The age of the Jenolan Caves, Australia

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The Jenolan Caves system is multi-phased with overlapping meteoric and hydrothermal speleogenesis. Dating of this system was elusive until recently when illite from clays assumed to be of paleokarstic origin was dated as being of Carboniferous age, implying that the Jenolan Caves are at least of that age. However, there are serious problems both with the karstological and dating approaches that led to this age determination. Some sediments appear to be older than the paleokarst that hosts them. The geomorphology, particularly the direction of the surface drainage, is difficult to explain unless pre-existing conduits of hydrothermal origin are admitted, which could have formed during the final stages of the Genesis Flood. The evolutionary interpretation of the paleokarst and the sediments in it is riddled with difficulties and leaves many basic questions unanswered. As for the dating, besides the well-known problems with the K–Ar radiometric dating method, the particular geological and karstological setting of the Jenolan Caves provides various sources of excess ^{40}Ar which would yield exaggerated ages.

Location and setting

The Jenolan Caves are located 175 km west of Sydney and are a major tourist attraction. The local Aborigines knew the caves as Binoomea (Dark Places) and probably considered them a dangerous place. In 1838 James Whalan discovered the caves as he was searching for missing cattle, possibly stolen by the cattle thief and escaped convict James McKeown. In fact, one of the less visited caves in the area is called McKeown's Hole. The initial name for the caves was Fish River Caves: the present name was adopted in 1884 after the government of New South Wales took over the management of the system in 1866. The name is derived from the Aboriginal for 'high place', referring to the heights above the caves.[1]

There are nine show caves and the sum of all known passages in the caves is 22,503 m.[2]

The caves even provided the name for the limestones in which they are located: the Jenolan Caves Limestone (JCL) believed to be of Late Silurian age. The JCL outcrops as a narrow band (250 m wide) over a strike length of 5 km in the caves area, continuing north as a series of isolated outcrops for a further 4 km, attaining a maximum thickness of 265 m at the Caves House (figure 1).[3] The dip is generally steep and quite variable, the layers being nearly vertical in many places.

To the west, the limestone is faulted against Ordovician andesite and laminated siliceous mudstone, whilst to the east the limestone is overlain by silicic volcaniclastics. To the north, east and south of the caves Carboniferous granitic plutons intrude the sedimentary sequence.[3]

The scientific literature about the caves is limited and leaves many significant karstological questions unanswered.

The caves

The Jenolan Caves proper consist of interconnected passages and rooms of various shapes and sizes, north and south of the 'centrepiece' of the location, the Grand Archway. The caves on each side of this major landmark are distinctly different: south of the Grand Archway the caves comprise a series of large dome-shaped chambers, termed cupolas, formed by the dissolution of the limestone and interconnected by north-south trending passages. Recent diving explorations in the Mammoth Cave, one of the Jenolan

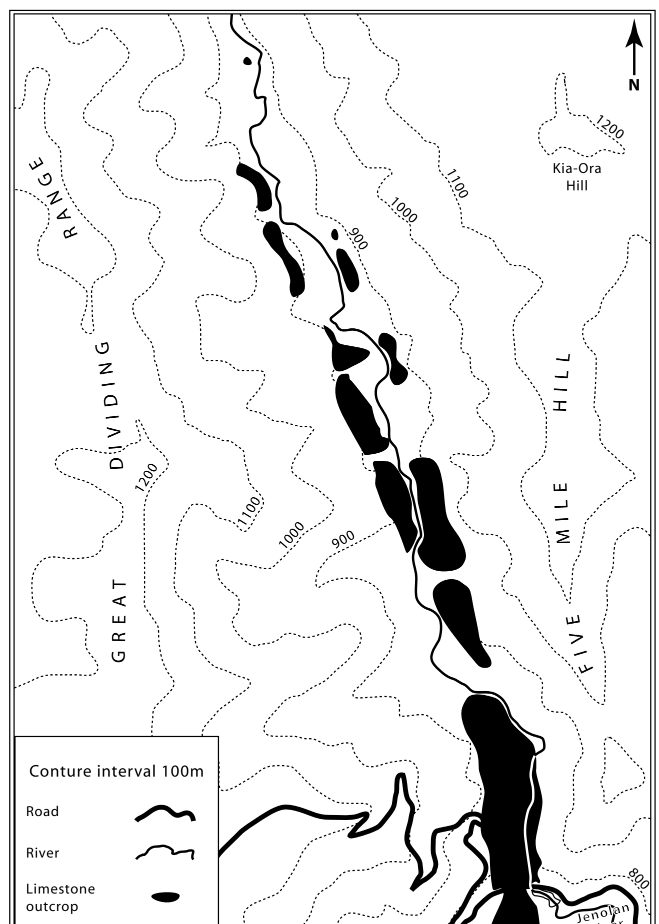

Figure 1. Outcrops of the Jenolan Caves Limestone in the Jenolan River area. (After Osbourne[4]). The 'Jenolan Caves' are contained mainly to the large limestone outcrop at the bottom of the diagram where road access is provided.

