TABLE 4.3: Fills; type and occurrence

Type of Fill	First Chamber	Second Chamber	Long Passage	Third Chamber	The Rift	Vertical Passage	Boulder Chamber
Breccia	x	x	x	x	x	x	
Breakdown	x	x	x	x	x	x	x
Earth: external	x			rare			
Earth: internal			x				
Re-solution	x	x	x	x	x	x	x

Earth fills of external origin

Externally derived earth fills cover a greater area than internally derived earth fills, but are almost entirely restricted to the First Chamber. A small deposit occurs at the eastern end of the Third Chamber, and it is composed of a cemented water-laid earth with a few sub-rounded gravel particles embedded in it. This deposit is limited to two small exposures in a scalloped section of the rock pile.

The deposits of the First Chamber are related to the present entrance as a point of ingress, and indicate a downslope migration of earth to the walls and then to the eastern end of the chamber. Numerous pits exist in this earth fill, the deepest providing an exposure of a 2m high vertical face, and all display an alternation of loose earth and calcium carbonate cemented earth, occasionally capped with flowstone. The earth is a medium grained grey-red to red-brown sand with a low clay fraction, and commonly contains rounded gravels up to 3mm in diameter. Typically, the deposits have been partially water-laid and are finely bedded, displaying between six and nine alternations of cemented and uncemented earth, the thickness of the layers decreasing towards the top of the exposure. The surface of the earth flow on the southern side of the chamber is capped with a weakly consolidated deposit of gravel containing occasional pebbles, all of which are iron stained. This gravel is cemented into a breccia in one exposure close to the foot of the entrance slope.

The main mound of collapse material in the First Chamber is partially buried by a grey-red earth of similar composition to the deposits along the wall but which is much drier. This deposit is also migrating downslope, and maintains its critical angle on the eastern end of the mound. The earth of this deposit is diluted by a high proportion of fine white powder which is thought to be the product of sub-aerial and biogenic decomposition of carbonate speleothems in this section.

A cemented earth fill is exposed in the upper 15m of the Vertical Passage. This fill contains a high proportion of sub-angular dolomite and chert pebbles, and is cemented within a matrix of calcium carbonate, large crystal faces frequently being apparent in the exposure.

Figure 4.6: Rounded chert pebbles in the lowest breccia

Breccias

Two major and one minor zone of breccia exposures are known, the major exposures being in the eastern half of the Second Chamber and the eastern half of the Long Passage, extending into the Third Chamber, and the minor deposit being along the northern wall of the First Chamber. The greatest exposure, in the eastern half of the Long Passage, has a distinct sequence of cemented breccias capped by flowstone carapaces. Remnants of breccia-supported carapaces also occur frequently on the walls of The Rift. Typically, the breccias consist of angular to sub-rounded dolomite and chert pebbles in a brown matrix of calcium carbonate cement. In the Long Passage, three breccias may be distinguished by their stratigraphic relations, the lowest breccia containing a large number of well rounded chert pebbles in a matrix similar to that of the other breccias (Fig.4.6). The breccias may also be distinguished by variations in the pebble types, since it is evident that the amount of included dolomite decreases in the younger breccias. The oldest breccia contains a high proportion of dolomite with respect to chert, the second, a high proportion of angular chert pebbles and little dolomite, and the third contains very little dolomite, being composed almost completely of rounded chert pebbles smaller than those of the second breccia.

A further breccia occurrence of only minor importance occurs in the Vertical Passage, and consists of surface weathered dolomite cobbles in a cemented brown earth matrix.

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The features preserved in the Wolkberg Cave have been presented in the preceding section. A synthesis of this information will now be attempted to determine the sequential history of the system, enabling the critical examination of applicable speleogenetic theories.

