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SEDIMENTOLOGICAL INVESTIGATIONS OF GOATCHURCH CAVERN AND SIDCOT SWALLET, BURRINGTON COMBE, SOMERSET

(Somerset O.S. 6in. to 1 mile ST45NE)

by
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ABSTRACT

A series of sediment samples were taken from Goatchurch Cavern and Sidcot Swallet in order to reconstruct the conditions of deposition within the cave systems and also the conditions prevailing in the Burrington Combe area as a whole. Little evidence could be found to suggest any stream-laid sedimentation in Sidcot Swallet and only a discrete deposition of similar stream sediments could be identified in Goatchurch Cavern. It is tentatively considered that Goatchurch Cavern and Sidcot Swallet were connected prior to the downcutting of the West Twin Brook Valley. A new survey is presented of Sidcot Swallet.

INTRODUCTION

Goatchurch Cavern (ST 47585823) and Sidcot Swallet (ST 47575829) are located on the west and east slopes respectively of West Twin Brook Valley of Burrington Combe, Somerset. The small valley stream originates upon Blackdown to the south, which is an Old Red Sandstone-cored pericline conventionally flanked by the Lower Limestone Shales and Avonian Limestone sequence. (Fig. 13).

The Combe has developed in the region of an in-filled pre-Triassic valley, although it is considered (Tratman, 1963) that the main part of the Combe was eroded during the Pleistocene as a result of surface river downcutting. The formation of the Burrington Combe caves is considered by Tratman (1963) to have been associated with this river downcutting, the major cave development being under phreatic or paraphreatic conditions, with little alteration under vadose flow. It is the intention of this paper, therefore, to present a detailed analysis of the remaining sediments in both Goatchurch Cavern and Sidcot Swallet in order to determine the validity of the proposed caves' speleogenesis suggested in parts by Cooper, (1922); Baker, (1924); Browne, (1925); Stride, (1945); Tratman, (1963) and reviewed in part by Drew, (1975). It was the contention, particularly of Tratman (1963), that Sidcot Swallet represented a post-Devensian exhumed lower section of Goatchurch Cavern and, together with other authors (for example, Donovan, 1969), that the various levels of cave passage development were related, at least in part, with the oscillations of a Pleistocene sea-level. It is, therefore, a further aim of this paper to compare the various sedimentary episodes that can be identified in each of the caves and to relate them to the previous speleogenetic ideas summarized by Tratman (1963).

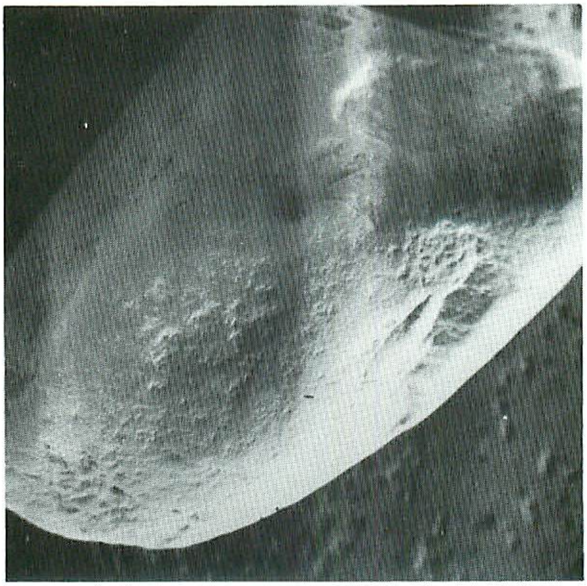

Plate 6.a. quartz particle.

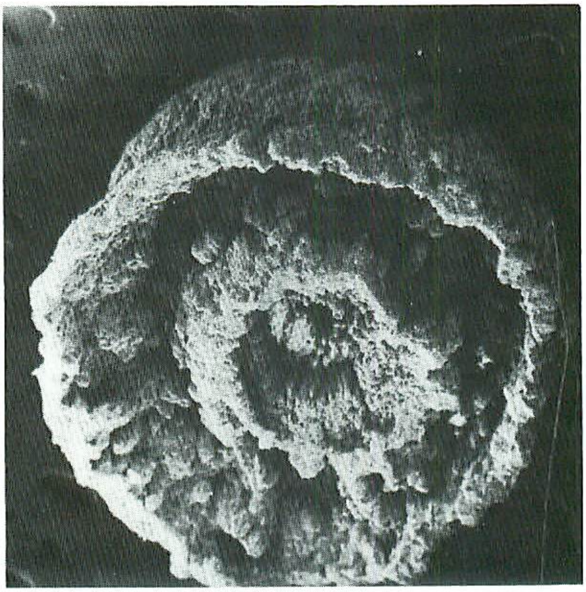

Plate 6.b. Fossil fragment.

The bane of any cave sediment study that attempts to reconstruct the past history of a cave is the lack of record. Often the very sedimentary phase that leads to the deposition of a sediment is responsible for the eventual modification or removal of that sediment. A fluvial cycle may both deposit and erode part, or the whole of a sedimentary layer, indeed the remnant sedimentary episodes left in a cave may represent a record punctuated more with gaps than sediments. Subsequent modification to the cave deposit may rework the material within the cave adding to it deposits, which themselves were reworked elsewhere in the system. The net result is the complete mixing of sediments that were both temporally distinct even within one small cavern, and spatially distant within and without the cave system as a whole. Despite this reworking and the disturbance caused by generations of inquiring scientists, at least since the work of Rutter (1829—see Baker, 1923) and Boyd Dawkins (1865), the sediments in Goatchurch Cavern and Sidcot Swallet can still provide invaluable clues to the origins and provenance of the present cave deposits. This, in turn, may shed a little light upon the origin and age of the caves.

In order to faciltate a detailed analysis of the two caves, accurate plans of the respective systems were required. The plan of Goatchurch Cavern, based on the survey produced by the Mendip Caving Group, provided the necessary framework for the Goatchurch Cavern study, but but the available Sidcot Swallet survey proved too general and often incorrect (produced by Sidcot School Speleological Society in 1938 and added to in 1941 (Stride, 1945)). In consequence, a survey was undertaken by one of us (IC) and the methods of field survey and compilation are presented in Appendix A.

GOATCHURCH CAVERN

The sediments collected in Goatchurch Cavern (Fig. 14) were taken after close inspection of the sample site to ensure that the material was not deposited as spoil by the many investigators who have dug in the cave. Close examination of the internal structures of the sediment bodies that were sampled revealed fine laminations, cross-bedding or other such ordered depositional features that could not be associated with spoil dumping. Many of the sample sites were located in small tubes and rifts which have been undisturbed since initial deposition, and others were located under stalagmite floors or on small ledges and pockets over two metres above floor level. In such positions spoil and human interference was extremely unlikely.