Table 1. Osbourne's[4] framework chronology for the Jenolan Caves. The number against the process indicates the number of times it has taken place.

Geological Era/Period	Phase	Event/Process	Feature	Example
Present	10	Stability	Low Mg Calcite Speleothems Continued Weathering Mg Rich Minerals	Orient Cave Ribbon Cave Ribbon Cave
Quaternary	9	Meteoric Speleogenesis 5 Exhumation	Nick Point Sediment Cliffs Breakdown	The Ladder, River Cave Exhibition Chamber, Lucas Cave
A number of Cainozoic Phases	8	Meteoric Speleogenesis 4 Paragenesis	Conduits Loops	The Slide, Lucas Cave Mons Meg, River Cave
? Tertiary	7	Meteoric Speleogenesis 3	Invasion Caves	Baal-River Passage
? Late Cretaceous	6A	Hydrothermal Speleogenesis 2 Hydrothermal Fills & Alteration	Crystal-lined Cavities Dolomitic Crystal Altered Algal Mats Altered Palaeokarst Non-Detrital Clay	Mud Tunnels, River Cave Pool of Cerebrus Cave Ribbon Cave Olympia Steps, Ribbon Cave River Lethe, River Cave
? Late Cretaceous	6	Hydrothermal Speleogenesis 2 Evacuation	Cupolas Halls Tubes	Persian Chamber, Orient Cave Jenolan Underground River Ribbon Cave
Permian	5	Cave fill & Landscape Burial	Fluvial Sediments	Dreamtime Cave
Permian	4	Meteoric Speleogenesis 2	Large Caves	Dreamtime Cave
? Early Permian	3	Hydrothermal Speleogenesis 1	Crystal-lined Cavities	Lucas Cave Entrance
? Latest Carboniferous	2	Marine Transgression and filling	Crinoidal and Laminated Carbonates	Olympia Steps, Ribbon Cave
? Late Carboniferous	1	Meteoric Speleogenesis 1	Phreatic Caves	Olympia Steps, Ribbon Cave

Caves, have revealed even larger, flooded cupolas—up to 100 m high—below the water table (Daniel Cove, official cave guide, personal communication, January 2004). There is also a large breakdown (formed by the breaking down of the ceiling and walls) chamber, the Exhibition Chamber.[3] Cupolas are not characteristic north of the Grand Archway, where multi-level, north-south trending passages are the norm. The northern caves contain significant amounts of coarse alluvial sediment which does not display evidence of high velocity flow.[3]

One major characteristic of the caves is that they repeatedly intersect what are believed to be paleokarstic deposits: these are deposits found in the caves that predate the cave formation.[3,4] Osborne[4] has proposed karsting episodes during the Late Carboniferous, Early Permian, Permian, Late Cretaceous, Tertiary and the Cainozoic (table 1).

Recently, the same author followed up by identifying clays inside the caves that have been dated to the Carboniferous.[3]

The Jenolan Caves conundrum

Existing literature acknowledges that, unlike the vast majority of documented cases, some sections of the Jenolan Caves and caves in other karst areas in Eastern Australia have developed along alleged paleokarst deposits which would have acted as guiding features. Some authors like Ford[5] believe that such situations are due to a different type of speleogenesis (cave formation), namely *per ascensum* hydrothermal speleogenesis. Hydrothermal solutions are driven by thermal convection through the limestone and in places have followed pre-existing paleokarst filling. Consequently Osborne[4] suggested that at least two of his proposed paleokarsting episodes, the Early Permian and the Late Cretaceous, were in fact hydrothermal.

There are not many cases in the karstological literature in which so many speleogenetic phases, allegedly covering over 300 million years, have unfolded in such a small lithostratigraphic unit. As a matter of fact, it may well be that this is the longest overlapping speleogenesis anywhere in the world!

