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DIFFERENT KINDS OF MORPHOGENETIC SPRINGS IN THE UPPER DILAR VALLEY (SIERRA NEVADA, GRANADA, SPAIN)

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ABSTRACT

We analyze the main factors influencing springs in the upper part of the Dilar valley (more than 2.200 m above sea level), at the heart of the metamorphic domain of the Sierra Nevada (internal zone of the Betic Range). We studied the most significant springs and developed a system of classification based on the main factors influencing water flow (morphologic, depositional, textural and tectonic).

Our results show the presence of an ground water flow with a very high hydraulic conductivity through different clastic deposits and, to a lesser degree, through fractures or the superficial alteration layer. Strong relationships were detected between water flow and morphological matter, i.e. (primarily) glacial and periglacial forms, crioclastic action forms and snowmelt.

KEYWORDS: Nevado-filabrides schists, subsurface water flow, springs, high mountain, Sierra Nevada

1.INTRODUCTION

The area studied is located in the upper Dilar valley (over 2.200 m above sea level, with an area of 15 km^2) in the Sierra Nevada mountains in the province of Granada, Spain (Fig. 1). It is composed of metamorphic metapelitic materials (mainly schists and micaschists) of the Nevado-filabrides complex, belonging to the inner zone of the Betic Range. The whole area is subject to a predominantly nival action, with varied and abundant recent evidence of glacial and periglacial quaternary forms and deposits.

At the lowest elevation of the study area, the vegetation is dense and low-lying "piornal". With increasing altitude comes a gradual change to tundra. Above 3.000 m there is an almost complete absence of vegetation.

Within this context, the following describes the various morphogenetic types of springs to be found. In the local terminology they are known as "borreguiles", "chortales" or "chorreras", depending on the existence and size of the surrounding grassy areas.

This study forms part of a recently developed area of research focusing on hydrologic patterns within the central metamorphic schists of Sierra Nevada (surface area 1.500 km^2). Relevant to this are papers by Castillo (1985, 1988, 1993) and Castillo et al. (1996) on the overall hydrology of the area and others by Al-Alwani et al. (1996), Pulido-Bosch and Ben Sbih (1996) and Castillo et al. (1996), on specific hydrologic aspects.

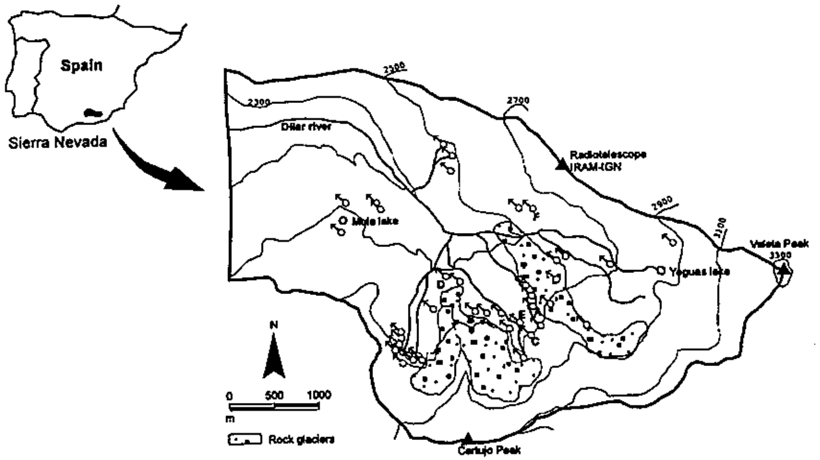

Figure 1. Studied area and springs location

As regards subsurface water flow in the nival area of Sierra Nevada (particularly above 2.000 m), very little is known, there existing no specific published reports or data. Our research suggests this flow is directly influenced by quaternary glacial and periglacial deposits, by crioclastic action and by snowmelt processes. There are numerous studies of glacial phenomena in Sierra Nevada (e.g. Soria et al, 1985; Esteban Amat, 1995) and these have played an important role in furthering our understanding of water processes.

2.RESULTS: some data on springs in the upper Dilar valley

During the hydrologic year 1996-97, and particularly the summer of 1997, we recorded the most significant manifestations of ground water drainage. Specific coordinates of the locations of springs were obtained by field observation and confirmed by aerial surveys. We located 39 springs and for each we recorded: a) stratigraphic section, b) map location at a scale of 1:10.000, c) elevation, using a precision altimeter (error 1 metre), d) air and water temperature (error 0,1°C), e) water samples for chemical analysis, f) distance from nearest snow (metres), g) approximate discharge.

