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A Cromwellian Warship wrecked off Duart Castle, Mull, Scotland, in 1653

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Chapter 4

SITE-FORMATION PROCESSES

4.1 Site-formation processes

Wreck-formation processes are infinitely variable, because the complex and interacting factors which constitute the surrounding environment and its evolution through time, the nature of the wrecked ship, and the circumstances of its loss, all combine to create a set of attributes unique to each site (Muckelroy 1978: 158–9; Martin 2011). But some general categories can be recognised. At one end of the scale a vessel may survive virtually intact, with its contents complete and more or less in situ, as was the case with *Vasa* (Hocker 2006). At the other end a ship may be so broken up and dispersed, and its component parts and contents so reduced by mechanical, chemical, and biological degradation, that there comes a point at which it effectively ceases to exist (Martin 2005).

In a majority of cases, however, wreck-formations lie somewhere between these extremes, and in reaching a state of balance within the environment they normally undergo three evolutionary phases. The first is characterised by dynamic anthropogenic input before and during the wrecking event. A phase of dynamic environmental input follows as the wreck and its natural surroundings interact physically, chemically, and biologically. Finally there is a stable phase in which the wreck's residual substance and distributive associations have become incorporated into an environment which, though modified by the wreck's intrusion, is once again balanced and stable. It should be noted that stability is never achieved in absolute terms, since some dynamic processes will continue slowly but inexorably. It is also possible that a stable situation may for various reasons revert to an unstable one, perhaps moving cyclically between one condition and the other. Nor will a single formation process be applicable to all parts of a wreck-site at any given time, and it is best to regard each wreck as a complex mix of many interrelated and interacting sub-formations.

A wrecking is an essentially human event, caused ultimately by the failings and misjudgements which lie on the debit side of our species's unique qualities of forethought, ingenuity, collaboration, invention, and enterprise. As a phenomenon it cannot therefore be analysed in purely predictive or abstract terms. It is human error, usually compounded by nature, which causes wrecks, and human cognition, resourcefulness, and the instinct to survive which seeks to avoid them or mitigate their consequences (Gibbs 2006). Human choices and decisions, which may be varied and sometimes irrational, must therefore be considered when seeking to understand the nature and consequences of the events which initiate wreck-formation processes.

This anthropogenically influenced phase leads to shipwreck, when the organised entity represented by a vessel's structure, contents, and functioning crew, together with its systems of propulsion, control, and management, breaks down as a consequence of ultimately catastrophic inputs. There follows an irreversible process of change, during which the ship leaves the world of human artifice and reverts to nature. At this stage the wreck can be characterised as a massive unstable anomaly within the environment into which it has been deposited, and nature will react until a state of balance has been restored. This phase may be extremely violent and short-lived, as when a ship strikes a reef in heavy seas and disintegrates in a matter of seconds, or it may, as in the case of a hull which has settled gently into a benign environment of soft anaerobic sediments, continue for years or even centuries (for example *Mary Rose*, Marsden 2009: 20–31; *Vasa*, Hocker & Wendel 2006).

In both cases, however, the dynamic phase is characterised by the wreck's status as an anomaly: it is unstable, it lacks integration with its surroundings, and it is prone to further disintegration and dispersal by external influences. Heavy items will trend downwards until they stabilise. Lighter objects, by virtue of their buoyancy, may relocate within the wreck or float away. Tides, surges, currents, and wave-action can induce movement which may result in the break-up of structures and the transport elsewhere of their fabric and contents. Scour may create depressions or build up deposits which can influence the destruction or preservation of wreck material. These effects will be influenced by the geology and sediment regimes of the sea-bed on which the wreck lies. The chemical composition and physical properties of the water, especially

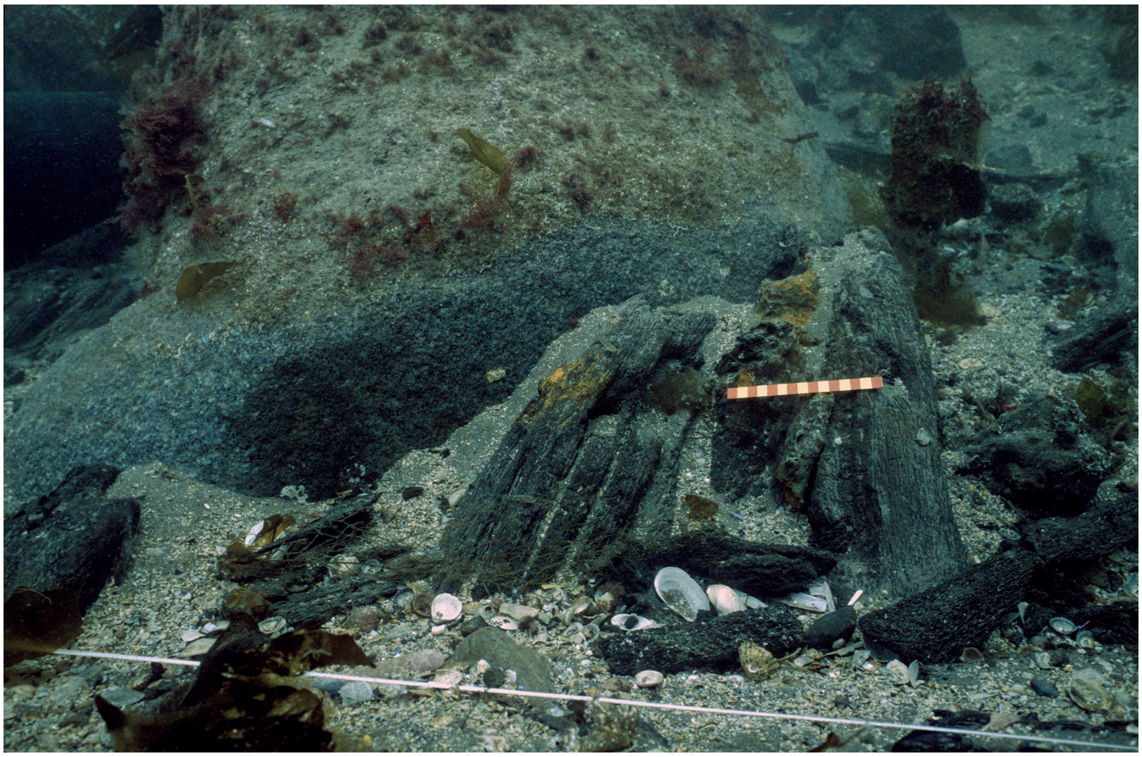

Illustration 117
The large boulder (Datum D) close to the forward bow quarter of the surviving wreckage. Note that the displaced and broken timbers rise up its side, and none was trapped beneath, indicating that the boulder was in place when the wreck was impaled on it (DP 173836)

seawater, its temperature, and the amount of dissolved oxygen it contains, will cause reactions of various kinds, particularly to metals (Gregory 1995; MacLeod 1995). Complex networks of electrolytic couplings between dissimilar metals, activated through seawater, will protect or corrode metals according to their relative corrosion potentials.

Organic materials will be susceptible to the effects of water-penetration, light and biological attack. Sea-bed movement may cause mechanical degradation, while rock-falls, the laying down or shifting of sediments, and other processes of geomorphological change may further influence the dynamic phase of wreck formation. Post-wrecking anthropogenic activity, particularly salvage or archaeology, may also be regarded as dynamic influences in the evolution of a wreck formation, while the deposition of unrelated material by rubbish-dumping, constructional work, or even the intrusion of a subsequent wreck, may further influence the formation characteristics of a site. Finally, sea-level change, geological upheaval, or land-reclamation may in various ways affect the environment and hence the nature of a wreck formation.

