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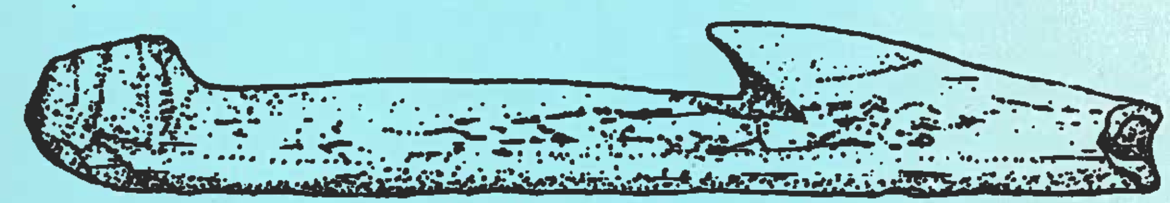
Underwater Archaeology in Montague Harbour

Interim Report on the 1992 Field Investigations

Volume I -Field (1992) and Technical (1991) Reports



Unilaterally Barbed Antler Harpoon Point (DfRu13:5635), recovered from below underwater sediments dating c. 6800 years b.p.

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Underwater Archaeology in Montague Harbour
Interim Report on the 1992 Field Investigations
(Two Volumes)
Volume I: Field (1992) and Technical Reports (1991)
Volume II: Artefact Catalogue of 1992 Collections
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Appendix II, Sediment Analysis of the 1991 Field Samples, by Doug Rutherford
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Underwater Archaeology in Montague Harbour
Interim Report on the 1992 Field Investigations

INTRODUCTION

Nineteen-ninety-two marked the fourth consequetive year of archaeological fieldwork within the Montague Harbour basin oriented to the identification and investigation of inundated cultural deposits. Fieldwork proper began August 13 and continued to September 8, 1992, with approximately two weeks additional work prior to and one week after this period to carry out logistical preparations and decommissioning. Besides the Principal Investigator, the project involved 5 hired staff persons and over 50 volunteer fieldworkers on both the land and under the water. Recorded vistitations to the site by members of the public exceeded 1,200, an increase of 400 over the previous year, partly due to increased media attention to the project which included television coverage at both the regional and national level.

The research was sponsored by the Underwater Archaeological Society of British Columbia and Yukon College, funded by generous grants by the British Columbia Heritage Trust and the Federal Department of Communication's Access to Archaeology Programme, and carried out under permits granted by the Archaeology and Outdoor Recreation Branch of the British Columbia Ministry of Municipal Affairs, Recreation, and Culture (Permit 92-86) and the British Columbia Ministry of Parks (Permit 2256).

Significant findings during the course of the 1992 fieldwork included the recovery of an antler harpoon point from below underwater sediments previously dated to circa 6,800 years bp. We also confirmed a dramatic change in the faunal material present at the base of the completely excavated underwater unit, comprised almost exclusively of upper littoral fauna. Strong evidence was also recovered for the location of a paleo-streambed within the eastern section of the study area. The representativeness of the artefact assemblage continued to grow. The mechanical logistics of the underwater caisson was improved and a testing of a smaller, single diver unit successfully carried out.

Subsequent analytical activities have focussed on organizing the sample materials through the seperation of its various elements, prior to its examination by appropriate specialists and the P.I. to develope the detailed faunal, macro-floral, sedimentological, elemental, micro-floral, and radio-carbon analyses. A comprehensive artefact database, incorporating metric and provenience data for all materials collected to date, has been developed. As well, faunal and sediment analyses for the 1991 samples, and representative drawings of the 1991 artefacts have been completed.

This short narrative will report on the methodology and initial results of the 1992 fieldwork. It will present results from previous seasons to provide an integrative context for the 1992 investigations. It will also review the analyses proposed to be undertaken over the coming months and make recommendations for additional fieldwork and analysis.

RESEARCH LOCALE AND RATIONALE

The goal of the research is to develop an in depth assessment of the potential, distribution, and nature of inundated cultural deposits within the Montague Harbour basin, a well-protected tidal embayment located on the southwestern shore of Galiano Island, in British Columbia's Gulf Islands chain (Fig. 1). The physiography of Montague Harbour mitigates much of the erosionary potential of tidal action and storm surge activity, particularly along its western shore. The harbour is well-protected from normal winds and extreme tidal currents, a fact which undoubtedly led to its occupation in the prehistoric past as well as its continued use as a favoured anchorage today.

The relative sea level (RSL) of the region has fluctuated during the Holocene; geological reconstructions propose a drop in RSL during the early Holocene of between 10 to 15 m, followed by a rise in RSL during the middle Holocene to approach present day levels by the late Holocene for the Victoria - Gulf Islands region (Clague, 1980; 1981; 1983; 1989). Geological cores and intertidal excavation within the basin itself carried out in 1990 confirm this model (Easton, 1992a), although the data suggest a much more rapid rise in sea level during the past 3,000 years than posited by Clague. The archaeological implications of such RSL change during the past have been presented previously (Easton 1985; 1988; 1989a; 1992b), but for those unfamiliar with this literature a review follows.

If we accept the assumption that most coastally adapted populations live close to the existing shoreline of the day, as they do today and have in the documented past, then rising RSL would inundate evidence of prehistoric shoreline occupations. Following on this assumption, a resolution to two apparent problems in Northwest Coast prehistory become possible.

The larger of these problems arise from the postulate that the earliest migrations to the New World occurred along a coastal route (Fladmark, 1979; Gruhn, 1988), but that the evidence of these migrations have since been inundated by rising sea levels during the late Pleistocene and early Holocene. For many years it has been maintained that there is no viable way of proving this proposition, since all evidence of these past movements would have been destroyed, but these arguments have been made by terrestrially orientated anthropologists. A contrary view would hold that it is possible that the material evidence of these early movements survive in a submarine environment and that all we lack are the methods of discovery and analysis. Recent geomorphological studies identifying glacial period coastal refugia lends support to this view (Luternauer, et al., 1989; Mann, 1983). The development of appropriate methods require, however, the implementation of a long-term research programme designed to articulate the natural processes which such sites would be subjected to as they are initially inundated and subsequently submerged, as well as methods of discovery and excavation. We have proposed that the investigation of nearshore submerged cultural resources is the best beginning to this programme (Easton, 1988; 1992b).

The second problem which can be addressed in a more direct way is that of a lacuna in the archaeological record of the central Georgia Strait region between approximately 3,200 and 9000 years ago. The culture history of the Georgia Strait is currently based on the identification of "culture types," as applied by Mitchell (1971; 1990) within the following sequence: Charles (c. 6500-3200 bp); Locarno Beach (c. 3200-2400 bp); Marpole (c. 2400-1600 bp); Strait of Georgia (1600-200 bp); and Developed Coast Salish (post-contact). While numerous sites representing the period from Locarno on have been located in the region, few sites of the Charles period are known, and fewer still which show clear evidence of a coastal adaptation (most are inland). Within the period prior to the Charles culture type and initial Holocene declaciation in the region, no coastal occupations have been identified. Relative sea level rise may explain this hiatus in the coastal archaeological record, as relevant sites would have been inundated by rising sea levels (Thomson, 1978; Fladmark, 1990). If we accept this proposition, it follows that any existing coastal settlements of this period will not be found, nor our understanding of the prehistoric adaptations and chronologies of human populations in the area be complete, until we discover and investigate these sites below the current sea level (Duff 1963; Mitchell 1971; Easton 1988).

Thus, the fieldwork can be placed within a broader context of a coherent underwater archaeological research programme designed to investigate submerged prehistoric cultural resources along the British Columbia coast, and elsewhere. It was anticipated that the current research would make at least a modest scientific contribution to our understanding of the effects of fluctuating sea levels on prehistoric populations and continue to develop the methods, skills, and data required to pursue a strategic prehistoric underwater archaeological research programme designed to address these important issues of British Columbia's coastal heritage. Given the longstanding maritime tradition of the First Nations of British Columbia, this is a heritage which must extend far beyond historic wreck deep into the prehistoric past. Thus, the theoretical implications of the Montague Harbour research is of local, regional, and international scope.

PREVIOUS RESEARCH

Prior Research in Montague Harbour

Montague Harbour itself contains a number of shoreline midden accumulations (Fig. 2), several of which have been excavated though, with the exception of DfRu-13, detailed reports on these are not available. Keen (1971) excavated a sample of the onshore midden at DfRu-22, the Pebble Beach site. Her brief (3 page) field report provides only a general indication of the location of excavation units and numbers of artefacts recovered; full presentation or analysis of the data was never completed. At least one salvage excavation was undertaken at DfRu-7, the Jackson Beach site, which lies across the harbour from DfRu-13 on the shoreline at the base of Sutil Mountain; here Mitchell recovered several basket remains from a midden eroded by a redirected stream bed. A collection of lithic artefacts from DfRu-7, as well as DfRu-11, the Goode's Beach site, has been initially described by Mitchell (n.d.). On the basis of the artefact's described by Mitchell, as well as those collected during our survey in 1990, there is a well-developed Marpole component, and perhaps an earlier Locarno component as well.

As well, both local private collectors and archaeological surveys have recovered artefacts from its beaches for decades. Several of these private collections are significant in terms of their size and range of artefact condition, particularly those which show various stages of wear by water action. Many of these pieces have likely been redeposited due to erosion of the shoreline middens, resulting from the occasional winter storm surge and cumulative sea level rise during the late Holocene. No comprehensive description of these materials has ever been undertaken.

DfRu-13, then, is the most well-described site within the basin. A detailed

monograph by Mitchell (1971) resulted from area excavations conducted in the mid-sixties; more recently, the site has been examined by Eldridge (1989).

Mitchell's excavations identified three cultural units at DfRu-13, corresponding to occupations of the Strait of Georgia, Marpole, and Locarno culture types. No evidence was found in the excavated deposits for an occupation prior to Locarno, although Mitchell noted the possibility of RSL rise and its implications (Mitchell, 1971:65-67).

Eldridge's more recent survey efforts recorded "undisturbed cultural deposits under the beach on the seaward side of the eroding midden deposits" in a series of auger tests (Eldridge 1989:6). The lowest cultural deposits below the high water line were encountered at the eastern end of the site, about 0.5 metres above hydrographic datum. Eldridge (1989:6) noted that the "presence of undisturbed cultural deposits below the high tide level supports Mitchell's contention that the site area may have subsided relative to sea level since earliest occupation." Among his conclusions was the recognition that these deposits are significant in their potential to contribute to our developing knowledge of inundated site formation processes, and he recommended their controlled test excavation to "determine the amounts, types, and age of cultural materials present, the preservational qualities of the deposits, . . . and the expected rate of destruction from beach dynamics" (Eldridge 1989:23).

Finally, Flemming's (1983:158-165) review of the potential survival of submerged lithic sites world wide included Montague Harbour as a site of note, based on its protection from an extended wave fetch and consequent low wave energy available for erosion; a proposition supported by our own efforts at predictive site modelling in the region (Easton 1989b).

Prior Research of the Montague Harbour Underwater Archaeology Project

1989

Cumulative research suggested, therefore, that Montague Harbour was a good candidate for the location of intact submarine cultural deposits of some antiquity, and led to three day exploratory excavations of the submarine zone in 1989 (Easton and Moore 1991). Two 1 x 1 m test pits were excavated by airlift; their location are shown in Figure 3. Following 25 cm arbitrary levels, Under Water Excavation Unit (UWEU) #1 was excavated to a depth of 45 cm, UWEU #2 to a depth of 70 cm;[1] excavated sediments were contained within surface baskets of 0.65 cm mesh and examined ashore. A total of 32 stone samples were collected and examined in detail to determine their cultural status. Three possible lithic artefacts were identified: a hammerstone cobble, from the surface of the sea bed; a large pebble fragment, very angular, with several smooth scars; and a small spatulate basalt "flake." Both of the latter lithics were heavily waterworn and the unequivocal characteristics of human use were not obvious. Both were recovered from the screen of material excavated from Unit B, at a depth of approximately 45 cm. In addition to the collected lithic material, a number of faunal remains were recovered and identified, including a bird bone, burned bone of a large mammal, a dog tooth, and a deer bone. Finally, the lower levels of the excavation displayed distinct charcoal fragments scattered throughout the matrix.

[1] Underwater excavation unit numbers 1 and 2 have been designated Units A and B, respectively, in previous reports.

1990

While the results of the 1989 tests were equivocal they were suggestive enough that a subsequent proposal for further research was approved for funding by the B.C. Heritage Trust in 1990. The fieldwork in 1990 included both intertidal and submarine excavations, and have been fully reported on in Easton (1992a).

A series of sediment cores were taken from throughout the basin. The cores documented both the location of what appeared to be stratified midden deposits, as well as evidence of past marine transgressions. The transgressions are evidenced in several cores which display a depositional sequence of basal clays, terrestrial soils, paralic sediments, and marine sands. The transgression has been dated on marine shell to 1240 - 950 cal. ybp (Beta 43710), on the lowest intertidal core; the sample comes from 0.8 m below tidal datum. The cores also provided direction as to where to undertake additional test excavations within the harbour.

Intertidal excavation was conducted offshore DfRu13 (Fig. 3), exposing well-stratified midden remains within the upper intertidal unit, and more homogenous deposits within the lower intertidal excavation unit. The complex stratigraphy combined with the radiocarbon dates from these units and the cores has led us to suggest that a relatively rapid marine transgression, within the range of 1 to 2 m, has occured over the past 2000 years.

A total of 51 artefacts were recovered from the intertidal excavation at DfRu-13, including a chipped stone point, several burins, a retouched pebble spall, utilized flake, and bone bipoint fragment; the remainder were flake debitage. They were recovered from throughout the intertidal units, and none are unequivocally diagnostic of any particular cultural assemblage, although based on the stratigraphy and radiocarbon dates we suggest that they are of probably early Gulf of Georgia or Marpole origin.

Excavations within the submarine zone were undertaken 80 m offshore at about 2.0 m below tidal datum, designated UWEU #3 (Fig. 3). The unit measured 3 by 2 m, and was divided into two interpretive areas, labelled "outer" and "inner." The "outer" area lay around the inside periphery of the unit for a half (0.5) m wide distance and constituted the defined "slump zone," or area within which we expected the unit walls to cave into as excavation proceeded. The "inner" area was made up of the centre area of the excavation unit into which little intrusive material was expected to be introduced. Thus we can apply a higher level of confidence to the *in situ* nature of materials recovered from within the inner unit, while the provenience of material from the outer unit must be regarded with less certainty. Excavation proceeded by 25 cm arbitrary levels, principally by airlift (a water dredge was used for a brief period, but was discontinued due to its poor lift capacity). All materials excavated were deposited directly by the lifts into 0.5 cm mesh baskets, resulting in an immediate loss of most sediments less than this size into the water. The baskets were then transported to shore where the material was water screened and examined. The submarine unit was excavated to the third level, that is between 50 and 75 cm below the surface of the bottom, before fieldwork time elapsed. Two submarine cores were taken of the remaining sediments below Level 3. Underwater level samples, though collected, cannot be considered representative of the levels, since our methods (trowelling selected sediments into plastic bags underwater) could not capture the full range of sediments present or demonstrate stratigraphic control.

The physical stratigraphy of the underwater unit consisted of about 15 cm of fine submarine sediments and crushed shell, below which lay an apparently homogenous stratum of densely packed articulated and disarticulated bivalves, within a matrix of sands and gravels. Similar to the year before (Easton and Moore 1991:275-76), this apparent homogeneity was broken, however, by the appearance at

about 75 cm below the surface of a notable increase in the number of small, rounded pebbles within the matrix. From the second level downwards, we also noted the appearance of charcoal and apparently fire altered rock, many of which had barnacle remains on them. Radiocarbon dates were obtained on 3 underwater samples: on marine shell from Level 3 (2039-1835-1630 cal. ybp; Beta 45195), on charcoaled wood from Level 4 (1300-1134-930 cal. ybp; Beta 43715), and on marine shell from Level 8 (6499-6297-6119 cal. ybp; Beta 43711); the latter two dates are on material recovered from the underwater core.[2]

Twelve lithic artefacts were recovered from the underwater unit. They are all of the flake form: one exhibits unifacial retouch, another evidence of utilization, while the remainder are flake debitage. Their distribution by level within the unit is relatively even.

Non-benthic faunal remains from UWEU #3 included six land mammal specimems (all likely deer, *Odocoilius hemionus*). In addition, within the benthic fauna were recovered numerous intertidal species not expected to be encountered within the submarine environment (e.g., *Mytillus edulus, Macoma nasuta, Balanus glandula, and Nucella sp*.). Their presence within the submarine sediments is strongly supportive of RSL rise; whether they represent culturally deposited midden remains is difficult to determine within the sampling procedure used, since it is conceivable they may represent redeposited remains washed down from the higher intertidal zone or natural remains from a period of lowered sea levels.

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[2] Radio-carbon dates presented in this paper have been calibrated to calendrical years based on the statistical corrections developed by Stuiver and Reimer (1986), accounting for solar effect and, in the case of marine shell, marine resevoir effect. The central number represents the established mean calendrical estimate, the first and last number the standard deviation to 2 sigma.

Detailed analysis of the 1990 data did not allow us to make definitive cultural interpretations due to the lack of unequivocally diagnostic artefacts, the ambiguity of the radio-carbon chronology, and the uncertainties inherent in the stratigraphic and faunal data. Notwithstanding these ambiguities, the data demonstrated several facts and suggested some additional working hypotheses supporting additional research. Our conclusions of facts included:

1. Holocene sea level rise is evidenced within and about Montague Harbour. Of particular note in this regard is the transgression documented in Core # 13, which suggests that sea level was at least 80 cm below present sometime between 1240 and 950 years ago, and at least 8.0 m below current sea level between 6499 and 6119 years ago.

2. Cultural evidence in the form of artefacts *are* located within the intertidal and nearshore submarine sediments offshore DfRu13.

3. Based on the analysis of expected ecological distribution of species elements, additional cultural evidence in the form of midden remains are present within the intertidal sediments offshore DfRu13; the lower intertidal and submarine sediments are more ambiguous in this regard.

4. Below an initial 10 cm of mixed beach sediments, the upper intertidal zone deposits display an apparent stratigraphic integrity. Radiocarbon dates from these units are stratigraphically coherent, as follows: Excavation Unit (EU) 3/4 Level (L) 9: 950-814-690 cal. ybp (Beta 43717); EU 14/15 L15: 970-926-760 cal. ybp (Beta 43712); EU 14/15 L 21/22: 1170-991-880 cal. ybp (Beta 43714).

5. Relative to the upper intertidal EU's, the lower intertidal (EU 25/26) and underwater excavation units are stratigraphically more homogenous; this is most likely a function of site formation factors, including

increased benthic bioturbation.

Identified ambiguities in the data and analysis included:

1. The relatively recent dates, combined with the stratigraphic integrity of the upper intertidal deposits, indicate a relatively rapid sea level rise during at least the past 1500 years. While our data suggest this, it must be recognized that it stands at odds with the prevailing geological interpretations of Holocene sea level rise within the region, which posits a much less dramatic rate of transgression during the late Holocene (Clague, 1981). Given the complex constellation of factors contributing to sea level change (Kraft, et al., 1985), area specific divergences from the generalized regional reconstruction of Holocene sea level change is not unexpected, however our data diverges quite dramatically. Local tectonic and sedimentological factors may account for this; alternatively, sampling error or data misinterpretation may also be contributing factors. In particular, our reliance on marine shell dates presents a notable two-fold problematic: first, the potential error in marine shell correction dates; second, given the fact that they represent the time of death of a single individual of a Phylum notable for burrowing behaviour, we must consider these dates with some caution.

2. Similar ambiguities are presented by the artefact remains from the lower intertidal and, in particular, the submarine excavation units. The lack of clearly stratified deposits, combined with our knowledge of bivalve behaviour, suggests the sediments have been considerably mixed by benthic bioturbation. We could only suggest, but not with the present data document, that this bioturbation may be vertically zonal; that is occuring in discrete vertical zones within which the sediments are

mixed, but which between zones is stratigraphically distinct. Complete excavation of the submarine sediments to the basal clays, combined with more rigorous sampling of the sediments excavated, should provide us with the data required to test this supposition. Without such supporting data the interpretation of the artefacts remain ambiguous; they may represent materials originally laid within the sediments or they may be secondary deposits resulting from transport by erosionary forces acting on cultural deposits closer to the present day shoreline.

In sum, the fieldwork in 1990 demonstrated that there were in fact prehistoric cultural remains to be recovered from both the intertidal and submarine sediments of Montague Harbour. Both the methodology and data of this work were not, however, refined enough to support definitive conclusions about the nature, extent, and interpretation of these deposits. Subsequent fieldwork was, therefore, carried out in 1991 to refine our methodology and collect additional data from both the intertidal and submarine sediments.

<u>1991</u>

The principal goals of the 1991 fieldwork were to:

1. Explore in more detail the nature of the lower levels of the intertidal deposits offshore DfRu13, and obtain additional comparative data from other intertidal zones within the basin.
2. Test the effectiveness of the use of a caisson structure to prevent slumpage within the underwater excavation unit.
3. Improve the systematic sampling of the underwater levels of excavation.

4. Obtain additional data on the nature of the lower levels of the underwater sediments.

Intertidal excavations were carried out at DfRu13 (three units and a small trench joining them; Fig. 3)), DfRu7 (one unit), DfRu22 (two units). Within the submarine excavation (designated UWEU #4 in Fig. 3), located approximately 90 m offshore DfRu13 at about 4 m below tidal datum, an eight by eight foot caisson was erected to attempt to prevent the contaminating slumpage of previous underwater excavations. It proved largely sucessful in doing so. In addition, level samples from each quadrant were collected using 25 cm diameter cores which were set into the sediments at the beginning of each level; little, if any, sediments were lost using this sampling technique, and we are fully confident in their stratigraphic location. Full unit excavation was completed to within Level 7, or about 150 cm below the surface of the bottom (bsb). A small (25 by 25 cm) test caisson was excavated within the NE quadrant to the basal clays, encountered between 220 and 230 cm bs.

As in the previous season, public participation was an important component of archaeology at Montague Harbour. Supported with funding from the federal Department of Communication's Access to Archaeology Program, two public interpreters were hired to greet public visitors and pre-arranged tour groups to the site and provide them with the opportunity to learn of the aims of the project, our findings, and to participate in a limited way, should they wish, through teaming them with experienced crewmembers working the screens. Over 800 documented visitors were welcomed to the site, including 2 local divers who toured the underwater excavation area. Written material provided visitors included an introductory pamphlet and a short reprint from *The Midden* (Easton, 1991). In concluding the site tours, each group was made aware of the sources of financial support the project received, as well as positive reinforcement on the need for informed stewardship of all archaeological resources.

The intertidal excavations demonstrated that both DfRu13 and DfRu7 share a similar upper intertidal stratigraphy, that is well stratified midden deposits containing artefacts and features; they also share approximately the same basal date (circa AD 900 - 1500). DfRu22, on the other hand, is markedly different in its stratigraphy, characterized by shallow (15 - 20 cm) unconsolidated beach sediments. These differences can be accounted for by the different energy regimes each inhabits; DfRu22 is exposed to a long fetch from the NE down Trincomali Channel, which can generate considerable wave and current action, while the others are both within the relatively protected environs of Montague Harbour proper.

Perhaps the most significant intertidal stratigraphic exposure in 1991 was the identification of what seem to be shell free mineral soils at the base of the intertidal deposits and above the basal clays at DfRu13 (Fig. 4). These shell free soils seem very similar in colour and texture to the soils currently found onshore away from the main midden. The single excavation unit at DfRu7 does not allow us to state conclusively that a similar penultimate stratum is present there as well; comparative sediment analysis of these samples is not yet completed.

The intertidal excavations at all sites recovered cultural artefacts. The DfRu22 assemblage is restricted to several (n=4) ubiquitous flakes. The DfRu7 assemblage (n=18) includes a single ground slate triangular point from 25 cm bs, a cobble spall with unifacial retouch from level 3 (c. 75 to 100 cm bs), and flake debitage, found throughout the excavation unit to the basal levels at 110 cm bs. Excavations at DfRu13 recovered over 60 lithic artefacts, including a stone fishhook shank, two ground bi-points (fish hooks for the shank?), a ground stone disk bead, several additional fragments of ground stone implements, a bone artefact which is reminiscent of a net gauge but quite small (2 x .75 cm), a ground ulna tool, and three chipped points. Significantly, two of these points were recovered from the "mineral soils"

layer at the base of the midden deposits. No additional radio carbon dates were generated for the DfRu-13 intertidal levels.

Within the underwater unit a very interesting stratigraphic sequence was encountered. Not unexpectedly, the underwater sediments were dominated by benthic bivalve remains; what was surprising was their concentration - clamshells were literally packed against each other within the sediments in considerable density. That at least some of these remains were natural is suggested by the fact that their *in situ* position was with valves joined and siphon end pointed towards the surface, which is their expected death position. Faunal analysis of level samples revealed, however, the presence of some species which we would not expect to find within the submarine environment and at the depths encountered, including *Balanus glandula*, an upper intertidal barnacle, and *Macoma sp.*, the bent-nosed clam, at depths of over two metres below the surface of the bottom. Another interesting stratigraphic component was encountered about 130 cm below the surface of the bottom, where we began to encounter increasing amounts of floral organic remains, principally twigs and broken branches, many of them burned, and some possibly cut. A more complete description of the underwater stratigraphic sequence will be discussed in the summary of the 1992 fieldwork, below.

Considerably more cultural artefacts were recovered from the underwater excavation in 1991 than in previous years (n=110), including a chipped stone point, a stone disk bead, and numerous flake tools.

Analysis of the data and materials recovered in 1991 includes the generation of additional radio-carbon dates, completion of faunal analysis of level samples and preliminary sediment analysis. [3]

A series of radiocarbon dates have been obtained for various levels of excavation. At DfRu7 the base of the deposits, at 110 cm bs, have been dated to 1590 ± 90 radiocarbon years bp; this date is slightly older than another date obtained for the basal deposits of the upper intertidal unit at DfRu13 last year (900 ± 60 radiocarbon years bp, at 109 cm bs). We are also processing the mineral soils samples from DfRu13 in the hope that dateable material may be obtained for this level as well.

Additional dates have been obtained for the underwater excavation unit; they are graphically presented in Figure 5. We can note that the clams from the middle of the deposit date to about 2500 years ago; the floral organic deposits are about 6,700 years old; while the bent-nosed clam population seems to be about 6,500 years old. These dates are stratigraphically coherent. The apparent discrepancy between the floral organic levels and the bent-nose clam level which lies below it might be accounted for, indeed expected, within the hypothesized inundation of terrestrial deposits, since the shell fish would have burrowed through the terrestrial sediments after they were inundated.

The submarine deposits are clearly mixed by benthic bioturbation, and perhaps other site formation factors as well. But the existence of recognizably discrete levels within the apparently homogenous fossil clam deposits suggests that the bioturbation may be restricted, to a greater or lesser degree, to specific depositional zones, allowing us to apply principles of superposition to the strata between the zones; the radiocarbon chronology for the marine deposits generally bear this out.

They also support one of the hypotheses which drive analysis - that we can

[3] Detailed reports on the faunal and sediment analyses of the 1991 materials are presented in the Appendix I and II, respectively, to this report.

expect to find evidence of a "reverse littoral sequence" through the underwater sediments. By this we mean that the lower levels of the deposits should exhibit evidence of terrestrial exposure; above this should lie environmental indicators of a high tide zone, followed by middle and lower intertidal indicators, and capped by relatively recent submarine sediments. Referring back to the generalized stratigraphy of Figure 9, this is borne out to some degree. In particular, the existence of the bent-nosed clam remains at over two metres within the sediments tells us that this level must have been within 10 cm of the intertidal surface at the time of their occupation some 6,500 years ago. In addition, given the species preference for brackish waters, the initial inundation of the overlying "terrestrial" deposits may have occured within a tidal lagoon environment within the basin. Such a proposition fits generally with our paleao-shoreline model developed earlier (Easton 1989b) which suggests the formation of a tidal lagoon in Montague Harbour at a RSL of - 11 to -13 metres.

Detailed faunal analysis of the underwater level samples (Pacific Identifications, 1992) also supports this suggestion. In particular, there seemed to be a significant decrease in the percentage by weight of "large clams" (which includes Butter [*Saxidomous giganteus*], Horse [*Tresus spp*.], and Littleneck [*Protothaca staminea*] clams, and large shell remains indistinguishable between these species) in the final level sampled, correalated with a corresponding increase in the amounts of barnacles (*Balanus glandula*); a suggestion not verifiable due to the small size of the final 1991 samples. Nevertheless, this seemingly significant reversal in proportions between middle to lower intertidal bivalves and upper intertidal univalves may represent an inundation of the barnacles habitat by rising sea levels circa 6.5 k years ago, and encouraged us to pursue complete excavation of UW unit #4 in 1992.

GOALS AND METHODOLOGY OF THE 1992 FIELDWORK

The principal goals of the 1992 fieldwork were:

1. Complete the full controlled excavation of underwater excavation unit #4;
2. Test a smaller caisson unit and collect additional data through the excavation of a lower intertidal unit during high water;
3. Excavate a cross section of the previous year's intertidal trench to examine the degree of subsequent bioturbation;
4. Initiate intertidal excavation of the region above the hypothesized paleo streambed;
5. Obtain a clear stratigraphic section and column samples of the shoreface of DfRu-22 for comparative purposes; and
6. On the completion of underwater unit #4, initiate a new underwater excavation unit one to two metres further below tidal datum, within the region of the hypothesized paleo streambed.

