the extremely smooth surfaced decorations of the massive phase, and was also responsible for the intensive solution necessary to produce the dominance of chert pebbles in the second breccia. Subsequent to the development of material for the second breccia, a drop in water level resulted in a phase of minor calcium carbonate deposition, and the cementation of the breccia, although no speleothems directly attributable to this phase are known.

A further phase of re-solution followed the period of minor deposition, re-solution occurring only up to the roof of the Second Chamber and not affecting the speleothems of the First Chamber. The second breccia underwent excavation during this phase, being breached to a depth of 3m to 5m, and it is probable that the breakdown fill of the Third Chamber was removed during this phase, since the carapaces of the first and second breccias are level, whilst that of the third, youngest, breccia slopes down into the chamber. It is probable that a large proportion of the fill in the Third Chamber was removed in solution, since the floor now consists predominantly of intensely weathered chert and has a cover of silt which is derived from chert breakdown.

The youngest of the three breccias was deposited at the end of this phase of re-solution, and consists of a mixture of internally and externally derived materials. This breccia occupies much of the eastern half of the Long Passage, and its source of entry, which is now sealed, may be located at the apex of the flowstone carapace which overlies the breccia. Further re-solution has occurred since the deposition of this breccia as it is itself breached in a number of places to a depth of 2m to 3m, and the rise in water level which accomplished this may have been responsible for the water [illegible] pillars in the Second Chamber.

The most recent phase in the development of the Wolkberg Cave has been a period of calcium carbonate deposition, and there are indications that deposition has not been a continuous process. Speleothem development during this phase has been restricted to minor stalactitic growth, including straws, helictites, the growth of nodular and needle like speleothems and the development of minor flowstone sheets and rimstone pools. The First Chamber has received a large amount of external fill during this phase, the fill being predominantly earth containing occasional sub-angular chert pebbles. The sequence exposed in a number of pits along the walls of the chamber indicates a series of alternations of earth fill and calcium carbonate deposition, presumably reflecting minor dry and wet phases respectively, or possibly seasonal alternations. Aerial decomposition of speleothems is currently occurring in the First Chamber, indicated by the powdery surface of the speleothems.

The evidence preserved within the Wolkberg Cave indicates that, following a phreatic origin, the history of the system has been dominated by a series of phases of calcium carbonate deposition alternating with phases of re-solution (Table 5.1). Since re-solution has occurred up to and including speleothems on the ceiling of the First Chamber, it may be assumed that some of the incursions of water causing re-solution completely filled the cave. It is evident that the First Chamber has undergone less re-solution than the Second, and the water marks which occur on pillars in the Second Chamber, indicate that some incursions only partially filled the system.

It is suggested that the incursions of water could be the result of periodic rises in the level of the piezometric surface. However, the total depth of the cave which is presently exposed above the level of this surface is of the order of 100m, indicating that lowering of the surface to this level has occurred. The maximum fluctuation of the piezometric surface known in the cave is reported to be 15m, and it is therefore difficult to conceive that simple fluctuations about the present level of the surface could account for all of the phases of re-solution. It is probable that some modification of this mechanism may account for much of the re-solution. It may be observed that a minor bevel in the surface morphology occurs 25m above the present stream level, implying that incision to the present stream level has not been a continuous process. If, therefore, the level of the piezometric surface was related to this minor bevel for an appreciable length of time during the later development of the cave, then marked fluctuations in the surface could account for the re-solution which has occurred.

Table 5.1: Summary of the developmental sequence of the Wolkberg Cave

	Phreatic development, fracture controlled
	Drainage
	Collapse modification
	Calcium carbonate deposition, first breccia
	First re-solution
	Calcium carbonate deposition, massive
YOUNGER	Second re-solution, re-working of first breccia
	Calcium carbonate deposition, second breccia
	Third re-solution, re-working of second breccia
	Calcium carbonate deposition, third breccia rounded pebbles
	Fourth re-solution
Present	Calcium carbonate deposition, earth fill

However, it is further necessary to postulate a climatic regime providing a greater contrast between wet and dry phases to account for the greater fluctuations of water level which have occurred.