PART THREE: SPELEOGENETIC THEORY AND THE WOLKBERG CAVE

CHAPTER FIVE

ORIGIN AND DEVELOPMENT OF THE WOLKBERG CAVE

The validity of the speleogenetic theories discussed in Chapter Two can only be assessed by a comparison of their implications with the evidence preserved within the cave. It is necessary to first determine the sequence of development which the system has undergone, and then to compare the implications of applicable theories with the derived sequence.

The history of the development of the Wolkberg Cave may be determined from a consideration of the features preserved within the cave, laying particular emphasis on relationships indicating the age of one occurrence relative to any other. The determination will comprise two parts, the first being a consideration of the primary development of the system, and the second a discussion of subsequent modifications to the primary form.

PRIMARY DEVELOPMENT

Locus of development

Bretz (1942) has indicated that a cave which has had a vadose origin or which has undergone vadose modification should display the features of a surface stream in particular, those features directly associated with the form of a stream such as branching tributaries and meander scars. The major criterion proposed was the form of the cave in plan view, which was predicted to be linear, with meander curves in detail. Bretz further described a number of features which are indicative of a phreatic mode of development, placing particular emphasis on the plan view of the cave and features preserved on the cavern walls.

The Wolkberg Cave displays no evidence of a primary vadose origin. The form is linear in plan, but the minor deviations which occur are controlled by fractures, as may be seen in the Third Chamber. Furthermore, the passage form displays no evidence of smoothing of such deviations, as would be expected were they related to a vadose origin. The true floor of the cave most likely approximates a sub-horizontal surface in long section, but no comparison of its form in relation to a stream thalweg may be made since the floor is completely obscured by fill materials. Bretz (1942) also showed that vadose passages should display scalloping in detailed cross sections of the walls. The walls of the Wolkberg Cave are, however, generally planar, as may be observed in The Rift.

Evidence supporting a phreatic origin is poor, the major indicators being the existence of minor joint controlled mazes, boxworks and the corrosion of joints, although the latter feature may be related to corrosion during subsequent incursions of water. It should be noted, however, that rarely are all possible indicators observed in any given cave. Although evidence supporting a phreatic origin is limited, that supporting a vadose origin is negative, and it is concluded that the Wolkberg Cave is phreatic in origin. The control of the development of the system within that zone will now be examined.

Localisation of the site of development

The sub-horizontal nature of the system and the absence of features typical of deep phreatic development imply that the Wolkberg Cave has developed in a zone of lateral flow within the piezometric zone. Localisation of water movement, and thus the selection of specific sites of solution within such a zone, may be controlled by a number of factors, in particular, lithology and structure. An examination of lithological variation through the stratigraphic column, particularly of the variation in the CaO and MgO content (Figs.3.4b and 3.4c), indicates that the site at which the cave has developed has no advantage over any other site in terms of the solubility of the rock.

In general, structural control of cavern development is strongly linked with hydrology, development being influenced by drainage along the strike, down the dip, or in other directions if influenced by features such as joints, faults or dykes. The Wolkberg Cave has developed at a shallow angle to the strike, and therefore the influence of strike and dip may be disregarded.

An analysis of the surface geology has failed to reveal the surface expression of any structural feature which might have exerted a direct control on the development of the cave (see Fig. 3.5). However, a comparison of the orientations of structural lineaments in the area with the orientation of the cave indicates that the system has developed parallel to one of the major lineament orientations (Fig.5.1a). Furthermore, a similar comparison with the orientations of surface joints reveals that the cave has developed parallel to a major joint orientation (Fig.5.1b).

Evidence from within the cave, in particular the association of planar surfaces on the walls of The Rift with fracture traces, indicates the existence of a plane of weakness parallel to the cave orientation. It is concluded therefore that the alignment of the Wolkberg Cave has been controlled by a planar structural feature of considerable extent, the available evidence indicating that the feature was a fault plane causing only minor displacement of one side in relation to the other.