The sediments were collected and returned to the laboratory with detailed sample site specifications which were further supplemented with a comprehensive cave log report. In most cases the samples were dried, sieved (22 standard sieve sizes were employed as recommended by Folk, (1968, p.24) and analysed for for sediment content (less than 63 microns) by means of a Quantimet 720 visual computer analyser). Unsieved fractions of selected samples were analysed further by

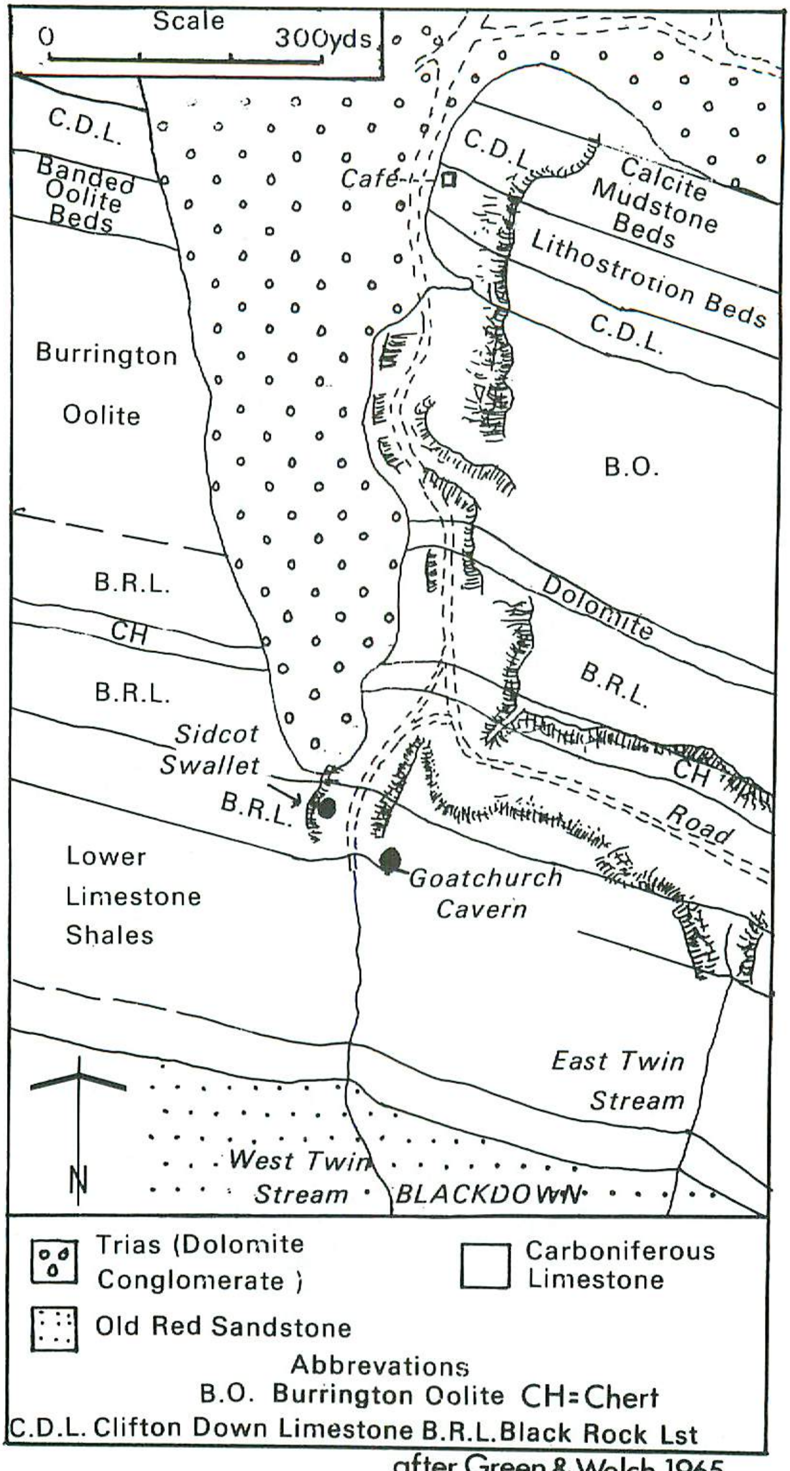

Fig. 13. Geology of Burrington Combe.

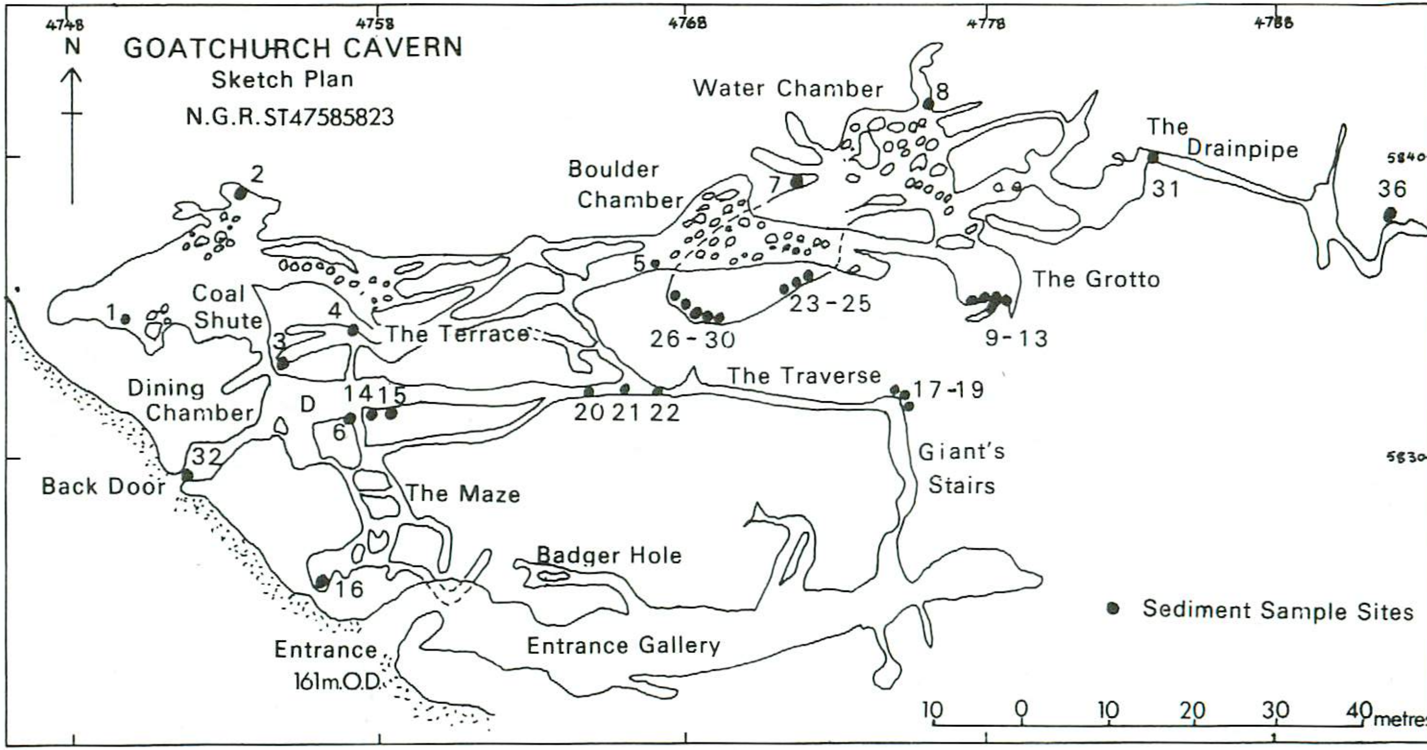

Fig. 14. Sample sites in Goatchurch.

binocular and scanning electron microscopes and the complete fossil assemblage of sieved material over 2mm. was removed by hand and weighed to obtain the fossil fragment percentage by weight. Similar preparation techniques were employed for the samples taken from Sidcot Swallet.

