

 $\dot{\alpha}$

57





 $\left\{ \right\}$



ij.

y's

to have entered the chamber by a similar route to that by which the breccia debris originally entered (Fig. 6.12).

39.

The influence of a hanging dolomite wall is presumed, since the travertime carapace issues from the highest parts of the chamber against the dolomite roof.

(6) Small Exit Deposit

Lying on the south-west side of the Exit Chamber, this deposit is in the form of a debris cone with a very thick (3m) travertine carapace, which has been largely destroyed. Like the large Exit Deposit its upper surface rises to the chamber roof, suggesting that it too entered as an influx from the hillsurface via an aven or slot. As in (5) it is presumed that the lower end of the slot acted as a hanging wall preventing the ingress of further hill talus. However, nlike the large Exit Deposit, the small Exit Deposit appears to be totally unaffected in any way by phreatic attack.

This Deposit consists of numerous small dolomite blocks (5 - 10cm³) embedded in a red sandy matrix, apparently externally derived. It lies directly beneath the east end of the Exit Area on fracture zone No. 5 (Fig. 5.1).

(7) Graveyard Deposit

Along the southern, western and eastern walls of the Graveyard Chamber, near floor level, lies a relatively small breccia body. Covered with a thin travertine carapace, this breccia body has collapsed downwards a short distance in the middle of the chamber, an example of the kind of breccia cone disintegration envisaged in the model (Fig. 6.3e). The slope of this breccia cone is shallow and lessens across the room (Fig. 6.13) suggesting the deposition of a wet rather than a dry debris. The breccia is pink with a bone-rich layer and few coarse inclusions. To is the deal of an infinite and the representation of the second of th

÷,



1) en 1) (2 1

15



Hanging dolomite walls appear to have prevented the total inundation and filling of this chamber by debris. Exwever, small cones of fitte red earth are deposited on the carapace surface in the innermost parts of the Graveyard Chamber, near the apex of the braccia cone (Fig. 6.13). This is the only record of a new unconsolidated deposit overlying a travertine carapace, most newer deposits accumulating <u>beneath</u> a carapaced breccia body. The occurrence of these small cones of red earth presumably indicates that new points of entry for external material have developed since the deposition of the breccia cone.

40.

(8) 'Entrance 6' Deposit

Entrance 6 is a pit 16m in diameter and 9m deep, from th. side of which a lime miners' shaft slants down into the cave system (Fig. 6.14) in the vicinity of the Graveyard Chamber entrance (point V, Fig. 5.1). The pit contains partly collapsed breccias overlain by recent soil. The breccia, which consists of a coarse sand matrix with few large fragments, is crudely laminated, suggesting deposition in water.

The Entrance 6 Deposit lies on one of the major fracture zones directly above parts of both the large Exit Deposit and the Graveyard Deposit (Fig. 5.1).

(9) Elephant Deposit

The debris masses grouped in this section \leq not all have the same source area; they have been grouped together because of their similarity and proximity to one another (Fig. 5.1) in the southern recesses of Elephant Chamber.

The Elephant Deposit consists of small bodies of breccia attached to the walls of the Elephant Chamber, as well as large unconsolidated deposits covering the floor and truncating all the passages leading off south and west from the main Elephant Chamber (Fig. 5.1, points 1 - 5).



as about the second states and

()







1.0

Trade and

The breccias are small stony agregates, often with a travertine capping, attached in many places to the maze of partitions on the south side of Elephant Chamber. They occur from 4m above the present floor, at increasing heights towards the blocked passages in the south. They seem to be remnants of a large talus slope which must have stretched once to the other side of the chamber (Fig. 6.15). These remnants represent the most extreme example of breccia cone destruction in Sterkfontein.

41.

The unconsolidated material of the Elephant Chamber floor and southern passages is apparently derived mainly from passages 1 and 4 (Fig. 5.1), and also from apertures in the roof of the Chamber (Entrance 1 Cluster - Fig. 5.1). Passages 1 and 4 are truncated by steeply rising slopes of hill talus and red soil. Passages 2, 3 and 5 are truncated by large boulders of dolomite and breccia. Except for those in passages 1 and 4, the deposits are not obviously related to particular lineament zones.