It is proposed that the primary form of the cave was a linear sub-horizontal system, the form in cross-section being similar to that preserved in The Rift, that is, a high narrow passage, although marked variations in width are implied by the size of the First, Second and Third Chambers. It may be seen that the expansion of passage width in the Third Chamber in particular has been controlled by fractures running transverse to the passage orientation, and this feature may also be observed in the First and Second Chambers, despite masking by subsequent doming of the ceilings. It is

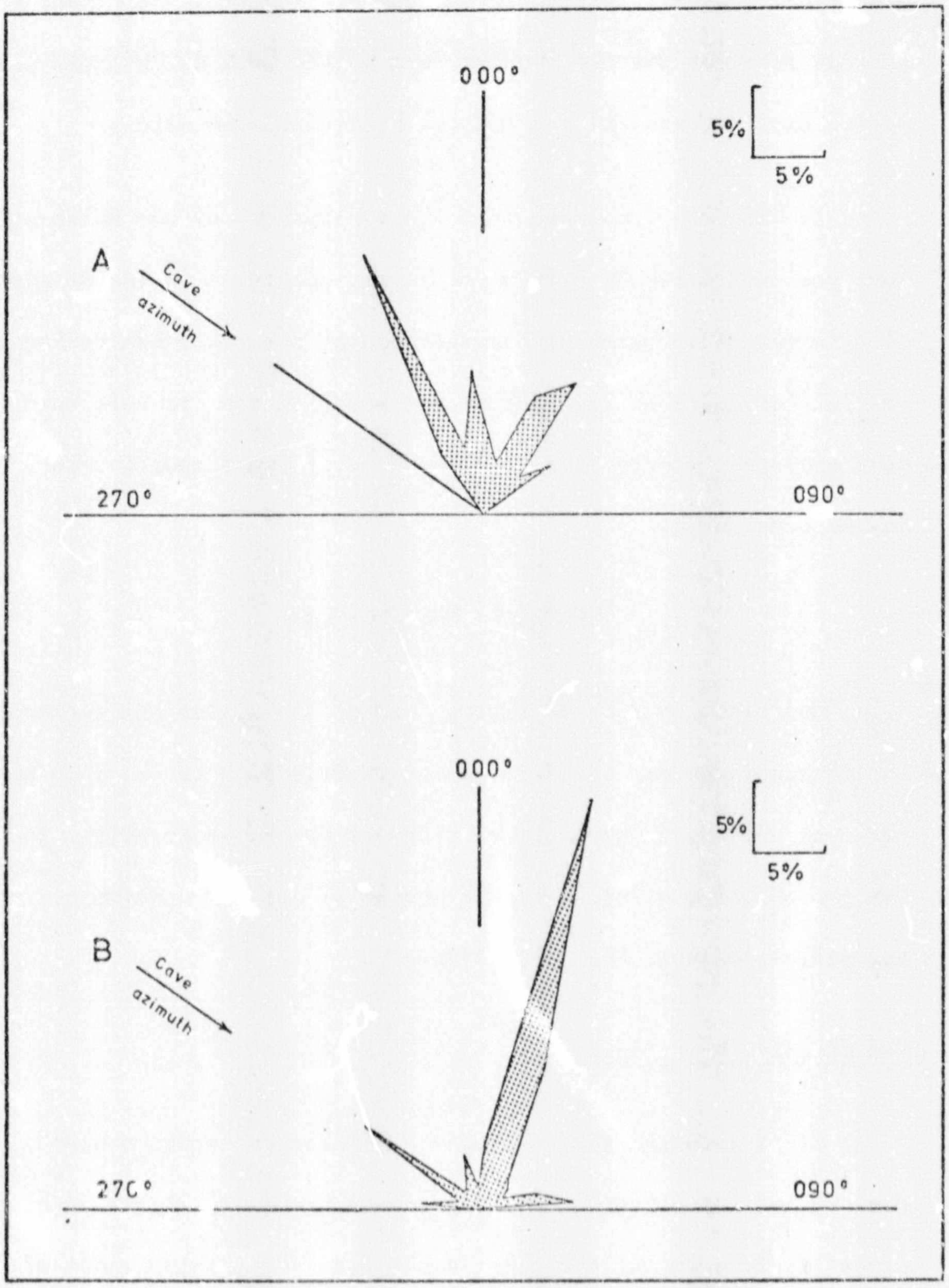

Figure 5.1: Comparison of the orientation of the Wolkberg Cave with:

a) the orientations of structural lineaments,
b) the orientations of joint sets.

