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First cosmogenic geochronology from the Lesser Caucasus: Late Pleistocene glaciation and rock glacier development in the Karçal Valley, NE Turkey

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ABSTRACT

Evidence of widespread alpine glaciations during the Late Pleistocene in mid-latitudes has long attracted attention of researchers. However, there were no studies that contain absolute ages in the Lesser Caucasus despite the fact that it is one of the major glaciated regions in Eurasia. Here, we present first cosmogenic ^{36}Cl surface exposure ages from the Karçal Mountains (41.24° N, 42.06° E, 3431 m a.s.l., above sea level) which is located in the most western part of the Lesser Caucasus in the northeastern Anatolia. In the Karçal Mountains, there are numerous valleys that have experienced significant glaciations since Late Pleistocene. We have investigated one of the largest valleys, the east-facing Karçal Valley, that hosts even a small (2926 m a.s.l.) recent glacier located at above 3000 m a.s.l. Fossil and recent rock glaciers along with lateral and recessional moraines exist in the valley. We conducted the study in two stages. First, we mapped the geomorphological units in the Karçal Valley in detail based on our field works and aerial photography. Later, we collected 10 rock samples from the fossil rock glacier and recessional moraines for cosmogenic ^{36}Cl surface exposure dating. The results outline a glacial chronology that is typical of the Last Glacial Maximum. Although the maximum extent and timing of the glaciation is not exactly known as lateral and terminal moraines were not suitable for sampling, recessional moraines indicate that the Karçal Valley palaeoglacier deglaciation started at least 19.9 ± 1.2 ka ago. Fossil rock glacier samples were dated to 15.7 ± 1.3 ka. These quantitative results are first in the Lesser Caucasus and compatible with previous ages obtained from other valleys in the nearby Eastern Black Sea region, Anatolian and some of the European Mountains.

1. Introduction

The high altitude mountains of Anatolia witnessed widespread glaciations during the Late Pleistocene (126–11.7 ka) (Fig. 1). Although most of these mountains have no recent glaciers, the geomorphological evidences show widespread palaeoglacier activity in the past. This is true especially during the Last Glacial Maximum (LGM), which refers to the peak in global ice volume during the last glacial cycle between 23.000 and 14.000 ^{14}C ka BP, with a mid-point at 18.000 ^{14}C ka BP (Shackleton et al., 1977; Hughes and Gibbard, 2015). This is documented both from the marine oxygen isotope record and from the global sea levels in corals (Mix et al., 2001). On the other hand continental data examined by Clark et al. (2009) indicated that glaciers reached their maximum positions between 26.5 and 20/19 ka, with rapid deglaciation occurring soon after.

In the beginning of the mid-19th century, evidence of actual and palaeoglaciers in Anatolia has been mentioned in the reports of many European researchers (Ainsworth, 1842; Palgrave, 1872; Krenek, 1932; Bobek, 1940; Messerli, 1967; Birman, 1968). Since the mid-20th century, Turkish scientists have also begun to publish their studies about glaciation in Anatolia (Erinç, 1944, 1952; Bilgin, 1972; Kurter, 1991; Doğu et al., 1993; Çiner, 2003, 2004; Sarıkaya, 2012a; Sarıkaya and Çiner, 2015). Over the last 10 years, the glacial chronologies of Anatolia have been refined with cosmogenic surface exposure dating studies (e.g., Akçar et al., 2007, 2008; Çiner et al., 2015; Sarıkaya et al., 2008; Sarıkaya and Çiner, 2017 and

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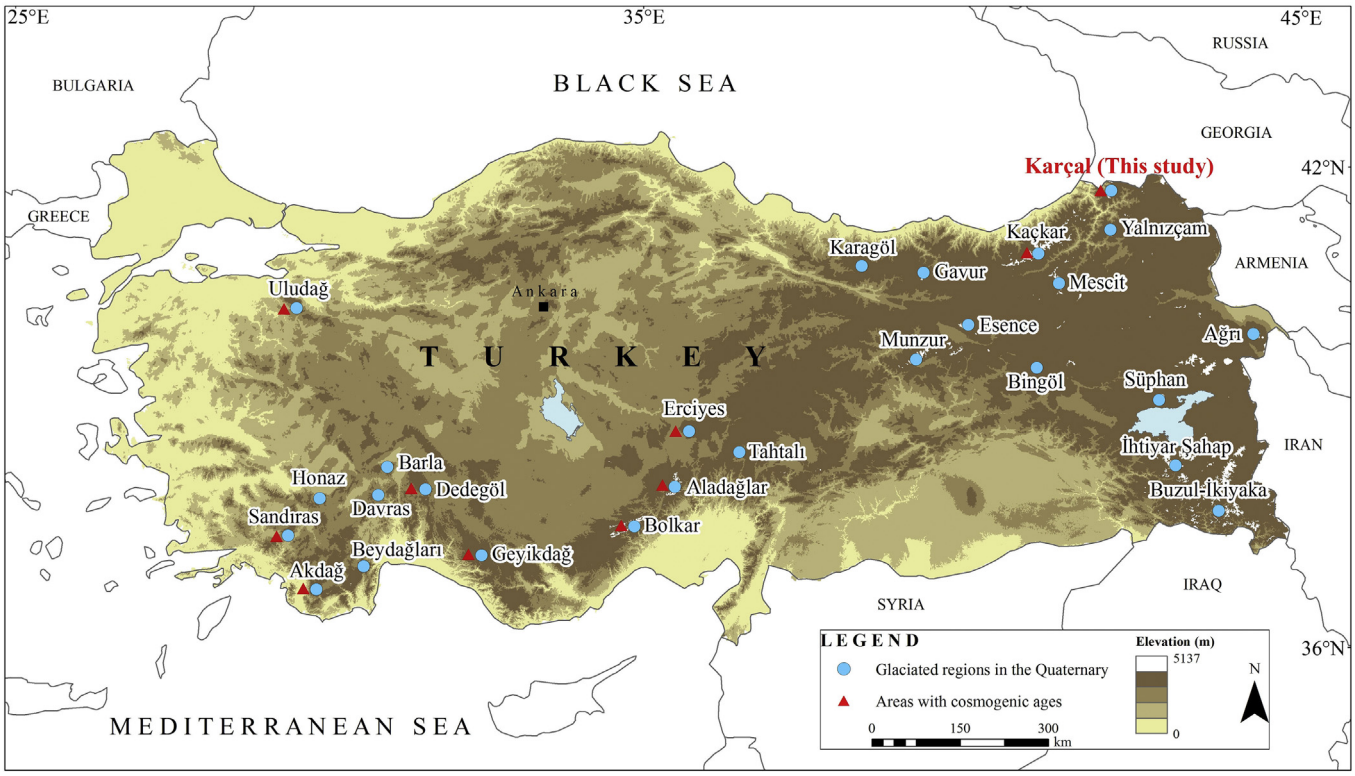