The floor deposit presumably consists partly of the material derived from the now-vanished breccia mound mentioned above. However, such material would be very difficult to recognise in a decalcified and possibly disturbed state. Also, the deposits exposed in an excavation in the floor can all be ascribed to the newer debris phase (derived from the southern passages and roof apertures). The bulk of the deposit appears to be a gravel leached of fines by drip and rain-water which must constantly wash over the present floor.⁴

The 'i-es have been washed to the lower levels and form a yellowish mud (Fig. 6.16) mixed with a black wad residue.

.

4

The trench dug in the floor deposits (point H, Fig. 5.1) revealed

⁴The deposit is reminiscent of leached alluvial fan gravel encountered in a road cutting in the dolomite area of the Hennops River valley 20km north eastwards. that a surface layer of recent soil overlies calcite chips (miners' rubble). The calcite chips in turn overlie the uncompacted gravel.

42.

(10) Fault Cave Deposit

The innermost passage of the Fault Cave (D-E, Fig. 5.1) is a collapse cavity, usually less than 5m high, developed within a large continuous body of breccia in origin similar to the Terror Chamber. Influxes of newer unconsolidated red sand. which have entered through a high, narrow, vertical shaft, have blocked the furthest end of the passage (E, Fig. 5.1). The breccia and the sand together form the Fault Cave Deposit.

The breccia consists of small angular cnert and dolomite blocks in a matrix of fine yellow-orange sand. The breccia forming the roof of the passage has been extensively redissolved indicating a rise in ground water levels in this low lying cave (60m below datum).

Since dolomite bedrock is not visible at any point in the pasage or on the hillsurface (due to a thick soil cover) fracture zone explanations of the location of the passage and deposits, be they fracture zone or otherwise, are conjectural.

This concludes the description of the cemented and unconsolidated deposits. It should be noted once more that the 'clay fill' which Bretz (1942) found so ubiquitous in American caves is not conspicuous, even if it exists at all in Sterkfontein cave. The calcareous deposits give evidence for past water level fluctuations, and some information concerning the date of deposition. The non-calcareous deposits are among the main determinants of the internal cave morphology. A model of debris cone development was presented, and the mode of development of each debris body examined in terms of it. Further, the location of each deposit body was related to the cave system revealing that debris influxes (except in Fault Cave) occupy only the large fracture zone chambers, south of the morphological line dividing the northern passages from the large southern chambers. The relationship of the deposits one to another, is discussed later.

• 43.

44,

PART III, DISCUSSION

CHAPTER 7 - THE CONTROLS OF LOCATION AND FORM OF THE CAVE SYSTEM

7.0 The theories of cave development to be considered with respect to the Sterkfontein Cave system may be summarised as follows: the twocycle theory of Davis (1930), and its modified version (Bretz, 1942) which includes an intermediate cycle of clay filling; the theories which postulate watertable control of the system (Brain, 1958; Brink and Partridge, 1965; Marker and Moon, 1969) and D.C. Ford's general theory which postulates three common cave-types, the vadose, deep phreatic and water table types (Ford, 1971); Bogli's theory of solution by mixing of karst waters (Bogli, 1971); the theories pertaining to structural control as the dominant and overriding control of the location and form of the system (King, 1950; Moon, 1972; and Waltham, 1971).

7.1 Location of the System

7.1.1 Areal Location

In a valley-wide perspective, Moon (1972) has shown that most of the caves in the Blaauwbank valley are aligned in an east-west direction. Furthermore he has demonstrated that the caves are directly controlled by compressional east-west trending fractures. Sterkfontein itself follows this pattern closely. As has been demonstrated earlier, the system has been cuntrolled dominantly by fracture zones which trend approximately eastwest. Cooke (1938) and King (1951) have both claimed this kind of structural control of the cave system, and this detailed study thus supports these earlier theories.

Although tensional fractures also occur in the dolomite of the



Γ

4

2

8 3

Γ.,

Fig. 7.1 Geological map showing structural determinants of cave system location

int.

an an an air an air

r.

 \mathcal{Y}_{i}

Sterkfontein hillock (Moon, 1972\, these are aligned north-south and have not exerted any control on the overall position of the system; the reason for this seems due to the fact that there are fewer north-south fractures. From observation underground it is apparent that the north-south fractures are unlike the east-west fractures which consist of zones of fracture rather than single lines of weakness. The north-south fractures have not had an overriding control over any part of the cave system.