Once the dynamic phase of a wreck's integration with the sea-bed is complete, a static, or stabilised, state will normally follow. This can happen quickly, and perhaps with little change to the ship's original form, as when a vessel sinks into and is encapsulated by semi-fluid mud. A broadly similar situation may obtain when a ship founders in mid-ocean and arrives more-or-less intact on a deep sea-floor where there is effectively no water-movement, oxygen, or light (Bascom 1976: 105–18). On the other hand the dynamic phase may be short-lived but so violent that much of the vessel's substance and most of its coherence is lost by the time stability is achieved (Martin 2011). But however reduced and dislocated the surviving elements of a stabilised shipwreck may be, their placements and associations will not be fortuitous or random, but logically explicable in terms of the processes by which they have been modified and distributed. Theoretically, if these processes are correctly interpreted, it should be possible to work backwards through the sequence and so draw conclusions about the ship before it became a wreck. Though this is rarely possible in absolute terms, most wreck formations, if the archaeological and environmental evidence is intelligently recorded and studied, are capable of significant reconstructive understanding through the medium of formation-processes analysis. This has certainly been true of the Duart Point shipwreck.

4.2 Observed site-formation mechanisms

Because the potential range and complexity of wreck-formation processes, and their interacting relationships through time, are almost infinite, a total understanding of them on any site is usually beyond human comprehension or available resources. But general trends and influences can often be observed and to some extent quantified and tested, while specific phenomena, often encountered serendipitously in the course of investigation, provide snapshots of particular processes in action which may help to inform the wider picture. During 12 seasons of field investigation at Duart Point an intimate familiarity with this small site was engendered among those who worked on it. From this, in conjunction with the routine procedures of recording and interpretation, regular exposure to an often-changing marine environment, and a questioning and discursive culture within our close-knit team, an empirical understanding of some of the factors driving particular formation processes has emerged. Before applying this evidence to the wreck as a whole, it will be helpful to present some examples of particular processes at work.

Stability of large boulders

This is apparent around the two large boulders (datums C and D) close to the aft and forward extremities of the wreck. Smashed structure impacted against the rock centred on **092.064** (D) has been pushed up against its side but is not trapped beneath it (Illus 117), while the extensive organic deposits to the west of the boulder centred on **266.093** (C) stop abruptly beside it and do not extend beneath or beyond it. These two boulders seem to have locked the hull in place at its forward and aft extremities when the ship arrived on the sea-floor, thus contributing significantly to the wreck's positional stability during the break-up sequence.

Cherub deposit

Among the exposed organic deposits noted during the rescue operation by the ADU in 1992 was a wooden cherub 5, one of the ship's decorative carvings, emerging from the sand (Illus 118). Its right wing (as viewed from the front) was propped against a plank so that the object lay at an angle of about 15° from the natural level of the sandy sea-bed, within which the left wing remained buried. The upper wing had been colonised by common barnacles (*Balanus crenatus*), with the heaviest infestation clustered around its upper parts. Less-intensive colonisation was evident on the right face and hair, while the left cheek and curls remained largely unaffected. The left wing, when excavated, was entirely free of biological infestation and its pristine surface condition indicated that it had never been attacked. None of the barnacles associated with the object was more than about six months old.

Illustration 118
Top: partly buried wooden cherub's head 5 photographed during the ADU's rescue and recovery operation in 1992. In the foreground are the remains of a staved costrel 184, collapsing as the sand-level falls. Between the two objects is a human ulna (Kit Watson, DP 173909). Bottom: the wooden cherub after recovery, showing the distribution of barnacles. Scale 25 centimetres (DP 173176)

From these observations it may be concluded that the cherub was buried shortly after its initial deposition and remained encapsulated in an anaerobic environment for 339 years, during which time it became waterlogged and fragile but suffered almost no biological or mechanical degradation. It was not visible during the Archaeological Diving Unit's first visit in 1991. During the following year the surrounding sediments dropped to levels below which they had not fallen since deposition, progressively exposing more than half the object and allowing biological colonisation on its previously unavailable surface. Had this process been allowed to continue the object would probably have become completely uncovered and all its surfaces exposed to attack. Once free of the encapsulating silts it would, almost certainly, have been displaced by the tidal current and carried eastwards from the site into deep water where – loose, fragile and vulnerable to further biological and mechanical degradation – it would rapidly have been destroyed.

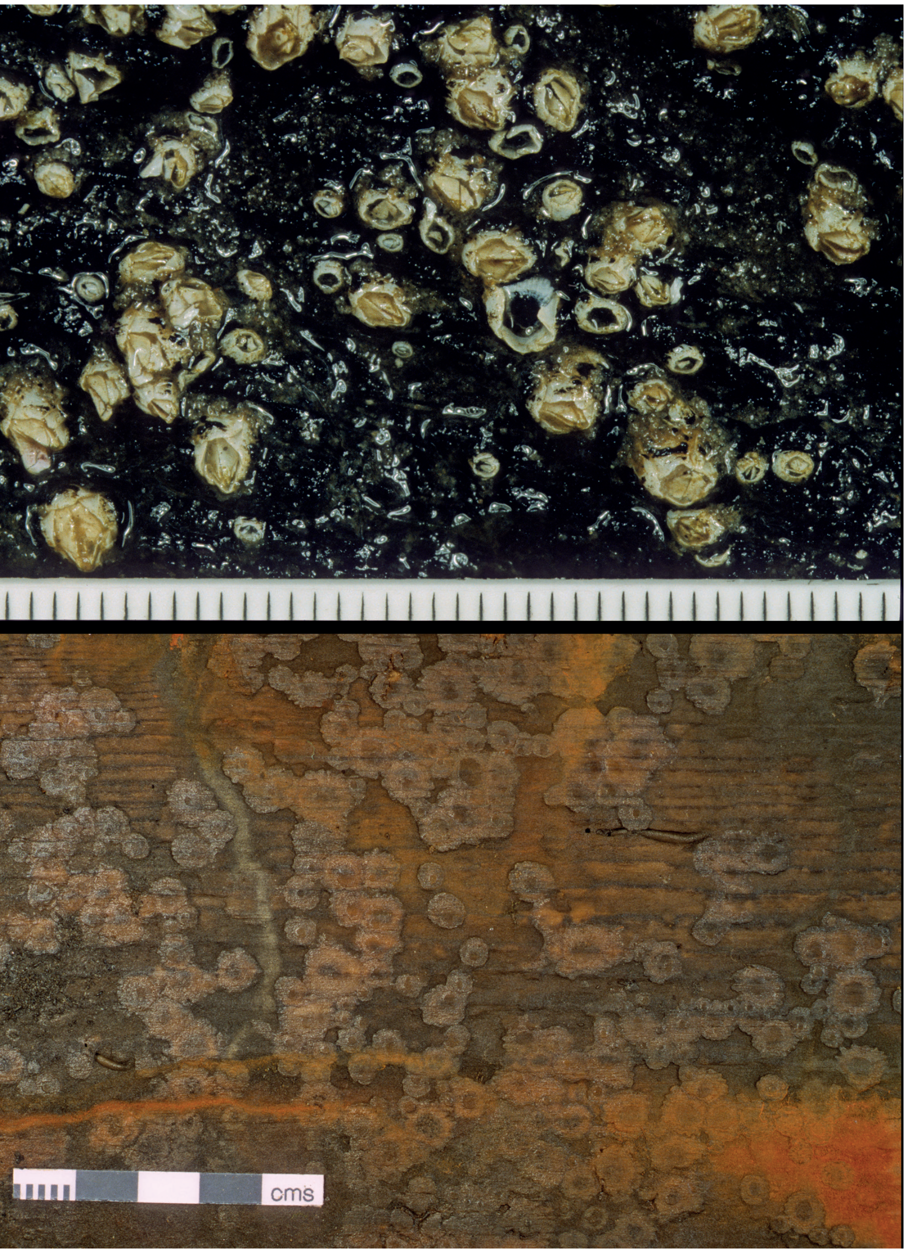

Illustration 119
Top: detail of barnacles colonising the exposed surface of the cherub carving. Scale in millimetres (DP 173722). Bottom: detail of a piece of pine panelling showing evidence of what was probably a short-term episode of barnacle colonisation before anaerobic burial. Scale 5 centimetres (DP 173723)

