

that deduced by Marker and Brook (1970). Whereas these workers were able to ascribe the water level fluctuations in Echo Cave tentatively to the major climatic oscillations of the Pleistocene, it is only known that the oscillations at Sterkfontein occurred after the deposition of the bone-rich breccia (approximately 2 million years before present) and prior to 50 000 years before present. The oscillations represented at Sterkfontein thus overlap those at Echo Cave.

## CHAPTER 10 : SUMMARY AND CONCLUSIONS

### 10.0 Summary

A summary of the results from the detailed analysis of the cave system are presented. Thereafter evidence of climatic oscillation is summarised. The relation of the results to various existing theories of cavern development and climatic change in Southern Africa is evaluated.

### 10.1 Morphology and Location of the System

10.1.1 The cavities comprising the system may be divided into two morphological categories:- the large main galleries, and the smaller passages to the north of these.

10.1.2 Main galleries are relatively narrow, sheer-sided, slot-like, elongated cavities with strong vertical development (up to 30m), and with earth floors which conceal the total original depth of the voids.

10.1.3 There is an approximate boundary between the large galleries and the smaller passages lying to the north of these. The smaller galleries dip variably to the north, are relatively wider than the main galleries and are often oval in cross-section.

10.1.4 The large galleries are aligned along major east-west compressional, fractures and fracture zones; they occupy the area of the hill in which the fracture zones are concentrated.

10.1.5 The smaller galleries to the north occupy an area largely devoid of major fracture zones, and are aligned along joints and occupy specific stratigraphic layers, often with small lands controlling the roof.

10.1.6 The smaller galleries have developed to the north of the

fracture zones in response to water-flow from the fracture zone voids towards the local drainage line.

10.1.7 The position of the cave system is thus determined by the location of fracture zones which have developed according to a specific pattern in the Blaauwbank River Valley. A 'possibly silicified fault' which bounds the cave system on its eastern or down-stream side, may have encouraged cave development by concentrating groundwater in the dolomite on its western or upstream side.

## 10.2 Erosional Detail

10.2.1 Erosional detail such as networks, partitions, rock-spans, flutes, joint-determined cavities, boxwork, stylolites, and protruding chert bands, points to an origin almost entirely phreatic.

10.2.2 A few features indicate flowing phreatic water, and one seasonal vadose stream flows in a phreatically formed passage.

10.2.3 Much evidence of percolating water action exists in the form of solution pits in the cemented breccias of the Fossil Cave and also in an underground chamber (Daylight Chamber). Large scale attack by percolating water appears to have caused the Exit Area which has been linked by solution of the breccias to the lowest parts of the cave system.

The slot-like form of the main galleries suggests upward elongation due to percolating water.

10.2.4 Small collapse-formed cavities were encountered centered on various joints, mostly in the inner parts of the cave system.

10.2.5 The cave system corresponds to Davis' (1930) formulation of cave development in that it underwent deep phreatic erosion and is now air-filled. It also corresponds to Ford's formulation (1970) that deep phreatic caves develop in steeply dipping rocks. The small northern

passages show control by specific layers within the bedrock, the importance of such controls being advocated by Gardner (1935), Glennie (1956) and Waltham (1971).

10.2.6 The Main galleries of the cave system do not correspond to any specific theories of cave development in that they have developed entirely according to the particular geological structure, the fracture-zone pattern of the Sterkfontein area. Within the confines of the area with the same geological structures, it may be possible to detect some systematic development of caves.

### 10.3 Water Levels in the Cave System

10.3.1 Cave sections indicate that the seven water bodies occupying the lowest parts of the cave system, all lie below the Blaauwbank River bed level by 5 - 18m, and that they decline in height towards the north-east, suggesting that they are crudely connected to one another (hydraulic gradient of the order of  $6^{\circ}$  north-eastwards).

10.3.2 Resurgence of the cave water is probably at the bedrock/alluvium contact in the Blaauwbank River, in the form of underflow.

### 10.4 CaCO<sub>3</sub> and Non-Calcareous Deposits

#### 10.4.1 Speleothems of Primary and Secondary Growths

(1) The accumulations of CaCO<sub>3</sub> (in economically exploitable quantities) occur in the cave system in a variety of forms: calcite in the form of stalactites, stalagmites, flowstone, calcite straws, rafts and helictites. Other forms are aragonite crystals (subaqueous and subaerial) which occur on all kinds of surface, and concoidal amorphous CaCO<sub>3</sub> in one locality.

(2) At least two distinct phases of CaCO<sub>3</sub> deposition are evident.

(3) The largest volumes of  $\text{CaCO}_3$  have accumulated along the roofs of the fracture controlled caverns.

#### 10.4.2 Non-Calcareous Deposits

(1) The non-calcareous deposits are of three types; Wad, the insoluble dolomite residue, collapse material derived internally, and coarse earthy deposits.

