The International Journal of Nautical Archaeology and Underwater Exploration (1985), **14**.4: 275–299

Sea Venture: A second interim report—part 1

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Introduction

Part 1 of this report is concerned with various aspects of the excavation carried out on the wreck of the *Sea Venture*, lost in 1609 off St. Georges Island, Bermuda (Fig. 1). In particular; the excavation techniques used, and the results of the preliminary hull surveys, carried out between November 1982 and November 1983. Various classes of material recovered during the excavation will be discussed and illustrated in part 2; currently in preparation.

The results of the previous phase of work, carried out by a team led by Allan Wingood on behalf of Bermuda Maritime Museum, were discussed in the first interim report (*IJNA* 1982, **11**.4: 333–347). It succeeded in establishing the identity of the wreck beyond any reasonable doubt, and with the security resulting from the formation of the Sea Venture Trust, a long-term view could be brought to bear on the excavation, conservation, study, and display of the material from the site.

Much of the remaining integral structure of the ship has been uncovered at one time or another by various workers since its discovery by Edmund Downing in 1958. In contrast to other wrecks 'worked' only for their contents, *Sea Venture's* hull was recognised as being

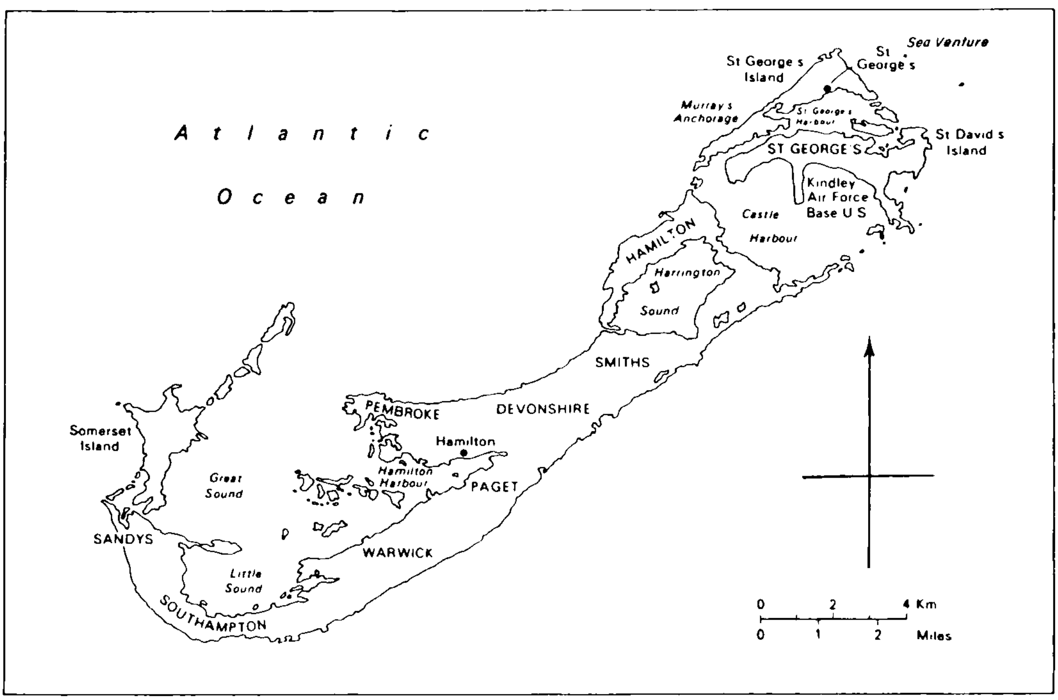

Figure 1. Map of Bermuda, showing approximate position of wreck site on Sea Venture Flat.

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important in its own right. What remains is a small percentage of the whole, and in other circumstances her timbers might have been ignored or even destroyed.

Luckily *Sea Venture* has proved to be no ordinary ship. When she left Plymouth in 1609, she embodied not only the hopes and aspirations of her passengers bound for the New World, but the commercial interests of their sponsors, 'The Virginia Company of London', the colonial aspirations of England, and most urgently, the desperation of those who were starving in the failing colony of Jamestown.

If her previous history is obscure[1], her last voyage by contrast was vividly documented. In the first interim report (Wingood, 1982) the story is recounted in more detail, based on the two most detailed first hand accounts by William Strachey and Silvanus Jourdan. They describe the desperate fight to stay afloat in what developed into a hurricane of appalling violence. That they survived for four days, sighting land when on the point of sinking, is the stuff of legend. The more so as that land was the dreaded Bermudas, supposedly inhabited only by demons and evil spirits. Miraculously all 150 people were landed safely and thrived for the ten months it took to construct two vessels in which to continue their journey to Jamestown. If it was the end of their adventures, it was a new beginning for Bermuda, because two men who stayed behind give *Sea Venture's* arrival the added significance of starting the permanent habitation of the islands.

It was probably Strachey's account of this incredible 'Wreck and Redemption' that either directly inspired, or at least aided William Shakespeare's writing of *The Tempest*[2].

It is not often that a shipwreck, or any archaeological site has quite such extraordinary strength of historical association, in addition to, but distinct from archaeological importance. To a considerable degree the former spotlights the latter, and in this case it has acted as a safeguard for the wrecksite as a whole, and the hull in particular. The detailed survey of these timbers became the priority of the 1982 season.

Excavation strategy

The priority of hull survey was based, as stated above, on the assumption that the major part of the surviving structure had been exposed at one time or another and that most of the associated deposit had been investigated in the process. The importance of detailed recording of the hull remains was obvious. Allan Wingood suspected that much of the deposit outboard had not been disturbed. This was to be left untouched initially, not only because of the stated priority but because at the time we were not equipped to deal with large quantities of finds. Excavation was only to be carried out where absolutely necessary in order to expose the structure for recording.

The initial aim was to produce a plan survey, and to this end loose sand and ballast was removed to expose the upper surface of the timbers. However, when this level was reduced to clean between the frames, it became apparent that in many places considerable pockets of undisturbed material remained. This material was easy to distinguish: where a space had been previously dug, a homogenous mix of coral sand and ballast pebbles could be followed all the way down to the outer hull planking. Unexcavated material in contrast was much more compact, contained a higher proportion of shingle and appeared to be much more organic in colour and texture.

This unexpected bonus necessitated a careful reappraisal. Excavation, as opposed to merely dredging away backfill, would require far more time, and necessitate adequate storage and conservation facilities. It was decided these should be provided, and that survey would be continued alongside the other aspects of excavation in a more comprehensive investigation. As a result, the plan shown in Fig. 2. is not comprehensive and will be augmented in due course.

Stratigraphy and excavation technique

Apart from removal of backfill to expose the hull where possible, work began outboard to establish the best excavation methods for the undisturbed areas.

The surface material, (layer 1) is white coral sand. It becomes grey below the top 25 mm, possibly due to non-oxidisation of organic material, for when left exposed it turns white after a few hours. Below the top 50–100 mm the sand contains shell, ballast pebbles, a few pottery sherds and eroded wood fragments (layer 2). It is only slightly less mobile than the

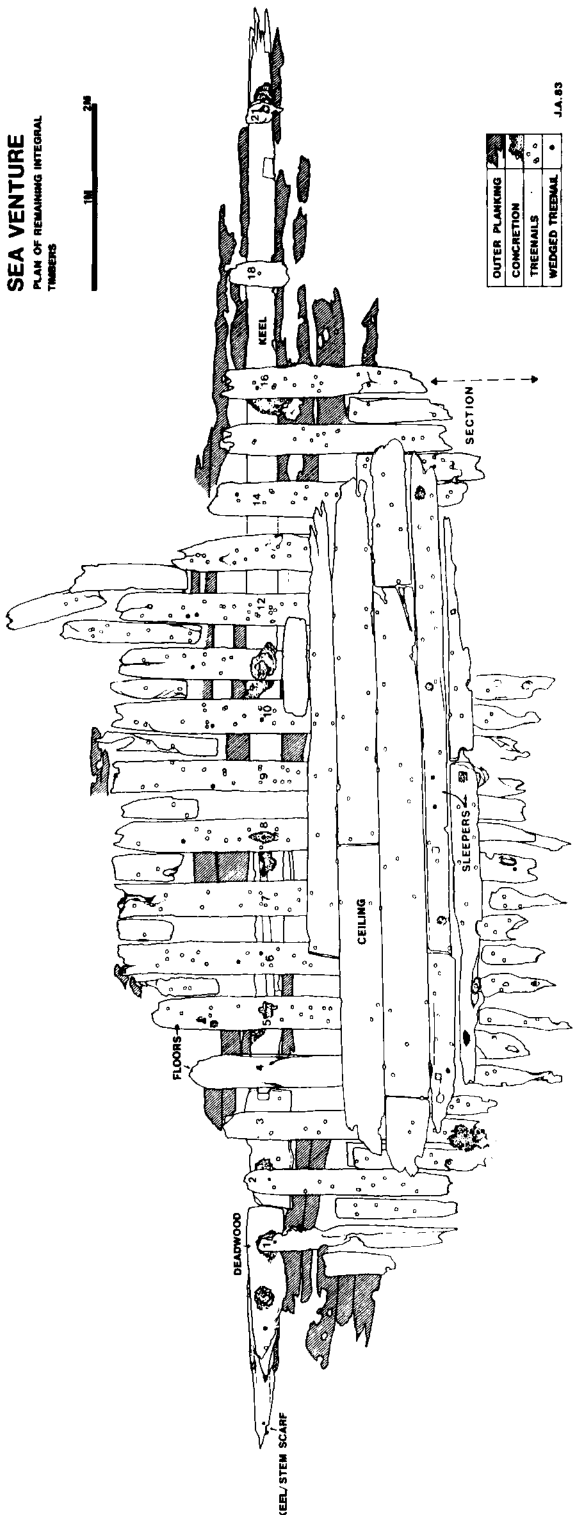

Figure 2. This plan of the integral timbers includes those elements that are close to their original position. Collapsed elements exposed by recent excavation will be added to the final version.

