LATE QUATERNARY FORAMINIFERAL BIOSTRATIGRAPHY OF THREE SHALLOW GEOTECHNICAL BOREHOLES IN HALIBUT CHANNEL, WESTERN GRAND BANKS OF NEWFOUNDLAND

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ABSTRACT

Sixty-seven samples from three borehoes in Halibut Channel, Western Grand Banks of Newfoundland, have been examined for Quaternary benthonic, Quaternary planktonic and reworked (Cretaceous / Tertiary) foraminifera.

Seven assemblages and four subassemblages have been recognized. These assemblages are: (1a) *I. algida - I. helenae - A. angulosa - Buccella spp.;* (1b) *C. reniforme - C. excavatum;* (2) *C. reniforme - C. excavatum - "Cibicides" spp.;* (3) *C. excavatum - "Cibicides" spp. - "Glabratella" spp.;* (4a) Low numbers - *C. excavatum - C. reniforme - "Glabratella" spp.* - reworked component; (4b) High numbers - *C. excavatum - C. reniforme - "Glabratella" spp.* - agglutinated component; (5) *C. excavatum - C. reniforme - "Glabratella" spp. - I. helenae* - agglutinated component; (6) *C. excavatum - C. albiumbilicatum - "Glabratella" spp.;* and (7) Low number - *C. reniforme - "Fursenkoina" spp. - "Glabratella" spp.*

Down hole in BH 1 the assemblage sequence is: assemblage 1a (0-0.5 m) and assemblage 4a (0.5-6 m).

Down hole in BH 4 the assemblage sequence is: assemblage 1a (0 m), assemblage 2 (0-1 m), assemblage 4a (3-6 m) and assemblage 4b (6-20 m).

Down hole in BH 2 the assemblage sequence is: assemblage 1b (0-1 mbsf), assemblage 2 (2-12 mbsf), assemblage 3 (12-13 mbsf), assemblage 2 (13-15 mbsf), assemblage 4b (16-17 mbsf), assemblage 2 (17-18 mbsf), assemblage 4b (18-19 mbsf), assemblage 6 (20-21 mbsf), assemblage 5 (21-23 mbsf), assemblage 7 (23-24 mbsf), assemblage 5 (24-32 mbsf), assemblage 4a (32-50 mbsf) and assemblage 4b (50-76 mbsf).

Assemblage 1a is a cold shelf assemblage. Assemblages 1b and 2 are cold shallow bank assemblages, 1b with relict *C. reniforme* and *C. excavatum.* They probably represent periods of higher salinity than today. Assemblages 3 is interpreted as an open water, very shallow bank / intertidal assemblage with normal marine salinities. Assemblages 4a and 4b are glacial marine assemblages. Assemblage 4a may have been deposited by grounded ice or by ice lifting of the ocean bottom. Assemblage 4b is a late glacial - immediate post glacial assemblage deposited proximal to or under an ice shelf. Assemblage 5 is an immediate post-glacial assemblage indicating meltwater was present. Assemblage 6 is interpreted as deposited in shallow water under hyposaline / outer estuarine conditions or channelized flow. Assemblage 7 is indicative of hyposaline and possible reduced dissolved oxygen conditions.

Seismostratigraphic, lithostratigraphic and physical property data are in good agreement with the interpretation of depositional environments, based on foraminifera. The glacigenic sequence in Halibut Channel is believed to represent the preserved sedimentary sequence of three glacial advances. Halibut Channel appears to have behaved as a fjord, the preserved sequences of each advance are thin and fragmented because most sediments were removed during each successive advance and bulldozed to the edge of the continental shelf and the slope. The first advance was pre-Middle Wisconsinan (pre 41ka BP), extensive, eroded bedrock and deposited a basal till on the bedrock surface across the entire shelf to the shelf edge. It is believed to have originated as Newfoundland centred ice and advanced to the south. The glacier was believed to be wet-based, with both freezing and melting occurring. Freezing incorporated glacial debris into the ice mass, melting released it.

The second advance is interpreted to have been by cold dry-based ice, loading and remoulding glacial marine sediment into a deformation till. Again, this advance appears to have been extensive, at least 400 m thick, and it may have originated offshore and not as Newfoundland centred ice. It occurred between 40 and 20 ka BP, and may correspond to the Late Wisconsinan advance.

The third advance, a very late Wisconsinan advance, may correlate to the Younger Dryas advance seen elsewhere in the Maritimes. It is believed to have been thin, temperate, wet-based ice, was short lived due to sea level constraints and formed the two till-tongues and subglacial meltwater channels. The transport and depositional mechanism for the lower till-tongue is believed to have been subglacial, over saturated sediment; for the upper till-tongue slumping and debris flow deposition are believed to have played a role.

A major erosional event, as evidenced by a major unconformity occurs at or near the sea bed. This unconformity may have been formed by grounded ice; but a more likely scenario is strong bottom currents carrying meltwater south in early Holocene times, when Halibut Channel behaved as a conduit between the subaerially exposed banks.

