## *Geomorphology of Blidinje, Dinaric Alps (Bosnia and Herzegovina)*

Stepišnik, Uroš; Grlj, Aleš; Radoš, Denis; Žebre, Manja

*Published in:*
Journal of Maps

*DOI:*
10.1080/17445647.2016.1187209

*Publication date:*
2016

*Citation for published version (APA):*
Stepišnik, U., Grlj, A., Radoš, D., & Žebre, M. (2016). Geomorphology of Blidinje, Dinaric Alps (Bosnia and Herzegovina). *Journal of Maps*, *12*, 163-171. https://doi.org/10.1080/17445647.2016.1187209

# Geomorphology of Blidinje, Dinaric Alps (Bosnia and Herzegovina)

[1]**Uroš Stepišnik,** [2]**Aleš Grlj,** [3]**Denis Radoš,** [4]**Manja Žebre**

[1] Department of Geography, University of Ljubljana, Aškerčeva 2, Ljubljana, Slovenia
[2] Harpha Sea ltd., Koper, Čevljarska 8, Koper, Slovenia
[3] Department of Geography, Universty of Zadar, Trg kneza Višeslava 9, Zadar, Croatia
[4] Geological Survey of Slovenia, Dimičeva ulica 14, Ljubljana, Slovenia

**Abstract**

Blidinje is tectonically derived lowland in the Dinaric Alps within Bosnia and Herzegovina. It is surrounded by the Vran, Čvrsnica and Čabulja Mountains. The Blidinje study area is predominantly built of carbonates, where karst, fluvial and glacial geomorphological systems interchange. We present a 1:25 000 geomorphological map covering a 100.5 km$^2$ at elevation span between 1200 m and 1900 m. The map results from a combination of a fieldwork mapping, interpretation of orthophotos, and analysis of digital elevation model. This map presents a distribution of landforms and sediments associated with the past and present karst, glacial and fluvial processes, such as different varieties of karst depressions, conical hills, erosional gullies, alluvial fans and large amphitheatre-like moraines. The focus of the presented map is to assist on-going studies in this part of the Dinaric Alps that seek to understand the dynamics of former glaciers and associated palaeoclimate.

**Keywords:** karst, glaciation, geomorphological map, Dinaric Alps, Blidinje

## Introduction

The Dinaric Alps are a range of the Alpine orogene parallel to the eastern Adriatic coast from Slovenia to north Albania. They extend across western Croatia, and the majority of Bosnia and Herzegovina, and Montenegro. The study area is located in the centre of this mountain range in the south-western Bosnia and Herzegovina. It consists of three interconnected lowered relief units which are predominantly built of carbonate bedrock: Svinjača in the south-west, Dugo Polje in the centre and Brčanj in the north-east. The area also includes the southern slopes of the Vran Mountain (2074 m a.s.l.), north-western slopes of the Čvrsnica Mountain (2226 m a.s.l.) and northern slopes of the Čabulja Mountain (1776 m a.s.l.) (Figure 1). The investigated area has several names; local people call it Polja (plural of polje), while in the literature the toponyms Dugo Polje, Blidinje Polje and Blidinje are to be found. The latter has its origin in Blidinje Lake (Figure 2(a)), located in the southern part of Dugo Polje. Also the Blidinje Nature Park established in 1995 was named after the lake. Therefore, our study area is referred to as Blidinje after the Blidinje Nature Park.

The Blidinje study area along with its surrounding mountains Vran, Čvrsnica and Čabulja belongs to the structural belt of the Outer Dinarides of Bosnia, specifically to the zone of Bosnia and Herzegovina high karst (Buljan, Zelenika, & Mesec, 2005). The Čvrsnica Mountain is a syncline, disturbed by young fault lines, positioned transverse to the dominant northwest-southeast direction of the main structure. The Vran Mountain is a similar morphostructural feature dissected by numerous folds, faults and thrusts (Šimunović and Bognar, 2005). The Blidinje area between the Vran, Čvrsnica and Čabulja Mountains is tectonically derived lowland. The study area is

predominantly built of more or less permeable Cretaceous and Jurassic carbonate rocks and their Quaternary re-depositions, that retain surface water in form of the above mentioned extensive but shallow Blidinje lake, and some intermittent streams in the Brčanj area (Raić & Papeš, 1968; Sofilj & Živanović, 1979; Šimunović & Bognar, 2005).

The initial geomorphological research of the Čvrsnica Mountain and surrounding areas was carried out by Cvijić (1899). He studied karst and mass movement landforms in the entire area of Čvrsnica, while he found traces of glacial action solely around the highest peaks. According to Cvijić (1899) the lowest terminal moraines are present at elevation of 1900 m. Grund (1902) identified glacial deposits at Dugo Polje and terraces of at least three separate glacial phases on the slopes of the Vran Mountain. Milojević (1935) partially confirmed earlier findings of Cvijić (1899) and Grund (1902), but he misinterpreted moraine ridges on the eastern side of Dugo Polje as fluvioglacial deposits. Moreover, he identified moraine ridges on the eastern side of Svinjača. Afterwards, traces of glaciation in the area of Blidinje were studied in detail by Roglić (1959). The author stated that a distribution of moraines east of Svinjača is a result of at least two separate glacial phases, while younger phase deposits are covering eastern part of Dugo Polje (Roglić, 1959). Moreover, he identified extensive glacial accumulations on the northern plateau of the Čvrsnica Mountain and outwash deposits covering part of Brčanj. Šimunović and Bognar (2005) argued that glaciers from the Čvrsnica Mountain descended also towards south and southeast towards deeply incised valleys. The authors ascribed upper and lower Würm age to the identified palaeoglaciers. Milićević and Prskalo (2014) mentioned a total of 26 preserved cirques on the Čvrsnica massif.

Besides Vran, Čvrsnica and Čabulja also some other mountainous areas of Bosnia and Herzegovina were affected by Quaternary glaciations (e.g. Cvijić, 1899; Grund, 1902; Milojević, 1935; Žebre & Stepišnik, 2015), as well as other high elevated sections of the Dinaric Mountains in Albania (Milivojević, Menković, & Ćalić, 2008), Montenegro (Hughes, Woodward, van Calsteren, & Thomas, 2011; Žebre & Stepišnik, 2014), Croatia (Marjanac & Marjanac, 2004) and Slovenia (Žebre, Stepišnik, Colucci, Forte, & Monegato, 2016; Žebre & Stepišnik, 2015). Not only they hosted cirque and valley glaciers, but also large ice caps, which were some of the largest in the Mediterranean owing to sustained moisture supply during cold stages (Adamson, Woodward, & Hughes, 2014). Although a great progress has been done recently on the palaeoglaciation studies, the Dinaric Alps still lack a precise glacial chronology and a comprehensive palaeoclimate interpretation. The only glacial chronology in the Dinaric Alps has been provided for the coastal (Hughes, Woodward, van Calsteren, Thomas, & Adamson, 2010) and central Montenegro (Hughes, 2010), using uranium series dates from secondary carbonates of tillites. These studies indicate four glacial phases, with the largest glaciers occurring before 350 ka, being significantly larger than during the Last Glaciation.