Osborne[4] and Osborne *et al.*[3] have pointed out that the Jenolan Caves have a special characteristic: parallel surface and underground drainages. The semi-dry channels of the Jenolan River and Camp Creek are closely followed, almost bend-by-bend, by the present underground drainages. This also appears to be the case for the paleochannels above the present rivers and previous, now dry or sediment-filled, caves.

These unusual characteristics are part of a broader characteristic of the Jenolan Caves and their surroundings which seems to be ignored in the literature I consulted. The surface drainage of the Jenolan River and Camp Creek is longitudinal to the structure in which the JCL represents a *limestone bar* that is, a narrow, long limestone outcrop surrounded by non-karstic formations. In countless field examples, such bars are cut more or less perpendicularly by the hydrographic network, oftentimes through some of the most spectacular gorges.[6] Such cases are even more characteristic when the limestone bars were covered by other sediments in which the valleys were encased. The Jenolan Caves area presents enough evidence to suggest that the limestone was at some point covered by Permian conglomerates and sandstones and that valleys were cut in those formations.

Figure 2. Recently cemented coarse gravel from the Thanksgiving Cave (Vancouver Island, Canada) found in an area frequently flooded by the subterranean stream. Note the cement-coated cobble in the centre.

Longitudinal drainages represent a marked exception and even when they occur, the valleys are cut along the boundary between the limestones and the adjacent rocks. The Jenolan River and Camp Creek, however, are mostly confined within the narrow, less than 300 m wide, limestone bar. Such a setting is most unusual and is an intrinsic characteristic of the limestone, implying that conduits existed within the limestone at the time it was first exposed to karsting. In other words, the limestones were already karstified without any connection with the surface! Only one type of karsting can achieve this: hydrothermal, *per ascensum* karsting.

Hydrothermal karsting

In the karstological literature 'hydrothermal' refers to 'warm water' as against hot mineral rich magmatic emanations. There is evidence that the same solutions can change their characteristics, dissolving rather than depositing minerals.[7] I have referred to this type of karsting as 'endogenous karsting'.[8] Osborne[3] does not define the Jenolan Caves as hydrothermal karsting (HTK) but his attribution of pyrite in the paleokarst fills to hydrothermal activity seems to suggest endogenous karsting rather than thermal water activity. HTK seems to always involve two stages: 1) the excavation of the karstic voids and 2) their total or partial filling with hydrothermal deposits.

I have dealt extensively with HTK,[9–11] especially in the context of paleokarsts, pointing out that paleokarst features surviving over extended periods of time in active karst areas represents a huge problem. Yet the scientific literature I consulted seems to completely ignore that and proposes repeated, overlapping hydrothermal and normal, meteoric karsting and speleogenesis over 300 million years, with each phase leaving its own signature and karst network. This involves marine transgressions which have invaded and filled the caves with layered crinoidal limestone.[3,4] Yet crinoids would have not lived inside submerged caves. The notion of limestone accumulation inside a submerged cave stretches the imagination especially in this case where the authors have specifically emphasized the lack of calcite in the cave samples.[12] The only kind of calcite found in these sediments is in the form of clasts coming from the host limestone.

I have seen recent calcite-cemented alluvia in Imperial Cave in the area where the lower fossil cave connects to the active cave. Cemented alluvia is a common feature in most active caves (figure 2) and I have even found it on the bottom of a *flowing* subterranean stream in the cave Huda lui Papară in Romania. But such cementing will never occur in salt water, during the submerged phase of the JCL.

In normal spelean conditions soluted calcite from the host limestone will always end up in the cave sediments, even more so after an alleged 8 phases of karstification covering 300 million years!

Osborne's description of the paleokarst deposits[3,4] suggests that they are a clearly separated entity within the host limestone. As the assembly of the JCL was submitted to HTK one would expect that all these entities—if they predated the HTK—would have been seriously affected and not preserved untouched. Such karsting develops by massive fronts of hydrothermal fluids ascending through the host rock and all existing discontinuities, paleokarst being a major discontinuity. Only meteoric speleogenesis, with passages acting as drains of infiltrated water, would cut through paleokarstic deposits and leave the rest unaffected.