INTRODUCTION

Considerable debate exists on the timing, extent, thickness and frequency of Wisconsinan glaciations on the continental margins of southeastern Canada (Grant, 1977a; Dyke et al., 1982; Grant and King, 1984; Prest, 1984; Dredge and Thorleifson, 1987; Dyke and Prest, 1987; Vincent and Prest, 1987; Fader and Piper, in Piper et al., 1990). These glaciations have left behind sequences of glacigenic sediments on the continental shelves (Syvitski, 1991, 1993; King and Fader, 1986; King et al., 1991; King, 1993), most of which are considered to be associated with the advance and retreat of the Late Wisconsinan ice sheets (Andrews et al., 1991). Study of these sediments has, until recent years, been limited due to inadequacy and failure of sampling techniques (King, 1993; Syvitski, 1993). However, the development of modern high-resolution acoustic equipment allowing the collection of subbottom acoustic information, grab samplers capable of sampling 1 tonne of coarse diamict, long coring facilities, and the capability of borehole drilling and sampling have facilitated the study of glacigenic sediments of the continental margin (Syvitski, 1993). In addition, recent observations and studies of modern marine abutting or ending glaciers and the accompanying (currently ongoing) depositional processes and resulting deposits, have provided a vast array of modern day analogues, and qualitative and quantitative depositional models to which Pleistocene glacigenic sequences can be compared and from which they can be interpreted (Syvitski, 1991). The applicability of these analogues and models, which generally reflect the waning stages of ice sheet retreat (Holocene conditions), to the regimes of Pleistocene ice sheets (ice-age conditions), is unknown and also a topic of debate (Powell, 1984; Pfirman and Solheim, 1989; Piper, in Piper et al., 1990; Solheim, 1991; Syvitski, 1991, 1993). Quantitative models can be based on theoretical or empirical considerations, built around a set of equations (Dowdeswell and Scourse, 1990). Qualitative models fall into two categories. The first is based on observations of processes and facies from modern glacial marine environments, but which may include some assumptions about sediment characteristics (Dowdeswell and Scourse, 1990). These types of studies first commenced in Antarctica (e.g., Carey and Ahmad, 1961; Anderson, 1972; Anderson et al., 1980a, 1980b, 1983, 1984, 1991; Drewry and Cooper, 1981; Orheim and Elverhøi, 1981; Domack, 1982, 1988; Blankenship et al., 1986, 1987; Drewry, 1986; Anderson and Molnia, 1986, 1989; Alley et al., 1987, 1989; Rooney et al., 1987; Kellogg and Kellogg, 1988; Dunbar et al., 1989) and spread to: Svalbard (e.g., Elverhøi et al., 1980, 1983, 1989; Elverhøi, 1984; Pfirman, 1985; Solheim and Pfirman, 1985; Solheim, 1985, 1991; Dowdeswell, 1986a, 1986b; Dowdeswell et al., 1986, 1993; Dowdeswell and Dowdeswell, 1989; Dowdeswell and Drewry, 1989; Pfirman and Solheim, 1989; Boulton, 1990; Solheim et al., 1990), Alaska (e.g., Powell, 1981, 1983, 1984, 1990; Molnia, 1983; Eyles et al., 1983; Mackiewicz et al., 1984; Powell and Molnia, 1989), the Canadian Arctic (e.g., Syvitski and Murray, 1981; Gilbert, 1982; Clarke et al., 1984; Syvitski, 1989; Andrews, 1990; Eyles and Lagoe, 1990; Andrews and Syvitski, 1994), Iceland (e.g., Boulton, 1979; Boulton and Hindemarsh, 1987) and most recently to Greenland (e.g., Stein et al., 1993; Dowdeswell et al., 1994). The second group (of quantitative models) involves processes inferred from observed lithofacies assemblages, seismic stratigraphies and morphological features, from both onshore and offshore paleo-sequences

(Dowdeswell and Scourse, 1990). The processes inferred are often based on one or more of the studies listed above, i.e. studies taking the first approach. This second approach has been applied to the offshore record of northern hemisphere glaciation on both sides of the Atlantic: beneath the Barents Sea / Norwegian Shelf (e.g., Vorren et al., 1978, 1983a, 1983b, 1984, 1986, 1988, 1989, 1990a, 1990b; Rokoengen et al., 1979a, 1979b; Vorren and Elvsborg, 1979; Elverhoi and Solheim, 1983; Elverhøi et al., 1983, 1989; Solheim and Kristoffersen, 1984; Holtedahl, 1986, 1988; Vorren and Kristoffersen, 1986; King et al., 1987; Sættem and Hamborg, 1987; Sættem, 1990; Haflidison et al., 1991; Sættem et al., 1991, 1992a, 1992b; Gataullin et al., 1993) and the North Sea / United Kingdom shelves (e.g., Holmes, 1977; Eden et al., 1977; Thomson et al., 1978; Boulton et al., 1981; Stoker and Bent, 1985; Stoker et al., 1985a, 1985b, 1993, 1994; Cameron et al., 1987; Stoker, 1988, 1990; Scourse et al., 1990; Stewart and Stoker, 1990; Stoker and Holmes, 1991) on the northeastern Atlantic margin; and to the eastern Candian Arctic (e.g., Gilbert, 1985; Praeg et al., 1986; MacLean et al., 1989; Vilks et al., 1989) and eastern Canadian continental margin (e.g., Barrie and Piper, 1982; Josenhans et al., 1986; King and Fader, 1986; King et al., 1987, 1991; Vilks et al., 1987; Josenhans and Fader, 1989; Syvitski and Praeg, 1989; Josenhans and Zevenhuizen, 1990; King, 1993) on the northwestern Atlantic margin. Seismostratigraphy, a valuable correlative tool, provides an internal acoustic characterization and local to regional geometry of the various depositional units; while strategically collected cores provide details of the lithologic and physical properties, the biologic environment, and time frame of these units (Vorren et al., 1989). The general weakness in utilizing the second approach is that sampling (i.e. coring) is the limiting factor; it is much easier to collect the geophysical data necessary to construct the seismostratigraphy and image the seafloor morphology; than to collect the subsurface material necessary to adequately sample the lithology and interpret the depositional environments. Consequently, marine studies tend to rely more heavily on remotely sensed seismic data. Most subsurface lithological information has come from seabed grab samples and short piston cores which only sample, at most, the top few metres of these sequences (Stewart and Stoker, 1990; Stoker et al., 1993). Careful examination of seismic profiles sometimes indicates older sediments in shallower stratigraphic positions, that can be cored at strategic locations allowing construction of a (partial) composite section (e.g. King and Fader, 1986; King, 1994, 1996). Compounding this, lithologic changes vary laterally and vertically; in glacial marine environments these changes can be extreme in variation and nature (abrupt to gradational) and scale (local to regional). Even with high-density sample coverage, boreholes or cores cannot be considered more than point sources (Stewart and Stoker, 1990; Stoker et al., 1993); many structural and textural characteristics and facies contacts can not be observed on this limited sampling scale.

Another complicating factor is that landward of the shelf edge, preservation potential is low except for the recessional part of the glacial sequence (Elverhøi, 1984); and this is strongly dependent on sea level fluctuations (Powell, 1984; Boulton, 1990). Records for the Canadian continental margin (Josenhans et al., 1986; King and Fader, 1986; Piper, in Piper et al., 1990) are fragmented compared to the depressed Norwegian Shelf (King et al., 1987) and central and northern North Sea, where active subsidence has allowed accumulation of thicker, more complete glacigenic sequences (Caston, 1977; Holmes, 1977;

Feyling-Hanssen, 1981, 1982; Cameron et al., 1987; Sejrup et al., 1987; Knudsen and Ásbjörnsdóttir, 1991).