After the initial evaluation, representative springs were selected for periodic checks of water temperature and discharge. This activity is to continue during the summer of 1997, after which complete reports will be prepared. The data obtained to date provides the basis for Figure 2 (altitudinal distribution of the springs), Figure 3 (water temperature - altitude relation), Figure 4 (relation between water temperature and distance from snow) and Figure 5 (water temperature in relation to discharge).

Figure 2 clearly shows how altitude influences the different properties of the springs. There is a notable absence of springs between 2.000 and 2.300 m and also above 2.900 m. More than 70% of the springs are to be found between 2.600 and 2.800 m, a surface area that corresponds to just 30% that of the upper valley.

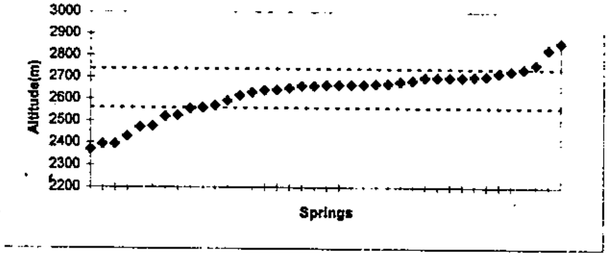

Figure 2. Altitudinal springs distribution

Figure 3 shows that, in July 1997, the temperature of spring waters was between 2 and 8°, with 70% of these in the range 2,5 to 4,5°C at altitudes of 2550 to 2.850 m.

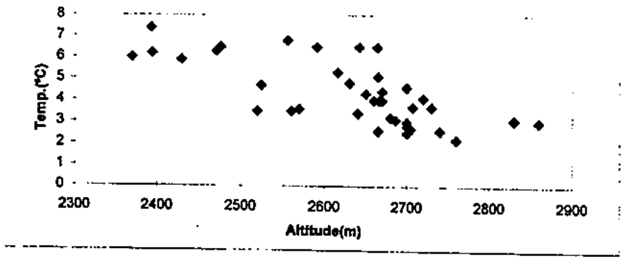

Figure 3. Temperature of springs water (July 1997)

The low correlation between these variables is due to the effect of other conditioning factors such as the differing orientation of the slopes, which produces different durations of snow cover.

A reasonably linear and positive correlation (R^2=0,75) was obtained between the variables of water temperature and distance from the nearest uphill snow (Fig.4).

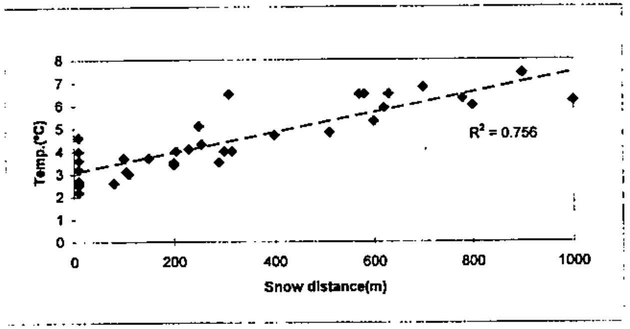

Figure 4. Water temperature in relationship to the distance from the nearest uphill snow

Finally, Figure 5, illustrating the relation between water temperature and flow discharge, shows the low correlation of these variables, although above-average temperatures were observed in the smaller springs.

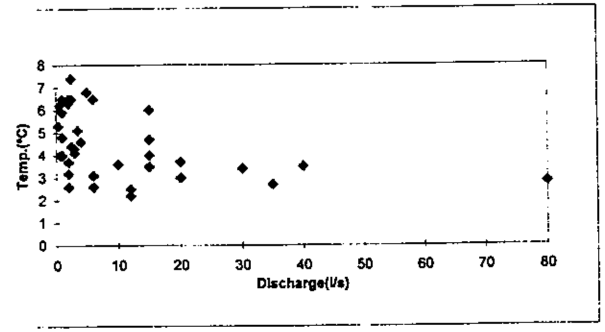

Figure 5. Water temperature-discharge relationship

The development of discharge and water temperature in some of the springs, as commented above, is currently being studied and thus the results obtained to date are only provisional. Nevertheless, there seems to be a rapid depletion, as a result of flow through highly permeable materials. Controls of discharge and air and water temperatures, designed to detect possible variations in flow and/or temperature in day/night cycles, produced minimal variations (except in air temperature), as illustrated in Figures 6 and 7 for typical springs such as A or B (Figure 1). This could be indicative of the scant relevance of inflow from the melting of permafrost and subterranean ice; such an influence should not be discounted for other sectors of the range (for example, the head of the Genil valley) and would require, given sufficient funding, further study. In this respect, it is appropriate to comment upon the physical difficulties involved in these field studies, which must be performed in mountainous areas of difficult access and under relatively high-risk climatological conditions.

