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Observations on the saxicavous habits of *Cepaea nemoralis* (Linnaeus, 1758) (Pulmonata, Stylommatophora, Helicidae) in the Pyrenees (France)

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ABSTRACT Since 1800 numerous geologists and biologists published several papers on the origin of holes in hard limestone observed in several countries of Europe and North Africa assuming that terrestrials snails were responsible for such a perforations. In the present paper a few observations on the saxicavous activities of *Cepaea nemoralis* (Linnaeus, 1758) in the Pyrenees (France) are reported.

KEY WORDS Saxicava; Helixigenic; Pyrenees; *Cepaea nemoralis*.

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INTRODUCTION

The phenomenon of saxicavous land-snails of Europe and North Africa, described and reported in numerous papers (Prévost, 1843, 1854; Figuier, 1858; Gaudin, 1860; Bouchard-Chantereaux, 1861; Marrat, 1864; Merle Norman, 1864; Brehm, 1869; Mackintosh, 1869; Roffe, 1870; Trevelyan, 1871; Bretonnière, 1888; Forel, 1888; Platania, 1890; Meunier, 1890, 1900; De Gregorio, 1890, 1916; Harlé, 1900; Wilson, 1913; Lamy, 1930; Kühnelt, 1932, Di Salvo, 1932, Rensch, 1932a, 1932b, 1937; Jamnik, 1997; Manganelli et al., 2000; Quettier, 2002 ; Liberto et al., 2010; Colomba et al., 2011), does interest different species including *Cepaea nemoralis* (Linnaeus, 1758) which is one of the most frequently cited.

A few of these rock-boring species are saxicavous only in some localities, while others make perforations in the rock as their biological constant characteristic.

Despite of different geographical areas and dissimilar atmospheric conditions, this phenomenon has always the same specific characteristics. Perforations are constantly on compact carbonate rocks and predominantly on the vertical or sub-vertical surface, on the side exposed to the prevailing direction of the rainfall; the galleries are always directed from the bottom up so that water can't penetrate inside, flooding them. The cast of a small group of holes made by *Cepaea nemoralis* in the Pyrenees (Fig. 1) is representative of its general characteristics; it is possible to find tunnels leading to the upper edge of the rock, but the origin of the perforations is always on the bottom; the hole-diameter varies from 2 to 3 cm and remains constant with no significant restrictions along the tunnels. Perforations begin with the construction of a single gallery, then a second one is added, a third one and so on, thus increasing in number and depth; the rock wall between several contiguous galleries gradually reduces up and finally disappears, leaving a large cavity the bottom of which appears completely pitted; sometimes *Cepaea nemoralis* dug their tunnels also through layers of calcite including fossils (Figs. 2-6).

DISCUSSION

As far as concerns observations on the saxicavous habits of *Cepaea nemoralis* in the Pyrenees (France), perforations in the rock made by these animals are usually observed in karst areas with partial or complete vegetation cover, being less abundant in exposed areas with isolated rocks; a few perforations can also be found in the plains, on isolated rocks or in limestone houses

Fig. 1

Fig. 2

Fig. 3

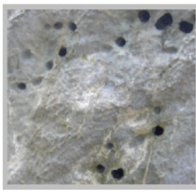

Fig. 4

Fig. 5

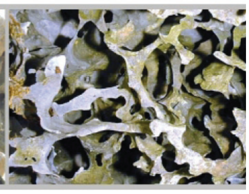

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10

Figure 1. The cast of a small group of holes made by *Cepaea nemoralis* in the Pyrenees.
Figures 2-6. General characteristics of perforations made by *Cepaea nemoralis* in the Pyrenees (France).
Figure 7. Pile Romaine of Luzenac (Ariège, France).
Figures 8-9. *Cepaea* trapped in the tunnels (Pyrenees, France).
Figure 10. Rocks completely altered and perforated by *Cepaea nemoralis* from Hider at Prat Bonrepaux (Ariège, France).

hand-made by man as is the case of “Pile Romaine” of Luzenac (Ariège) (Fig. 7).