The question arises as to why a particular set of intersecting fracture zones favoured the development of this cave system. Two geological factors provide some explanation.

(i) The fault bounding the cave system on the eastward or downstream side. It was mentioned above that 'a possibly silicified fault' (Brink and Partridge, 1968) bounds the system on the east, running northsouth and intersecting the river bed to the north. If this fault indeed acts as an impermeable barrier, damming up ground water in the dolomite to the west, it may explain the location of a cave system within this saturated dolomite (A, Fig. 7.1).

(ii) The underlying dolerite sill. The dolerite sill which underlies the cave system outcrops a short distance to the south of it, and it too may have acted to concentrate the ground water in the angle between the sill and the abovementioned fault which it intersects (A, Fig. 7.1). It may be argued that ground water is more likely to collect on the southern side of this sill, since the greater area of dolomite occurs on its southern side (the large area stretching \pm 3km southwards to the Witwatersrand hills). However, a borehole sunk into the dolomite on the south side of the sill was dry at a depth of 97m. below datum, i.e. 37m below the lowest water body in the cave system. This suggests that the sill is either not acting as a dam for ground water from the south, or that the ground water to the south is very much lower than that in Sterkfontein, and thus part of a

completely disconnected and separate hydrologic system. It is also possible that the borehole simply did not strike any cavities containing water, however.

7.1.2 Altitudinal Location

In the vertical plane, the location of the cave may well be related to the fact that the hilltop dolomite contains numerous bands and layers of chert. It cannot be said conclusively that the <u>greatest</u> concentration of chert occurs in the hilltop dolomite strata, but this appears likely.

The effect of a concentration of chert layers in the dolomite strata of the hilltop is twofold:

(i) Ground water flow would be concentrated on the underside of the chertz strata, leading to cave development (Waltham, 1971; see also 7.2.4 (1) below: Origin of Fossil Cave), and

(if) The chert bands, being relatively resistant under local conditions would reduce the rate of hill summit lowering by surface weathering.

The first of the abovementioned effects may thus explain the altitudinal location of the cavern voids beneath the hilltop, and the second helps explain why the caves are preserved at the present levels.

The possible effects of water-table control are discussed below (7.2.2).

7.2 Form of the System

7.2.1 Phreatic Origin and Vadose Modification

The morphology of the cave system is a result of phreatic erosion. Features found at all levels in the cave system, and described in detail above, are predominantly of phreatic origin. In that the system has now been largely drained of water, Davis' two-cycle theory applies in

 $\left(\right)$

a general way (Davis, 1930), although many parts of the syst i have been submerged deep in the phreas more than once. With the ______ption of one small passage in the Fault Cave, the system has not suffered any modification by vadose stream action. This contrasts with Bretz's finding that caves in the U.S.A. are usually modified by vadose stream action (only 44 out of 107 caves studied were purely phreatic in origin - Bretz, 1942).

47.

Recent work suggests that caves in the Transvaal are generally purely phreatic in origin (Brain, 1958; Marker, 1971). Although the lack of vadose modification of Sterkfontein may be due to its location beneath a small hill, distant from local drainage lines, this alone is not an adequate explanation.

Bretz (1942) has shown amply that underground drainage patterns can be radically different from surface patterns in terms of direction of flow, watershed positions and volume of flow. Lack of surface water generally, the badly integrated nature of the groundwater system (7.2.3 (1) below), and the steeply dipping attitude of the rocks, have probably all contributed to the lack of vadose modification at Sterkfontein.

7.2.2 Deep Phreatic Development, and Water Table Control

(1) Deep Phreatic Development

In his recent formulation of cave development theories, Ford (1971) postulates that deep phreatic caves, as a common cave type, develop optimally in steeply dipping rocks where the resurgences are downdip. Characteristic of this type are bedding-controlled passages ('dip-tubes') descending through a vertical distance of at least 8m. (Ford, 1971). In Sterkfontein the passages north of the main fracture-zone galleries are controlled by various beds in the dolomite (4.2 above). Many of these descend continuously through large vertical distances (50m in Lincoln's Cave). If these northern passages are regarded as 'dip-tubes', as indeed it stems they must be, then they indicate that Sterkfontein is to be



0 0

11

÷ 🗘

hand the fo

de l

Fig. 7.2 Sterkfontein water paties and ve positions and surface levels a metres : and tum)

and the second second and the stand of the second second second second second second second second second second

00

classed as a deep phreatic cave.