In general terms, the proposed methodology to achieve these objectives was similar to that practiced in 1991. The underwater excavations continued by 20 cm levels, the intertidal by 25 cm, with all excavated material water screened through five cm screen mesh. Several baskets of the lower levels of the underwater excavation were airlifted into surface holding baskets of 2 cm mesh; comparison of the mass and volume retained in these baskets to that of the baskets lined with 5 cm mesh produced

a fairly consistent ratio of nearly 2 to 1,[4] suggesting that the 5 cm mesh baskets which dominated the excavation of underwater unit 4 lost as much as 47 to 48% prior to being brought to shore. What real effect this has had on our recovery of artefacts and other data is difficult to say. Certainly, the sediment samplers deployed in every level have succeeded in recovering a representative sample of the finer sediments otherwise lost, however small artefacts (less than 5 cm) contained in the excavated material may have been lost to us.

The smaller caisson deployed in the lower intertidal zone was completely welded structure measuring 1 by 2 metres, and constructed with a heavier gauge steel plate (1/8" flatstock) than used previously, the bottom ends ground sharply to form a bifacial bevel, and with 5 cm gussetts welded to each corner to provide a strong surface for driving the caisson into the sediments. The outside of the caisson was treated with a rubberized sealant (automobile undercoat) to reduce the occurance of oxidation; the inside was treated similarly and also painted with white Tremclad to increase the interior reflection and ambient light within the caisson. The latter dramatically improved the visibility within the caisson while the former seemed to work, although the period of submergence was relatively short. A third underwater caisson, measuring 2 by 2 metres was similarly constructed to complete the excavation of underwater unit #4, since we found it impossible to lower the existing caisson structure any further than about 1.8 metres. This was likely due to the considerable pressure being exerted on the sides of the existing structure. The new

[4] Volume differences (in Litres) of measured material were as follows (2mm/5mm mesh): 20/10, 22/12, 15/6, 20/10, 24/15, 35/20, 18/8, 30/8. Weight differences (in Kilograms) were similarly proportioned, viz.: 37/21, 29/18, 34/15, 25/14, 31/16, 51/28, 25/11, 43/19. Thus, the simple average minimum loss in 5mm mesh is approximately 47% by volume, 48% in mass.

isson was subsequently slipped into the existing structure (which measured 2.2 by 2 metres), and successfully driven to the base of the deposits. The white interior oduced a significant increase in light.

In an attempt to prevent the regular clogging by the larger clam shells present the underwater sediments, new underwater lifts were constructed of a larger meter (30 cm), an effort which met with measured success, and noteably reduced down time of excavation lifts due to clogging. Their general design was also proved by the use of a dispersing ring placed within the lift to expand the initial a to which compressed air was introduced; the expectation was that this dispersal uld result in a net increase in lift capacity, an expectation that was met. ditionally, improvements were made both to the compressed air hose connection l control valve located at the excavation end which, combined with a larger set of dles improved the diving excavators control of the lifts. Further improvements e also made to the excavation collection baskets and floats which received the flow of the lifts at the surface and the procedure by which they were removed from floats in preparation for transport to the shore.

Documentation of the excavation was also improved through the development ecord forms designed specifically for the unique context of the excavations at ntague Harbour. They have assisted in developing a more comprehensive and sistent record of the progress and findings of the excavation. As well, 1992 was first year in which we were able to use underwater video technology to plement other forms of documentation.[5] In general the unit performed beyond ectations, producing clear, colour video which will enhance both subsequent

The unit, purchased with funds provided by the Access to Archaeology grant in l was not able to be deployed in that year because its shipment from the supplier delayed until after the completion of fieldwork.

analysis and provide a highly accessible means by which non-divers can experience more fully the work conducted underwater. The video footage is currently being edited to produce a short diver's view of excavation for use in the field and other promotional opportunities.

Cross cut excavation of last year's intertidal trench was conducted by sliver shovelling a unit of approximately 2 by 0.5 metres to the basal clays within the middle intertidal zone. Excavated material was examined for artefacts and large faunal material. The subsequently exposed stratigraphy was documented through profiling and photography.

The excavation of the intertidal area adjacent to the hypothesized paleo-streambed proceeded within a single 1 by 1 metre unit just below the high tide berm. Due to the unexpected complexity and depth of the stratigraphy exposed within this unit it was the only intertidal excavation in the area.

A 50 cm wide face of the high point of the midden at DfRu-22 was cleared to obtain a profile of the stratigraphy present at this site and obtain a column sample for comparative purposes. Of particular interest were several perceived layers of rounded pebbles within the stratigraphy which suggested possible relict beach material from a period of marine transgression.

Finally, because the full excavation of underwater unit #4 required the entire fieldwork period, a new underwater excavation unit was not initiated.

INITIAL RESULTS OF THE 1992 FIELDWORK

The full excavation of Underwater Unit #4, with good stratigraphic and provenience control, now allows us to assess in greater detail the coherency of the underwater sediments offshore DfRu13. Although the unit represents the only fully excavated underwater unit, and as such a very limited sample, and additional documentary analysis of fauna and sediments is required, a general description of the unit's stratigraphic sequence can be made.

Figure 5 represents the proposed stratigraphic sequence. The initial sediments are comprised of marine silts populated with active contemporary benthic populations; this extends for some 10 to 20 cm. Below this lie more consolidated sediments, within which are found both live and dead butter (*Saxidomous sp.*) and horse (*Tresus sp.*) clams. The next stratum is characterized by an almost complete abscence of live benthic organisms and a high concentration of the remains of dead clam species, for the most part *Saxidomous sp*. This begins at about 50 cm below the surface and extends through to about 180 cm, when their relative presence drops dramatically, replaced by large proportions of crushed barnacle and mytiluss, whole and broken Macoma shell, and large numbers of *Littorina*, principally *scutulata*, with smaller numbers of *sitkana*. Even within the "fossil clam layer," however, the apparent homogeneity is broken by the introduction of discrete elements which may identify distinct stratigraphic layers which we believe the bivalves subsequently bore through.

The first of these is a pebble layer, encountered in all three submarine excavation units since 1989, at about 70 cm below the surface. The pebbles are two to four cm in diameter and are generally rounded. The next distinct stratigraphic component is defined by a notable increase in the relative number of large cobbles

and sandstone slabs. Many of these carry concreted bases, and, in some instances, whole remains of barnacle (identified exclusively as *Balanus glandula*). This level is found between approximately 90 to 125 cm below the surface of the bottom. Towards the lower levels of the "cobble layer," and extending for about 15 cm, the sediments are extremely hard packed. It was as the sediments became more viscuous that we began to increasingly encounter the floral organics.

This "floral" level extends from about 130 cm through the remainder of the excavated sediments though, like the fossil clams, they decrease in their occurance in the lowest levels. The most notable characteristic of the floral organic level is the tremendous number of seed cones within it; over 2,000 were collected, considerably more were discarded. While a full identification of the sample inventory has not been completed, the seed cones include members of the Family Pinaceae (*Abies amabilis*-the Balsam fir and *Pseudotsuga menziessi*-the Douglas fir) (Lauriault, 1989). As well, it was in the lowest levels that a number of smaller seeds were recovered, none of which have been accurately identified at this point.

The next identifiable stratum begins at about 200 cm below the surface, where we began to recover remains of *Macoma sp.*, the bent-nose clam, a small bivalve whose general habitat does not extend beyond about 10 cm below the surface (Rickets, et al., 1985; Kazloff, 1983). At about the same level, there is a notable increase in the proportional presence of crushed and occasionally whole barnacle remains. Crushed mussel also becomes more apparent and, at about 220 cm bsb, the littoral snails begin to appear. Finally, for about 20 to 25 cm above the bedrock, clays which are honeycombed with a series of channels ranging from several to 10 cm are present.

At first the channels in the clay were thought to have been created by one or a combination of three factors: benthic burrowing, terrestrial root activity, or terrestrial rodent burrowing. The first has been discarded based on the size and orientation of the channels; their size does not match well with the burrows associated with the species present at these levels, and they extend in all directions, contrary to an expectation of benthic burrows within the vertical plane. Terrestrial root and rodent activity, while not discarded, also seem innappropriate explanations for similar reasons of size and orientation. A fourth explanation has been offered by a geologist, which is that the channels were created at the time of glacial decay, in which a vortex stream moves beneath the glacier, often scouring channels in the sediments below. Further investigation of this possible explanation is needed.

The initial identification and inventory of artefacts recovered in the underwater excavation adds a further 55 artefacts to the sample, bringing the total number of artefacts recovered from underwater unit #4 to about 165.[6] Of greatest potential significance is a unilaterally barbed antler harpoon point, recovered from below the sediments dated in 1991 as c. 6800 ybp; a sample of this artefact has been submitted for radio-carbon dating. Other cultural material includes a net weight, several hammerstones, about 50 flakes, at least six of which are retouched. Table 1 presents an inventory of artefacts recovered in 1992 by artefact type, while Appendix III presents additional provenience and metric data.

The main intertidal test pit excavated at the eastern edge of the beach at DfRu13 exposed an unexpected stratigraphy (see Figs. 6 & 7). The initial layer of eroded broken shell and pea gravels was generally thicker here than in excavations to

[6] This figure must be regarded as provisional, based on our collection strategy which allowed inclusion of artefacts which may have been degraded by erosion; the final figure, once a more detailed assesment of the artefacts occurs, will no doubt be lower. However, we can state confidently, that there are over 100 unequivocal specimems in the sample.

the west, reaching depths of up to 30 cm. Below this a dark brown soil layer appeared and continued for about 5 cm. The next level was composed of clays with a number of well preserved organic remains, including bark, sticks, and a large piece of cedar; this layer ranged from 3 to 11 cm in depth across the W wall profile. The clays overlaid a more "typical" midden strata, of about 30 cm depth, which became increasingly black and greasy; this likely represents the leached midden phenomena described in Stein (1992), which we have identified as the "stein" layer in our profiles. Beginning at about 70 cm bs, the dark matrix began to be replaced with a gravelly olive soil, completely shell-free. Finally, at about 100 cm below the surface fine sands, by appearance fluvial in origin, appeared; these sands extended through the remainder of the deposits excavated to 160 cm bs. A series of core samples to a maximum depth of about 220 cm bs retrieved similar matrix. No basal clays were encountered in the unit before it was judged to be too unsafe to excavate further. Both arbitrary and natural level column samples were taken from the unit for further analysis.

Seventy-three artefacts were recovered from this excavation unit. Their distribution was throughout all layers except the sands. An inventory of collected artefacts are presented in Table 1. None of the *in situ* artefacts are diagnostic; the points and ground slate knife were surface finds.

The documentation of the stratigraphy at DfRu22 is presented in Figure 8. Level, column, and several potential radiocarbon samples were collected. A bone wedge was recovered in the course of this work.

CUMULATIVE ANALYSIS TO DATE

Preliminary analysis of samples collected in 1992 has been initiated, in preparation for respective specialist analysis. This has been principally focussed on sorting level samples according to particle size, and seperating the sediment and faunal elements of the matrix. Once this is completed, the faunal material will be identified and quantifed by Pacific ID, while the sediments will be analysed for element distribution and microfloral materials. The large faunal specimens recovered have been identified and are described in Table 2. Of the 17 bones only 5 are fish, and two can be identified as sea mammal, while 3 are deer bones, 3 more unidentified land mammal remains (likely deer); 4 are mammal bones which cannot be identified further. The high incidence of land mammal bones in the lower deposits offshore are suggestive.

An initial inventory of the collected artefacts has been completed, including metric descriptions, and a computerized database to integrate all artefacts collected over the past four seasons is being developed. Radiocarbon samples from the harpoon and the littoral snails from the underwater excavation have been submitted for dating; prior to removing the sample from the harpoon several replicas were made by casting, and photographs and drawings of the artefact produced. Additional radiocarbon samples may be submitted for the intertidal materials. Final reports on the faunal and sedimentological analysis of the 1991 material have been completed (they are presented as appendices to this report), and drawings of significant and typical artefacts collected through 1991 are complete. Another sub-investigation underway is the collection of all historic survey data of the harbour. This includes geographical and hydrological maps and records, as well as photographs and aerial photos from the historic period. From this we hope to be able to build up at least a modest appreciation of shoreline erosion during the last century based on empirical, rather than anecdotal, data.

Clearly, there remains considerable analysis to which the material data of the Montague Harbour excavations may be subjected; additional reports of the results of these analyses will be produced as they are completed.

data.

There remains considerable analysis to which the material data of the Montague Harbour excavations may be subjected. It is intended to continue to accumulate completion of different elements as resources allow and to complete the final integrative analysis of all materials within the context of the Principal Investigator's doctoral dissertation at the University of Alaska Fairbanks in 1994-95.

RECOMMENDATIONS FOR FURTHER STUDY

Besides the continued analysis of the material data collected to date the primary recommendation arising from our work in 1992 is to initiate a new 2 x 2 m underwater excavation unit (#5) to gain a controlled comparative sample to the material collected from underwater excavation unit #4. The location of this new unit should be several metres deeper, at between 8 to 10 metres below tidal datum. It should also be located within the vicinity of the paleo stream bed hypothesized to be present in the eastern side of the harbour. The existence of this streambed, originally indicated on our sub-bottom profile conducted in 1990, is strongly supported by the intertidal excavation documented above, in which a considerable strata of fine sands, quite likely of fluvial origin, were encountered. If such a watercourse did exist at some time in the past, it makes good sense that evidence of human occupation might be located adjacent to it.

We have made the point in past reports that the work we are engaged in at Montague Harbour has been necessarily exploratory and developmental. However, we believe that we have achieved notable results for our efforts, including verifying that there are, in fact, cultural deposits in the form of artefacts to be recovered from both the intertidal and submarine sediments within the harbour. We strongly urge the continuance of investigations of this sort in Montague Harbour, and elsewhere as well, as an area of enormous potential to resolve many outstanding issues in our understanding of our coastal prehistory.

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FIGURES

FIGURE 1: Montague Harbour in Relation to the Pacific Coast

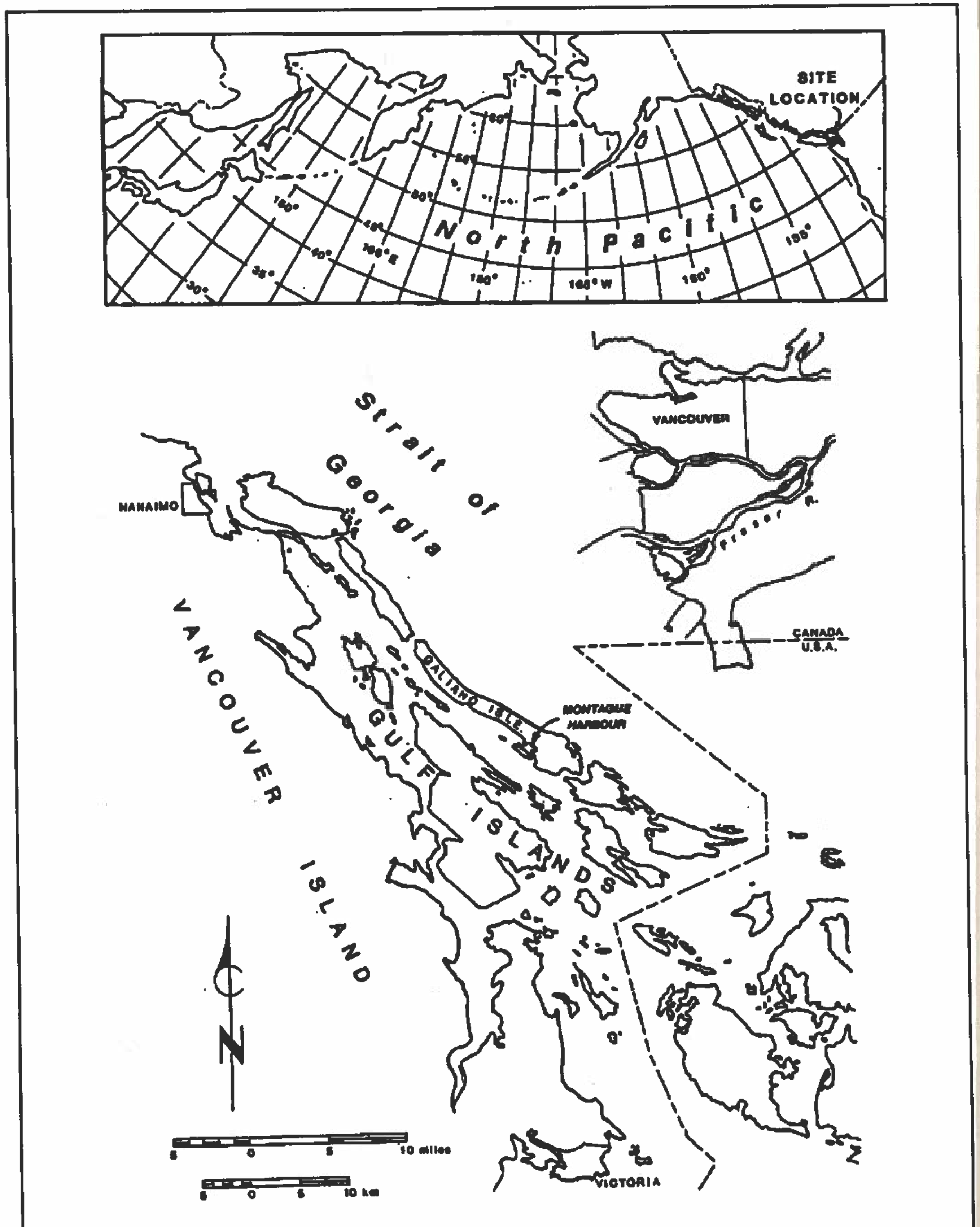
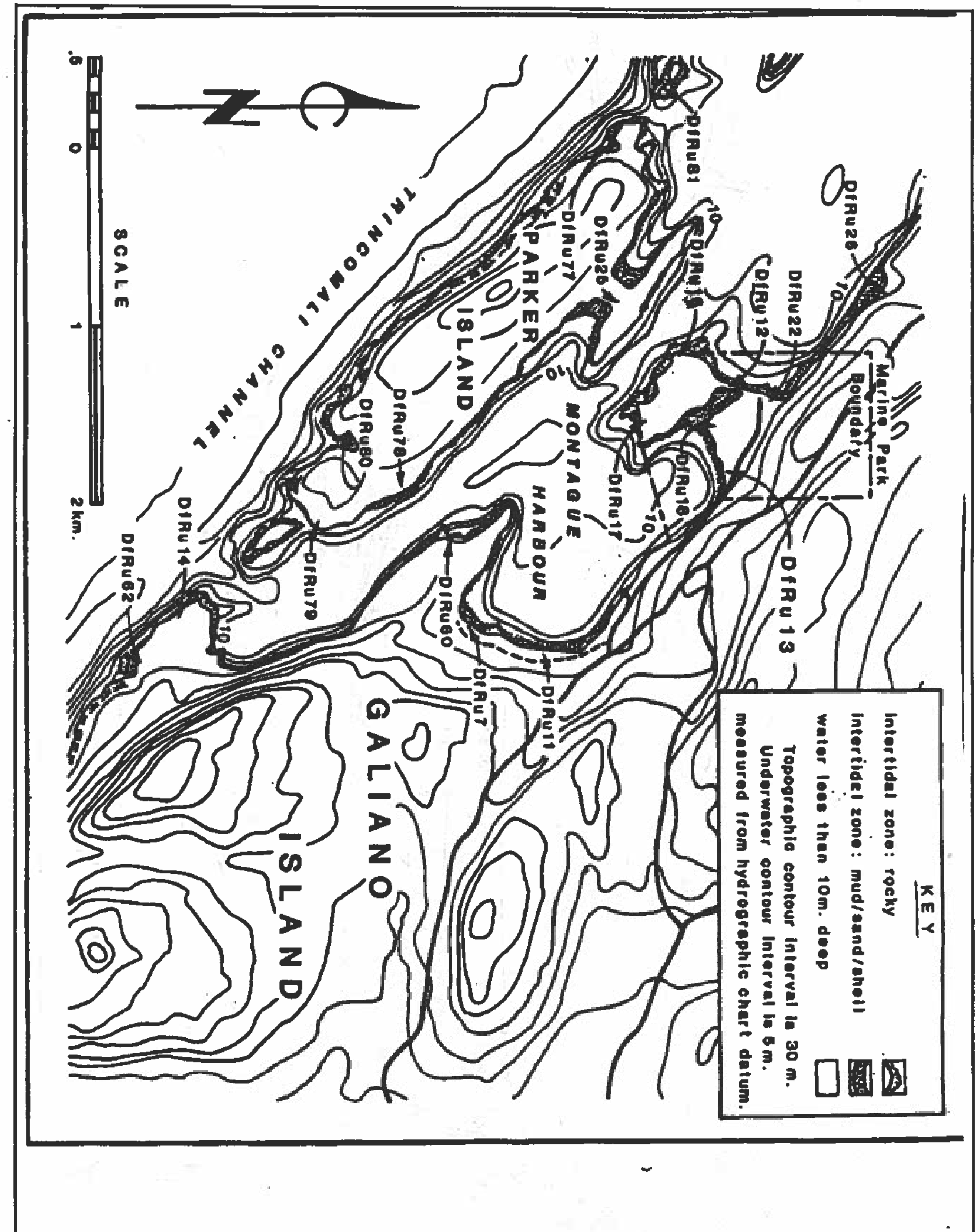