Fluctuations about the higher general piezometric surface may be postulated to account for re-solution occurring during the first three phases, where the rise in water level was to the roof of the First Chamber in the case of the first two phases, and to the roof of the Second Chamber during the third phase. The most recent phase of re-solution may be related to the present level of the piezometric surface, since the rise in water level was sufficient only to fill the Second Chamber partially. It is probable that the general rise in water level at any stage may have been accentuated by perching on the flowstone surfaces which have predominanted throughout the cave. The present effects of such surfaces may be seen in the existence of perched pools, such as the Sarcophagus Pool and the sump in The Rift. The mechanism has been further aided by minor re-solution of speleothems due to the ingress of meteoric water, as may be seen in the entrance shaft and, to a limited extent, in the Second Chamber.

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An examination of the evidence preserved within the Wolkberg Cave indicates that its development has been a complex process. The establishment of this sequence of development will enable the implications of relevant speleogenetic theories to be examined, and the validity of those theories to be assessed.

CHAPTER SIX

AN ANALYSIS OF SPELEOGENETIC THEORY

A model of cavern development in tilted strata, characterised by the development of mature cavern passages at the top of the phreatic zone when the water table has a uniform level and flow for a long period of time has been proposed by Davies (1960). Frequently, such development will show a coincidence in the elevation of passages and river terraces, and the cave may contain a large amount of clastic fill, particularly clays and fine silts. Observations within the Wolkberg Cave show very little agreement with the predictions of this model. The long section of the cave is difficult to interpret due to the large volume of fill present, but the general form may be described as sub-horizontal. The prediction of accordance of cave passages with river terraces cannot be considered in this context as only minor terracing associated with present incision has occurred in the Molopatsi valley. The cave lies slightly below an erosional bevel, but the relationships between its development and that bevel are not clear. The cave contains a large amount of fill material, but the bulk of it is block breakdown or breccias, the only sands being externally derived, and the minor silts being the result of chert decomposition.

Ford (1971) outlined two modes of phreatic development in tilted strata with a dip of greater than 5^{o}. The first of these, termed deep phreatic development, may occur with phreatic drainage in the direction of the dip, and is characterised by dip tubes oriented in the down dip direction, with joint chimneys cutting through the strata to connect adjacent dip tubes, features which are not displayed by the Wolkberg Cave. In the case of drainage along the strike, Ford predicts that the cave developed will be quasi-horizontal, and oriented along the strike. The long section of the Wolkberg Cave may be described as quasi-horizontal, but a close examination of the orientation of the system indicates that it is not aligned with the strike, as it diverges from that measure by 15° to the North. Thus, the latter proposal of Ford (1971) does describe the general form of the Wolkberg Cave, although the direction of elongation of the cave is anomalous in terms of the predictions.

It has been proposed that the Makapansgat systems have developed in a zone of intensely shattered rock, the fractures in which were sealed with calcite prior to excavation under phreatic conditions (King, 1951). No evidence for the existence of such a calcite filled fracture zone exists in the Wolkberg Cave as ceiling exposures are commonly bedding planes displaying no micro-fractures or calcite filled veins. A zone of shattered rock is oriented transverse to the line of the cave slightly below the entrance pitch, but this zone is not calcite filled, nor has it effected any major control on the cave form.

A speleogenetic model relating development to erosion cycles has been proposed by Brink and Partridge (1965), the cave developed being characterised by at least two passage levels, control of voids by joints and fractures, and enlargement of avens to the surface allowing the ingress of surface sands and detritus. Development is aided by the formation of subsidence caverns due to collapse into pre-existing voids, the possible enlargement of avens at the surface to sinkholes through which a rapid accumulation of surface materials may occur, and the cementation of these accumulations to produce cave breccias.

There is little evidence that the Wolkberg Cave has developed on more than one level. Two minor levels do occur in the system, but these are perched on the crests of breakdown piles, and, furthermore, the volume of fill would obscure the relations between levels. Brink and Partridge (1965) predict that subsidence will occur into pre-existing voids, and this has occurred, although into one level only. The development of the system has been controlled by a fracture plane, and agreement also occurs with the prediction that later development will be accompanied by the entry of surface materials into the system. However, it should be noted that the proportion of external material contained within the cave is minimal. Breccias cemented by calcium carbonate occur within the system, but they are composed of internally derived material, although the youngest of the three breccias present does contain externally derived chert. The evidence preserved in the Wolkberg Cave therefore exhibits only limited agreement with the proposals put forward by Brink and Partridge (1965).

The discussion above has indicated that only limited agreement occurs between the predictions of a number of theories of speleogenesis and the features preserved in the Wolkberg Cave. The model proposed by Brink and Partridge (1965) affords the greatest agreement, partially accounting for the primary development whilst presenting only a general outline of the later development. The horizontal nature of the system is predicted by Ford (1971), but the alignment of the system at a shallow angle to the strike is anomalous.