The global eustatic maximum lowering of sea-level during the Late Wisconsinan of -120 m (Emery and Garrison, 1967; Milliman and Emery, 1968; Shackleton, 1987) left much of the southeast Canadian continental margin emergent during and post deglaciation; superimposed upon the preserved shelf record are both eustatic changes and isostatic adjustments, i.e. crustal depression due to ice loading, followed by uplift, regression / transgression, depending on location relative to migration of the crustal forebulge (Walcott, 1970; Quinlan and Beaumont, 1981, 1982; Boulton, 1990), and the temporal relationship between eustatic and isostatic adjustments (Boulton, 1990).

In addition to sedimentological and mineralogical studies, analyses of sediment physical properties and microfossils, particularily foraminifera, can enhance and more specifically define the environment of deposition and aid in interpreting the post depositional history. Foraminifera are good indicators of depositional environments (Mudie, in Piper et al., 1990). Empirical correlations can be made between the modern distribution and (percent) occurrence frequency of species, or species associations; and characteristics of the overlying water mass. Selected species / species associations may then be considered diagnostic and indicative of specific environmental conditions / regimes. Recurrence of these species / assemblages in the fossil record are then also associated with similar depositional environments. The foraminiferal content of surficial and near surficial sediments, marginal, proximal and distal to some modern glacial fronts, has recently been documented (e.g., Feyling-Hanssen, 1964; Nagy, 1965; Elverhøi et al., 1980; Elverhøi,1984; Schafer and Cole, 1986, 1988; Hansen and Knudsen, 1992; Hald et al., 1994; Jennings and Helgadóttir, 1994; Korsun et al., 1995) providing limited modern baseline assemblages for comparison to fossil glacigenic assemblages. Numerous cores and boreholes have been drilled through thick glacigenic sequences of the North Sea / United Kingdom continental shelves and Barents Sea / Norwegian Shelf and the foraminiferal content has been examined in many of these (Hughes et al., 1977; Gregory and Harland, 1978; Gregory et al., in Thomson et al., 1978; Vorren et al., 1978, 1983a, 1984, 1989; Feyling-Hanssen, 1981, 1982; Mangerud et al., 1981; Østby and Nagy, 1981, 1982; Knudsen and Lykke-Andersen, 1982; Skinner and Gregory, 1983; Knudsen, 1984, 1985, 1986, 1992; Hald and Vorren, 1984, 1987; Feyling-Hansen and Knudsen, 1986; Long et al., 1986; Sejrup et al., 1987; 1989; Jensen and Knudsen, 1988; Stoker, 1988, 1990; Hald et al., 1989, 1990; Lykke-Andersen, 1990; Haflidison et al., 1991; Poole et al., 1991, 1994; Knudsen and Ásbjörnsdóttir, 1991; Seidenkrantz, 1992, 1993a, 1993b; Knudsen and Sejrup, 1993; also many unpublished internal reports by Neele and van Leuwan, Netherlands Geological Survey, some of which are summarized in Laban, 1995). On the Canadian margin, the foraminiferal content of boreholes drilled through glacigenic sequences on Sable Island Bank and Banquereau, Scotian Shelf, have also been analysed (Miller, 1989a, 1989b, 1993, in press; Amos and Miller, 1990); though these sequences are interpreted to record a sand-dominated, high energy, morainal bank setting (Amos and Knoll, 1987; Boyd et al., 1988; Amos and Miller, 1990; King, 1993). All these studies provide information on Pleistocene glacigenic foraminiferal assemblages.

Study area

The continental shelf south and east of Newfoundland, known as the Grand Banks of Newfoundland, is geologically one of the best studied shelves in Canada. It has been subject to extensive geophysical surveys and seabed sampling due to recent hydrocarbon exploration and proposed development (Amoco and Imperial, 1973; Arthur et al., 1982; Fader and Miller, 1986a). The Grand Banks of Newfoundland consist of a series of shallow banks extending from Rose Blanche Bank in the southwest to Grand Bank in the east, which are separated from one another and the Island of Newfoundland by deep channels and enclosed basins (Fader and Miller, 1986a, 1986b; Fader and Piper, in Piper et al., 1990; Dalrymple et al., 1992).

Halibut Channel, on the western Grand Banks of Newfoundland, is a shelf-crossing linear depression, that connects Placentia Bay to the north with the shelf edge east of St. Pierre Bank. It represents one of the few areas on the Grand Banks of Newfoundland where a thick sequence of glacial sediments are preserved in a complex stratigraphy. Here the low-resolution airgun seismic reflection data (Moran, 1987) shows two features: (1) a series of acoustically incoherent units which can be traced across the shelf to the shelf edge, the upper two sequences have the wedge shaped geometry of "till-tongues"; and (2) infilled buried channel-like complexes.

A series of boreholes were positioned to sample the major seismostratigraphic intervals (water depth 167 m) and to concentrate at the seaward end of a series of these features termed "till-tongues",which acoustically are wedge-shaped bodies of incoherent reflections interpreted as till, that interdigitate with well-stratified glacial marine material. An offset borehole (BH 4) was positioned to penetrate the 2 upper till-tongues. Glacial models have been proposed to describe the glacial processes that develop such a till-tongue stratigraphy (King and Fader, 1986; King et al., 1987; Josenhans and Fader, 1989; King et al. 1991) but boreholes through till-tongues on the eastern Canadian margin (or elsewhere) had never been collected to verify the interpretation (Moran, 1987; Fader and Moran, 1988). King and Fader (1986) had attempted to sample till-tongues on the Scotian Shelf utilizing conventional piston coring techniques; but they were limited to penetrating exposed or near surface material which in many cases had been influenced by postglacial transgression and modern oceanographic processes. This till-tongue model has attracted considerable attention and been critiqued concerning both the interpreted constructional morphology and geometry; and the role of local slumping and development of debris flow deposits associated with the tongues (Syvitski, 1991; Stewart and Stoker, 1990; Stoker et al., 1993). King et al. (1991) modified the original model to include aspects of slumping in the formation of the tongues, but further emphasized their utilitarian nature in delineating ice grounding zone positions; and importance in indicating ice advance and retreat.