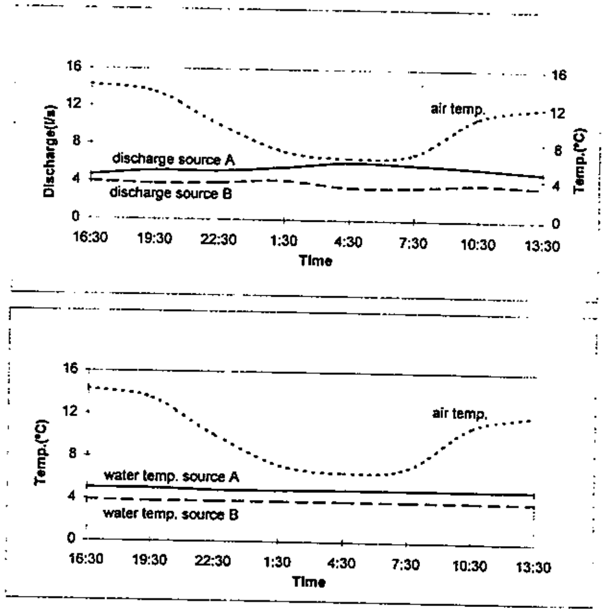

Figure 6 ;7. Daily variations in spring water temperature and discharge for the rapresentative sources A and B (Figure 1).

3. DISCUSSION: main factors influencing flow and emergence conditions

The data obtained for the springs of the upper Dilar valley (representative of the highest part of the Sierra Nevada), as described in the previous section, and in particular the field geological observations enabled us to identify the principal factors affecting flow and emergence conditions. Those aspects with greatest relevance to subsurface flow are considered below, namely depositional, morphologic, textural and tectonic factors, together with others of lesser importance within the study area. In most of the springs studied, flow and/or emergence conditions were determined by various of the above-named types, i.e. they were of mixed characteristics.

3.1.DEPOSITIONAL CONTROL

The existing subsurface flow is strongly related to highly permeable detritic forms. Nearest the peaks, at the foot of cliffs and escarpments, there are abundant debris fans and carpets (mainly crioclastic), producing what are known in the region as "Cascajares" or "Canchales" (and as "Pedrizas" in other Iberian systems).

Together with these deposits, and generally at a somewhat lower altitude, there exist deposits that are clearly morainic, either lateral moraines or rock glaciers, with very little fine fraction, due to the scant movement of the glaciers.

All these detritic forms (together with others of different origin and lesser importance), located in the Dilar valley at an altitude of over 2.600 m, are responsible for the existence of a flow of great hydraulic conductivity; thus there are no signs of water derived from snowmelt above an altitude of 2.900, to the peaks at about 3.400 m.

Many springs are to be found at the limits (both frontal and lateral) of these detritic forms (frequently coinciding with changes in gradient or with the appearance of rocky thresholds, etc.). Figure 8a shows a simplified diagram of the springs, according to their "depositional" origin. Springs A,B,D (Figure 1) are examples of highly influenced by this type of control.

3.2. MORPHOLOGIC CONTROL

The glacial action that affected the Sierra Nevada in the Quaternary (Riss, Wurm, Tardiglaciar ; Messerli, 1965), apart from creating moraines, as discussed above, also formed various cirques, kegs and shoulder pads; these forms currently appear to be topographically "hanging" with respect to the fluvial system. In the Dilar valley, and especially on its left bank, oriented towards the north, the greatest inflexion in the gradient occurs between 2.500 and 2.800 m above sea level.This attenuation of the gradient, which on occasions creates a convex form (over-excavation forms) itself plays an important role in the emergence (and surface retention on occasions; glacial lagoons) of the subsurface flow.

The reduction of the gradient diminishes hydraulic transmissivity due to the consequent loss of flow velocity and thus favours processes of emergence. Many of the springs examined exhibit this change of gradient, located on the left bank of the Dilar river. In general, it is here, directly associated with the springs, that the "borreguiles" or water-meadows of greatest size and beauty are to be found.

Another type of morphologically controlled spring is that caused by incisions of the fluvial system in alteration or deposit levels. However, these are not very frequent in the study area, being more commonly found at lower altitudes.

Figure 8b shows a spring-type related to morphological control. An example of this type of spring is the C (Figure 1).