FIGURE 2: Location of Prehistoric Shoreline Deposits in Montague



Harbour
FIGURE 3: Site Location of Excavations, 1989-1992

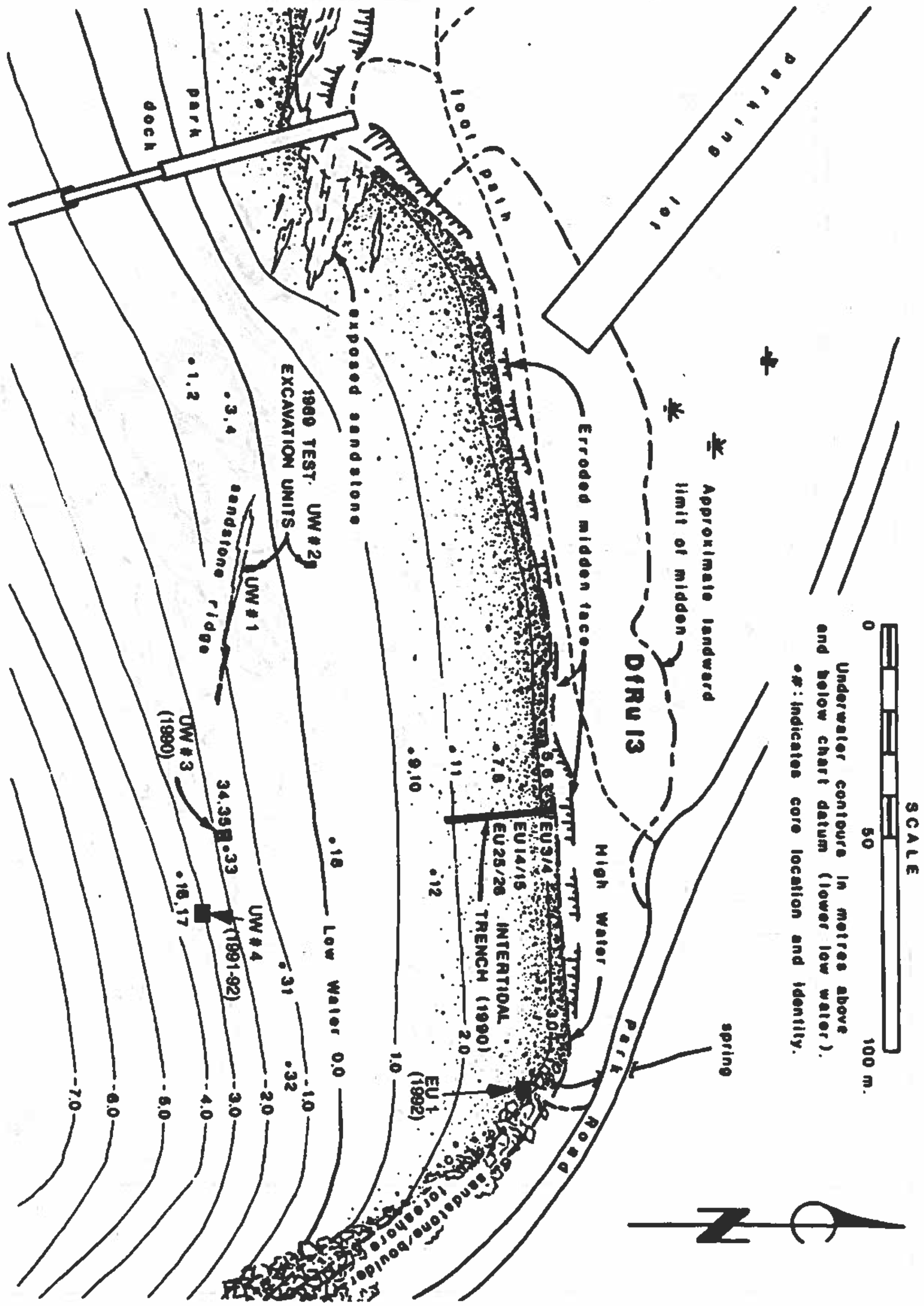


FIGURE 4: DfRu13, Intertidal Profile, East Wall - 1991

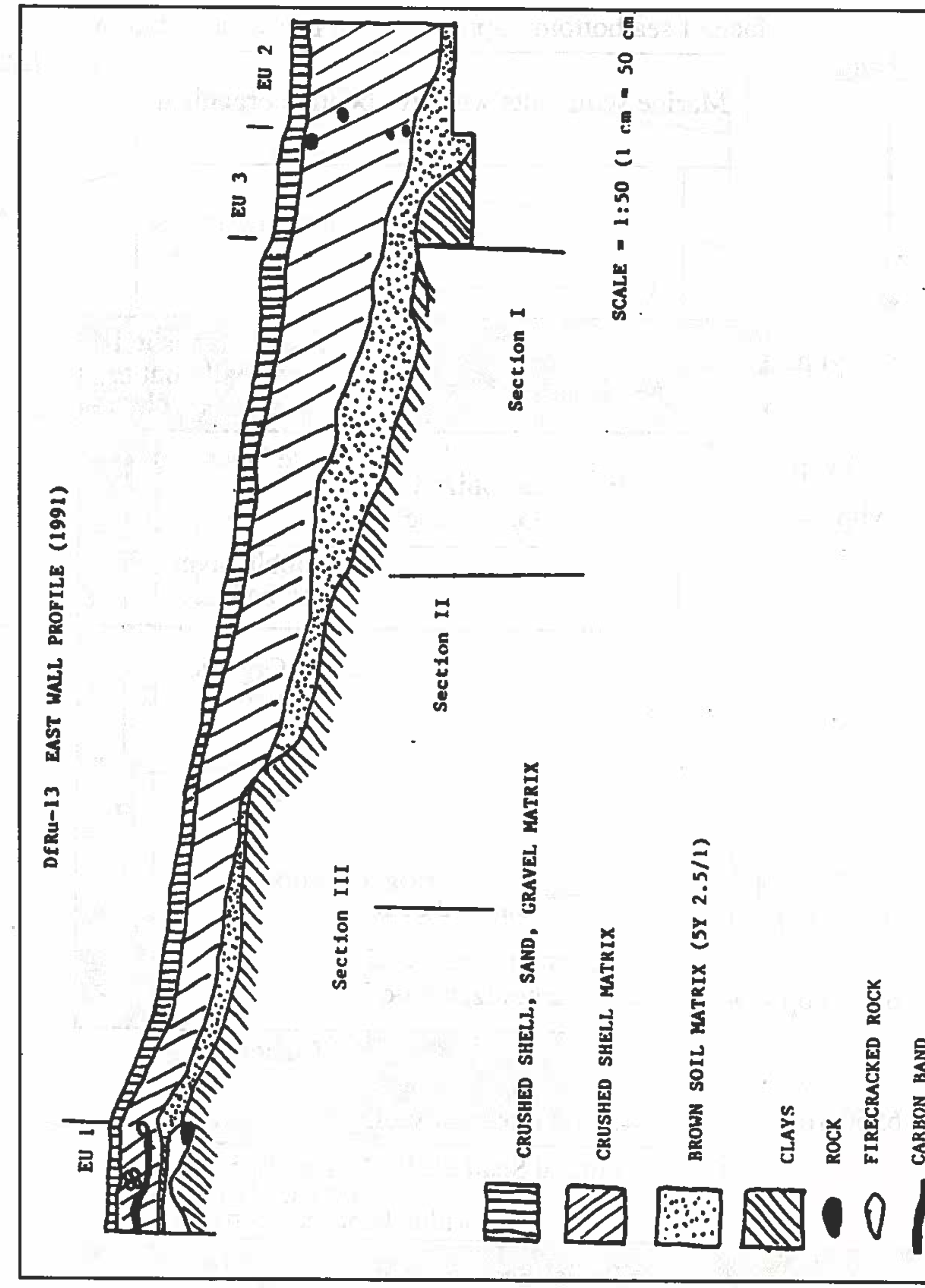


FIGURE 5: DfRu13, Underwater Profile, UW # 4

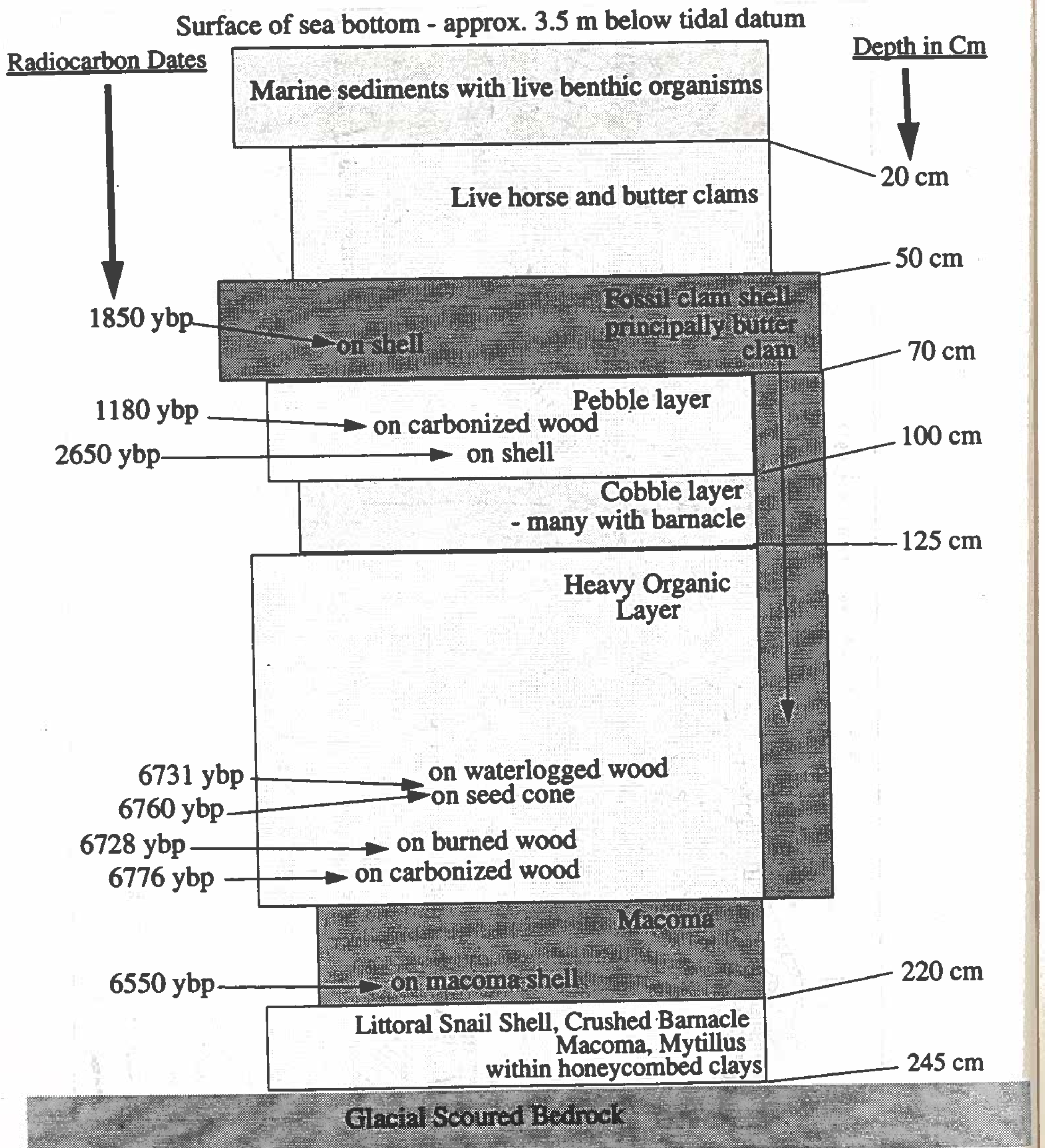


FIGURE 6: DfRu13, EU1 Profile, North Wall - 1992

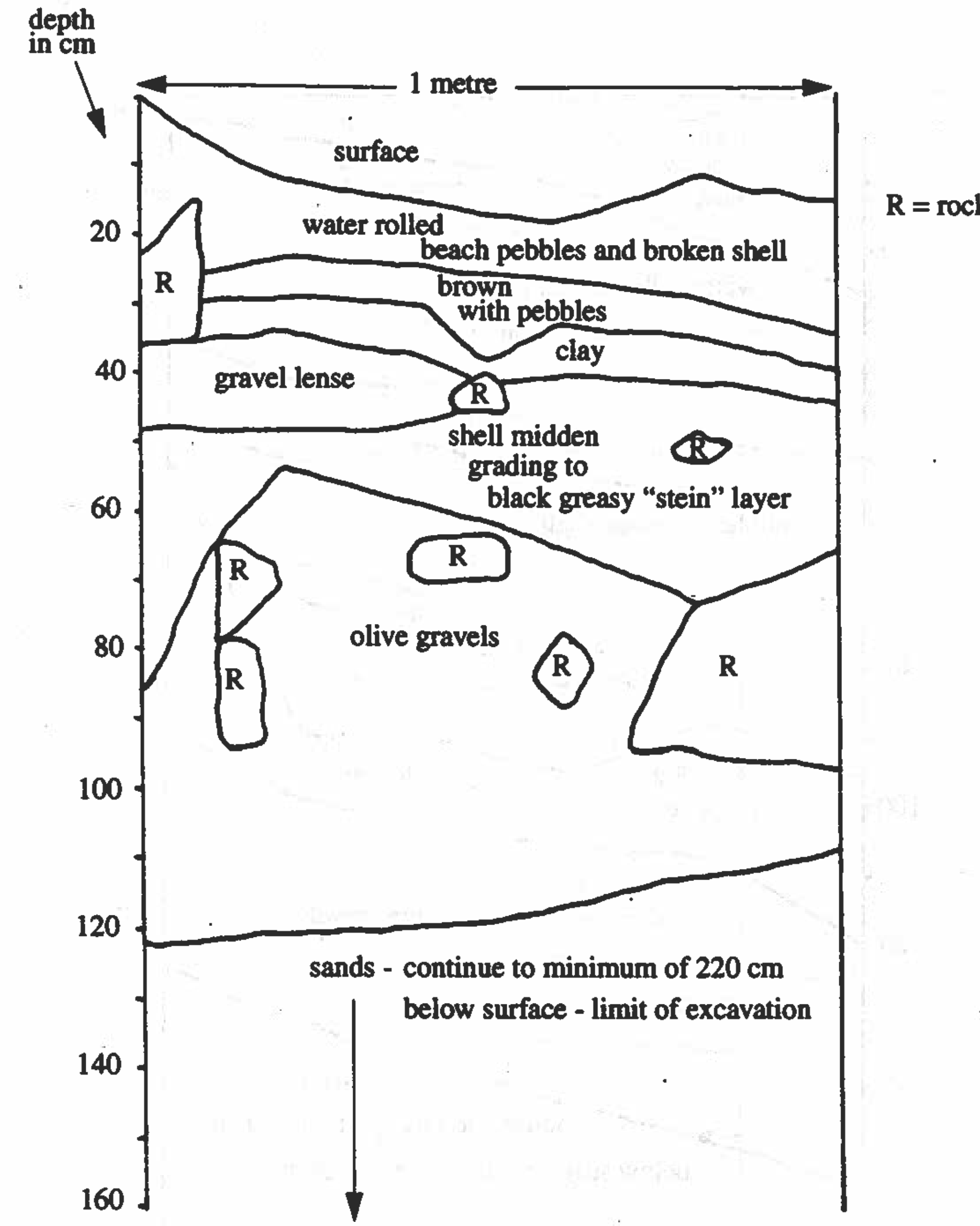


FIGURE 7: DfRu13, EU 1 Profile, West Wall - 1992

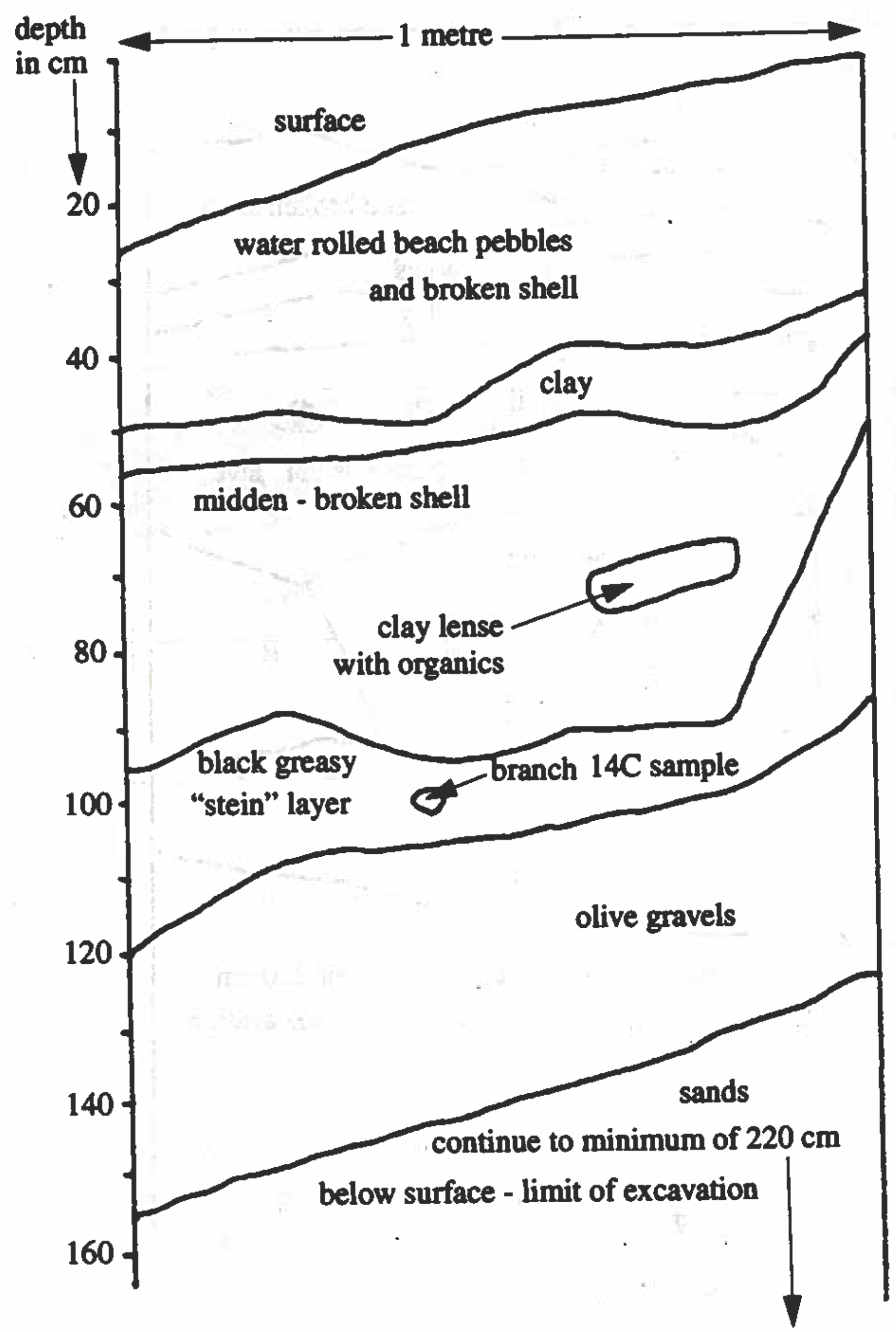
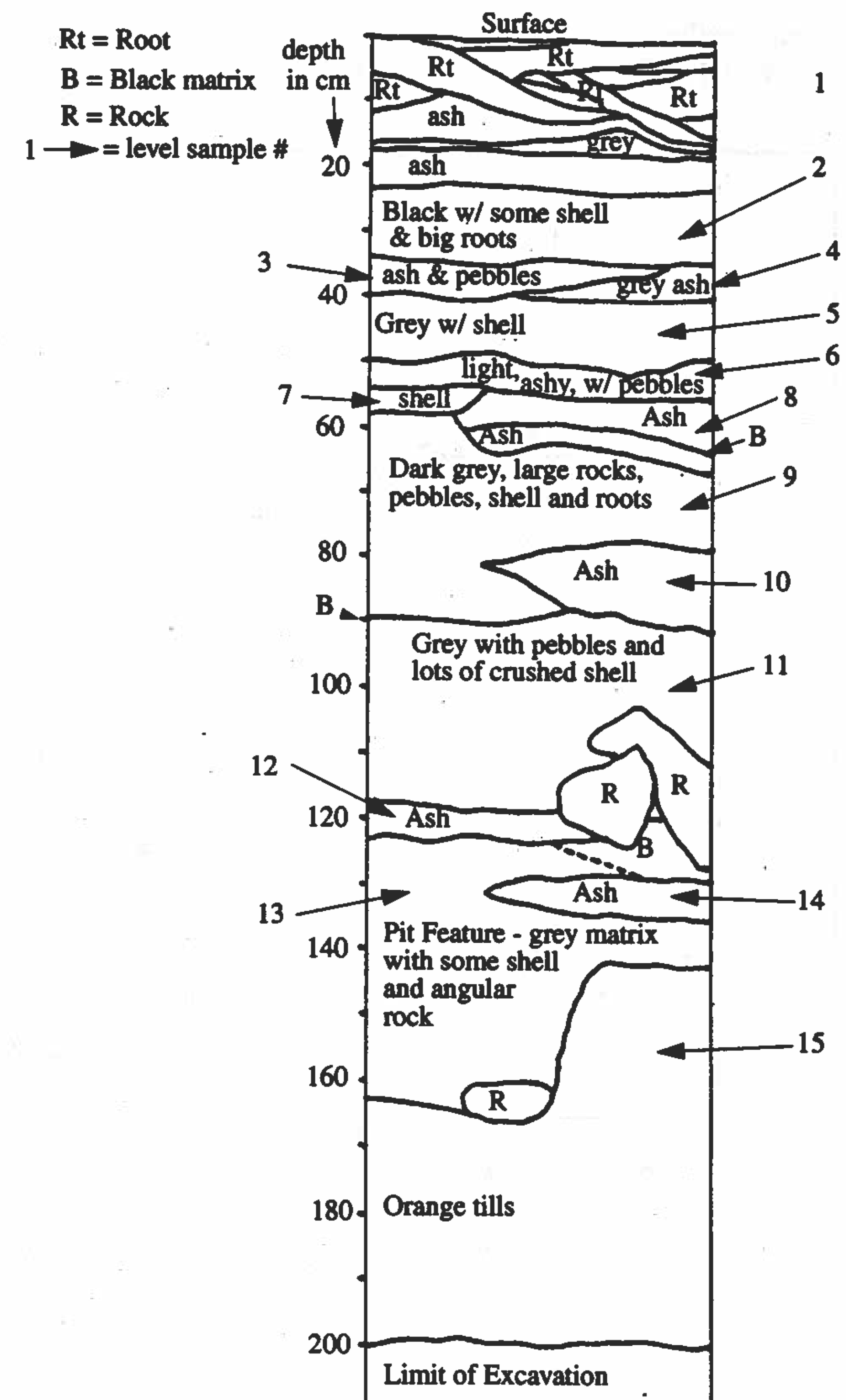


FIGURE 8: DfRu22, Section Profile - 1992



TABLES

TABLE 1: Artefact Inventory by Type, DfRu13 - 1992

Artefact Type	Intertidal EU1	Underwater UW4	Underwater UW5	Total
<u>STONE</u>				
Chipped Stone				
abrader	1	1		
anvil stone	1			
hammerstone		1		
pecked net weight		1		
leaf shaped point	2			
microcore	1			
core/core fragment	2	1		
pebble flake	1	4		
pebble flake w/ unifacial retouch	1	1		
pebble flake w/ bifacial retouch		1		
utilized flake	10	1	1	
complete flake	40	36	69	
split flake				
broken flake	1			
flake fragment	5	3	1	
debris	4	1	1	
Ground Stone				
ground slate knife	1			
ground slate fragment		1	1	
<u>BONE</u>				
unilateral barbed harpoon		1		
<u>TOTALS</u>	70	53	73	

TABLE 2: Large Faunal Specimen Inventory, DfRu13 - 1992

Provenience	Identification
EU1, L6	fragment of land mammal bone
EU1, L10	small fragment of mammal bone, eroded (n.b. listed as basket 66)
UW4, L8 SE	unidentified large mammal bone
UW4, L8	spiral, calcerous worm casing
UW4, L11	Deer, body of lumbar vertebrae, epiphyses fused, edges eroded (note provenience = 1.95x.99, 1.91 dbb)
UW4, L9NE	rock oyster shell
UW4, L9SW	unidentified bone (sea mammal?), eroded
UW4, L9A[7]	unknown sample, perhaps cartilage from a dogfish, skate, or such
UW4, L9A	large sea mammal bone fragment, eroded
UW4, L9SW	Flatfish bone, *L. ceratohyal*
UW4, L10SE	Dogfish, one vertebra; also calcareous worm casing, straight.
UW4, L11SW	Flatfish, one vertebra
UW4, L11NW	Dogfish, one vertebra
UW4, L11SE	small, eroded fragment of mammal bone
UW4, L11NW	antler section, probably Deer; could have been removed from antler for artefact raw material, but no actual tool marks discernable (field artefact #5777)
UW4, L11SE	chiton plate; also limpet shell, *Tectura persona*
UW4, L12NE	Deer, fragment of body of thoracic vertebra, epiphysis fused, eroded
UW4, L12NE	*Littorina scutulata*?, one shell
UW4, L12NW	Flatfish, one vertebra
UW4, L12SW	two fragments of land mammal bone; one may be an artefact but is too worn to determine
UW4, L12NW	Rock oyster and edible mussel (*Mytillus edulis*)
UW4, L12SE	Limpet, *Tectura persona*, 1 shell
UW4, L12NW	fragment of land snail
UW5, L3S	unidentified large mammal bone, eroded

"There are a total of 17 bones in the sample. Of these, 5 are fish, 3 are flatfish, 2 are dogfish. There were no unidentified fish bones. The 12 mammal bones ared divided into 3 definite deer bones (counting the antler fragment), 3 land mammal bones (likely deer), 2 sea mammal bones (including 1 questionable one), and 4 unidentified mammal bones. It appears that land mammals (deer in particular) are most common, but the sample is really to small for major conclusions." Becky Wigen, faunal analyst, Pacific ID.

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[7] "A" in quadrant section refers to "all quads," i.e., the basket was not restricted to a single quad, usually due to final levelling before beginning new levels.

APPENDICES

APPENDIX I: Faunal Analysis of the 1991 Level Samples

APPENDIX II: Sediment Analysis of the 1991 Level Samples

APPENDIX III: Initial Artefact Inventory of the 1992 Field Season

APPENDIX I

FAUNAL ANALYSIS OF THE 1991 LEVEL SAMPLES

DfRu13 MONTAGUE HARBOUR
1991 EXCAVATIONS

FAUNAL ANALYSIS REPORT

This report covers the analysis of faunal material collected during the summer of 1991 from several units excavated in the intertidal zone, as well as a slit trench connecting those units, and whole matrix samples taken from each level of the underwater excavation, plus unusual items collected by hand during the underwater excavation.

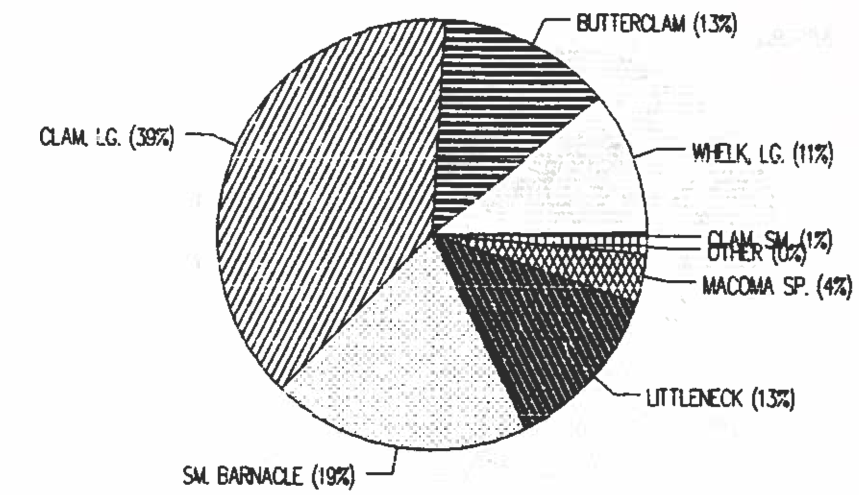
Analysis of the Underwater Matrix Samples

There were two matrix samples collected from different quadrants for most levels. There were no matrix samples for Level 9. One sample for each level was screened through nested screens in the lab, with the smallest screen being 2mm mesh. Everything in the screens was identified to the lowest possible taxon. All material is quantified by weight and spire and umbo count where relevant. In addition, I used the volume of the samples (9819 cubic cm) in order to calculate the density (grams per cubic cm.) of all constituents. Unfortunately, I could not calculate the density of the Level 10 sample because I do not know its volume. The categories used in the identifications followed those established in the 1990 report.

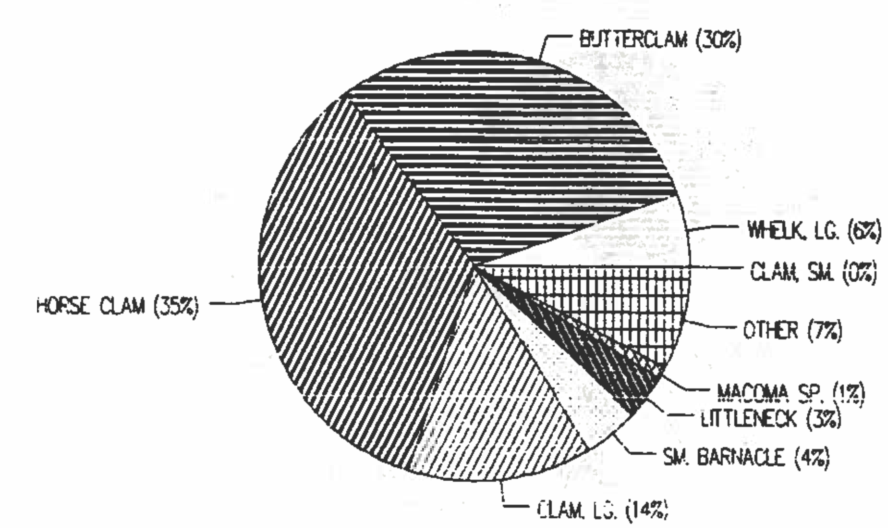
The pie charts of weight clearly show that the large clams (including butter clam, horse clam, littleneck clam, Macoma spp. and large clam) are the dominant taxa, with Level 10 the only exception. The frequency of the large clam portion ranges from a low of 69% in Level 1 to a high of 89% in Level 7. Level 10 is quite dramatically different. Here the large clams only constitue 32% of the matrix by weight. Usually butter clam is the largest part of the clam category, but in Levels 2 and 5 horse clams are more frequent than the butter clams. (A quick glance through the unanalyzed samples confirms this pattern.) Horse clams are reported to live from 0.5 to 1.0 meters deep (Rickets, et al. 1985:376), so Level 2 may represent the shallowest specimens and Level 5 the deepest (perhaps the oldest individuals?). This interpretation still leaves unanswered the question of why there are no or few horse clams in between those levels.

The remaining 10 to 20% of the samples are made up of a variety of taxa. Small barnacles and large whelks are probably the most common. The small barnacles appear to be mostly Balanus glandula, based on the appearance of the scutum (one of the mouth parts) in particular. The large whelks are probably mostly the wrinkled purple, but are so severely broken as to be unidentifiable. The whelk fragments are invariably sharp edged, in other words not broken by being rolled around on the beach. I described my perplexity over how it occurred to a marine biologist (Jane

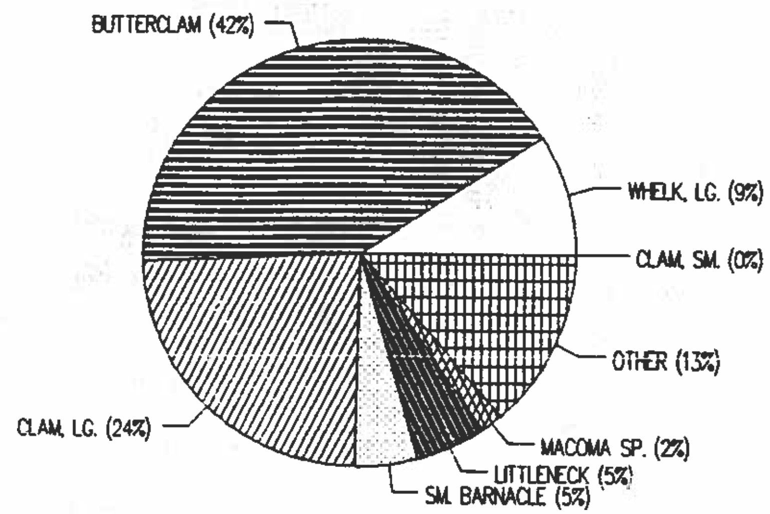
DfRu13 UW 1991
LEVEL 1 SE



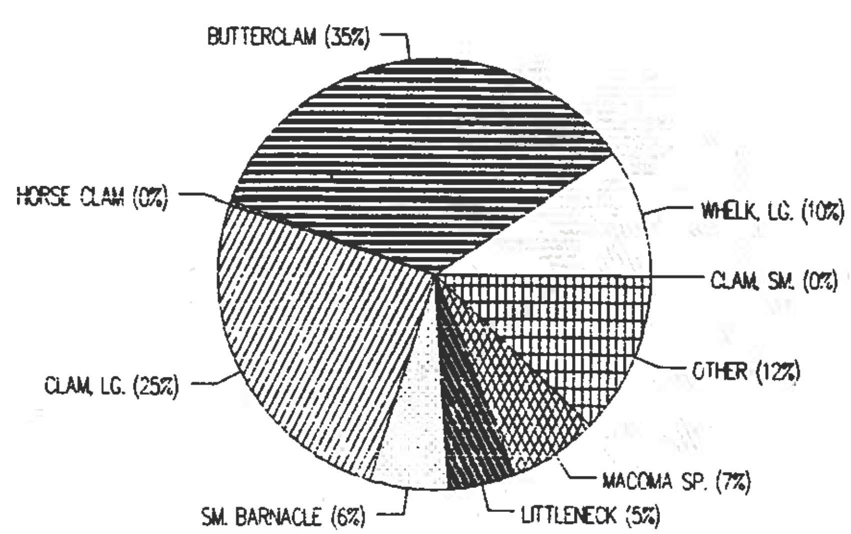
LEVEL 2 SE



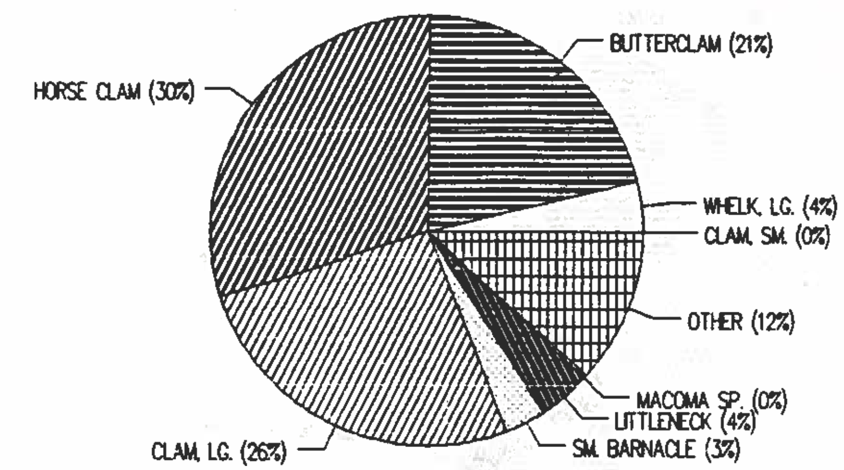
DfRu13 UW 1991
LEVEL 3 NW



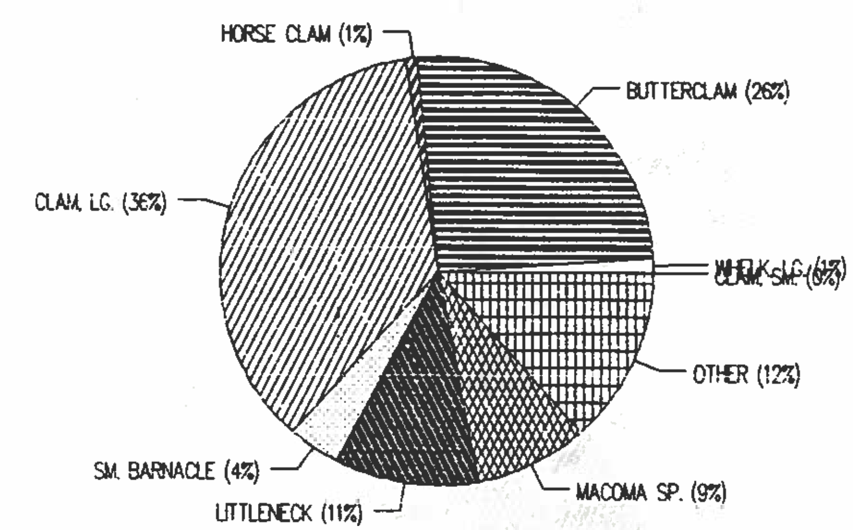
LEVEL 4 NW



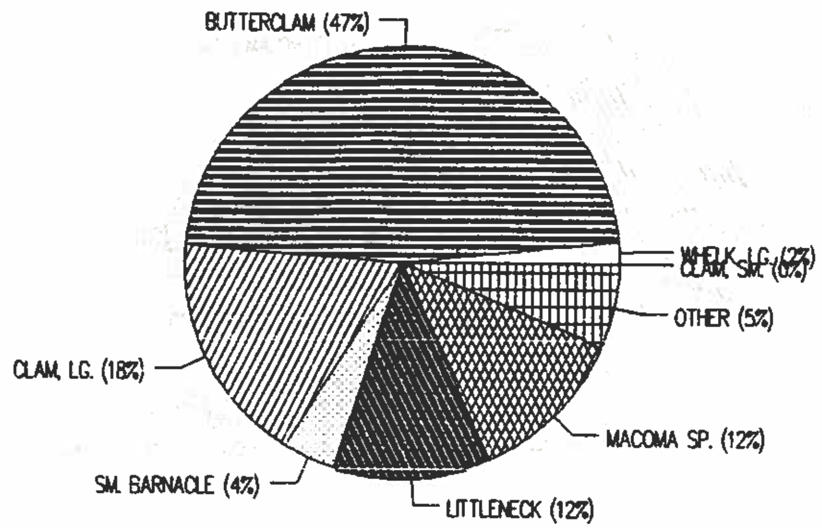
DfRu13 UW 1991
LEVEL 5 NE



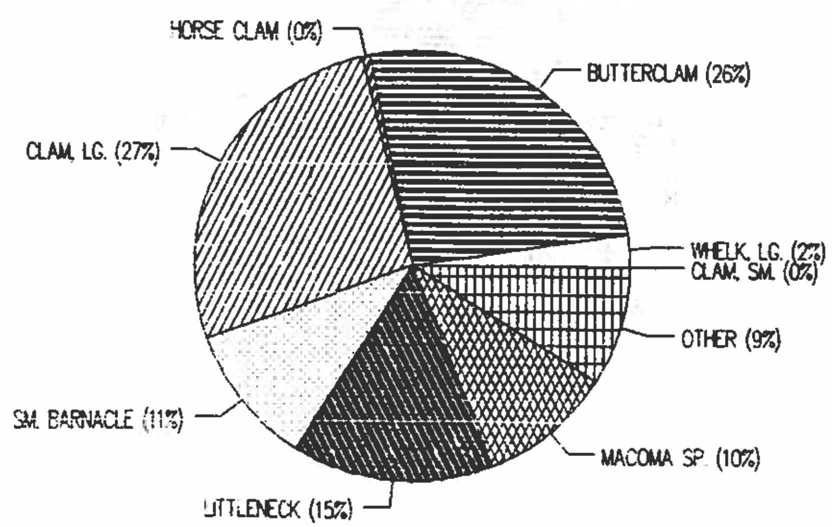
LEVEL 6 SW



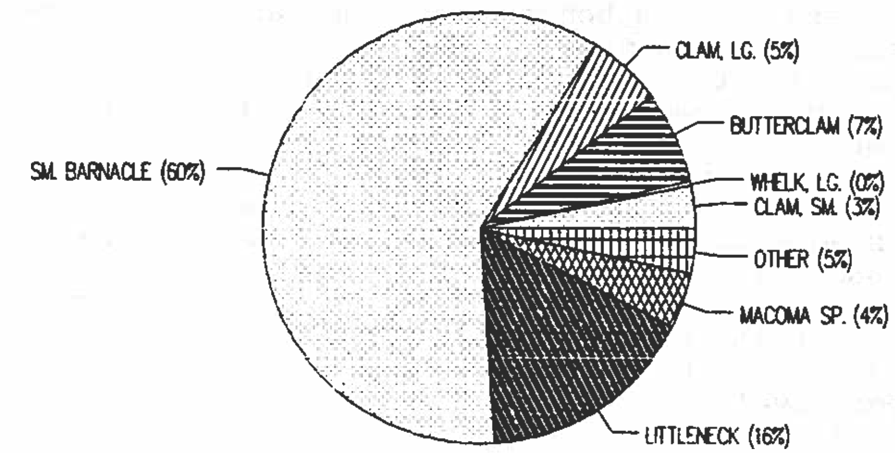
DfRu13 UW 1991
LEVEL 7 SE



LEVEL 8 NW



DfRu13 UW 1991
LEVEL 10 BASKET 225



Watson) who says snails are eaten by crabs, who break the snails'shells in the process. I have been unable to confirm this in any references but it would explain the breakage patterns.

