Geol. Paläont. Mitt. Innsbruck, ISSN 0378–6870, Band 25, S. 1–242, 2001

ENDOKARST EVOLUTION RELATED TO GEOLOGICAL, TOPOGRAGRAPHIC AND CLIMATIC EVOLUTION IN THE LOMBARD SOUTHERN ALPS

Alfredo Bini & Paola Tognini

The longest and deepest cave systems in Lombardy (Northern Italy) are found in the Southern Alps, where the most karstifiable formations crop out, with the highest karst potential. The structural setting is very favourable to deep karst systems (km-scaled syncline folds), together with favourable palaeoclimatic, morphologic and topographic factors.

The idea of the evolution of a region, and of its related endokarst, as a sequence of distinct-in-time phases (as by Davis at the end of the 18th century) is hard to die, but after the modern concept of speleogenesis and karst evolution, early endokarst began to form as the area was raised above sea level and kept on developing during Alpine orogenesis: morphogenesis does not follow tectogenesis, but it is contemporary to it, and in the meanwhile the regional topographic and climatic evolution strongly controls the genesis, evolution and characteristics of endokarst.

Some Lombard endokarst systems have been the object of detailed studies, the most interesting of them being the systems of Campo dei Fiori (over 25 km caves, maximum depth -640 m), of Mt. Bisbino, of Pian del Tivano (over 30 km caves, maximum depth -560 m) and of Northern Mt. Grigna (with the highest cave density in Lombardy, and the deepest Lombard cave, -1170 m deep).

A global analysis taking into consideration caves geometry and morphology, their tectonic and structural setting, the position, facies and characteristics of cave deposits and speleothemes, enriched with U-Th dating, allowed the endokarst evolution to be reconstructed and compared with the regional tectonic, palaeogeographic and palaeoclimatic history, from the moment the area was raised above sea level, when the main karstification phase began: caves are considered to be an integral part of a region and must therefore be studied together with it.

After geological studies, the emersion of the Lombard Southern Alps is estimated to be early Miocene, or late Oligocene, in age by dating of valleys filling and by the occurrence of palaeovalleys which fed the sub-marine canyons where the Southern Molasse was laid down.

Older valleys networks are cut by Messinian valleys (dated on the basis of their sediment content in the Varese district). The main evidence of old valleys is given by seismic profiles showing deeply embanked palaeovalleys often continuing under the Po Plain sediment cover, several km southward: dating of their sediment filling proves ages from Messinian on, so that valleys should predate both sediment deposition and the Messinian Entrechment.

Analysis of soils and weathering products prove that during Alpine orogenesis climate was tropical humid: under such conditions, rock weathering was intense and karstification sped up. Alpine uplifting played an active role in creating an increasing relief energy, which controlled the topographic and morphologic evolution of the region, promoting the entrenchment of the long, deep Southalpine valleys: this was a very favourable condition to the development of deep caves systems, too. Valleys and endokarst features are therefore inferred to develop before Messinian Entrenchment and when glaciations began (late Pliocene) they were obviously preexisting, so that glacial modelling on endokarst

was minimal and restricted to high mountain regions.

Lombard Southern Alps endokarst exhibits several examples of caves systems not in equilibrium with the present topography: this proves endokarst is old and formed and evolved under topographic and climatic conditions quite different from present ones. Evidences of a non-equilibrium situation are corroborated by field data, such as:

1 – endokarst systems cut by younger erosion surfaces (i.e.: by glacial scouring) and valleys, causing a fragmentation of the endokarst systems, originally continuos, into smaller sub-systems. Caves systems cut by younger valleys can be observed at different scales, from the valley presently filled with the Como Lake, to its tributary gorges, to small lateral vallets at higher altitudes.

2 – syngenetic galleries are observed at different altitudes, much higher than the present base level (1.200-1.400 m above the p.b.l. in the Pian del Tivano system, 1.800-2.000 m in the Grigna system, 900 m in the Campo dei Fiori system): they are different in age and related to different base levels, which were continuously evolving while karst was evolving.