The deepest borehole drilled (BH 2) was also positioned through one of the infilled channel-like features. This feature probably originated as a result of subglacial meltwater flow. The occurrence of these channels in a till-tongue section is unusual; due to water depth constraints (King et al. 1991).

In this study, the foraminiferal content of the Halibut Channel sediments were analysed, described and interpreted. This provides insights into depositional environments; combined with lithology, sediment physical properties, regional (low-resolution) and high-resolution seismic reflection data and age (AMS ^{14}C dating) the glacial regimes and ice sheet dynamics, including ice extent can be interpreted from the glacigenic sediment sequence in Halibut Channel.

Stratigraphic co-occurrence of subglacial channel-like features and till-tongues

The occurrence in Halibut Channel of shallow, subsurface, infilled channel-like features clearly cross-cutting till-tongues, is believed to be unique. A general depositional sequence of sheet diamicton, and mud dominated till-tongues and moraines, is believed to have formed in water depths greater than 75 m by grounded ice, possibly with a floating front (King et al., 1991; King, 1993), e.g., Emerald Basin (King and Fader, 1986; King et al., 1991) or the Norwegian Shelf (King et al., 1987; King et al., 1991). Channels are associated with sand dominated, high-energy meltwater discharge deposits of a morainal bank, believed to have formed in less than 75 m of water on a tidewater front (King et al., 1991; King, 1993), e.g. Sable Island Bank (Boyd et al., 1988, Scott et al., 1989). In Halibut Channel the geologic setting is unusual, a large shelf crossing channel confined laterally by two banks (St. Pierre and Green Banks), which may have behaved as a fjord in the Late Pleistocene when the banks were subaerially exposed (and possibly ice covered). Estimates of sea level place the minimum water depth at the borehole site between 57 and 77 m (the low stand on the Grand Banks is believed to have been -90 to -110 m, Fader et al., 1982; King and Fader, 1986; Fader, 1989; Fader and Piper, in Piper et al., 1990; Dalrymple et al., 1992), very close to the 75 m mark. Isostatic adjustments would have resulted in regression, followed by transgression (similar to the most of the Island, particularily the south coast) (Catto, 1992; Liverman, 1994; Liverman and Batterson, 1995) so sea level may have been close to 75 m for an appreciable amount of time.

Observations and descriptions of channel-like features are rather recent (subsequent to Flinn, 1967; Woodland, 1970; Dingle, 1971; and Wright, 1973) and three types of channel-like features have been noted, based on size and geometry. The first are referred to as tunnel or subglacial valleys; they are narrow, deep incisions up to 450 m deep, with steep valley walls and have been noted in the subsurface: of the North Sea (Dingle, 1971; Holmes, 1977; Thomson and Eden, 1977; Stoker et al., 1985a, 1985b; Cameron et al., 1987; Wingfield, 1990; Laban, 1995), of the Barents Sea (Vorren et al., 1990b; Sættem et al., 1992a), on the Scotian Shelf (see King et al., 1974, Fig. 5; King, 1993, Fig. 5; 1994, Fig. 10), on Whale Bank (Grand Banks, Fader and Miller 1986b, Fig. 5) and northwest Grand Bank (King and Fader, 1992). They are also exposed on the east coast of Ireland (Eyles and McCabe, 1989; McCabe et al., 1987, 1990, 1993) and in Germany (Ehlers, 1981; Ehlers and Grube, 1983; Ehlers et al., 1984, and references therein). They are believed to have formed subglacially by catastrophic meltwater discharges (Ehlers, 1981; Grube, 1983; Ehlers et al., 1984; Smith, 1985; Bent, 1986; Long and Stoker, 1986; Boulton and Hindmarsh, 1987; Boyd et al., 1988).

The second type are more variable in geometry; they are broader and have gently sloping sides, though they may be up to 300 m deep (Wingfield, 1990), to 450 m deep (Eyles, 1987; Boyd et al., 1988; Scott et al., 1989; Lagoe et al., 1989, 1994) from 2 - 5 km wide and from 6 - 25 km long (Wingfield, 1990), and may be open-ended channels or enclosed incisions. In the North Sea, where there is good seismostratigraphic control, some of these features are mapped as enclosed incisions (Thomson and Eden, 1977; Wingfield, 1990, Figs. 2a, 2b). On the Scotian Shelf features with similar cross-sections (Boyd et al., 1988, Fig. 4; Scott et al., 1989, Fig. 3) have been mapped as a complex network of channels (Boyd et al., 1988, Fig. 2). At the eastern shelf edge of Grand Bank channels up to 300 m (and one 5-6 km wide) have been mapped (Fader and Miller, 1986a, 1986b; Lewis et al., 1987; Sonnichsen et al., 1994). Eyles (1987), Eyles and Lagoe (1990) and Lagoe et al. (1989,1994) describe megachannels in the Yakataga Formation in Alaska; lithofacies and foraminiferal analysis of the channel-fill sediments in Armentrout's Channel and have led them to conclude that this represents a sea valley. Ehlers et al. (1984) and Wingfield (1990) present reviews on the documented occurrences and theories of formation. The enclosed features are believed to have formed below, what was then present sea level. Wingfield (1990, Fig. 5) believes the most plausible theory on the formation of the channels / minor incisions is by catastrophic meltwater discharge (i.e. by jökulhaup plunge pools) at the subaerial or tidewater margin of an ice sheet. Boulton and Hindmarsh (1987) have quantitatively modeled channel and tunnel valley formation and similarily concluded that the location (subglacially, in relation to the ice sheet margin) of the point of initiation of melting will determine if channels or tunnel valleys form. If melting is initiated at the terminus and progressively extends up glacier, the system can remain stable and piping can develop to produce channels. If discharges are high sediment creeps towards the channel and is removed by water flow as it intrudes into the (ice) tunnel, thus initiating tunnel valleys. A positive feedback effect results; ensuring that once excavation has begun further deepening will be concentrated in the same place. The larger, distal parts of channels produce tunnel valleys. If melting occurs far from the terminus and progressively extends up glacier, high subglacial water pressures will build up which cannot be relieved by flow through the distal frozen-bed zone. If these form at or near the drainage divide, water-floored sediment cavities might develop, which would probably extend in the direction of lowest water pressure gradient, the direction of glacier flow (the encloded incisions of Wingfield, 1990?). The resulting instabilty of the ice in the inner zone may also result in a glacier surge (Boulton and Hindmarsh, 1987).

