Proc. Univ. Bristol Spelaeol. Soc., 2000, 22 (1), 111-117

REVIEWS

Speleogenesis: Evolution of Karst Aquifers. edited by Alexander B. Klimchouk, Derek C. Ford, Arthur N. Palmer and Wolfgang Dreybrodt, with Members of the Commission of Karst Hydrogeology and Speleogenesis, International Speleological Union. 2000 National Speleological Society Inc. Huntsville, Alabama, U.S.A. HB 527pp. Price $60 ISBN: 1-879961-09-1.

When I started caving, in my early teens, I joined a club whose older members impressed two pieces of advice on their callow recruit. "Caves are where you find 'em," said one, and I wondered why. "Take people as you find them," said another, and I wondered how. There is perhaps more similarity between people and caves than one might think. Both conform to a narrow range of basic architectures, yet individuals display a bewildering variety within it. In both, the characteristics of a mature specimen are strongly determined by origin and early development. Both are influenced by and exert profound influence upon their environment. There the conceit ends, save that to the modeller, geomorphologist, hydrologist or explorer, as to the geneticist, physiologist, psychologist or lover, intensive and extensive study are both spiced by surprises.

The subtitle of "Speleogenesis" is "Evolution of Karst Aquifers". It is highly successful in its main task which might be summed up as "Speleogenesis, or Evolution of Sub-Surface Karst". The question of how this relates to aquifers in general comes later. The book sums up four decades of research by mostly European and North American speleologists, showing how caves originate and develop in different geologic, hydrologic and geomorphic settings, how form reflects origin, and how the development of caves by solution in turn alters the character of the aquifers they are embedded in. It is an encyclopaedic volume, the work of forty four contributors, four editors and a five-member Special Publications Committee of the National Speleological Society of America. The result, *e pluribus unum*, combines magisterial survey with diversity of opinion by means of a structure in which short or medium-length essays are combined in sections arranged hierarchically as Parts, Chapters and articles. There is evidence of firm but not stifling editorial control on the diverse material received, one article even concluding with a printed exchange of comments between editor and authors.

Historically, the various branches of earth science have each tended to begin with a period of field observations and categorisation which was generally followed by competing attempts to summarise by means of explanatory models. These usually increase in complexity and diversity over time but remain conceptual and obstinately difficult to use for prediction. Sooner or later the controversies arising from competing models provoke reductionist attempts to resolve the issues by introducing new data or concepts from chemistry and physics, and parts of the subject move into the laboratory as a result. As the fundamental processes involved gradually become clearer and can be successfully described mathematically, theoreticians emerge who attempt to explain the diversity of field phenomena by means of holistic simulations based on a few processes operating over time under various constraining conditions. Speleogenesis provides a good example, and the different stages are covered historically in Part 2. The first chapter in Part 3 sets out the variety of geologic settings in which caves occur and emphasizes speleogenesis as a process that can affect soluble rock during any or all stages of the crustal cycle of diagenesis, deep burial, exhumation and near-surface groundwater circulation. The editors regard this broadly evolutionary perspective as fundamental to the book's message for both speleologists and hydrogeologists. From a speleological viewpoint, it

certainly shifts emphasis away from the topographically constrained, sink-resurgence systems which, since they must in principle have connections with the surface, comprise the best-known type of explored caves. The remainder of Part 3 comprises six more chapters which describe the lithological and stratigraphic controls on cave inception and show how the variety of cave patterns are related to the interactions of structure and hydrology both above and below the water table.

While Part 3 relies largely on the synthesis of geological observations from the field against a background of theory, Part 4 is devoted to a reductionist description of fundamental processes and their synthesis into holistic computer models of the early origins of caves. Chapter 4.1 deals with chemical equilibria and kinetics in the solution of karst rocks, linking laboratory and theoretical studies to variation of solution rates with climate at the global scale. Chapter 4.2 is the heart of the book. It describes in three sections how chemical kinetics and groundwater potential theory can be combined in models that simulate the initiation and enlargement of individual conduits and the development of networks. Networks of enlarged voids form while they are still far too small to be called caves, but their characteristics are imprinted and inherited by explorable systems because of runaway enlargement of selected routes. These achieve primacy because they are the first to become permeable enough for water to reach the outlet boundary of an aquifer before it becomes chemically saturated. Such routes become proto-caves: they enlarge at runaway rates and because of their swiftly enhanced permeability the heads within them drop and the flow of enlarged but as yet smaller voids in the rest of the aquifer is re-directed towards them. Those that in turn break through to the first proto-cave become tributaries, and so a network is built up as a template on which all further development to full cave size takes place. The spatial patterns resulting from such computer simulations of interacting chemistry, flow and aquifer permeability bear striking resemblances to both hardware laboratory models and the organisation of real caves. These models do seem to constitute a more complete explanation of the *early* stages of speleogenesis than previous conceptual ideas along the same lines, because they combine general laws of chemical and flow processes (the "karst iron rules of hydrology"?) with initial and boundary conditions that in principle can be adjusted to reflect the great variety of geologic and topographic settings in which caves are actually found. In this sense the models are predictive theories which are adaptable to any specific situation. Although they are still too crude to emulate more than the simplest of settings they are nevertheless rather successful within these limits.