When galleries are particularly complex in structure, *Cepaea* often remain trapped inside the tunnels because of increasing size of shells (Figs. 8-9), whereas sometimes specimens happen to die in the holes for natural causes. As already observed in some areas that in the past were the seat of an intense activity of saxicava and today show a luxuriant vegetation covering the holes inside of which *Cepaea nemoralis* can rarely be found, in various locations of the Pyrenees, as the cliffs of Hider at Prat Bonrepaux (Ariège), *Cepaea* specimens are not encountered anymore. In this place, for example, there was a rocky area of over 100 square meters completely altered and perforated every centimeter (Fig. 10) now abandoned by *Cepaea nemoralis*, with ivy and moss invading the tunnels and the ground vegetation extremely abundant. Since it is a location away from human settlements and activities, this ecosystem was probably altered due to natural causes.

Some literature papers above-mentioned, report that saxicavous land-snails dissolve the rock by using an acidic substance. In 2002 an experiment carried out by some CNRS researchers revealed that after placing a few *Cepaea nemoralis* specimens in some purposely-cut blocks of limestone, several eroded areas showing the same shape as the foot of the *Cepaea* previously resting on the blocks were found.

It was observed that on the Pyrenees there is a change in the orientation of the perforations correlating to higher altitudes, probably due to the colder air currents from the Atlantic Ocean. At the local level, in each perforated area, the tunnels have a prevailing orientation that, in the same site, can vary by more than 20°, with the exception of very chaotic rocky areas where it can vary by up to 180°. In other places, along the banks of rivers where the last limestone rocky groups appear on the surface, at about 260 m above sea level and well protected in the valleys, the orientation of the holes is of nearly 360°, with a few predominant directions depending on the sites, including on the eastern side of the massif. As clearly visible on the graphs showing the orientation of the perforations between 1,000 and 2,000 m above sea level (Fig. 11), the more increasing the

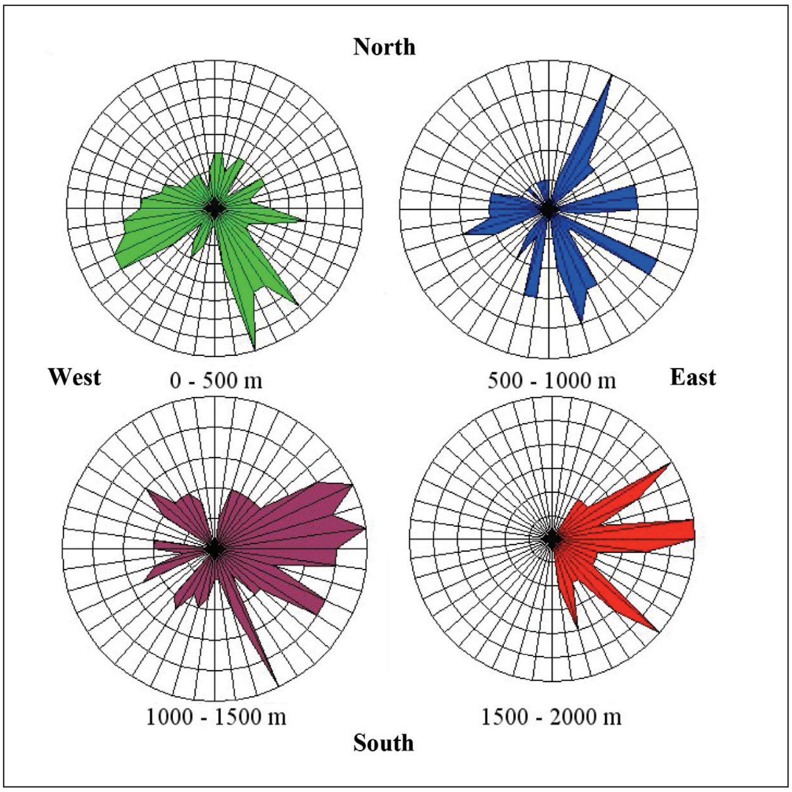

Figure 11. Orientation of perforations made by *Cepaea nemoralis* on the Pyrenees (France) at different altitudes, expressed in m above sea lave.

altitude the more the hole-angle is reduced and the western areas of the mountains, more exposed to the natural elements, do not show nearly any perforations at all.