Another characteristic of the deep phreatic caves is the 'jointlift tube' (in conditions where the rock dip is steeper than the hydraulic gradient - Ford, 1971). At Sterkfontein the dolomite dips at 30° and the hydraulic gradient averages $6\frac{1}{2}^{\circ}$ downdip (Fig. 7.2). Ground-water must therefore gain stratigraphic height to reach resurgence level (Blaauwbank River streambed). Joint-lift tubes might therefore have been expected in Sterkfontein in terms of Ford's theory.

See)

48.

However, there are no examples of such tubes, probably because so little of the system is wholly bedding controlled; the fracture zones control the major part of the system, and Ford's formulation would obviously not apply under such special local circumstances. Nevertheless, the bedding controlled cavities which do exist suggest the deep phreatic cave pattern of Ford's theory, rather than the water-table cave type.

12 376

(2) Water-Table Control

Certain features of the cave system indeed suggest a water-table origin for Sterkfontein. Evidence cited by earlier workers in support of this theory will be discussed.

It has been argued above that the passages north of the large fracture zone galleries do not indicate water that ontrol because they occupy specific strata continuously through a vertical distance of up to 50m. Ford (1971) has said: 'Discussion of a wate. table control is irrelevant where the amplitude of the phreatic loop¹ was greater than c.25 ft.'

This opinion is accepted for Sterkfontein where the bedding controlled passages indicate phreatic loops of at least 50m.

'Phreatic loop' is Ford's term for a composite feature made up of a joint-lift tube and a dip tube.

However, the question of the morphology of the main galleries remains: the floors of these galleries are approximately horizontal, and those of the two largest galleries are at accordant levels. These two facts, in addition to the size and altitude of the Fossil Cave 50m above the other gallery floors, have persuaded earlier workers that Sterk ontein developed at two distinct water levels, and hence was related to the erosion surfaces in the area (Brink and Partridge, 1965). Although the cave system may be related to regional water levels and the associated erosion surfaces, there is doubt whether the features previously regarded as indicative of water-table control should in fact be regarded as such For instance, it appears that the Fossil Cave does not in fact have a dolomite bedrock 'floor' separating it from the underground chambers. The existence of such a floor would suggest that water-table controlled cavities had developed above and below it. It is argued below (7.2.4 (2))that the Fossil Cave simply consists of the upper part of a widened fracture zone of great vertical extent. This widened fracture zone becomes the Tourist Cave at lower levels, and it may well extend far below the present floor level of the Tourist Cave. Similarly it may well have extended above the level of the Fossil Cave. It seems therefore, that discussion of cave development at two distinct levels (Fossil Cave and Tourist Cave levels) cannot be supported.

The present floor levels in the large galleries, as well as gallery-widening near these floors have been taken in the past to represent a level of water-table erosion. However, the p: :ent floor levels may not truly represent the lowest parts of the void eroded in the dolomite: the floor material may be many metres thick, especially in view of the opinion that the dominant control of cave development is the erosionally widened fracture. Thus present floor levels may simply reflect the amount of infilling by surface materials of underground cavities.



-

0

 Σ

1

conversion of the second state of the second state of the







This insoluble fill-material may have protected the dolomite beneath it from solutional attack while directing erosion against the cavern walls, thus causing the caverns to widen laterally The insoluble fill-material may well have caused water bodies in the caverns to be perched above the level of the general piezometric surface in the local area.

* 50.

Overall it appears that the evidence for water-table control in the underground caverns is not convincing. Such possibly indicative features as do occur (floor levels and cavity widening at floor 'evel) can be ascribed as easily to the effect of floor deposits, as to regional water levels.

Waltham (1971) has shown that cave development may be initiated along a fracture line at any level where impermeable bands, fault breccias, or 'lenticular openings on non-planar faults'occur (Fig. 7.3). Such structural factors may also be responsible for the development at a particular level of the main gallery floors and for the lateral widening of galleries at approximately floor level which exist in the Sterkfontein system.