The aim of this map is to present the geomorphological complexity of the Blidinje area (Main map). Many studies already described this area from the geographical, geological and geomorphological point of view; however, their cartographic presentations do not offer a comprehensive insight into the full fluviokarst, glaciokarst and karst landscape interactions. With this map and its descriptive part we aim to produce a quality presentation of the results obtained through exact and thorough fieldwork as well as the study of the aforementioned literature.

**Methods**

The geomorphological map of the Blidinje area (Main map) is a result of a fieldwork mapping, accompanied by the analysis of a 20 m resolution digital elevation model (DEM), orthophotos

("Geoportal Web Preglednik," 2016), GoogleEarth images and topographic maps at a scale 1: 25 000 ("Geoportal Web Preglednik," 2016).

The methods used in this research follow the concept of morpholithostratigraphy (Hughes, 2010). A 100.5 $km^2$ large study area was mapped in detail during fieldwork campaigns in the course of summers 2014 and 2015. Geomorphological mapping was supported by the use of topographic maps and Global Positioning system (GPS) navigation device. Maps of landmine contamination from the 1992-1995 war, which were provided by the Bosnia and Herzegovina Mine Action Centre, were also essential while performing field survey. Fieldwork data accompanied with the analysis of Yugoslavian basic geological maps at a scale of 1:100 000 (Papeš, 1972; Raić, Ahac, & Papeš, 1976; Sofilj & Živanović, 1979) assisted us in distinguishing between different geomorphological systems. Apart from geomorphological mapping, special attention was placed in describing glacial and alluvial deposits. The latter are of very diverse origin in the Blidinje area owing to the interchanging characteristic of karst, glaciokarst and fluviokarst geomorphological systems and related processes. The final morphogenetic interpretation of the mapped geomorphological features was made also taking into account rather scarce geomorphological and geological bibliography about this area (Milićević & Prskalo, 2014; Milojević, 1935; Roglić, 1959).

The Main map was prepared in ArcGIS 10.3.1, using shaded relief and 50 m interval contours derived from 20 m DEM as a base layer. Yugoslavian basic geological maps at a scale of 1:100 000 served as a source for cartographic presentation of a simplified distribution of lithological units in the Main map. The geographic datum used is WGS 1984 and the projection a Transverse Mercator.

**Results**

The area of Blidinje can be divided into four main morphographic units. The central unit is the area of lowered relief, which is elongated in the southwest-northeast direction. It consists of three detached, predominantly flat areas that are separated by zones of slightly elevated relief. The three flat areas are engulfed within surrounding high mountain massifs. The most dominant one is the Čvrsnica Mountain toward southeast. In the direction of north is the Vran Mountain and to the south is the western part of the Čabulja Mountain.

General relief outlines are strongly influenced by geological structure. The whole area of Blidinje with the surrounding high mountain plateaux is part of one overthrust nappe. The nappe is dissected by a number of regional faults into separated uplifted areas within compression zones. The central part of the study area is a lowered relief, which was formed along extension zone. The entire area consists of carbonate bedrock or carbonate derived Quaternary deposits. Geomorphological processes and features on the surface are rather diverse regardless of relatively uniform lithological settings. Local variations in surface gradients, type of bedrock, tectonic settings, and past environments of colder climates are influencing a typical functioning of different areas as karst, fluviokarst and glaciokarst.

Karst landscape is located within limestone and some dolostone areas that have moderate surface gradients. A well-developed subsurface drainage within karst results in vertical runoff of precipitation, prevailing chemical weathering, and formation of typical rounded depressions on the surface (Gams, 2003; Williams, 2003). Fluviokarst landscape is typical for tectonically deformed limestone areas as well as for majority of dolostone areas. This type of landscape is generally functioning as karst with subsurface drainage. Nevertheless, intense mechanical weathering of the surface, owing to intense frost action in colder climate periods or tectonic deformations, is causing thicker regolith cover to develop. As a result, temporary local surface streams will appear, causing

local erosion and deposition of material. Active and non-active erosional gullies on carbonate slopes with high gradients and alluvial fans further down the gullies are typical features of a well-developed fluviokarst (Field, 1999; Gunn, 2004; Roglić, 1958). Glaciokarst areas are actually just de-glaciated karst areas, where functioning of geomorphological processes is generally limited to chemical weathering of the surface and almost complete subsurface drainage. As a result, geomorphological features, products of past glaciations, are well-preserved (Smart, 2004; Žebre & Stepišnik, 2015; Žebre & Stepišnik, 2015). Glacial deposits, mostly carbonate derived till and tillite, are widespread in the study area. They commonly consist of matrix-supported diamicton with subangular to subrounded clasts. They form large terminal moraines likely of different generations. Some of the moraines resemble rather regular amphitheatre-like shape, hosting up to 150 m deep depressions. Even though they are deposited within karst and behave as a karst surface, streams sporadically appear due to their thick semipermeable layer. These streams, which were active during glacial retreat or intense weather events, conditioned a formation of gullies and dry riverbeds.

The study area of Blidinje is an elongated depression between the Čvrsnica, Vran and western Čabulja Mountains. It is oriented in the southwest-northeast direction and is ~ 20 km long and 2–5km wide. The Blidinje depression is further divided in three lowered relief units, infilled by various sediments derived from surrounding slopes. The northeasternmost unit is known as Brčanj (Figure 2(b)). It has completely levelled floor, surrounded by the Vran Mountain in the west and the Čvrsnica Mountain in the east. It limits to an elevated, slightly levelled karst area toward south, while toward north to a narrow ridge that separates Brčanj from deeply entrenched canyon of the Doljanka River, a right tributary of the Neretva River. The flattened floor of Brčanj is situated at an elevation of ~ 1200 m; it is ~ 3 km long and nearly 1 km wide. It mostly consists of fine-grained sediments. Its eastern and southern slopes are completely made of limestone bedrock covered by characteristic karst features. The northern slopes are composed of dolostone, and therefore dissected by a number of non-active gullies. The eastern slopes are covered with an extensive proglacial fan having an area of ~ 2.2 $km^2$ that is situated below extensive (~ 4.4 km in diameter) terminal moraine complex, deposited from the northern Čvrsnica Mountain. A number of small streams are emerging from the foot of the fan. They are meandering toward southeast margin of the flattened floor, where streams are submerging inside ponors situated on the contact with limestone bedrock. The entire area of Brčanj is filled with fluvioglacial deposits from the fan and possibly periglacial deposits from inert gullies in the northern fluviokarst slope, and can be thus considered as a piedmont-type polje according to the hydrological function classification system (Bonacci, 2004a, 2004b, 2013; Ford & Williams, 2007; Gams, 1978; Williams, 2003).