As calculated in England by Stanton (1986), the drilling speed of *Cepaea nemoralis* is equal to 1.5 mm in 10 years. As demonstrated by the same author, knowing the speed of drilling and the main orientation of holes, it is possible to reconstruct the original position of some blocks of limestone reworked or processed by man. For example, the "Dolmen de Comminge" (Camarade-Ariège), a megalithic construction with numerous perforations made by terrestrial molluscs shows, on the horizontal part, a group of reversed perforations, thus suggesting that this block of several hundred pounds was originally placed in reverse with an orientation differing from the current one by about 85°; moreover, the vertical walls show further perforations that attest these movements and reversals occurred during the assembly of the construction (Fig. 12). Another example is that of the "Pile Romaine" of Luzenac (Ariège), a building dated between the I and IV century A.C, more than 7 meters in height, located in a field along the road D618. When the front of the northwestern side of the building collapsed, it was subject to saxicavous activities of land-snails that bored holes in the blocks of limestone just below the mortar. Taking into account that perforations are, on average, 95 mm long, it can be inferred that the building collapsed about 630 years ago, around 1380.

Probably, *Cepaea nemoralis* perforates the limestone mainly to escape the cold temperatures of winter; in fact, during the winter this species is usually under the soil at a depth of about 20 cm, avoiding the frozen ground for a few months. Measurements carried out in September 2011 on the temperature of the subsoil at 20 cm compared to the temperature inside a tunnel of the same length bored by *Cepaea nemoralis* showed that there is a difference with respect to the temperature at the soil-level (Fig. 13). In particular, the soil is sensitive to any changes of outside temperature; an increase of 16 °C causes in the ground, five hours later, a temperature increase of 5 °C. On the rocks there are not the same variations; the change occurs in about eight hours, but the range is only 1/10 of the outside temperature, i.e. for an increase of 16 °C, the temperature in the rocks increases only by 1.5 °C (Chabert, 1980; Guillou-Frottier et al., 1998; Benhammou & Draoui, 2011). Figure 14 summarizes the temperatures recorded in September-November 2011, in order to show either the trend curves in rock and soil during the summer and winter time or the condition of rocky micro-environments when temperature is extremely high or low.

Perforations in the rocks made by *Cepaea nemoralis* also protect these animals against predators such as the common shrew (*Sorex araneus* Linnaeus, 1758: Mammalia, Soricidae), several species of insects and birds; that's probably the reason why *Cepaea nemoralis* spend long periods inside the galleries even in summer.

CONCLUSION

Observations on the saxicavous activity of *Cepaea nemoralis* in the Pyrenees region (France) reported in this paper confirm numerous works previously made on this item. In particular, the main cause that leads these land-snails to rock-boring is likely to be the need to escape the cold temperatures of some rocky habitats, expecially during the winter. Hence, as suggested by Sacchi (1955a, 1955b) who hypothesized that the same phenomenon in *Cornu aspersum* (O.F. Müller, 1774) and related species of Algeria and in *Erctella mazzullii* De Cristofori & Jan, 1832 complex from Sicily (see also Colomba et al., 2011) was the result of the adaptation to dry and arid climatic conditions occurred in past geological periods, climatic factors may be the prevalent cause of saxicavous habits of mollusc species in different geographical areas all over the world.

