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Editorial: Cave Deposits: Processes, Approaches and Environmental Significance

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Editorial on the Research Topic

Cave Deposits: Processes, Approaches and Environmental Significance

Caves are natural cavities accessible to humans mainly formed by the dissolution of carbonate and evaporitic rocks and, occasionally, by subsurface weathering in quartz-bearing rocks (Ford and Williams, 2007). While the different morphogenetic processes can quickly shape and dissolve landforms at the Earth's surface, caves can remain intact for several millions of years, thus surviving the landscapes in which they were formed (Granger et al., 2001). Water flowing through caves carries chemical and physical signals in the form of dissolved ions and clastic sediments that, accumulating within them, can form detailed archives of environmental and climatic change occurring at the Earth's surface (White, 2007). These deposits are among the most important continental paleo-environmental archives, offering a wide array of physical, geochemical, and biological proxies concerning climatology, hydrology, tectonics, ecology, and biology; at very different timescales (from sub-annual to orbital) and going back millions of years. Additionally, caves have been inhabited since prehistory and preserve anthropogenic sediments crucial to the understanding of human evolution, adaptation, and behavior. In the last decades, cave deposits have been targeted by numerous studies, and the progressive improvement of analytical methods now allows obtaining detailed, high resolution and well-dated records of present and past climate and environmental changes (Fairchild and Baker, 2012). Because speleothems have been preferentially the subject of these studies, the aim of this Research Topic is to present recent results and implications concerning the study of other types of cave infillings and sediments: precipitation and alteration minerals, water transported sediments, wall-weathering materials, biogenic (including anthropogenic) formations, cave ice and gravitative debris. The purpose is to furnish a state-of-the-art on methodological approaches, analytical procedures and dating methods, thus offering a novel and comprehensive view on cave deposits.

Four articles of this Research Topic collection concern cave clastic sediments, which, despite being volumetrically the most common deposits in caves, are much less studied than speleothems due to the difficulties of dating and determining their source and depositional mechanisms (Springer, 2005).

Kurečić et al. investigated an allogenic sedimentary sequence in Cerovačka Cave (Croatia), accumulated as a complex combination of breakdown, diamicton, and slackwater deposits. This study highlights how differences in facies formation in caves can lead to the understanding of the complex interplay between geomorphologic, tectonic, and climatic processes over the past tens of thousands of years, which would otherwise leave no trace at the surface. By firmly anchoring the chronology of the deposit with luminescence and radiocarbon dating, the authors prepare the scene

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for future, detailed investigation that could reveal centennial to millennial environmental variability and dynamics of human societies as recorded by the various proxies harbored in the investigated sedimentary sequence.

Sauro et al. report on the potential of clastic sediments for reconstructing the paleogeographic evolution of a karst system at high altitude in the Dolomites (southern Italian Alps). In their reconstruction, authors identified the source of the clastic infilling of the Raponzolo Cave and applied cosmogenic isotopes and U-Pb dating to constrain the burial time. Such multi-dating approach allowed them to reconstruct the evolution of the karst system, concluding that speleogenesis occurred since the Late Miocene because of the interplay between climatic triggers and tectonics. This contribution confirms the high potentiality of cave clastic sediments as tool to reconstruct ancestral evolution phases of the karst system and its response to multiple forcing.

Nannoni et al. describe a particular type of recent cave deposits where a significant portion of the detrital material is produced by the numerous marble quarries that impact the karst area of the Apuan Alps (Northern Italy). Mineralogical composition of sediments collected along karst waterways and springs shows variable proportions of calcite associated with dolomite and silicates. Cave deposits of natural origin have usually a fine-sand grain size whereas present spring sediments have a more variable grain-size distribution. Through innovative techniques of morphometric and chemical-physical analysis of sediments, it was possible to distinguish, although qualitatively, the particles of natural origin from the anthropogenic ones.