South of Brčanj, a levelled karst area is situated ~ 60 m above the polje floor. This limestone surface is completely covered by various doline-sized karst depressions and non-distinct conical hills (Figure 2(c)). Toward east and west is limited by a number of proglacial and fluviokarst fans that are situated at the footslope of surrounding mountains. Southern limits of this area present extensive glacial deposits that are part of a central depression of the Blidinje area, which is referred to as Dugo Polje. Its floor is elongated in the northeast-southwest direction. The polje is enclosed by steep slopes of the Vran Mountain to the north and by large moraines covering the footslopes of the Čvrsnica Mountain to the south. The southwest margin of Dugo Polje, separated by a couple of ridges from the prolongation of the Blidinje lowland, is less clear. The floor of Dugo Polje gradually descends from ~ 1240 m a.s.l. in northeast to 1180 m a.s.l. in southwest, where Blidinje Lake is inundating lower sections. These are covered with fine-grained sediments. Stretches of abrasion terraces close to the southern and eastern shores are positioned up to 7 m above the mean lake level and indicate to a much larger extent of the flooded area during past periods. Upper sections of the Dugo Polje floor to the northeast and north are completely covered with fluviokarstic and proglacial fans. Northern

slopes above Dugo Polje are built of limestone and dolostone bedrock. The limestone slopes have higher gradient and are dissected by gullies that are predominantly present within tectonically deformed bedrock. Density of gullies in dolostone is much higher and the slopes are completely remodelled by gullying. Slopes in south and east are also made of limestone, but are dissected by few gullies. Nevertheless, majority of the Dugo Polje area is covered with extensive glacial deposits. Three major moraine complexes cover this area. The easternmost is the most extensive terminal moraine complex. It forms large amphitheatre-like shape of parallel moraine ridges, having a total diameter of ~ 3 km. These moraines were not disturbed by any significant post-glacial process owing to a glaciokarst environment, and are therefore well-preserved (Figure 3(a)). In addition, the outer rim of the moraine loop is dissected by non-active riverbeds, formed by proglacial or postglacial streams. Below them are extensive fans covering parts of Dugo Polje. The largest fan has an area of 3.4 $km^2$. Two similar, but smaller loops of terminal moraines cover Dugo Polje to the west. The depression of Dugo Polje can be defined as a karst polje regarding its morphometry and hydrological function. It can be further classified as a border-type polje because of inflows from fluviokarst areas or as a piedmont-type polje due to former inflows from glaciated areas (Ford & Williams, 2007; Gams, 1978).

Elevated area southwest of Dugo Polje that separates it from the southwesternmost depression is referred to as Svinjača. Svinjača is surrounded by foothills of the Vran Mountain to the north and the western Čabulja Mountain to the south. It is ~ 3.5 km long and up to 1.5 km wide, having a flat floor at an elevation of ~ 1170 m. The lowest section of this depression in the northwest is filled with fine-grained sediments, while other parts of the floor are built of coarser deposits, such as sands and gravels. Majority of surrounding slopes are built of dolostone hosting fluviokarst landscape with well-developed gullies and alluvial fans. All fans beneath the northern slopes are merged into one compound alluvial fan with an area of 3.7 $km^2$. The northwestern section of this large fan is predominantly built of cemented alluvial deposits with dry riverbeds and dolines on the surface (Figure 4(a), 4(b) and 4(c)). This type of fan can be termed as a relict alluvial fan (Stepišnik, 2010) where deposition of alluvium along with erosion in the hinterland of the fan is inert. The southeastern slopes are built of typical hummocky moraines, originating from the Čvrsnica Mountain (Figure 3(b) and 3(c)). Below them is proglacial fan, covering large section of the Svinjača floor. There are no surface streams in the Svinjača depression. Even though we can define its hydrological function in the same way as in the case of Dugo Polje, Svinjača is a combination of a piedmont and border-type polje owing to a presence of fluviokarst and proglacial deposits filling the polje (Ford & Williams, 2007; Gams, 1978).

**Discussion and conclusions**

The Blidinje area was occupied by piedmont type glaciers (Figure 5) as can be recognised from the palaeoglacial landform morphology, which exhibit large lobate moraine ridges or hummocky moraines on a predominantly levelled surface. The exceptionally well-preserved moraines indicate that the largest piedmont glacier lobe was ~ 3 km wide and more than 100 m thick. Piedmont glaciers in Blidinje formed due to unconfined plain, adjacent to the mountain (Barr & Lovell, 2014). However, majority of moraines surrounding the Čvrsnica and Čabulja Mountains were deposited by steep outlet glaciers, which drained the ice fields into narrow basins, preventing the development of extensive glacier lobes. These moraines are significantly less preserved than the lobate moraines in Blidinje, because they were reworked or completely washed away by fluvial erosion. This situation is particularly common for the mountains in the southwestern Bosnia and Herzegovina, where non-carbonate rocks underlie carbonate massifs, forming fluvial relief with restricted space for the

formation of a piedmont type glacier. However, several past glaciated high plateaux in the Dinaric Alps are surrounded by karst poljes, containing some of the thickest and best-preserved glacigenic deposits in the Mediterranean (Adamson et al., 2014; Žebre et al., 2016). An example of well-preserved outwash and till deposits is Orjen Mountain in Montenegro (Adamson et al., 2014; Hughes, 2010).

The presented geomorphological map illustrates the distribution of landforms related to glaciations, fluvial action and karst processes in Blidinje, located in the central Dinaric Alps. This map provides a framework for on-going geomorphological investigations in the wider Blidinje area, including the Vran, Čvrsnica and Čabulja Mountains. The acquired data suggest a complex nature of the study area, characterised by the interchanging karst, fluvial and glacial geomorphological systems that are worthy to be investigated further on. Especially large amphitheatre-like moraine complexes and alluvial fans identified in the study area are noteworthy for storing sedimentological record of past glaciations that can be used for dating, glacier reconstruction and implications for palaeoclimate in this part of the Dinaric Alps.

**Software**

ESRI ArcGIS 10.3.1. was used for map production, including digitizing, georeferencing, DEM analysis and final layout composition.

**Acknowledgements**

We express gratitude to referees O. Bonacci, P.D. Hughes and B. Cattoor for constructive comments which helped us to improve the quality of this paper.

**Map design**

The Blidinje geomorphological map was designed to show a reader an interaction of different varieties of karst geomorphological system. These varieties are designated with different colours: brown, green and violet. An additional yellow colour refers to depositional areas that are of different and/or mixed origins (e.g., fluvial, glacial and even periglacial). All the subsequent layers, representing different geomorphological features were added as points, lines or transparent symbolized polygons. Coloured symbols were used to represent various form groups.

**Figure captions**

Figure 1: Location of Blidinje in a regional and local context. Study area is marked with a black line.

Figure 2: (a) Blidinje Lake located in the lowest part of Dugo Polje. The view towards the NE. (b) The karst polje Brčanj in the NE side of the Blidinje area. The view towards the NE. (c) Slightly elevated karst surface between Brčanj and Dugo Polje covered by doline-sized depressions.

