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Rates of condensation corrosion in speleothems of semi-arid northeastern Brazil

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Condensation corrosion is a little studied, but important dissolutional process that occurs within caves in many karst settings around the world (for a review see Dublyansky and Dublyansky, 2000). Condensation corrosion occurs when air equilibrates with the cave atmosphere, becomes acidic and dissolves the bedrock and speleothems. It is a later vadose process that apparently depends on air circulation patterns, number of entrances and general configuration (vertical range, presence of ponded water, passage shape, etc) of the cave. Both bedrock and speleothems can be affected by the process, resulting in weathered outer surfaces. Condensation corrosion in speleogenesis has been regarded as responsible for dissolutional modification during later stages of cave development of coastal (Tarhule-Lips and Ford, 1998) and hypogenic caves (Hill, 1987; Palmer and Palmer, 2000).

The Campo Formoso Karst area of northeastern Brazil holds very extensive cave systems, such as Southern Hemisphere's longest cave, the 97 km long Toca da Boa Vista. These caves show remarkable features of condensation corrosion such as cupolas, weathered cave walls yielding dolomitic sand, "air scallops" and corroded speleothems. Weathering rinds up to 5 cm thick occur in both dolomite bedrock and speleothem surfaces. Unlike the dolomite, speleothems usually do not disintegrate but change to a milky white opaque porous calcite that is in marked contrast with the fresh crystalline calcite. The area is presently under semi-arid climate and the cave atmosphere is characterised by high internal temperatures (27-29 °C) and low relative humidity (mean of 73% for sites away from entrances).

Despite being such a widespread process, rates of condensation corrosion have so far been reported only from caves in the coastal area of the Caribbean (Tarhule-Lips and Ford, 1998). In this study, rates of condensation corrosion in speleothems were derived by determining thickness of weathering rind and age of last unaltered calcite. These rates represent minimum rates because speleothem growth ceased later than age obtained, and also condensation corrosion may not be continuous in time. Due to variable thickness of weathering layer (usually thicker at the top and thinner at sides of stalagmites), maximum and minimum thickness were obtained for each sample. Dating was performed through the alpha spectrometric U-series method in the first unaltered calcite layer beyond the weathering rim. Dating of the weathered portion of the calcite is not possible due to radionuclide remobilisation. U-series analyses and condensation corrosion minimum rates are reported in Table.

TABLE

Uranium series analyses and condensation-corrosion minimum rates for selected samples from Toca da Boa Vista.

Sample	U (ppm)	$^{234}U/^{238}U$	$^{230}Th/^{234}U$	$^{230}Th/^{232}Th$	$^{234}U/^{238}U$ initial	Age (ka)
TBV1-95	0.171 ± 0.002	1.46 ± 0.02	0.869 ± 0.016	57	1.76	182.9 ± 10.5
TBV-17T	0.420 ± 0.006	1.73 ± 0.02	0.744 ± 0.014	754	2.06	129.8 ± 5.5
TBV-32	0.050 ± 0.001	1.18 ± 0.02	0.962 ± 0.022	24	1.39	275.2 (+41 –38)
TBV-41	0.103 ± 0.004	1.50 ± 0.07	0.801 ± 0.030	206	1.76	152.7 (+21 –19)
TBV-46	0.043 ± 0.003	1.40 ± 0.10	0.707 ± 0.039	33	1.56	123.2 (+25 –21)

Sample	Age (ka)	Weathering rind thickness (mm)	Rate (mm/ka)
		Range	Range
TBV1-95	182.9 ± 10.5	5.0 - 71.0	0.026 - 0.41
TBV-17T	129.8 ± 5.5	0.1 - 1.0	0.00074 - 0.0080
TBV-32	275.2 (+41 –38)	3.0 - 16.0	0.0095 - 0.067
TBV-41	152.7 (+21 –19)	1.5 - 7.0	0.0086 - 0.052
TBV-46	123.2 (+25 –21)	0.1 - 1.0	0.00067 - 0.0098

The rates obtained vary over two orders of magnitude. They appear to be highly site specific, and are probably heavily dependent on the local atmospheric conditions, although more sampling is needed to confirm this relationship. The data shows that rates are dependent primarily on thickness measured, as range of ages is quite small. Tarhule-Lips and Ford (1998), in the very different littoral caves of the Caribbean, have estimated condensation corrosion rates based on experiments using gypsum tablets. Their reported mean value of 24 mm/ka, much higher than observed in the Campo Formoso caves, suggest that the process may be episodic in the area, not occurring during speleothem growth phases associated with wetter periods.

Although the rates reported by Tarhule-Lips and Ford (1998) indicate that condensation corrosion may actually enlarge cave passages in the normal (10^4 – 10^6 ka) time range of speleogenesis, in the Campo Formoso caves the process appears to play a minor speleogenetic role, being responsible for later modification of cave walls and speleothems.

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