Such a fate appears to have befallen the upper staves of a small wooden costrel 184, the remains of which lay partly buried immediately in front of the cherub. For as long as the surrounding sediments were deep enough to cover the cherub, the costrel too would have been buried, its staves held together by the matrix of sand even though the withy hoops which bound it had become waterlogged to a point at which they retained virtually no mechanical strength. But as soon as the top of the object was exposed by the lowering of sediment levels its upper staves, no longer held together other than by the ineffectual hoops, were carried away by the current. The still-buried elements remained intact and in good condition, as was evident when the remains of the object were finally excavated and recovered.

Between the cherub and the costrel was a human ulna, part of a single skeletal assemblage scattered throughout the aft interior of the wreck. The distribution of this individual's bones was restricted to a deposit identified as the collapsed interior of the stern, which suggests the following hypothesis. Soon after death the corpse is likely to have become buoyant from gases produced by the early stages of decomposition, and that it did not then float away suggests that this part of the ship's interior remained sufficiently intact for long enough to trap and retain it. When the body eventually sank back into the accumulating sediments within the ship it would have been in a condition ripe for dismemberment by scavenging fauna, explaining the random distribution of bones within the context of the collapsed stern interior. Though the time taken for these processes to take place cannot be quantified with any precision, they do suggest that the stern structure remained at least partially intact for a significant period after the wreck's initial deposition.

A piece of wooden panelling, found securely buried at **099.098** among other material which had not been biologically attacked, showed evidence of previous barnacle infestation, although no live animals or shells were present on its surface. It may be presumed that this piece had been exposed for some time before becoming incorporated in a deposit of uninfested material (Illus 119).

A more complex depositional sequence can be postulated for the framed-and-panelled door 17 at **083.090/094.088** (Illus 70–2). Most of its surfaces are unabraded and free from biological infestation, apart from a band of heavy barnacle colonisation beneath a run of panelling in direct contact with the door's upper surface. Part of the door was also overlain by a gun-port lid. Neither side of the panelling, or the gun-port lid, shows any sign of infestation. The conclusion must be that these objects had been disposed elsewhere before final deposition, perhaps because of their proclivity to float before becoming waterlogged. If still buoyant but trapped inside the hull, the door may have exposed part of its surface to barnacle colonisation before sinking and integrating with other items to take up the configuration in which they were found.

Transom and binnacle complex

The archaeology of this isolated organic deposit has already been described (Chapter 3.2, Area 1). From a wreck-formation perspective the relevant factors are that the binnacle 88 appears to have been deposited in a partially abraded state on a sea-bed of loose gravel, where it stabilised *c* 100mm below the present sediment surface (Illus 63). Its upper surviving elements, only the top edges of which show evidence of continuing abrasion, lie >20mm below the surface, a depth which thus defines the lower limit of post-wrecking sea-bed movement in the area. Parts of it, however, have been subject to attack by shipworm (*Teredo navalis*) and gribble (*Limnoria lignorum*). There is no means of knowing how much more deeply it may once have been buried. The adjacent transom-timber, though buried to the same lower horizon as the binnacle, with its top surface uncovered in places, is heavily abraded on all faces. This suggests that it had undergone a more prolonged episode of exposure prior to final burial and stabilisation. Under the transom-timber, and in contact with it, was an unabraded barrel-end, indicating that abrasive mechanisms had not penetrated to this lower horizon since deposition. The main phase of the transom-timber's degradation must therefore have taken place somewhere else.

The most likely explanation is that the timber, which had once been an integral component in the framework of the stern, had survived as part of an articulated structure which remained proud of the sea-bed for a substantial period following the wreck's initial deposition, leaving it exposed to biological degradation exacerbated by the strong current. We may surmise that within this structure a significant number of organic objects had become trapped and protected, including the binnacle, compass components, and a barrel-end, and that in due course part of the stern with some of its contents broke away to be transported down-current where a sequence of secondary break-up and deposition occurred. During this process much was probably carried away and lost, but the temporary intrusion of a substantial piece of structure probably induced the scour and infill which assisted in the burial of this isolated sub-deposit.

Wooden chest deposit

Within the collapsed stern deposit, at **092.084/098.093**, were the buried remains of an open wooden chest 110. Its excavated state is shown in Illus 77, and its stratigraphy in Illus 78. The significance of this isolated receptacle of sedimentary deposition is that it provides a closed stratigraphical snapshot of the post-depositional burial sequence which occurred at this part of the wreck. It suggests that after an initial period during which a limited amount of silting took place concurrently with the distribution of organic debris across the site (Layer 3), there was a major deposition of clean silt uncontaminated with wreck material which filled the chest to a depth of at least 0.3m (Layer 2). This has a bearing on the interpretation of site-formation processes in the stern area which will be discussed later.