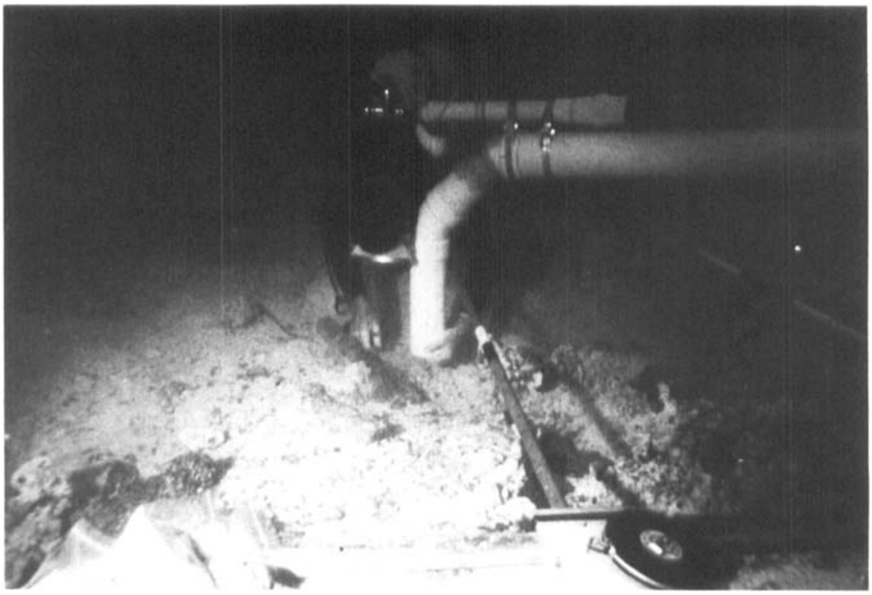

Figure 3. A diver excavating outboard the port side. Supported by the poles he is held off the deposit and holds the dredge just close enough to remove light spoil.

sand above and has probably been disturbed relatively recently. The third layer marks the beginning of undisturbed material. It is more compact and able to hold a vertical section. The component materials are similar to the layer above except that the sand is lighter in colour, finer in texture, and clay-like, possibly due to organic inclusion. Timber within this layer was better preserved, and pottery sherds showed little abrasion.

This immediate evidence of a stratigraphic sequence, however simple, necessitated an excavation procedure that exceeded merely sifting through mobile sand and ballast. Nor could it be indiscriminately sucked up an airlift into a sieve, to the detriment of organic material and to relationships between finds. The technique that has proved most thorough is the use of a water suction dredge, neutrally buoyant and at low power; just sufficient to lift ballast pebbles. It is not used as a digging tool but only to remove spoil. This allows methodical work over an area or against a section. The maxim is that if at any time the excavator does not know exactly what is going up the dredge, then the rate of work is too fast. Tools used, apart from hands, are 1–2 in paint brushes, trowels, and dental picks. Paint brushes are by far the most useful, reducing the silt and sand content of a deposit without destroying its cohesion. Hand fanning, an established technique with many advantages, and discussed in detail by Keith Muckelroy (*Maritime Archaeology* 1978: 49–50), is not as effective in this case. Even the most gentle hand fanning was found to cause disturbance of the material in a way that was uncontrollable. The result was a constant layer of loose material, mostly small ballast pebbles, that obscured what was *in situ* below or behind it. In this situation small objects are harder to see, fragile objects may be unwittingly damaged, and the signs of a layer change may not be seen as soon as they should be.

Although the dredge is not as manoeuvrable or as easy to use as the ubiquitous plastic airlift, it is a more suitable excavation aid in these circumstances. Speed of water movement in the gully is generally slow, but even when there is no current the discharged spoil drops out of suspension quickly without significantly reducing visibility. Another advantage is that the material is not dispersed and can be replaced on the ship's structure after recording. This avoids too large an area of timber being exposed at any one time or for too long.

The areas excavated within the structure were merely the gaps or 'spaces' between frames; in effect miniature trenches, the deposit having no continuity above the upper surface of the timbers. Finds or samples were either measured to specific points on the structure, trilaterated from datum points on the main timbers or plotted in three dimensions using the 'DSM' method which is described below. For areas outside the convenient reference of the ship's structure two poles were laid continuing the line of selected frames. The poles, the hull and the coral at the edge of the gully delineated the excavation area. As well as marking the limit of excavation at that stage, the poles provided diver support, enabling them to avoid touching the excavation with anything other than the tool in use (Fig. 3). They did not form a grid in the archaeological sense. With the survey methods referred to above, excavated material, whether outboard or inboard, could be related directly to the ship.

Outboard stratigraphy

The first three layers described above are found over most of the site outboard. But despite the apparently level sand floor of the gully the deposit on the North East (starboard) side is generally very shallow. Each layer is only a few centimetres in depth, layer 3 coming down onto coral. On the South West (port) side the coral is deeper, accounting for the ship's angle of heel to port by 10°. It is this side, protected by a greater depth of material which is better preserved. In general the timbers lie within layers 2 and 3. It was soon obvious that whereas on the starboard side parts of the keel and floor timbers were lying on the coral floor, on the port side large areas of the deposit continued below the underside of the timbers. In order to ascertain the quantity of material to be dealt with on this side of the site, a section was cut continuing the line of the last substantial floor timber aft; number 16 indicated in Fig. 1[3]. In the event the depth of material was even greater than anticipated. After cutting the section to a depth of 0.60 m below the upper surface of the floors there was no sign of the underlying coral. By this stage there were nine distinct layers in the deposit becoming progressively more consolidated and organic as depth increase (Figs 4 & 5).

In these layers several significant finds were made. These included part of a lead cloth seal, a bronze apothecary's cup weight (one of a nest), (Fig. 6*a*, 6*b*), a jetton or casting counter, brass pins, pottery, barrel hooping and fragments of leather. This context was undoubtedly undisturbed and therefore of prime importance. Although the deposit on the port side was obviously deeper in general, this section might prove to have been cut fortuitously in the deepest pocket in the coral. Dissection of this material was as slow and as painstaking as possible, not only to recover as much information as possible, but to allow the results of sample analysis, revised technique, or other research to modify procedures if necessary. The section was backfilled at the end of May 1983 and reopened in November the same year. There was no loss of definition or cohesion in the material. As clean sand had been used as the initial layer of backfill material, the horizon between the two materials was easily seen.

In conjunction with reopening the section an area 3 m square was to be excavated between the hull and the edge of the gully. Taken down layer by layer it would allow the position and relationship of collapsed structural elements and artefacts to be seen in plan, but with constant reference to the section. To date the section has proved representative of the areas as a whole, providing valuable insight into the material below and the impending layer changes. Although the change between layers is obvious in section, it is often not so easily seen in plan.

By the end of November 1983 the area had been taken down to layer 3, revealing a number of collapsed structural elements and concreted iron fastenings. The section had been advanced by 0.30 m. It was now 0.70 m below the upper level of the floor timbers, about 0.80 m below mean sea bed level. There was still no sign of coral and the tenth distinct layer had been reached (Fig. 7).

Inboard stratigraphy

The inboard stratigraphy, while not quite as complex as that outboard, is also informative. The deposit between frames 9 and 10 is an example as the material was undisturbed

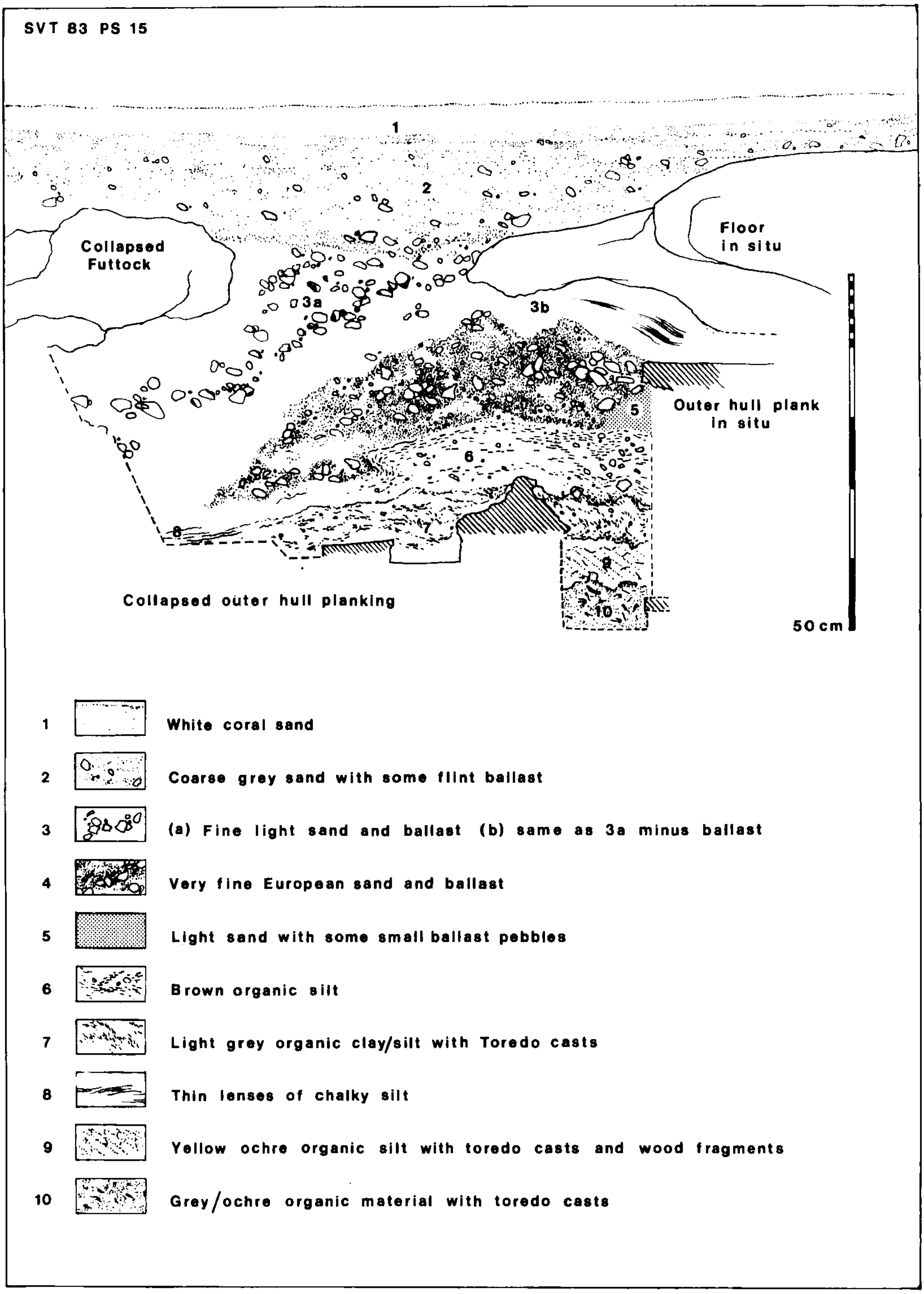

Figure 4. Section through deposit outboard of port frames.