Figure 3: (a) Amphitheatre-shaped terminal moraine on the eastern side of Dugo Polje below the Čvrsnica Mountain. (b) Hummocky moraines E of Svinjača. View towards the N. (c) Lateral moraine E of Svinjača.

Figure 4: (a) Orthophoto (Geoportal Web Preglednik, 2016) and (b) photo of relict alluvial fan in the NW part of Svinjača, dissected by dolines (c).

Figure 5: Cross section from the upper (Y-Y`) and lower (X-X`) part of large lobate moraine ridges and a sketch of the palaeo-piedmont glacier thickness (in blue) in Blidinje. For locations of the two cross sections refer to the Main map.

**References**


Adamson, K. R., Woodward, J. C., & Hughes, P. D. (2014). Glaciers and rivers: Pleistocene uncoupling in a Mediterranean mountain karst. *Quaternary Science Reviews*, *94*(0), 28–43. http://doi.org/http://dx.doi.org/10.1016/j.quascirev.2014.04.016

Barr, I. D., & Lovell, H. (2014). A review of topographic controls on moraine distribution. *Geomorphology*. http://doi.org/10.1016/j.geomorph.2014.07.030

Bonacci, O. (2004a). Poljes. In J. Gunn (Ed.), *Encyclopedia of caves and karst science* (pp. 599–600). New York: Fitzroy Dearborn.

Bonacci, O. (2004b). Ponors. In J. Gunn (Ed.), *Encyclopedia of caves and karst science* (pp. 600–601). New York: Fitzroy Dearborn.

Bonacci, O. (2013). Poljes, ponors and their catchments. In A. Frumkin (Ed.), *Treatise on geomorphology* (pp. 112–120). Amsterdam: Elsevier.

Buljan, R., Zelenika, M., & Mesec, J. (2005). Park prirode Blidinje, prikaz geološke građe i stukturno-tektonskih odnosa [Geologic and Tectonic settings of the Park of nature Blidinje]. In I. Čolak (Ed.), *Prvi međunarodni znanstveni simpozij Blidinje 2005* (pp. 11–24). Mostar: Građevinski fakultet Sveučilišta u Mostaru.

Cvijić, J. (1899). *Glacijalne i morfološke studije o planinama Bosne, Hercegovine i Crne Gore [Glacial and Morphological Studies about Montains of Bosnia, Herzegovina and Montenegro]*. Beograd: Srpska kraljevska akademija.

Field, M. S. (1999). *Lexicon of Cave and Karst Terminology with Special Reference to Environmental Karst Hydrology*. Washington: U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, Washington Office.

Ford, D., & Williams, P. D. (2007). *Karst Hydrogeology and Geomorphology*. Chichester: Wiley. Retrieved from http://books.google.si/books?id=oxsa9nbQxuEC

Gams, I. (1978). The polje: the problem of definition: with special regard to the Dinaric karst. *Zeitschrift Für Geomorphologie*, *22*(2), 170–181.

Gams, I. (2003). *Kras v Sloveniji v prostoru in času [Karst of Slovenia in space and time]*. Ljubljana: Založba ZRC.

Geoportal Web Preglednik. (2016). Retrieved from http://www.katastar.ba/

Grund, A. (1902). Neue Eiszeitspuren aus Bosnien und der Hercegovina. *Globus*, *78*(9), 173–174.

Gunn, J. (2004). Fluviokarst. In J. Gunn (Ed.), *Encyclopedia of Caves and Karst Science* (pp. 751–753). New York: Fitzroy Dearborn.

Hughes, P. D. (2010). Geomorphology and Quaternary stratigraphy: The roles of morpho-, litho-, and allostratigraphy. *Geomorphology*. http://doi.org/10.1016/j.geomorph.2010.07.025

Hughes, P. D., Woodward, J. C., van Calsteren, P. C., & Thomas, L. E. (2011). The glacial history of the Dinaric Alps, Montenegro. *Quaternary Science Reviews*, *30*(23–24), 3393–3412. http://doi.org/http://dx.doi.org/10.1016/j.quascirev.2011.08.016

Hughes, P. D., Woodward, J. C., van Calsteren, P. C., Thomas, L. E., & Adamson, K. R. (2010). Pleistocene ice caps on the coastal mountains of the Adriatic Sea. *Quaternary Science Reviews*, *29*(27–28), 3690–3708. http://doi.org/http://dx.doi.org/10.1016/j.quascirev.2010.06.032

Marjanac, L., & Marjanac, T. (2004). Glacial history of the Croatian Adriatic and Coastal Dinarides. *Developments in Quaternary Science*, *2*(PART 1), 19–26. http://doi.org/10.1016/S1571-0866(04)80053-8

Milićević, M., & Prskalo, M. (2014). Geomorfološki tragovi pleistocenske glacijacije na Čvrsnici [Geomorphological Traces of Pleistocene Glaciation of the Čvrsnica Massif]. *E-Zbornik - Elektronički Zbornik Radova Građevinskog Fakulteta*. Retrieved from http://www.gfmo.ba/e-zbornik/e_zbornik_07_07.pdf

Milivojević, M., Menković, L., & Ćalić, J. (2008). Pleistocene glacial relief of the central part of Mt. Prokletije (Albanian Alps). *Quaternary International*, *190*(1), 112–122. http://doi.org/http://dx.doi.org/10.1016/j.quaint.2008.04.006

Milojević, B. Ž. (1935). Čvrsnica. *Hrvatski Geografski Glasnik*, *6*(1), 17–23.

Papeš, J. (1972). Osnovna geološka karta SFRJ. K 33-11, Livno [Basic Geological Map of SFRJ. K 33-11, Livno]. Beograd: Savezni geološki zavod.

Raić, V., Ahac, A., & Papeš, J. (1976). Osnovna geološka karta SFRJ. K 33-23, Imotski [Basic Geological Map of SFRJ. K 33-23, Imotski]. Beograd: Savezni geološki zavod.

Raić, V., & Papeš, J. (1968). *Osnovna geološka karta 1:100.000 - Tumač za list Imotski K 33-23 [Basic Geological Map 1:100.000 - Booklet for Sheet Imotski K 33-23]*. Beograd: Savezni geološki zavod.

Roglić, J. (1958). Odnos riječne erozije i krškog procesa [Relationship between river erosion and karst process]. *V. Kongres Geografa FNR Jugoslavije*. Cetinje: Savez geografa Jugoslavije.

Roglić, J. (1959). Prilog poznavanju glacijacije i evolucije reljefa planina oko srednje Neretve [Supplement to the Knowledge of Glaciation and Relief Evolution of the Mountains Near Middle Neretva River]. *Geografski Glasnik*, *21*(1), 9–34.

Smart, C. C. (2004). Glacierized and glaciated karst. In J. Gunn (Ed.), *Encyclopedia of caves and karst science* (pp. 804–809). New York: Fitzroy Dearborn.