The paleofills and the associated problems

The way Osborne *et al.*[3] present the geological and karstological setting of JCL and the paleofills raises a series of problems if compared to other more or less similar documented locations.

a) An overly long period of continuous karsting

Osborne *et al.*[3] have recently dated ten primary cave paleofills from the Jenolan Caves, as well as six surface samples, using the K–Ar method on illite, and in one case dating cave clay, using the fission track method on zircon grains. The ages yielded cover the interval from the Devonian (Emsian) to Middle Jurassic (Bathonian) with the majority of cave samples falling within the Carboniferous-Permian, from the Tournaisian to the late Ufimian, roughly 100 million years. This implies that the JCL has been submitted to karsting for all of that time. Using the existing measured karst denudation rate (KDR) in New South Wales, namely 24 mm ka^{-1} in the Coleman Plains,[12] at least 2.4 km of limestone would have to be removed during this period. Though not clearly specified in the texts, it appears that even the earliest alleged paleokarst features are similar to the most recent ones, which are controlled by the nearly vertical bedding planes. This seems to imply that the tilting of the JCL occurred in the earlier stages of the Variscan Orogeny, hence the 2.4 km of limestone would not have been removed from a more or less horizontal structure but from a nearly vertical one.

Adding the other postulated karsting phases and assuming a similar KDR, the total height of that limestone bar would have been at least double. For the sake of a simpler argument, let us assume that for all the rest of the Carboniferous—nearly 100 Ma—the JCL was covered by other sediments which are now completely missing. This would be very difficult to prove and even more difficult to admit in a karstological context. Shaw and Flood (1993), quoted by Osborne *et al.*,[3] believe that up to 5 km of rock was removed from the Lachlan Fold Belt, of which the JCL is part, during the Late Carboniferous! That means that the assumed removal of limestone was not due to karsting but to some other, more energetic erosional episode.

Assuming the Late Carboniferous lasted for a maximum of 33 Ma, the erosional rate would have been 150 mm ka^{-1}, much higher than any measured KDR. Obviously, if the period was shorter, the erosion rate would have been even more intense. Under such circumstances karsting processes would have been extremely intense and would have left much more visible landmarks than the ones found in the field. Also, the issue of longitudinal drainage as mentioned above becomes even more problematic since now we have to account for the preservation of a preferential drain in a very narrow band of rock for 360 Ma whilst the regional erosion has eroded away all other formations. A series of perpendicular gorges cutting the limestone bar would be a much more appropriate interpretation.

b) An unreasonably deep burial

Based on the assumptions above, one can infer that the portions of the JCL that are exposed today would have been buried at the time of the Late Carboniferous to at least 5 km depth at which low grade metamorphic features should be present. I find it very difficult to believe that karsting, even as HTK, could have occurred at that depth without voids being constantly compressed leaving no room for infills. It therefore seems very unlikely that the ages determined for the clays could fit any known karsting scenario.

Timing discrepancies

Osborne *et al.*[3] make no reference in their text to the discrepancy between the timing of karsting/speleogenetic phases as shown in table 1 and the span of the alleged ages the radiometric dating has yielded. Thus it is assumed that the first meteoric karsting phase occurred in the Late Carboniferous, yet the oldest karst filling is dated to the Early Carboniferous (Tournaisian) and is hydrothermal! So when and how did those infilled karst voids form? Invoking a Devonian karsting episode does not really work in the general context of their paper because one of the cave samples was dated as Devonian. This represents a different type of clay filling in a joint-like feature, unlike the true karstic samples dated as Carboniferous. Their paper provides no answers, merely listing them as topics for further research.

The K–Ar dating method: more problems

This method is based on the decay of ^{40}K, with a half life 1.39 x 10^9 years[13,14] to ^{40}Ar. The problems with using ^{40}K–^{40}Ar have been frequently described. Austin has dealt in detail with the excess of ^{40}Ar in dacite in a lava dome on Mount St Helens formed in 1986 and which yielded a K–Ar age of 0.35 ± 0.05 Ma.[15] The reason for this is inherited argon from the magma itself which was incorporated in the phenocrysts while they were formed. In the Jenolan Cave situation the mineral dated was illite, a phyllosilicate with three layers very similar in structure to muscovite.

As mentioned before, Osborne[4] proposes at least two hydrothermal speleogenetic phases. The dated illite is believed to come from *in situ* alteration so that the radiometric dates represent the age of the hydrothermal alteration rather than the age of the altered mineral. Under such circumstances, no sample should be dated earlier than the Late Cretaceous, the age of the last alleged hydrothermal phase.

Recent research[16] has also revealed another source of Ar in pure authigenic, recent to present-day smectite from Pacific sediments:

> '… excess ^{40}Ar, which represents radiogenic ^{40}Ar released from nearby altered silicates, might be temporarily adsorbed at the surface of the rock pore spaces and is therefore available for incorporation in nucleating and growing particles'.