Figure 5. View of the port side section shown in Fig. 4.

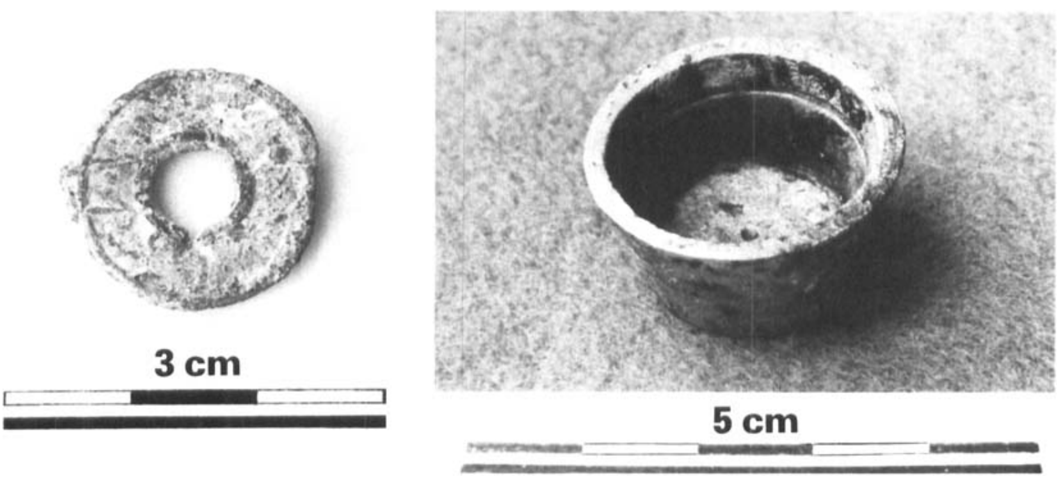

Figure 6. A, Half a lead cloth seal; B, bronze cup-weight, one of a 'nest'. Both from the deposit shown in Fig. 4 (layer 5).

throughout the space. A compact mix of coral sand and shingle ballast was reached 50 mm below the upper surface of the floors. It was readily distinguished from the loose sand and ballast pebbles above (layers 1 and 2). Below this was a layer of light finer grained coral sand, silt and crushed shell. Over the keel this came down to what looked like fine white clay. In fact it was only the top 3–4 mm of a lens of brown organic material, under which was a fine brown sand of silica as opposed to local coral. This was the lowest level in the ship. The configuration of these layers is shown in the section drawing (Fig. 8).

Figure 7. Detail of the port side section after it had been deepened to reveal a tenth layer.

In every case where excavation has continued through the lower organic material, or under the hull, the same sand has been found. It undoubtedly comes from the ship's ballast and had washed out during the voyage, slowly at first but in greater quantities as the severity of the storm increased. The limber boards were not fastened in any way, nor were the seams of the ceiling planking particularly tight. With the amount of water that must have been surging through the ballast it would easily have percolated down into the space between floors. It has been found compacted in all the limber passages examined so far. Shingle was the primary ballast material in English ships for centuries before *Sea Venture* and its use continued well into the 18th century, if not later. Sand and other silty materials were avoided where possible due to the stench and greater chance of disease, but there was often no choice. Even the preferred shingle dug from beaches, estuaries and rivers contained a certain amount. Sand washing out of the ballast and 'stoaking' the limbers, as well as being foul-smelling, remained a constant problem until shingle and similar material was replaced by solid ballast[4]. Certainly *Sea Venture's* blocked limbers agree well with Strachey's description of the suddenness with which the water appeared above the ballast [see *IJNA* (1982) **11**.9: 33].

Despite the presence of sand and organic matter, and judging by the amount of uniformly sized flint pebbles, *Sea Venture's* ballast appears to have been clean shingle. It was probably

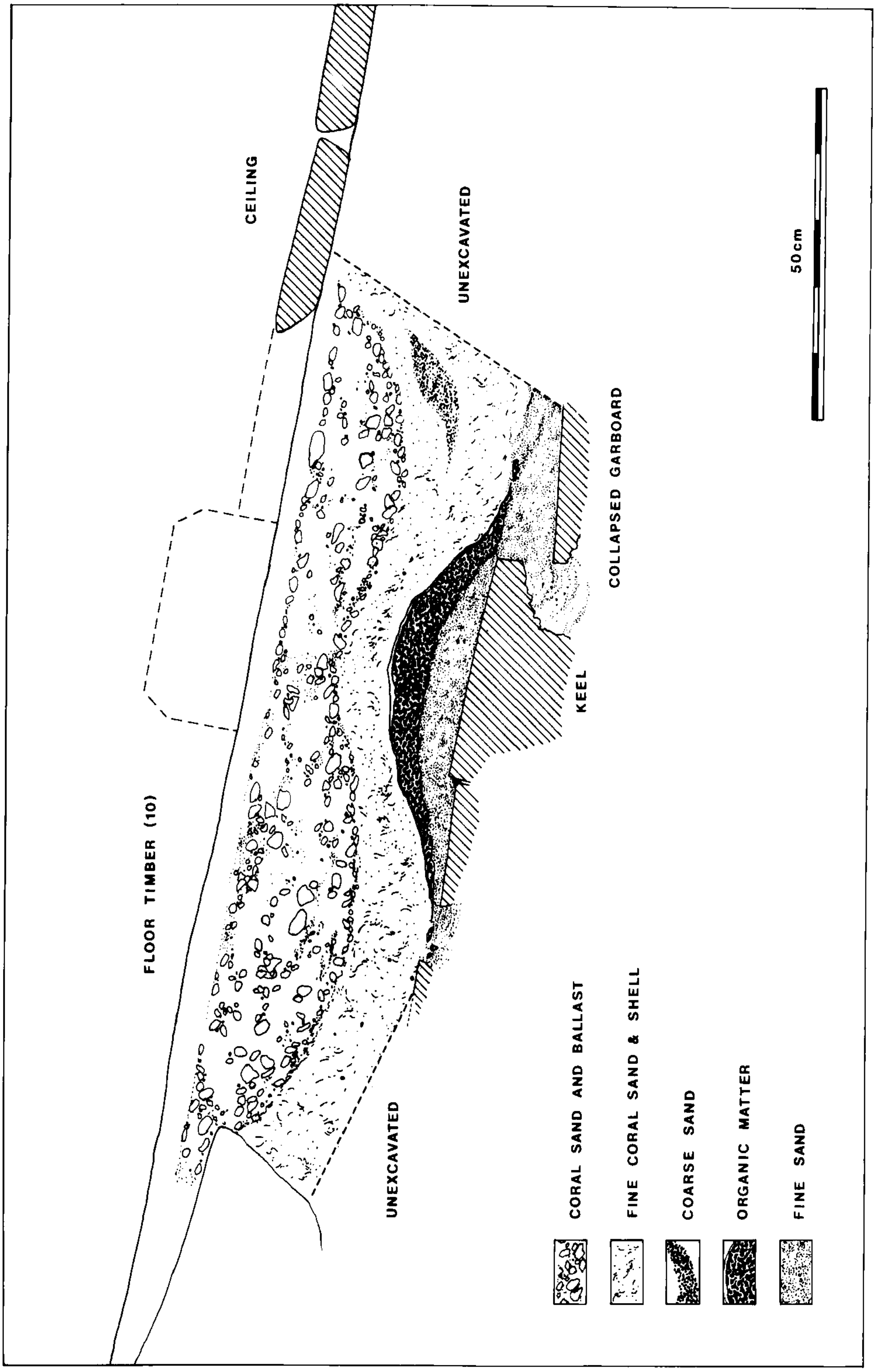

Figure 8. Athwartship section cut through the deposit between floors 9/10.

stowed in or near Plymouth just prior to departure. Unfortunately this type of flint shingle occurs all the way from East Anglia down to Cornwall, so its exact origin has not yet been ascertained. It is unlikely that Captain Christopher Newport, who had made several Atlantic crossings, or for that matter Sir George Somers, now a part owner as well as Admiral, would have set sail with putrid ballast. However, even if it was clean at the outset it would not have remained so for long. With 150 people aboard, most of whom would have stayed below decks in rough weather, it is not hard to imagine how unwholesome conditions must have become. The diseased condition of those arriving in Virginia after such voyages was the subject of a letter written by William Capps in 1623 to John Ferrar; an official of the Virginia Company of London:

> The first cause is for want of Cleaneliness, for betwixt the decks there can hardlie a man fetch his breath by reason there ariseth such a ffunke in the night that it causeth putrifaction of the bloud and breedeth a disease much like the plague.

Little further explanation of the organic material in the deposit is necessary, except that it was probably augmented by a substantial quantity of foodstuffs and stores that were smashed in the storm and spoiled.

With the ship lodged firmly on the reef, the sand settled (layer 5 in the section), and the less dense organic material settled out above it (layer 4). It remained in this state throughout the subsequent decay and eventual subsidence of the hull to the bottom of the gully. Coral sand and shell (layer 2), found its way into the space above layer 4, below the ceiling planking. Initially only fine particles could gain access, but with the gradual decay of the ceiling the intrusive material became increasingly coarse. At some point the eroded planks disappeared entirely, either through storms or another mechanical agency, allowing the larger ballast pebbles to settle below the top of the floor timbers (layer 1). Eventually some of the outer planks, already severely eroded, collapsed, allowing the sand to run out through the gaps, in this case either side of the keel. This event is demonstrated in the section by the subsidence of the material above.