A small amount of bone was present in the Level 5 sample. One unidentifiable mammal bone fragment, one fish vertebra fragment and a possible staghorn sculpin otolith were recorded. There was no bone in any of the other matrix samples. Some fragments of crab shell were recovered from Levels 1, 2, and 3.

The specimens collected from the baskets are listed in Table 1. There were 28 bones recovered, certainly more than found in the matrix samples. Eighteen of the bones were from Baskets 94-126. I could not determine whether these are the result of human activity or were simply deposited by natural means. The presence of several whole wrinkled purples helps support my feeling that the broken whelk fragments are wrinkled purples as well. The only other specimen of note was the presence of a great red sea urchin spine in Basket 113.

There are several vertical changes in the underwater deposits. Both the weight and density of the sand clams (*Macoma* spp.) drops by half from Level 6 and continues low in the upper levels. I believe this may represent an environmental change. The sand clams are typical of sandy, muddy protected environments, while the butter and littleneck clams prefer sand mixed with gravel. The bent-nose clam (*M. nasuta*) is very tolerant of stale water, "hence it is often the only clam to be found in small lagoons that have only occasional communication with the sea" (ibid:379). At lower sea levels conditions might have favoured the sand clams over than the other clams, which changed as the sea level rose.

Another change is a substantial increase in the quantity of large whelks, again seen in both the weight and density figures. Beginning with Level 5 the quantity of the whelks doubles and maintains that high frequency in the upper levels. I am fairly certain all of these whelks are the wrinkled purple (*Nucella lamellosa*). Whelks are typical of protected rocky beaches, predating on mussels and barnacles, with the wrinkled purple in particular concentrating on barnacles. All of these samples show a moderate quantity of barnacles and almost no mussels at all which fits nicely with the wrinkled purple's preferences. Notice that the increase in the whelks corresponds with the decrease in the sand clams. Perhaps this is also an indication of an environmental change.

The density and/or weight of the small barnacles also changes vertically, but it doesn't follow a pattern similar to the sand clams and whelks. Instead the barnacles are in their highest quantities at either end of the samples, Levels 1 and 2, and 8 and 10. Level 10 shows the highest percentage by weight of any of the levels, 60% (unfortunately I don't know the volume of the sample and

TABLE 1: LIST OF SPECIMENS COLLECTED IN BASKETS, 1991

Basket 7	Clam fragments, small barnacles
Basket 13	Japanese oyster shell
Basket 15	2 jingle shell valves
Basket 16	1 rockfish vertebra
Basket 19	4 jingle shell valves
Basket 20	large mammal vertebra fragment, whelk fragment
Basket 23	1 jingle shell valve, large whelk fragment
Basket 28	1 flatfish vertebra
Basket 30	2 fragments of green sea urchin test
Basket 36	1 lean dog whelk
Basket 38	1 leafy hornmouth
Basket 45	1 rockfish vertebra
Basket 46	1 deer phalange
Basket 81	1 fish vertebra (Lingcod?)
Basket 94	1 porpoise vertebra centrum, 2 mammal fragments, 1 fish vertebra
Basket 97	1 mammal fragment
Basket 104	1 cod vertebra, 1 large grebe foot phalanx
Basket 105	1 littorine
Basket 106	1 rockfish atlas
Basket 110	3 wrinkled purples, 2 littorines, 1 Bittium sp.?
Basket 113	1 red sea urchin spine, small barnacle
Basket 116	2 cod vertebrae, 1 fish vertebra fragment
Basket 118	1 rockfish L. quadrate, 1 fish vertebra fragment
Basket 122	1 cod vertebra, 1 fish vertebra
Basket 126	parchment-like casings from tubeworms, 1 great sculpin vertebra, 2 fish vertebrae
Basket 131	1 bone fragment
Basket 138	1 shield limpet
Basket 140	1 wrinkled purple, 2 lean dog whelks, 1 Bittium?, 2 mussel fragments, small barnacle plate
Basket 141	1 rockfish atlas
Basket 144	1 complete small barnacle, calcareous tubeworm shell
Basket 166	1 fish vertebra fragment
Basket 176	parchment-like casings from tubeworms
Basket 178	1 wrinkled purple, 1 large whelk fragment
Basket 179	1 wrinkled purple
Basket 181	harbour seal canine
Basket 193	calcareous tubeworm shell
Basket 200	calcareous tubeworm shell, small barnacles, 1 littorine
Basket 202	12 littorines
Basket 222	calcareous tubeworm shell
Basket 223	1 littleneck clam, 1 *Macoma* sp., small barnacles, edible mussel fragment
Basket 225	small barnacle, 1 false Mya valve

couldn't calculate density). Barnacles, of course, have to have either rocks or shells to grow upon, and have to on the surface. Perhaps, the two peaks of barnacles represent a long term stable bottom, with little deposition of new material, so that the barnacles would accumulate. While the period of lower barnacle density might indicate a period of continuous deposition on the bottom, limiting the number of barnacles that could grow there, or thinning the density of the barnacle deposit. Alternatively, the low period of barnacles might suggest a lack of the necessary rocks or shells to grow on, although this doesn't fit well with my suggestion of a rockier (or "shellier"?) period beginning in Level 5.

Having suggested that the above vertical changes might suggest an environmental change in the bay (as the result of sea level changes presumably), let me point out that the other taxa present don't change in quantity in any particular fashion. I have a feeling that it would be possible to argue that the continuity of most of the taxa indicates a long term stable environment. Perhaps in a gross sense this is true. Montague Harbour would always have been a protected bay with at least some mud and sand areas. Changes may have involved only degrees. For example it may have been more protected with less water movement when the sea level was 10 meters lower.

Analysis of the Intertidal Zone Excavation Units

Three excavation units were dug in the intertidal zone, Unit 1 in the lowest part and Units 2 and 3 progressively higher. A slit trench was excavated joining the units, with Section 1 next to Unit 1 and Sections 2 and 3 respectively higher in the intertidal zone. All bone was collected and examples of interesting shellfish.

Table 2 shows the results from the bone identification. Somewhat surprisingly, Unit 1 and Slit Trench Section 1 have the largest amount of bone in them, even though that is the area farthest down the beach. A total of 69 fish and 28 mammal bones were recovered from Unit 1, the bulk of which were from Level 2. Eight types of fish were identified, with rockfish being the most common, 45% of the identified fish bones. The other fish were found in low numbers. One sturgeon scute was identified. The scute was from an individual larger than my 85 cm., 4 kg. comparative specimen. The bulk of the mammal bones were unidentifiable to species and could only be called large land mammal. It is quite probable that most or all of these are deer. Deer was the most commonly identifed species of mammal.

Excavation Unit 2 had no fish bones and only a few mammal bones, with most (if you can call 3 out of 4 bones most) in the lower half of the unit. Excavation Unit 3 had no bones at all. Sections 2 and 3 of the Slit Trench had a few bones each.

TABLE 2: DfRu13 1991 Intertidal Units

	EXCAVATION UNIT 1 LEVELS					EXCAVATION UNIT 2						
	1	2	3	4	TOTAL	1	2	3	4	5	6	TOTAL
DOGFISH		2			2							
STURGEON			1		1							
HERRING		1			1							
SALMON		2			2							
LINGCOD		1			1							
SURFPERCH		4			4							
ROCKFISH		11	2		13							
CABEZON		5			5							
TOTAL	0	26	3	0	29	0	0	0	0	0	0	0
UNID. FISH		34	5		39							
PORPOISE										1		1
DEER			1	1	2				1			1
LARGE LAND MAMMAL		10	4		14	1					1	2
TOTAL		10	5	1	16	1	0	0	1	1	1	4
MAMMAL		5	3	4	12	1						1

	SLIT TRENCH SECTION 1				SECTION 2			SECTION 3			
	1	2	3	TOTAL	1	2	TOTAL	1	2	3	TOTAL
PILE PERCH		1		1			0				0
PACIFIC COD				0			0			3	3
TOTAL		1		1			0	0	0	3	3
UNID. FISH		1		1							
DEER			1	1							
LARGE CARNIVORE				0	1		1				
LARGE LAND MAMMAL				0	1		1			1	1
LARGE MAMMAL		1		1			0				
TOTAL	0	1	1	2	2	0	2			1	1
MAMMAL					1	3	4				

The shellfish recovered in these units cannot be quantified because of their judgemental selection, however the species present are interesting. Large barnacle plates were collected in Units 1 and 2. These are probably from Semibalanus cariosus, which is the most likely barnacle to attain that size. It "prefers steep shores with strong currents and considerable wave action" (Ricketts, et.al.:1985:270), so I would not expect it to live within Montague Harbour. This is confirmed by its total absence in the underwater deposits. This barnacle then is probably a good indicator of human formed midden deposits in Montague Harbour. I think the same may be said of the giant red sea urchin spines and test fragments found in these excavation units. Giant red sea urchins usually inhabit "only the deeper pools and the rocky shores extending downward from the low-tide line" (ibid:100). It was found in only one basket and none of the matrix samples from the underwater samples and may be a good midden indicator.

The materials recovered in 1991 excavations seem to confirm the suggestions and results from the 1990 season. The intertidal material from both years looks like archaeologically deposited midden. The underwater material is either a completely natural deposit or a mixture of midden and natural deposits. Looking at the results from the 1990 intertidal matrix samples the presence of a large quantity of edible mussel, reasonable amounts of large barnacle and large amounts of water worn shell seem to be the hallmarks of the midden deposits. None of these are present in the underwater materials from either 1990 or 1991. The complete lack of any water-worn shell in the 1991 underwater matrix samples seems particularly important to me. If midden is being inundated by a sea level rise I would assume a large amount of material would be eroded onto the beach and abraded for a time before being completely under water. My conclusion at this point is that the underwater deposits represented by these matrix samples are most likely a natural deposit.

Rebecca Wigen
Pacific ID
August, 1992

DfRu13 Species List 1991

SHELLFISH

Butterclam Saxidomus giganteus
Native Littleneck Clam Protothaca staminea
Basket Cockle Clinocardium nuttalli
Horse Clam Tresus spp.
Edible Mussel Mytilus edulis
Sand Clams Macoma spp.
False Mya Cryptomya californica
Jingle Shell Pododesmus macrochisma
Japanese Oyster Crassostrea gigas
Sculptured Nut Shell Acila castrensis
Fine-lined Lucina Lucina tenuisculpta

Shield Limpet Lottia pelta
Large Whelk Nucella spp. (cf. lamellosa)
Wrinkled Purple Nucella lamellosa
Small Whelk Nucella spp.
Periwinkle Littorina spp./Lacuna spp.
Bittiums Bittium spp.
Lirulate Margarite Lirularia lirulatus
Smooth Margarite Margarites marginatus
Sculptured Rock Shell Ocenebra interfossa
Lurid Rock Shell Ocenebra lurida
Lean Dog Whelk Nassarius mendicus
Leafy Hornmouth Cerastostoma foliata
Dove Shell Alia gausapata
Wrinkled Slipper Shell Crepidula dorsata
White Slipper Shell Crepidula nummaria

Small Barnacle Balanus cf. glandula
Large Barnacle Semibalanus cariosus

Green Sea Urchin Strongylocentrotus droebachiensis
Giant Red Sea Urchin S. franciscanus

Chiton Mopalia spp.?

Crab Decapoda

Tubeworms Family Annelida
Parchment-like tubes may be Phoronopsis harmeri; calcareous tubes may be Serpula vermicularis. Both suggestions based on distribution and commmonality

Scientific names taken from Kozloff, 1987

FISH

Dogfish	Squalus acanthias
Sturgeon	Acipenser sp.
Herring	Clupea harengus
Salmon	Oncorhynchus spp.
Lingcod	Ophiodon elongatus
Surfperch	Embiotocidae
Pile Perch	Rhacochilus vacca
Pacific Cod	Gadus macrocephalus
Cod	Gadidae
Rockfish	Sebastes spp.
Cabezon	Scorpaenichthys marmoratus
Great Sculpin	Myoxocephalus polyacanthocephalus
Flatfish	Pleuronectiformes

MAMMALS

Porpoise	Delphinidae
Harbour Seal	Phoca vitulina
Deer	Odocoileus hemionus
Carnivore	Carnivora

BIRD

Large Grebe	Podicepididae

SHELLFISH CONSTITUENTS   COLUMN SAMPLE UNIT : UNDERWATER 1991

	L:1SE	L:2SE	L:3NW	L:4NW	L:5NE	L:6SW	L:7SE	L:8NW	10.00
	UNBURNT	UNBURNT	UNBURNT	UNBURNT	UNBURNT	UNBURNT	UNBURNT	UNBURNT	UNBURNT
MYA SP.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SAND/BENTNOSE	26.21	19.28	18.18	46.32	7.62	86.88	98.95	95.32	10.54
CLAM (MACOMA) %	3.05	0.76	1.90	6.58	0.43	8.69	11.93	9.83	4.16
CLAM SP. (LG)	281.52	351.45	230.73	178.20	457.99	359.06	147.18	260.55	13.71
%	32.79	13.82	24.15	25.33	25.95	35.90	17.74	26.88	5.41
CLAM SP.(V. SM)	3.81	1.70	0.62	0.67	0.53	0.43	0.72	2.35	8.71
(* SEE BELOW)%	0.44	0.07	0.06	0.10	0.03	0.04	0.09	0.24	3.44
BARNACLE (SM)	141.55	108.76	45.63	40.96	55.33	38.54	30.81	101.90	152.01
%	16.49	4.28	4.78	5.82	3.14	3.85	3.71	10.51	60.00
BARNACLE (LG)	0.30	1.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%	0.03	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
WHELK (LG)	78.19	140.73	87.35	68.51	68.43	12.27	13.31	22.75	0.87
%	9.11	5.53	9.14	9.74	3.88	1.23	1.60	2.35	0.34
SEA URCHIN	0.02	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
UNIVALVE**	3.16	2.98	2.09	2.59	5.83	3.53	1.66	4.78	0.75
%	0.37	0.12	0.22	0.37	0.33	0.35	0.20	0.49	0.30
UNIDENT.SHELL	130.25	189.96	117.14	81.94	195.45	124.55	50.14	70.43	2.07
%	15.17	7.47	12.26	11.65	11.07	12.45	6.04	7.26	0.82
SUBTOT.SHELL(GMS)	858.53	2543.94	955.46	703.46	1764.90	1000.28	829.65	969.45	253.36
%	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
TOTAL SHELL	858.53	2543.94	955.45	703.46	1764.90	1000.28	829.65	969.45	253.36

SITE: DfRu 13 COLUMN SAMPLE UNIT : UNDERWATER 1991

		L:1SE	L:2SE	L:3NW	L:4NW	L:5NE	L:6SW	L:7SE	L:8NW	L:10
TOTAL WEIGHT (GMS)		932.28	2609.35	1009.52	862.41	1969.17	1053.61	931.05	1047.68	285.54

COMPONENTS
(weight & % of sample total)

		L:1SE	L:2SE	L:3NW	L:4NW	L:5NE	L:6SW	L:7SE	L:8NW	L:10
ROCK		67.04	60.09	53.53	158.34	200.96	47.99	100.19	67.17	28.24
	%	7.19	2.30	5.30	18.36	10.21	4.55	10.76	6.41	9.89
FLORA		6.50	5.00	0.29	0.50	1.95	3.05	1.17	9.47	2.39
	%	0.70	0.19	0.03	0.06	0.10	0.29	0.13	0.90	0.84
CHARCOAL		0.21	0.32	0.24	0.11	1.00	2.29	0.04	1.59	1.55
	%	0.02	0.01	0.02	0.01	0.05	0.22	0.00	0.15	0.54
BONE		0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00
	%	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
SHELL		858.53	2543.94	955.46	703.46	1764.90	1000.28	829.65	969.45	253.36
	%	92.09	97.49	94.64	81.57	89.63	50.80	89.11	92.53	88.73

SHELLFISH CONSTITUENTS
(weight & % of shell total)

SPECIES		L:1SE UNBURNT	L:2SE UNBURNT	L:3NW UNBURNT	L:4NW UNBURNT	L:5NE UNBURNT	L:6SW UNBURNT	L:7SE UNBURNT	L:8NW UNBURNT	L:10 UNBURNT
MUSSEL		0.15	0.06	0.00	0.20	0.31	0.13	0.12	0.89	0.30
	%	0.02	0.00	0.00	0.03	0.02	0.01	0.01	0.09	0.12
COCKLE		3.92	1.31	0.00	0.55	1.04	2.50	0.31	9.20	5.16
	%	0.46	0.05	0.00	0.08	0.06	0.25	0.04	0.95	2.04
BUTTERCLAM		94.40	756.64	396.83	244.49	375.89	256.04	389.47	250.93	17.76
	%	11.00	29.74	41.53	34.76	21.30	25.60	46.94	25.88	7.01
LITTLENECK		93.47	80.95	48.46	35.69	66.25	108.41	96.46	145.57	41.48
	%	10.89	3.18	5.07	5.07	3.75	10.84	11.63	15.02	16.37
HORSECLAM		0.00	887.10	0.00	2.72	528.70	6.77	0.00	4.55	0.00
	%	0.00	34.87	0.00	0.39	29.96	0.68	0.00	0.47	0.00
ROCK OYSTER		1.58	1.18	8.43	0.62	1.53	1.17	0.52	0.23	0.00
	%	0.18	0.05	0.88	0.09	0.09	0.12	0.06	0.02	0.00

QUANTIFICATION OF VERY SMALL SPECIES
*/** NOTES VERY SMALL INDIVIDUALS OF THE SPECIES LISTED HERE
THAT HAVE BEEN WEIGHED TOGETHER IN THE ABOVE TABLE

* BIVALVES	L:1SE	L:2SE	L:3NW	L:4NW	L:5NE	L:6SW	L:7SE	L:8NW	L:10
LITTLENECK:	12	13	3	4	2	2	3	6	5
BUTTERCLAM:	5	4			4			2	3
COCKLE:	1		1				1	1	3
MACOMA:	19	16	3	2	1		3	8	9
MYA SPP:	6	1	2	3	1	2	2	6	43
UNDETERMINED:			2	4	2		2		
OTHER BIVALVE:	4				2			1	
OYSTER:									

** UNIVALVES INCLUDE:	L:1SE	L:2SE	L:3NW	L:4NW	L:5NE	L:6SW	L:7SE	L:8NW	L:10
BITTIUM SP:	9	9	5	3	5		1	6	
LITTORINE SP:	12	1	2	3	3	5	3	25	2
MARGARITES SP:	3	3			1			1	
OTHER SP.		8		1	4		1	1	
LIMPET								2	
LEAN DOG WHELK	2	1	3	1	8	13	8	15	3
SMALL WHELKS	2	2	5	6	6	2			
LARGE WHELKS	6	21	6	4	5	1	4	3	

SITE: DfRu 13

1991 UNDERWATER COLUMN SAMPLES VOLUME DATA

		L:1SE		L:2SE		L:3NW		L:4NW		L:5NE	
TOTAL WEIGHT (GMS)		932.28		2609.35		1009.52		862.41		1969.17	
COMPONENTS		(weight, % & volume of sample total)									
		WEIGHT	VOLUME	WEIGHT	VOLUME	WEIGHT	VOLUME	WEIGHT	VOLUME	WEIGHT	VOLUME
ROCK		67.04	0.0068	60.09	0.0061	53.53	0.0055	158.34	0.0161	200.96	0.0205
	%	7.19		2.30		5.30		18.36		10.21	
FLORA		6.50	0.0007	5.00	0.0005	0.29	0.0000	0.50	0.0001	1.95	0.0002
	%	0.70		0.19		0.03		0.06		0.10	
CHARCOAL		0.21	0.0000	0.32	0.0000	0.24	0.0000	0.11	0.0000	1.00	0.0001
	%	0.02		0.01		0.02		0.01		0.05	
BONE		0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.36	0.0000
	%	0.00		0.00		0.00		0.00		0.02	
SHELL		858.53	0.0874	2543.94	0.2591	955.46	0.0973	703.46	0.0716	1764.90	0.1797
	%	92.09	0.0000	97.49	0.0000	94.64	0.0000	81.57	0.0000	89.63	0.0000

SHELLFISH CONSTITUENTS
(weight & % of shell total)

SPECIES		L:1SE		L:2SE		L:3NW		L:4NW		L:5NE	
		WEIGHT	VOLUME	WEIGHT	VOLUME	WEIGHT	VOLUME	WEIGHT	VOLUME	WEIGHT	VOLUME
MUSSEL		0.15	0.0000	0.06	0.0000	0.00	0.0000	0.20	0.0000	0.31	0.0000
	%	0.02		0.00		0.00		0.03		0.02	
COCKLE		3.92	0.0004	1.31	0.0001	0.00	0.0000	0.55	0.0001	1.04	0.0001
	%	0.46		0.05		0.00		0.08		0.06	
BUTTERCLAM		94.40	0.0096	756.64	0.0771	396.83	0.0404	244.49	0.0249	375.89	0.0383
	%	11.00		29.74		41.53		34.76		21.30	
LITTLENECK		93.47	0.0095	80.95	0.0082	48.46	0.0049	35.69	0.0036	66.25	0.0067
	%	10.89		3.18		5.07		5.07		3.75	
HORSECLAM		0.00	0.0000	887.10	0.0903	0.00	0.0000	2.72	0.0003	528.70	0.0538
	%	0.00		34.87		0.00		0.39		29.96	
ROCK OYSTER		1.58	0.0002	1.18	0.0001	8.43	0.0009	0.62	0.0001	1.53	0.0002
	%	0.18		0.05		0.88		0.09		0.09	

SITE: DfRu 13

		L:6SW		L:7SE		L:8NW	
TOTAL WEIGHT (GMS)		1053.61		931.05		1047.68	
COMPONENTS							
		WEIGHT	VOLUME	WEIGHT	VOLUME	WEIGHT	VOLUME
ROCK		47.99	0.0049	100.19	0.0102	67.17	0.0068
	%	4.55		10.76		6.41	
FLORA		3.05	0.0003	1.17	0.0001	9.47	0.0010
	%	0.29		0.13		0.90	
CHARCOAL		2.29	0.0002	0.04	0.0000	1.59	0.0002
	%	0.22		0.00		0.15	
BONE		0.00	0.0000	0.00	0.0000	0.00	0.0000
	%	0.00		0.00		0.00	
SHELL		1000.28	0.1019	829.65	0.0845	969.45	0.0987
	%	50.80	0.0000	89.11	0.0000	92.53	0.0000

SHELLFISH CONSTITUE
(weight & % of shel

SPECIES		L:6SW		L:7SE		L:8NW	
		WEIGHT	VOLUME	WEIGHT	VOLUME	WEIGHT	VOLUME
MUSSEL		0.13	0.0000	0.12	0.0000	0.89	0.0001
	%	0.01		0.01		0.09	
COCKLE		2.50	0.0003	0.31	0.0000	9.20	0.0009
	%	0.25		0.04		0.95	
BUTTERCLAM		256.04	0.0261	389.47	0.0397	250.93	0.0256
	%	25.60		46.94		25.88	
LITTLENECK		108.41	0.0110	96.46	0.0098	145.57	0.0148
	%	10.84		11.63		15.02	
HORSECLAM		6.77	0.0007	0.00	0.0000	4.55	0.0005
	%	0.68		0.00		0.47	
ROCK OYSTER		1.17	0.0001	0.52	0.0061	0.23	0.0000
	%	0.12		0.06		0.02	

SHELLFISH CONSTITUENTS

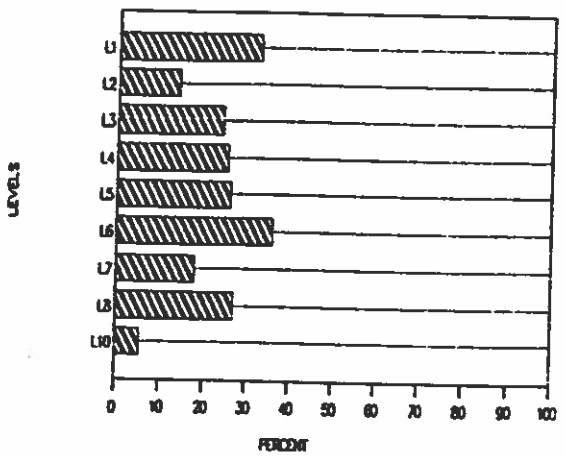
1919 UNDERWATER COLUMN SAMPLE VOLUME DATA

