Boletín de la Asociación de Geógrafos Españoles N.º 52 - 2010, págs. 349-351
I.S.S.N.: 0212-9426

INCREASING ARIDITY IN SIERRA NEVADA SINCE THE MID-HOLOCENE INFERRED FROM LAKE SEDIMENTS

Marc Oliva, Antonio Gómez Ortiz y Lothar Schulte
Departamento de Geografía Física y Análisis Geográfico Regional, Universidad de Barcelona

I. INTRODUCTION

The south-eastern corner of the Iberian Peninsula is expected to be one of the most affected areas by climate change in Europe. Until the end of the 21st century, precipitation could decrease about 20-30% and mean annual temperature could rise by 2 to 6ºC (IPCC, 2007; The climate change in Spain. State of the Art, 2007). In order to deal with the present-day climate trend we require more information about past climate changes. Sedimentary records and particularly lake sediments can provide data about Holocene climate variability at a high temporal resolution. Lakes are sedimentary archives that contain information on the palaeoenvironmental evolution of its drainage basin considering several influences: climate, geology, human impact, etc. (O'Sullivan, 2004).

During the last decades there has been an exponential increase in the number of papers related to lake sediments for palaeoclimatic purposes, especially focused on Holocene climate variability. From the study of the cores collected in three lakes of the southern slopes of Sierra Nevada, we have reconstructed the palaeoenvironmental change and landscape evolution in this massif over the last 6 millennia. Consequently, we have deduced the climate conditions responsible for palaeoecological changes in this high semiarid range.

II. REGIONAL SETTING

Sierra Nevada is a massif of the Betique range that concentrates the highest peaks in the Iberian Peninsula (figure 1). The study area focuses on the high valleys of the westernmost section of Sierra Nevada, where landscape is essentially shaped by Pleistocene glaciations. Lithology is mainly composed of schists, without carbonate rocks.

The nakedness of the slopes contrasts with the large number of endemic species developing on the periglacial environment (Molero Mesa & Pérez Raya, 1987), though vegetation cover is very sparse and spatially confined to valley floors and shorelines of mountain lakes (*borreguiles*). At 2500 m mean annual temperature is 4.4ºC and precipitation totals 700 mm, mostly concentrated between October and April.

We present data from three lakes located in the current periglacial belt, at altitudes ranging from 2700 to 3100 m: Aguas Verdes (AV), Rio Seco (RS) and Lagunilla de Rio Seco (LRS). In this massif lakes have a glacial origin, filling glacial depressions or being dammed by moraines. Lakes are very oligotrophic (Pulido-Villena et al., 2006) and tend to be small and shallow (2-4 m depth). Their location is shown in figure 1 and their main characteristics are resumed in table 1.

III. MATERIALS AND METHODS

We collected manually 6 cores: 3 from in AV, 2 from RS and 1 from LRS. In this paper we discuss results corresponding to cores AV-2, RS-1 and LRS-1, from where we have AMS datings. Subsampling was performed at every centimetre interval and standard laboratory analyses were carried out on dry and sieved samples (<2 mm): magnetic susceptibility, organic matter content (OC and C/N ratio), texture and X-ray fluorescence. Calibrated ages were obtained with the CALIB 5.0.2 program (Reimer et al., 2004).

IV. RESULTS

Figure 2 shows the geomorphological location of the three sampled lakes in their respective drainage basins. Data from each lake are examined and discussed separately (figures 3, 4 and 5), with the interpretation of the different proxies used for the reconstruction of the palaeoecological evolution of the summits of Sierra Nevada during the last millennia.

We sent eight samples for AMS dating but only three of them show consistent results. Resedimentation processes seem to be responsible for the incongruence of the other five datings in lakes with extremely low sedimentation rates (~1 cm/90 years). Furthermore, we assumed a continuous sedimentation rate throughout the cores, which may also induce errors to the chronology. Therefore, environmental evolution inferred from lake sediments provides a relative chronology for landscape changes in Sierra Nevada but can not yield an accurate framework for the onset/offset of the slope processes in the massif.

Texture and geochemical properties of the cores reveal the existence of several periods characterized by an enhanced geomorphic activity alternated with phases dominated by more stable slopes. In this sense, lake sediments provide a chronology for slope instability in Sierra Nevada over the last 6 ka BP.

In the three studied cores we distinguish up to eight phases with active slope processes that are characterized by a higher proportion of coarse-grained sediments (sands), low organic matter contents and peaks in MS, Fe and Ti concentration with low Ca/Ti values (F_1-F_8). In contrast, we also detect periods in which prevailed the deposition of fine-grained sediments (silt and clay), with increases of the organic fraction, diminution of MS, Fe and Ti and higher Ca/Ti ratios. During these phases slopes tended to be more stable, with soil formation and a dense vegetation cover developing around the lakes.

The similar evolution of the C/N ratio and OC contents reflects the low productivity of these oligotrophic lakes and the terrestrial origin of the organic matter present in the sediments. Since ~4.2 ka BP, the C/N ratio and OC values record a gradual decrease that suggests a sparser vegetation extent and a lower biological productivity in the lake catchments.

V. DISCUSSION

Lacustrine sedimentation in Sierra Nevada is controlled by geomorphological processes occurring over different temporal and spatial scales. Feedback mechanisms within different variables control the rates of sedimentation in these lakes: snow cover, seasonal frost, permafrost, water availability, vegetation cover, soil formation and human impact.

The tentative chronology derived from lake sediments records eight active slope phases during the last 6 ka BP with an approximate timing of: 6.2?-6 (F_8), 5.8-5.6 (F_7), 5.2-4.6 (F_6), 3.7-3.2 (F_5), 2.5-2.2 (F_4), 1.8-1.6 (F_3), 1.2-0.9 (F_2) and 0.6-0.25 (F_1) ka BP (figure 6).

Active slope periods in Sierra Nevada were conditioned by moist climate conditions and lower temperatures. A thicker snow mantle implied more snow patches in late spring and early summer, providing a longer and larger runoff that transported more mineral particles onto the lakes. Otherwise, warm and dry conditions were not propitious for slope processes, vegetation cover spread over the catchments and less material was deposited into the lakes. Warm temperatures combined with wetter conditions expanded a dense grass cover surrounding the lakes and peat was formed.

The decrease of the OC and C/N ratios in lake sediments since the Mid-Holocene reflects an increasing aridity that has conditioned a diminution of the aquatic and terrestrial production in the catchments (figure 7). The progressive arid trend initiated after the relatively moist HWP in the Iberian Peninsula (Carrión et al., 2007) hinders vegetation growth in the headwaters of the highest western cirques. The lower runoff during the snow-free season implies a decrease of the sediment transfer and slope activity is inhibited, with a very scarce vegetation cover in the southern valleys of Sierra Nevada.

VI. CONCLUSIONS

Sediments from high mountain lakes in Sierra Nevada give evidence of eight phases with enhanced slope activity in the present-day periglacial environment. Texture data and geochemical properties of these lakes have confirmed the existence of several periods propitious for geomorphic activity and others that were more favourable for slope stabilization. The diminution of the organic matter content in the cores suggests that climate gradually turned to be more adverse for vegetation growth in the highest valleys of Sierra Nevada. The comparison of our data with other proxies of southern Iberian Peninsula and northern Africa (Gasse, 2000; Pantaleón-Cano et al., 2003) shows evidence of an arid trend that started ~4.2 ka BP in Sierra Nevada, when the headwaters of the highest catchments had a much denser vegetation cover.