Summary of the results of a reconnaissance study of late Quaternary benthic foraminifera from the central continental shelf of western Canada

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Abstract

Seven foraminiferal biofacies were identified in samples from five Quaternary cores collected from the Queen Charlotte Sound-Hecate Strait area of western Canada. These biofacies include: two relict lower to middle bathyal biofacies introduced to shallow depths during a colder interval; four biofacies representative of various neritic depth environments; and a biofacies characteristic of shallow banks. Species such as Buliminella elegantissima have proven useful in tracking the migration of the Fraser Glaciation forebulge across the region, while high concentrations of Cassidulina reniforme at certain core intervals, indicative of glacial or near glacial conditions, signals a return to cooler conditions between about 10 000 and 12 000 years B.P. This cool interval approximately corresponds to the Younger Dryas event of Europe and eastern North America.

Résumé

Sept biofaciès à foraminifères ont été identifiés dans des échantillons provenant de cinq carottes du Quaternaire prélevées dans la région des détroits de la Reine-Charlotte et d'Hécate dans l'Ouest canadien. Ces biofaciès comprennent: deux biofaciès résiduels correspondant à un milieu bathal inférieur à moyen, mis en place à de faibles profondeurs pendant un intervalle plus froid; quatre biofaciès représentatifs de divers milieux abyssaux néritiques; et un biofaciès caractéristique des bancs peu profonds. Des espèces telles que Buliminella elegantissima se sont avérées utiles pour retracer la migration du front de la glaciation de Fraser dans la région, tandis que des concentrations élevées de Cassidulina reniforme dans certains intervalles de carotte, dénotant des conditions glaciaires ou presque glaciaires, indiquent un retour à des conditions plus froides entre il y a 10 000 et 12 000 ans environ. Cet intervalle de froid correspond approximativement au Dryas récent de l'Europe et de l'est de l'Amérique du Nord.

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INTRODUCTION

The Quaternary sedimentary record of the Queen Charlotte Sound-Hecate Strait region of the Georgia-Hecate Depression of coastal British Columbia is important because of the clues that these sediments provide about the paleoceanographic history of Canada's west coast (Fig. 1). In addition, renewed oil industry interest in the depression has sparked a major research impetus in an effort to better understand the Neogene depositional history of the basin and potential hazards to hydrocarbon exploration. As part of this effort Patterson (1989) made a biostratigraphic and paleoecological examination of benthic and planktonic foraminifera from the southern part of the basin.

The purpose of the present research was to analyze the foraminiferal faunas found in Quaternary core samples from Queen Charlotte Sound. Foraminiferal assemblages have been shown to be very useful in recognizing temperature and salinity changes expected in water masses during glaciation and deglaciation. The resulting foraminiferal distributional data coupled with the sedimentological and geochronological results (Luternauer et al., 1989a, b) are used to determine paleoenvironmental conditions during Quaternary deposition at these sites. A good understanding of the sea-level history is essential to the rigorous interpretation of offshore geohazards to hydrocarbon exploration. Qualitative and quantitative analysis of benthic foraminifera at closely spaced sampling intervals should provide supporting evidence for suspected rapid water depth changes accompanying a regression *ca.* 13-10 ka and a subsequent (*ca.* 10-9 ka) transgression, as indicated by sedimentological results. Finally, as there has never been a thorough examination of Quaternary foraminifera from this area, this research will provide a valuable base line on foraminiferal distribution and ecology for future researchers (see Patterson (1990) for a complete discussion of previous work).

METHODS AND MATERIALS

Forty-six samples were obtained from five Geological Survey of Canada vibracores collected from Queen Charlotte Sound off the coast of British Columbia (Fig. 1). Core END 87A-023 was collected from Cook Bank off the northwestern tip of Vancouver Island, core END 84B-04 and END 84B-07 from the margin of Moresby Trough off the southeastern tip of Queen Charlotte Island, and cores END 84B-08 and END 84B-10 were collected from Goose Island Trough southwest of Calvert Island (Fig. 2). Locations of cores are as follows:

Core END 87A-23, Latitude 50°59.94'; Longitude 128°26.55'

Core END 84B-04, Latitude 52°14.72'; Longitude 130°09.05'

Core END 84B-07, Latitude 52°16.70'; Longitude 130°12.27'

Core END 84B-08, Latitude 51°31.07'; Longitude 128°23.11'

Core END 84B-10, Latitude 51°28.14'; Longitude 128°25.14'

All samples were boiled with soda ash to cleanse the tests of the foraminifera contained in the sample. Samples were then rinsed using 63 m screens to retain the foraminifera. Samples containing excessive amounts of sand were dried, and the foraminifera separated from the sand by floatation in sodium polytungstate (s.g. 2.28). These samples yielded a fauna of 95 species. Forty-three of the 46 samples were found to contain at least some foraminifera, and 40 of these samples contained populations large enough for statistical analysis (Patterson and Fishbein, 1989).