	L:1SE WEIGHT	VOLUME	L:2SE WEIGHT	VOLUME	L:3NW WEIGHT	VOLUME	L:4NW WEIGHT	VOLUME	L:5NE WEIGHT	VOLUME
MYA SP.	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000
%	0.00		0.00		0.00		0.00		0.00	
SAND/BENTNOSE	26.21	0.0027	19.28	0.0020	18.18	0.0019	46.32	0.0047	7.62	0.0008
CLAM (MACOMA) %	3.05		0.76		1.90		6.58		0.43	
CLAM SP. (LG)	281.52	0.0287	351.45	0.0358	230.73	0.0235	178.20	0.0181	457.99	0.0466
%	32.79		13.82		24.15		25.33		25.95	
CLAM SP.(V. SM)	3.81	0.0004	1.70	0.0002	0.62	0.0001	0.67	0.0001	0.53	0.0001
%	0.44		0.07		0.06		0.10		0.03	
BARNACLE (SM)	141.55	0.0144	108.76	0.0111	45.63	0.0046	40.96	0.0042	55.33	0.0056
%	16.49		4.28		4.78		5.82		3.14	
BARNACLE (LG)	0.30	0.0000	1.76	0.0002	0.00	0.0000	0.00	0.0000	0.00	0.0000
%	0.03		0.07		0.00		0.00		0.00	
WHELK (LG)	78.19	0.0080	140.73	0.0143	87.35	0.0089	68.51	0.0070	68.43	0.0070
%	9.11		5.53		9.14		9.74		3.88	
SEA URCHIN	0.02	0.0000	0.08	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000
%	0.00		0.00		0.00		0.00		0.00	
UNIVALVE**	3.16	0.0003	2.98	0.0003	2.09	0.0002	2.59	0.0003	5.83	0.0006
%	0.37		0.12		0.22		0.37		0.33	
UNIDENT.SHELL	130.25	0.0133	189.96	0.0193	117.14	0.0119	81.94	0.0083	195.45	0.0199
%	15.17		7.47		12.26		11.65		11.07	
SUBTOT.SHELL(GMS)	858.53		2543.94		955.46		703.46		1764.90	
%	100.00		100.00		100.00		100.00		100.00	
TOTAL SHELL	858.53		2543.94		955.46		703.46		1764.90	

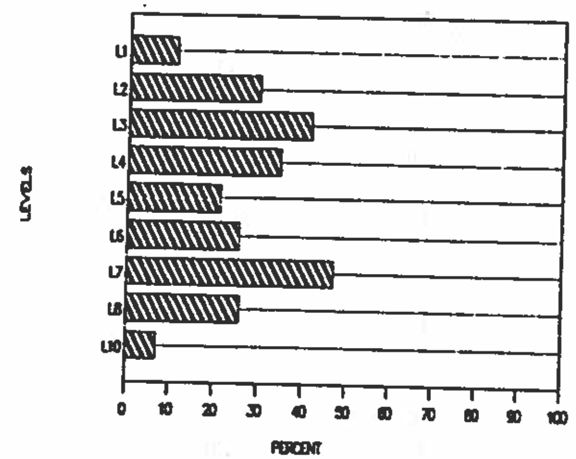
SHELLFISH CONSTITUE

	L:6SW WEIGHT	VOLUME	L:7SE WEIGHT	VOLUME	L:8NW WEIGHT	VOLUME
MYA SP.	0.00	0.0000	0.00	0.0000	0.00	0.0000
%	0.00		0.00		0.00	
SAND/BENTNOSE	86.88	0.0088	98.95	0.0101	95.32	0.0097
CLAM (MACOMA) %	8.69		11.93		9.83	
CLAM SP. (LG)	359.06	0.0366	147.18	0.0150	260.55	0.0265
%	35.90		17.74		26.88	
CLAM SP.(V. SM)	0.43	0.0000	0.72	0.0001	2.35	0.0002
%	0.04		0.09		0.24	
BARNACLE (SM)	38.54	0.0039	30.81	0.0031	101.90	0.0104
%	3.85		3.71		10.51	
BARNACLE (LG)	0.00	0.0000	0.00	0.0000	0.00	0.0000
%	0.00		0.00		0.00	
WHELK (LG)	12.27	0.0012	13.31	0.0014	22.75	0.0023
%	1.23		1.60		2.35	
SEA URCHIN	0.00	0.0000	0.00	0.0000	0.00	0.0000
%	0.00		0.00		0.00	
UNIVALVE**	3.53	0.0004	1.66	0.0002	4.78	0.0005
%	0.35		0.20		0.49	
UNIDENT.SHELL	124.55	0.0127	50.14	0.0051	70.43	0.0072
%	12.45		6.04		7.26	
SUBTOT.SHELL(GMS)	1000.28		829.65		969.45	
%	100.00		100.00		100.00	
TOTAL SHELL	1000.28		829.65		969.45	

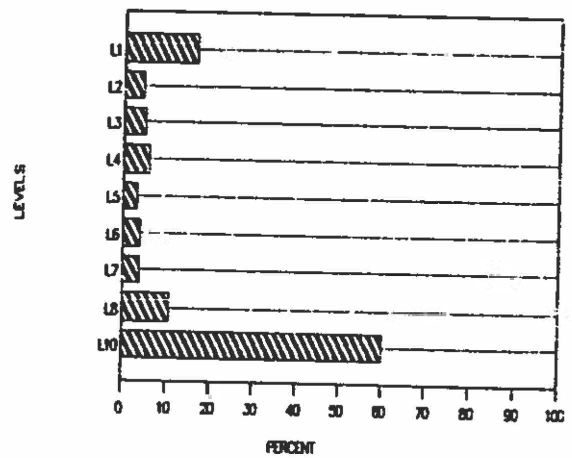
LARGE CLAM



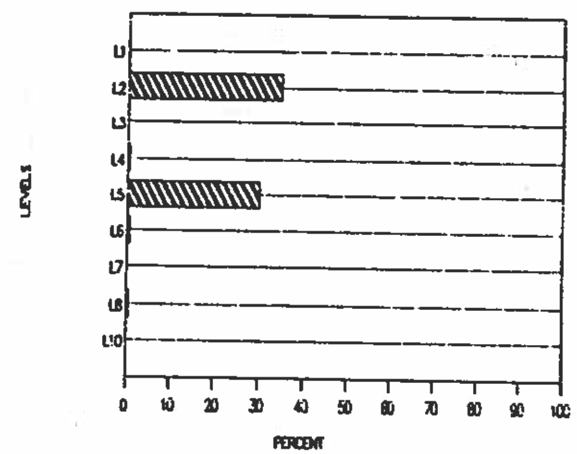
BUTTER CLAM



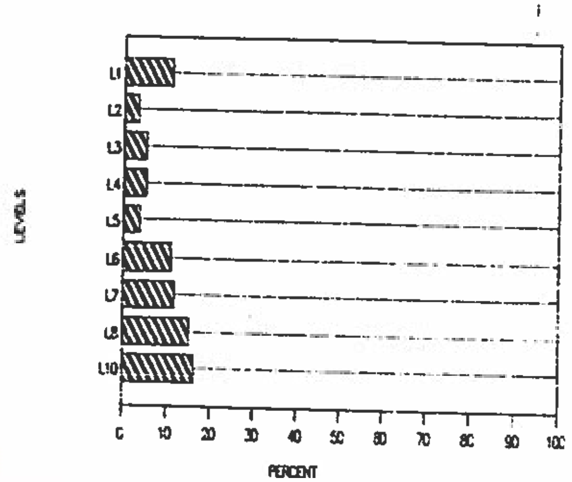
SMALL BARNACLE



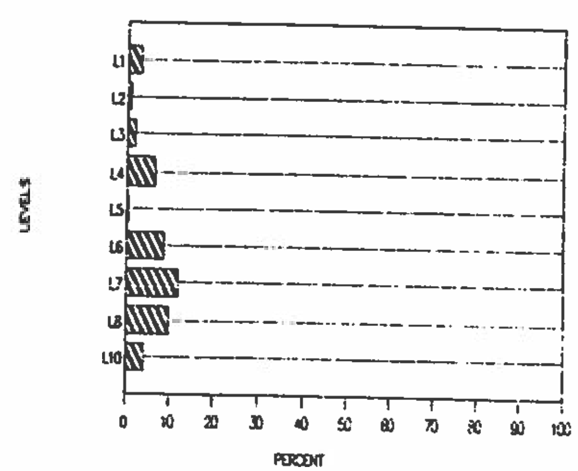
HORSE CLAM



LITTLENECK CLAM



MACOMA SPP.



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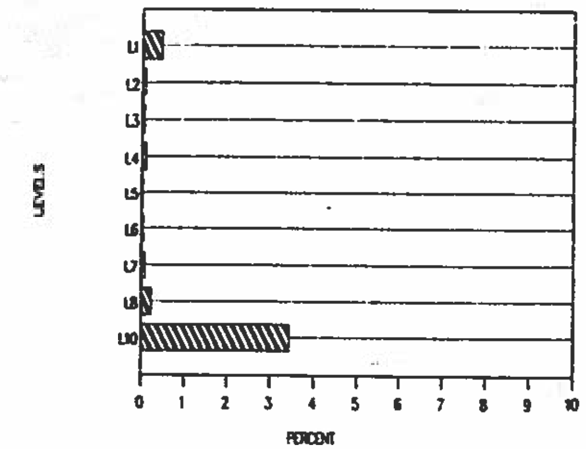

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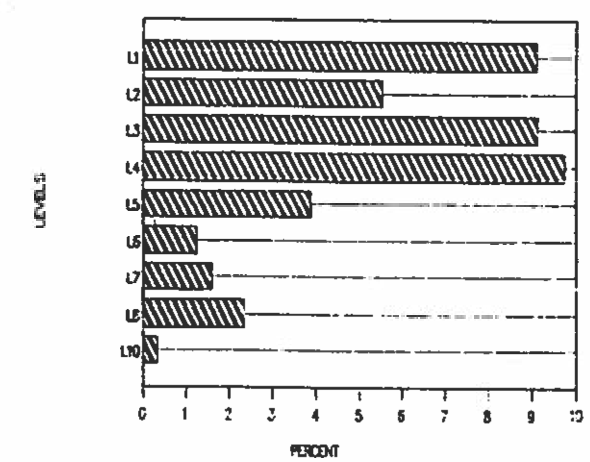
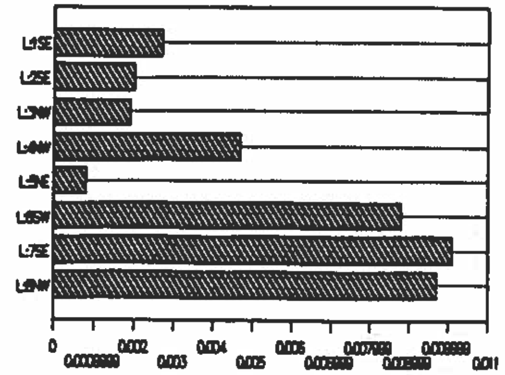
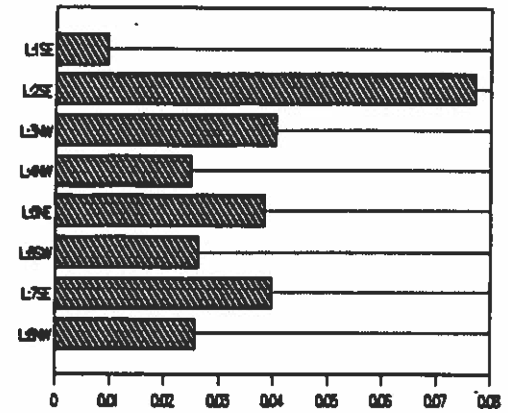


DENSITY

MACOMA SPP.



BUTTERCLAM



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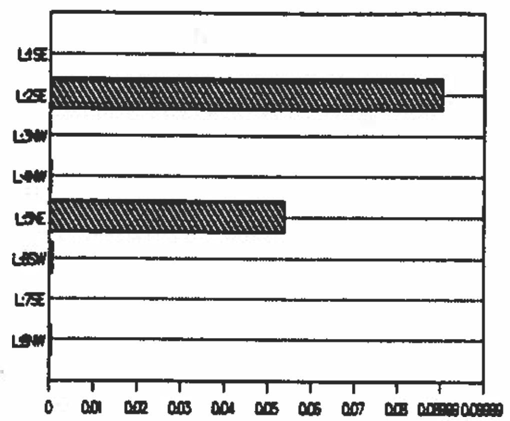

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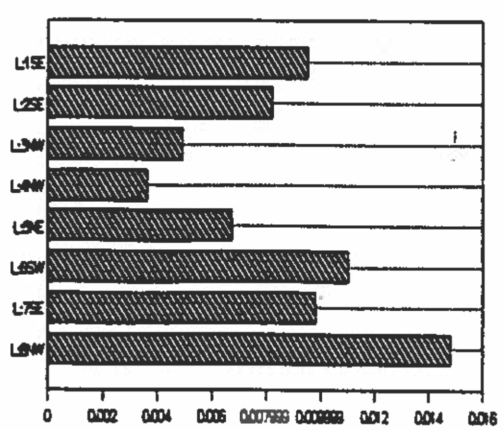
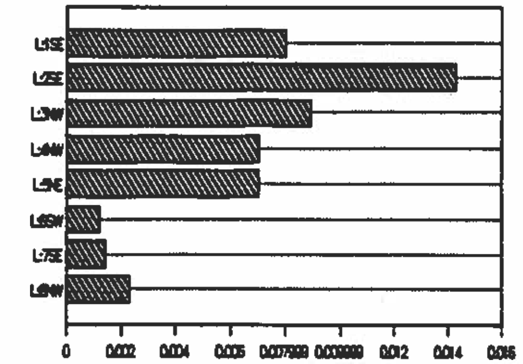
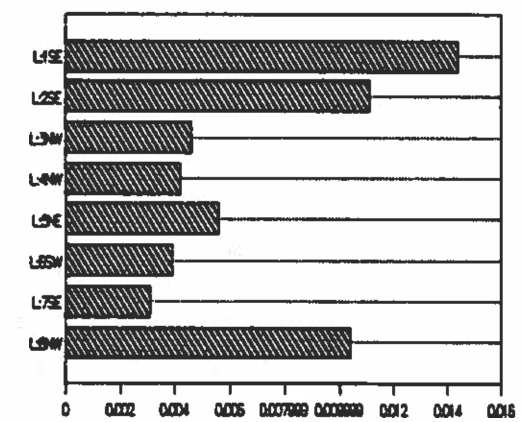


DENSITY

LARGE WHELK



SMALL BARNACLE



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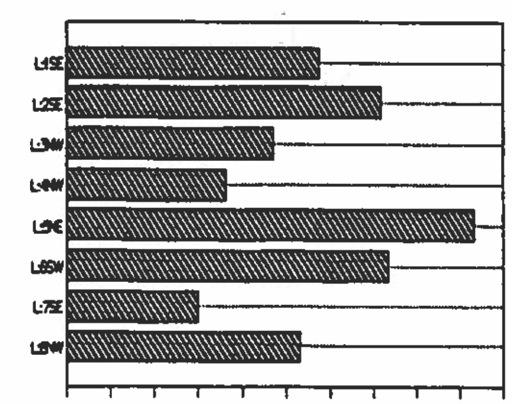

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APPENDIX II

SEDIMENT ANALYSIS OF THE 1991 LEVEL SAMPLES

Analysis of Underwater, Intertidal, and Land Excavation Unit Soil Samples Montague Harbour (DfRu-13), British Columbia 1991 Excavations

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June, 1992

Introduction

The Montague Harbour (DfRu-13) 1991 excavations recovered a number of soil samples. The underwater excavations, dug to a total of ten 20 cm levels, yielded a caisson sample from each of four quandrants from each level. Samples were also taken for backshore and intertidal units. Analysis of the soil was conducted to determine potential trends, both chemical and physical, which may assist in the analysis of the site and to provide data which may be of use for future excavation planning.

Methodology and Observations

Samples were sifted using a mechanical shaker and a series of graduated screens to sort soil samples into particle size groupings. Each sample was agitated for seven minutes. Screen sizes used 25 mm, 4 mm, 2 mm, 1 mm, 500 µm, 250 µm, 125 µm, and 63 µm meshes to isolate each groups. Volumes were measured using a graduated cylinder and weights were measured using a triple spring balance. Weights were measured to .1 gm, while volumes were recorded to 5 cc, unless the total group volume was less than 100 cc. The complete data is listed in Tables 1-3 and Figures 1-4.

Soil particles were examined microscopically using a 3.6X lens to determine potential trends in particle size, mineralogical composition, and to search for plant or faunal microfossil constituents for later analysis. Particles were described in terms of particle roundness (Powers 1953; Folk 1955). Particle size gradations for aggregate samples were classified using the U.S. Department of Agriculture scale (Foth and Turk 1972; Brady 1974). All samples contained charcoal and floral and faunal contaminants.

Seventeen samples were submitted to Northern Analytical Labs Ltd., Whitehorse, for chemical analysis of major and trace elemental constituents (NAL File #92-1162). Samples, each weighing >50 gm and comprising particles smaller than 125 µm, were air dried for two weeks and submitted in paper bags for analysis. Samples were analyzed using whole rock Atomic Absorption Spectrometry (AAS) (Butler and Kokot 1971) and inductively coupled plasma optical emission spectrometry (ICP-OES) (Reed 1990).

The underwater samples consisted primarily of sand-sized particles from each level (Figures 5-7), with a moderate decrease in sand-sized particles in Level 10, which demonstrated a moderate increase in silt and clay-sized particles. Particle roundness was principally angular to subrounded for the various levels. The degree of angularity may be an effect of larger particles being broken through wave and tidal action (Davis 1983; Chamley 1990.) Comparisons were only made with particles smaller than 500 µm in size. Aggregate samples greater than 500 µm were largely comrised of nonmineral inclusions, primarily fragments of the shells of marine molluscs. This contamination made direct correlation of coarse sand and gravel sized particles between the underwater samples and those of other site areas impossible.

Some discrepencies were noted between samples for each level (Table 1). Therefore, a mean value was determined for each level for the underwater samples and this was used for level by level contrast.

The mineralogical constituents were identified visually and the results compared to major elemental analysis for further confirmation. Thin sectioning was not performed to provide more definite confirmation. Each of the underwater samples was similar. The principal constituents for each were milky and transparent quartz [SiO_2], which comprised greater than 90% of all samples, with smaller amounts of orthorhombic and monoclinic pyroxenes, olivine [$(Mg,Fe^{+2})_2SiO_4$], orthoclase feldspar [$KAlSi_3O_8$], and biotite [$K(Mg,Fe^{+2})_3Si_3AlO_{10}(OH)_2$].

Comparative data are seen from two areas. Samples from land and intertidal localities were analyzed (Table 2, 3). The backshore samples (Figure 8), Hill #1 and #2, were compared using particle, aggregate, and chemical analyses. Particles from an intertidal excavation unit 1 (EU1) were also subjected to particle and aggregate analysis (Figure 9). These contrast sharply to the underwater samples. In both areas, particles were rounded to subrounded in form, and the mineralogical constituents were primarily quartz (>98%), with minor percentage compositions of biotite, olivine, and orthoclase feldspar.

Few trends were exhibited by the chemical analyses (Tables 4-6; Figures 10-26), the possible result of skewing by one of the submitted samples (see below). SiO_2 compositions show no definite pattern (Figure 10), although an increase in percentage concentration may be indicated from Level 3 to Level 9 if the results from level 8 are discounted. A similar increase may also be indicated in Al_2O_3 concentrations (Figure 11). Decreasing amounts of Fe_2O_3 (Figure 12), MgO (Figure 13), and CaO past Level 3 (Figure 14) also are apparent. The latter is probably the direct effect of the decreasing influence of invertabrate intrusion in the lower levels. Na_2O (Figure 15) concentrations show no trend whatsoever. Concentrations of K_2O also indicate a gradual decline with depth (Figure 16), although the Level 8 returns also appear to be anomolous. TiO_2 (Figure 17) concentrations are stable through most of the levels but show a sharp decrease from Level 8 to Level 9. Stable concentrations of P_2O_5 (Figure 18) and MnO (Figure 19) were observed, while those of Cr_2O_3 (Figure 20) show no definite order. The chemical analysis of the two backshore samples, Hill #1 and #2, are strikingly different from the underwater samples, with the exceptions of values for MgO, K_2O, TiO_2 and Cr_2O_3.

Three items of significance may be determined from the chemical analyses of major element concentrations of the underwater samples. The first of these is that the

Level 8 values appear to be anomolous, in that a number of potential trends appear to be disturbed by the Level 8 data. This may be the result of only a single sample from this level being submitted for chemical analysis (the aggregate for Level 8 NW weighed less than 50 gm and was, therefore, too small for analysis) and the results may have been skewed.

Secondly, there appears to have been extensive chemical weathering in the marine environment, indicated by declining values with depth for Fe_2O_3, MgO, K_2O, and possibly TiO_2. The decline in CaO values may more likely be seen as a reflection of invertabrate instrusion mentioned above. The extent of this weathering may be seen in the example of Fe_2O_3 returns, which decline from a high value of 3.41% to 2.83% in Level 9. The variation is even greater, from a maximum of 3.83%, if the value for Level 8 is considered. Fe is highly resistant to chemical weathering (Rőssler and Lang 1972:274, Table 112).

There is a great deal of difference between the values for the underwater and backshore samples submitted for chemical analysis. The degree of variation, with seven of eleven elements displaying returns outside the range of variation for the underwater samples, are of adequate significance to consider the backshore samples as being chemically different in nature.

The degree of chemical weathering also seems supported by trace element chemistry, determined through ICP-OES. Sr values (Figure 22) decline from Level 3. Concentrations of Zr (Figure 24) and Y (Figure 25) sharply decline between Level 8 and Level 9. A steep decline, from 10 ppm to 5 ppm is seen between Level 1 and Level 2 values for Nb (Figure 26). Ba values (Figure 21) appear to increase, however, from Level 3 to Level 7 and decline in the two lower levels. No pattern is indicated in La concentrations (Figure 23).

Somewhat closer correlation may be seen between the underwater and backshore sample trace element chemistry. Values for Ba, Zr, Y, and Nb for the backshore samples do fall within the range for the underwater samples. However, three of the seven elements tested did provide results with contrasting ranges of variation.

Conclusions

Two principal conclusions may be drawn from the analysis of soil samples from DfRu-13. The first of these is that direct relationships between the land excavation units and intertidal units (Hill and EU1 samples) may not be observed with the soil samples from the underwater units. This is the probable result of differing formational process affecting the development of sediments in infralittoral, beach and backshore depositional environments.

Littoral environments are classified as a transitional sedimentation zone (Krumbein and Sloss 1963:251, Table 7-2). Infralittoral sediments show a tendency to be finer grained with increasing distance seaward (Davis 1983:361; Chamley 1990:192), an effect of both wave and tidal action on sediment deposition and alteration after deposition (Chamley 1990:185). The submerging coastline in the Montague Harbour area also contributes to the difference between sediments in the infralittoral, intertidal, and backshore areas. During the early process of submergence, wave action erodes the shore and large quantities of sediment are dragged away toward the head of the bay. This contributes to steep slopes along the shoreline, which permit maximum exposure to erosion and increasing amounts of sediment for redeposition. This is the period of maximum transport of sediments. Equalibrium establishes when sediments transported into the bay level the sea bottom and reduce wave and tidal energy, causing the shoreline to become less steep through time and the potential stabilization of a sand beach (Twenhofel 1961:121-122). Further, although their effect is minor in areas of high wave energy, biological agents provide organic detritus to sediments in an infralittoral zone (Krumbein and Sloss 1963:259), a mixing of sediments through bioturbation, and alteration of chemical compositions (Butzer 1982:110-117).

The effects of tidal, wave, and biological action produce sediments of a variety of constituents due to high energy erosion and redeposition of transported materials. These act in conjunction to provide an environment which varies considerably from the backshore area and major differences in particle shape, size, and mineralogical and chemical composition are to be expected (*c.f.* Twenhofel 1961:144). Sample contamination through the inclusion of marine shell and precipitation of Ca and Na will also serve to provide differing results from the underwater and intertidal and backshore units.

The second conclusion may be drawn through aggregate and mineralogical analyses of the underwater samples. Aggregate analysis indicates that the underwater sediments are largely comprised of sand, an expected result of a beach environment (Chamley 1990:192). The mineralogical constituents, quartz, pyroxene, and olivine, are also characteristic of beach sands (Twenhofel 1961:224-228; Dietrich and Skinner 1990:Plate 4). The biotite and feldspar may represent either local parent material or an influx of material through tidal or wave redeposition. It is not presently determinable whether the prehistoric inhabitants of Montague Harbour were camped directly on the beach itself or submergence has caused the alteration of the matrix of occupation levels into a sandy one following occupation.

This inference may hold important significance for future excavation planning. The presence of beach sand to the depth of level 10 suggests that this may not be the maximum extent of shoreline prior to submergence. It is true that there is an increase in silt and clay size particle aggregate in the Level 10 sample; however, this may be an effect of the post-submergence depositional environment, due to the greater length of

time submerged and the higher rates of deposition during earlier periods of submergence, rather than a reflection of the maximum extent of Wisconsinan shorelines. Further excavation at greater depths may locate deeper and older occupation layers on the site.

Table 1. Soil aggregates, DfRu-13, underwater samples, 1991 excavations.

Site DfRu-13	Level 1.00 Quadrant NE			
Screen	Weight	%	Volume	%
25 mm	842.50		900.00	
4 mm	726.50		750.00	
2 mm	672.50		625.00	
1 mm	565.40		450.00	
500 µm	844.00	74.04	700.00	72.92
250 µm	243.10	21.32	200.00	20.83
125 µm	46.30	4.06	50.00	5.21
63 µm	6.60	0.58	10.00	1.04
Total	1140.00	100.00	960.00	100.00
Density	1.19 gm/cc			
Sand	98.96%			
Silt/Clay	1.04%			

Site DfRu-13	Level 1.00 Quadrant SE			
Screen	Weight	%	Volume	%
25 mm	1944.60		1400.00	
4 mm	1605.20		110.00	
2 mm	1916.60		1350.00	
1 mm	2575.40		1850.00	
500 µm	2607.80	56.34	1950.00	77.69
250 µm	972.40	21.01	435.00	17.33
125 µm	553.40	11.96	105.00	4.18
63 µm	495.00	10.69	20.00	0.80
Total	4628.60	100.00	2510.00	100.00
Density	1.84 gm/cc			
Sand	99.20%			
Silt/Clay	0.80%			

Table 1 (Cont'd).

Site DfRu-13	Level 2.00 Quadrant SE			
Screen	Weight	%	Volume	%
25 mm	1658.60		1200.00	
4 mm	1759.70		1280.00	
2 mm	1625.90		1125.00	
1 mm	1471.50		950.00	
500 µm	1775.10	45.20	1175.00	62.67
250 µm	1025.90	26.12	485.00	25.87
125 µm	596.30	15.18	155.00	8.27
63 µm	529.90	13.49	60.00	3.20
Total	3927.20	100.00	1875.00	100.00
Density	2.09 gm/cc			
Sand	96.80%			
Silt/Clay	3.20%			

Site DfRu-13	Level 2.00 Quadrant SW			
Screen	Weight	%	Volume	%
25 mm	1646.40		1800.00	
4 mm	1444.30		1625.00	
2 mm	1376.30		1450.00	
1 mm	1049.70		1050.00	
500 µm	1152.40	52.32	1075.00	52.06
250 µm	700.90	31.82	650.00	31.48
125 µm	213.70	9.70	200.00	9.69
63 µm	135.40	6.15	140.00	6.78
Total	2202.40	100.00	2065.00	100.00
Density	1.07 gm/cc			
Sand	93.22%			
Silt/Clay	6.78%			

Table 1 (Cont'd).

Site	DfRu-13	Level	3.00 Quadrant NW	
Screen	Weight	%	Volume	%
25 mm	777.90		1000.00	
4 mm	699.60		750.00	
2 mm	605.20		600.00	
1 mm	613.90		400.00	
500 µm	801.90	79.20	650.00	77.15
250 µm	183.30	18.10	160.00	18.99
125 µm	25.70	2.54	30.00	3.56
63 µm	1.60	0.16	2.50	0.30
Total	1012.50	100.00	842.50	100.00
Density	1.20 gm/cc			
Sand	99.70%			
Silt/Clay	0.30%			

Site	DfRu-13	Level	3.00 Quadrant SW	
Screen	Weight	%	Volume	%
25 mm	452.10		500.00	
4 mm	480.80		500.00	
2 mm	444.80		400.00	
1 mm	365.70		325.00	
500 µm	459.90	49.65	375.00	51.02
250 µm	322.10	34.77	250.00	34.01
125 µm	83.60	9.03	60.00	8.16
63 µm	60.70	6.55	50.00	6.80
Total	926.30	100.00	735.00	100.00
Density	1.26 gm/cc			
Sand	93.20%			
Silt/Clay	6.80%			

Table 1 (Cont'd).

Site	DfRu-13	Level	4.00 Quadrant SE	
Screen	Weight	%	Volume	%
25 mm	876.30		1000.00	
4 mm	309.20		300.00	
2 mm	210.50		200.00	
1 mm	145.80		125.00	
500 µm	185.80	46.55	150.00	45.18
250 µm	166.60	41.74	125.00	37.65
125 µm	29.20	7.32	32.00	9.64
63 µm	17.50	4.38	25.00	7.53
Total	399.10	100.00	332.00	100.00
Density	1.20 gm/cc			
Sand	92.47%			
Silt/Clay	7.53%			

Site	DfRu-13	Level	4.00 Quadrant NW	
Screen	Weight	%	Volume	%
25 mm	530.00		650.00	
4 mm	338.00		400.00	
2 mm	267.30		250.00	
1 mm	217.80		175.00	
500 µm	319.90	54.35	250.00	56.18
250 µm	223.10	37.90	150.00	33.71
125 µm	31.40	5.33	25.00	5.62
63 µm	14.20	2.41	20.00	4.49
Total	588.60	100.00	445.00	100.00
Density	1.32 gm/cc			
Sand	95.51%			
Silt/Clay	4.49%			

Table 1 (Cont'd).