Sofilj, J., & Živanović, M. (1979). Osnovna geološka karta SFRJ. K 33-12, Prozor [Basic Geological Map of SFRJ. K 33-12, Prozor]. Beograd: Savezni geološki zavod.

Stepišnik, U. (2010). Relict alluvial fans of Matarsko podolje and Vrhpoljska brda, Slovenia. *Zeitschrift Für Geomorphologie*, *54*(1), 17–29.

Šimunović, V., & Bognar, A. (2005). Geomorfološke značajke Parka prirode Blidinje [Geomorphologic

Features of the Natural park Blidinje]. In I. Čolak (Ed.), *Prvi međunarodni znanstveni simpozij Blidinje 2005* (pp. 25–40). Mostar: Građevinski fakultet Sveučilišta u Mostaru.

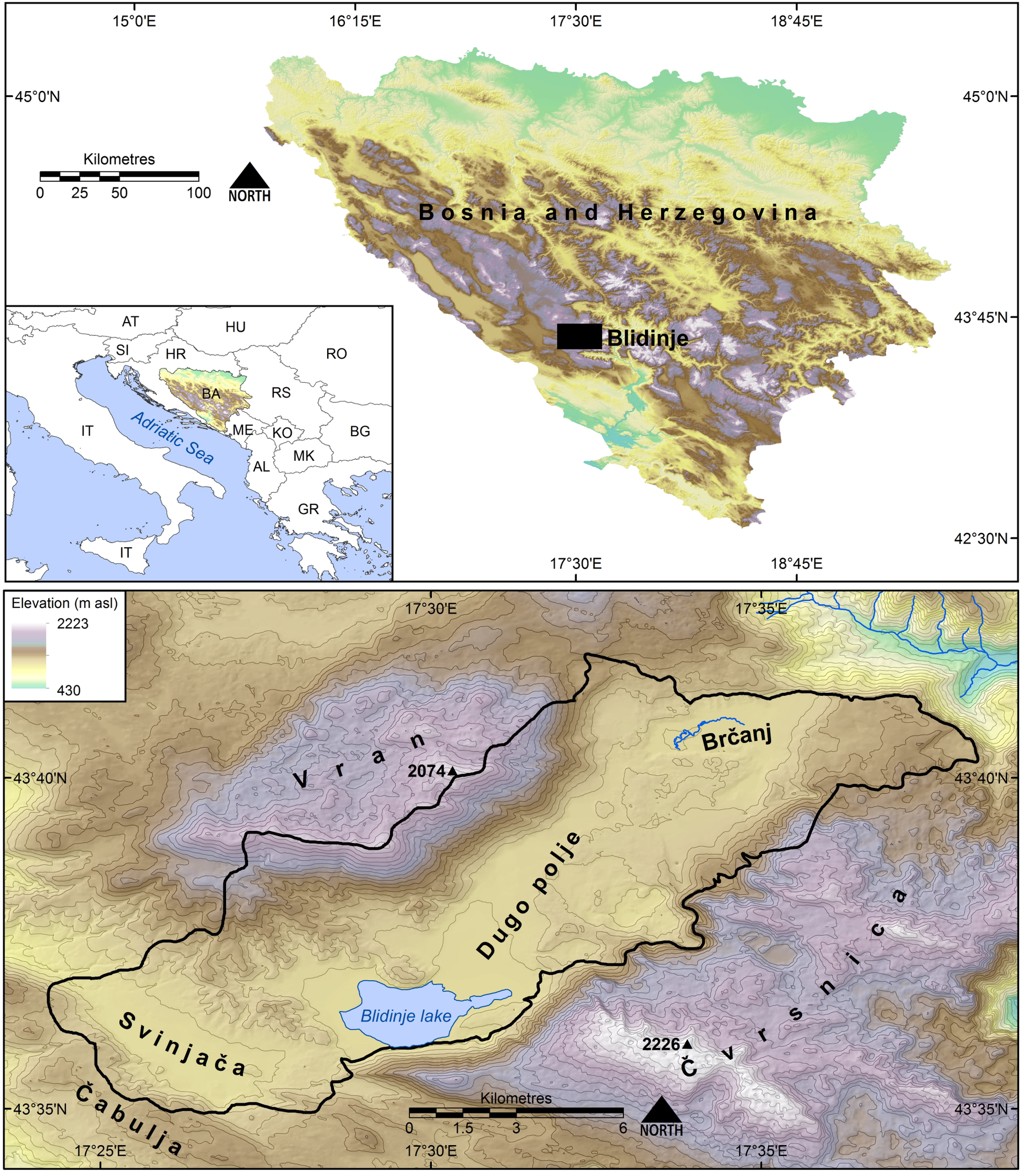
Williams, P. D. (2003). Doline. In A. Goudie (Ed.), *Encyclopedia of Geomorphology* (pp. 266–270). New York: Routledge.

Žebre, M., & Stepišnik, U. (2014). Reconstruction of Late Pleistocene glaciers on Mount Lovćen, Montenegro. *Quaternary International*, *353*(0), 225–235. http://doi.org/http://dx.doi.org/10.1016/j.quaint.2014.05.006