In other words radiogenic Ar produced in adjacent rocks can easily contaminate secondary illite; the higher the ^{40}Ar contents, the older the sample is supposed to be. It is interesting to notice that Osborne *et al.*[3] make no reference to possible sources of ^{40}Ar contamination. Yet one sample dated to 167.12 ± 3.60 Ma, which corresponds to the Middle Jurassic (Bathonian), is described as 'weathered andesite' from 'Mesozoic dykes': however, these dykes are not shown on their map. This could well be a possible source of excess Ar within the JCL itself.

In addition to this, this paper presents many other magmatic formations in the areas adjacent to the Jenolan Caves: Early Devonian volcanics, Carboniferous granite and Carboniferous basic intrusions.

It is very difficult to believe that with so many close sources of contamination, all the ^{40}Ar in the dated samples comes from the decay of ^{40}K in these same samples! Therefore it is perfectly reasonable to question the Carboniferous age of the cave sediment samples.

A simpler scenario

A simpler solution to all of these problems can be proposed: there weren't eight speleogenetic/karsting phases during 300 Ma. The majority of Jenolan Caves were formed by hydrothermal karsting in four stages[11] from the final moments of the Genesis Flood to the present.

In stage 1, while the limestone was still submerged, hydrothermal solutions (HTS) produced during the paroxysmal stages of the Genesis Flood, were ascending through the crust causing rapid diagenesis.[11] Locally, as diagenesis depleted the mineral contents, the same solutions became aggressive, dissolving the rocks they helped create. Such situations have been recorded in the case of hydrothermal metasomatic ore deposits.[7] Though still *en masse*, the circulation of these aggressive solutions was partly controlled by the textural and structural features of the newly-formed JCL. The larger karstic halls and cupolas connected by large conduits were formed by such solutions. As the solutions were more aggressive at depth, the size of the karstic voids should increase with depth, which is exactly what explorations at the Jenolan Caves have revealed. This runs counter to a meteoric speleogenesis.

In stage 2, during the recessive stage of the Genesis Flood,[17] the entire sedimentary sequence emerged from the sea and was tilted, the JCL being still covered by massive non-karstic deposits. The HTS activity changed, the convectional *per ascensum* movement being gradually replaced by a gravitational *per descensum* flow. This flow was controlled by the structural features of the limestone. Confined between non-karstic deposits, in its search for an outlet, the drain became mostly longitudinal. The lack of cupolas north of the Great Archway suggests that the drain was from the north towards the south, along large passages with some of the cupolas becoming temporary collectors. The large amounts of HTS and the increased pressure resulted in a dramatic acceleration of the karsting processes, the cupolas and halls rapidly growing in size. Many authigenic sediments, mainly clay minerals from the insoluble fraction in the dissolved limestone, were generated during this time and they travelled extensively through the system, being trapped and rapidly cemented in what we could call 'hydrodynamic traps'—lateral, calmer passages.

During stage 3, erosion brought the JCL to the surface. By this time most of the HTS in the system were chemically dampened as the supply from inside the crust had practically ceased. At some point the fluid-filled system was opened by erosion and the fluids rapidly drained. The longitudinal north-south subterranean drain was thus made available not only to infiltrating water from the surface but also to surface streams which were pirated by this ready-made drainage system.

Surface erosion would have eventually reached some of these drains, causing ceiling collapse and turning the passages into surface river channels. Thus the Jenolan River and Camp Creek were formed, preserving segments of the old conduits and even erosional ledges paralleling the remaining subterranean drains. This pre-existing drain was already so deeply entrenched that it ran and still runs counter to the normal hydrographic trends for a limestone bar geomorphic setting.

The upper chambers and conduits that were partially or completely drained were reached by infiltrating water which was probably much more aggressive than it is today due to the abundance of organic materials in the adjacent Flood-laid sediments. As a result, speleothems started growing very quickly.

Stage 4 corresponds more or less to the present conditions; no HTS are present. Meteoric speleogenesis reshaped the existing voids and surface erosion further dissected the cave system of the Jenolan Caves, leading to the present complex setting. The constant decrease in precipitation and consequently the reduced flow in the subterranean drain have left many of the passages dry. The deep, below water table, cupolas had their fluids gradually replaced by the infiltrating water, with many of these large reservoirs acting today as annexes to the main drain.[18]

Conclusions

Though recently hailed as the world's oldest (340 Ma) open cave system,[19] the Jenolan Caves system can be explained as the result of hydrothermal karsting during the final stages of the Noahic Flood, subsequently reshaped and disorganized by meteoric speleogenesis and surface erosion.