Site DfRu-13 Level 5.00 Quadrant NE

Screen	Weight	%	Volume	%
25 mm	1001.20		1200.00	
4 mm	449.90		510.00	
2 mm	272.60		275.00	
1 mm	259.50		225.00	
500 µm	1105.10	68.52	850.00	67.46
250 µm	445.80	27.64	350.00	27.78
125 µm	49.30	3.06	40.00	3.17
63 µm	12.60	0.78	20.00	1.59
Total	1612.80	100.00	1260.00	100.00

Density 1.28 gm/cc

Sand 98.41%
Silt/Clay 1.59%

Site DfRu-13 Level 5.00 Quadrant SW

Screen	Weight	%	Volume	%
25 mm	698.10		800.00	
4 mm	297.90		325.00	
2 mm	202.70		200.00	
1 mm	160.50		150.00	
500 µm	473.30	49.02	360.00	47.56
250 µm	419.20	43.41	325.00	42.93
125 µm	52.60	5.45	42.00	5.55
63 µm	20.50	2.12	30.00	3.96
Total	965.60	100.00	757.00	100.00

Density 1.28 gm/cc

Sand 96.04%
Silt/Clay 3.96%

Table 1 (Cont'd).

Site DfRu-13 Level 6.00 Quadrant SE

Screen	Weight	%	Volume	%
25 mm	729.90		800.00	
4 mm	261.00		250.00	
2 mm	147.20		125.00	
1 mm	136.60		130.00	
500 µm	383.40	62.69	260.00	60.47
250 µm	205.60	33.62	150.00	34.88
125 µm	22.30	3.65	20.00	4.65
63 µm	0.30	0.05	TRACE	TRACE
Total	611.60	100.00	430.00	100.00

Density 1.42 gm/cc

Sand >99.99%
Silt/Clay TRACE

Site DfRu-13 Level 6.00 Quadrant SW

Screen	Weight	%	Volume	%
25 mm	848.60		900.00	
4 mm	254.80		250.00	
2 mm	190.50		170.00	
1 mm	195.20		170.00	
500 µm	507.00	47.26	400.00	49.38
250 µm	483.70	45.09	350.00	43.21
125 µm	67.20	6.26	40.00	4.94
63 µm	14.90	1.39	20.00	2.47
Total	1072.80	100.00	810.00	100.00

Density 1.32 gm/cc

Sand 97.53%
Silt/Clay 2.47%

Table 1 (Cont'd).

Site DfRu-13	Level 7.00 Quadrant NW			
Screen	Weight	%	Volume	%
25 mm	352.80		400.00	
4 mm	118.30		110.00	
2 mm	98.40		80.00	
1 mm	95.50		75.00	
500 µm	257.70	35.72	200.00	36.04
250 µm	367.70	50.97	275.00	49.55
125 µm	71.20	9.87	50.00	9.01
63 µm	24.80	3.44	30.00	5.41
Total	721.40	100.00	555.00	100.00
Density	1.30 gm/cc			
Sand	94.59%			
Silt/Clay	5.41%			

Site DfRu-13	Level 7.00 Quadrant SE			
Screen	Weight	%	Volume	%
25 mm	522.80		600.00	
4 mm	189.10		200.00	
2 mm	124.10		125.00	
1 mm	107.40		80.00	
500 µm	392.50	52.11	275.00	49.55
250 µm	297.50	39.50	220.00	39.64
125 µm	57.40	7.62	50.00	9.01
63 µm	5.80	0.77	10.00	1.80
Total	753.20	100.00	555.00	100.00
Density	1.36 gm/cc			
Sand	98.20%			
Silt/Clay	1.80%			

Table 1 (Cont'd).

Site DfRu-13	Level 8.00 Quadrant NW			
Screen	Weight	%	Volume	%
25 mm	899.50		1000.00	
4 mm	395.80		400.00	
2 mm	313.00		300.00	
1 mm	643.30		530.00	
500 µm	1121.50	82.75	950.00	83.77
250 µm	210.90	15.56	160.00	14.11
125 µm	22.90	1.69	24.00	2.12
63 µm	TRACE	0.00	TRACE	0.00
Total	1355.30	100.00	1134.00	100.00
Density	1.20 gm/cc			
Sand	>99.99%			
Silt/Clay	TRACE			

Site DfRu-13	Level 8.00 Quadrant SE			
Screen	Weight	%	Volume	%
25 mm	697.70		950.00	
4 mm	235.20		260.00	
2 mm	145.30		150.00	
1 mm	126.50		110.00	
500 µm	340.20	33.13	255.00	31.99
250 µm	539.80	52.57	412.00	51.69
125 µm	102.40	9.97	80.00	10.04
63 µm	44.50	4.33	50.00	6.27
Total	1026.90	100.00	797.00	100.00
Density	1.29 gm/cc			
Sand	93.73%			
Silt/Clay	6.27%			

Table 1 (Cont'd).

Site	DfRu-13	Level	9.00	
Screen	Weight	%	Volume	%
25 mm	1799.50		2150.00	
4 mm	756.00		750.00	
2 mm	84.30		49.00	
1 mm	60.50		32.00	
500 µm	74.10	28.30	33.00	22.1
250 µm	98.20	37.51	64.00	42.95
125 µm	83.30	31.82	47.00	31.54
63 µm	6.20	2.37	5.00	3.36
Total	261.80	100.00	149.00	100.00
Density	1.76 gm/cc			
Sand	96.64%			
Silt/Clay	3.36%			

Site	DfRu-13	Level	10.00	
Screen	Weight	%	Volume	%
25 mm	295.10		400.00	
4 mm	107.00		125.00	
2 mm	47.30		45.00	
1 mm	31.00		30.00	
500 µm	35.30	39.75	27.00	38.03
250 µm	37.20	41.89	27.00	38.03
125 µm	11.60	13.06	10.00	14.08
63 µm	4.70	5.29	7.00	9.86
Total	88.80	100.00	71.00	100.00
Density	1.25 gm/cc			
Sand	90.14%			
Silt/Clay	9.86%			

Table 2. Soil aggregates, Hill samples, DfRu-13, 1991 excavations.

Site	DfRu-13	Sample	Hill #1	
Screen	Weight	%	Volume	%
25 mm	552.8		400.0	
4 mm	152.1		110.0	
2 mm	82.0		70.0	
1 mm	131.2		110.0	
500 µm	240.5	41.0	175.0	34.7
250 µm	186.7	31.8	145.0	28.7
125 µm	74.1	12.6	80.0	15.8
63 µm	85.0	14.5	105.0	20.8
Total	586.3	100.0	505.0	100.0
Density	1.2 gm/cc			
Sand	79.2 %			
Silt/Clay	20.8 %			

Site	DfRu-13	Sample	Hill #2	
Screen	Weight	%	Volume	%
25 mm	437.1		300.0	
4 mm	87.9		85.0	
2 mm	71.3		85.0	
1 mm	103.5		120.0	
500 µm	139.2	44.0	150.0	40.0
250 µm	102.6	32.4	125.0	33.3
125 µm	43.6	13.8	60.0	16.0
63 µm	30.9	9.8	40.0	10.7
Total	316.3	100.0	375.0	100.0
Density	0.8 gm/cc			
Sand	89.3 %			
Silt/Clay	10.7 %			

Table 3. Soil aggregates, excavation unit 1, DfRu-13, 1991 excavations.

Site DfRu-13 Sample EU1 0-10cm

Screen	Weight	%	Volume	%
25 mm	803.5		800.0	
4 mm	517.5		450.0	
2 mm	543.1		520.0	
1 mm	771.2		700.0	
500 µm	220.5	87.7	300.0	87.0
250 µm	28.3	11.3	40.0	11.6
125 µm	2.6	1.0	5.0	1.4
63 µm	0.1	0.0	TRACE	0.0
Total	251.5	100.0	345.0	100.0

Density 0.7 gm/cc

Sand >99.9%
Silt/Clay TRACE

Site DfRu-13 Sample EU1 10-20 cm

Screen	Weight	%	Volume	%
25 mm	1014.1		1200.0	
4 mm	574.0		575.0	
2 mm	579.0		620.0	
1 mm	483.9		550.0	
500 um	321.3	63.7	380.0	56.3
250 um	136.5	27.1	225.0	33.3
125 um	37.0	7.3	50.0	7.4
63 um	9.5	1.9	20.0	3.0
Total	504.3	100.0	675.0	100.0

Density 0.7 gm/cc

Sand 97.0 %
Silt/Clay 3.0 %

Table 3 (Cont'd.)

Site DfRu-13 Sample EU1 20-30cm

Screen	Weight	%	Volume	%
25 mm	407.0		450.0	
4 mm	281.7		350.0	
2 mm	291.9		325.0	
1 mm	289.5		375.0	
500 µm	273.3	48.1	350.0	48.3
250 µm	127.9	22.5	160.0	22.1
125 µm	82.3	14.5	110.0	15.2
63 µm	85.0	15.0	105.0	14.5
Total	568.5	100.0	725.0	100.0

Density 0.8 gm/cc

Sand 85.5 %
Silt/Clay 14.5 %

Site DfRu-13 Sample EU1 30-50cm

Screen	Weight	%	Volume	%
25 mm	390.6		325.0	
4 mm	481.1		410.0	
2 mm	1146.7		1200.0	
1 mm	981.2		1200.0	
500 µm	287.8	46.6	400.0	47.9
250 µm	197.5	32.0	250.0	29.9
125 µm	89.8	14.5	125.0	15.0
63 µm	42.1	6.8	60.0	7.2
Total	617.2	100.0	835.0	100.0

Density 0.7 gm/cc

Sand 92.8 %
Silt/Clay 7.2 %

Table 3 (Cont'd.)

Site DfRu-13 Sample EU1 50-60cm

Screen	Weight	%	Volume	%
25 mm	873.6		700.0	
4 mm	437.8		400.0	
2 mm	373.5		350.0	
1 mm	362.6		375.0	
500 µm	380.3	50.1	350.0	43.5
250 µm	238.1	31.3	250.0	31.1
125 µm	79.1	10.4	105.0	13.0
63 µm	62.1	8.2	100.0	12.4
Total	759.6	100.0	805.0	100.0

Density 0.9 gm/cc

Sand 87.6 %
Silt/Clay 12.4 %

Site DfRu-13 Sample EU1 60-70cm

Screen	Weight	%	Volume	%
25 mm	657.9		700.0	
4 mm	165.0		175.0	
2 mm	121.4		110.0	
1 mm	98.8		75.0	
500 µm	68.0	40.4	65.0	35.5
250 µm	68.7	40.8	75.0	41.0
125 µm	15.2	9.0	15.0	8.2
63 µm	16.5	9.8	28.0	15.3
Total	168.4	100.0	183.0	100.0

Density 0.9 gm/cc

Sand 84.7 %
Silt/Clay 15.3 %

Table 4. Major oxide concentrations from underwater samples and land samples, DfRu-13, 1991 excavations, determined through AAS.

Sample	Lab #	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Cr_2O_3	L.O.I.	Sum
L1	DR-1	61.40	11.68	3.18	1.38	8.27	3.26	1.35	0.64	0.30	0.05	0.017	8.1	99.96
L1	DR-2	62.57	11.65	3.33	1.45	6.98	3.33	1.31	0.69	0.26	0.05	0.016	8.0	99.93
L2	DR-3	59.23	11.58	3.42	1.60	10.71	2.85	1.40	0.61	0.22	0.04	0.11	12.1	99.96
L2	DR-4	59.96	11.59	3.32	1.49	8.53	3.22	1.21	0.65	0.22	0.05	0.011	9.4	99.95
L3	DR-5	51.78	10.11	3.16	1.35	14.25	2.78	1.26	0.56	0.28	0.05	0.010	14.0	99.96
L3	DR-6	55.37	11.40	3.41	1.60	10.80	2.91	1.27	0.61	0.20	0.04	0.009	12.0	99.95
L4	DR-7	53.62	10.63	3.38	1.40	12.78	3.09	1.18	0.62	0.27	0.06	0.10	12.6	99.99
L4	DR-8	62.11	11.12	3.10	1.22	8.74	3.07	1.21	0.65	0.30	0.06	0.013	8.0	99.94
L5	DR-9	62.81	12.19	3.36	1.34	7.68	3.38	1.18	0.73	0.19	0.06	0.016	6.7	99.96
L5	DR-10	60.71	11.73	3.27	1.38	8.84	3.36	1.17	0.69	0.20	0.06	0.014	8.2	99.96
L6	DR-12	65.31	12.83	3.02	1.28	6.44	3.67	1.16	0.67	0.17	0.06	0.014	5.0	99.67
L7	DR-13	67.23	12.51	2.97	1.24	5.98	3.54	1.27	0.64	0.17	0.06	0.014	4.0	99.93
L7	DR-14	66.89	12.86	3.12	1.27	5.84	3.58	1.18	0.70	0.15	0.06	0.016	3.9	99.98
L8	DR-15	60.62	12.97	3.83	1.58	7.38	3.24	1.48	0.68	0.22	0.06	0.014	7.5	99.90
L9	DR-17	71.66	12.17	2.83	0.91	4.82	3.31	1.18	0.41	0.09	0.05	0.005	2.3	99.98
HILL 1	DR-19	53.28	15.83	5.65	1.44	3.21	2.48	0.95	0.74	1.58	0.10	0.010	14.4	99.96
HILL 2	DR-20	53.80	13.66	4.56	1.19	3.17	2.54	1.26	0.63	1.01	0.11	0.008	17.7	99.92

Table 5. Mean major oxide concentrations, per level, from underwater samples and land samples, DfRu-13, 1991 excavations, determined through AAS.

Sample	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Cr_2O_3
Level 1	61.99	11.67	3.23	1.42	7.63	3.30	1.33	0.67	0.28	0.05	0.017
Level 2	59.60	11.59	3.41	1.55	8.66	3.14	1.25	0.66	0.22	0.05	0.011
Level 3	53.58	10.76	3.29	1.48	12.53	2.85	1.27	0.59	0.24	0.05	0.010
Level 4	57.86	10.88	3.24	1.31	10.76	3.08	1.20	0.64	0.29	0.06	0.012
Level 5	61.76	11.96	3.32	1.36	8.26	3.37	1.18	0.71	0.20	0.06	0.015
Level 6	65.31	12.83	3.02	1.28	6.44	3.67	1.16	0.67	0.17	0.06	0.014
Level 7	67.06	12.69	3.05	1.26	5.91	3.56	1.23	0.67	0.16	0.06	0.015
Level 8	60.62	12.97	3.83	1.58	7.38	3.24	1.48	0.68	0.22	0.06	0.014
Level 9	71.66	12.17	2.83	0.91	4.82	3.31	1.18	0.41	0.09	0.05	0.005
Hill 1	53.28	15.83	5.65	1.44	3.21	2.48	0.95	0.74	1.58	0.10	0.010
Hill 2	53.80	13.66	4.56	1.19	3.17	2.54	1.26	0.63	1.01	0.11	0.008

Table 6. Trace element compositions, ICP-OES, DfRu-13 land and underwater samples, 1991 excavations.

Sample	Ba	Sr	La	Zr	Y	Nb
DR-1	552.0	749.0	46.0	529.0	23.0	15.0
DR-2	549.0	654.0	24.0	460.0	18.0	5.0
LEVEL 1	550.5	701.5	35.0	494.5	20.5	10.0
DR-3	528.0	754.0	11.0	347.0	14.0	5.0
DR-4	546.0	757.0	17.0	356.0	16.0	5.0
LEVEL 2	537.0	755.5	14.0	351.5	15.0	5.0
DR-5	471.0	1081.0	32.0	434.0	14.0	5.0
DR-6	494.0	897.0	11.0	390.0	16.0	5.0
LEVEL 3	482.5	989.0	21.5	412.0	15.0	5.0
DR-7	491.0	1011.0	15.0	394.0	17.0	5.0
DR-8	563.0	780.0	40.0	623.0	20.0	5.0
LEVEL 4	527.0	895.5	27.5	508.5	18.5	5.0
DR-9	555.0	732.0	4.0	543.0	14.0	5.0
DR-10	564.0	774.0	28.0	532.0	20.0	5.0
LEVEL 5	559.5	753.0	16.0	537.5	17.0	5.0
DR-12	748.0	687.0	20.0	507.0	18.0	5.0
LEVEL 6	748.0	687.0	20.0	507.0	18.0	5.0
DR-13	590.0	650.0	38.0	480.0	24.0	5.0
DR-14	1163.0	648.0	26.0	533.0	22.0	5.0
LEVEL 7	876.5	649.0	32.0	506.5	23.0	5.0
DR-15	635.0	691.0	20.0	516.0	20.0	5.0
LEVEL 8	635.0	691.0	20.0	516.0	20.0	5.0
DR-17	592.0	600.0	12.0	130.0	6.0	5.0
LEVEL 9	592.0	600.0	12.0	130.0	6.0	5.0
HILL 1	827.0	497.0	48.0	242.0	26.0	5.0
HILL 2	825.0	465.0	30.0	290.0	18.0	5.0

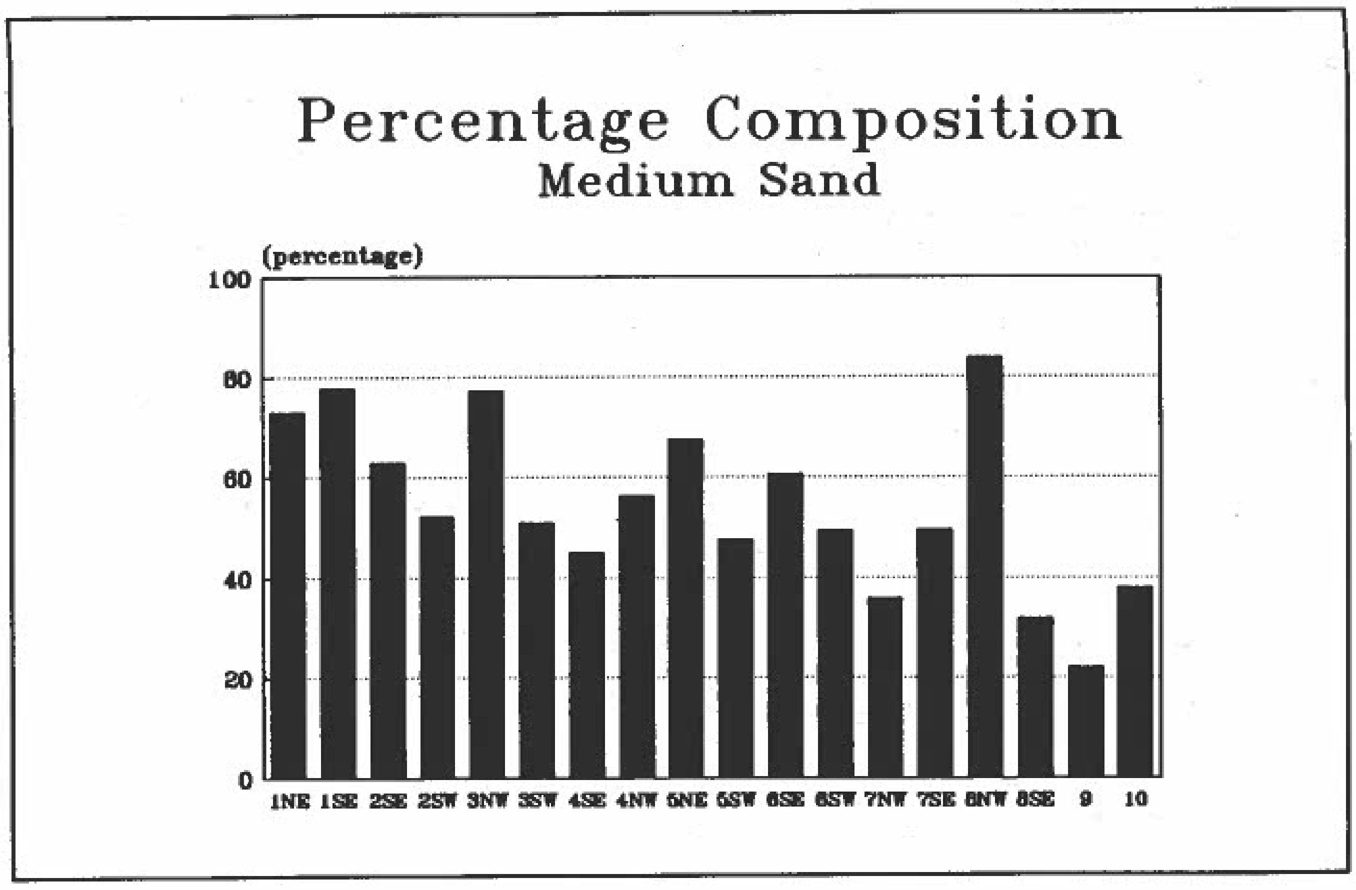

Figure 1. Histogram showing percentage composition of 500-250 μm particles, underwater samples from DfRu-13, 1991 excavations.

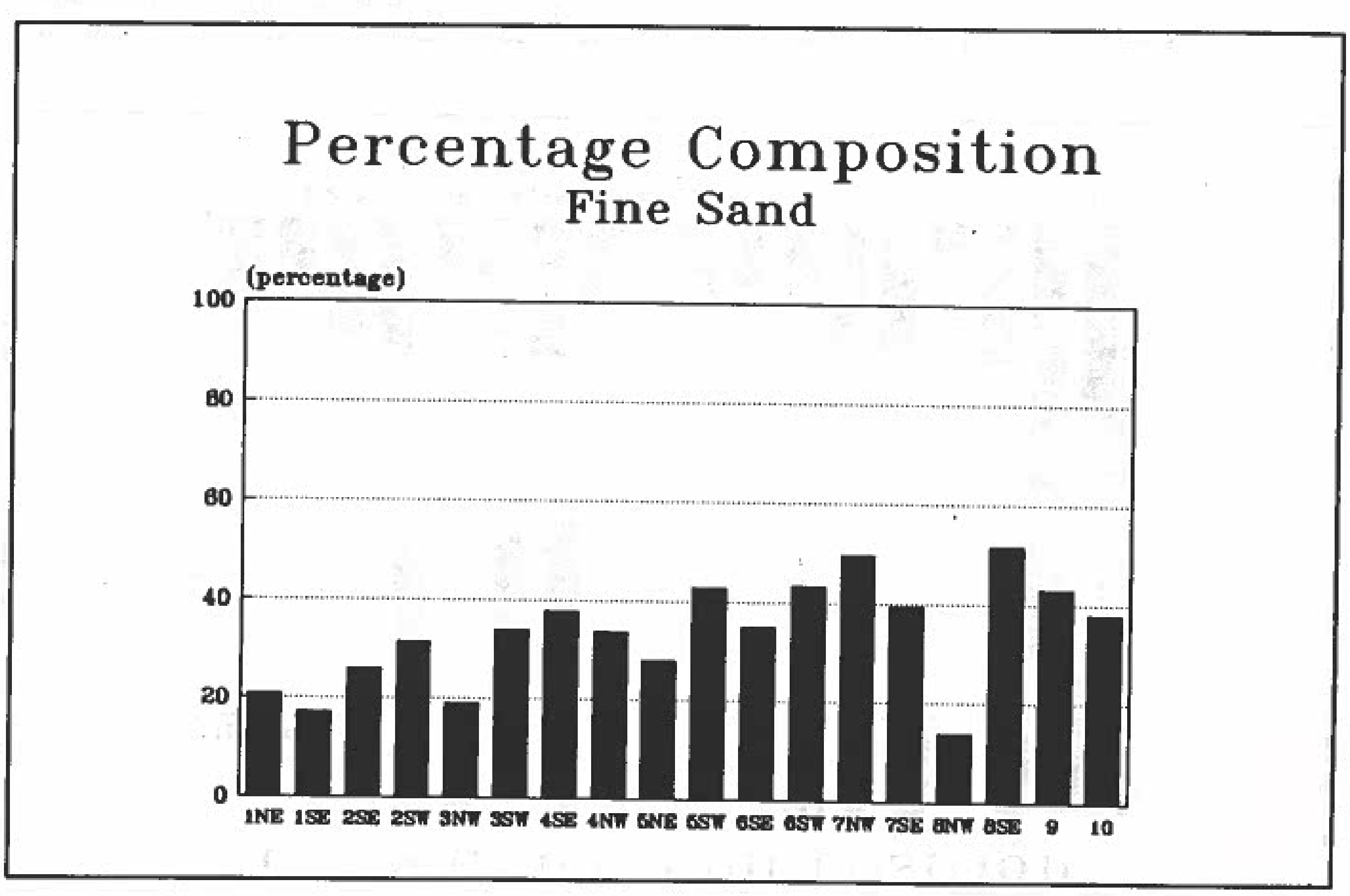

Figure 2. Histogram showing percentage composition of 250-125 μm particles, underwater samples from DfRu-13, 1991 excavations.

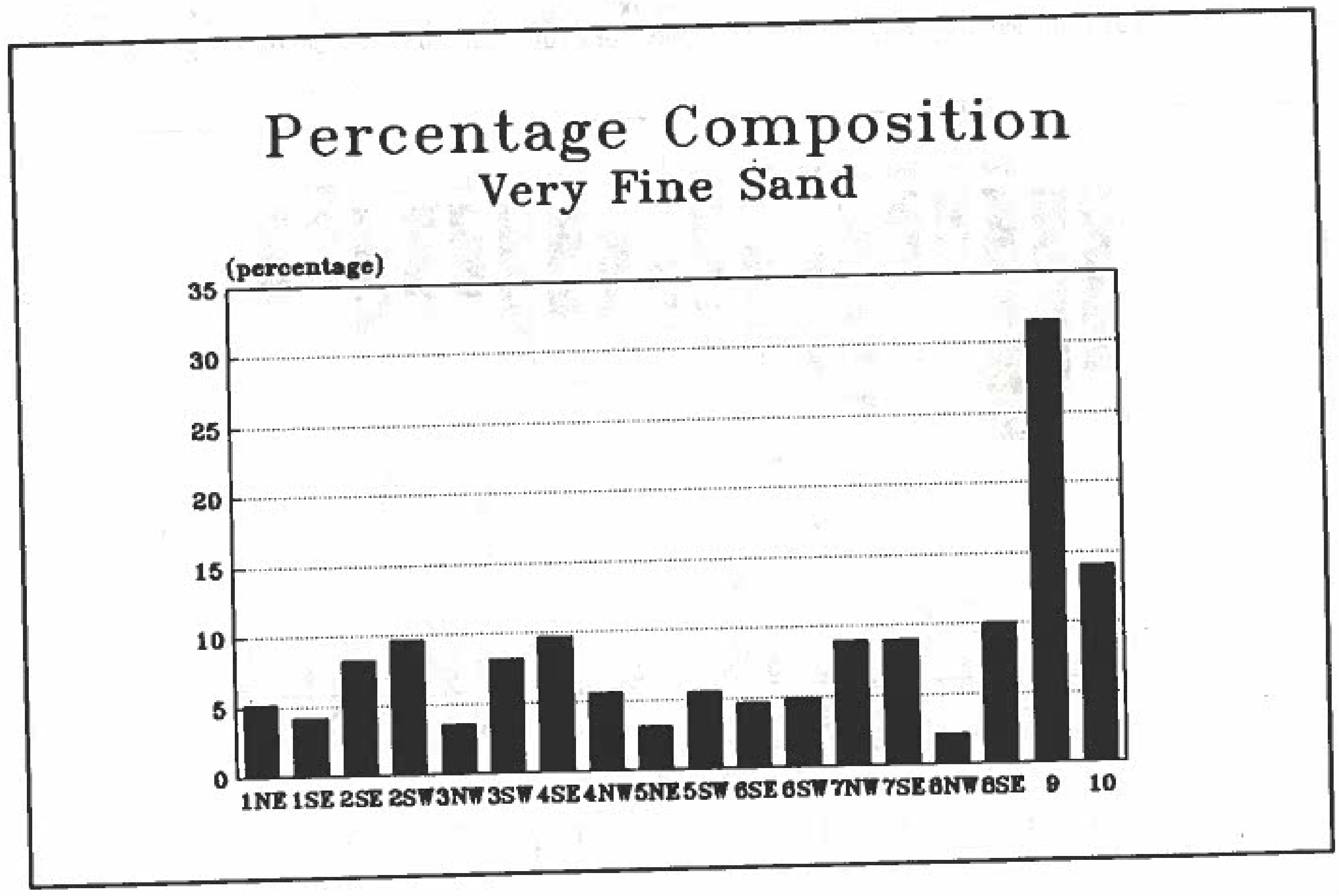

Figure 3. Histogram showing percentage composition of 125-63 μm particles, underwater samples from DfRu-13, 1991 excavations.

