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Recent morphodynamics of alpine lakes in Southern Carpathian Mountains using high-resolution optical imagery

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ABSTRACT

This study reveals for the first time the surface area evolution of glacial lakes in the Romanian Carpathians over 47 years. The research also advances our understanding of the potential of satellite-based remote sensing techniques to monitor the geomorphologic evolution of 27 rock basins into glacial lakes in the Retezat Mountains, Southern Romanian Carpathians. These mountains host most of the glacial lakes in Romania, including both the widest and deepest glacial lakes.

Using high-precision orthorectification and co-registration techniques, the surface area extension and reduction of 27 shallow water bodies ranging in size from 0.10 to 9.14 ha were analyzed over two time intervals (1968–2007 and 2007–2014). The total surface area increased only by 1% between 1968 and 2014, with over half of the growth occurring during the last 7 years of the study period.

Analysis of the surface area extension and reduction revealed that catchment aspect, catchment size, lake elevation, land cover, topography, and lake depth are the main environmental factors controlling the present state of the glacial lakes in the central part of the Retezat Mountains. The results suggest that the different behavior of glacial lakes within the north-facing valleys compared with the evolution of the lakes settled in southern exposed valleys is mainly due to climatic and geomorphologic particularities of the opposing slopes. On the northern side, the lakes are slowly decreasing due to more intense geomorphologic activity of both the erosivity of precipitations and periglacial processes (e.g., gelifraction, mass wasting, and permafrost degradation). High altitude lakes generally are increasing because of the longer duration of the ice cover and the smaller amounts of sediment yielded by the nature of the soil (or lack thereof) and vegetation cover in the alpine area. Lakes with small catchments show the highest variability, displaying significant changes, whereas shallow lakes are the most prone to horizontal and vertical silting. These controls, which regulate changes in lake basin sizes, provide baseline information on current trends in the evolution of Romanian Carpathian alpine lakes. The methodology applied here could be widely applicable to other similar environments, with widespread implications for understanding the global effects of climate change on alpine lakes.

1. Introduction

Glacial rock basins, along with cirques and glacial valleys, are among the longest-lasting and most relevant traces of glaciation in the Romanian Carpathians, despite the fact that this area was glaciated solely during the Late Pleistocene (Urdea, 2000; Mîndrescu, 2006). Post-deglaciation, these rock basins turned into lakes, which occasionally evolved into peat bogs or were completely silted. Around 270 glacial lakes (including glacial peat bogs and peat bogs with pools) are estimated to exist in the Romanian Carpathians (Mîndrescu et al., 2015); they are spread unevenly with the largest share (81%) located in the Southern Carpathians. Many of these lakes are of scientific interest, acting as sensitive and accurate climatic repositories (storing climatic and other types of data in their sediments); albeit typically, they have smaller surface areas and depths than other glacial lakes elsewhere in Europe.

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The study of the origin and morphometric characteristics of alpine lakes in the Romanian Carpathians began in the early 1900s by de Martonne and Munteanu-Murgoci (1900), de Martonne (1906–1907), Loczy (1904) and Phlepps (1914). Based on the bathymetric measurements and geomorphologic observations, they assigned the glacial origin of several lakes in the Southern Carpathians. The mapping of glacial lakes was continued by Năstase (1960), Trufaş (1961, 1963), and Iancu (1961). The first inventory of the glacial lakes in the Romanian Carpathians was made by Pisota (1971); to date, his work remains unparalleled in terms of scale and thoroughness, despite the upgrade of field research techniques. Pisota used the plumb line and a theodolite to perform precise measurements necessary for bathymetric sketches and lake perimeter surveys. However, the sketches he produced have no coordinates, thus making it difficult to conduct any comparative analyses. Later on, Decei (1981) published data and maps of a few glacial lakes from Romania. He used similar methods, and it is likely that on occasion he based his research on information from Pisota (1971). More recently, Vespremeanu-Stroe et al. (2008) presented new and more precise data regarding the morphologic and morphometric characteristics of 13 glacial lakes in the Southern Carpathians. Their study was the first that noted some inaccuracies in the measurements made by Pişota.