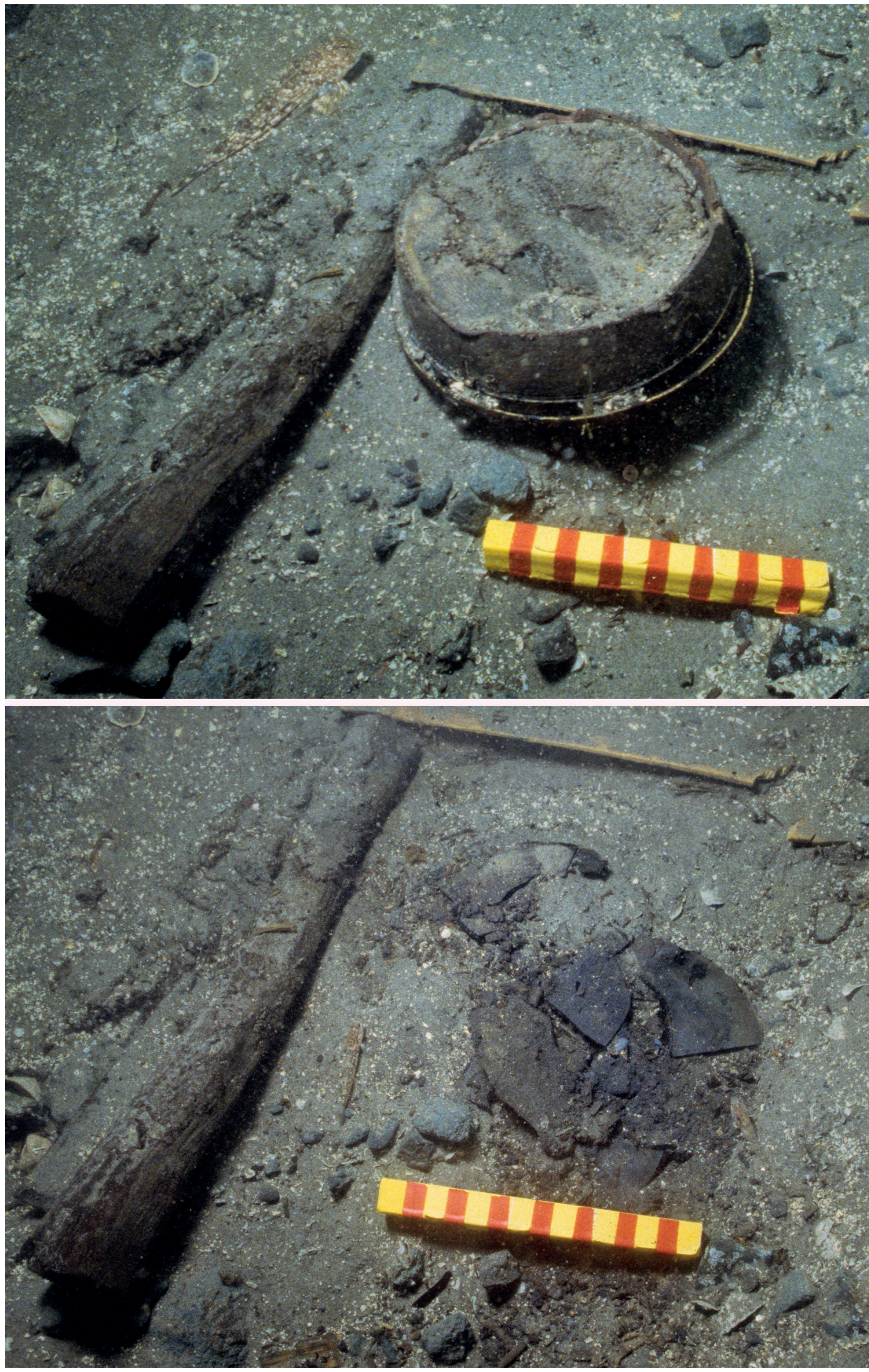

Illustration 120

Top: inverted mariner's compass 91, in situ after excavation. Its base is cracked and imploded (DP 174253). Bottom: shattered glass face of the compass after removal of the bowl. That it retains its circular shape indicates that it broke when the compass reached the sea-bed, and that neither object has moved since. Scale 15 centimetres (DP 174255)

Illustration 121
The surviving starboard floor-timbers 1.8A, 2.5A and 3.0A. The keelson, running diagonally from top centre to centre right, has been reduced to its bottom few centimetres by a combination of shipworm (*Teredo navalis*) attack and abrasion. The sectioning effect of the abrasion shows the extreme honeycombing produced by *teredo* borings. This is also seen in the eroded ends of the floor-timbers (DP 173768)

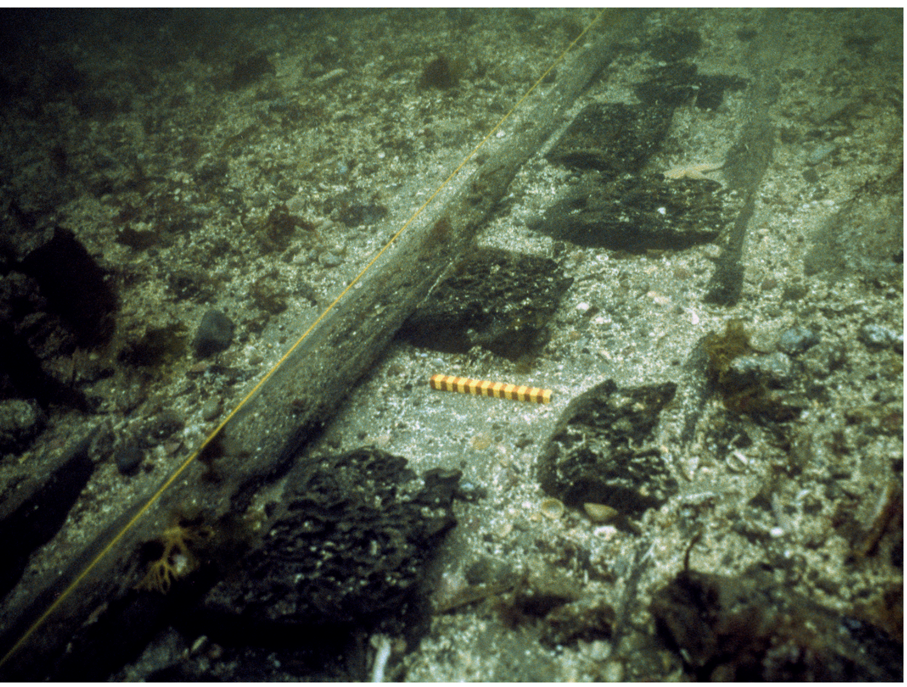

Illustration 122
Exposed frame-timbers, ceiling planking (along the yellow line), and partly buried outer planking (towards right) at the port midships side of the surviving structure, looking aft. Although the ends of the planks have been reduced to a flat conformity with the sea-bed by biological attack and erosion the longitudinal timbers are relatively unaffected, showing that the deposits on this side of the wreck are more stable than on the starboard side. Scale 20 centimetres (DP 173773)

Protection and exposure of the collapsed stern deposit

A major part of the stern structure appears to have remained partly intact for a significant period after deposition. This no doubt explains the exceptional condition of items from the collapsed stern interior. In this connection it is relevant to describe a destabilising event which occurred during the second-highest spring tide of 1993 (tidal range at Oban 4.2m) on 20 August, and the three days that followed. The high tidal range, with its concomitant increase in current flow during the ebb, coincided with a north to north-westerly wind which rarely dropped below Force 4 and frequently reached Force 5 or 6 for the next three days. By 4pm on the 23rd it was gusting occasionally to Force 8. During Low Water on 21 August it was observed that waves breaking on the shallow western end of Duart Bay were displacing considerable quantities of sand, which discoloured the water up to 500m from the shore. At the start of the ebb tide this discoloured water moved eastwards in a distinctive narrow band around Duart Point, reaching the wreck-site about an hour after slack water.

Team members on site at the time, who were on the point of terminating their dive because of the increasing run of the ebb, experienced a sudden and severe loss of visibility, from *c* 8m to *c* 2m, caused by the transport of suspended sand across the site. They also noted that previously unexposed organic material was being uncovered on the up-slope (shoreward) side of the wreck, particularly towards its eastern end. The following day, when conditions had moderated, it was noted that a substantial area of organic wreckage, extending across *c* 4m × 4m, had become uncovered (Illus 68). Most of the material, which included fine panelling and part of a wooden lantern, was in a condition which suggested that this was the first time it had been exposed since it became incorporated into the environmental matrix shortly after wrecking. However some areas close to the pre-exposure surface showed evidence of light infestation by barnacles (*Balanus crenatus*), no longer active, which indicated that here there had been at least one previous, though relatively brief, episode of exposure and reburial. Adjacent to this deposit, and rising above it, was a structural timber whose upper part was heavily abraded, indicating the horizon above which sediments were more mobile. That it had survived at all, however, suggests that for much of the time it too had been buried. These observations indicate cyclical episodes of exposure and re-burial of varying intensity, although the August 1993 incident was one of unprecedented severity. The probable reason for this is considered below.