The third type of feature occurs on a much smaller scale; they are referred to by Wingfield as minor incisions with open-ended geometry, they formed above what was then sea level, and have been mapped as sometimes occuring within the major incisions in the North Sea (Flinn, 1967; Jansen, 1976; Long and Stoker, 1986; Cameron et al., 1987; Wingfield, 1990). King (1993, Fig. 5) also illustrates channels on this scale and interprets them as having formed subaerially on the Scotian Shelf in a morainal bank, glacial fluvial braided delta setting. There are also a few isolated occurrences of subsurface channels of these dimensions and cross-sectional geometry at Hibernia, northeastern Grand Bank (Fader and Miller, 1986a, 1986b).

The channel-like features seen on the seimic profiles in Halibut Channel occur on the same scale as the third type of feature listed above. In Halibut Channel there is not sufficient seismic control for a complete assessment of the geometry. They are up to 40 m wide and 25 m deep. They appear to be infilled subsequent to the erosional event that formed them. Based on sea-level constraints they formed and infilled well below sea level. The foraminiferal studies may aid in interpreting the depositional environment; by comparision with the foraminiferal content of boreholes drilled in the channelized areas of Sable Island Bank and Banquereau (Miller, 1989a, 1989b, 1993, in press; Amos and Miller, 1990), the channels of the North Sea (Hughes et al., 1977; Jensen and Knudsen, 1988; Cameron et al., 1987; Knudsen and Åsbjörnsdóttir, 1991; Knudsen and Sejrup, 1993; and many unpublished reports by Neele and van Leuwan, Netherlands Geological Survey, some of which are summerized in Laban, 1995) and in the tunnel valleys of Germany (Knudsen, 1976, 1993). Foraminiferal studies have also been completed on raised subglacial channel sediments in the Irish Sea Basin (Haynes et al., 1977, 1995; Eyles and McCabe, 1989; McCabe et al., 1990) in raised marine deposits on the Danish coast (Knudsen, 1978) and in the Yakataga Formation, Gulf of Alaska (Eyles and Lagoe, 1990; Lagoe et al.,1989, 1994).

Foraminifera in glaciagenic sediments

Boulton (1986) and Syvitski (1991) applied the word "paradigm" to models or "rules of thumb" applied in glaciology (Boulton, 1986) and glacial marine sedimentary deposits (Syvitski, 1991); and in each case recent observations have resulted in these authors suggesting paradigm revision. For example, one paradigm (Boulton, 1986) was based on glacier movement over rigid smooth passive surfaces, revised by the evidence of deformable beds underlying modern glaciers and deformation structures in subglacial sediments or sediments recently exposed by glacier retreat (Boulton, 1979; Blankenship et al., 1986; Alley et al., 1987, 1989). Similarily Syvitski (1991) suggested re-examination of three other paradigms related to glacigenic processes and reflected in glacigenic deposits.

Another paradigm in need of revision pertains to the faunal content of glacigenic sediments (in this case only foraminifera will be discussed) and that paradigm states that: *Generally tills are barren, or contain only rare fragments of poorly preserved foraminifera, which are probably redeposited and of no direct paleoenvironmental significance*. In this paradigm much hinges on the meaning and application of the word 'till'; till *sensu lato* (of the INQUA commission, Dreimanis, 1989) includes those tills formed by secondary processes and consequently when 'till' is broadly defined the paradigm is invalid. Both Mudie (in Piper et al., 1990) and Syvitski (1991) qualify this paradigm by applying it to only 'basal tills'. However, in some instances an interpretation of till is based on sediment just penetrated at the base of a few conventional piston cores, and then applied as lithologic control to a thick sequence over a large area, even though there may be good seismic coverage (Mudie and Guilbault, 1982; Osterman, 1982; Scott et al., 1984; Praeg et al., 1986). Stewart and Stoker (1990) and Stoker et al. (1993) have cautioned that the glacigenic environment is one known for extreme facies variations and cores obtained from these environments act as little more than point sources. Though these tills and other diamicton / drift deposits interpreted as deposited subglacially appear to be barren of foraminifera (e.g., Thomson and Eden, 1977; Stoker and Bent, 1985; MacLean et al., 1989; Vilks et al., 1989), other tills (particularily those formed by secondary processes) are not (e.g., Macfadyn, 1940, 1942; Haynes et al., 1977; Vorren et al., 1978, 1983a, 1990a; Elverhøi et al., 1980; Elverhøi, 1984; Sejrup et al., 1987; 1989; Eyles and Lagoe, 1990; Haflidison et al., 1991), or contain low numbers / poorly preserved fragments of foraminifera (Vorren et al., 1981; King and Fader, 1986;

Josenhans et al., 1986; Sejrup, 1987; Josenhans and Fader, 1989; Hald et al., 1989, 1991; Scourse et al., 1990).

The origins of the paradigm are uncertain. It has only been recently that sediments ice-marginal to ice-proximal to modern glaciers, or in sediments exposed by recent glacier retreat, have been analysed for foraminferal content, providing modern analogues for comparison to fossil Pleistocene assemblages. Assuming applicability, these studies are relatively few (Feyling-Hanssen, 1964; Nagy, 1965; Elverhøi et al., 1980; Schafer and Cole, 1986, 1988; Hansen and Knudsen, 1992; Hald et al., 1994; Jennings and Helgadóttir, 1994; Korsun et al., 1995). Sampling resolution may not be fine enough, or the sediment layer deposited post subglacial so recent and consequently thin, that it may be impossible to separate foraminifera which may have been indigenous to the subglacial environment (deposited during a glacier advance or surge) from those deposited post retreat. Access to the sea-floor in ice-infested waters or beneath ice shelves is difficult at best (Dowdewell and Scourse, 1990).

