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Thermo dynamical approach to cave development simulation (MTDC) in epigenetic karst

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During the last 20 years the author has attempted to develop an algorithm for the mathematical modeling of the spatial distribution and geometry of cave passages. The general model has been structured to forecast the 2-D position of the underground passages, their interconnection and the evolution of the cave patterns. Several real cave systems have been modeled with an acceptable degree of accuracy and the model validation have been based in the continuous improvement of its physical, mathematical and conceptual basis and the hydrogeological research and speleological exploration and surveying of the simulated cave systems. Primarily developed in epigenetic H2CO3-CaCO3 karst systems it has been recently extended to the simulation of hypogenetic H2S-H2SO4 cave systems.

Tested under different initial and boundary conditions, the thermodynamic approach of cave development simulation (MTDC) has allowed to: a) The derivation or extension of different sets of governing equations describing -in time and space- the development of limestone caves. b) The forecast of the geographical position and some geometric characteristics of both unknown and known cave passages. c) To test -in particular cases- the theories developed to explain the origin and evolution of some of the simulated cave systems.

After the development of a conceptual model of Karst systems and cave development suitable to mathematically describe them and the processes involved in cave excavation, a special effort was devoted to derive the driving equations describing the physical governing laws, the transport phenomena, the statistical continuity of the governing physical properties among each constitutive space accounting, in particular, to their inertia, time-dependability, the effect of the scale factor, the linear and non-linear feed back loops, the interaction between the acting forces and fluxes and the entropy vari-

ation. Mass, moment and energy transfer processes were solved in terms of transport functions droved by non-equilibrium thermodynamics. Work within the system has been described by energy-dissipation functions among the constitutive spaces far they could be defined as self-regulated energy dissipation structures. Thus, entropy changes due to the synergy among the energy-dissipation functions and mass-moment-energy transfer equations are described by multiple thermodynamic coupling. Triggering dissolution effects are considered by relating thermodynamic coupling among chemical reactions and vectorial phenomena in anisotropic media. Thermodynamic fluctuations derived from the time and space coincidence among the onset of the dispersion phenomenological coefficients, the non-linear high velocity fluxes -and related forces- and the increase of the dissolution rate are computed like single pulsations in random time. Boundary conditions should provide that initial time is very much shorter than total time and, when approaching infinite the probability of the functional extremals could be considered negligible.