It is quite clear that the collapse of the outer planking only occurred after the wreck had reached the floor of the gully. If it had taken place while the hull was stranded in mid-water both the fine sand and the organic material would have been dispersed. It is also clear that a considerable time elapsed between the initial settling of layers 4 and 5 and the final collapse of the ceiling. In other spaces where the ceiling was removed more quickly there was no opportunity for the fine coral sand, shell and other intrusive matter to enter the void under the planking. In these cases the ballast had collapsed onto, and become intermixed with the organic layer. Where there has been no collapse of the outer hull planking, the intrusive layer is either very thin or only present where the ceiling is still intact. Below the ceiling in many places there is still a gap that has allowed free passage of water. This has resulted in the severe erosion of the underside of the planking, in contrast to the fair inboard surface protected by ballast.

Sediment analysis

As the information retrievable directly from a ship and its contents progressively reduces with erosion, a certain amount of that information is transferred to the accumulating deposit. A considerable percentage of this will be in non-artefactual form. Recognising and extracting this material is one thing, but to fully utilise it in discerning more about the ship as a whole requires a thorough understanding of the mechanics of its deposition. For that reason sediment samples are being examined in two ways: firstly with regard to the cultural and environmental aspects, ie. fragmentary remains of objects, stores or food, as well as flora and fauna; secondly by a physical, chemical and biological analysis to establish the precise nature of the component materials of the various layers.

The lower levels of the deposit around the *Sea Venture* contain a higher proportion of organic material, and correspondingly less indigenous coral sand than one might expect. This is due to a variety of reasons. It seems that either there was very little sand present when the hull finally settled on the floor of the gully, or it was removed as part of that process. The documentary sources indicate that the hull remained lodged up on the reef for some years[5]. If this was so the keel would have been about

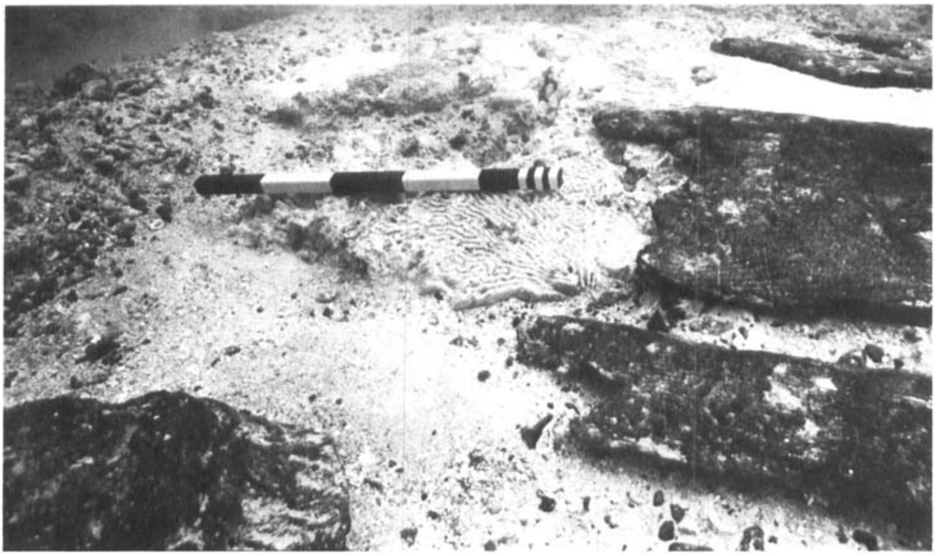

Figure 9. One of the coral heads ground down by the hull. It can be seen running under the centre plank.

6–10 ft (1.82–3.04 m) above the floor of the gully. Due to the funnel shape formed by the reef the flow of water is either up or down the gully whatever the state of the tide. The hull would have effectively lidded the gully and might have accentuated this movement, scouring away much of the sand. Alternatively, water movement may have prevented any substantial build-up of sand until a catchment framework was provided by the sunken hull. A third and more likely possibility is that when the lower half of the hull, still largely intact, sank to the bottom of the gully it would have settled through whatever material was present until it came to bear upon the uppermost coral heads. That subsequent movement took place is shown by several of these coral heads that have been ground by the timbers to conform to the shape of the hull (Fig. 9). This is a good illustration that the interaction that occurs between a wreck and its environment is never entirely one way, even in warm shallow sub-tropical water. While this movement of the hull was continuing, and before it began to disintegrate further, its proximity to the sand floor would have caused severe scouring, even in the deeper pockets under the port side. As the hull began to disintegrate, complete and fragmentary objects passed through the structure to become assimilated into an accumulating deposit formed of organic and inorganic material from the ship, as well as natural sediments. From the lowest levels of organic material associated with the ship (seen so far), there seems to be a general increase in sand content through to the surface layer. In other words there is a progressive increase in the amount of coral sand and naturally occurring material deposited, corresponding to the gradual reduction of movement and progressive decay of the structure. It is a sequence of events such as this that is strongly suggested by the section (Fig. 3). However, although this interpretation fits the various classes of evidence evaluated so far, it is only a working hypothesis which may or may not be confirmed by detailed analysis of the sediments.

Throughout the excavation samples have been taken of every distinct layer. All have been taken more than once where possible. Some layers, such as thin lenses of organic material in a section, can only be sampled in small quantities. Normally samples are 0·5 k and 1 k. Larger block samples and column samples are not practical due to the relatively small amount

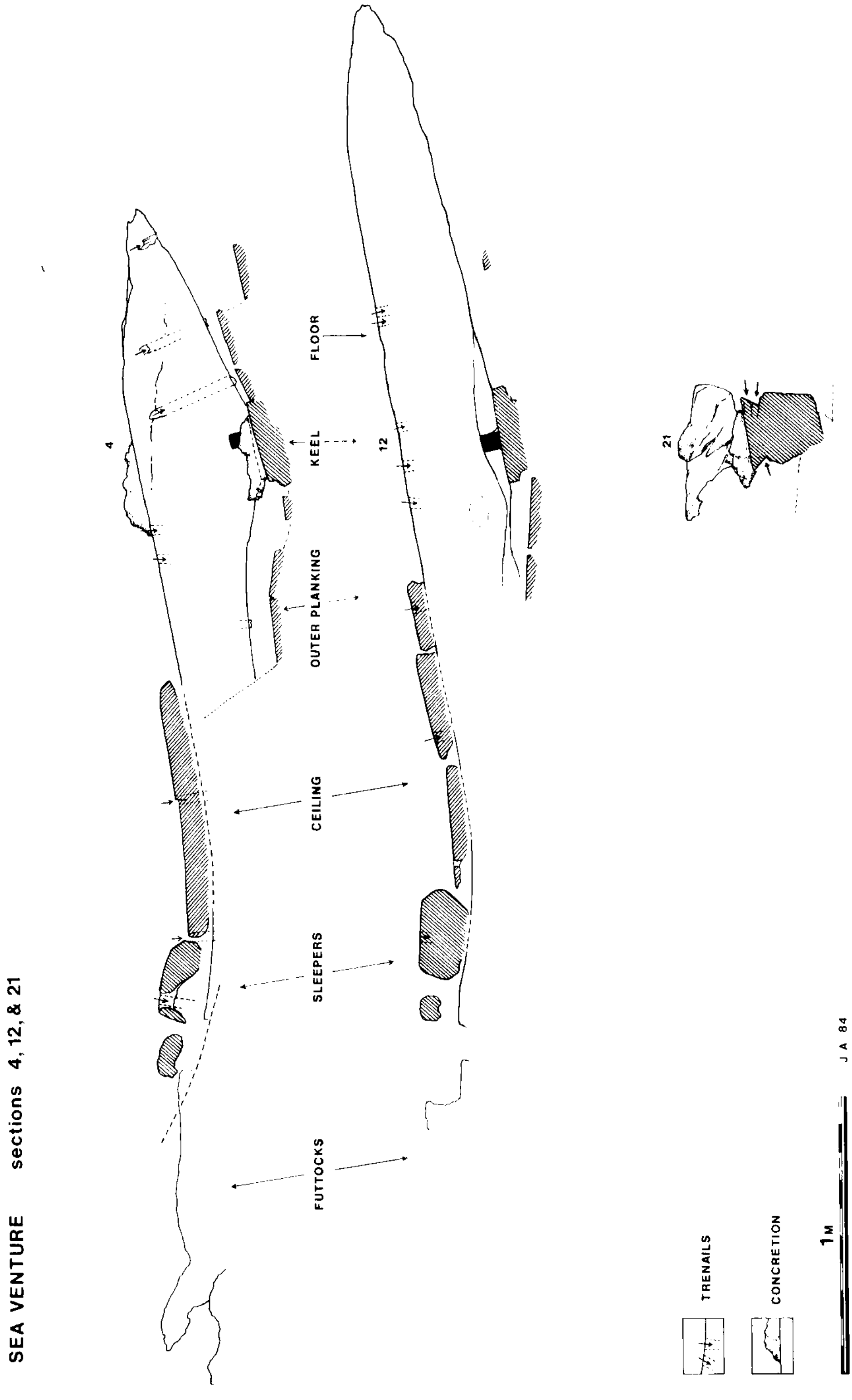

Figure 10. Profiles of the hull looking forward at frames 4, 12 and 21.

of deposit involved. It would also be impossible to cut such a quantity without adversely affecting the archaeology of the remaining context. Another difficulty is that such a sample could not be collected in one block due to the generally fragile cohesion of the material. The validity of five kilos of deposit shovelled piecemeal into a container would be highly dubious. Fine sediment and organic particles are washed out, and the sample is easily contaminated. Reliance was therefore placed on several smaller but distinct units that could be bagged and sealed with minimum disturbance.

Preliminary examination was carried out in Bermuda. Two sets of sub-samples were then taken back to the Mary Rose Trust laboratory in Portsmouth. To date one set has been examined for environmental material such as insect remains and seeds etc. Considering the small quantity so far examined the results are promising. The other samples have undergone particle size analysis and have been tested for organic content. Initial results are consistent with interpretations made in the field, particularly regarding the very high organic content of various layers. Currently more detailed analysis is in progress to identify both the organic and inorganic materials.