Since no one theory adequately describes the development of the Wolkberg Cave, it is necessary to derive a model for its genesis which may further be applied to other cave systems.

A MODEL OF CAVE DEVELOPMENT IN THE TRANSVAAL

It is proposed that the development of the Wolkberg Cave has occurred in a zone of lateral flow in the phreatic zone, along paths controlled by a structural feature. Following this development, rejuvenation of surface streams has resulted in a lowering of the piezometric surface, and modification of the primary form of the cave has occurred due to roof breakdown. Calcium carbonate deposition occurred also at this time, resulting in a liberal development of speleothems which have since been almost completely removed by the phase of re-solution which caused the cessation of this phase. During the depositional phase, the breakdown material within the cave was cemented to form a breccia which has since been re-worked by re-solution. A phase of massive calcium carbonate deposition followed this re-solution, and its cessation was marked by the onset of a further phase of re-solution. A third depositional period followed, resulting in the development of a second breccia which was subsequently excavated by a rise in the water level. A fourth depositional phase, accompanied by the entry into the system of rounded pebbles, followed this rise of the piezometric surface, and resulted in the formation of a third breccia. This breccia has itself been excavated by a more recent rise in the water level, promoting re-solution. The current phase in the history of the cave has been dominated by the ingress of an earth fill through the entrance shaft, and the development of delicate speleothems throughout the system.

It is suggested that this proposed model of development be extended to and tested against the evidence preserved in other caves in the Transvaal to aid in the development of a more general speleogenetic model for that region. Before such testing can take place, however, it should be noted that the Wolkberg Cave has been controlled by a relatively rare structural feature, namely, a fault. It may be necessary to consider that development may also be controlled by other structural features, in particular, joints. Furthermore, throughout its development, the cave has had only one major and one minor opening permitting the ingress of surface materials, so that most of the fill is of an internal origin. It may be found that other cave systems contain a greater proportion of external fill materials, although the relative sequence of phases of deposition should concur with the model proposed. The sequence of development subsequent to the drainage of the cave has been controlled to a marked extent by water level fluctuations which it is thought were related to the rejuvenation of surface streams, and caution is therefore necessary in the application of this model to other drainage basins.

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PART FOUR: CONCLUSIONS

CHAPTER SEVEN

CONCLUSIONS

Speleogenetic models have occupied a large portion of karst literature in recent years, but little concurrence regarding the most appropriate has been achieved. This situation exists both on a global and on a regional scale, and it is with the latter level that the present study is concerned. In the Transvaal, where the bulk of the known caves occur within the same dolomite unit, a number of studies of cavern genesis have been undertaken, but agreement on the precise mode of development is limited.

One of the largest caves in the Transvaal, the Wolkberg Cave, has been examined in the present study. A detailed examination of the features preserved within the system has enabled the sequence of development to be derived, and the implications of a number of relevant theories have been compared with this sequence to enable an assessment of their validity to be made in this context.

In particular, the conclusions of this study are:

(i) the Wolkberg Cave is a horizontal phreatic cave whose primary development occurred in a zone of lateral water movement and was controlled by a major structural feature;

(ii) following drainage of the system, collapse modification due to roof failure occurred, resulting in the domed ceilings which now dominate some portions of the cave, and the ubiquitous cover of fill materials on the floor of the system;

(iii) the more recent history of the system has been dominated by phases of calcium carbonate deposition interspersed by periods of re-solution of speleothems;

(iv) the general form and primary development of the system are only partially described by the proposals of Ford (1971);

(v) the proposals of Brink and Partridge (1965) provide only a general outline of the development of the cave subsequent to its primary development;

(vi) no one theory adequately describes the genesis of the Wolkberg Cave.

In the light of the latter conclusions, a model of speleogenesis for the Wolkberg system has been derived, based on the developmental sequence of that cave. It is suggested that this model should be applied, with caution, to other caves in the Transvaal, to enable the development of a valid model applicable to that region. The extension of this model to other areas should not be attempted without strong considerations of the geomorphic history of those regions, since it would be naive to attempt a direct correlation of development where different conditions may have affected the recent development of a cave system. Furthermore, it must be considered that two major bodies of speleogenetic theory exist, the first describing primary development in general, and the second being a more detailed description of development applicable on a regional scale. It is to this latter body of thought that attention must be directed, since it will enable an examination of the detailed controls of cavern development.

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