The standard evolutionary interpretation of the complex cave system assumes no less than eight speleogenetic phases including both meteoric and hydrothermal activity. This leads to many problems, discrepancies and unanswered questions.

Clay sediments in alleged paleokarst dissected by the cave passages have been dated by the K–Ar method as Carboniferous. However, the K–Ar method is notoriously error-prone, contamination being the most important issue. The geological and karstological situation in the area provided abundant sources of contamination which could have easily led to an excess of ^{40}Ar and consequently exaggerated ages. In an attitude that has been consistent for many years now, radiometric dating prevails over logic, geomorphology and karstology. It seems that the accelerated return of neo-catastrophism in geology is being compensated by a desperate quest for antiquity of landscapes, both surficial and subterranean, and Australia has long been a first stage for this quest.

References

1. Jenolan Caves, <en.wikipedia.org/wiki/Jenolan_Caves>, 19 December 2006.
2. Gulden, B., World's longest caves, 25 October 2006, <www.caverbob.com/wlong.htm>, 19 December 2006.
3. Osborne, R.A.L., Zwingmann, H., Pogson, R.E. and Colchester, D.M., Carboniferous clay deposits from Jenolan Caves, New South Wales: implications for timing of speleogenesis and regional geology. *Australian J. of Earth Sci.* **53**: 377–405, 2006.
4. Osborne, R.A.L., The Origin of Jenolan Caves: Elements of a New Synthesis and Framework Chronology. *Proc. Linn. Soc. NSW,* **121**:1–27, 1999.
5. Ford, T.D., Some thoughts on hydrothermal caves. *Cave and Karst Science* **22**(3):107–118, 1995.
6. Cocean, P. and Silvestru, E., The Role of Magmatism in the Genesis of Isolated Massifs Karst Relief of the Trascau-Metaliferi Mountains. *Travaux de l'Institut de Spéléologie 'Emil Racovitza'*, Bucuresti, **XXVII:**89–93, 1988.
7. Mârza, I. and Silvestru, E., First Mention of the Hydrothermal Karst Phenomenon Associated to Neogene Metasomatic Suplhide Ore deposits from Rodna Veche. *Studia Universitatis 'Babes-Bolyai'*, Geologica-Geographica Cluj-Napoca **XXXIII**:77–81, 1988.
8. Silvestru, E., Propositions pour une classification litho-génétiquedes formes karstiques et apparentées. *Karstologia*, La Rivoire, France. **Nr. 15:**55–57, 1990.
9. Silvestru, E., Paleokarst—a riddle inside confusion, *Journal of Creation* **14**(3):100–108, 2000.
10. Silvestru, E., The riddle of paleokarst resolved, *Journal of Creation* **15**(3):105–114, 2001.
11. Silvestru, E., A Hydrothermal Model of Rapid Post-Flood Karsting, *Proc .5th Internat. Conf. Creationism*, Creation Science Fellowship Inc., Pittsburgh, PA, pp. 233–241, 2003.
12. Osborne *et al.*, ref. 3, pp. 391–392.
13. Jennings, J.N., The Blue Waterholes, Coleman Plains, NSW, and the Problem of Karst Denudation Rate Determination, *Trans.Cave.Res. Gp.G.B.* **14**:109–117, 1972.
14. Pilot, J., *Les isotopes en géochimie (Méthodes et applications)*, Doin, Editeurs, SA, Paris, p.15, 1974.
15. Austin, S.A., Excess Argon within Mineral Concentrates from the New Dacite Lava Dome at Mount St Helens Volcano, *Journal of Creation* **10**(3):335–343, 1996.
16. Clauer, N., Towards an isotopic modeling of the illitization process based on data of illite-type fundamental particles from mixed-layer illite-smectite, *Clay and Clay Minerals* **54**(1):116–127, 2006.
17. Walker, T., A biblical geologic model, *Proc.3rd Internat.Conf.Creat.*, Creation Science Fellowship Inc., Pittsburgh, pp. 581–622, 1994.
18. Mangin, A., Contribution a l'étude hydrodinamique des aquifères karstiques. Thèse Doct. Sci. Nat. in *Annales de Spéléologie* **29**(3):283–332; **29**(4):495–601; **30**(1):21–124, 1975.
19. Jenolan Caves 340 million years old, 26 July 2006, <news.ninemsn.com.au/article.aspx?id=117074>, 19 December 2006.

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