Syvitski (1991) refers to Boltunov (1970) and states that Boltunov (1970) described basal till as having no indigenous fauna / flora. Careful examination of the English translation (Boltunov, 1970) of the (Russian) Boltunov (1969) paper reveals no mention of foraminifera; and only brief mention of molluscs on Table 2. Nagy's (1965) foraminiferal analyses of bottom samples collected from Spitsbergen is listed in the references, but is not referred to in the English translation of the text (Boltunov, 1970). Nagy (1965) examined material ice-marginal to ice-proximal to glacier fronts in Spitsbergen and found only one sample barren of foraminifera. No subglacial material was collected or examined.

Interpretation of foraminiferal (and indeed all faunal) assemblages obtained from glacigenic sediments is hampered by problems of recognition of reworked elements (e.g., Dreimanis, 1970; Austin and McCarroll, 1992). Given the polygenetic aspect of glacigenic sediments and tills in particular; faunal components can be: indigenous (and introduced; both with the potential to live in the environment); reworked (penecontemporaneous, extant, transported); reworked (penecontemporaneous, extant, *in situ*), pre-Quaternary (extinct / chronstratigraphically distinct).

Mudie (in Piper et al., 1990) commented that the fauna contained within basal tills is "probably reworked and of no real paleoenvironmental significance." Though the reworked foraminifera may indicate no information about the final depositional event, they nonetheless may impart insights into the original environment of deposition. The pre-Quaternary reworked component of glacigenic foraminiferal faunas was one of the first allochthonous components recognized and noted in Quaternary glacigenic sequences by European foraminiferalologists (e.g., Mangerud, 1970; Feyling-Hanssen, 1971, 1981, 1982; Andersen 1971; Jørgensen, 1971; Knudsen, 1971a; Mangerud et al., 1981; Hald and Vorren, 1984; Sejrup et al., 1989; Hald et al., 1990; Haflidison et al., 1991; Hald and Steinsund, 1992; Seidenkrantz,1993a, 1993b; Poole et al., 1994). These workers found (extinct) pre-Quaternary species reworked into Quaternary deposits containing Quaternary foraminfera. In North America, Thomson (1983), and on the North American margin, Miller and Scott (1984) and Scott and Medioli (1988) were noting similar occurrences. Miller (1989a, 1989b, 1993, in press) and Amos and Miller (1990) identifed the reworked (pre-Quaternary) species and treated the reworked fauna as a separate entity; they noted a sharp, pronounced first appearance of reworked foraminifera at consistent depths bsf (below sea floor) across Sable Island Bank and Banquereau (Scotian Shelf) and were able to utilize abundant horizons of reworked fauna as a correlation tool. In addition, Miller (1993, in press) noted Quaternary / Tertiary extant species deep in the section, underlying the Cretaceous reworked fauna. This revealed that during the Late Pleistocene there was still exposed Tertiary bedrock, which was then eroded and redeposited during a late glacial advance. This erosion exposed the underlying Cretaceous bedrock, which was subsequently eroded and redeposited above the (redeposited) Tertiary material.

Vorren et al. (1981, 1983a, 1984) made mention of Quaternary foraminferal assemblages found in diamictons with species belonging to three distinct "environmental" (i.e. climatic: arctic, boreal and boreo-arctic) groups. Hald and Vorren (1987) addressed the problem of distinguishing Quaternary allochthonous and autochthonous faunal components in more detail by considering the ecology of the various species within assemblages, correlating mixed faunas to ice-rafting frequency, noting preservation and the physical state of the tests, and also documenting the distribution of pre-Quaternary (chronostratigraphically distinct) tests. Miller (1989a, 1989b, 1993, in press) also recognized Quaternary / Tertiary (Q / T) reworked, extant species which were clearly from different environments (generally shallower, deeper, reduced salinity, or warmer water) and has referred to them as 'environmental erratics' (Miller, in press). These are usually the result of post-mortem, pre-deposition transport. Post-mortem transport and its effects on depositional assemblages has been studied in a variety of modern depositional environments (e.g., Murray, 1970; Culver and Banner, 1979; Sturrock and Murray, 1981; Murray et al., 1982; Thomas and Schafer, 1982; Wang and Murray, 1983; Snyder et al., 1990). Applying modern analogues, other workers have separated out those species not consistent (environmentally) with the overall environmental interpretation in glacigenic assemblages (Haynes et al., 1977, 1995; Huddart, 1981a, 1981b; Sejrup et al., 1987, 1989; McCabe et al., 1990, 1993; Austin, 1991, 1994; Haflidison et al., 1991; Poole et al., 1991, 1994; Austin and McCarroll, 1992; Hald and Steinsund, 1992; Peacock et al., 1992) and utilized them in interpreting the depositional environment. There is a potential for environmental erratics, those Q / T species clearly from different environments, to be traced back to their bedrock source(s). This in turn may provide information about sediment sources, volume of sediment eroded, ice flow directions and ice transport distances.

The most difficult component to separate from the indigenous fauna can be those forms that may be *in situ* resedimented; but recognizing *in situ* resedimented material may be crucial in correctly interpreting diamictons / tills that have been subjected to secondary processes, i.e. ice loading of glacial marine sediment or glacial marine sediment that has been subject to iceburg turbation. Sediments may have lithologic / acoustic characteristic consistent with a subglacial origin; the foraminiferal content may indicate that it wasn't subject to subglacial processes; or give some other indication as to the origin.