3 – cave passages are often too large with respect to the present catchment: the hydrogeologic basins in the past should have been much larger (i.e.: Pian del Tivano, Grigna, Campo dei Fiori);

4 – most endokarst in the Como Lake surroundings have their main springs below the present lake level (Pian del Tivano, Grigna), karst features have been observed below lake level and some caves exhibit a complex network of drowned galleries, some tenths of m deep;

5 – some springs are burden under sedimentary cover post-dating springs formation (i.e.: Campo dei Fiori main springs, covered with late Pliocene- Quaternary deposits);

6 – some caves contain sediments brought into caves by rivers, which are not consistent with any river possibly flowing into caves in the present topographic situation and contain grains of rocks which at present have been completely eroded away in the surroundings (i.e.: Campo dei Fiori).

7 – caves passages and concretions are deformed by late-Alpine tectonics correlated with deformation phases dated at surface by dating sediments they affect (early Pliocene, early Pleistocene) (Campo dei Fiori, Bisbino).

8 – speleothem radiometric dating often shows ages older than the method limit (350 ka), even older than 1.5 Ma (on the basis of their $^{234}U/^{238}U$ ratio). A very old age for the oldest speleothemes is inferred on the basis of the relations with cave deposits and on their weathering state. Some speleothemes are engulfed into sediments related with climate changing and glacial advance phases, so that caves must predate.

As for the evolution of karst, a global analysis of caves morphologies and minerals points out:

1 – one palaeokarstic phase during episodic raising above sea level of the Esino Formation carbonate platform during Ladinian (i.e.: Northern Grigna);

2 – one hydrothermal karst phase, probably affecting just small areas close to intensely tectonised areas (i.e: Northern Grigna, Mt. Tremezzo), related to the eo-Alpine and neo-Alpine thrusting;

3 – one "pseudoendokarstic" phase, due to very deep pedogenetic processes under a hot humid tropical climate (i.e.: Mt. Bisbino) giving rise to peculiar morphologies; soil formation under tropical hot humid climate is detectable over large areas in Lombardy, not only on carbonate parent material, and the process is likely to be continuos from the uplifting above sea level (early Miocene) till late Pliocene climate worsening pre-dating the beginning of Plio-Quaternary Ice Age;

4 – one deep "classical" karst phase: the evolution of this phase is related to topographic evolution and is controlled by base level changing (due to neo- and late-Alpine tectonic uplift, to Messinian Entrenchment and to Pliocene marine transgression).

Furthermore, analysis of facies, lithology and grain weathering in caves deposits point out dramatic changes in climate, with a changing from

biostatic (alloctonous caves deposits very scarce or absent) to rhesistatic situation (mobilisation of tropical soils brought into caves from surface) and a progressive cooling, with suffering and final disappearing of the vegetation cover, related to late Pliocene climate worsening, the precursor of the first glacial advances (recorded by deposition of alloctonous materials into caves). Analysis of caves deposits and U-Th speleotheme dating allowed reconstructing the alternating warm and cold climate related to Plio-Quaternary glaciations (in the studied area, at least 13 glacial advance phases have been detected during the last 2.6 Ma).

As a synthesis of field data interpretation, integrated analysis of endokarst points out:

1 - caves origin is old, and due to a long period with a hot humid climate and a contemporary intense tectonic uplifting, while the Plio-Quaternary glaciations do not played any role in endokarst morphogenesis, their influence being on the contrary basic in controlling caves deposits;

2 - karstification is a continuos-in-time process (although it undergoes phases of rapid morphogenesis and phases of predominant cave sedimentation and concretioning);

3 - karstification is contemporary to geological and geographical evolution, being controlled by the tectonic, topographical and climatic history of the region.

Authors' address:
Alfredo Bini, Paola Tognini, DIST, University of Milano, Via Mangiagalli 34, 20133 Milano, Italy