DISCUSSION

Analysis of Late Quaternary benthic foraminifera in cores from Queen Charlotte Sound and Hecate Strait has yielded new information on the paleoceanographic history of the region. These results are discussed in much greater detail and all foraminiferal taxa are fully illustrating in Patterson (in press). Q-mode cluster analysis separated samples into seven groups distinguished by seven benthic foraminiferal biofacies: the *Gyroidina-Bolivina* Biofacies and *Gyroidina-Seabrookia* Biofacies are relict lower to middle bathyal faunas introduced to shallower depths when cooler water masses influenced the area; the *Cribroelphidium* Biofacies, *Islandiella* Biofacies, *Epistominella* Biofacies, and *Buccella* Biofacies are all similar in faunal makeup and characterize varying depositional conditions at neritic depths; and the *Lobatula-Gavelinopsis* Biofacies characterizes shallow banks.

The upper part of the B_1 unit, the entire B_2 unit of cores END 84B-08 and END 84B-10, and the B_2 unit of the deeper water Core END 84B-04 are characterized by relatively high proportions of *Buliminella elegantissima*, indicating an environment enriched in nutrients (Snyder, 1989; Fig. 3). In a study centred around the mouth of the Columbia River, Harmon (1972) identified abundant vascular plant debris and large populations of diatoms in association with the maximum abundance zone of *Buliminella elegantissima*. The terrestrial plant debris that sustained *Buliminella elegantissima* may have been flushed into Goose Island Trough from

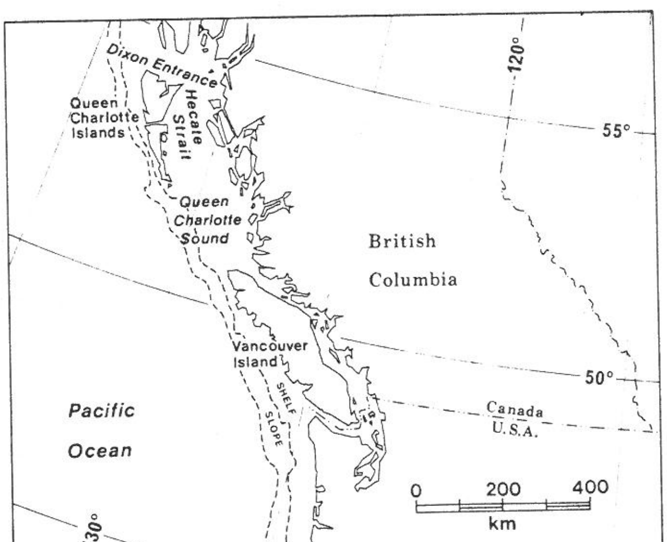

Figure 1. Continental shelf of western Canada showing location of Queen Charlotte Sound and Hecate Strait.

subaerial exposures of Goose Island Bank or Sea Otter Shoals and/or from an area adjacent to a much larger ancestral Calvert Island. Sedimentological evidence that relative sealevels in this area were at least 95 m lower has been provided by several marine and land-based studies in the area (Howes, 1981; Clague et al., 1982; Luternauer et al., 1989a; Barrie and Bornhold, 1989). Changes in the proportion of *Buliminella elegantissima* throughout the cores provides evidence of the degree of relative sea-level change in the area at the time. The increase in the proportion of *Buliminella elegantissima* in the cores through the B_1 and B_2 lithological units suggests an increasing supply of terrigenous debris accompanying marine regression. It is interesting to note that the maximum abundance spike of *Buliminella elegantissima* in these cores occurs in the B_2 lithological unit. Luternauer et al. (1989b) suggested that the winnowed and lagged sediments of this unit, observed in cores throughout the region, were deposited during the period of lowest sealevel. The lagged B_2 deposits of cores END 84B-08 and END 84-10 were deposited between 11 000 and 12 000 years B.P. The gradational nature of the lower contact of the B_2 unit provides sedimentological evidence of a gradual regressive event (Luternauer et al., 1989b). Although lagging has undoubtedly caused some reworking of *Buliminella elegantissima* specimens, the present-day preference of this species for shallow, nearshore habitats along the west coast indicates a probable minimal difference between thanatocoenosis (death assemblage) and the time-average taphocoenosis (generated by lagging) in the B_2 units at these sites (Fürsich and Aberhan, 1990). Immediately following deposition of the B_2 unit, the proportion of *Buliminella elegantissima* inhabiting the area dropped precipitously. A very rapid transgression of the terrestrial source of this debris best explains the sudden collapse of this population. The sharp contact of the upper