The aim of our study is to evaluate the present state of the glacial lakes in the central part of the Retezat Mountains by analyzing the rates of change in surface area of 27 glacial lakes over the last half century. This study aims to assess the impact of environmental variables (climate, land cover, geomorphology, and hydrology) on the dynamic of these lakes. It is the first study that uses very high-resolution imagery and high precision remote sensing techniques to quantify subtle lake morphologic changes that are diagnostic of the current geomorphological and climatic dynamics in this mountainous environment. This is of direct interest because most of the studies in the Carpathian-Balkan area focused on relatively early (Late Glacial and Early Holocene) environmental changes (Feurdean et al., 2014). Nevertheless, interest has increased recently in the reconstruction of more human-driven impacts on the environment and events focused over the last decades (e.g., post industrial revolution and following political change from the mid-1940s and the late 1980s) (Hutchinson et al., 2015).

2. Site description

The Carpathian Mountain chain of central-eastern Europe is the largest mountain range by area in Europe. The highest peaks only reach 2500 m, an elevation not high enough to host present-day glaciers. However, during the glacial phases of the Late Pleistocene, these peaks supported small glaciers that did not reach the foreland (Urdea et al., 2011). Although the glacial advance was less extensive in the Carpathians than in the Alps, mainly due to a more continental climate and lower altitudes (Reuther et al., 2007), glaciers descended 1000–1200 m above sea level (a.s.l.) in the highest mountain units of the Southern Carpathians (e.g., Făgăraş, Retezat, Parâng) (Urdea, 2004).

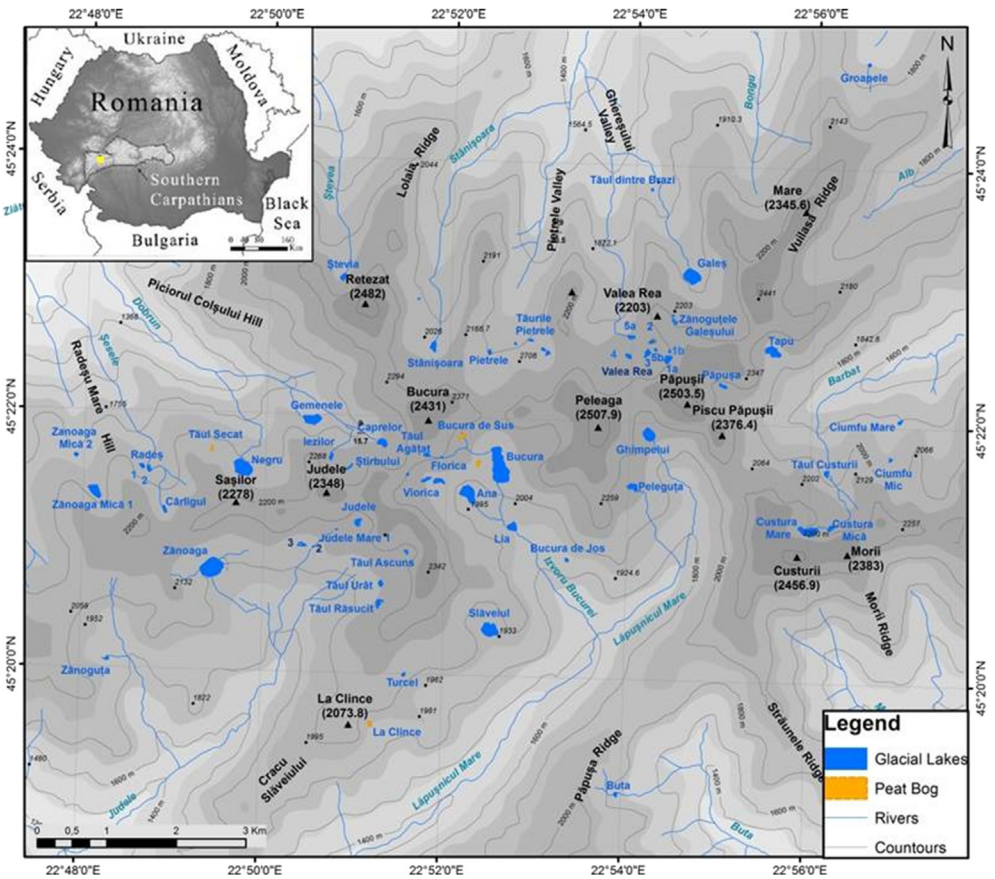

Fig. 1. Glacial lake distribution in the Retezat Mountains, Romania. An SRTM digital elevation model with 200 m contour lines was used as background. In the inset, the location of the study area is shown in yellow. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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