human activity in the early Iron-Age of the Altai (ninth-third century BC) is found in greatest abundance in association with landforms left by the formation and drainage of the vast glacial lakes during the Pleistocene (the glacial lakes' floors and the regressing glacio-fluvial platforms). These are found throughout the region in both intermontane depressions and upland plateaus—in the Kuray-Chuya Basins (the Chuya Lake), the Argut, Koksu and Dzhazator River Valleys (the Samakha Lake) and the Bukhtarma River Valley (the Bukhtarma Lake), all are associated with the staged retreat of MIS 2 glaciers in the Katun', the Southern Chuya and the Southern Altai–Naryn Ranges, respectively. Rich seasonal (late spring-early summer) grasslands are presumed to have been the primary impetus for this occupation of rather remote and difficult-to-access places, such as Plateau Ukok (which is also a former glacial basin) (Rudoy et al. 2000) (Fig. 3b). Another reason for this focus of activity may have been the existence of mountain permafrost, found today above ca. 2000 m altitude. The hypothesis on the major geographic expansion during the early Scythian period apparently linked to ameliorated climate across mid-latitude Eurasia—with increased humidity due to reduced solar activity during the early

first mill. BC (van Geel et al. 2004)—should be treated with care. Most of the Altai-Sayan area was occupied by significant prehistoric populations before that time (see above). This hypothesis also contradicts the pollen records from the mountain lakes from the very centre of the study area showing on the opposite, expansion of steppe-vegetation and climate cooling (Blyakharchuk et al. 2007).

The circular burial mounds constructed from the granitic boulders found in the active riverbeds and the erosional top-surface glacio-fluvial terrace pavements (Fig. 2b), or angular blocky gneiss fragments (Fig. 4a) represent the most characteristic and well-evident archaeological feature in the Southern Altai arid landscape. The contextual site geoarchaeology associated with the alpine zone glacial and glacial deposits, and the corresponding geomorphic settings of the open mountain steppes apply equally to all of the principal Pazyryk burial complexes in the Russian Altai (Pazyryk, Tuekta, Bashadar, Uzuntal, Kuderge, Ulandryk, Yustyd, Barbugazy, Saliyugem, Bertek, Ak-Alakha and some other) as well as in East Kazakhstan (Uryl', Zhambul, Berel') found in the topographic range from 1100 to 2200 m asl (Rudenko 1952, 1953, 1960, 1970; Gavrilova 1965; Artamonov 1973; Kubarev 1987, 1991, 1992; Molodin 1994; Polosmak 2001; Gheyle et al. 2005; Gorbunov et al. 2005; Samashev 2001, 2011, 2014) (Fig. 1). A very similar topographic distribution to the Scytho-Siberian Iron Age burial mounds is found in the neighbouring regions of Tuva and Khakasia in the West Sayan Mountains, East Kazakhstan, NE China and northern Mongolia (Gryaznov 1980; Chugunov 1994; Chikhachev 1974; Polosmak 2013).

The changing landscapes of the Altai and the specific adaptive patterns of the early nomadic communities are evidenced by the present archaeological data from the Eneolithic through until recent historical times (Gheyle 2009). A common trait of all these communities is the practice and preservation of a traditional pastoral economy. Marked shifts in the distribution of vegetation zones, associated with the sub-Boreal climatic deterioration (Litt et al. 2001), are evident across southern Siberia in the mid- and late Holocene records from the southern Urals to the Russian Far East (Ryabogina 2001; Zakh et al. 2010; Rudaya et al. 2012, 2016; Zhilich et al. 2017; Chlachula and Krupyanko 2016). In SW Siberia, this development is documented by a general prevalence of open steppe vegetation elements under a relatively warm and dry climate with isolated birch forests between 4400 and 3750 year BP (Rudaya et al. 2012). Similar conditions are presumed in the Altai region between ca. 3900 and 3600 yr. BP with widespread distribution of cold, open mountain-steppe communities dominated by *Artemisia*, Chenopodiaceae and Cyperaceae followed by taiga-forest re-establishment in the foothills under temporally ameliorated climate at ca. 2700 year BP (Bykova and Bykov 2014; Rudaya et al.

2016). These climate change patterns were accentuated by negative atmospheric humidity during the period ca. 3400–2600 cal/year BP, which resulted in progressive regional aridification and the expansion of steppe landscapes across southern Siberia.