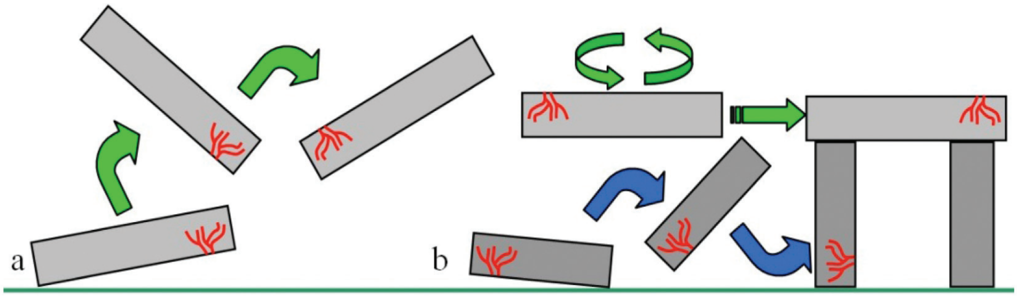

Fig. 12

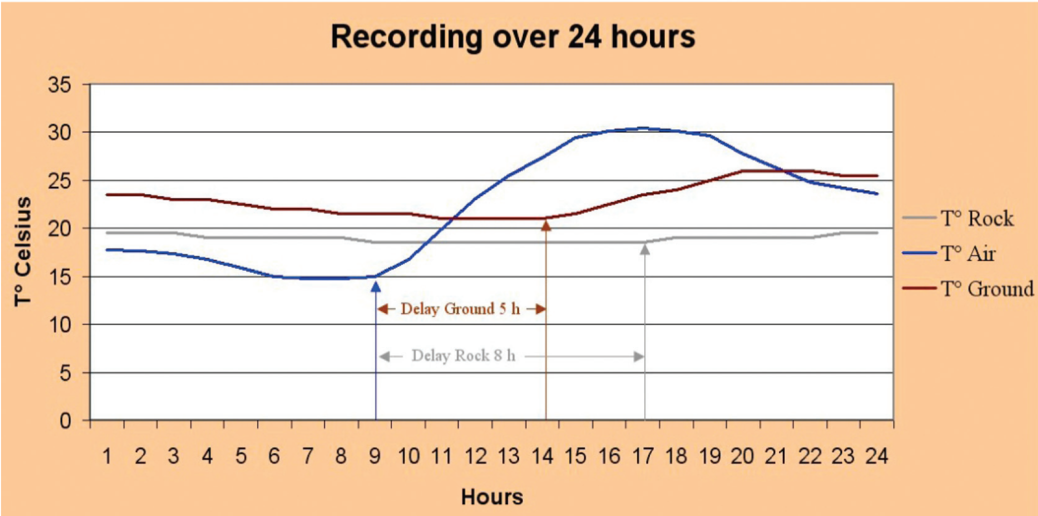

Fig. 13

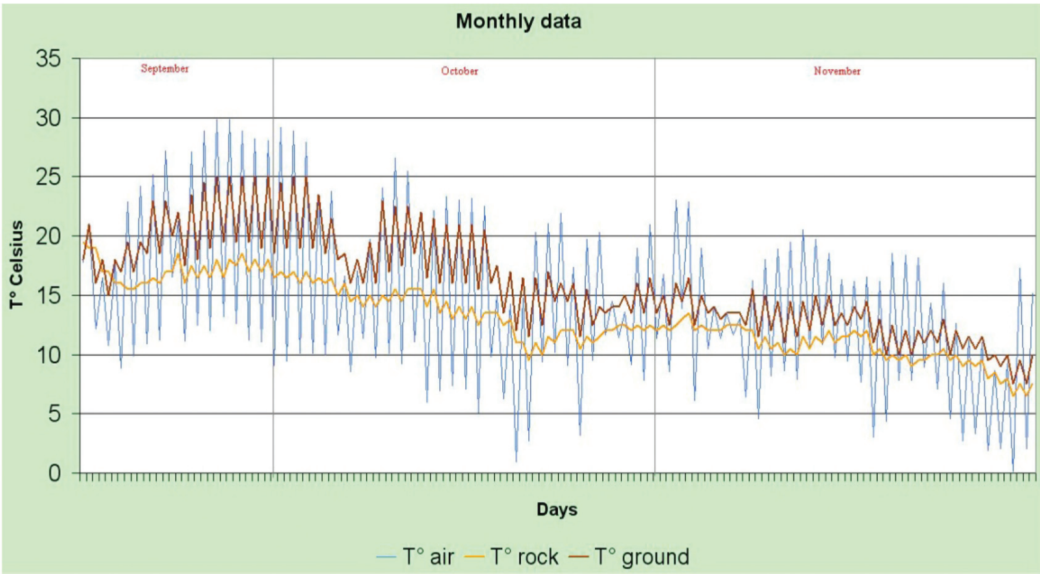

Fig. 14

Figure 12. Orientation pattern of perforations of *Cepaea nemoralis* from Dolmen de Comminge (Camarade-Ariège, France)
Figure 13. Measurements carried out during the day in September 2011 on the atmospheric temperature, temperature of the subsoil at 20 cm and in a tunnel of the same length bored by *Cepaea nemoralis* (Pyrenees, France).
Figure 14. Temperatures recorded in September-November 2011 (Pyrenees, France), showing the trend curves in rock and soil during the summer and winter time.

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