Patania et al. introduce the topic of preservation of archaeological sediments in cave-entrance/rockshelter environments. They explore the archaeological sequence of the Kisese II Rockshelter (Tanzania) highlighting that natural and anthropogenic processes promoting soil instability and erosion, also contribute to the loss of archaeological sediments, thus hampering our ability to reconstruct human adaptive strategies. Their geoarchaeological approach consider several variables (soil, vegetation, fauna, and anthropogenic features) in charge of enhancing surface processes, thus offering innovative tools to support archaeologists and heritage specialists. This multi-scalar approach seems essential for the construction of appropriate mitigation strategies for the preservation of archaeological cultural heritage.

Three papers deal with peculiar wall formations of chemical or biochemical origin.

Bernardini et al. describe a unique stromatolite-like manganese-rich deposit on cave walls in Grotta del Cervo (Central-southern Italy), and using a multidisciplinary investigation show that patina records the dynamics of the palaeofloods during which it was deposited. Combining geochemical and microbiological analyses, the authors make a compelling case for the possibility of using the internal microstratigraphy of the deposit as an archive of the succession of both flood events and processes within single-flooding events, opening a window into a novel proxy for past climatic reconstructions.

Jurado et al. investigated a common but still puzzling type of parietal deposit: vermiculations. The study concerns an alpine cave subjected to extreme climate conditions, located in Central Italian Alps and recently discovered thanks to the local glaciers retreat. The authors present a detailed geomicrobiological study revealing microbial communities dominated by 13 main phyla of *Bacteria* and contained a negligible percentage (<1%) of *Archaea*. The two major bacterial classes were *Gammaproteobacteria* and *Betaproteobacteria*, whose metabolic traits are associated to the nitrogen cycle. In addition, psychrophilic and methanotrophic bacterial groups were identified. Many uncultured members indicate the presence of still unexplored microbial taxa.

Piccini et al. presents a preliminary investigation on a very peculiar type of crusts or nodules covering the rock walls of inactive conduits in the Monte Corchia Cave (Apuan Alps, Northern Italy). Samples were analyzed by diffractometry and SEM-EDS revealing the occurrence of hydroxyapatite or fluorapatite mixed with Fe/Mn incrustations and allogenic clastic particles. Crusts are interpreted as related to precipitation during a waterfilled phase. Phosphate nodules are almost entirely composed by hydroxyapatite or fluoroapatite and could be the result of long-term chemical (or bio-chemical) precipitation in air-filled environments.

Despite speleothems are the most studied cave deposit, only one paper deals with them, demonstrating that caves offer a wide variety of secondary formations, the analysis of which is just in the initial phase. Weber et al. investigate four Holocene stalagmites from Hüttenbläserschachthöhle cave (Germany) by applying a detailed multiproxy approach (stable C and O isotopes, trace elements composition and Sr isotopes). They evaluate the proxy data consistency by comparing the different stalagmites and found coherent variations over overlapping periods. They also evaluate the robustness of the inferred climatic variations by comparing with a coeval record obtained from the nearby, well-studied Bunker Cave. Overall, the study highlights the importance of a multi-proxy approach, and the need to replicate speleothem records within a cave system, and ideally using several caves from the same region.

Finally, a paper concerns with the most ephemeral deposit occurring in caves: ice. Kern and Perşoiu review past achievements in reconstructing past environmental changes based on the study of multiple proxies harbored by cave glaciers and, based on their (and collaborators) 20 + years-long expertise, propose a *Cave Ice Sedimentary Architecture and Deposition (CISAD)* approach for further similar studies. CISAD would (in the author's vision) put mechanisms behind ice accumulation and those responsible for climate-proxy relationships first, and once these are understood, subsequent studies should proceed to reconstruct past climate and environmental variability.

As a whole, this collection shows a wide, well-differentiated panorama of conventional and unconventional cave materials that can be investigated and analyzed, offering efficient reconstruction of past environmental changes. By highlighting *other-than-speleothems* deposits we wish to draw attention

especially on these as archives of past natural and anthropic environmental histories.

AUTHOR CONTRIBUTIONS

All the authors made a substantial direct and intellectual contribution to the work and approved it for publication.

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