Hull structure

The surviving integral structure shown in the plan (Fig. 1) consists of 15·5 m (52 ft) of keel and eighteen floor timbers in various states of preservation, lying between some ceiling and outer hull planking. It is a relatively small proportion of the hull, but as much of it survives as one unit due to the fortuitous circumstances of the site, it retains a considerable amount of detailed information. On the starboard side, due to the shallow deposit, the floors have been badly eroded. The ceiling has been completely removed, and only a few fragments of outer planking remain wedged between the floors and the coral. On the port side the situation is far better, the floors amidships surviving to their original length. The ceiling is in relatively good condition having been protected by the ballast, and the outer planking, while still very eroded is more continuous. The profiles 4 and 12 in Fig. 10 show the typical configuration.

The keel is 0·341–0·346 m ($13\frac{1}{2}$–$13\frac{3}{4}$ in) wide amidships and tapers either side of the mid frames. It was probably constructed in three sections, the stern section of which is missing. The general size of the timbers, documented tonnage of the ship, and the position of keel bolts astern (Wingood, 1982), suggest a keel

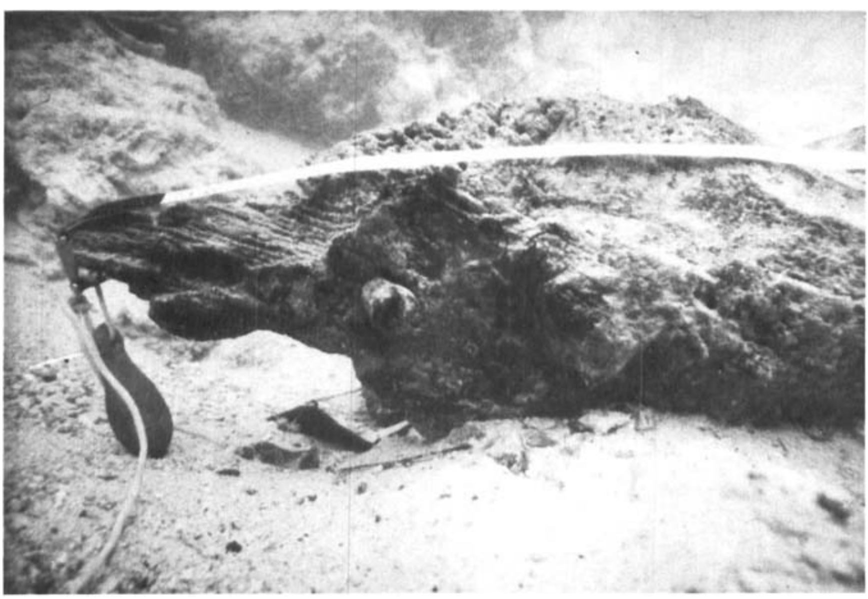

Figure 11. Forward end of the keel showing the vertical tabling and a horizontal trenail.

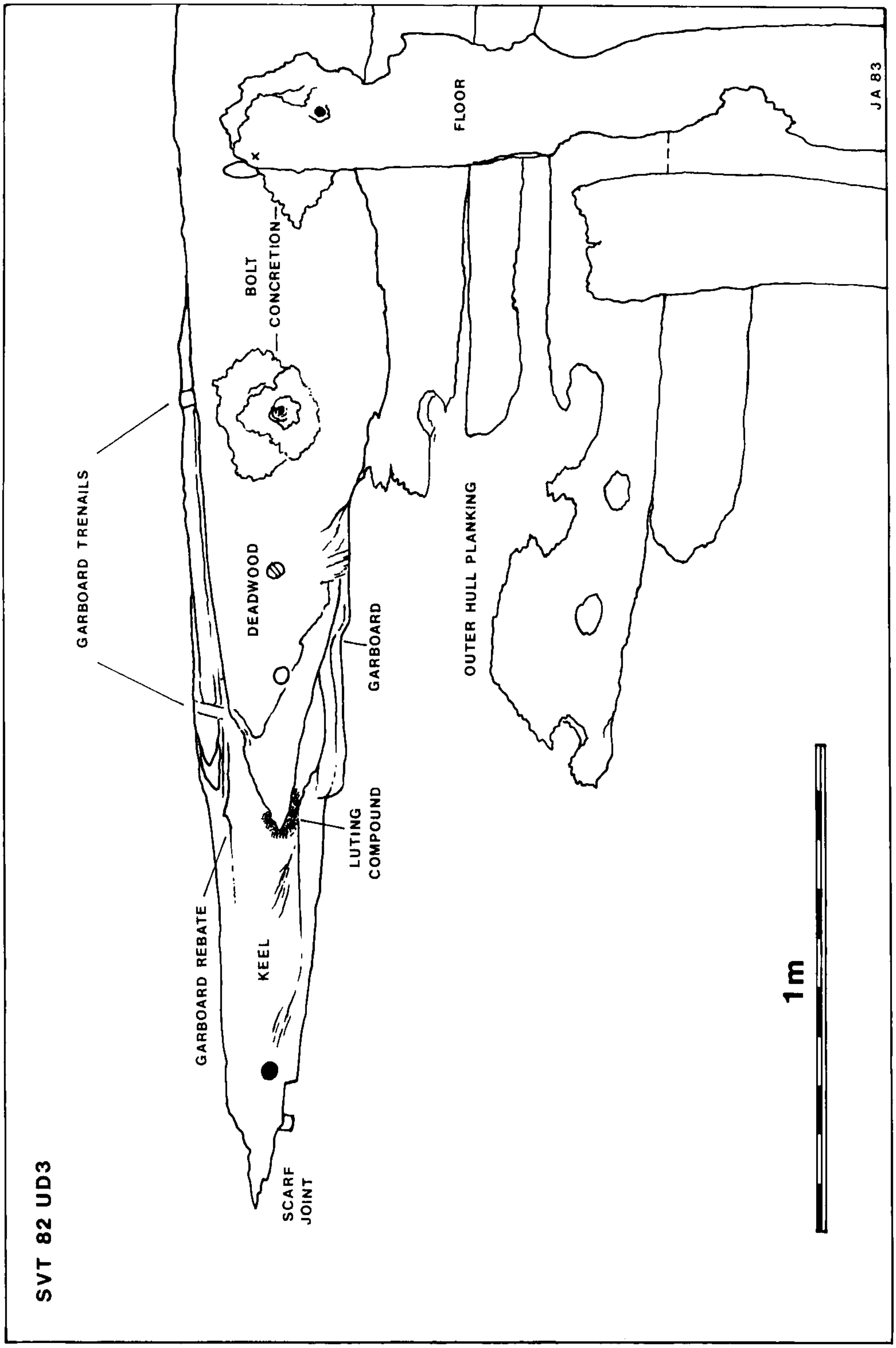

Figure 12. Tracing of the original underwater plan drawing, at scale 1:10, showing details of the forward end of the keel and deadwood.

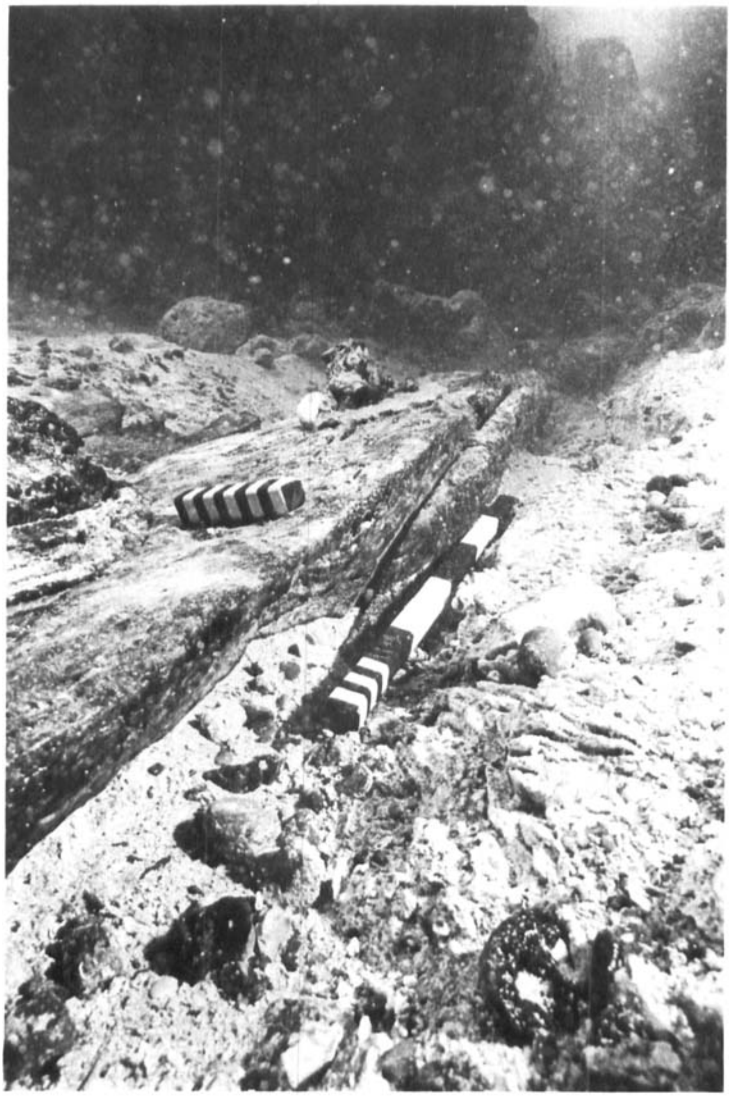

Figure 13. Looking forward along the starboard side of the keel and deadwood at the bow.

length of about 22–23 m. Forward it survives as far as the beginning of its scarf with the stem (Fig. 11).

