

Paired moraine-dammed lakes: a key landform for glaciated high mountain areas in the tropical Andes of Peru

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The tropical mountain range of the Cordillera Blanca hosts one of the main concentrations of proglacial lakes in high-mountain settings worldwide, which have formed as a result of the dominant trend of modern glacier retreat. Based on empirical data from field research in over 20 valleys and the analysis of air and satellite images, a genetic classification of major lake types with their barriers and a generalized model for the distribution of the present lakes and paleolakes was set up. The origin of the lakes and their recurrent distribution pattern are associated with the individual stages of the Pleistocene to modern glaciation and their corresponding geomorphological landforms. Characteristic repetitive moraine sequences are found in the upper parts of numerous valleys of the Cordillera Blanca. In terms of the spatial arrangement of the lake types, combined lakes are classified as a distinct composite lake type. These lakes occur at nearly the same elevation or at successively lower elevations, and form characteristic lake sequences of two or more lakes. They may occur as multi-moraine-dammed lakes or mixed combined lakes such as moraine-rock-dammed lakes or multi-debris-dammed lakes. From special interest are in this study the paired moraine-dammed lakes (e.g. Lagunas Qoyllurcochas, Lagunas Safuna Alta and Baja). They are composed of the Great Endmoraine (GEM), primarily formed during the Little Ice Age and earlier, and the pre-GEM, formed during the Holocene. Both moraines are located in rather close vicinity to each other at a distance of 1–3 km. In contrast to the prominent sharp-crested GEM, the pre-GEM is a low-amplitude end-moraine complex, which usually does not exceed a few meters to tens of meters in height. The latter is often composed of several inserted moraine ridges or an irregular hummocky moraine landscape. It is argued here that the process of formation of these combined lakes is mainly controlled by a combination of distinct topographical and climatic factors.