predicted, however, that at first, the widened sections of the passage retained the rectangular form of the bulk of the passage, having similar vertical but greater horizontal dimensions.

It has been concluded that the development of the Wolkberg Cave was controlled by a fracture plane, resulting in the development of a linear cave system with a rectangular cross-section having the general form of a rift. Subsequent modifications to this form have occurred, and the type and sequence of these modifications will now be considered.

SECONDARY MODIFICATION

Modification of the primary form of the system has occurred in two major phases, the first being modification of the form by collapse and the development of piles of breakdown material, and the second being a succession of phases of calcium carbonate deposition followed by re-solution.

Modification by collapse

It is proposed that collapse modification occurred upon drainage of the primary cave. Drainage was controlled to a minor extent by lowering of the water table due to the enlargement of voids and, to a more marked extent, by rejuvenation of surface streams. Breakdown of a cave roof is initiated by the tendency for beds in the roof to act as single beams, supported only at the extremes, which in flat lying limestones generally allows a maximum width of flat roof of 30m. The tendency for collapse to occur is enhanced in tilted strata since the intersection of joints and bedding planes with the ceiling will result in a series of small, unsupported triangular beams (Fig.5.2), and the effect is aided by the removal of buoyant support upon drainage (White and White, 1969).

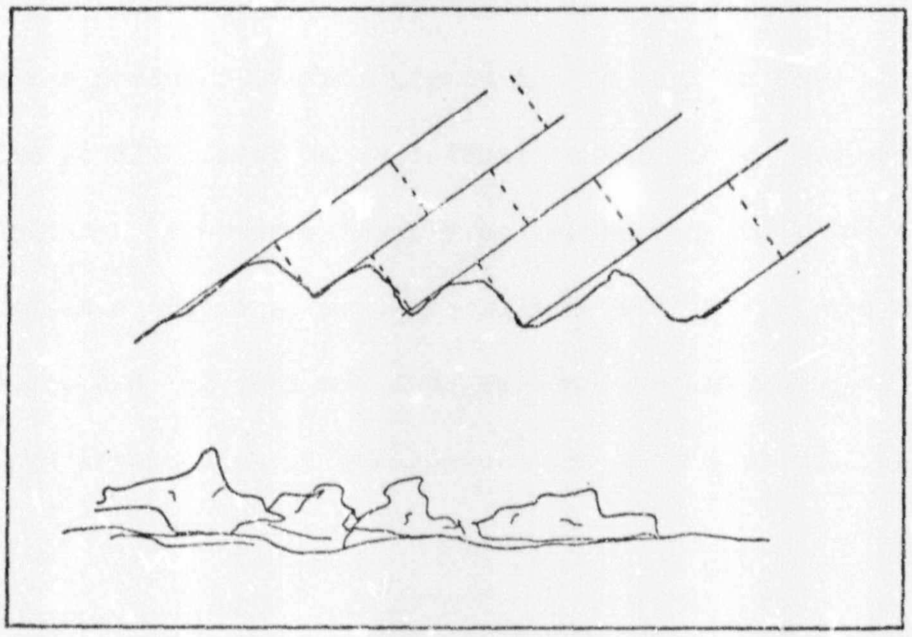

Figure 5.2: The influence of tilted strata on roof form (after White and White, 1969).

Modification under these conditions will continue until a stable roof form is attained, and this is typically a dome, permitting two separate cantilever beams to provide support.