Sediment Grain-Size

The overall size analysis of the various clastic fragments that go together to constitute a sediment deposit is susceptible both to original source sediment size and subsequent transportational stream power. The multiple phases of deposition, erosion and autochthonous dilution to the externally derived sediments produce assemblages which tend to reflect the processes that have gone together to form that sediment. More significantly, the grain size of allochthonous sediments reflects the mechanism of entry and subsequent deposition into the cave. The various sample grain size analyses presented below therefore require interpretation with reference to details of sample site notes and sedimentary log (Appendix B).

The sand-silt-clay triangle presented in Figure 15 reflects the variation in the type of sediment types found in Goatchurch Cavern with the coarsest samples (that is, those with the highest sand-size content) being found in the present-day streamways. All four of the samples containing in excess of 90% sand-sized material were located either in The Final Rift (Fig. 14; 36) or from the small streamway in the Water Chamber (Fig. 14; 23, 24 and 25). It would appear that these samples reflect the present-day winnowing effect of the highly incompetent stream that now occupies the previous streamway, thus resulting in the removal of fine-grained material deeper into the system.

It is of interest to note also, that those samples with sand-sized sediment content less that 70% constitute another discrete areal assemblage. The sediments appear undisturbed from their final depositional attitude and comprise wholly the samples taken from outside the cave, wholly the samples analysed from The Grotto (Fig. 14; 9, 10 and 13) and wholly the samples taken in The Water Chamber in other areas than the current streamway (Fig. 14; 7, 8 and 27). Together with a rather anomalous, well-laminated deposit taken from a high level phreatic tube in the westerly end of The Terrace (Fig. 14; 4), these deposits constitute all of those samples containing less than 70% sand-sized material.

It would appear from the field notes, that the finer grained deposits found in Goatchurch Cavern comprised both autochthonous breakdown of local shale bands which occur within the limestones, together with well-laminated deposits that may represent stream laid, redistributed autochthonous deposits, or equally, stream laid allochthonous deposits of a similar nature to those at present found upon the West Twin Brook Valley. Whether the deposits related to allochthonous input or merely result from redistributed autochthonous shale-derived material will be considered below in the light of lithological, micromorphological and palaeontological evidence presented.

Editor's footnote: autochthonous ("same soil") = derived from the surrounding deposits; allochthonous ("other soil") = derived from deposits elsewhere.

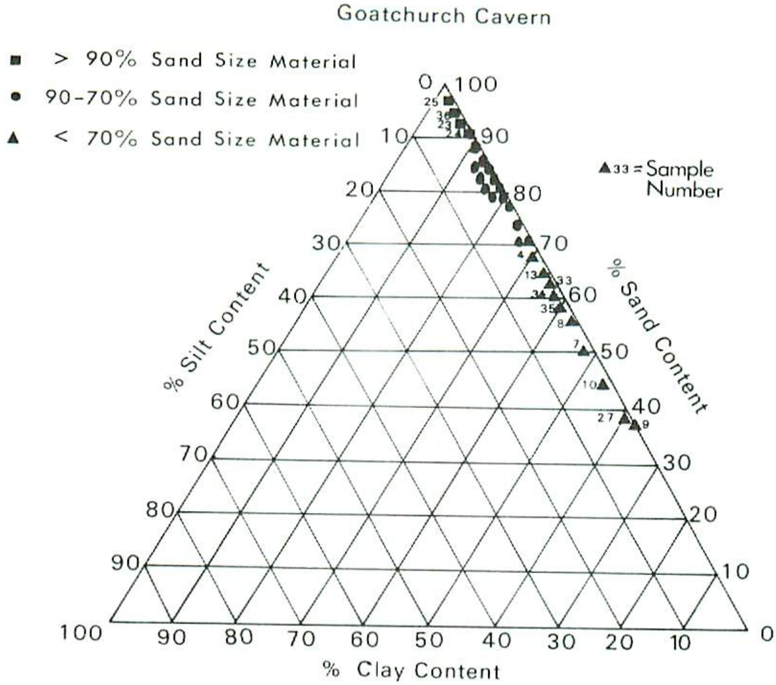

Fig. 15. Sand-silt-clay triangle, Goatchurch.

The remaining sediments analysed from Goatchurch Cavern consist of between 70% and 90% of sand-sized material and have been derived from the upper levels of the cave. The samples within this group include those higher deposits taken from The Traverse (Fig. 14; 17, 18, 19, 20, 21 and 22), a sample from the upper levels of the chamber below The Coal Shute (Fig. 14; 1) and a composite sample from the upper levels of The Maze (Fig. 14; 16). None of these deposits have been derived from small pockets; most are related to breakdown areas or areas considered to be close to the surface hillside (e.g. samples 1 and 16).

A detailed size analysis of the three major sediment groups identified in Goatchurch Cavern (Fig. 5) can be represented by means of summation grade curves for three relatively typical deposits that fall within the limits of each group. The stream-winnowed deposits are typified by the grade curves for sample 24 (Water Chamber, streamway) which shows a median grain size of 0.3mm. (medium sand-sized) and a concentration of sand-sized particles. There is a notable absence of clay and silt-sized particles, taken presumably as a result of winnowing of a previous deposit.