(2) Wad collects underwater: it is found extensively in the lower parts of the cave system as a wall coating, and is another pointer to the phreatic origin of the cave system. Normally it is found as a black powder or jelly-like substance, but it is also found cemented into breccia.

(3) Collapse material is found in the inner recesses of the system in comparatively small quantities. Any such material in the main chambers is buried beneath the large influxes of hillslope debris.

(4) Coarse earthy deposits are ubiquitous in the caves, especially in the large galleries. They consist of red earth with subangular stones and some collapsed boulders. Though usually roughly stratified these deposits do not display sorting within individual strata. They contain some bone and artefact material and may be cemented to different degrees of hardness.

(5) These deposits cover most floors and many cavern walls. They occupy the major fracture-zone chambers as large continuous bodies of debris. It is apparent that these deposits are externally-derived hillslope materials.

(6) The coarse earthy deposits often occur as two distinct entities, viz. a cemented and carapaced deposit situated above an uncemented, uncara-paced deposit: the upper cemented deposit often shows evidence of phreatic attack on its underside.

(7) The large unconsolidated debris cone of the Milner Deposit has different constituents from the overlying cemented deposit, and is therefore not a decalcified, subsided portion of the cemented deposit, as suggested by Robinson (1962).

(8) A model has been proposed to explain stages of development of the deposit masses.

(9) No epoch of clay fill, as proposed by Bretz (1942), ever affected Sterkfontein as a specific stage in the development of the cave system. Well developed fracture zone avens allowed coarse external debris to enter in very large quantities, unlike the very fine soil filling recognised by Bretz.

(10) Surface breccias are connected with underground breccias through distances of at least 35m. The breccia material enters by, and accumulates in widened, near-vertical fracture zones.

(11) Archaeologically in particular it is important to note that the lower parts of the thick deposits will be older than the upper parts.

(12) It is accepted that the coarse fraction of the bone-poor breccia of the Fossil Cave is of collapse derivation. The fine matrix material of this breccia, however, is believed to be infiltrated into the coarse fraction dolomite blocks with the aid of percolating water. Therefore this deposit cannot be accepted as a climatic indicator, as proposed by Brain (1958).

(13) Unconformities between the three contiguous surface breccias in the Fossil Cave do not necessarily represent time hiatuses; they represent changes to different modes of deposition. The collapsed bone-poor breccia is simply an interruption in the continuous, gradual accumulation

of the bone-rich deposits, i.e. the deposit mass is conformable, as Brain (1958) originally suggested, and not unconformable as Robinson (1962) viewed it.

(14) The upper chocolate brown breccia, of the Fossil Deposit, probably accumulated in a void caused by the compaction of the underlying deposits, rather than in a void caused by collapse of the underlying deposits into the underground system as proposed by Robinson (1962).

#### 10.5 Evidence of Climatic Oscillations

It has been mentioned that breccia matrix analyses have been used to make various climatic influences. As doubt has recently been thrown on these interpretations they will not be discussed.

10.5.1 Re-solution features on many travertine masses in the cave system indicate that water levels in the caves have fluctuated in the past.

10.5.2 Such fluctuating water levels are best explained by climatic oscillations which affected the hydrological regime of the Sterkfontein area.

10.5.3 Water level fluctuations have occurred at three detectable levels in the cave system. The two upper-level examples indicate two climatic changes each; the low level fluctuations indicate only one definite climatic oscillation.

10.5.4 All three sets of water level fluctuations occurred prior to 50 000 years before present. The upper level fluctuations probably occurred before the bone-bearing breccia accumulated, whereas the lower two sets occurred after this breccia had accumulated (bone-bearing breccia dated variably between 1,75 and 2,5 million years before present).

10.5.5 The climatic fluctuations evident from the past lake

levels cannot at present be equated with the other evidence of climatic change from the Transvaal.

10.5.6 Variations in the thickness of successive travertine deposits, indicating variation in either the rate of deposition or the duration of deposition, also indicate climatic fluctuations.

#### 10.6 Conclusion

The two hypotheses being tested in this thesis can now be evaluated in the light of the conclusions listed above. The two hypotheses are

1. That the Sterkfontein cave system fits the models of cave development established elsewhere in the world.
2. That the Sterkfontein cave system, like other cave systems in the Transvaal, preserves evidence of climatic oscillations.

It is apparent from the conclusions that the first hypothesis may be only partially accepted, since the major cavities of the system are unique, having developed along a series of fracture zones. The minor cavities, however, fit most closely the theory of cavern development in dipping rocks as proposed by Ford (1971). Also, Sterkfontein fits Davis' very general 'two-phase' theory of cavern development (Davis, 1930), since it is almost entirely a phreatically formed cave.

In relation to the second hypothesis the conclusions indicate that it can be accepted. Distinct changes both in the volume of calcium carbonate deposition, and in the cave water levels have undoubtedly occurred. Such changes can best be explained in terms of changes in surface climatic conditions.

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