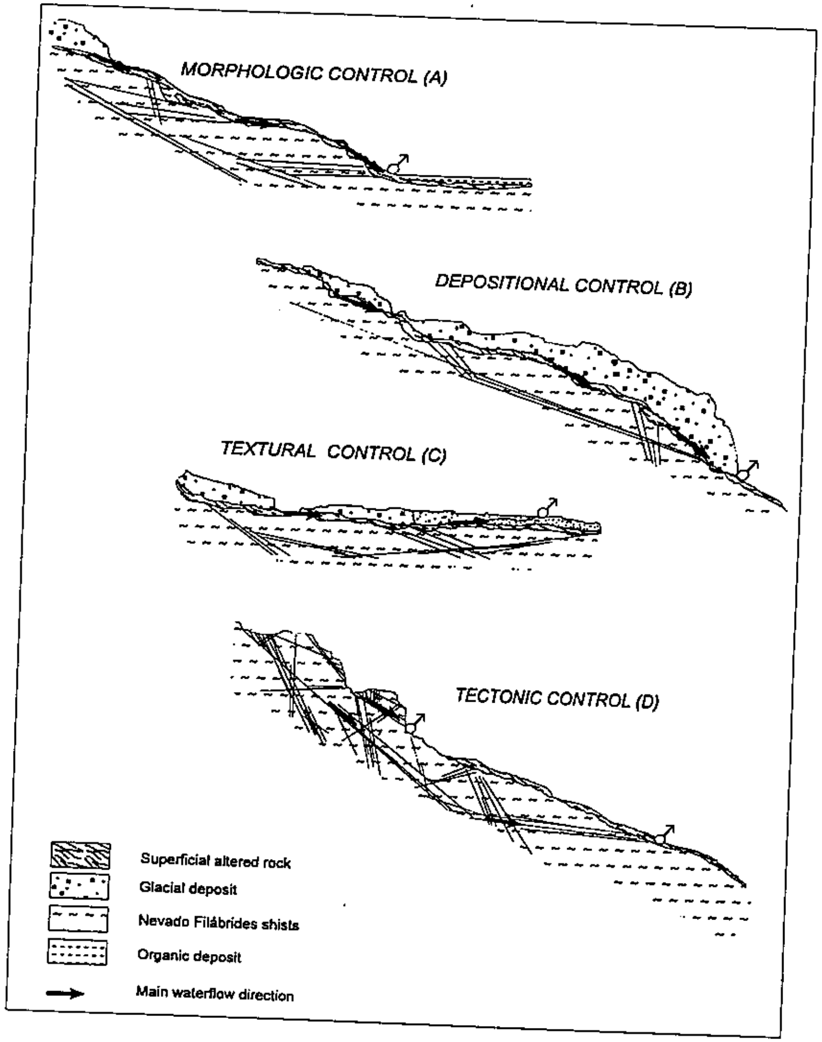

Figure 8. Schematic sections of the purposed spring models. A :morphologic control (mainly slope inclination decrese). B :depositional control (water flow through detritical bodies). C :textural control (grain size variation in the water flow direction). D :tectonic control.

3.3. TEXTURAL CONTROL

Another, less frequent, series of springs occurs when there is a gradual change in permeability in the direction of the flow, within the alteration and/or deposition zones, due to the existence of finer fractions (till, intermediate moraines, basal moraines). This textural control is strongly related both to the distance from the peaks (altitude) and to the changes in slope gradient. Figure 8c shows a diagram of springs exhibiting this type of control. Spring E (Figure 1) is an example of highly influenced by this type of control.

3.4. TECTONIC CONTROL

The intense fracturing of the Sierra Nevada schists (as evidenced on the north face of Alcazaba or Mulhacén, in the Genil valley or Tajos de la Virgen in the Dilar valley) produces a certain degree of circulation; in no case, however, is this common in the upper part of the Dilar valley. This is due, above all, to the scant extension of the mountain ranges (lacking alteration layers or detritic forms) and to the low penetrativity transmissive fractures. Nevertheless, surface infiltration is significant, although water flow descends laterally towards detritic contact forms such as debris cones and carpets. Some springs were observed to emerge through fractures, and these are sometimes associated with deposits of iron oxides. Figure 8d shows a diagram of this type of spring. An example of this type of spring is the F (Figure 1).

3.5. OTHER TYPES OF CONTROL

At lower altitudes (below 2.000 m), but also on occasions at altitudes similar to those of the study area, other types of control are significant, such as flow through alteration and edaphic levels, through structural discontinuities (tectonic surfaces, highly broken terrain, etc.) or through more intensely fractured drainage-levels (even karstified zones and marble), producing springs of distinct characteristics.

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