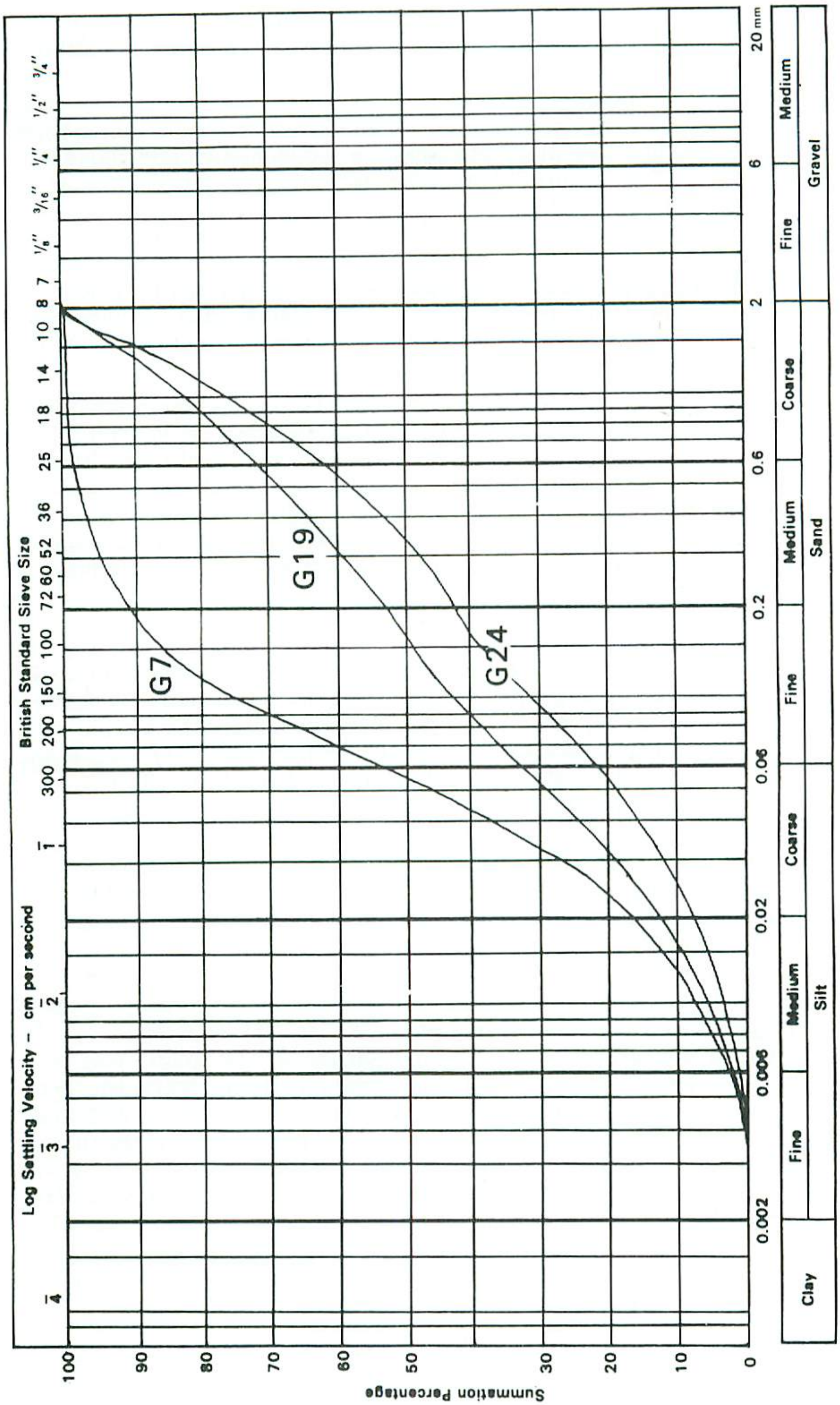

Fig. 16. Summation grade curve.

The summation grade curve (Fig. 16; G7) represents those deposits with predominantly less than 70% sand-sized particles (median 0.06mm, coarse silt), and significantly low percentages of coarser material over 0.2mm in diameter. These deposits have been identified during field sampling to comprise areas of localized autochthonous shale-band breakdown and also areas of successive sedimentation and stalagmite deposition (The Grotto). Whether the obviously stream-laid Grotto sediments represent a subaqueous redeposition of autochthonous deposits or merely a similar grain-size deposition of allochthonous material is at yet uncertain. It must be conceded, however, that a similar grain-sized assemblage could be sedimented out of semi-suspension by a suitable selective, low stream-power flow. Further examination of the micromorphological characteristics and palaeontological content is necessary before determining exact provenance.

A summation grade curve reflecting the general character of the third, "upper-level" deposit (Fig. 16; G19) portrays the general grain-size features of the group. The predominantly sand-sized fraction (median 0.15mm., fine sand-sized) contains a small clay-sized percentage and a generally small silt-sized fraction. There is, however, a high proportion of coarse sand present in the assemblage due in the main, to localised breakdown of both the host limestone and the interbedded shale bands.

Particle Lithology Variation

The general variation in sediment particle composition (or rock-type) depends upon grain-size, sediment provenance and sedimentary processes (both depositional and post-depositional) that have acted upon the grains. For wholly autochthonous deposition host rock-type is the controlling factor of the resultant sediment. For wholly allochthonous deposits a combination of provenance rock type and depositional processes govern the final sediment characteristic. For allochthonous, autochthonous and mixed sediment types (the last is most usual in cave sediments (Bull, *et. al.*, in prep.)). later post-depositional modification processes are perhaps the most important mechanisms of change for "fossil" sediments.

In Goatchurch Cavern much of the sediment has derived from limestone and shale parent-rocks. The angular nature of many particles suggests autochthonous breakdown, whilst the sub-angular, sub-rounded appearance of a small percentage of the grains may well indicate some form of fluvial transportation. It has previously been shown, however, (Bull, 1976) that autochthonous limestone and shale breakdown in caves can adopt a sub-rounded habit almost at the time of deposition, if not as an inherent characteristic of the breakdown. However, truly exotic particles do not exist in Goatchurch Cavern, although the percentage weight of these samples studied is very low (less than 0.5% in all cases, but see also the work of Browne, 1925, presented below in the discussion and conclusions). It is this allochthonous fraction that can indicate provenance.

Quartz particles, both sand-sized and clay-sized can be found in small amounts in Goatchurch Cavern. Detailed analysis of the host limestone by scanning electron microscope and electron probe analysis has revealed very little quartz in relevant-sized particle form and it can be assumed therefore that much of this fraction is allochthonous. It is significant to note that only eight samples taken from Goatchurch Cavern contain quartz, five are in the active streamways Fig. 14; 23, 24, 25 and 28, all from The Water Chamber and 36 from The Final Rift), and three are what have tentatively been suggested by Tratman (1963) as being of a soliflucted origin (1, 13 and 16). The discrete occurrence of quartz particles, particularly in these latter deposits would tend to suggest an external origin for the deposits, especially as the samples can be seen to be a one-phase deposition rather than a multiphase laminated sedimentation. These findings would tend to corroborate Tratman's original postulation. The active streamway samples may well have concentrated originally low percentages of quartz into a more concentrated form by later winnowing of cave deposits, although the quartz may have been subsequently introduced by surface-fed streams in a relatively recent period.

The well rounded nature of the sand-sized quartz particles (Plate 6.a) can be considered to be the product of a previous sedimentary cycle. It is likely that the quartz has been introduced into the cave by streams derived from Blackdown to the south which originate upon Old Red Sandstone. Although the quartz may have been derived from a once more widely spread Triassic deposit, the micromorphological markings upon the quartz grains suggest a quiet fluvial regime akin to the conditions of the Old Red Sandstone. Previous work on the Old Red Sandstone of South Wales (Bull, 1975) supports this suggestion.

The finer grained, clay-sized quartz particles found in small percentages in the deposits of Goatchurch Cavern appear to represent small quartz cleavage plate rock flow derivatives as portrayed, for instance by Neiter and Krinsley, (1976); Bull, (1976); Krinsley and Smalley, (1973) and Smalley, Krinsley and Vita-Finzi, (1973). These quartz cleavage plates represent the small-scale breakdown products of more substantial mechanical erosion acting upon the sand grains. Accumulations of these minute quartz particles can be termed rock flour or, more specifically quartz-flour (Rouse and Farhan, 1976). The small percentage of fine quartz suggests that the material is not loessic in origin. Furthermore it is not possible to reconstruct the surface palaeoclimate at the time of deposition of these "fines" in the cave from quartz surface feature morphology studies. However, it may be inferred that no glacial or concentrated periglacial quartz deposits are at present to be found in the cave. Whether the surface derived material originally comprised little or no quartz, (which is a common product both of Old Red Sandstone periglacial weathering and of glacial deposition) is uncertain. Equally, the high quartz-content material could have been subsequently removed from the cave. It may be considered here that the former alternative is more plausible and this would then infer deposition in Goatchurch Cavern predominantly from a non-glacial source material. Periglacial derived debris must also have been of a minimum.

Fossil Content

Goatchurch Cavern has developed within the highly fossiliferous Black Rock Limestone, a little above the Lower Limestone Shales, and in consequence much of the coarse fraction of the cave deposits contains autochthonously derived fossil fragments from the Black Rock Limestone. In order to determine a measure of autochthonous breakdown, even within the redeposited sediments in the cave, each of the fossil fragments (largely crinoid ossicles or brachiopod fragments) were carefully removed by hand from the coarse fraction (greater than 2mm.) of each sample taken from Goatchurch Cavern (Plate 6.b).