Above the keel, the foremost three frames rest on two sections of deadwood that are butted together (Figs 12, 13). The aft section was rebated 40–50 mm into the forward face of floor 4 with a channel cut into it giving access to the limber hole (Fig. 14). Aft the keel also ends at what appears to be an eroded scarf joint, but the scarf joint between the two surviving sections is tight and sound. All three are cut vertically. Additional examples, which together with those of the *Mary Rose* (1510), *Dartmouth* (new keel 1678), and *Victory* (1759) cast more doubt on the hitherto common belief that keel scarfs were usually cut horizontally. In detail the preserved scarf joint of *Sea Venture* is similar to that of the *Dartmouth* (Martin, 1978). It was sealed with a luting compound of animal

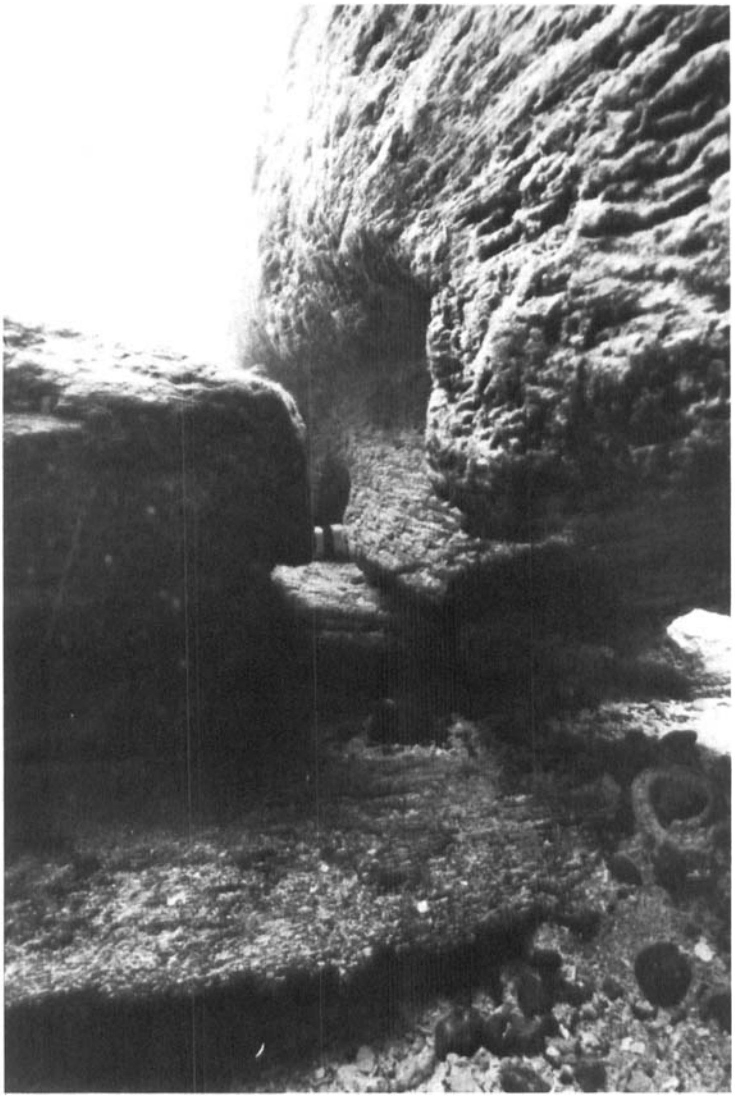

Figure 14. Aft end of deadwood and rebate in floor timber 4.

hair and pitch, except at the edge of the keel where it was sealed with oakum. Capping pieces were let into a rebate in the upper surface of the keel, also sealed with hair and pitch. One end of the joint is hidden by a floor but it appears that one length covered the diagonal seam, while small pieces were let in over the butt end (Fig. 15).

The keelson is no longer present. The only visible remaining evidence is the cast impression of its underside in two of the bolt concretions.

The port side ceiling extends in fair condition as far as the 'sleepers', which were heavy stringers providing additional longitudinal strength, as well as binding the joints between the floors and futtocks. They were scarfed together forming a continuous belt of timber the length of the hull. The ceiling planks were also intentionally cut thick enough to contribute to hull strength.

In addition to the ceiling proper, there are a series of eroded short planks about 1.1 m in

Figure 15. Forward end of a vertical scarf joint in the keel, showing the covering pieces let into the rebate over the seam.

length and with no indication of any fastenings. Only one remained *in situ*. It lay next to the line of the keelson, so presumably they were limber boards, removable to give access to the space between floors.

Unfortunately the joints between the floors and futtocks, despite being covered by the sleepers are very eroded, probably due to scour erosion when the hull was more intact. It is probable that they were simple splayed or angled butt joints. Strength in this joint was not of prime importance, for that was achieved through overlapping adjacent timbers. The first futtocks were set between the rung heads (ends of the floor timbers), overlapping the joint between the floor and the second futtock. They are often referred to as spacers, a term that belies their importance. This is perhaps due to their short length, and the fact that they do not lie in the main line of the frame. Also there is no direct fastening to the adjacent floors. However, they have to be short due to the acute curve of this part of the ship's hull section, and it was the fastenings to the outer hull planks and ceiling that provided the integrity. The result was solid timber along the turn of the bilge, further strengthened by sleepers positioned inboard over the joints:

> Sleepers are those timbers that lie fore and aft the bottom of a ship on either side of the keelson just as the rungheads do go. The lowermost of these is bolted to the rungheads and the uppermost to the futtocks, and so these between them do strengthen and bind fast the futtocks and the rungs, *which are let down by one another and have no binding but these sleepers* (my italics). Sir Henry Mainwaring, 1623.

It is this principle of construction with its simpler schematic layout, at least in the lower hull, that shows the radical difference from the more complex and more flexible systems of the previous century. The rapid development in hull design that occurred in the late 16th century was one of the factors that enforced a more rigid framing system at least in the lower hull. With the sharp curves inherent in English ship design of this period, the shape of the hull now to a large extent dictated where joints in the frames would have to be. The increasing size of ships, and the scarcity and extra expense of compass timber were additional constraints. It is interesting to note that in the very year *Sea Venture* sank; Phineass Pett was being severely criticised, not only for designing the *Prince Royal* with a 'flat of Floor' that was considered too wide (for the time), but for cutting curved frames out of straight timber.

The potential weakness of a hull shape that left no alternative to aligning the joints in the most acutely curved section of the hull is obvious. The solution in structural terms is shown in the surviving timbers of *Sea Venture*.

Fastenings

The majority of the hull fastenings are trenails. Some are wedged, but most are not. A few show caulking cuts, but these have only been found where the surface of the timber is pristine. More may have been finished this way but would be almost invisible on an eroded surface. However many appear to have simply been sawn off unwedged and uncaulked. Some are flared producing the characteristic oval shape, although some that appear to be so have in fact been driven at an angle. These various characteristics can indicate a number of things, such as the possible use of different wood types, or merely the direction from which the trenail was driven. The required finishing; wedge, caulking or otherwise could depend on a number of circumstances which samples will clarify. The cross section of the trenails is octagonal, and the trenail holes are approximately 33 mm in diameter.

The trenails do not appear to have been driven in a strict pattern. Colin Martin found the same thing in the case of the *Dartmouth* hull planking (1690) and suggested that the lack of symmetry was intentional. This would avoid setting up lines of weakness thus reducing the chance of splitting (Martin, 1978). It would certainly seem to be the case here, for some trenails have obviously been positioned with great precision where necessary.

One such example is the placing of several trenails in the seams between ceiling planks. This occurs too many times to be coincidence, and also occurred in the *Dartmouth* outer hull planking (Martin, 1978). Another example is the trenails fastening the garboard to the keel, where the hull lines become finer either side of the midship section. Obviously in this instance trenails set along the same line cannot be avoided, as the point of entry into the garboard is restricted by the height of the rabbet, but this is offset by its greater thickness. To achieve maximum cohesion the angle at which the trenails are driven through to the keel is varied, as much as possible in the vertical plane (Fig. 10; 21), and quite considerably in the horizontal plane (Fig. 12).

In addition to trenails, various main structural elements are fastened with iron. Amidships every third floor timber is bolted. Forward of the point where the deadwood begins they are all bolted, but astern they are less frequent. The sleepers were bolted to the floors and futtocks, and judging by the collapsed concreted bolts outboard, so were the stringers above. The keel bolts were clenched over washers, but examination of collapsed bolts from elsewhere in the hull showed that both clenched and pinned bolts were used.

Survey

The conditions on the site allow a wide range of survey methods to be used. Although different techniques are used for different aspects of recording, in attempting to achieve a high order of accuracy, more than one technique is used in any given situation. Not only does this provide a cross check between one method and another, but results in a very full coverage of every stage of the excavation.

The remaining integral hull timbers are relatively flat and are easily surveyed in plan by various methods. The initial plan was made using a drawing grid (Fig. 16). The frame was constructed of rigid steel conduit, 1 metre square, standing on adjustable legs. It was double strung with fine nylon cord into 10 cm squares, the double stringing acting as a visual plumb-bob. As there was no significant depth restriction, time could be taken to ensure accuracy. The centre line of the pre-disturbance survey grid, set up by Allan Wingood, was retained as an initial datum line. It ran down the approximate centre line of the keel. Datum nails were set in each floor timber, plumbed into position from the datum line. The drawing grid was then set against these and moved outwards as the survey proceeded. The underwater drawings were made at 1:10 on draughting film. The results were then laid together, and with various direct check measurements, traced to form the plan (Fig. 1). That they can be orientated along

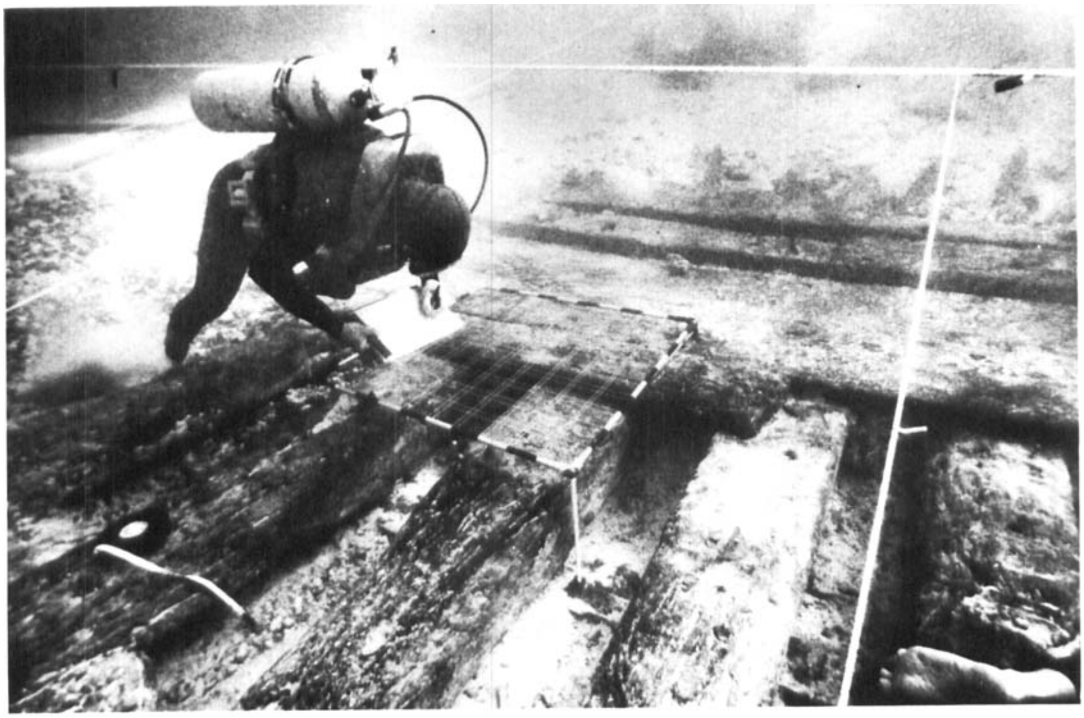

Figure 16. Drawing grid survey (Photo Brian Luckhurst).

a known centre line makes this task considerably easier and quicker.