Fig. 1. The distribution of high mountainous areas that experienced palaeoglaciation and locations where cosmogenic surface exposure dating was applied in Turkey.

references therein; Reber et al., 2014; Zahno et al., 2009; Zreda et al., 2011) to the point that Turkey is now considered to have one the best-dated records of its kind in the world (Hughes and Woodward, 2017).

Here, we present our new findings on the Karçal Mountains, which is located in the most northwestern part of the Lesser Caucasus Mountains that runs parallel to the Greater Caucasus Mountains, aligned W-NW to E-SE, ~100 km to its south. This mountainous mass is one of the regions with the clearest evidence of Late Pleistocene glaciation in northeastern Turkey. However, it has been discussed in few studies probably because it is less accessible than the nearby Eastern Black Sea Mountains. Late Pleistocene glaciation in the Karçal Mountains first attracted the attention of Rickmer-Rickmers (1900, 1934), who reported large glaciers, one of the three in the Eastern Black Sea region. Later, Gürgen and Yeşilyurt (2012) reported five cirque glaciers in the Karçal Mountains. Recently, Dede et al. (2015) classified rock glaciers in five valleys (Çamdalı, Karçal, Sakız, Yamukdiken and Ziyaret valleys) on the Karçal Mountains, taking into account their appearance and formation mechanisms based on permafrost creep (Wahrhaftig and Cox, 1959) and ice cored rock glacier (Whalley and Martin, 1992) classification system.

The aim of this study is to provide detailed geomorphological evidence of the Late Pleistocene glaciations in the Karçal Valley, one of the largest valleys in the region, and elucidate the first glacial chronology of the mountain range using cosmogenic ^{36}Cl surface exposure ages obtained from recessional moraines and a fossil rock glacier. Later, we compared our results with nearby Lesser and Greater Caucasus Mountains in Georgia and Armenia, Eastern Black Sea Mountains in Turkey and European Mountains in general. Finally, we presented the current status on surface exposure dated moraine ages in whole Turkish glaciated mountains in order to understand the extent and timing of Last Glacial Maximum (LGM) glaciations in this part of the world.

2. Physical geography and geologic settings

The Karçal Mountains are located in the western part of the Şavşat district in northeastern Anatolia. The deep fluvial tributaries of the Çoruh River separate the Karçal Mountains from the Eastern Black Sea Mountains. The highest peak of the Karçal Mountains is ~40 km away from the Black Sea coast and ~15 km from the Georgian border (Fig. 2).

Within the study area, Karçal Peak (3431 m a.s.l.) is the highest point and the valley floor where Çermik Creek flows, is the lowest point (1500 m a.s.l.). Çermik Creek and its tributaries flow into the Çoruh River and incise deep valleys into the eastern slopes of the mountain. The Karçal Valley, named after the mountain, is one of the major ones, and runs about 5 km E-W on the eastern side of mountain. The width of the valley is 500 m upstream, and reduces to less than 250 m downstream. The slope of the floor of the Karçal Valley varies between 15 and 30%.

The geology of the Karçal Mountains is mainly composed of Cretaceous volcanic rocks, limestones and Eocene volcanics consisting of andesitic-basaltic lavas and pyroclastic rocks (Keskin, 2013). Main lithologies within the Karçal Valley are made up of diorite, hornblende, dacite and rhyolite (Yılmaz et al., 1997). These units are partly covered by Quaternary moraines and alluvium along the valley floor (Fig. 3).

Since there is no nearby meteorological station in the study area, we used the climate data set provided by Hijmans et al. (2005) at www.worldclim.org with 1 km^2 spatial resolution to estimate prevailing climatic conditions. This data indicate that the average annual temperature is around 0 °C in the study area. While average summer temperatures do not exceed 10 °C, winter averages are below −10 °C. Depending on the altitude, precipitation values are about twice as those at Artvin station, which is the nearest meteorological station located at 628 m a.s.l. In the study area, more than half of the precipitation (55%), which is approximately 1000 mm