In nature, the separation of the fossil fragments from the host limestone took place by gentle solution of the limestone, leaving the silicified fossil fragment protuding from the rock. (Green and Welch (1965) have presented field data relating to the silicification of the Black Rock Limestone although little mention is made of the differential silicification of the fossil fragments in bioclastic limestones). Subsequent removal by one of a number of processes resulted in the deposition of the fragments into the sediment body.

Since all of Goatchurch Cavern (and indeed, Sidcot Swallet) is developed within the same highly fossiliferous limestone, it should be possible to determine an average fossil-debris content by carefully monitoring extreme, discrete site anomalies. Indeed, the average fossil-debris content for all the samples taken in Goatchurch Cavern and also from nearby surface localities approximated 7% by weight. Local anomalies to this general value, however, proved the most informative since the fossil-debris content in the upper series of the cave (that is, The Traverse and above) averaged 1.7% whilst the lower series averaged 9.25% fossil fragments in that part of the deposit greater than 2mm. in diameter. Further, of those samples taken from above 2 metres above the cave floor only 1.7% fossil fraction could be found. This contrasts with 7.0% fossil fraction previously mentioned for the cave as a whole. Clearly, there appears to be a process by which concentrations of criniod and brachiopod silicified fragments can accumulate in areas of the cave, other than in those places fed by a high anomalous concentration in their host limestone. Since the lower limits of fossil content, even in the finest grained samples, rarely falls below 1.5% by weight (exceptions being in areas of direct autochthonous shale band breakdown which is itself devoid of fossils), it can be supposed that this represents at least the lower limits (perhaps the 'normal' average) of fossil-debris input by autochthonous processes. Any large increase in concentration may then suggest a resorting within the cave system, especially since the average fossil-debris found in the coarse fraction of the surface samples (samples 32-35) grouped closely around the mean 1.7% by weight value.

The distinct areal variation in fossil-debris can be explained as being the consequence of the very process by which it originated. Slow phreatic solution of the matrix limestone would leave the silicified fossil fragments protruding. Subsequent vadose action would remove the protruding fossils concentrating them within streamways. The percentage of fossil-debris within the coarse fraction would then be a function of the surface area of limestone within a cavern, the percentage of silicified fossil fragments within the host limestone and the degree of subsequent winnowing and resorting of the deposit as a whole. The latter variable is the most important in the understanding of the caves' sedimentary history and it will be seen in a following section that this autochthonous fossil-debris input represents a distinct phase in the sequence of sedimentation in Goatchurch Cavern.

SIDCOT SWALLET

Sediments collected from Sidcot Swallet (Fig. 17) were prepared and analysed in a similar manner as is described above for the sediments taken from Goatchurch Cavern. Similar precautionary measures were taken to avoid the risk of sampling disturbed material, however, the sampling procedure was less problematical than in Goatchurch Cavern as many of the sample sites were sealed with flowstone or located in extremely small fissures. The tight nature of the entrance to Paradise (see Fig. 19) prevented one of us (PB) from taking part in the field sampling or survey reconnaissance work of that part of the cave.

Sediment Grain Size

Twelve samples were taken from Sidcot Swallet and from the area around the cave (Fig. 17), generally in areas of concentrated deposition. Three samples were taken from the Parallel Face Chamber in order to assess any temporal variation in conditions of sedimentation between successive periods of flowstone deposition, and a further sample was taken from the Boulder Chamber which, surprisingly, contains very little sedimentation even on ledges or in high level pockets. Further samples collected below The Lobster Pot and in Paradise were taken carefully in order to avoid the Terminal Dig spoil which is generally spread about the lower regions of the cave.

The sediment character of the samples taken from Sidcot Swallet (Fig. 18) show a low percentage of clay-sized fragments (less than 0.5% per sample) but, compared with the Goatchurch Cavern sediments, a relatively high percentage of silt-sized sediment (Fig. 17; 1, 3, 4, 10, 11 and 12 all contain in excess of 55% silt-sized sediment). Samples exhibiting low silt and clay-sized material can also be found in the same area as those of high silt-sized sediment. Samples 4 and 5 (located on Fig. 17) show a large difference in sediment character (Fig. 18), although they originated in close proximity to each other. This contrast reflects the different variations in overall sediment grain size that can be produced by the addition of autochthonous shale band breakdown into a

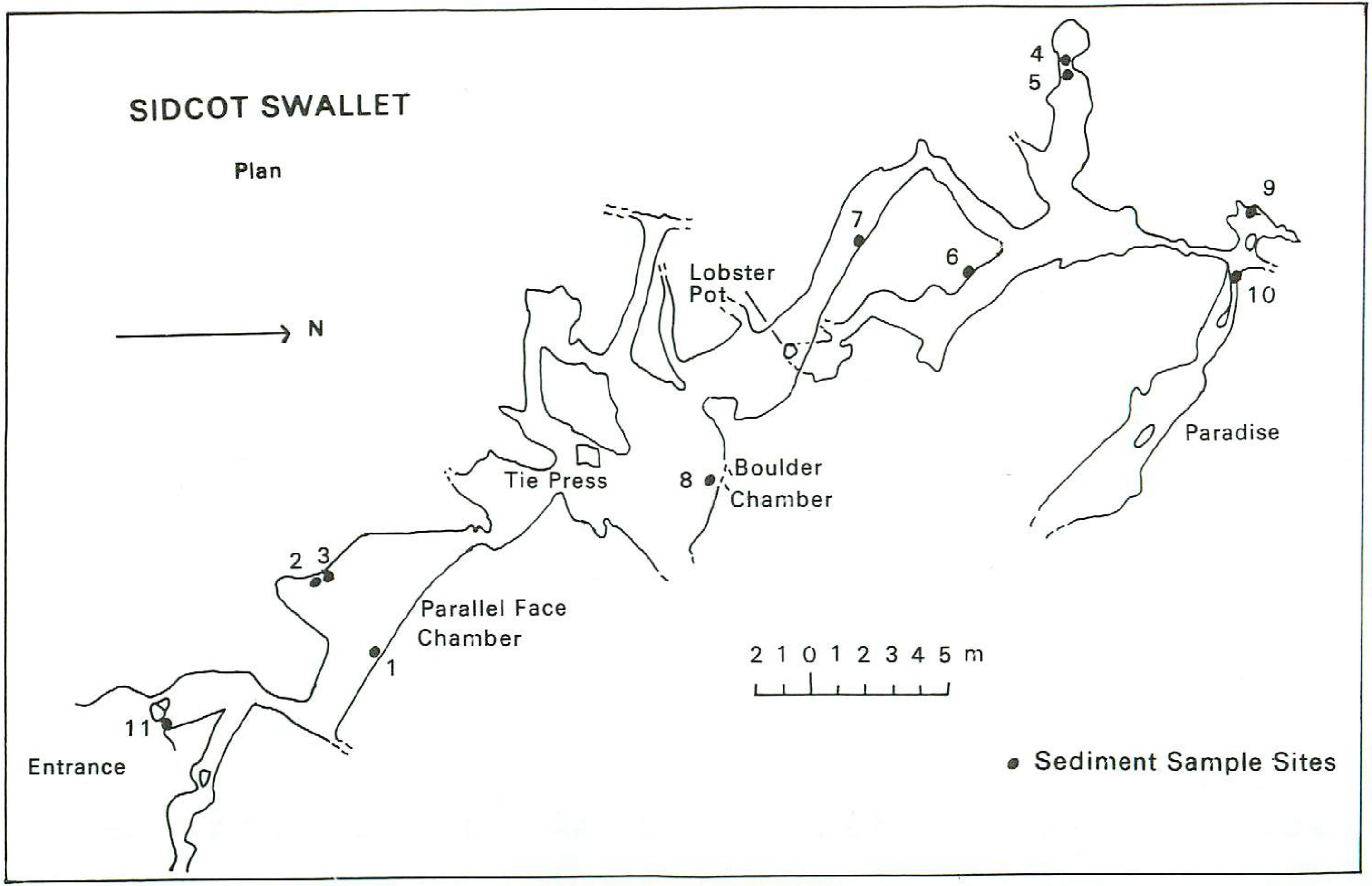

Fig. 17. Sample sites in Sidcot.