Austin (1991) and Austin and McCarroll (1992) report an example from raised glacigenic deposits surrounding the Irish Sea Basin, where foraminferal faunas contain a mixture of shallow temperate, boreo-arctic, cosmopolitan, deep water, Pliocene and early Pleistocene forms. The debate hinged on whether or not all forms are reworked; or if the boreo-arctic forms are *in situ* and the remainder derived. Two depositional models were proposed for these sediments, one a sequence of proximal to distal glacial marine sedimentation; the other a sequence of basal meltout till and sediment gravity flows. Careful sampling and division of the species into ecologically distinct groups revealed that the faunas are uniform stratigraphically and no proximal to distal transition, as reflected by the fauna, was observed. The uniformity of the faunas throughout the sequence led Austin (1991) and Austin and McCarroll (1992) to conclude that the terrestrial model of sedimentation was more likely than a glacial marine scenario. Similarily, Hald et al. (1990, 1991) found a total lack of stratigraphic variation in a *Cribroelphidium excavatum - Cassidulina reniforme* fauna in western Barents Sea boreholes; and concluded that both in situ and transported (including environmental erratics) Quaternary species had been reworked into the sequence; particularly into the fauna in the basal till. This view was supported by amino acid analysis (a D-alloisoleucine / L-isoleucene eperimization ratio, alle/Ile) of *C. excavatum* (Hald et al., 1989). Reworked foraminifera resedimented into a younger Quaternary sequence barren of indigenous fauna may place age constraints on sediments otherwise lacking chronological control. A good example of this occurs on northeastern Grand Bank at a petroleum production area known as Hibernia, in sediments overlying petroleum bearing strata within the Jeanne d'Arc Basin. Seismostratigraphic studies have revealed a large near surface wedge-shaped deposit of sands interpreted acoustically to represent deltaic deposits (Lewis et al., 1987; Parrott et al., 1989; Stofflyn-Egli et al., 1992; Sonnichsen et al., 1994; Sonnichsen and Cumming, 1996) and believed to be Tertiary in age (Lewis et al., 1987; Parrott et al., 1989), based in part on the presence of Miocene to Holocene palynomorphs (Bujak Davies Group, 1987a, 1987b, 1987c, 1987d). Boreholes 88-400-6 and 88-401-G1/G1A sampled through this sequence (Moran and Mosher, 1990; Moran et al., 1990; Mosher and Sonnichsen, 1993) were largely barren of foraminifera, but a section 63-69 mbsf (BH 6) contained a preserved pocket of extant foraminifera, interpreted as reworked (Miller et al., 1990, 1992). Amino-acid analysis of *Cibicides sp.* cf. *C. reflugens* de Montfort produced an alle/Ile ratio consistent with a Middle Pleistocene age (Miller et al., 1992). This places a maximum age constraint of Middle Pleistocene (probably younger) on the final depositional event, previously believed to be Pliocene or older; and has resulted in a revision of the interpreted age for this feature (Stofflyn-Egli et al., 1992; Sonnichsen et al., 1994; Parrott et al., 1995; Sonnichsen and Cumming, 1996).

Stoker (1990) and Stewart and Stoker (1992) have commented on the difficulty in establishing what is the indigenous component of the fauna; but as pointed out by Austin (1994), with careful sampling and selection of taxa the problems associated with disturbed foraminferal stratigraphies can be minimized; and all foraminiferal information need not be discounted based on the assumption that the "fauna (that) is partly or wholly reworked" (i.e. King, 1994).

PREVIOUS STUDIES

Wisconsinan glacial history of western and southern Newfoundland

A view of Laurentide Ice sweeping across the entire land and marine region of eastern Canada in Late Wisconsin time, to near the edge of the continental shelf became popular in the 1920's (Prest, 1984) and continued until the 1980's (i.e. Denton and Hughes, 1981). Those working on reconstructions of global ice sheet limits and volumes during the last glacial maximum, ca. 18 ka (i.e. CLIMAP Project Members, 1976; Denton and Hughes, 1981; Hughes et al., 1981), envisioned a massive ice sheet, with ice streaming southeastwards over the Maritime Provinces and through the Gulf of St. Lawrence; with a contiguous southeastern salient over Newfoundland. They placed the limits of this grounded ice 50-100 km beyond the present coastline, and stated that the edge of the continental shelf was the only effective constraint limiting expansion. Ice streams coursened seaward through deep channels, such as the Laurentian Channel (Denton and Hughes, 1981; Hughes et al., 1981).

It wasn't until the early 1970's (based on the work of Prest and Grant, 1969; followed by Brookes, 1970a, 1970b; Prest, 1970, 1973; Grant, 1977a) that the concept of Newfoundland and adjacent offshore areas affected by one or more Newfoundland centred ice caps became widely accepted (Grant and King, 1984); however, there was always a school (of land-based mappers) who supported this view of limited Newfoundland centred ice, including: Bell (1884), Chalmers (1895); Bailey (1898), Fairchild (1918), MacClintock and Twenhofel (1940), Widmer (1950) and Jenness (1960). Grant (1969a, 1970, 1977b, 1987, 1992) provided detailed evidence that the Laurentide Ice Sheet covered (only) the tip of the Northern Peninsula of Newfoundland up to an elevation of 300 m, above which the island based ice cap was dominant (Liverman and Batterson, 1995). Mapping and reconstructions have produced a wide variety of Late Wisconsinan proposed terminal ice positions south of Newfoundland.

The western margin of Newfoundland has been extensively mapped by Grant (1969a, 1969b, 1977a, 1977b, 1987, 1989) and Brookes (1969, 1970a, 1970b, 1974, 1977a, 1977b); these studies plus regional syntheses by Grant and King (1984) and Dyke and Prest (1987) showed during the last and most limited of three successive glaciations ice-margins were restricted to near-coastal positions, a view contradictory to that of the ice sheet reconstructionists. These three glaciations were determined based on three altitudinally separate zones of differential rock weathering along the west coast. Grant (1989) estimated the oldest to be as old as oxygen isotope stage 12 (ca. 430 ka BP) and the second to be stage 6 (ca. 140 ka). The youngest is believed to be Late Wisconsinan. Minimalists (the land-based mappers) view these weathering zones as nunataks; those taking a maximum view (the reconstructionists) have postulated cold-based non-erosive ice glaciating these weathering zones (Liverman and Batterson, 1995). Both theories have broad reaching implications for the offshore areas.

Henderson (1972), Grant (1975), Tucker and McCann (1980), Leckie and McCann (1983) and Brookes (1989) mapped the southeast coast where they documented evidence of four glacial episodes and their limits.

The process of Late Wisconsinan deglaciation was interrupted by a re-advance, recognized in several places around the Island (Liverman and Batterson, 1995). Grant (1992, 1994) dated the re-advance in the north at ca. 11

ka BP. Brookes (1969, 1974) examined coastal cliff sections in the southwest, adjacent to Cabot Strait, and postulated an ice advance perpendicular to the coast 14 ka BP, followed by a marine overlap and a later ice re-advance at 12.6 ka BP. The stratigraphic interpretation of this date has recently been called into question (Liverman and Batterson, 1995). The marine limit of +44 m at 13.6 ka (Brookes et al., 1985) is probably contemporary with deglaciation at this site (Boulton, 1990).