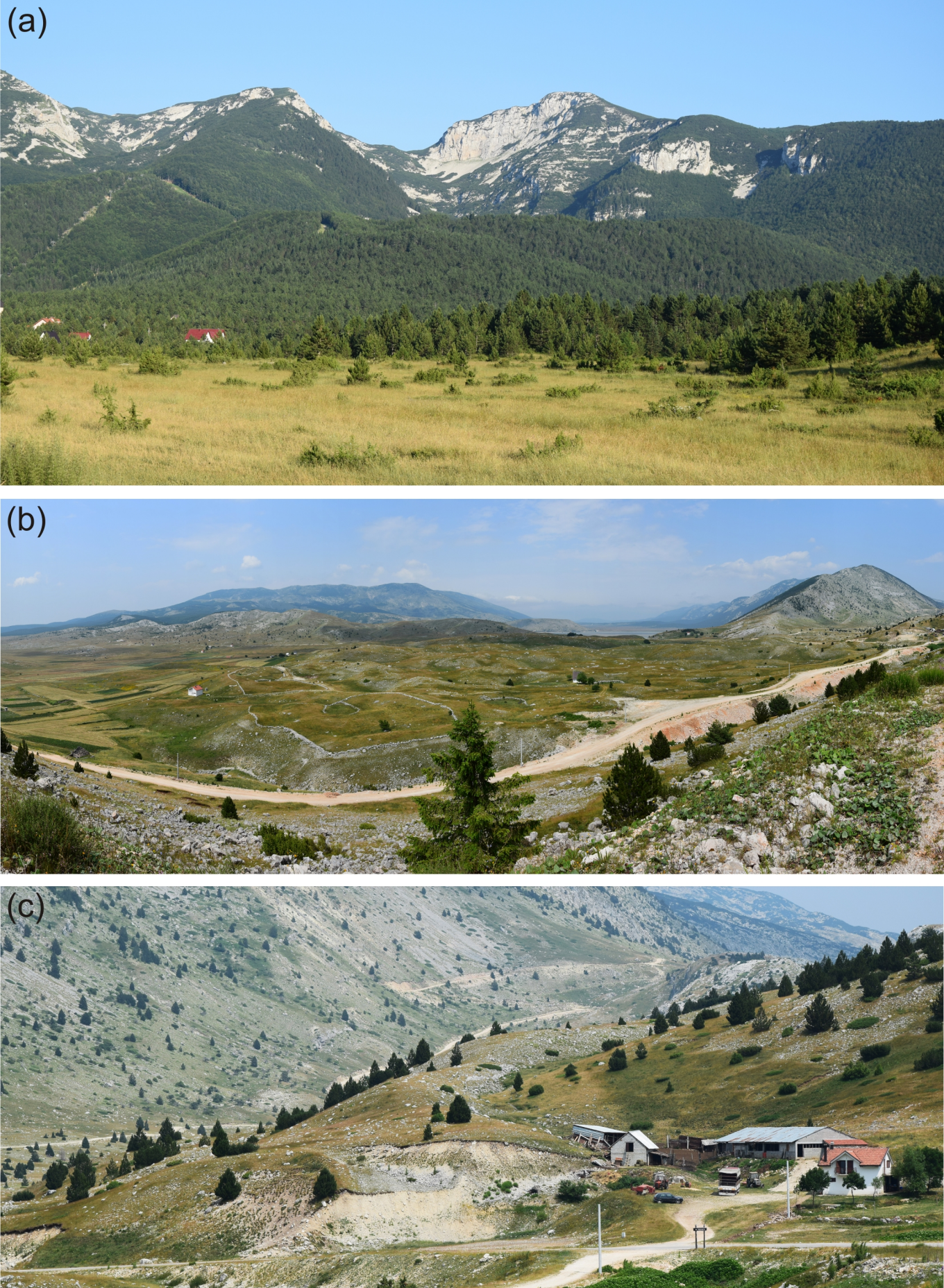
Žebre, M., & Stepišnik, U. (2015). Glaciokarst geomorphology of the Northern Dinaric Alps: Snežnik (Slovenia) and Gorski Kotar (Croatia). *Journal of Maps*, 1–9. http://doi.org/10.1080/17445647.2015.1095133

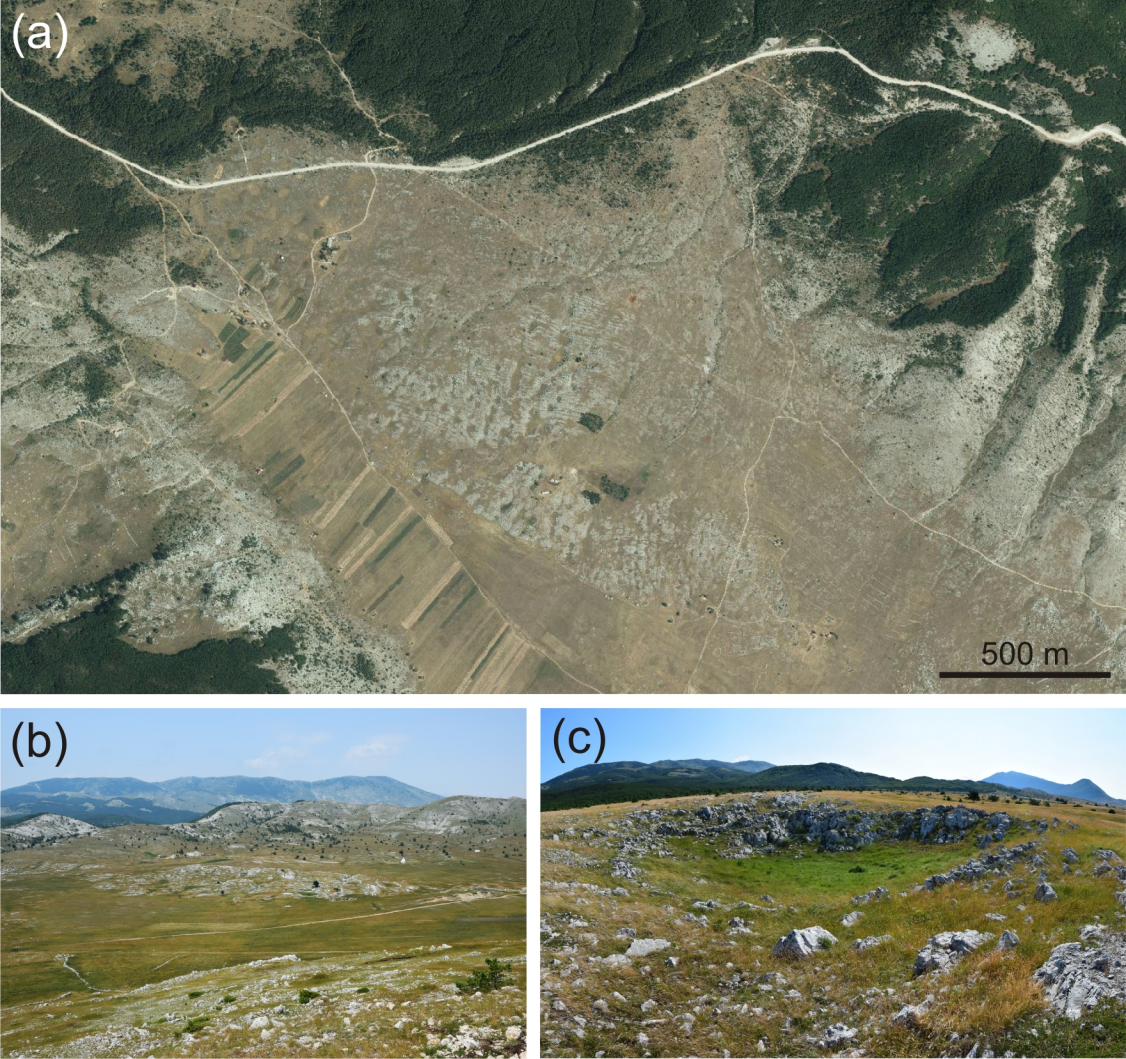
Žebre, M., & Stepišnik, U. (2015). Glaciokarst landforms and processes of the southern Dinaric Alps. *Earth Surface Processes and Landforms*, *40*(11), 1493–1505. http://doi.org/10.1002/esp.3731