In conjunction with the drawing grid survey, a photo-mosaic was produced also based on 1 m square. A camera frame was constructed giving a stand off distance of 1·22 m (4 ft). With a 15 mm lens the coverage was approximately 2·5 × 1·5 m, but only part of the image lying within the metre square was used. Each frame was printed at 1:10 using the metre square as a guide. Where necessary the tone of each print was adjusted with varied exposure. With 50% overlap, the match between the individual prints is good and agrees well with the drawn plan. The assembled mosaic was then rephotographed on a cartographic camera with a negative size of 24 × 20 inches (0·610 × 0·508 m). The stern half of the structure is shown in Fig. 17. The bow section is currently being printed and assembled.

In addition to these indirect methods, specific structural features and details are surveyed using ordinary tapes and rules.

Athwartship hull sections along the line of the floor timbers are in the process of being drawn. The first three are shown in Fig. 9. A calibrated datum line was set up along the centre line of the floor timber. Vertical measurements were taken at ten centimetre intervals along the datum line, and to any significant points such as seams or fastenings. In addition, dimensions of each element or component distance was measured and the angle of slope taken with an inclinometer. The datum line angle was also taken, together with a DSM fix on both ends.

The DSM or 'direct survey method', was developed by Nic Rule, in response to the specific survey problems encountered on the Mary Rose excavation. Prior to this, established practice was standard trilateration to obtain the plan position of an object or point, and then plumbing for depth below datum. As the excavation progressed deeper into the hull this became increasingly slow, difficult and inaccurate. Most significantly the inaccuracy was

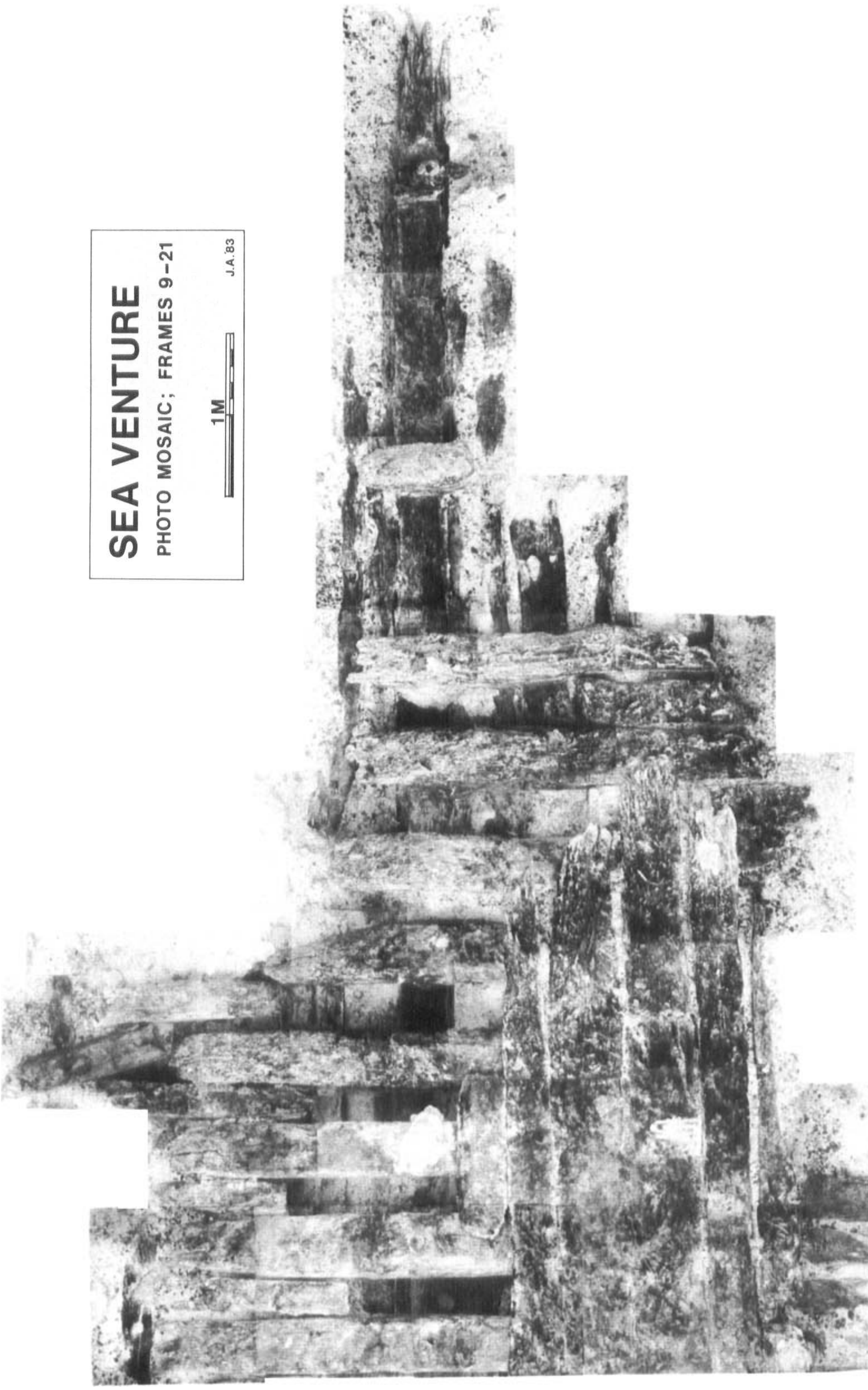

Figure 17. Photomosaic of the stern half of surviving integral structure. (Rephotographed by Roger Homer, Portsmouth Polytechnic.)

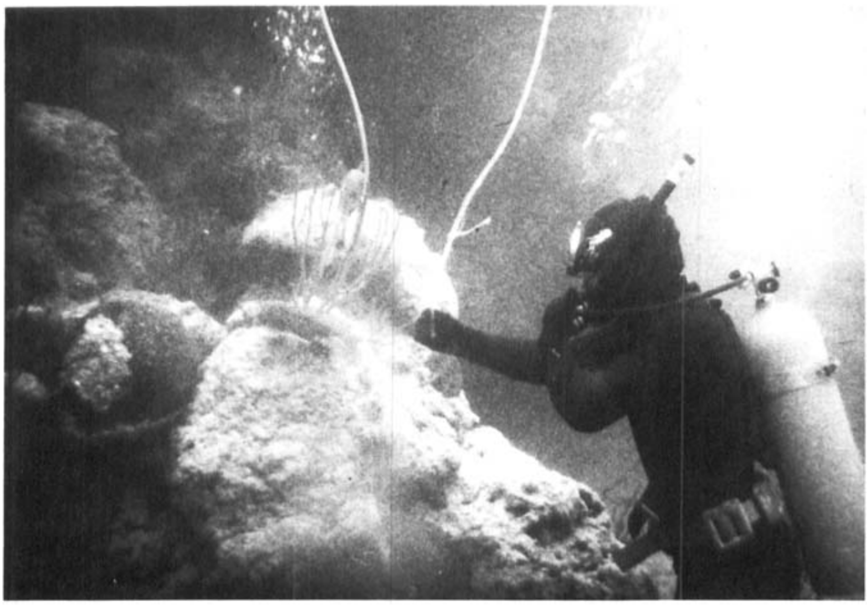

Figure 18. A datum point for the 'direct survey method'. A strong galvanised steel spike is hammered into the coral. A polystyrene float fits tightly onto the spike and is adjusted to a common level with the bubble tube.

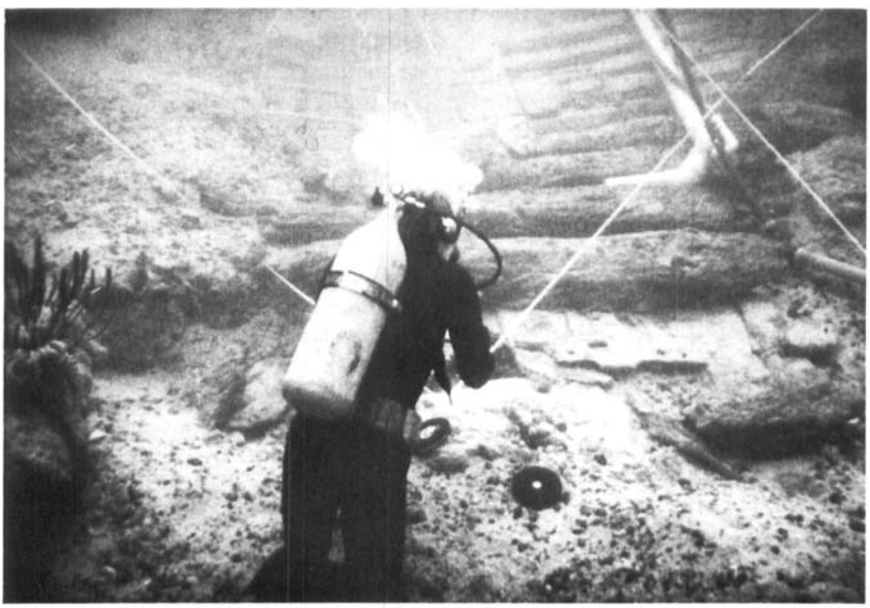

Figure 19. A diver surveying the eroded ends of outer hull planking and a coral head that has been ground down by the hull (see also Fig. 9).

impossible to quantify. Despite its development for a specific site, DSM is extremely versatile, illustrated by the ease with which it was transposed to the *Sea Venture*. The primary datum points were a series of steel spikes set into the coral surrounding the hull. They were set to the same level using a bubble tube (aqua-level), approximately 1·5 m above the general level of the hull (Fig. 18). They were then trilaterated in to each other as accurately as possible, thus forming an initial grid of known primary datum points. To survey an object or structural point, a tape is drawn from any four of the datum points directly to the object (Fig. 19). The object or point measured in this way, in effect becomes the apex of an inverted four sided pyramid, and its position in three dimensions can be plotted geometrically. To do this for every point surveyed would be very tedious, but the method was conceived for use with a computer. It is not only extremely accurate, but the accuracy of each position is quantified, and probable errors indicated. An inherent advantage is that any fixed point surveyed by DSM can then itself be used as a datum. Although sophisticated it is easy to use, and since its introduction several refinements have been made[6].