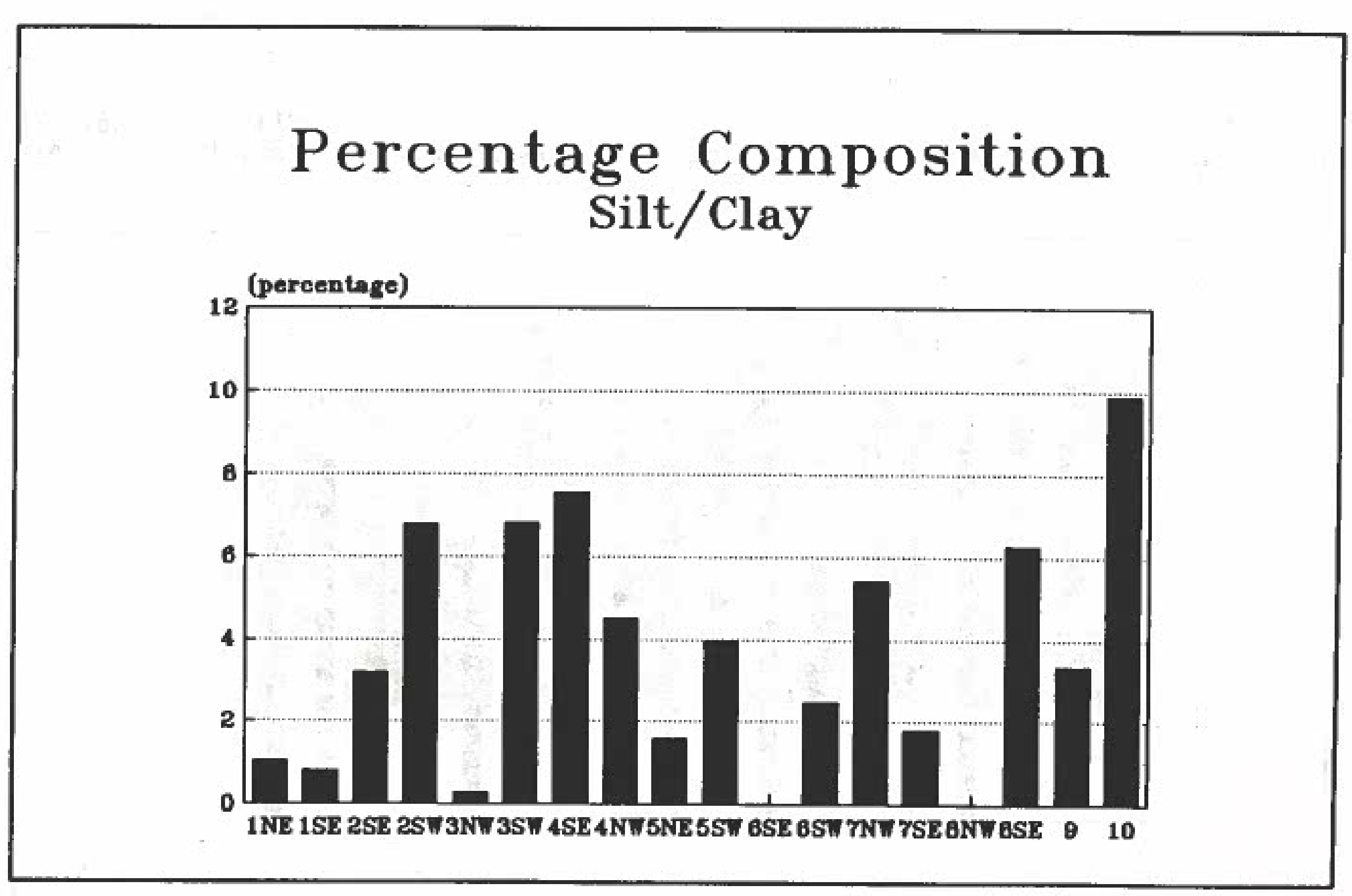

Figure 4. Histogram showing percentage composition of <63 μm particles, underwater samples from DfRu-13, 1991 excavations.

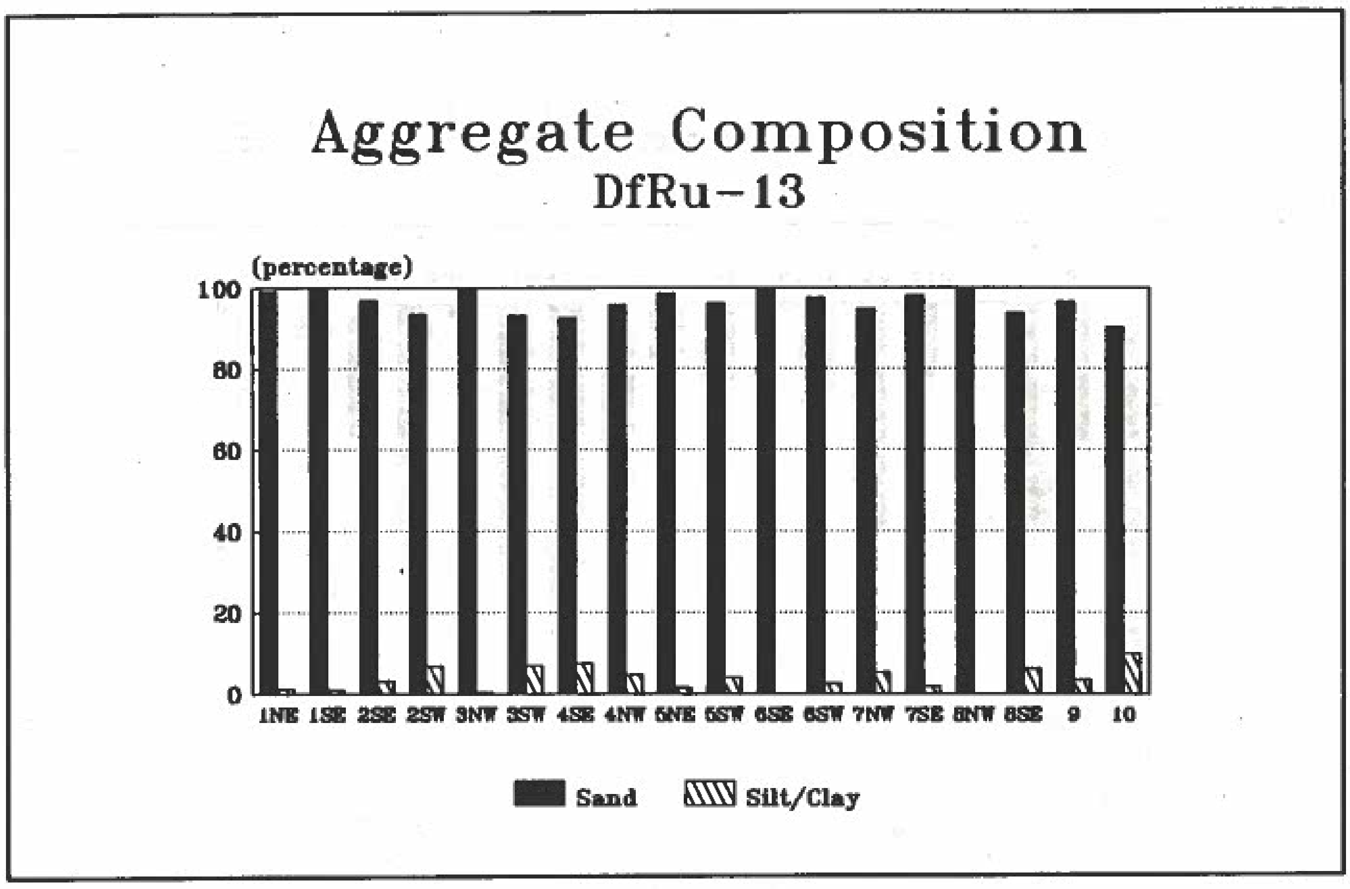

Figure 5. Histogram showing percentage composition of underwater samples from DfRu-13, 1991 excavations.

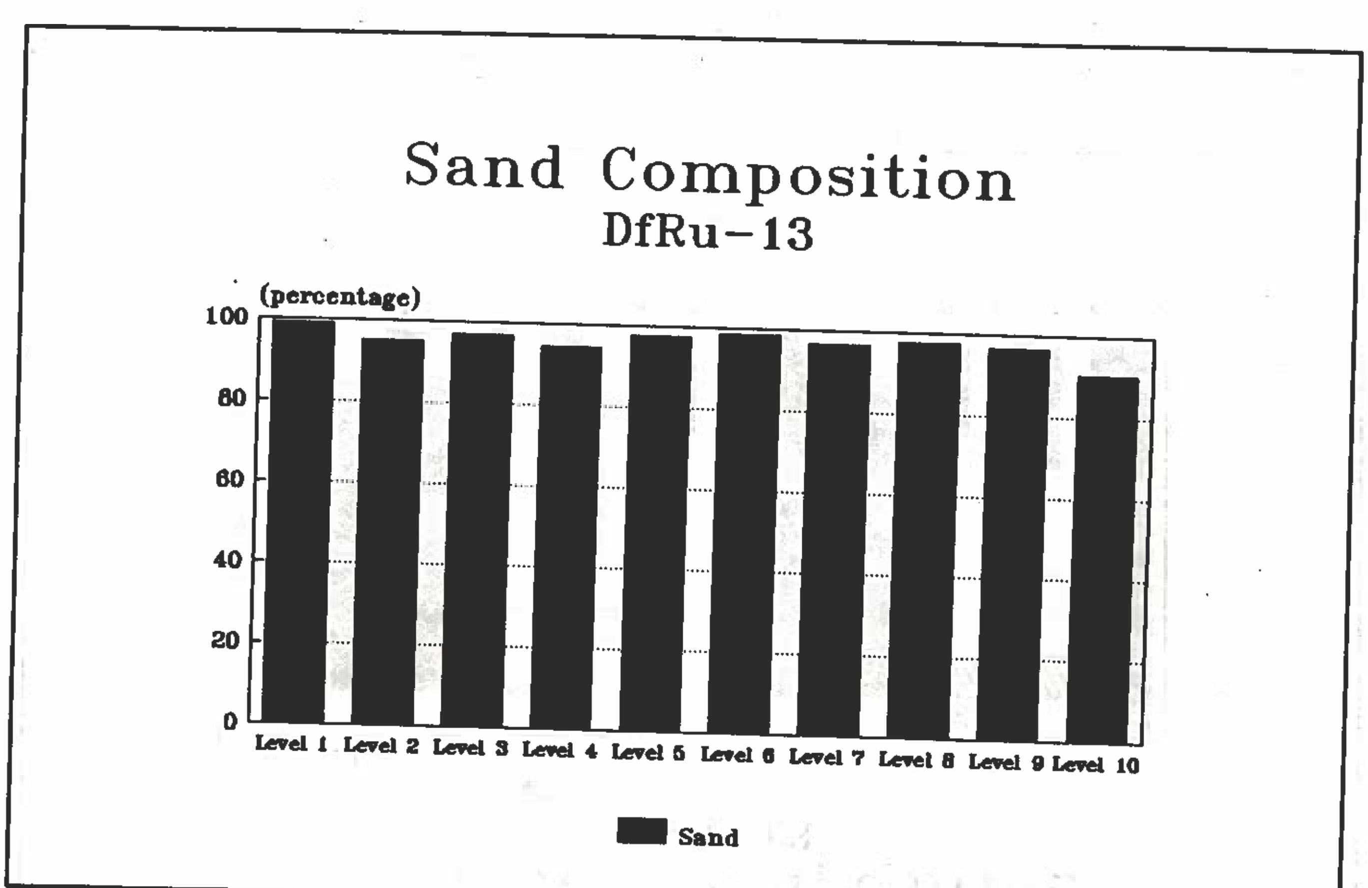

Figure 6. Histogram showing percentage composition of sand-sized particles (500 µm - 63 µm) from underwater samples, DfRu-13, 1991 excavations.

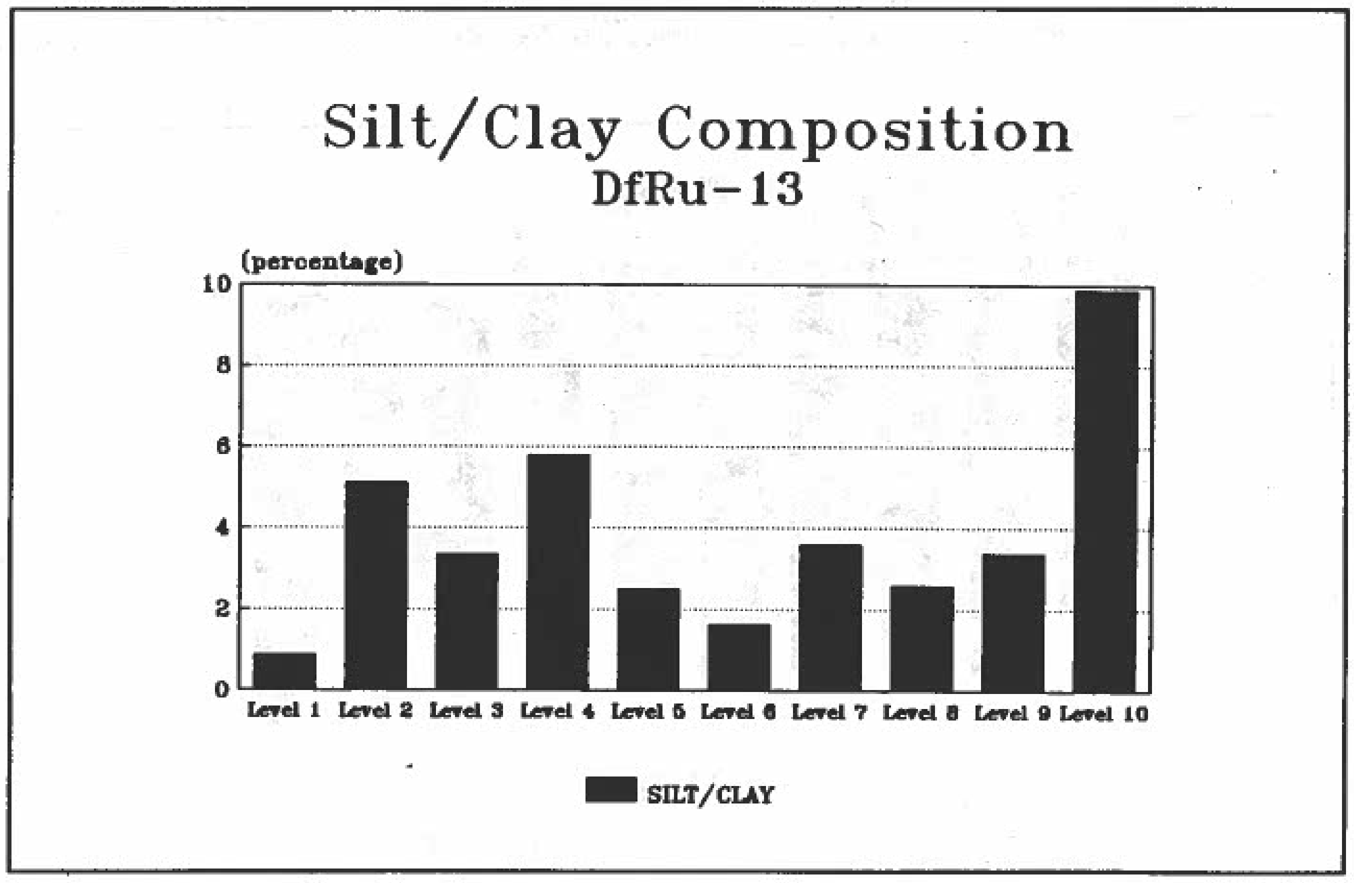

Figure 7. Histogram showing percentage composition of silt and clay size particles (>63 μm) from underwater samples, DfRu-13, 1991 excavations.

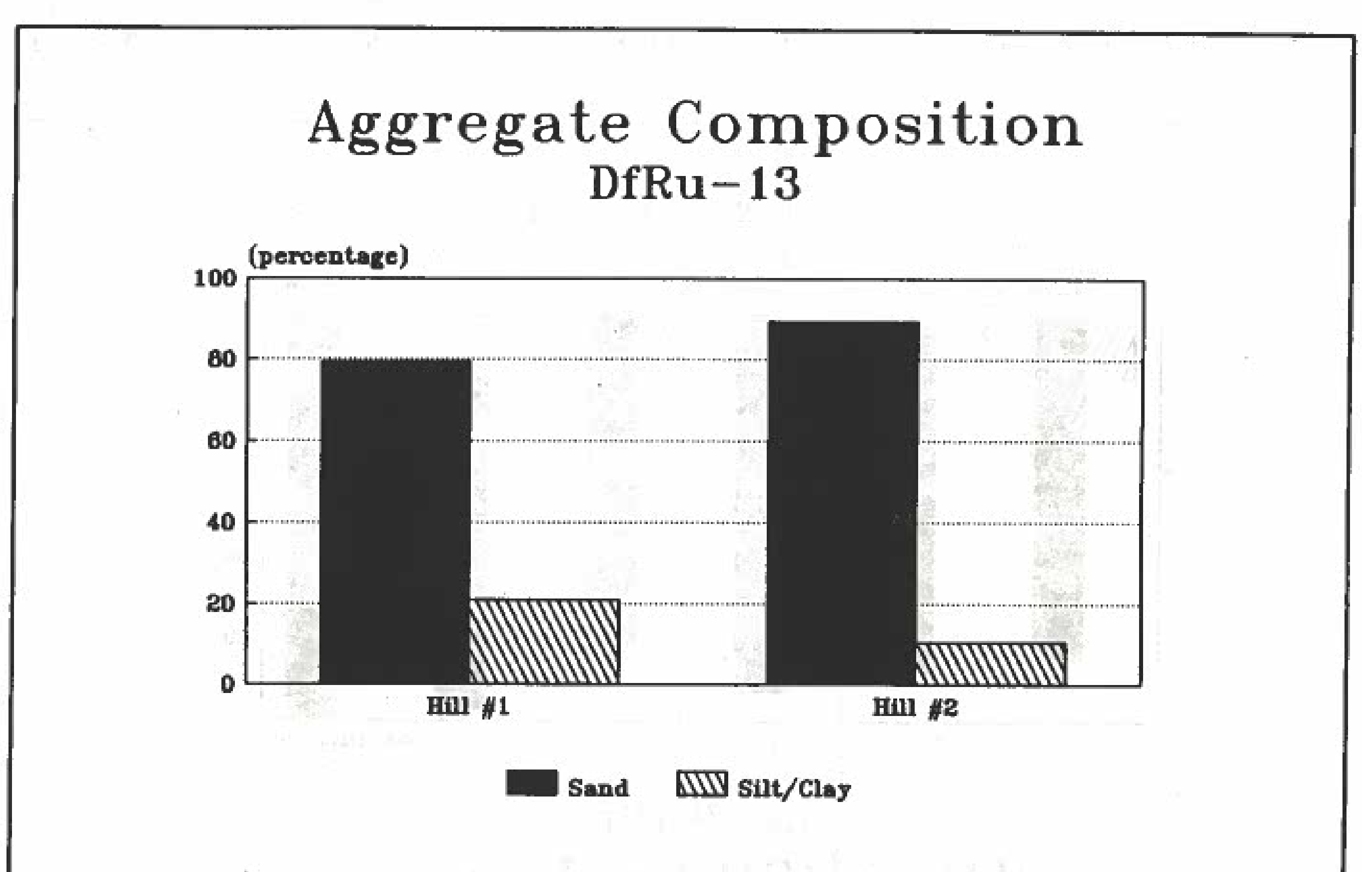

Figure 8. Histogram showing percentage composition of soil aggregates, Hill samples, from DfRu-13, 1991 excavations.

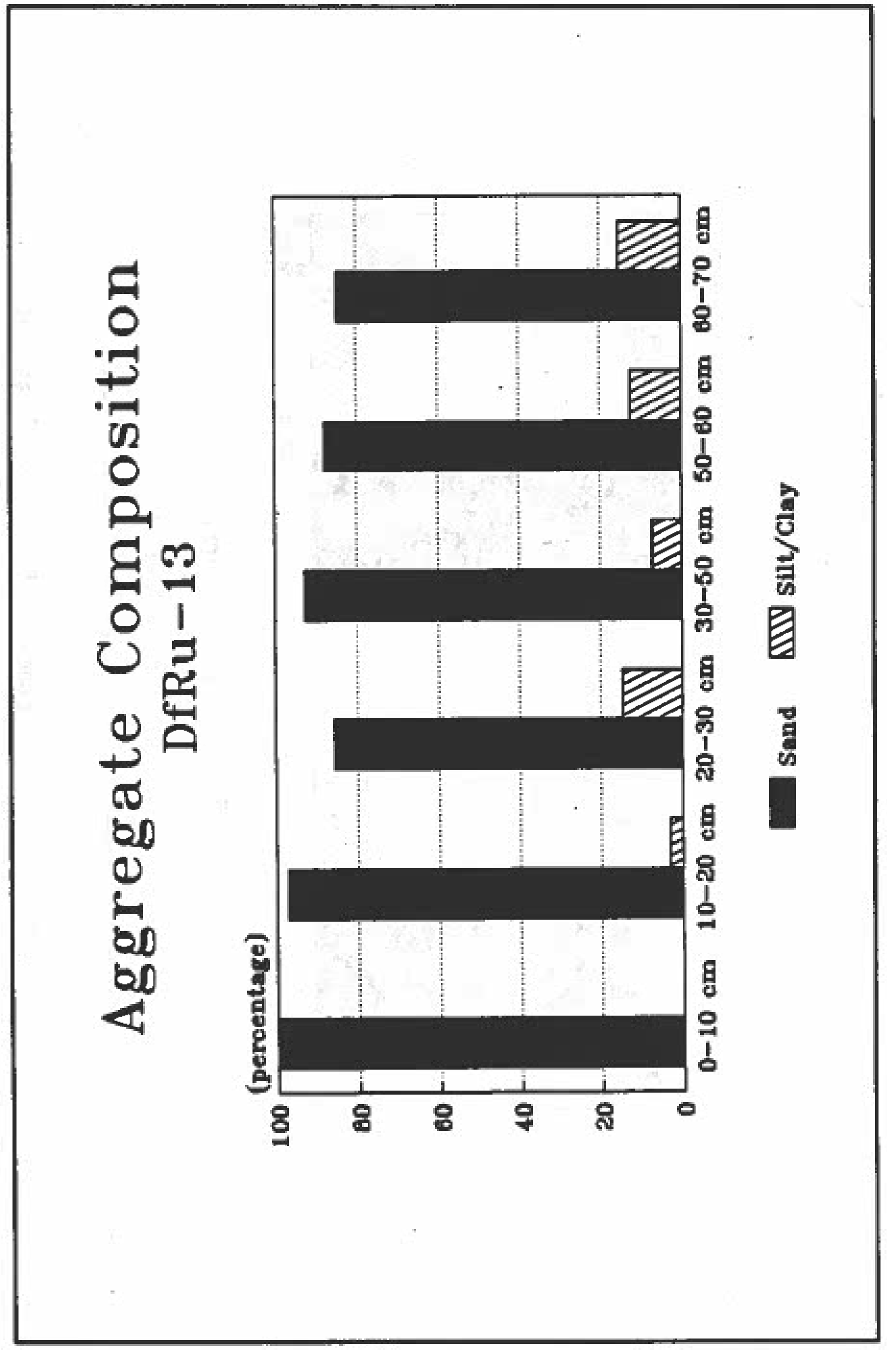

Figure 9. Histogram showing percentage composition of soil aggregates, excavation unit 1, DfRu-13, 1991 excavations.

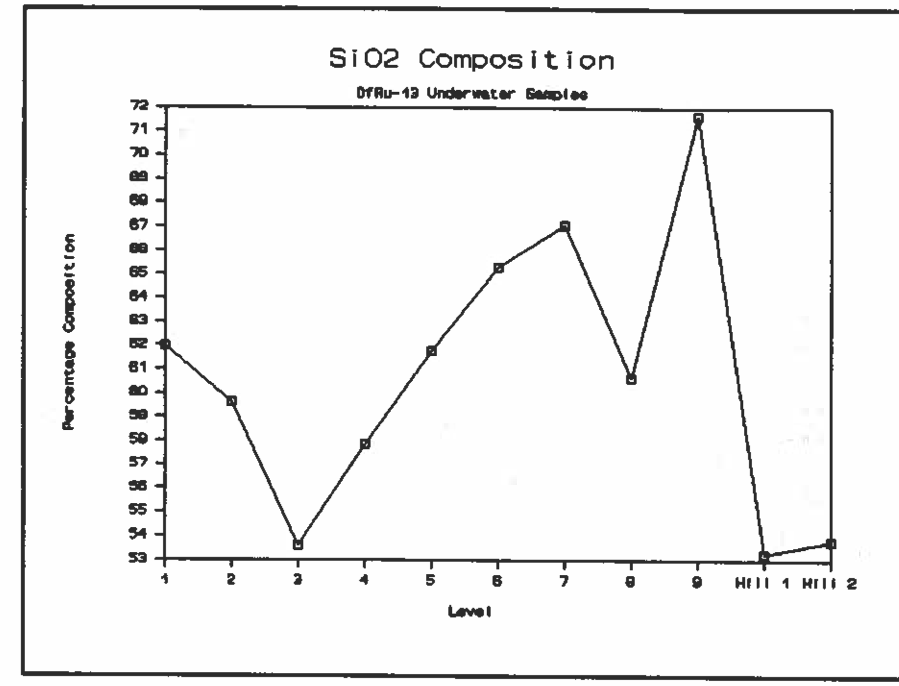

Figure 10. SiO_2 composition of underwater and hill samples, AAS, DfRu-13, 1991 excavations.

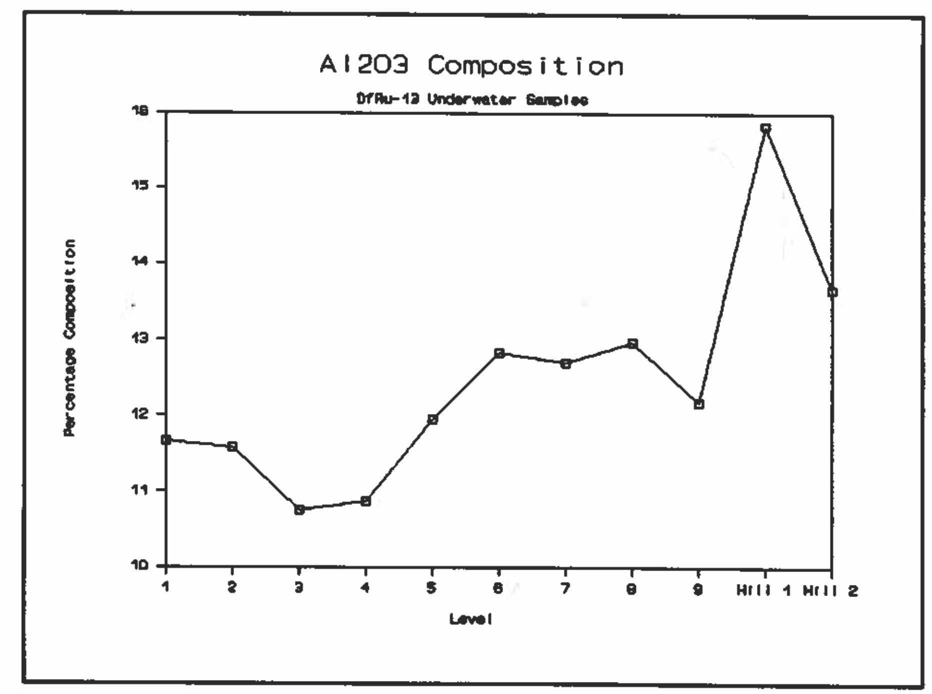

Figure 11. Al_2O_3 composition of underwater and hill samples, AAS, DfRu-13, 1991 excavations.

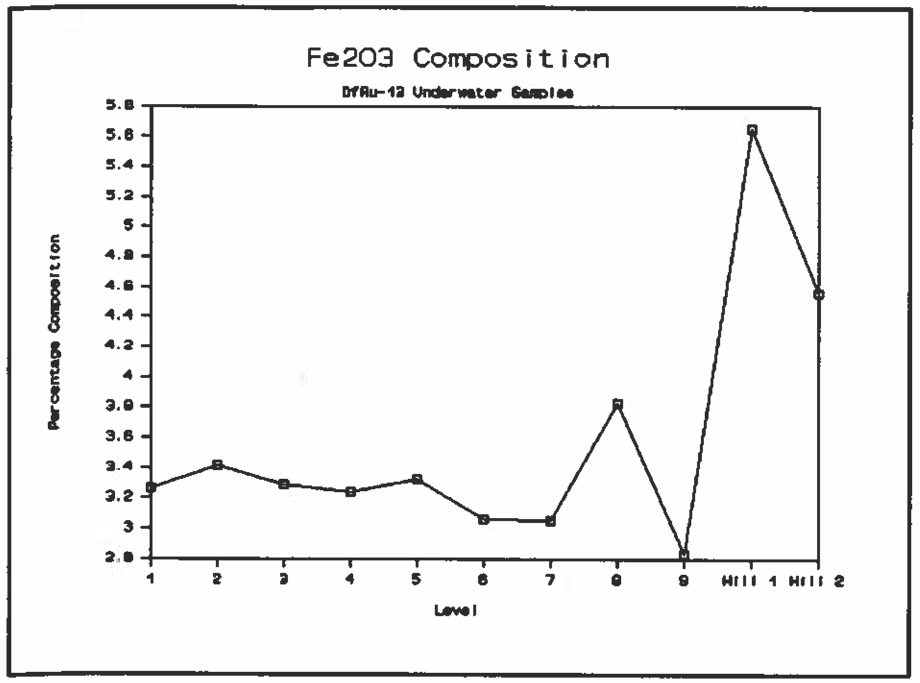

Figure 12. Fe_2O_3 composition of underwater and hill samples, AAS, DfRu-13, 1991 excavations.