7.2 3 <u>Characteristics of the Water Levels in the Cave System</u> Gradients

(1)

It has been shown that the water levels in the caves vary by as much as 10m (Lincoln's Cave and the Lake: 48m below datum; Fault Cave 58m below datum. See Figs. 7.4 and 7.2). Brink and Partridge (1965) have postulated that water-tables within the Transvaal dolomites are uneven during phases of river incision. The Blaauwbank River is at present incising its valley into the African planation surface (of which the Sterkfontein hillock is believed to be a depressed remnant); the uneveness of the water table within the caves thus appears to support the opinion of Brink and Partridge (1965). One might even regard the water levels as indicating waterbodies virtually or totally independent on one another, if it were not for the fact that the levels descend approximately in the direction of the nearby Blaauwbank riverbed. This suggests some degree of integration in hydrologic network.

Evidence of current flow within the phreas has been presented: domelike cavities eroded upwards into the breccia of the Milner Deposit suggest a gentle phreatic current. An analysis of hydraulic gradients between the several water bodies in the Sterkfontein Caves supports this evidence of current flow. Assuming some primitive integration between the water bodies, it is evident that the maximum hydraulic gradient in the cave system is that between the two water bodies in Lincoln's Cave (Fig. 7.2). Over a distance of 45m. the gradient is 1:5 (11⁰), which is steeper than the extreme gradients measured in the Swiss Alps by Bogli (1:10 -Bogli, 1971). It is recognised that such gradients cause strongly flowing sub-watertable currents (Bogli, 1971).

This finding supports the morphological evidence of flow in Sterkfontein, and verifies Bretz's evidence of current flow in the phreas (Bretz, 1942).

(2) That the hydrological regime in the Sterkfontein area is not altogether simple, is illustrated by the fact that the water levels in the system lie at or below the incised oed of the Blaauwbank stream.

It has been showr that the water levels in the cave system descend well below (12m) the level of the incised Blaauwbank river bed. It has also been argued that a primitively integrated system of phreatic connections seems to exist between the water bodies, and that they appear to drain towards the Blaauwbank stream.

The explanation of this situation seems to lie in the thickness of alluvial material beneath the present river bed. The stream has



already incised 8m into the terrace and theoretically it should rest on another 12m at least, in order for the cave water to drain away at the alluvium-dolomite contact level (Fig. 7.5).

7.2.4 Origin of the Fossil Cave

(1) The Fossil Cave Roof

Brain (1958) invoked the collapse of a very large dolomite block to explain the origin of the Fussil Cave, quoting Sterkfontein as an example of the collapse type cavern, as opposed to the solutional type, in his general theory of cavern development in the Transvaal (Brain, 1958). Robinson (1962) agreed that the roof of the Fossil Cave was a collapse feature, but argued against the collapse of a single large block of dolomite. He regarded Brain's explanation as unlikely, and postulated that 'repeated collapses at various heights and of various degrees of magnitude' had caused an irregular roof to develop.

It is apparent from the cave plan (Fig. 5.1) that the Fossil Cave is underlain by slot-like passages. These are developed in dolomite bedrock. With Robinson (1962) therefore, it is difficult to believe that the Fossil Cave was formed by the collapse of one exceedingly large dolomite block, as Brain postulated (Brain, 1958).

As stated, Robinson (1962) attributes the Fossil Gave roof to repeated small collapses. He bases his views on these facts: firstly that the few visible portions of the Fossil Cave roof (especially on the west wall of the Type Site) are planar features dipping with the bedrock dip; secondly that 'numerous examples of collapse unon. und' exist; and thirdly that the roof of the Fossil Cave is irregular as far as can be seen.

The present writer regards these facts to be inconclusive of small scale collapse; it seems as likely that the Fossil Cave roof was a solutional feature. This opinion is supported by the fact that the



largest expanses of cavern ceiling in the cave system are planar features dipping with the bedrock, and developed at bedding planes within the dolomite. These large ceilings (Exit Chamber 600m², Lincoln's main chamber 300m²) appear to be solutional features; they display such phreatic features as joint controlled cavities, deep and shallow, and the ceiling surface is gently undulating, unlike the flat cleavage planes which characterise collapse along bedding planes. Also, as far as can be seen, no collapse blocks lie on the floors beneath these ceilings. The north-west side of the Exit Chamber ceiling is deeply indented (3-4m) by joint-determined cavities which have been carried upwards purely by solution, thus indicating that solutional attack may also produce an 'irregular' ceiling.

