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# MODELLO GENETICO ED EVOLUTIVO DEI MULINI GLACIALI SULLA BASE DI OSSERVAZIONI SUL GHIACCIAIO DEI FORNI (ALTA VALTELLINA, ITALIA SETTENTRIONALE)

**ABSTRACT:** TOGNINI P., *Genetic and evolutive model for glacial sinkholes on the basis of field observation on Forni Glacier (Valtellina, Northern Italy).* (IT ISSN 0391-9838, 2001).

Since 1994, glacial sinkholes in Forni Glacier (Valfurva, Northern Italy) have been the object of systematic observation, with the aim to understand their genetic and evolutive mechanisms, their geometric arrangement and the hydrodinamics of related en- and subglacial aquifers.

Field observations every year required to locate caves entrances on a field-measured survey network, in order to measure their annual movements, together with the survey of the main caves, which let us appreciate changes in shapes, dimensions, depths and surface stream water supply. Measurements have been made of ice discontinuities, such as jointing and foliations: they proved to exert a strong control on caves systems geometrical arrangement and morphologies.

As for the origin and evolution of these caves systems, some models are at present being proposed; these models are very similar one to the others despite they have been carried on independently by different researchers in different glaciers all over the world: this suggests the existence of a general process, which is valid independently of the dimensions and the characteristics of flowing of any glaciers, provided they are temperate enough to allow ice melting and liquid water circulation. The suggested general models are mainly based on local and non-continuous-in-time field observations on a large number of glaciers all over the world, while only very few systematic studies have been carried on for several years on the same glacier, both in Italy and abroad: the data on Forni Glacier are therefore interesting, because they are field corroboration of mainly theoretical models.

On Forni Glacier about fifty main caves and many other minor ones have been detected. The caves systems are organised in a series of sinkholes, or *moulins*, aligned along certain directions (mainly sets of main discontinuities, related to ice jointing and foliations). They entirely or partly catch the water flowing along surface *bédières*, leading water circulation from surface to englacial, or possibly subglacial, zones.

Thanks to the thin ice-sheet, which is about 100 m thick in its thicker portion, the englacial flow may be drained towards the subglacial zone, where englacial caves systems are cut by deep fractures and crevasses at the glacier front.

In each system, downstream *moulins* are year by year fossilised by the forming of new sinkholes in an upper stream position: fossilised *moulins* are gradually carried downstream by glacier flowing, so that it is possible to observe sinkholes in all their different phases of evolution, from a proto-*moulin* phase, merely a fracture enlarged by ice melting and water friction, to large sub-circular shafts, some meter large and over 40 m deep, to relict, completely fossil *moulins*, whose dimensions gradually decrease because of plastic collapse when water feeding stops.

Every year, the formation of new sinkholes was observed, always in the same position with respect to the bedrock, probably just above rock rises, which create in the overlaying ice tensional conditions inducing open jointing, which, in its turn, causes surface water to seep at depth. During summer season, neoformed *moulins* fossilise downstream sinkholes that survived during winter season. A systematic observation of the caves allowed us to estimate an age: a time span of 6 year is assessed from the moment a proto-*moulin* is formed, generally at the intersection of two or more discontinuities sets, to the moment, after reaching its maximum size, the *moulin* gets fossilised and deprived of water feeding by the forming of new upstream sinkholes, getting gradually narrower by ice plastic collapse, till it finally disappears.

The observation of very peculiar ice textures inside *moulins* suggests that during winter season ice caves might get completely filled with water because of a raising of the water-table caused by ice closing discharge points at the glacier front. The drowning of the caves and the subsequent formation of secondary ice, possibly completely filling the englacial conduits, probably cause the surviving of *moulins* season by season: when deprived of water feeding, these features are in fact very prone to collapse and disappear in the course of few weeks.

The maximum depth of the sinkholes is about 40 m; curiously, the depths of the explored shafts (about 30 in number) do not show an homogeneous distribution, and three main depth classes are observed, at about 2-3 m, 10-15 m and 35-40 m depth. Obviously, the active shafts are the deepest ones. Proto-*moulins* on their way of forming often exhibit a depth (10-20 m) which is considerable if compared with their small diameter (few centimetre, or decimetre).

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