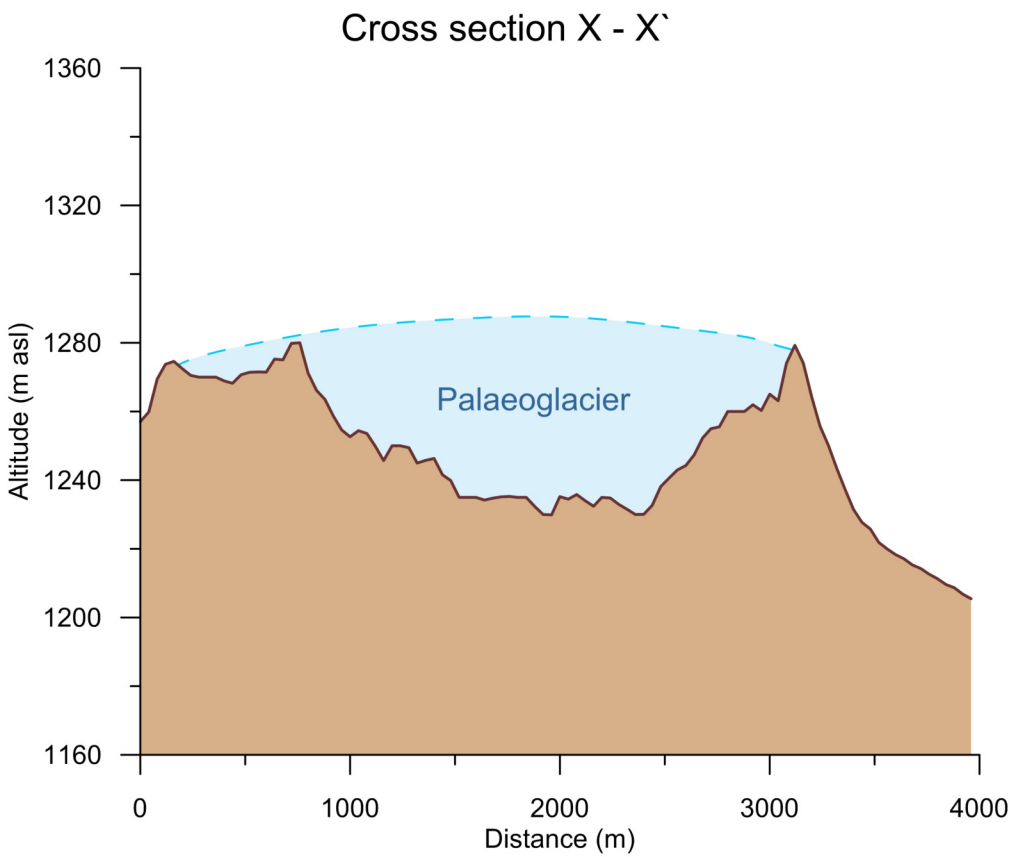
Žebre, M., Stepišnik, U., Colucci, R. R., Forte, E., & Monegato, G. (2016). Evolution of a karst polje influenced by glaciation : the Gomance piedmont polje (northern Dinaric Alps). *Geomorphology*. Amsterdam [etc.]: Elsevier.

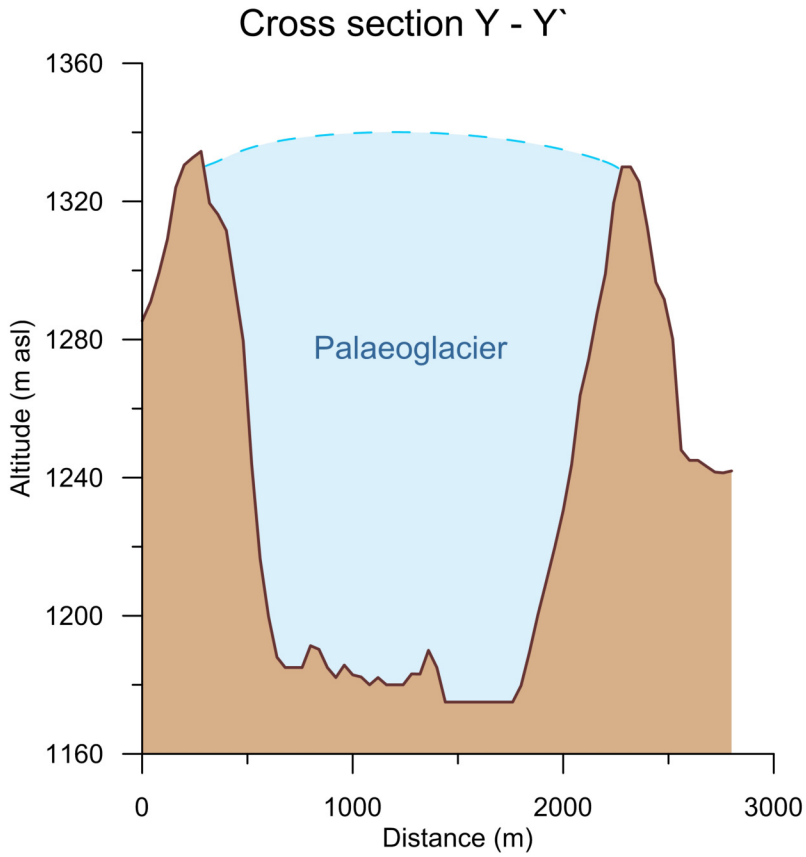

15°0'E
16°15'E
17°30'E
18°45'E
45°0'N
43°45'N
42°30'N
Kilometres
0 25 50 100
NORTH
Bosnia and Herzegovina
Blidinje
AT
HU
SI
HR
RO
BA
RS
IT
Adriatic Sea
ME
KO
BG
MK
AL
GR
IT
Elevation (m asl)
2223
430
17°35'E
17°25'E
43°40'N
43°35'N
Vran
2074
Brčanj
Dugo polje
Blidinje lake
Svinjača
Čabulja
2226
Čvrsnica
0 1.5 3 6


(a)
(b)
(c)


(a)
(b)
(c)


(a)
500 m
(b)
(c)


Cross section X - X`
1360
1320
1280
1240
1200
1160
Altitude (m asl)
Palaeoglacier
0
1000
2000
3000
4000
Distance (m)


Cross section Y - Y`
1360
1320
1280
1240
1200
1160
Altitude (m asl)
Palaeoglacier
0
1000
2000
3000
Distance (m)