53.

It seems justified therefore, to claim that the Fassil Cave roof may also have been a solutional feature.

The mode of formation of such ceilings appears to be due to cavern formation <u>beneath</u> an impermeable bedrock layer due to ground water <u>rising</u> through the stratigraphic succession. Waltham (1971) has suggested speleogenesis of this particular kind, under a set of conditions which are fulfilled in Sterkfontein, namely that the hydraulic gradient should be less than the regional dip, that impermeable strata should exist to concentrate ground water circulation, and that the bedrock should dip towards the resurgence. In Sterkfontein the hydraulic gradient was shown to be less than 11[°] north towards the local drainage line. The rockdip is $30^°$. rth and the hydraulic gradient is therefore less, causing the groundwater to rise through the stratigraphic succession to reach resurgence level (Fig. 7.6). The ceiling of Lincoln's main chamber is a shale band, which appears to have concentrated the rising ground waters beneath it, to form the cavern and the related planar roof feature.

Shale bands are also known in the region of the Fossil Cave

roof (Brink and Partridge, 1968). It may be concluded that the Fossil Cave may have developed as a solution feature, i.e. phreatically, just as the other major features of the cave system developed. Very little of the character of the Fossil Cave roof is known, and either the collapse or the solutional theories of development may prove true. It is important to realise however, that planar roofs dipping with the bedrock do not necessarily indicate collapse, as has been claimed in the past.

54.

(2) The Fossil Cave Floor

Brain (1958) considered that the floor of the Fossil Cave would necessarily be the upper side of the collapse block which he hypothesised had collapsed into the underground caves, leaving a large cavity, the Fossil Cave, above it. Robinson (1962) showed that the existence of a collapse block of this size was highly unlikely. Also, it was mentioned above (1) that a series of passages exist underground, developed in bedrock, within the void supposedly occupied by the large collapse block. It is apparent that any floor which may have existed was not the upper side of a large collapse block.

14

Robinson nevertheless regarded the Fossil Cave as having a floor at approximately the level of the Milner Deposit cone carapace peak i.e. at a level of \pm 30m below datum (Robinson, 1962) (Fig. 8.7). Debris was viewed as having accumulated on this floor, a floor which subsequently collapsed into a lower tier of caverns, at the western end of the Fossil Cave.

It seems very likely, in the light of this study that the Fossil Cave did <u>not</u> have τ edrock floor at all, but that its floor was in effect the floor of the present-day underground caverns, another 16-20m lower. The reasons for this proposal are as follows:

(i) The south wall of the Daylight Chamber is a vertical, almost smooth dolomite face, without ledges or protuberances of more than a few



051

Statest States - 1998

4

0

Fig. 7.7 Plan of Fossil Cave excavation with relative positions of underground caverns (see text for explanation)



centimetres. This is true of the entire visible height of the south wall of the Daylight Chamber where it extends westwards down towards the Elephant Chr. er, becoming as much as 30m high in parts. With Robinson (1962), ient writer believes that this sheer, cliff-like wall is a good example of the vertical cave development which results from phreatic attack along vertical fractures in dolomite bedrock.

Since this south wall is aligned along a major fracture zone it is reasonable to suppose that it continues eastward, towards point 'C' (Fig. 7.7) as a sheer dolomite face. As no suggestion of a floor can be seen to the west, it seems improbable that a floor exists eastwards of the Daylight Chamber as a support for the Fossil Deposit, (it is argued below (3) that the south wall of the Daylight Chamber is in fact also the south wall of the Fossil Cave) as Robinson's model suggests.

(ii) From the Exit Area a subvertical shaft descends directly (d-c-f, Fig. 7.7) into the low-lying Terror Chamber with no evidence of a bedrock floor at \pm 30m below datum, as required by Robinson (1962), to impede the influx of surface debris.

(3) North and South Walls

Ŵ

Bearing in mind that Robinson (1962) envisaged the Fossil Cave with a floor at a comparatively shallow level, his reconstruction of the north and south walls appears true, i.e. a small portion only of the north wall is visible (a-b, Fig. 7.7) because of the existence of much of the original cave roof (areas A and B, Fig. 7.7). At lower levels it is difficult to predict much of the nature of the north wall, although it appears to follow fracture zone No. 4 (Fig. 8.2).