deposit. Unlike Goatchurch Cavern much of the sediment in Sidcot Swallet has been preserved within a stalagmite layer, thus preventing much post-depositional modification from taking place.

None of the samples collected exhibited any internal lamination or apparent arrangement of sediments. It can therefore be concluded that the deposits, although laid down by gentle moving water, did not have a source that pulsed the sediment into a standing body of water in response to external macro-scale events. In comparison to the pulsed nature of deposition in Goatchurch Cavern, Sidcot Swallet sedimentation appeared to have been more homogeneous, alternating with flowstone deposition.

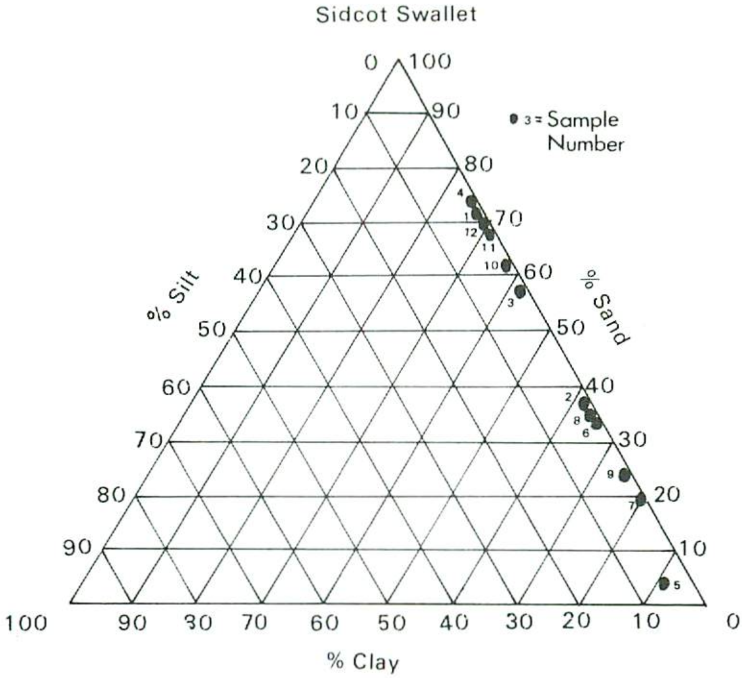

Fig. 18. Sand-silt-clay triangle, Sidcot.

Particle Lithology Variation

The sedimentary particles visually examined from Sidcot Swallet contained no quartz fragments of any size. The absence of such material is taken to indicate the lack of stream-laid allochthonous sand-sized particles that have been identified both from Goatchurch Cavern and from the surface sediments in West Twin Brook Valley. Samples 1, 2, 3, 4 and 5 (Fig. 4) contained larger fragments of autochthonously derived limestone and shale fragments while the other samples contained surprisingly few larger particles. It would therefore appear that autochthonous breakdown does not occur throughout the complete size range

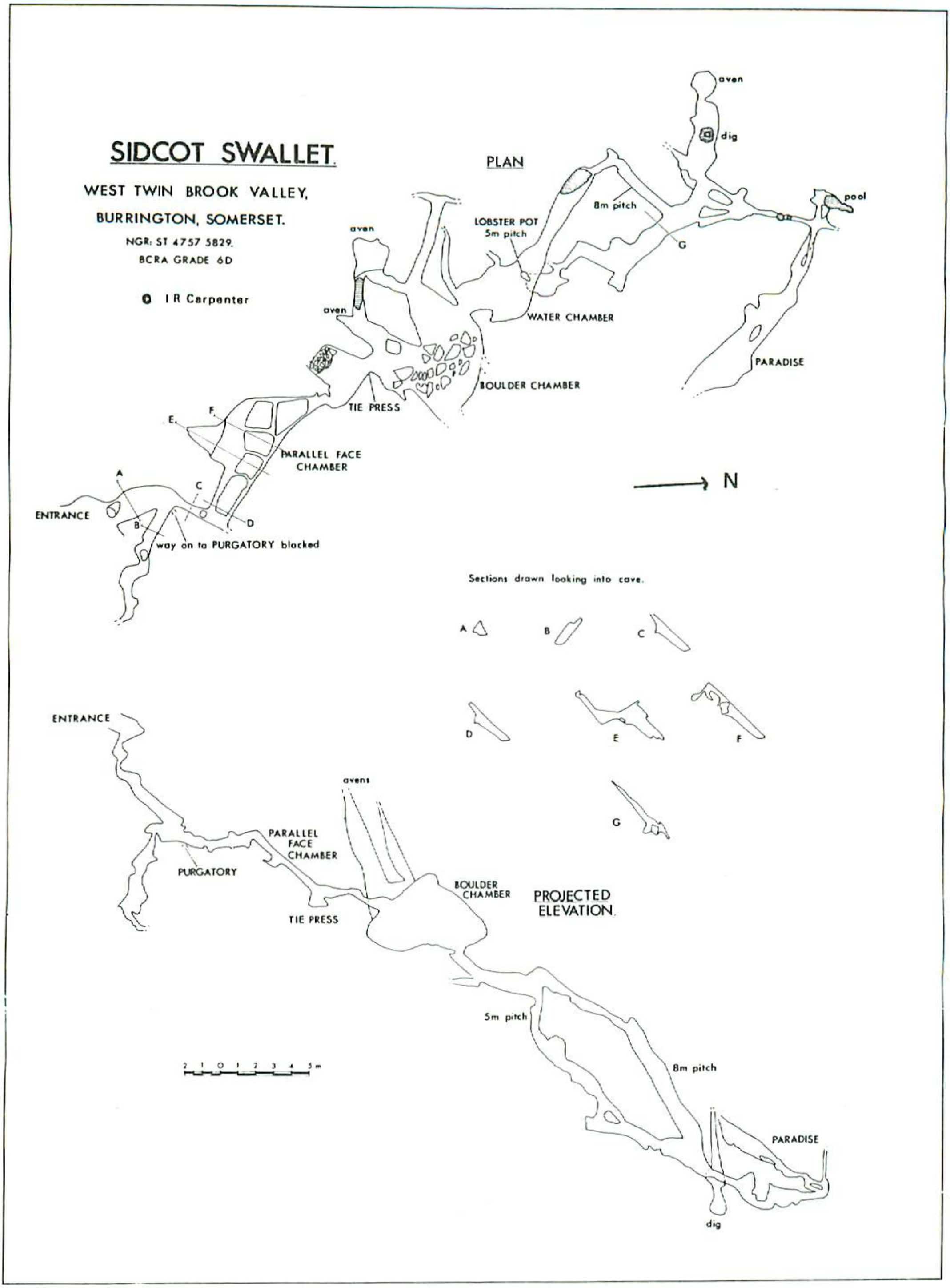

Fig. 19. Survey of Sidcot Swallet.

