The little known impact of bats and bat guano in the late stages of cave morphogenesis

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Introduction

- Symbolic hosts of caves, from individuals to huge colonies (-> 40 M)
- **Corrosion** related to bat presence and guano deposits
- Widespread: intense in **tropics**, significant in **temperates**, also present in marginal areas (temperate mountains)
- **Inherited** marks of **past presence** => paleoenvironment studies
- Often only considered for the **origin of phosphate minerals** [HILL & FORTI, 1997; ONAC & FORTI, 2011, and references therein]
- **Very rare attentions to their speleogenetic role** [LUNDBERG & MCFARLANE 2009, 2012, 2015; FORTI et al., 2006]

=> significant speleogenetic processes
=> speleomorphic role
=> diagnostic features

Influence of bat presence

through metabolism and wastes catabolism

[LUNDBERG & MCFARLANE 2009, 2015, MARTINI, 1993; MIZUTANI et al., 1992; SPEAKMAN & RACEY, 1994; WEBB et al., 1994]

- **Air temperature increase: + 1-16 °C** (daily cycles)
- **H_2O vapor release**: 5.2 g / day => 150 kg / day (for 28 000 individuals)
- **CO_2 release**: 0.8 to 5.4 g / day
  => condensation of warm humid air on cool walls => corrosion

- **Urea:** 0.2 mg / day => 450 g / day (for 2 M individuals)
- **Guano:** 0.5 cm³ / a => 100 m³ / a (for 2-4 M individuals)
- **Phosphates:** 3 kg / ka (for «1» individual)

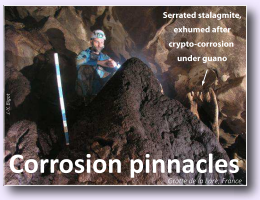
=> volatilization of CO_2, NH_3 (1000-2000 ppm) **=> corrosive condensation**
=> pH 2-4 at the base of guano piles **(acids: sulfuric, phosphoric, nitric)**

- **Mechanical erosion:** desagragation of weathereds wall by anchorage
- **Significant evolution by wall retreat => 3 to 34 mm / ka**

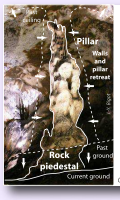
Detail of the claws of a Rhinolophus ferrumequinum *hung to the wall, making mechanical desagragation of weathered walls*

Thick guano deposit exposed by mining. Arid environment allows conservation of bat bones of the extinct Tadarida constantinei *, which age is > 400 ka* [POLYACK et al. 2006]

Crypto-corrosion under guano

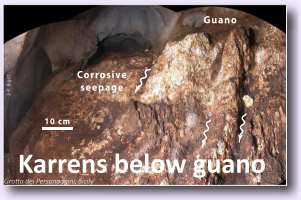


Corrosion pinnacles

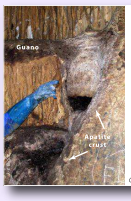


Rock piedestal

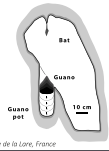
Ground corrosion
≈ 20-40 mm / ka

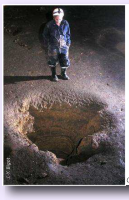


Karrens below guano



Guano pots

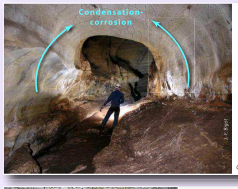




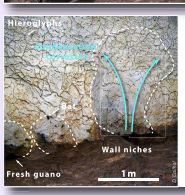
Guano pits

From acidic excretas of hematophage vampires

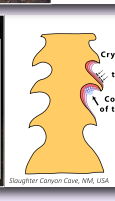
Corrosive convections



Smoothed walls and ceiling



Wall niches, corrosion channels, drip holes



Pillar corroded by niches

Bats and guano marks

Excretas and urine trickle

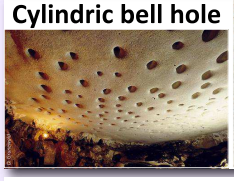
Dark trickle

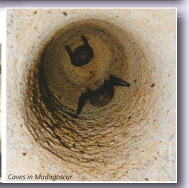
Phosphate crust on weathered limestone block