Stability of deposition

An intact mariner's compass [91] in excellent condition was found at **060.096**, towards the eastern extremity of the wreck, buried some 0.15m deep in sediment and covered by

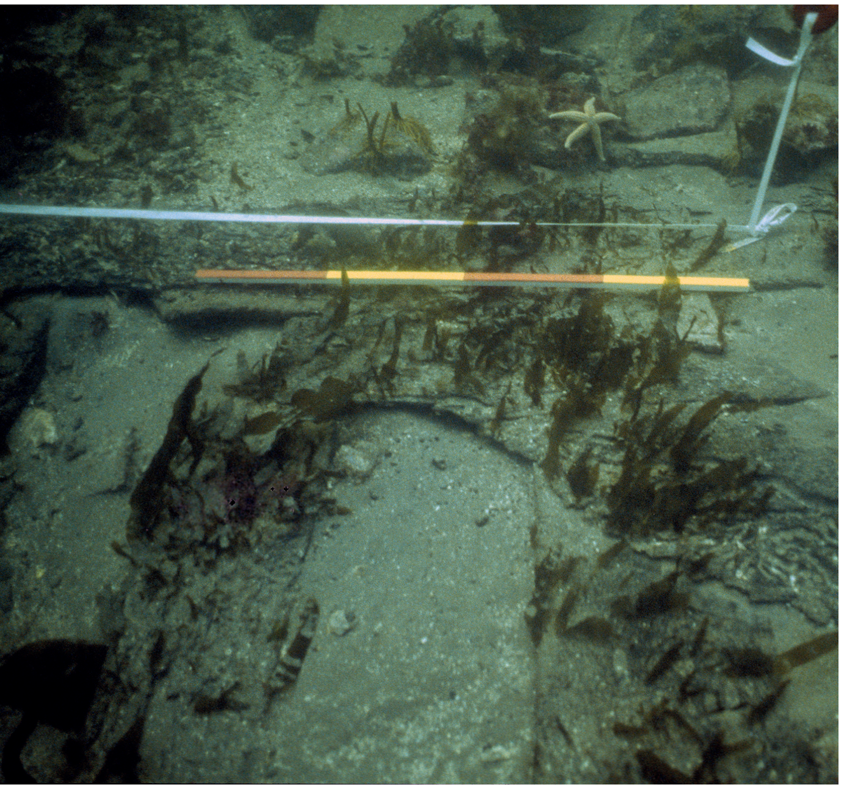

Illustration 123
Heavily eroded starboard-side frame-timbers at the Master-Frame ⊗ (left) and Frame 0.65F (right). Eroded ceiling planking, reduced to wafer-thinness, is indicated by the tape-axis. These timbers are in the early stages of colonisation by juvenile *Laminaria hyperborea*, which indicates that in spite of the extreme erosion they had until recently been buried, showing that this part of the wreck is subject to cyclical episodes of exposure and reburial. Scale 1 metre (DP 173719)

a wooden plank. The bowl was inverted and the base had imploded, indicating that when the object sank it had been air-filled and air-tight, and must therefore been held down by some container or structural element (Illus 120). Its sealed glass front must have remained intact until at some time during its progress to the bottom, some 10m down, where the external pressure would have doubled, the wooden base gave way. That the broken glass and the compass were still in close association when found demonstrates that neither has moved since primary deposition, and that burial was rapid.

Cycles of exposure and reburial

Beneath the two ballast-mounds substantial elements of the bow and the aft-of-midships parts of the lower hull are probably well preserved in secure anaerobic environments, though to protect the site's integrity these areas have not been excavated apart from a limited intrusion close to the hull's forward extremity. Between the ballast-mounds some 8m of the surviving midships section of the lower hull is partly exposed, though towards the port-side bilges it is covered with a lining of clay and gravel associated with the ballast. Extensive abrasion and biological activity has removed much of the upper substance of the wood, suggesting that it has been subjected to a succession of exposure episodes (Illus 121–2). A similar process was noted on the lower hull-remains of *Dartmouth*, just across the Sound of Mull (Martin 1978: 39–40). It was clear that some of these timbers had been in a buried state within the comparatively recent past, since their eroded surfaces were in the early stages of colonisation by juvenile plants of *Laminaria hyperborea*, for which the heavily degraded but hard surface of the wood provided good adhesion for the holdfasts (Illus 123). No adult specimens were present. These observations suggest that this part of the wreck has been affected by cyclical episodes of exposure and reburial, probably over a long period, and that, to judge by the developmental stage of the indicator growth, these previously eroded timbers had been in a fully buried state within the previous year.

A similar conclusion can be drawn from the characteristics of a small wooden bowl 179 which became exposed at **055.087** during the winter of 1992/93 (Illus 124). On recovery it showed evidence for at least three episodes of partial exposure: a recent one indicated by a clean break (mid-front in the photograph), an earlier one indicated by a slightly eroded fracture-line (to the right), and an area of degradation towards the left which has allowed at least one barnacle to colonise the surface.

Corrosion of guns as indicators of site-formation processes

Ian MacLeod

The amount of water-movement across the site is the primary determinant of the rate at which iron guns corrode, since the rate of decay is controlled by the flux of dissolved oxygen to the concreted surface (MacLeod 1995; 2006). The corrosion

Table 4.1
Corrosion rates observed on the Duart Point guns

Gun no	*Corrosion rate mm/year*	*Water depth (m) low water springs*
1	0.180	6.0
2	0.183	6.3
3	0.189	6.5
4	0.066	6.6
5	0.019	6.6
6	0.121	6.2
7	0.124	7.0

Illustration 124
Turned wooden bowl 179, largely intact and unabraded but showing evidence of three episodes of partial exposure: a recent clean break; earlier biological attack and abrasion around the rim; and a single colonising barnacle (DP 173699)

rates observed on the guns at Duart Point are summarised in Table 4.1, where it can be seen that the average corrosion rate of Guns 1, 2 and 3 is approximately 50% higher than that observed for Guns 6 and 7, while Gun 4 demonstrates roughly two-thirds of the corrosion rate of the first three guns, and Gun 5, which lies half-buried under the cliff-face, shows only 10% of the corrosion rate of Guns 1 to 3. It has been found that the corrosion rate of iron is logarithmically dependent on water-depth, and for an open-ocean wreck the calculated mean corrosion rate for the Duart guns would be 0.186 ± 0.002 (MacLeod 2006). Inspection of the data in Table 4.1 shows that Guns 1 to 3 are corroding at the expected rate, and that all the other guns are corroding at lower than expected rates.

Overlaying the depth-contour map (Illus 39) on the location of the guns it can be seen that the first three pieces are lying proud of the sea-bed on a somewhat elevated natural platform. Guns 6 and 7 are located in low depressions of the sea-bed and are therefore not fully exposed to the same water-movement as Guns 1–3. Since the corrosion rates have been determined on the long-term depths of decay (depth of graphitisation) it is clear that Guns 6 and 7 have been buried under sediment for *c* 30% of the time since deposition. On the same basis Gun 4 can be seen as having been buried for *c* 65% of the time and Gun 5 for *c* 90% of the time. This interpretation is based on the assumption that the guns suffer negligible corrosion when fully buried. It is understood that guns buried on a wreck do continue to corrode, but at a greatly reduced rate, so the relative corrosion rates indicate that defined parts of the wreck have been buried for significant periods since their original deposition. Thus the corrosion profiles of the guns on the Duart Point wreck-site represent clear evidence that the site has been subjected to significant changes since 1653. The data from the guns also assist in the interpretation of the site-formation processes and the general distribution of the decay-patterns which have been observed with the wooden structure and artefacts and the rates of colonisation by marine organisms such as kelp.