in Sidcot Swallet. The large boulders and slabs that can be seen in the cave relate to a slab or block breakdown phase that would produce little associated fine-grained debris. Such a discrepancy between the Goatchurch Cavern autochthonous breakdown and that of Sidcot Swallet is thought to be a function of local lithological variation, perhaps the degree of local silicification of the limestone (although the two caves are developed within the same beds) and, or, the process of post-depositional erosion and removal of the fine-grained sediment debris. The latter alternative would, however, then seem to contradict the very presence of finer grained sediments in Sidcot Swallet than in Goatchurch Cavern.

Fossil Content

The ten samples taken from Sidcot Swallet contained less than 0.1% by weight fossil-debris in the coarse fraction. The almost total absence of fossil-debris in a cave that presently exhibits protruding silicified fossil fragments throughout its length, must suggest a process variation between Sidcot Swallet and Goatchurch Cavern. The lack of vadose action in Sidcot Swallet, following phreatic or para-phreatic solution in the cave, may explain the lack of fossil debris in the sediment fractions, assuming that such action occurred in the higher Goatchurch Cavern. Significantly, the two samples taken from the surface in the region of Sidcot Swallet (samples 11 and 12) contained an average of 1.9% fossil-debris, in similarity both with the surface samples above Goatchurch Cavern and the upper levels of that cave. Although it is possible that less solutional activity of the limestone may have prevented fossil fragments from falling off in such large numbers as in Goatchurch Cavern, it must be noted that Sidcot Swallet was formed at a lower level than Goatchurch Cavern, and was likely, therefore, to have remained phreatic for a comparatively longer period of time. (The Old Entrance in Goatchurch Cavern is at 162m. O.D. and the bottom, The Drainpipe, is a 153m. O.D. whilst the Sidcot Swallet entrance is at 143m. O.D. and the bottom at 117m. O.D.) The question still remains, however, as to the present whereabouts of the silicified debris that must have resulted from the initial solutional enlargement of the cave.

It may be suggested that this material was washed deeper into the cave together with the fine sediments winnowed from the autochthonous deposits. This would then imply a relatively large system beyond the present cave limits, in order to facilitate both drainage of water and a suitable deposition area for the sediment. Unfortunately, such vadose flow would erode the fine, protruding silicified fossil fragments causing accumulations of the debris at the onset of flow decrease or ponding. The overall absence of fossil fragments in the Sidcot Swallet deposits remains, then, a puzzling anomaly.

DISCUSSION AND CONCLUSIONS

The general sediment analyses of both Goatchurch Cavern and Sidcot Swallet are similar although specific differences between the deposits allow separate depositional histories to be put forward for each cave. It must be remembered, however, that the patchy nature of the undisturbed deposits prevents detailed events from being identified through any period of time, particularly in Goatchurch Cavern where excavations for bones and shells have been undertaken as far back as 1829 (Baker, 1924, reporting on the work of Rutter). Indeed, Browne (1925) reports on the removal of *12 tons* of earth and stone from The Traverse and remarks on the general paucity of shells and rodent remains. Fortunately a record was made of the general lithological and morphological features of the gravels and coarse deposits from The Traverse and this is in part reproduced with modifications below (Table 4) (modified from Browne, 1925, p. 130).

TABLE 4 Analysis of samples from a trench in The Traverse

	1st ft.	2nd ft.	3rd ft.	4th ft.	5th ft.
Rounded	8.0	3.4	3.2	2.5	2.6
Sub-Angular	67.5	82.6	80.6	75.2	44.4
Angular	24.5	14.0	16.2	22.3	53.0
Old Red Sandstone	92.4	96.8	85.0	69.2	54.9
Shales	4.0	2.0	1.8	0.3	1.2
Chert	0.4	0.3	—	—	—
Stalagmite	1.0	0.6	11.0	19.5	19.9
Limestone	1.0	—	1.2	11.0	23.6
Silicified fossils	0.8	0.3	1.0	—	0.2

(figures in columns represent percentages)

It is immediately apparent from Table 4 that little of the gravel content was of autochthonous origin, nor was it extensively rounded. The vast amount of gravel derived from the Old Red Sandstone of Blackdown entered the cave during a considerable phase of vadose stream action. Initial deposition within The Traverse reflected the removal of broken stalagmite, flowstone deposition and limestone elsewhere in the cave and the subsequent accumulation of predominantly autochthonous gravels, in response to a check in the stream flow, perhaps due to the flooding of the cave below The Traverse. The low percentage of silicified fossil fragments would further support the contention of rapid autochthonous-derived material although it may equally reflect a bias in sampling techniques of only the very largest fossil fragments.

Breakdown and accumulation of flowstone and limestone fragments in the earlier depositional history of the stream in The Traverse may tend to suggest stream flow preceding a cold phase. Tratman (1963) has shown that the present air circulation within the cave would suggest the ability of freeze-thaw within the passages, indeed this would seem likely if the stream had flowed from The Giant's Stairs and The Entrance Chamber where breakdown from freeze-thaw would be at a maximum.

The presence of a stream of such power would explain not only the deposition of vast quantities of gravel in The Traverse but also the erosion and subsequent downstream transportation of the silicified fossil fragments. It has been shown above that high percentages of fossil fragments can, at present, be found in association with stream action and it can therefore be suggested that the increase in fossil fragments in the area of the cave below The Traverse is a response to the stream action that deposited material in the upper levels of the cave. Further, if the stream that flowed in The Terrace swept fossil fragments on into the cave system, the absence of fossil-debris in Sidcot Swallet would either suggest that a direct link did not exist bewteen Goatchurch Cavern and Sidcot Swallet, at least enabling vadose flow between the two caves, or that a link may have existed, but the fossil fragments and other coarse stream debris were prevented from being carried through the whole system by ponding back of water. Phreatic or para-phreatic conditions would then check any coarse bedload movement between the caves, and this would explain also, both the anomalously low fossil content in the Sidcot Swallet sediments and the non-eroding, protruding siliceous fossil fragments still present in the host limestone.

It is of interest to note that this present study has found quartz particles (or Old Red Sandstone fragments) only in discrete areas of the cave, whilst the gravel studies (Browne, 19?5, here presented as Table 4) have shown high percentages of this material. It would appear that this gravel sequence examined in The Trave e provided the last remaining clues to the more ancient vadose action in Goatchurch Cavern, whilst the significance in the quartz particles identified in this present study would reflect perhaps more a solifluction debris than fluvial action. It would seem, therefore, that the previously suggested solifluction deposits (Tratman, 1963) in the Back Door (or New Entrance) and The Grotto would hold true in the light of this study, together perhaps, with a further soliflucted deposit in The Maze.

Present-day fluvial action is responsible for the coarse debris in The Final Rift. The quartz content in the gravels would then reflect deposition by a stream, itself derived from the surface, although from a different direction to the more ancient stream.