Major roof breakdown in the Wolkberg Cave has occurred in the First Chamber, the eastern half of the Second Chamber and in the Third Chamber. The mound of collapse material in the First Chamber is related to the domes in the ceiling of that chamber, and its elongate form has developed due to the filling of the width of the primary passage with an extension of deposition along the length of the passage where there were no constraints. The higher dome of the entrance has been controlled in detail by the occurrence of large stromatolitic domes, and the features of the entrance indicate that it was partially opened during the collapse phase.

The size of the lower level dome and flat topped mound which occur in the Second Chamber indicate that here the primary cavity was not as wide as that of the First Chamber, enabling a stable roof to be attained by an arch of smaller dimensions. It is probable that the Third Chamber contained a similar mound of material, since the form and size of the chamber indicate an origin similar to that of the First and Second Chambers, but the material has since been excavated, predominantly by solution during more recent incursions of water.

Minor modification of the Long Passage and The Rift has also occurred, modification at all but one site being related to the primary phase of collapse. The collapse of a large ceiling block at the latter site occurred during a later phase of excavation within the system, since [illegible]ock rests upon two excavated breccias.

Subsequent development

The development of the Wolkberg Cave subsequent to the period of roof breakdown has been limited to calcium carbonate deposition and re-solution, only minor changes in the form of the cave having occurred since that time. A sequence of phases of calcium carbonate deposition interspersed by periods marked by pronounced re-solution can be determined from speleothem features and the relationships of speleothems to other fill materials.

The first phase of speleothem development is now indicated only by remnants, but is thought to have been a phase of pronounced deposition, producing a coating of decoration on the walls and ceilings, and causing the breakdown pile to be cemented to form the oldest of the three breccias. The close of the phase is recorded by the development of a flowstone cap over much of the breccia, and this was followed by a phase of intense re-solution. The effects of the re-solution were the excavation of some of the cemented breccia and the reduction of decoration to a thin veneer on the walls and ceiling, as may be observed in the First Chamber. The depth of excavation of the first breccia, indicated by the relative position of breccia carapaces and the products of the next phase of deposition, was of the order of 15m, but this resulted in only minor re-working of the breccia since the second, massive, phase of speleothems overlie relatively unaltered first breccia material. Since the dolomite content of the second breccia is considerably reduced in comparison to the first, it is thought that the bulk of the material excavated was removed in solution.

The second phase of deposition was characterised by the development of massive speleothems, including shawls and pillars up to 30m high, as may be observed in the Second Chamber (Fig.5.3). Speleothems of this phase were deposited on weathered cemented breakdown consisting of sub-rounded dolomite cobbles. A modification of the phase has occurred in the First Chamber, where the existence of minor flowstone carapaces protruding from pillars indicates the incursion of earth fill materials late in the phase. Thus, the pillars developed as large structures and were then almost completely buried by a fill which was partially capped with a flowstone sheet. These sheets now exist only as carapace remnants, the gradients of which indicate that the point of entry of the material was in the vicinity of the present entrance. It is likely that much of the fill consisted of earth, since no traces remain. During this massive carbonate phase, the wall of flowstone and pillars separating the First and Second Chambers was developed, and a carapace of flowstone and shawls formed on exposed breccia remnants in the Long Passage and The Rift.

The cessation of the massive depositional phase was marked by the onset of a second phase of re-solution which has affected all speleothems of the prior phases, indicating that the system must have been completely filled with water. Re-solution is indicated by the smoothed, bleached surfaces of all speleothems of the massive phase, and also by further minor re-working of the previous breccia to produce the second breccia. The latter is composed of internally derived material, as is the first, but is composed of sub-angular chert pebbles with only a small amount of dolomite, in comparison to the dominant proportion of dolomite in the first breccia. It is probable that this phase of re-solution produced

Figure 5.3: Decoration in the Second Chamber