This trend undoubtedly facilitated prehistoric human adaptation to the open upland landscapes of the Altai: to its high mountain plateaus and increasingly arid intermontane depressions, watered only by seasonal ice-ablation streams and small thermokarst (alas) lakes. The diverse geological and geomorphic context of the mapped early Iron-Age archaeological sites and the inhabited palaeo-landscapes subjected to Holocene environmental transformations (such as an increased top-surface erosion and sediment-replacement) may be used as proxy tools for mapping human ecology and the culture-historical evolution in the broader Altai region during the last ca. 10,000 years. The extreme climate (with winter temperatures falling down to  $-55^{\circ}\text{C}$  on the Plateau Ukok) meant that adaptation to this environment was a prerequisite for the year-round occupation of the southern Altai's mid- and late Holocene mountain settings. In addition to climate, regional endogene processes associated with the continuous uplift of the Altai Mountains generating strong earthquakes in the Chuya Basin at the recurrent interval of ca. 400 years contributing to a local fluvial system transformation (Agatova et al. 2014) may have effected, to some extent, the prehistoric and early historical environmental adjustment and the social-economic stability of the spatially dispersed nomadic communities. Due to the geographic location within the active orogenic zone (Buslov et al. 2004; Cunningham 2005), earthquakes continue to affect the Southern Altai area with a disastrous impact to modern occupation sites. Overall, the complex prehistoric and early historical economic activities of the southern Altai populations were directly influenced by the sequenced climatic and corresponding environmental changes pre-requiring secure adjustment to specific (alpine and steppe) mountain settings eloquently and best-manifested by the Scythian cultural monuments. The past regional natural events together with the social-economic, demographic and political factors predisposed the persistence of the Holocene pastoral populations, their occupation habitat, and the pathways of their cultural evolution.

## Conclusion

The Gorno Altai represents one of the scientifically most fascinating places of south-western Siberia. The mapped geographical distribution and the contextual geological and geomorphic position of the archaeological monuments and cultural records reflect the past climatic shift and environmental transformations following the Last Glacial responded to by the specific prehistoric adaptation

strategies adjusted to the extremely continental mountain settings. The sequenced human history of this territory and its relationship with particular topographic zones and land-forms entailed into a multi-proxy geoscience framework provides testimony on dynamic interactions of people and past landscapes. The Quaternary geological evolution of the broader Altai with its multiple phases of glaciation documents major geomorphic restructurings with activated erosion in the alpine zone and accumulations of thick (pro)glacial, alluvial, proluvial, lacustrine, and aeolian deposits in deep intramontane basins, which were subsequently periodically occupied by people. The southern areas experienced major relief transformations as seen in preserved relict geomorphic features in the upland and mountain regions, which formed the geo-environmental context of early human settlements and activity persisting semi-continuously until today. The large-scale mass-wasting processes that sculptured the present landscape, after the cataclysmic drainages of glacier-dammed lakes at the final stage of the Last Ice Age (MIS 2), created the most suitable geo-environmental conditions for the Holocene inhabitation. Glacial-lacustrine terraces in the main mountain valleys above the modern floodplains of the Chuya, Katun', Argut and Bukhtarma Rivers were the principal geo-settings of Southern Altai occupied by prehistoric and early historic pastoralist communities across the broad ( $>2600\text{--}800\text{ m}$ ) altitudinal gradient. The regional sub-boreal landscape aridification is believed to have fostered successful Eneolithic and Bronze Age adaptation to the mountain steppe ecosystems, with the younger stage (1350–400 year BC) partly coeval with the formation of the Scythian cultural milieu. Reconstruction of the evolution and dynamics of the Holocene climates that ultimately predetermined the current mosaics of the mountain steppe, boreal and alpine ecosystems in the Altai—together with the effects of anthropogenic activities (animal grazing and forestry)—provide an essence to our studies of change in the past human societies of this region and delivers new insights on the process and the environmental background of early peopling of this territory. Degradation of its frozen grounds due to present climate warming in southern Siberia leads to destruction of archaeological remains sealed in the permafrost, threatens preservation of the uniquely rich organic cultural records, and forces shifts in the pattern of modern human settlement.

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## Compliance with ethical standards

**Conflict of interest** The author declares that there is no conflict of interest.

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