The greater diversity of the real over the computer world is surveyed in Part 5, which returns methodologically to the categorisation and synthesis of field observations. Twenty four short articles describe cave development in coastal, deeply buried, confined, and unconfined aquifers subject to topographic and structural influences varying from flat-bedded cratonic cover to Alpine thrust belts. Hydrothermal drivers of flow and solution are included, as are the effects of sulphuric acid. Speleogenesis in non-carbonates (gypsum, salt and quartzites) is dealt with separately in Part 7, but could have been included here.

Perhaps surprisingly, the majority of the book takes for granted that the reader will understand the origin and significance of the various internal features of caves that have been the subject of much description and analysis from Bretz onwards. This may be because they belong to the realm of cave *development* and not to that of *origins* (genesis) which is the main theme of Parts 3 and 4. Internal morphology is surveyed briefly and analytically in Part 6 which includes a novel diagram treating scallops, tubes, paragenetic trenches, corrosion notches, cupolas, pockets, pendants and spongeworks as facies expressions of the combinations of velocity, chemical aggressiveness and sediment content that are possible in the cave waters that produced them.

The final section, Part 8, pursues the implications of all this speleogenetic knowledge for our understanding of aquifers in the wider context of hydrogeology. It takes a determinedly conduit-centred view, one essay maintaining that virtually all flow through all unconfined carbonate aquifers occurs through channel networks. While this could be true if one includes fissures of ~1 mm aperture as "channels", it is tendentious to include such small voids as being karstic in their hydrogeological function, or to maintain that where larger fissures occur they necessarily dominate all flow through the aquifer. Simple calculation shows that if lesser voids are plentiful then large ones can only dominate the average permeability if they are plentiful also, which is frequently not the case even in strongly karstified aquifers. Flow in ~1 mm fissures is usually laminar and therefore does not possess the turbulence which is the hydraulic signature of karstic *hydrological* behaviour. We should distinguish between the origin of such fissures (which is relevant to speleogenesis, since many may be solutionally enlarged and a few will become the forerunners of future caves) and their present hydrological function as pathways for laminar or Darcian flow. By making this distinction we can see that there is indeed a spectrum between conduit-dominated and diffuse-dominated flow among different aquifers, and even among different parts of the same aquifer. The point that conduits and large fissures are nevertheless more important than some hydrogeologists think they are is not helped by insisting that all aquifers are "channel"-dominated, especially if one neglects to define "channels" in terms of size, connectivity and spacing. The issue is easily resolved by invoking the concept of heterogeneity which is common parlance in mainstream hydrogeology. To the extent that the speleological community tends to be inward looking, speleologists may now have only themselves to blame if their contribution to the science of hydrogeology as a whole is misunderstood or overlooked. A future meeting of minds is unlikely to be promoted quickly by the following, from the book's third paragraph: "The advances in cave science are poorly appreciated in … 'mainstream hydrology' which retains a childlike faith in flow models developed in the sand box." The subsidiary clause may have contained some truth twenty years ago, but today it is rubbish, and an opportunity is being lost by saying it so tauntingly.

"So many caves; so little time left in which to find them." This fatalistic thought of my advancing years is tempered now by a brighter prospect. I shall return, again and again, to this rich and fascinating book, not just as a *vade mecum* for finding the varieties of caves I may never see, but as a companion and stimulus to further thought about caves, speleogenesis and how real aquifers work. The editors modestly dissemble when they write, "This book does not pretend to be a definitive text on speleogenesis". It need not pretend, as from now on no serious discussion can fail to refer to it.

Tim Atkinson

Secret underground cities. An account of some of Britain's subterranean defence, factory and storage sites in the Second World War by N. J. McCamley. Leo Cooper, 1998. Paperback 1999, 273 pp., £14.95. ISBN 0 85052 733 3.

The pioneer spelaeologist E. A. Baker and his friends, frustrated by the lack of caves in the London area, explored Chiselhurst 'caves', dene holes and even the Fleet Sewer in about 1906. Chiselhurst 'caves' are chalk mines with an irregular plan of galleries and pillars similar to those of some of the Bath Stone mines. Legends involving the Druids were assiduously nurtured by the owners. Baker, perhaps unwisely, got into a dispute with local 'antiquaries' unwilling to relinquish romantic beliefs about subterranean rituals at Chiselhurst.