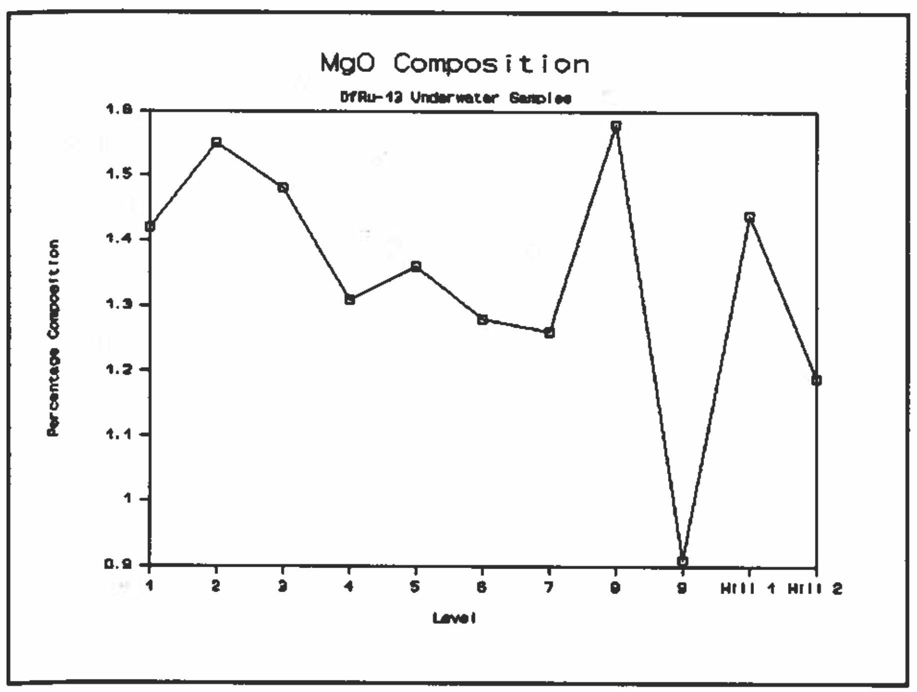

Figure 13. MgO composition of underwater and hill samples, AAS, DfRu-13, 1991 excavations.

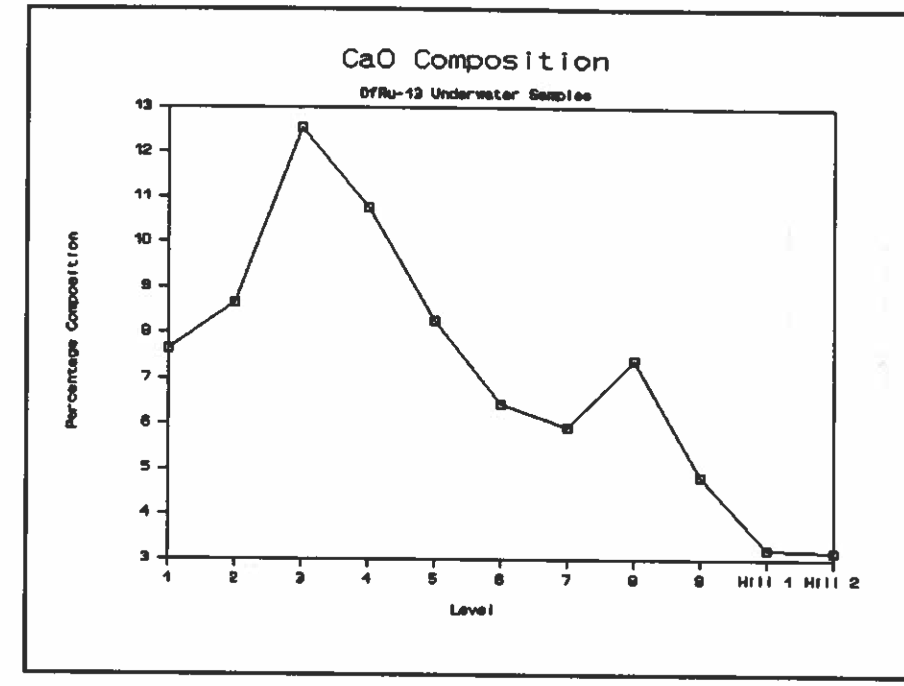

Figure 14. CaO composition of underwater and hill samples, AAS, DfRu-13, 1991 excavations.

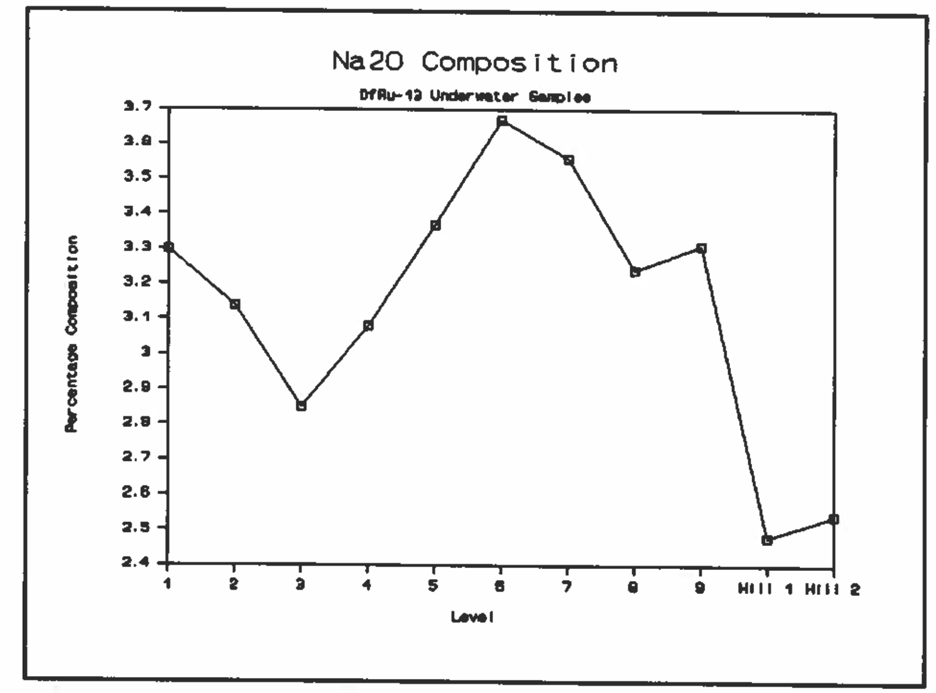

Figure 15. Na_2O composition of underwater and hill samples, AAS, DfRu-13, 1991 excavations.

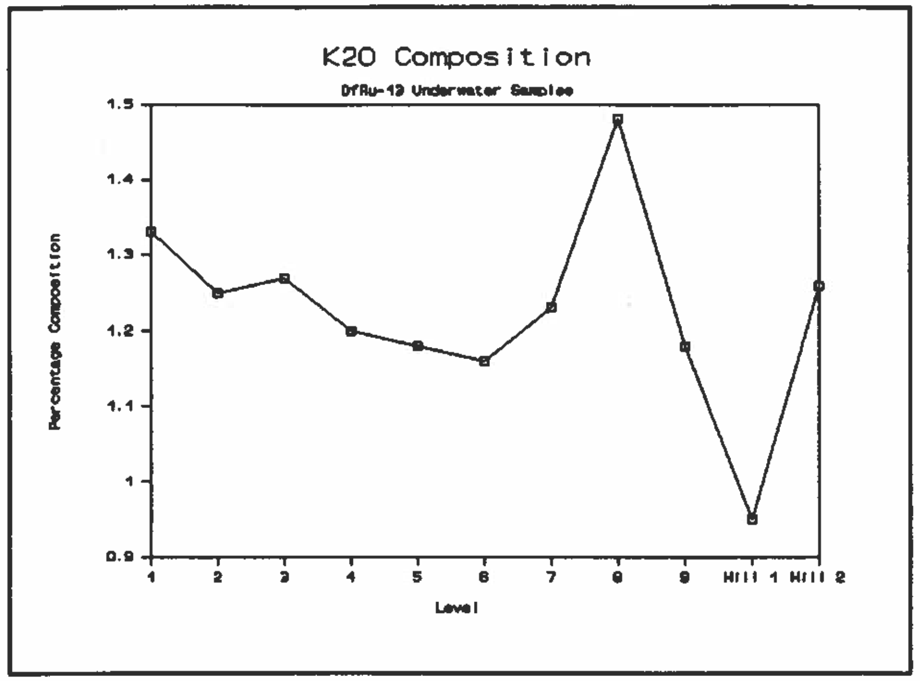

Figure 16. K_2O composition of underwater and hill samples, AAS, DfRu-13, 1991 excavations.

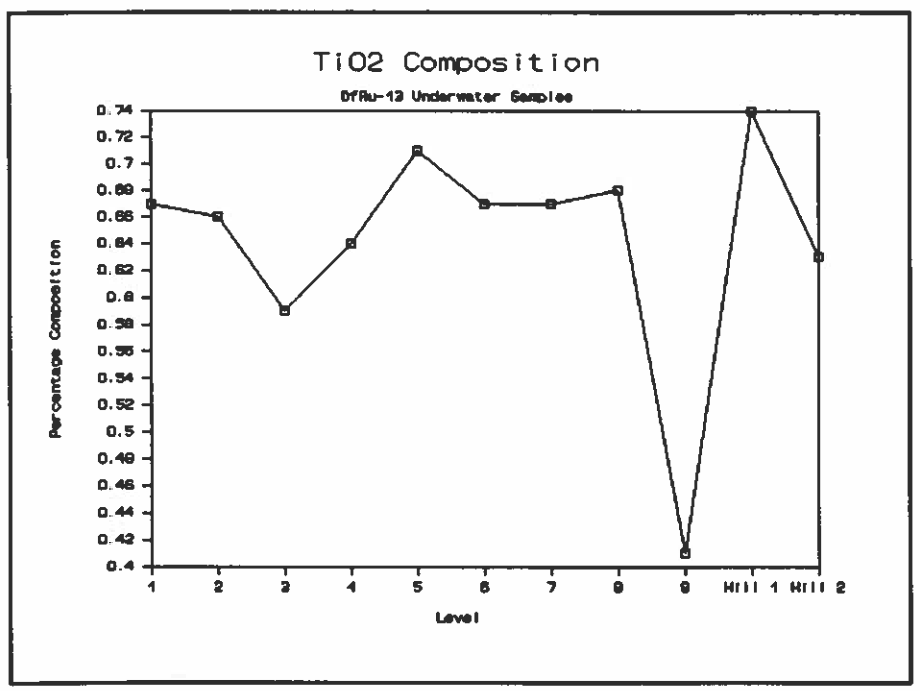

Figure 17. TiO_2 composition of underwater and hill samples, AAS, DfRu-13, 1991 excavations.

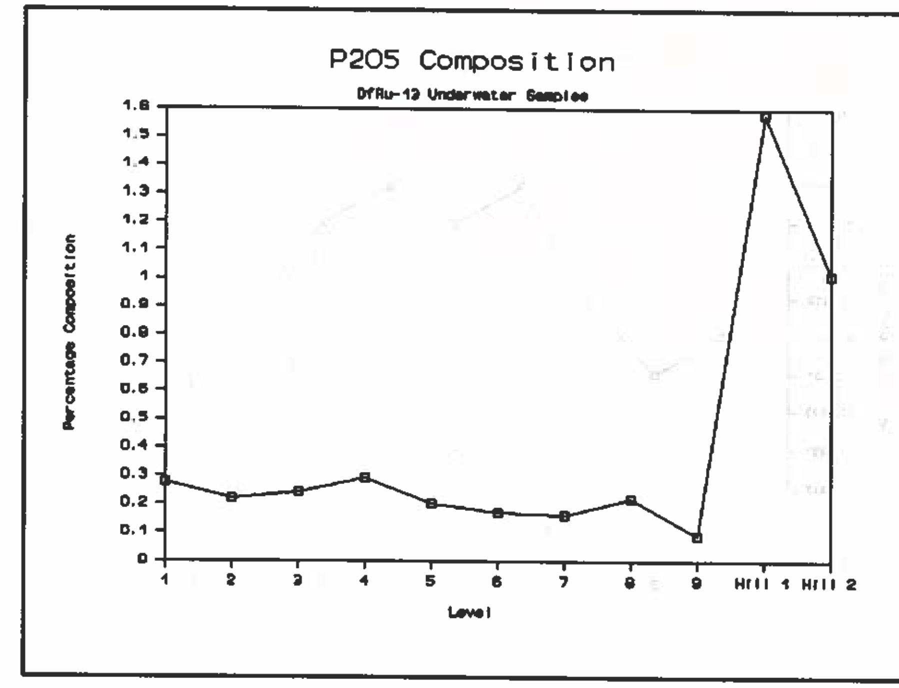

Figure 18. P_2O_5 composition of underwater and hill samples, AAS, DfRu-13, 1991 excavations.

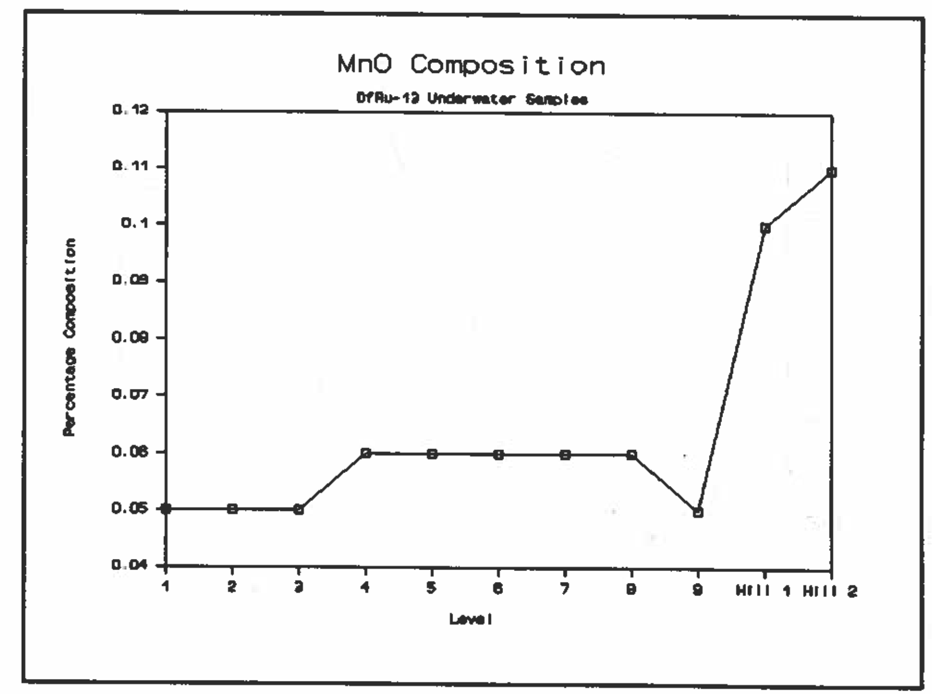

Figure 19. MnO composition of underwater and hill samples, AAS, DfRu-13, 1991 excavations.

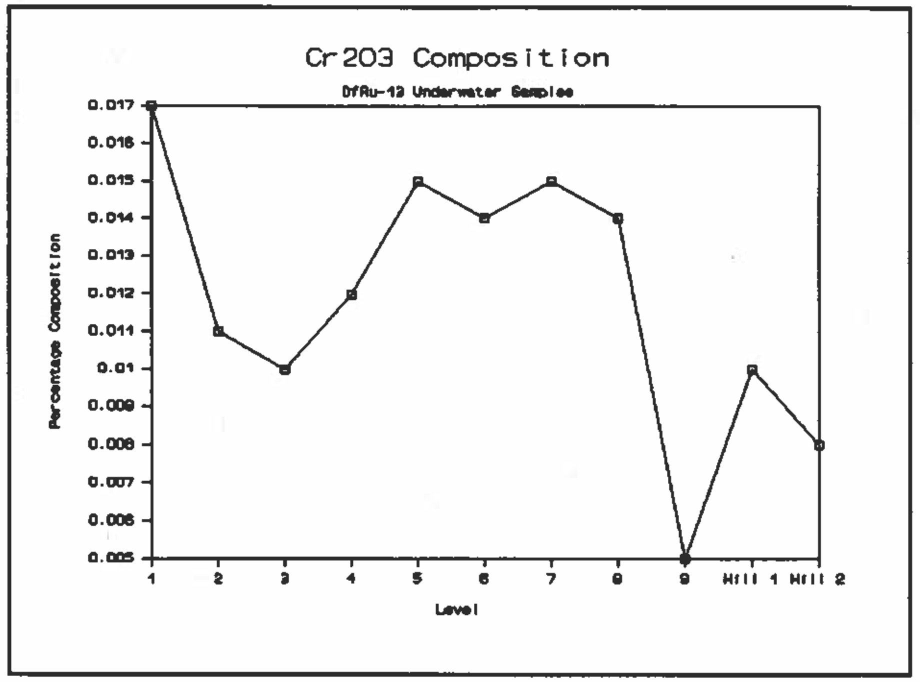

Figure 20. Cr_2O_3 composition of underwater and hill samples, AAS, DfRu-13, 1991 excavations.

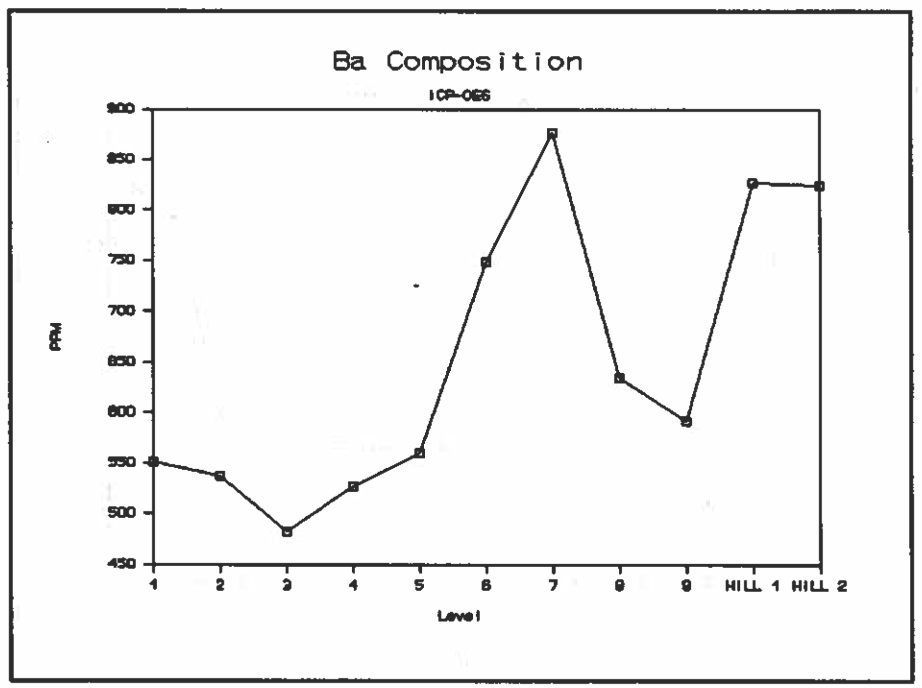

Figure 21. Ba concentration, ICP-OES, underwater and backshore samples, DfRu-13, 1991 excavations.

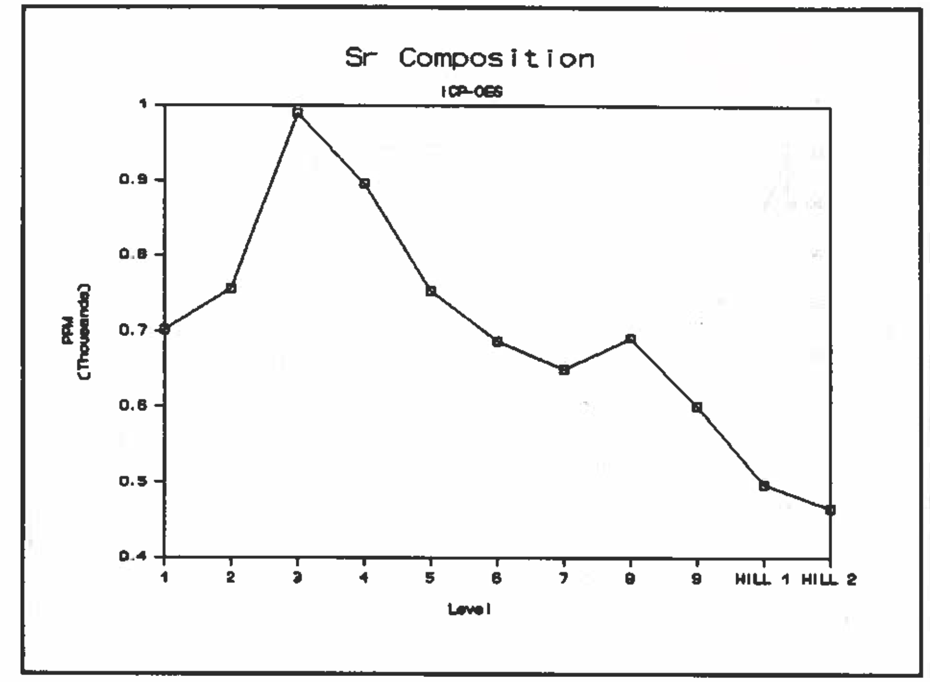

Figure 22. Sr concentration, ICP-OES, underwater and backshore samples, DfRu-13, 1991 excavations.

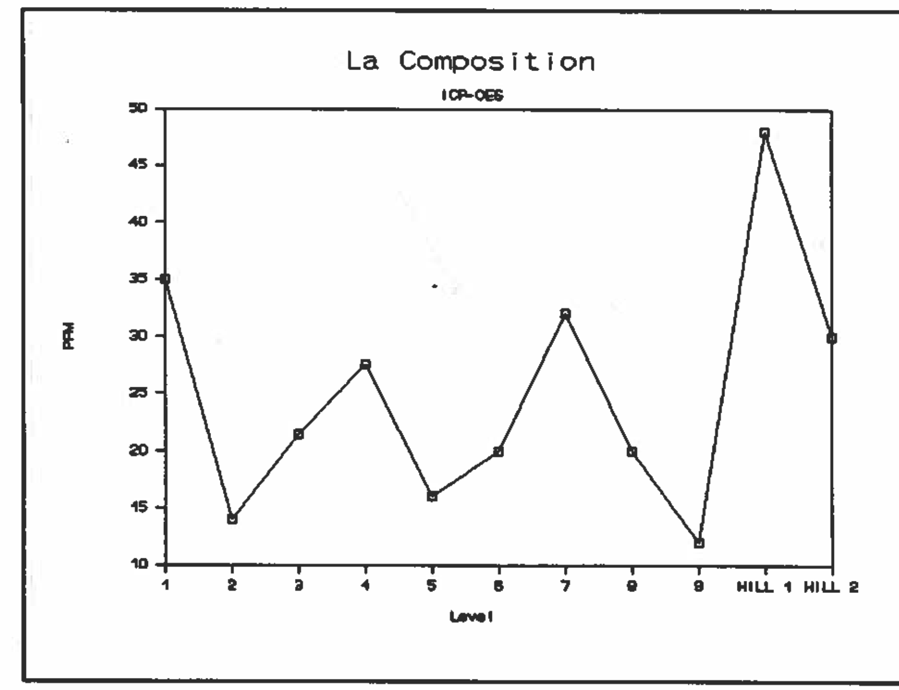

Figure 23. La concentration, ICP-OES, underwater and backshore samples, DfRu-13, 1991 excavations.

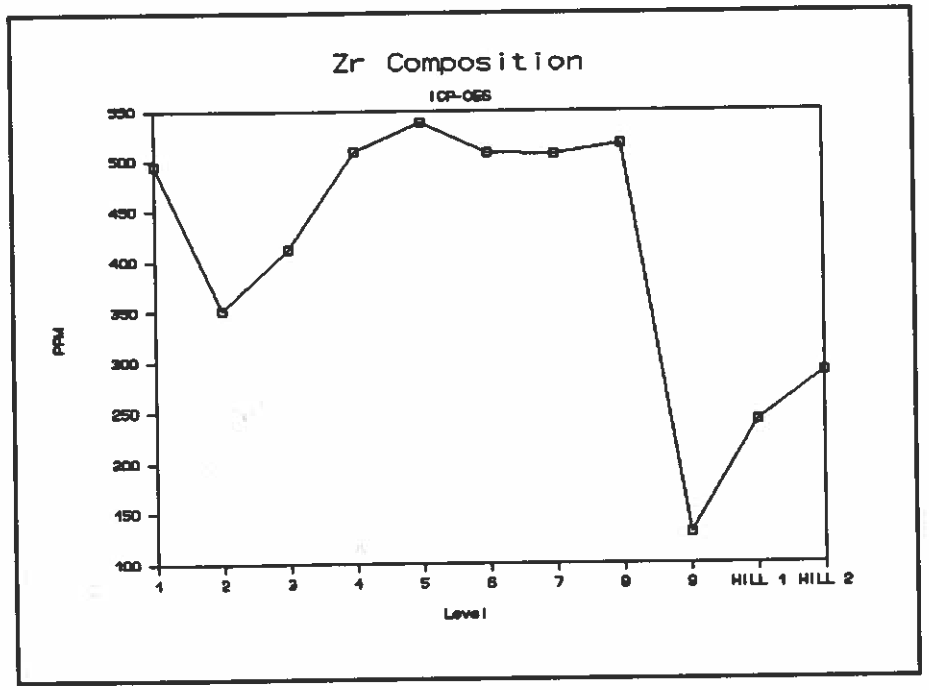

Figure 24. Zr concentration, ICP-OES, underwater and backshore samples, DfRu-13, 1991 excavations.

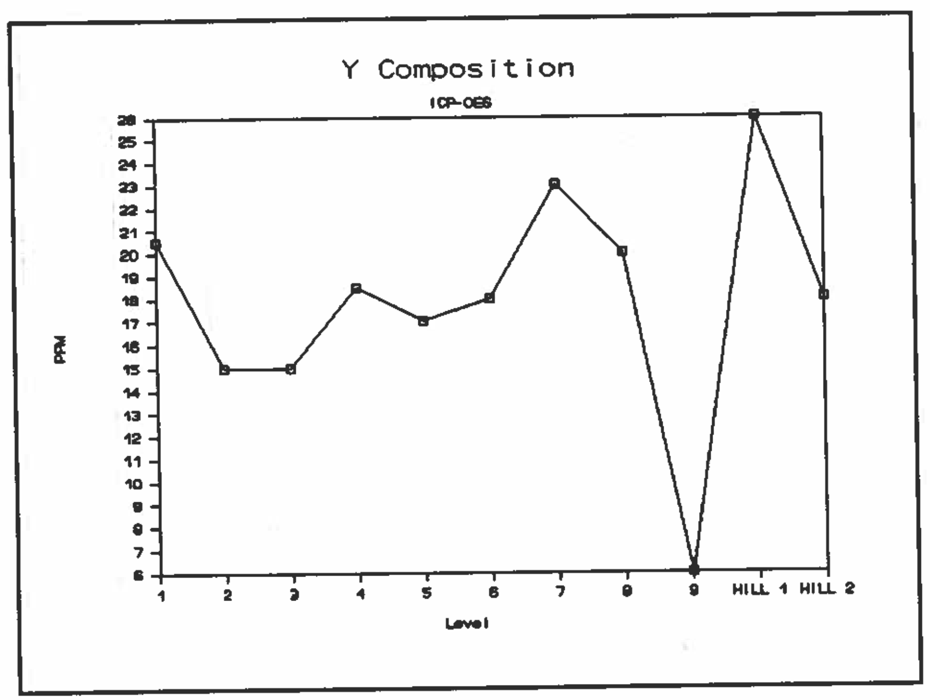

Figure 25. Y concentration, ICP-OES, underwater and backshore samples, DfRu-13, 1991 excavations.

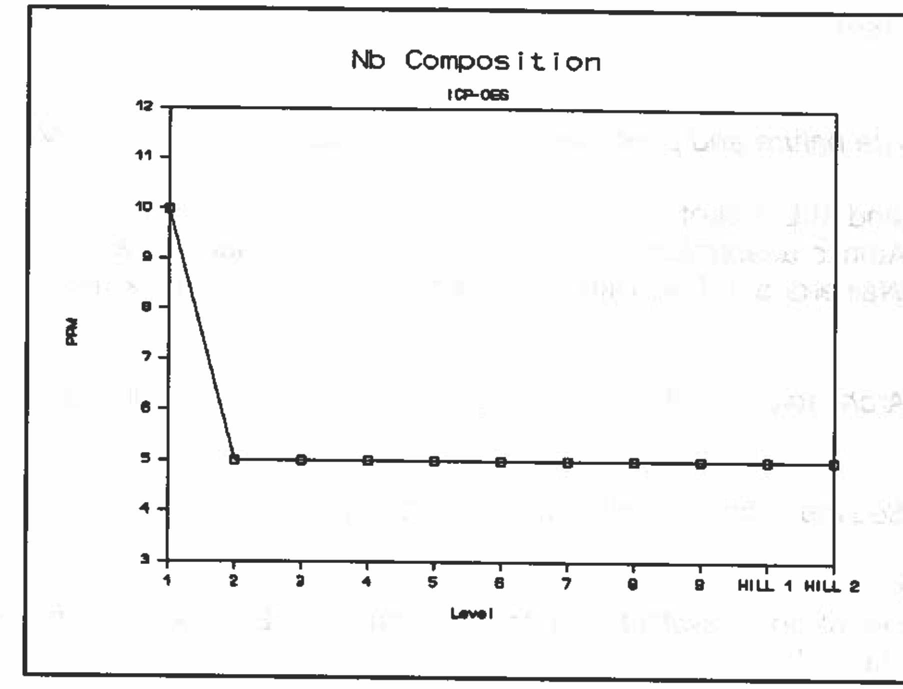

Figure 26. Nb concentration, ICP-OES, underwater and backshore samples, DfRu-13, 1991 excavations.

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