Recent work by Jacobsen et al (2013) on the corrosion of the American Civil War submarine *H L Hunley* (1854) has shown that deterioration of the cast iron of the bow and sections of the turrets and hull-plates has been controlled by the combination of erosion and corrosion in the fast-flowing and sediment-rich waters of Charleston Harbour. In the case

Illustration 125
Top: biological infestation at the surviving edge of the wooden binnacle 88. The single shipworm tunnel (*Teredo navalis*), about 10mm in diameter, bores into the interior of the wood, dwarfing the surface nibbling of gribble (*Limnoria lignorum*) (DP 173733). Bottom: characteristic infestation by gribble, following the grain on the surface of the wood. Scale in millimetres (DP 173734)

of the Duart wreck the corrosion of the guns is as predicted on the basis of the depth of the site (MacLeod 2006) and so it is apparent that despite the strong currents and the amount of sediment movement at Duart Point this mechanism does not apply to the guns. Gun 8, which appears to have been completely buried until its exposure by excavation in 2000, had suffered minimal corrosion.

Evidence of biologically induced mechanisms

It is clear that the biological ecosystems associated with the site are varied, interactive, and complex. Our understanding of their effect on site-formation processes is based largely on empirical observations made during the course of the work, so of necessity it is over-simplified and partial. This aspect has, however, proved helpful in constructing archaeologically based hypotheses which seem to explain various site-formation mechanisms, and it is hoped that our experience will stimulate more systematic research into this largely neglected topic.

Exposed wood in sea-water inevitably suffers biological attack. Two species of wood-devouring animals predominate on the Duart Point wreck, shipworm (*Teredo navalis*) and gribble (*Limnoria lignorum*). The former is not a worm but a bivalved mollusc which bores into the interior of the wood leaving a hole *c* 10mm in diameter, often lined with a calcareous deposit (Illus 125). The latter is a very small isopod crustacean, seldom more than 3mm long, which attacks the outer surfaces of wood along the grain. The two species often operate together. The activities of non-wood-boring animals, mainly crustaceans, may also, by exposing wood through burrowing, induce shipworm and gribble infestation (Illus 126).

Active biological transport

On occasion direct biological activity can lead to the movement of archaeological material. An observed example involved half of a Hebridean *crogan* pot 144, which was found lying loose on the sea-bed some 20m down-current from the eastern end of the site (Illus 127). Since the object no longer retained an identifiable archaeological association with the wreck, the possibility that it is intrusive cannot be discounted, although the chances that it derives from another source are slight. Closer inspection revealed the pot's recent history. It had been buried save for a circular area some 150mm in diameter, revealed by a dense patch of barnacle

Illustration 126
Top: burrow-scrapes thrown up by creatures seeking shelter beneath the hull-timbers. Scale 15 centimetres (DP 173749). Bottom: a long-clawed squat lobster (*Munida rugosa*) in its lair beneath eroded ship timbers (DP 173740)

Illustration 127
Hebridean *crogan* pot 144 with the attached kelp plant (*Laminaria hyperborea*) which acted as a sail in the current to drag it off the site. Scale 20 centimetres (DP 173721)

Illustration 128
Top: section through sediments close to the binnacle deposit showing alternating levels of gritty sand and gravels. A razor shell (*Ensis siliqua*) has been exposed next to the upright 25cm scale (DP 173697). Middle: the highly aggressive velvet swimming crab (*Liocarcinus puber*), which abounds on the site, may have been responsible for the dispersal of human remains in the collapsed stern area (DP 173741). Bottom: partly collapsed shoe 205 with human vertebrae and a clay-pipe stem within it (DP 174136)

growth. This provided a convenient surface for a young kelp plant (*Laminaria hyperborea*) to establish itself and begin to grow. As it prospered the sediment level fell, as indicated by light barnacle colonisation across the rest of the pot's surface. In due course a point was reached at which the drag of the plant's developing fronds in the current overcame the pot's diminishing hold on the sea-bed, and this unusual symbiotic partnership of vegetable and anthropogenically modified mineral began its journey away from the site, as indicated by drag-marks.

During excavation it was noted that the deeper deposits of sand and shingle, particularly at the eastern end of the site, carry large populations of razor shells (*Ensis siliqua*). These burrow vertically into the sediment and feed through a tube which extends into the water and retracts when threatened (Illus 128). The animals appear to have little detrimental effect on the archaeological deposits into which some had penetrated, but when exposed they are defenceless against predation. In particular they excite a voracious feeding-frenzy among the numerous velvet swimming crabs (*Liocarcinus puber*) (Illus 128), which swarmed into the area being excavated to seize the exposed razor shells by their muscular 'feet' and scurry off to nearby lairs. Such behaviour might explain the dispersal of the skeletal remains of the only known human victim of the wreck, whose substantially complete bone assemblage was recovered disposed randomly throughout the aft organic deposit but not extending beyond it. This suggests that the after hull was still partly intact when this activity took place, providing predators with numerous secure lairs within it but restricting their movement beyond. One even appears to have taken up residence in a shoe (Illus 128)

Apocryphal stories of hermit crabs (*Pagurus bernhardus*) adopting artefacts such as clay-pipe bowls as mobile homes have long been current among underwater archaeologists, though I know of no positively authenticated example. However this mechanism might provide a plausible explanation for a phenomenon observed on the site over two successive monitoring visits in 1992. In October of that year an eroding area in which an organic deposit had been uncovered was consolidated by the application of sterile gravel obtained from a local quarry. A month later a clay-pipe bowl of mid 17th-century date was noted lying on the gravel surface (Illus 129). The pipe was of the same type as others found on the wreck, and the possibility that it had been contained within the intrusive gravel can be discounted. Transport by an animal such as a hermit crab seems the most likely explanation.

4.3 Interpretation of site-formation processes

The wreck lies on a shingle bottom with some intrusive rocks and smaller stones at the foot of the rock-face which slopes from the shore just east of Duart Point. The forward and aft ends, as argued above, seem to have been held in place by two large boulders. A primary axis, with a mean bearing of *c* 300° (T) viewed from aft, is represented by the keel which is probably largely intact throughout its *c* 18m length, defined by its estimated forward extremity at **280.060** and the lower

Illustration 129
Top: a hermit crab (*Pagurus bernhardus*) which has adopted the shell of a common whelk (*Buccinum undatum*) as its home (DP 173747). Bottom: clay-pipe bowl of distinctive 17th-century form, similar to others recovered from secure contexts on the wreck-site, lying on top of gravel derived from a quarry on shore and laid as a consolidant a month earlier. This object can only have come from elsewhere on the site, and transport by a young hermit crab is a possibility. Scale in centimetres (Steve Liscoe, DP 173666)

sternpost at **096.074**. Forward of the mainmast-step the lower structural complex is heeled some 15° to port, while the lower stern assembly is heeled in the same direction to *c* 25°, suggesting that a twist or fracture has occurred somewhere beneath the aft ballast-mound. Notwithstanding this, the lower structure appears to be substantially articulated along the full axis of the keel.

The keel-axis runs nearly parallel with the shore, with the Low Water Mark 15m distant from the stern and 21m from the stem. Documentary sources reveal few details about the circumstances of the wrecking, except that it took place during a violent storm lasting '16 or 18 hours'. Since Duart Bay is the only viable anchorage in the vicinity, this implies that the wind came from the north-west quarter, so as to carry the vessel from its anchored position in the bay to Duart Point. It may be postulated that the vessel hit the rocky shore broadside-on with her bow towards the north-west, sustaining catastrophic damage to the lower port hull (though none was identified in the limited areas available for inspection). It is likely that those few still on board (the majority of her people having already landed) took this opportunity to escape, though at least one individual remained within the aft interior. Sinking would quickly have followed and the ship, weighed down by ballast and guns, trended down the rock slope as a largely coherent entity to settle on the shingle bottom at its foot, heeling towards the shore at the angle she would normally have adopted when beached.