Robinson's surface observations of the position of the south wall tie in closely with the position inferred from the Daylight Chamber (C. Fig. 7.7). Robinson (1962) suspected this connection which the present study verifies. It was argued above that this wall is probably a simple and constant feature for its entire length (Elephant Chamber - Daylight

Chamber - Exit Area), which acted as a sheer, high (up to 30m even at present) containing wall against which the Fossil and Daylight deposits has accumulated.

56.

(4) East and West Walls

Robinson's argument for the existence of these two walls is tenuous. The eastern wall he placed at the eastern extremities of the present-day breccia outcrops (c-g, Fig. 7.7). As argued below (8.5), these breccias probably once filled the Exit Area completely, at least as far as D (Fig. 7.7) at the eastern end of the Exit Area, and at least to the level of the present hillside. Breccia has since been found 17m west of the line regarded by Robinson as the western extremity of the Fossil Cave (Fig. 7.7). Underground breccia bodies, apparently connected with the Fossil Deposit, are found far to the west of Robinson's 'west wall'.

But besides the fact that new breccias have been located and hew interpretations of the extent of the eroded breccia bodies have arisen, the concept of sheer north-south aligned walls does not agree with the observeu facts of the cave system. The nature of the caves at the east and west ends of the Fossil Deposit is that of closely spaced, <u>east-west</u> trending avens and slots ('partitions' at the base of the Tourist Cave entrance stairway are good examples - they lie directly beneath the 'rest wall' area and are probably a close representation of the original morphology near the present surface). The actual extent of the deposit east and west is probably determined mainly by the position of the original debris influx points, and then, by hanging walls (bridges between partition walls) at different levels.

Ŀ

The new interpretations presented above arise from a different, und hopefully a more complete picture of the mode of development of the cave system; the major element in this picture is that of fracture zones causing strong vertical development of cave voids.

(5) Percolating Water and 'Mischungskorrosion'

It has been mentioned above that the main galleries of the cave system have 'eveloped on fracture zones, and that they taper upwards becoming mere slots in the dolomite at the highest points. Some avens actually pierce the roof of the gallery and reach the surface; others become encrusted with travertine. Brain (1958) attributed the upward tapering to percolating aggressive meteoric water acting once the water level dropped. It is also possible that the slot-like character of the roofs developed before the water level dropped, i.e. during the phreatic phase, by the action of percolating water mixing with the phreatic water, becoming aggressive thereby (Bogli, 1971), and enlarging the phreatic cavity upwards. Both processes may have been active in the past.

57.

The effect of percolating water on the deposition and erosion of cave fillings is discussed in Chapter 8.

7.3 .ssessment

The Sterkfontein cave system appears to have developed in the simplest way, by phreatic erosion of a few dominant fracture zones and bedding planes. Even the evidence of flowing phreatic water is minimal, although present day differences in water level (supporting the idea of a piezometr.c surface in the Transvaal dolomites) indicate that water bodies are crudely connected and therefore also that current flow probably existed.

In that the caves are now mainly filled with air, the cave system fits Davis' two-cycle theory of cavern development (Davis, 1930). But the caves have not suffered vadose erosion, except in one small passage, and in this respect they do not conform to Davis' or Bretz's theories (Davis, 1930; Bretz, 1942). Sterkfontein conforms best to Ford's recent description of a <u>deep phreatic cave</u>, which he views as different from vadose and water-table caves (Ford, 1971); there is little vadose evidence and none of water-table control in Sterkfontein, although the latter has often been invoked by previous workers. Hence there is no evidence of erosion-surface control.

Water levels in the caves all lie below the external drainage level (Blaauwbank River bed). Since the levels indicate an integrated system of water bodies, it appears that the water outlet must lie beneath a thick layer of alluvium in the river bed, and escape as underflow at the bedrock/alluvium contact. It has been computed that the alluvium must be rt least 20m thick, if this explanation of water levels is true. Sweeting (pers. comm.) has called South African karst 'a soil covered karst', and thick allogenic alluvial beds with surface and ground water behaving at least partially independently may prove to be a common characteristic of 'soil-covered karst'.