Bell holes and cupolas

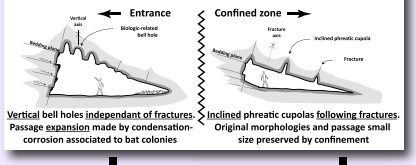
Bell holes with apatite trickles

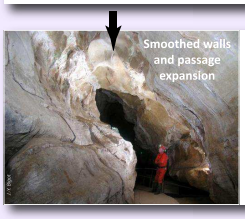
Cylindric bell hole



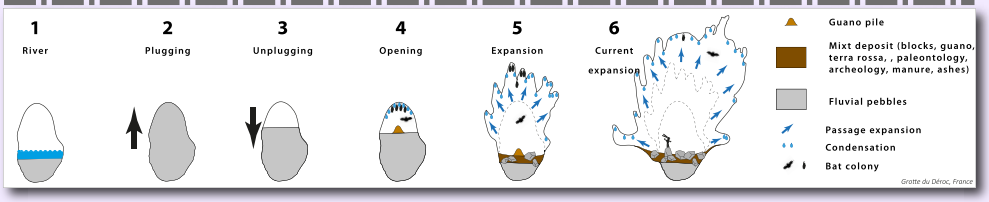


Distinct morphology when influenced by bats





Expansion of passages



Conclusion

- **Cupolas and bell holes, wall niches, pillars corroded by niches, phosphate trickles, guanot pots and pits, rock piedestals...**

=> diagnostic features

- **Significant evolution by wall retreat (up to 50 cm in 15 ka!)**

=> expansion accounting sometimes for 75-90 % of the volume

=> locally, major speleogenetic and speleomorphic process

Outlooks

- **Quantitative role of microbes** (cyanophyceas, actinomycetes ???)
- **Long-term denudation rates** (U/Th dating)
- **Monitoring** (T, RH, pH, CO_2, H_2S, NH_3, SO_2...)
- **Short-term denudation rates** (tablets)
- **Morphometry** (photogrammetry)

=> understanding of corrosion processes

=> interpretation of archeological remnants

=> conservation of prehistoric art

References

FORTI P., GALLI E. & ROSSI A. 2006. Peculiar mineragenetic cave environments of Mexico: the Cuatro Ciénegas area. *Acta Carsologica*, 35, 1, 79-98.

HILL C. & FORTI P. 1997. *Cave minerals of the world* (2nd ed.). National Speleological Society, Huntsville, Alabama, 464 p.

LUNDBERG J. & MCFARLANE D.A. 2009. Bats and bell holes: the microclimatic impact of bat roosting, using a case study from Runaway Bay Caves, Jamaica. *Geomorphology*, 106, 1–2, 78–85.

LUNDBERG J. & MCFARLANE D.A. 2012. Post-speleogenetic biogenic modification of Gomantong Caves, Sabah, Borneo. *Geomorphology*, 157-158, 153-168.

LUNDBERG J. & MCFARLANE D.A. 2015. Microclimate and niche constructionism in tropical bat caves: a case study from Mount Elgon, Kenya, in FEINBERG J., GAO Y. & ALEXANDER E.C. JR. (Eds.). *Caves and Karst Across Time*, Geological Society of America Special Paper, 516, 19 p.

MARTINI J.E.J. 1993. A concise review of the cave mineralogy of Southern Africa. *Proceedings of the XIth International Congress of Speleology, Beijing, China*, 72–75.

MIZUTANI H., MC FARLANE D.A. & KABAYA Y. 1992. Nitrogen and carbon isotope study of Bat Guano Core from Eagle Creek Caven Arizona, U.S.A. *Journal of the Mass Spectrometry Society of Japan*, 40, 57-65.

ONAC B.P. & FORTI P. 2011. State of the art and challenges in cave minerals studies. *Studia UBB Geologia*, 56, 1, 33-42.

POLYAK V.J., ASMEROM Y. & RASMUSSEN J.B.T., 2006. Old bat guano in Slaughter Canyon Cave. *New Mexico Geological Society Guidebook*, 57, 23-26.

SPEAKMAN J. & RACEY P. 1994. Post-prandial urine loss and its relation to ecology in brown long-eared and Daubenton's bats. *Journal of Zoology*, 233, 165-173.

WEBB P.-I., SPEAKMAN J.-R. & RACEY P.-A. 1994. Post-prandial urine loss and its relation to ecology in brown long eared (Plecotus auritus) and Daubenton's (Myotis dèbentonii) bats (Chiroptera: Vespertilionidae). *Journal of Zoology*, 233, 1, 165-173

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Milestones and Challenges in Karstology

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