The applications on *Sea Venture* are twofold: firstly, for fixing specific points on the hull, which can either form an independent survey, or can be used to corroborate conventional plans and sections. Secondly, for surveying finds and samples. It is especially useful for recording the three dimensional positions of objects that lie outside the convenient reference points of the hull, yet which lie in an associated undisturbed context.

Conclusion

Although the *Sea Venture* site is fairly small, the many classes of information retrieved are in some cases still at a preliminary stage of investigation. The environmental work in particular is an enormous task involving analysis of various samples by specialists who may be thousands of miles apart. So definitive conclusions cannot be arrived at immediately. However, the potential return is very high.

Other aspects already invite evaluation. One example is the weight of archaeological evidence as a whole concerning the history of the hull after wrecking:

The configuration of the coral reef is consistent with Jourdan's first hand account of the ship driving into the narrowing gully and jamming:

> And there neither did our ship sink but . . . fell in between two rocks, where she was fast lodged and locked for further budging; whereby we gained not only sufficient time . . . safely to set and convey our men ashore . . . but afterwards had time and leisure to save some good part of our goods and provision . . . with all the tacking of the ship and much of the iron about her . . . for the building and furnishing of a new ship and pinnace.

Reference has been made above to the work that occurred sporadically after this initial leisurely salvage; which indicates that the hull could have remained above the bottom of the gully for a considerable period of time[5]. The stratigraphic evidence and the flattened coral heads indicate that when the hull finally arrived on the sea bed it was still a very substantial mass. They provide details of the process of decay which have an important bearing on the interpretation of material in general. Yet the sequence of events they indicate could have happened within a wide time band. While compatible with the documentary evidence, they do not confirm it.

It is the biological evidence that puts the whole thing into perspective: The outer hull planking is so eroded that it must have been exposed for a relatively long period of time, even considering immersion in sub-tropical water. Had the hull sunk to the floor of the gully immediately or soon after wrecking, the degradation would not be as extensive. Erosion through scour action would certainly reach some distance under the hull, but not completely. However the underside of *Sea Venture's* keel is just as eroded as the underside of the farthest outboard plank. It has a corrugated surface typical of wood left exposed underwater for a long period of time. This is caused by biological attack softening the wood which is then followed by mechanical abrasion. Either form of attack on its own results in a completely different appearance. Such severe biological attack, for which a reasonable supply of oxygen is pre-requisite, and which extends across the total outer surface of the hull, indicates long exposure in mid-water.

Such cross matching between documentary and physical information offers a useful control that can be applied to other sites where one or other class of evidence is not as comprehensive.

As far as direct information is concerned, again the potential return is good. Several hundred artefacts have now been recovered from the site, excluding the thousands of small arms shot. In total they constitute a unique selection of some of the equipment, stores and personal possessions carried aboard an English colonial ship in 1609.

As for the ship itself; it is a result of a period of intense development in English Naval architecture. The most successful qualities of several prototypes of the early and mid 16th century had been fused together to produce an extraordinary vessel; referred to as the 'Elizabethan Galleon' for want of a better term. These vessels while not ideal for any one task, were brilliant general purpose ships. They fought the Armada, gave safety from pirates in the trade to the Levant, and spearheaded the colonial thrust across the Atlantic. This development reduced the distinction between warships and large merchant ships. The former were likely to be more robust, but merchant ships were readily assimilated into the navy in time of war. The difference in English built ships was more one of purpose than of design. A common complaint during the mid to late 17th century was that English shipwrights could only build 'defensible' ships of warship type. Although fast and manoeuvrable they were uneconomic for bulk trade, especially in competition with the Dutch *fluits* that 'measure little and stow much' (George Weymouth, 1610).

Currently hull lines are being drawn based on the measurements of *Sea Venture's* existing timbers using the various geometric design rules of the period. They indicate *Sea Venture's* builders were aware of the design methods current at the time, rather than building her; 'Only by uncertayn traditionall precepts, and by deceiving ayme of theyre eye' (Weymouth).

Although incomplete, the remains of ships such as *Sea Venture* will prove to be of great importance, collectively if not individually. They will not only increase our knowledge of their respective periods, but will endorse or modify existing hypotheses based largely on documentary and iconographic evidence.

Acknowledgements

Of the many people who have given their time and expertise to the project, only a few can be mentioned here. That there are so many is testimony to the generous support for the project by Bermudians in general, and by many people overseas. The project would simply not be possible without them.

For stimulating and channelling this support, the credit goes to the board of governors of the Sea Venture Trust, under the initial chairmanship of Reggie Tucker, and subsequently Robert Chappell. Few boards command such a wide range of professional skills at top level. Being members of an island community, they also have a knowledge of the sea and maritime operations that gives a practical edge to their support for all aspects of the project.

A special debt of gratitude is owed to Allan 'Smokey' Wingood, and his wife Peggy. As founding members of the Sea Venture Trust (Director of Operations and Secretary, respectively), their energy is inexhaustible. They not only provide a home base during diving seasons but undertake the endless series of associated tasks, including research, that in effect constitute a full time job.

The excavators for the period concerned were: Anson Nash, Robert Steinhoff, Dr Brian Luckhurst, Kirsten Luckhurst, Stephen Cook, and Brian Billings. The project is indeed fortunate to be able to call on a pool of such competent and experienced divers. They have regularly given their time and energy both above and below the water, bringing with them the professionalism of approach that has made them successful in their own fields.

The diving operations were carried out from the Bermuda Biological Station for Research, where the Director and staff have rendered many services over and above those contracted for.

In addition I would like to express my thanks to the following: Jack Lightbourne, Vice Chairman of the Trust, for the loan of his boat during one of the diving sessions. The Bermuda Police Department for the use of a forensic laboratory for preliminary examination of samples. Stanley Johnson of the Bermuda Fire Department, who maintained our water pump, ensuring total reliability. The Directors and staff of the Mary Rose Trust, in particular Margaret Rule, Director of Research, who was instrumental in my involvement with this project. Also my former colleagues who have given valuable help in many aspects of post-excavation work, notably Ian Oxley, and John Buglass of the Environmental Archaeology Department, who have initiated a programme of work on the sediment samples. I am also very grateful to Nic Rule, who spent many hours with me on the computer, processing DSM data.

Notes

[1] A ship of the same name built in 1603, researched by Mrs Marilyn Peterson, could be the same vessel, despite disparity in tonnage figures (120–300). Assessment rules for capacity and deadweight, as well as declared tonnage were highly variable. For reasons and examples, albeit earlier, see Burwash (1947), Davis (1967) and Friel (1983).

Lionel Cranfield, one of the original owners of this Vessel, sold his share on 1 June 1609, the day before *Sea Venture* left England. He was also a member of the Virginia Company of London.

[2] Shakespeare had probably read both Strachey's and Jourdan's accounts before writing *The Tempest*. Some of the most striking parallels between Strachey's letter and the play are discussed in the introduction to 'A Voyage to Virginia in 1609' edited by Louis B. Wright. Strachey knew many of the Virginia Company officials, as did Shakespeare. His own patron, The Earl of Southampton, was one of the backers of the project. Strachey was also a friend of Ben Jonson and knew others of Shakespeare's circle.

[3] The frame numbering is temporary and merely reflects the order in which they were uncovered.

[4] Probably the most eloquent reference to all aspects of the problem is contained in a letter written in 1689 by Lieutenant William Kiggins of the *Dartmouth*. It was cited by Colin Martin (1978: 34) in his discussion of the ballast from the ship but is worth repeating here in part: 'Our ships' company is sickly, one great occasion of it is our ballast being so bad, stinking and all of a quagmire, and sandy that it stoaks the limbers, that the water has no course to the pump.'

[5] 'Many conclusions he tried about the Sea Venture, the Wracke of Sir George Somers, but he got onely for his paines but two peece of ordnance.' From Smith's 'Virginia' edited by Lefroy; passage concerning Richard Norwood and Governor Moore 1612–15. '. . .from thence he went to the Sea Adventure, the wracke of Sir George Somers, the hull though two or three fathoms in water, they found imperished and with much a doe weighed a sacre, her sheat anchor, divers barres of iron and pigs of lead, which stood the plantation in very great steade' (*Historye of the Bermudas or Summer Islands*, Lefroy, 1882).

Although Lefroy attributes the second passage to Smith, it is thought that it concerns salvage operations directed by Nathaniel Butler who was governor from 1619–1622. The reference to the depth of the hull being only two or three fathoms deep (12–18 ft) (3·66–5·49 m) implies that the hull was still lodged up on the reef. 8–12 ft (2·44–3·66 m) is the approximate depth range of the top of the reef below surface. Today the shallowest part of *Sea Venture's* hull lies in 25 ft of water at low tide. The description of being 'imperished' seems surprising so long after wrecking but the gulley is remarkably well protected; the seaward reefs breaking up the heavy swell.

[6] Nic Rule has written a comprehensive description of the 'Direct survey method': forthcoming publication, Mary Rose Trust Research Paper.

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