The lack of sedimentation, at least of the coarser debris, in that portion of the cave below The Traverse may then reflect ponding back of water during the period of deposition of the allochthonous sedimentation. This would have been most active immediately after a freeze-thaw period, laying down deposits from vadose action in The Traverse and most likely in the Entrance Chamber. It may be considered then, that the sediments in The Traverse were continually deposited in a relatively short period of time and probably not the result of redeposition from the Entrance Chamber deposits since the temporal and lithological variations in The Traverse appear too constant to represent resorted materials. Prior to this gravel deposition, Goatchurch Cavern and Sidcot Swallet were fully developed with no coarse sediment, the fine grained sediments derived from insoluble shale and limestone residue or from weathered replacement of the limestone itself (Monroe, 1974). Selected accumulations of siliceous fossil fragments and other insoluble residues may well have occurred, perhaps later to be removed by the initial influx of a stream which eventually ponded up causing the localized deposition of gravels in The Traverse. High level sedimentation, for the most part laminated, would then have resulted from the ponding of water further up The Giant's Stairs. One such episode would account for deposition at all levels, explaining both the fine grained nature of this deposition and the general paucity of fossil fragments whether they be derived in part or in whole from transportational rather than *in situ* deposition.

Following this relatively wet phase, little sedimentation has occurred, in consequence of downcutting and abandonment of Goatchurch Cavern and the isolation of Sidcot Swallet with no major vadose sedimentation. The lack of this stream-laid material in Sidcot Swallet would then be explained by the relatively low powered West Twin Brook Stream and also reflect the absence of much debris on the surface at this time. Earlier, during vadose action in Goatchurch, much periglacially derived material would have accumulated upon Blackdown eventually to be washed into the cave or further downstream into Burrington Combe.

Subsequent to this downcutting, cave sedimentation in both Sidcot Swallet and Goatchurch Cavern had been minimal, although soliflucted materials in Goatchurch would indicate a further cold spell post-dating The Traverse gravel deposition. Predominant sedimentation processes have, in more recent times, been confined to small scale resorting, redistributing and a larger scale allochthonous breakdown of the shale bands within the host limestone.

Significantly, major erosion has occurred only in the last two hundred years with the advent of scientific investigations. It is of great importance that Browne (1925) published the data relating to gravel contents in The Traverse, otherwise this present study, already incomplete due to the patchy nature of the record, would have been unable to attempt an explanation of the pattern of sediments either in Goatchurch Cavern or Sidcot Swallet. Professor Tratman has clearly pointed out (pers. comm.) that in order to determine the record of events in a cave, very often it is necessary to remove, and hence, destroy that same record. It is imperative, therefore, to publish results, no matter how unimportant at the time, in order that future studies might benefit.

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APPENDIX A

SIDCOT SWALLET SURVEY

The survey (Fig. 19) was undertaken by one of us (IC) in order to obtain a large-scale, accurate survey of Sidcot Swallet, the framework of which could be used to produce more detailed spelaeological work. Initial surveying set up fifty-two primary stations by means of a Suunto compass (KB-14/360R), both forwards and backwards in an attempt to eliminate gross error. Clinometer readings (using a Suunto PM-5/360PC) were also taken in both directions. If, when calculating the primary survey, any gross errors were detected, that part of the cave was re-surveyed until the gross error was found and corrected. Detail was then added to the framework after a further, second stage survey.

The survey, complying with the B.C.R.A. grade 6D (Judson, 1974), minimised error by ensuring good intervisibility between stations and by careful elimination of gross error, achieved by independently recording results at all stages of the survey. The awkward shape of Sidcot Swallet, and the restricted, deeply sloping bedding, necessitated the use of tape, clinometer and compass alone, enabling readings to be taken to one half degree and measurements to the nearest centimetre. The resultant plan and projected elevation of the cave (Fig. 19) varied quite considerably from the Bristol Exploration Club survey (1972) and includes, for the first time, a survey of the tight Paradise section of the cave.

APPENDIX B

CAVE SEDIMENT SAMPLE SITES

GOATCHURCH CAVERN

Sample No. (Prefix G)	Comments
1.	Extensive fill in all cavities. Site of dig.
2.	Floor of dig. Sandy sediment.
3.	Protected floor of dig.
4.	Very good site. Fill from cracks in small phreatic tube, 15cm. diameter. Very little coarse material.
5.	Boulder Chamber. Fill in small phreatic tube. Wet. (2 different colours present on drying—lab. note)
6.	From small streamway.
7.	From small intermittent stream.
8.	Silty. Dry, undisturbed 2 metres up. Large scale deposit.
9.	Material from under stal. floor. Undisturbed.
10.	Material above stal. floor. Coarser than G9?
11.	Loose rock, undisturbed, in small chamber.
12.	As G11 with remnants of flowstone.
13.	Sediment under G11 and G12. Undisturbed.
14.	Sediment from dry pool 3m. above streamway.
15.	Sediment from wet pool 3m. above streamway.
16.	Terminal Dig.
17.	V. suspicious dig. Caked dig spoil?
18.	Cave earth? Loose scrapings from wall deposit 3m. up.
19.	As G18 in fissure 2m. up.

Sample No. (Prefix G)	Comments
20.	Well consolidated deposit 3m. above floor.
21.	Coarse deposit in 7cm. fissure, 3m. above floor.
22.	From Trat's archeol. Dig on floor.
23.	Revisited Water Chamber deposit. From stream pool.
24.	W. Chamber. Isolated pool in recess (first pool in cave wall up from small waterfall drop (12cm.)).
25.	Cave earth. Unconsolidated. 1m. above stream in narrow cleft. Dry. 2.5m. from G24. Undisturbed, up to 3cm. thick. Fossil-rich rock above. Source?
26.	2m. high. Coarse cave earth. Good site.
27.	Crack, not cylindrical. Behind jammed boulder. Fine. (from tight rift to Boulder Chamber 1.5m. above floor, 10m. from rift).
28.	Cave earth under stal. 4m. above streambed. A source of stream debris? Choke deposit 1m. thick. Pool site (G6) 8m. downstream. Angled in fissure up to 15cm. wide.
29.	Layered limey mudstone deposit.

30. Cave earth? Weathering *in situ* from clayey band. 1.5m. above floor of Water Chamber. Dry.
31. Entrance to Drainpipe floor. Relatively recent deposit?
32. Entrance sediment.
33-35. Surface sediments above Goatchurch Cavern.
36. Final Rift deposit.

SIDCOT SWALLET

Sample No. (Prefix SS) — Comments

1. Surface sediment sample in Parallel Face Chamber.
2. Sample from below small stal. floor. Undisturbed.
3. Sample near SS2 stal. absent. Undisturbed.
4. Below false floor. Structureless. 5cm. thick.
5. Below SS4. Cave earth? Contains angular fragments of calcite?
6. Sediment below Lobster Pot. Undisturbed. Contains birdseye structuring.
7. Composite sample of deposit 40cm. thick below stal.
8. Sediment under flowstone above dig at bottom of aven.
9. From small phreatic pocket.
10. From phreatic tube 2.25m. above floor. Yellow in colour and coarse in texture.
11. Outside entrance to Sidcot Swallet.
12. On top of hill above cave. West slopes of West Twin Brook Valley. On Black Rock Limestone Group.