The formation of cave voids by means of collapse has been strongly advocated for Sterkfontein by Brain (1958) and Robinson (1962). However, little evidence of this kind of cavern formation has been encountered. Strong vertical development of narrow fracture cavities can explain the observed features at Sterkfontein: broad expanses of roof, which are more prone to ollapse, are not as common in the caves. Corrosion by the mixing of wate.s (Mischungskorrosion - Bogli, 1971), may have acted with percolating aggressive water (Brain, 1958), to produce the narrow aven-like galleries of Sterkfontein.



CHAPTER 8

59.

DEVELOPMENT AND IMPLICATIONS OF THE STERKFONTEIN CAVE DEPOSITS

8.0 The deposits of Sterkfontein can be classified as calcareous and non-calcareous. The former are relatively small in volume and are generally found as part of the large non-calcareous deposits. It is these large deposits, their mode of accumulation and subsequent erosion, and a discussion of the theories pertaining to them which are the subjects of this chapter.

The model of debris cone development presented earlier is briefly stated. Then it is discussed in relation to the various deposits in the cave system. The features of the deposits are then discussed in terms of the theories of other workers who have been concerned with cave deposits in general and the Sterkfontein deposits in particular: Bretz's (1942) theory that an epoch of clay filling intervenes between the phreatic and vadose phases; hypotheses concerning modes of deposit accumulation, past climates, and the ages of hominid and other fossils (Brain, 1958 and Robinson, 1962).

8.1 The Model of Debris Cone Development

The model, presented earlier, attempts to explain how unconsolidated deposits can be found so often at lower levels than cemented breccias in the Sterkfontein debris cones.

It has been proposed that an initial influx of surface debris accumulates in a cavern as a cone-shaped mound which grows upwards until the supply of debris is halted by an interruption such as a hanging wall (partitions which do not reach the floor of a cavern), or a protrusion from the coof of a cavern (rig. 8.1a). The core is cemented by carbonate-charced percolating waters, during or after deposition. A travertine carapace usually covers the debris mound finally. Later, phreatic waters rise and attack the cemented cones by corroding the calcite cement. The waters undermine the cones and carry away or disperse the loosened debris material (Fig. 8.1b). The cone is undermined and subjected to attack by aggressive meteoric water percolating from a now-lowered hill-surface: parts of the cone collapse, eventually causing the original debris inlet route to be re-opened, and new hill-slope debris enters (Fig. 8.1c and d).

The general result is that reworked deposits and newly entered material are found beneath older cemented deposits, an inversion of stratigraphy which should be noted when interpreting cave deposits in Southern Africa where changes in past water levels are suspected.

The deposits in the cave system all follow this model to different degrees: Milner Deposit displays a very large secondary influx ('The Mound'), and Elephant Deposit www almost entirely destroyed, with very little newer material entering to fill the void. Terror and Fault Cave Deposits do not appear as cones but simply as slot fillings - there were apparently no hanging walls to interrupt the inflow of debris and thus prevent these slots from filling completely. Daylight Deposit has been attacked from beneath and above, by phreatic and percolating water. The small Exit Deposit is apparently much younger than the large Exit Deposit, since the latter has been attacked by phreatic water, whereas the former shows no sign of attack, and both lie in the same chamber.

8.2 Debris Penetration of the System

Hillslope debris has penetrated to the lowest parts of the cave system. In this section of the Discussion some attempt is made to give an account of some of the various routes by which the debris has entered; it also attempts to establish the connections between the deposits, since



Author Wilkinson M J Name of thesis Sterkfontein cave system: evolution of a Karst form 1973

PUBLISHER:

University of the Witwatersrand, Johannesburg ©2013

LEGAL NOTICES:

Copyright Notice: All materials on the University of the Witwatersrand, Johannesburg Library website are protected by South African copyright law and may not be distributed, transmitted, displayed, or otherwise published in any format, without the prior written permission of the copyright owner.

Disclaimer and Terms of Use: Provided that you maintain all copyright and other notices contained therein, you may download material (one machine readable copy and one print copy per page) for your personal and/or educational non-commercial use only.

The University of the Witwatersrand, Johannesburg, is not responsible for any errors or omissions and excludes any and all liability for any errors in or omissions from the information on the Library website.