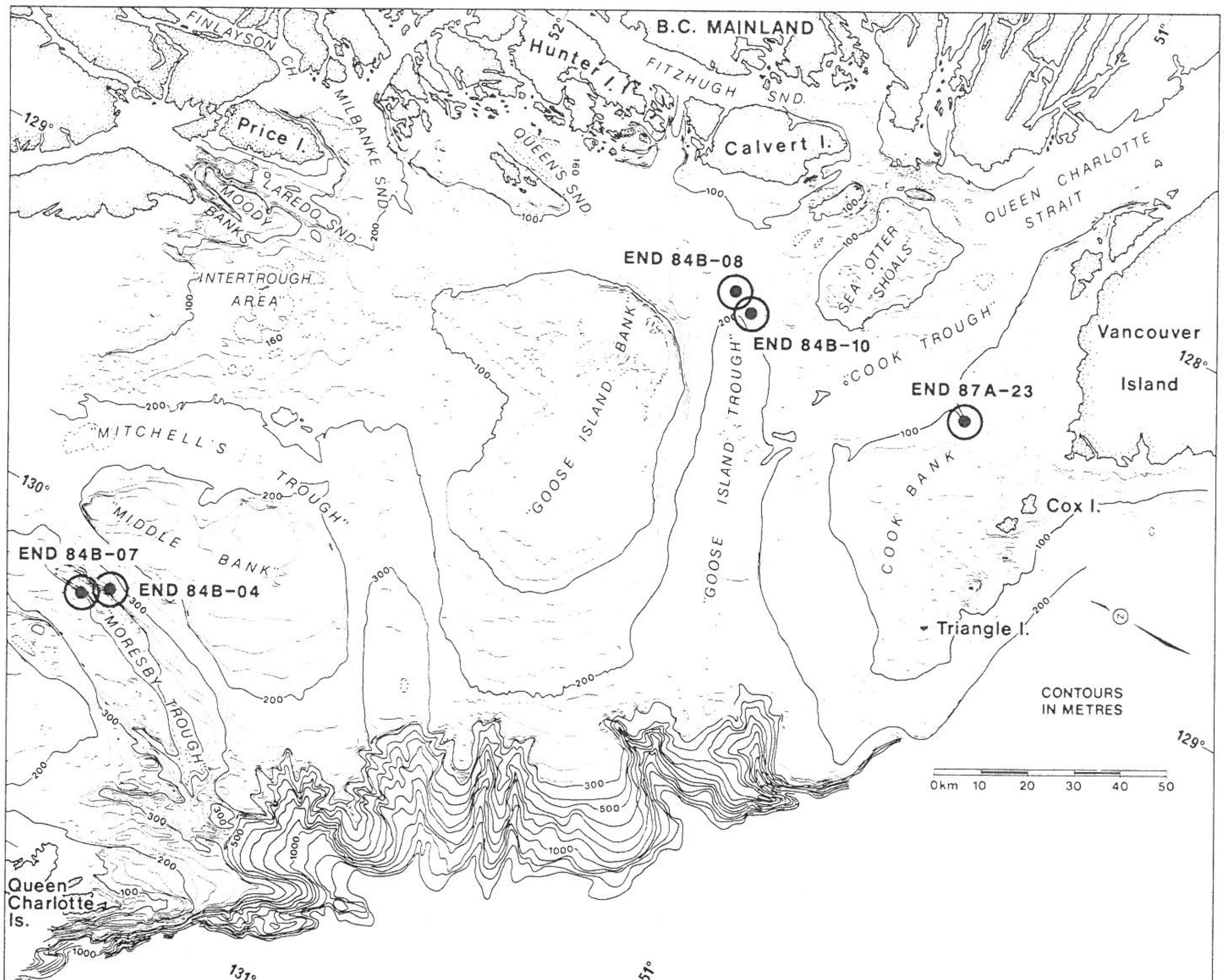

Figure 2. Bathymetric map of Queen Charlotte Sound and southern Hecate Strait (after Luternauer and Murray, 1983) showing location of cores (encircled solid dots) from which Late Quaternary benthic foraminifera were examined.

margin of the B_2 unit with B_3 sediments also supports the hypothesis of rapid subsidence (Luternauer et al., 1989b). Clague (1983) and Luternauer et al. (1989a) suggest that rapid migration and collapse of the forebulge during deglaciation would result in this scenario.