During the initial trauma of wrecking much will have floated away and further structural damage been caused by the ripping-out of masts and rigging and the displacement of heavy items such as guns. Then the ship probably settled in a damaged but relatively complete state, held in place by the well-packed ballast which had barely shifted throughout the episode. We have no means of knowing whether the current was running when the wreck occurred, but the first ebb tide would have pivoted the hull into its present heading of 300° if it had not already adopted this orientation. That same ebb would have brought with it an initial flow of suspended silt which, as we have seen, characterises tidal behaviour across the Point during strong north-westerly winds. Normally this material would not affect the morphology of the sea-floor, where mechanisms of deposition and removal had reached a state of balance which maintained a more-or-less constant bathymetric profile, to which (apart from minor cycles of change) it would subsequently revert when the stable phase of the site-formation process had been reached.

When the wreck arrived, however, it would have presented a massive anomaly, which would rapidly have accumulated silt on the open decks, and within the hull through ports and hatches, and perhaps breaks in the structure. The effect would have been greatest towards the stern where, as we have seen, the flow of the current eddies inshore. It was probably during this phase that the first layer of material, consisting of fine grey silt interspersed with fragmented organic material (of which vast quantities will have been generated during the wrecking process), fell into the open chest in the aft interior of the ship. During the early phases of deposition much fragmented organic matter from within the hull, consisting of wood, fibre, leather and peat, also gathered in the interstices between the frames (Chapter 6.4).

Within the ship considerable dislocation of loose or inadequately secured items will have occurred during the sinking and its aftermath. Heavy objects will have trended downwards, while buoyant material will have floated upwards until it reached the surface or was restrained by intervening structure. Such material will have tended to accumulate in natural traps beneath the decks, especially where deck-structures met bulkheads or the ship's sides and stern. Although these floating organic deposits will have been internally chaotic and upwardly displaced, they will not normally have moved far from their original locations before escaping altogether or becoming trapped. Such accumulations will have been particularly heavy inside the after part of the ship, where the panelled compartments will not only have acted as efficient traps but will also, when their lightly pegged fastenings decayed, themselves have contributed to the richness and substance of the organic deposits observed during the excavation of this part of the wreck.

This hypothesis explains the presence within the aft deposit of material from the collapsed transom and stern interior, the formation processes of which we may now attempt to interpret. While the ship remained substantially intact and heeled some 15° to port, the interior of the hull would have continued to accumulate silt rapidly, indicated by the clean grey deposit – Level 2 – in the open chest. We may surmise that an equally rapid build-up was occurring throughout the hull, particularly towards the stern, where there were more places for silt to accumulate including, probably, an additional upper deck. This extra weight, and its higher distribution, would have exacerbated the twisting moment of the stern to port, already induced by the angle at which the ship sat. Whether gradually or as a single episode, this in time broke or distorted the aft keel and allowed the stern to rotate a further 10° to port, greatly increasing the twisting moment and eventually precipitating a partial collapse of the aft structure, during which its upper port side broke away from the keel and deadwood and fell onto its side. As it did so the organic deposits trapped inside, separated into at least two layers by the deck sequence, together with accumulated silt now filling the interior, slid onto the collapsed structure beneath to form a kind of archaeological lasagne in which waterlogged organic deposits and silt horizons became interlayered.

The distinctive hard-edged eastern boundary of this deposit implies that during its formation it had been restrained by a structure, now lost, which had lain in a straight line on the sea-bed, at a raking angle to the keel-axis and extending vertically upwards. This can only have been the flat transom stern, lying on its side. It has been suggested above that elements of the transom structure remained partially intact for long enough to suffer heavy erosion and biological degradation before breaking free to deposit a transom-timber and other material some 10m down-current from the location of the collapsed stern. A comparable break-up sequence in which a transom stern has detached itself from the longitudinal axis of a ship and stabilised on its side has been noted on the wreck of the Nämdöfjärd *kravel* near Stockholm (Adams & Rönnby 2013: 76–82).

The above hypothesis does not explain the occurrence of well-preserved and unabraded material indubitably associated with the outside of the transom structure within the layered stratigraphy of the collapsed stern interior. These include decorative carvings, window-lights, and components associated with a roofed quarter-gallery, a window-arch and a stern hawse-hole. It is possible that carvings directly associated with the Stuart regime had been removed from the exterior of the ship and stowed below, but most lack the symbolic associations that would have been offensive to republican sensibilities, and in any case their removal would probably have compromised the ship's structural integrity. A more likely interpretation is that during the break-up of the stern much of the starboard-side transom collapsed inwards and downwards along with the starboard side of the after hull, leaving part of the port transom complex, still attached to the rolled-out port side of the hull, to retain the stern contents along the angled line which defines the edge of the organic deposit. In this way elements of the outer stern structure and decoration might have become incorporated within the organic matrix. The deposit may have for a time been capped by fallen starboard-side elements of the collapsed stern when they disintegrated, which would perhaps account for the gun-port lid at **088.087**.

The formation processes operating at the forward part of the wreck appear to have been less complex. Forward of the aft ballast-mound the surviving structure retains a constant 15° heel to port, which is the natural sit of the hull. Some 5m of the keelson, its top surface much reduced by abrasion, defines the central axis of the ship from just aft of the mainmast-step to the point at which it becomes covered by the forward ballast-mound. Because of the heel to port relatively little structure on the starboard side has survived, amounting for most of its length to 1m or less from the axis of the keelson, but widening to just under 2m as it approaches the forward ballast-mound. The port side, however, survives to more than 3m from the keelson-axis along the full length of exposed timber between the ballast-mounds. This length incorporates the lower turn of the bilge and a complete run of overlapped floor-timbers and first futtocks. Excavation extended this run 2.5m further aft, confirming the deepening of the bilge as the hull began its flare towards the stern.

The clearly defined edge of the forward ballast-mound, the well-packed appearance of its stones, and its position along the ship's central axis, suggests that its post-wrecking displacement has been minimal. Its width and shape, coupled with its considerable mass (estimated at 6 tons), therefore indicate that the ship had a bluff-ended bow, a conclusion reinforced by the evidence recorded at the forward extremity of its surviving hull. The heavily abraded nature of keel, keelson, and frames at this point suggests that the lower forward hull had been unburied for an extended period, and this suggests that most of the bow structure – and by implication the remaining hull as far back as the postulated break beneath the aft ballast-mound – had remained substantially intact for some time after deposition. This would have generated significant scour, particularly around the bow, facing directly into the current.

Excavation beyond the port-side edge of the forward ballast-mound identified spill associated with the upperworks of the ship at this point, particularly bricks and tiles from the galley structure. This area also included Gun 4, which closely reflects the matching position of Gun 5 on the starboard side. They were probably paired forward-facing bow pieces, as argued in Chapter 7.4.

Hypothesis of the wrecking event and its aftermath

On 13 September 1653 the ship lay with five consorts and two smaller vessels at anchor in Duart Bay. Most of her complement was ashore, and much of the vessel's cargo of military hardware and provisions had been unloaded. With little warning the fleet was struck by a severe north-westerly gale during which three of the ships broke free from their anchors and were wrecked. One came ashore at Duart Point, broadside-on with her bow pointing approximately NNW. With her lower port-side hull extensively holed she filled rapidly with water and sank, bumping down the 35° rock slope still largely intact. At the foot of the slope she settled with her keel resting on the gravel sea-bed, heeled to port at her natural sit of about 15° (Illus 130). Her forward port quarter was impaled on a large rock (**266.093**), which stove in much of the adjacent structure, while her lower stern was restrained from movement seawards by another rock at **092.064**. Significant damage was probably sustained during the wrecking event, and over the following few days, by the movement of heavy items within the hull and the tearing out of masts, spars, and rigging by wind and water action. Further, though probably limited, damage may have been caused by rescue or salvage attempts from the shore.