# Geomorphology of Blidinje, Dinaric Alps (Bosnia and Herzegovina)

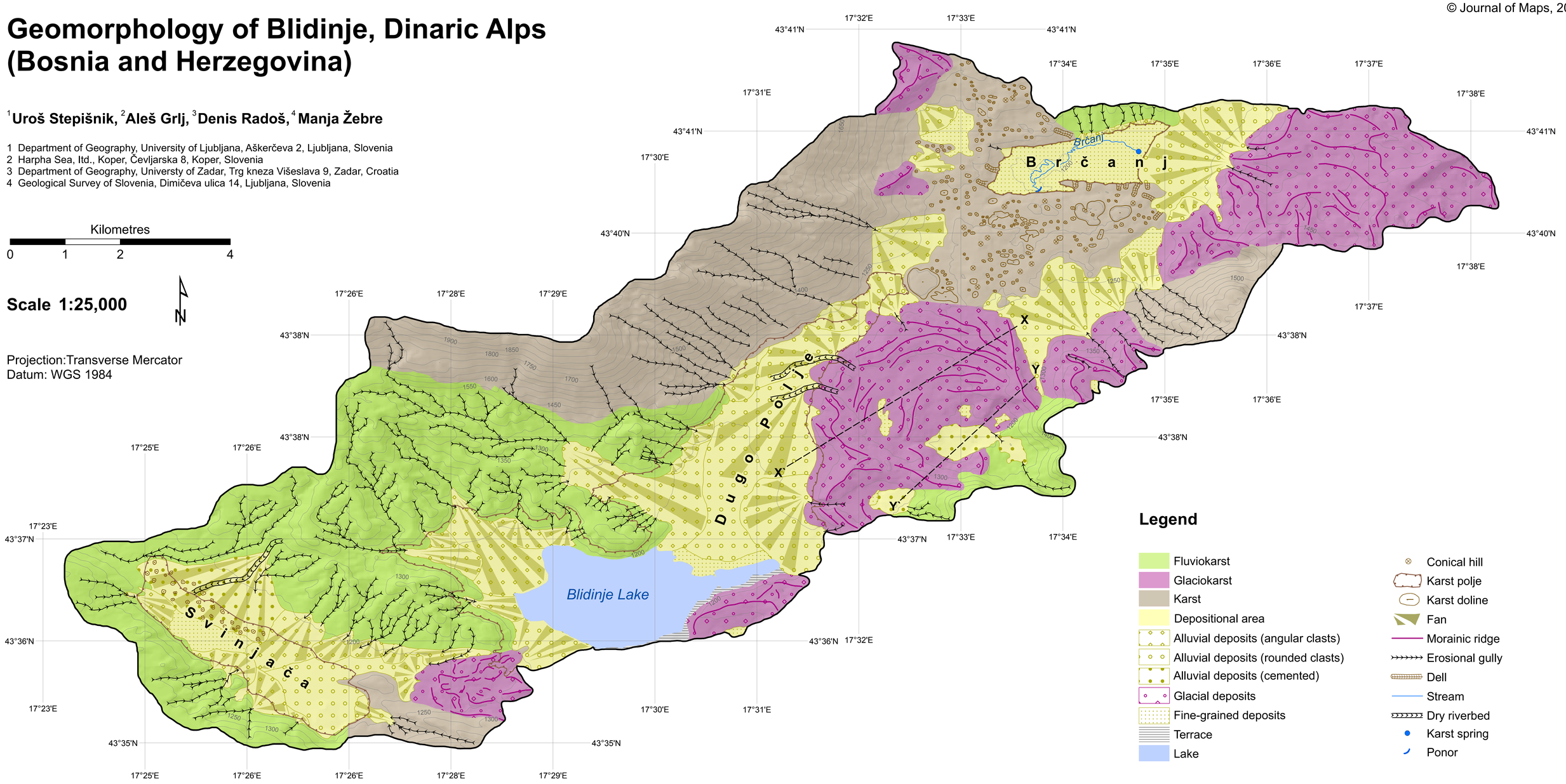
[1]Uroš Stepišnik, [2]Aleš Grlj, [3]Denis Radoš, [4]Manja Žebre

1 Department of Geography, University of Ljubljana, Aškerčeva 2, Ljubljana, Slovenia
2 Harpha Sea, ltd., Koper, Čevljarska 8, Koper, Slovenia
3 Department of Geography, Universty of Zadar, Trg kneza Višeslava 9, Zadar, Croatia
4 Geological Survey of Slovenia, Dimičeva ulica 14, Ljubljana, Slovenia

Kilometres
0 1 2 4

**Scale 1:25,000**

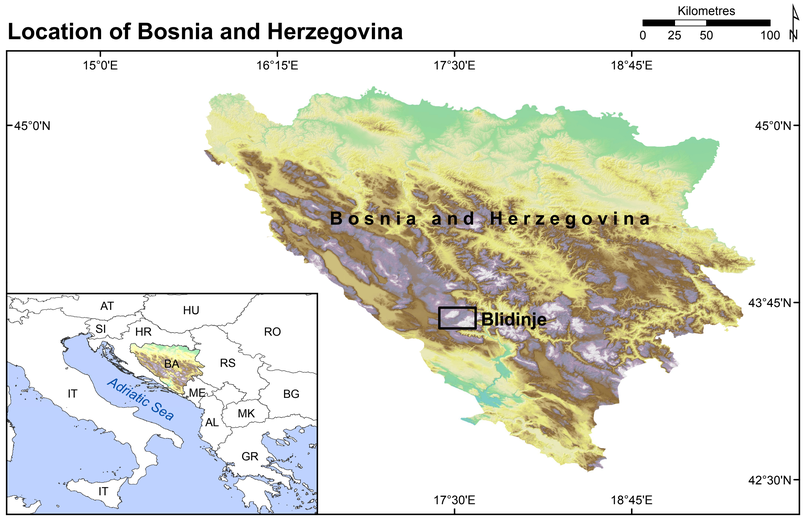
Projection:Transverse Mercator
Datum: WGS 1984



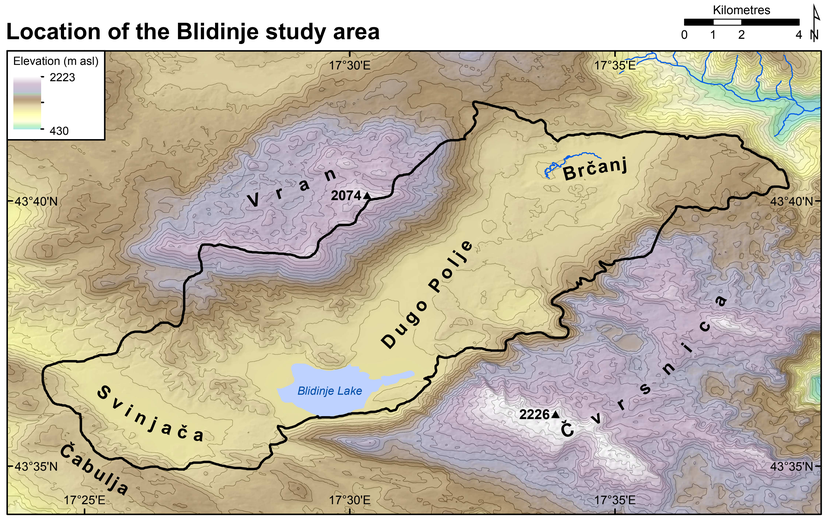

## Legend

- Fluviokarst
- Glaciokarst
- Karst
- Depositional area
- Alluvial deposits (angular clasts)
- Alluvial deposits (rounded clasts)
- Alluvial deposits (cemented)
- Glacial deposits
- Fine-grained deposits
- Terrace
- Lake
- Conical hill
- Karst polje
- Karst doline
- Fan
- Morainic ridge
- Erosional gully
- Dell
- Stream
- Dry riverbed
- Karst spring
- Ponor

## Location of Bosnia and Herzegovina




## Location of the Blidinje study area




## Simplified geological map of the study area