High proportions of *Cassidulina reniforme* characterize the upper part of the B_1 unit through the lower part of the B_3 lithological unit, indicating that water temperatures were generally quite cool during deposition of this interval (Fig. 3). The presence of high proportions of this species in all cores (spanning an interval between approximately 12 000

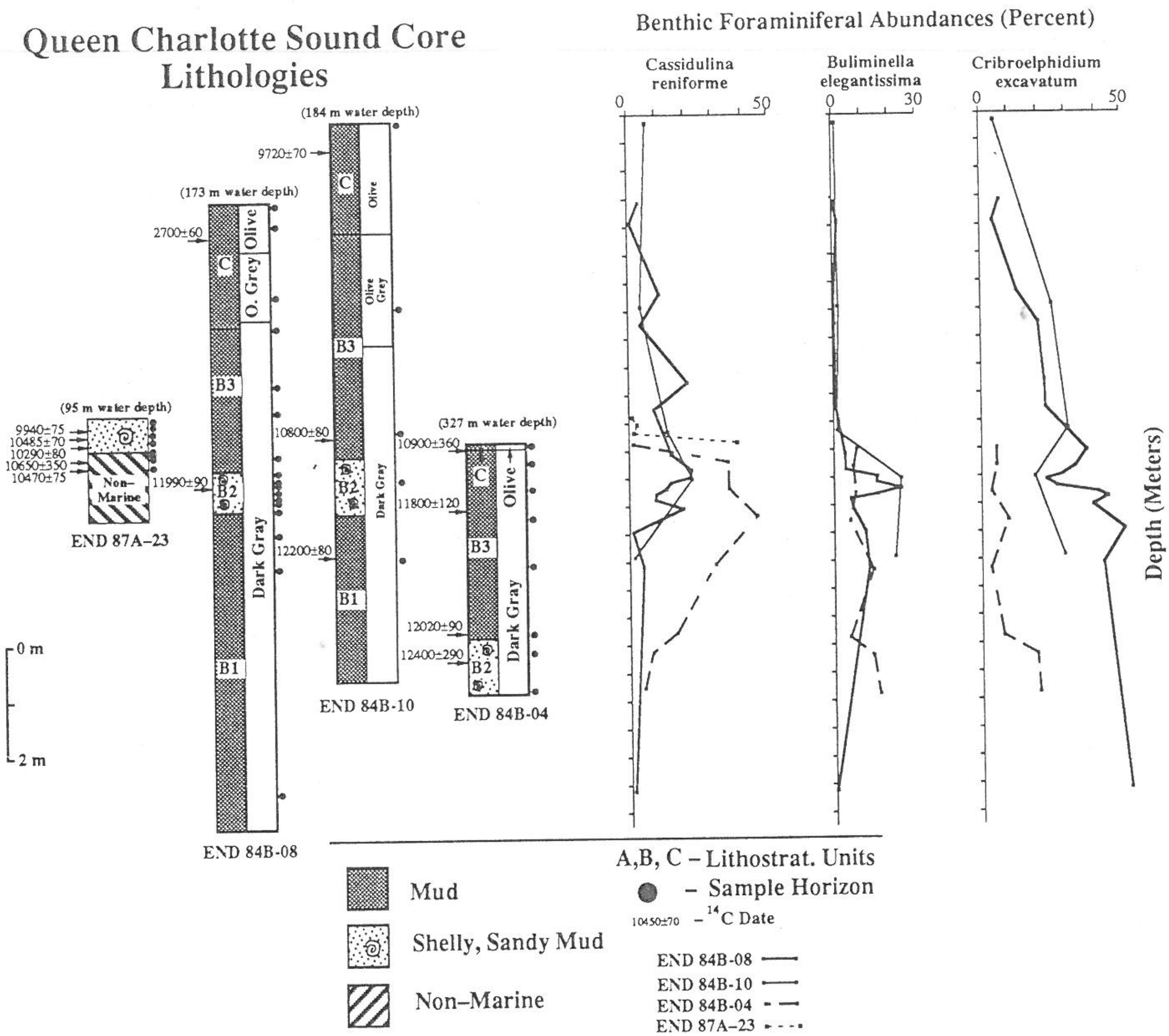

Figure 3. Correlation between cores END 84B-04, END 84B-08, END 84B-10, and END 87A-23 showing lithology, ^{14}C radiocarbon dates given in years B.P., foraminiferal biofacies, and distribution of key indicator species through the cores interval. Correlation of cores is based on best alignment of ^{14}C dates. Faunal distribution patterns show a substantial increase in the proportion of the near-glacial indicator species *Cassidulina reniforme* about 12 000 years B.P. and a tailing off in numbers of the same species about 10 000 years B.P. The proportion of the high organic content indicator species *Buliminella elegantissima* increases dramatically in intervals characterized by diachronous lag deposits indicating a shallow, coast proximal position. *Cribroelphidium excavatum* decreases in relative abundance through the cores in response to habitat reduction following the cessation of glacial conditions.

and 10 000 years B.P.) indicates a major cooling of marine waters off the coast of British Columbia. The presence of high proportions of this species, long associated with very cold water (glacial or near-glacial) regimes (Sejrup and Guilbault, 1980), indicates a brief return to cooler conditions during deglaciation, at roughly the same time as the Younger Dryas event of Europe and eastern North America. Based on a shift in the coiling of the planktonic foraminifera *Neogloboquadrina pachyderma*, in turbidites from the central California continental margin, Brunner and Ledbetter (1989) also identified a cooling event about 11 000 years B.P. Evidence of terrestrial cooling has also been found in the Pacific Northwest. Subalpine pollen spectra have been recorded in the BC-2 Zone -- dated at 11 000 to 9200 years B.P. -- at Bear Cove near Port Hardy on Vancouver Island (Hebda, 1983). Pollen of similar age from the terrestrial part of core END 87A-23 is also subalpine in nature, indicating a cooler climatic interval. This interval correlates very well with the similarly dated Younger Dryas cooling event recorded from marine and terrestrial sediments from Europe (Mörner, 1970, 1976) and eastern North America (Mott et al., 1986; Broecker et al., 1988), indicating that they may be related. However, evidence of previous warmer terrestrial conditions at either