Notwithstanding the violence of the primary event, the hull remained at least partially intact for a considerable period. It represented a destabilising intrusion within the balanced dynamics of current and sediment transportation peculiar to this location, and its presence generated rapid and massive accumulations of silt, much of which entered the hull. Silting was particularly heavy towards the stern, where the eddying current entered gaps in the hull, filling the decks with silt which trended towards the downwards-tilted port side. As the weight of silt increased, and the structural integrity of the hull diminished, a point was reached at which the entire stern complex twisted a further 10° to port, distorting or perhaps breaking the keel and keelson some 6m forward of the sternpost. This movement would have tipped the silt deposits further to port, and at this point the mixing of silts with partly waterlogged organic material which had become trapped in the stern during the initial wrecking process may have begun.

After an unknown but perhaps quite short period the heavy, and now structurally weak, silt-laden upper-stern structure, upon which the increased angle of heel had induced an even greater turning moment, broke away from the keel, keelson, and aft deadwood and collapsed onto its side, carrying the transom with it. Much of the port-side transom remained intact, lying on its side and still partly attached to the after-framing. Four pieces of the ship's main armament (Guns 1, 2, 3 and 6), which appear to have been mounted in broadside pairs on each side of the main deck towards the stern, were also deposited during this process, as was the small minion drake, which may have been mounted at the stern pointing aft through the transom (see Chapter 7).

As the stern collapsed onto its side the mixed silt and waterlogged organics slid across the decks and accumulated in layers to become recognisably stratified archaeological deposits, restrained at their after ends by the remains of the transom. Some of the starboard-side transom structure, including elements of decorative carving which had probably dropped off when their iron fixings corroded, became incorporated in the general collapse and deposition of the stern complex. This material, as evidenced by its generally pristine condition, was probably deposited quite soon after the wrecking event. Other parts of the transom, however, appear to have retained a level of structural coherence in an exposed environment before their eventual dislocation and transport elsewhere. This is indicated by the abraded condition of the decorated transom-timber which became

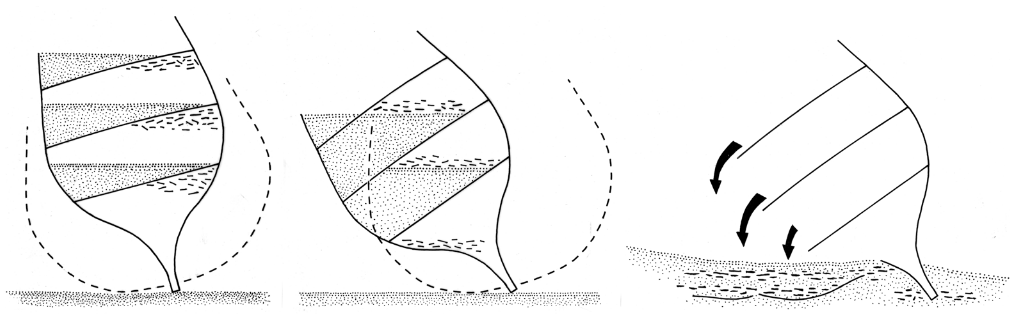

Illustration 130
Hypothetical deconstruction process of the ship's after structure following initial deposition of the wreck

relocated some 8m north-east of the main stern deposit. That it had once been part of a larger structure containing other material from the wreck is evidenced by its association with a less-heavily eroded binnacle, compass-base, and barrel-end.

The processes which conditioned deposition of the wreck's forward parts were less complex. That at least the lower part of the bow had remained substantially intact for some time after deposition is evidenced by the scour-induced erosion identified at the lowest forward structural extremity. However, at the outset significant damage had been caused to the lower port quarter by being impaled on a large boulder, while Guns 4 and 5, which seem to have been situated on the main deck close to the bow, probably fell to the sea-floor during or soon after the initial wrecking event, as the survival of primary hull-structure immediately beneath Gun 4 appears to suggest.

Although silt will undoubtedly have accumulated in the forward hull through ports and hatches, this area is less affected by eddying and so the build-up would have been less rapid and acute than at the stern. Nor was the progressive twist and collapse to port which had occurred at the after part of the hull evident here. Gradual decay, in which the mechanisms of mechanical abrasion, biological attack, and water-movement played their inter-related parts, is the more likely scenario, culminating in environmental balance and a largely restored configuration of the sea-bed broken only by the intrusive mounds of the two ballast-piles. The process involved a relatively cohesive deposition of material from the galley, which would have been located in the forecastle at main-deck level, among and just beyond the port-side edge of the forward ballast-mound. Allowing for the 15° tilt of the hull, its present position lies beneath its postulated original location.

Stabilisation and adjustment

After the stern and forward sections of the wreck had stabilised as described above, the natural processes of silt-deposition and -removal reached a state of balance, creating a sea-bed configuration adjusted to accommodate the surviving wreck features now incorporated within it. This was probably significantly deeper, particularly towards the stern, than the pre-wreck configuration because of the build-up of silt around and on top of the deposited material, as postulated above. In reaching this conclusion I am indebted to the suggestions of Steve Liscoe, a former member of the Archaeological Diving Unit, whose recorded observations of the site's condition in 1991–2, and subsequent discussions, have been invaluable. The site's stability would have been maintained by the cover of *Laminaria hyperborea* which flourishes over the main wreck area. The thickly clustered stout stems and broad fronds of this robust alga present a strong resistance to water-flow, slowing it to negligible levels at the interface between the water and the sea-floor. This boundary layer minimises the effects of erosion, and probably over time encourages a limited build-up of sediment.

It is likely, however, that later major north-westerly storms, following the one recorded on 13 September 1653, from time to time damage or remove the protective cover of *Laminaria*, and it is probable that on such occasions temporary destabilisation occurs. This is evident in the archaeological record through indications of exposure and subsequent reburial in some parts of the site. It may also help to explain the major episodes of exposure in the early 1990s which precipitated the present project. It is also possible, though unlikely, that seismic events along the Great Glen fault may have had occasional destabilising effects. However it is probable that the extreme nature of the recent destabilisation was unintentionally exacerbated, if not caused, by human intervention.

It is clear that the site was significantly disturbed following John Dadd's initial discovery in 1979, and by unknown divers in 1991–2 after the Archaeological Diving Unit's first visit in 1991. Further disturbance occurred during the visit by the Dumfries and Galloway Club in 1992, although this was mitigated by their subsequent responsible and selfless behaviour. This conclusion has emerged with hindsight. No irresponsibility or malice was involved, and no criticism of anyone is intended. As a preliminary to investigations on the site, however – by John Dadd in 1979, by the ADU in 1991 and 1992, by the Dumfries and Galloway divers in 1992, and subsequently by our team – it was routine, as it has been elsewhere, to clear away the cover of *Laminaria* to reveal features for investigation and recording. This is akin to the cutting down of vegetation on a terrestrial archaeological site. However, as we now know, such removal on this site can trigger erosion, especially if the sea-bed had previously been disturbed by indiscriminate excavation. Fortunately the trend can readily be reversed by the application of appropriately placed sandbags. Not only does this provide protection for the exposed deposits but it also creates a surface on which *Laminaria* quickly grows, thus re-establishing the site's natural stability.