the Bear Cove site or from the nonmarine portion of Core END 87A-23 are lacking. Earlier pollen profiles from the Bear Cove site are primarily pioneering in nature and older sediments from Core END 87A-23 have not been examined for their pollen content. However, Heusser (1960) in an analysis of Late Pleistocene pollen profiles from the east side of Vancouver Island and Mathewes (1973) in a similar analysis of sediments from the Fraser Valley both reported an increase in the proportion of *Tsuga mertensiana* between 11 000 and 10 000 years B.P., isochronous with the Younger Dryas cooling event. Heusser (1973) suggested that this species became more abundant because of a climatic cooling, although Hebda (1983) suggests that an increase in moisture levels would have had a similar effect.

The B_1 sediments of the lower part of cores END 84B-08 and END 84B-10 were deposited shortly after deglaciation, as evidenced by the presence of large proportions of *Cribroelphidium excavatum* in this interval (Fig. 3). *Cribroelphidium excavatum* is an important component of modern foraminiferal faunas on the shelves surrounding North America and Europe, particularly at higher latitudes, where it commonly composes more than 30% of the fauna (Cockbain, 1963; Vilks et al., 1979; and Miller et al., 1982). In Pleistocene sediments, this species has long been associated with glacial conditions, particularly in Wisconsin-aged occurrences where it often constitutes 60-80% of the foraminiferal fauna (Feyling-Hanssen, 1976; Knudsen, 1976; Osterman, 1984; Hald and Vorren, 1987; Rodriguez and Richard, 1986). However, Hald and Vorren (1987) pointed out that this species also lives today in lower latitude areas of the North Atlantic, albeit in much lower numbers. These workers suggested that this species is as much a salinity indicator as a temperature indicator, because these areas are subject to shifting salinities. Furthermore, the low abundance of the cold-water indicator *Cassidulina reniforme* at this horizon suggests that depressed salinities rather than very cold water conditions explain the high proportion of *Cribroelphidium excavatum*. The proportion of *Cribroelphidium excavatum* declines gradually toward the surface through both cores. Osterman (1984) suggested that the reduction in the proportion of *Cribroelphidium excavatum* in modern oceans is related to habitat reduction precipitated by the retreat of glaciers and associated reduction in suitable environments for this species. If this hypothesis is correct the distribution of this species in these cores suggests a gradual response to loss of ecospace.

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