In the southeast, the Avalon Peninsula was not overridden by glacial ice from central Newfoundland, it supported its own ice cap (Catto et al., 1995). The outer limit of the last re-advance along the south coast was placed by Grant (1977a) along a prominent end moraine that skirts the coast and crosses the top of Burin Penninsula. The development of numerous small separate ice caps during deglaciation has been recognized and documented (Catto et al., 1995). Deglaciation of the Avalon Peninsula commenced shortly after 10.1 ka BP (Rogerson, 1983) and deglaciation of eastern coastal sites on the peninsula lagged even further behind (Macpherson, 1982). In one of the four glacial episodes documented for the south coast, ice appears to have moved onshore from an ice dome on the continental shelf (Grant, 1975; Tucker and McCann, 1980). A similar off-shore ice centre was earlier proposed for areas east of Cape Breton Island (Grant, 1971). Slatt (1974, 1977) studied the surficial sediments on southwestern Grand Bank, and concluded that at some point in Wisconsinan time, an ice-cap lapped the western edge. Stehmen (1976) observed submerged tills in northern Placentia Bay (above a Pleistocene low sea level terrace) and suggested that these tills had been protected during transgression beneath grounded ice or an ice shelf. Fader and Miller (1986a, 1986b) and Fader (1989) have suggested the Tail of the Bank sandy mud deposit (presently occurring in water depths as shallow as 55 m) owed its existence to an offshore centred ice dome, which isostatically protected it from subaerial erosion during the lowstand, and subsequent transgression; and recently Miller and Fader (1995a, 1995b) have found glacial marine foraminifera in cores collected from this deposit, supporting the local independent ice cap theory.

Fader et al. (1982) have concentrated on marine mapping and interpreting submerged features south of Newfoundland, and determined that the shelf south of Newfoundland was extensively glaciated during what they believed was Late Wisconsin time, though the timing is uncertain. Fader et al. (1982) suggest that the adjacent Laurentian Channel was covered with buoyant Late Wisconsinan ice that was in contact with the seabed over bedrock topographic highs where it deposited large moraines (e.g. the Laurentian Moraine).

Bonifay and Piper (1988) recognized a late ice surge in Halibut Channel to the continental slope off St. Pierre Bank. The age of this ice tongue, 11.5 - 12 ka BP corresponds to the late re-advance recognized by Brookes (1969, 1977a), Grant (1992, 1994) and to the Younger Dryas re-advance of the Maritimes (Mott et al., 1986; Amos and Miller, 1990; Miller, 1993, in press; Levesque et al., 1993; Mayle et al., 1993a, 1993b; Anderson and Macpherson, 1994; King, 1994, 1996; Mott, 1994; NASP members, 1994; Mayle and Cwynar, 1995a, 1995b).

Micropaleontology

Surface and near surface sediments

Very little has been done on the modern distribution of foraminifera in the surficial sediments of the Grand Banks of Newfoundland. Sen Gupta and McMullen (1969) described the sedimentary facies and constituent (total) foraminiferal assemblages on the Tail of the Bank. Sen Gupta (1971) completed a more detailed study of the living foraminifera found on the Tail of the Bank in samples collected in the summer of 1967. Tests of 88 species were collected, but staining techniques, employing rose Bengal, indicated that only 43 species were living at that time (Sen Gupta, 1971). The species diversity has a patchy distribution but the highest values are found in the western part of the Tail. The most widespread species is *Islandiella islandica* (Nørvang) [=*I. algida* + *Cassidulina reniforme*] found to be present (by Sen Gupta) in the living population at 80% of the stations. Sen Gupta (1971, Table 2) shows that at any given station *I. islandica, Elphidium clavatum* (=*Cribroelphidium excavatum*),*Cibicides lobatalus* [=*Lobatula lobatala* plus *Cibicides reflugens*],*Elphidium subarcticum* [=*Cribroelphidium subarcticum* and*C. albiumbilicatum*],*Virgulina loeblichi* (=*Stainforthia concava*, *Fursenkoina fusiformis, F. pauciloculata, F. rotundata*), or *Nonionellina labradorica* is dominant at some stations in the eastern part of the Tail of the Bank, while *Virgulina loeblichi, Nonionellina labradorica* and *Elphidium clavatum* are dominant at stations on the western part of the Tail.

Sen Gupta (1971) found the species *Cribrostomoides crassimargo* (=*Veleroninoides crassimargo*), *Elphidium bartletti* (=*Cribroelphidium bartletti*), *Globobulimina auriculata*, *Quinqueloculina stalkeri* (=*Axiopolina parva*), *Recurvoides turbinatus* (=*R. contortus*) and *Reophax curtus* (= *R. fusiformis*) living at only 25 stations found clustered around the southwestern part of the Banks.

Sen Gupta (1971) explains the high numbers and the presence of species generally restricted to more southern waters by the presence of the mixed water mass: Slope water produced by a mixing of central Atlantic and Labrador waters. The eastern part of the Tail is covered mainly by Labrador Current water.

Burns (1987) completed a surficial study of Whale Deep; including examination of Huntec DTS data and analysis of foraminiferal samples from an IKU boxcore, one vibro-core and two piston cores. Burns (1987) found four benthonic foraminiferal assemblages: a *C. reniforme* assemblage, a *C. reniforme - C. lobatalus* (=*L. lobatula*) assemblage, a *C. reniforme - E. excavatum* (= *C. excavatum*) assemblage and a *C. reniforme - Glabratella wrightii* assemblage. All of these faunas are cold water glacial marine assemblages. The absence of a modern fauna indicates that relicit sediments are at the surface and very little sedimentation is occuring there today.

Miller and Fader (1995a, 1995b) have looked at the foraminiferal content of four piston cores collected from the Tail of the Bank (Grand Bank) sandy mud deposit (Fader and Miller, 1986a, 1986b). Miller and Fader (1995a, 1995b) recognized five benthonic foraminiferal assemblages: a *C. reniforme - I. algida - I. helenae* assemblage; a *Fursenkoina spp. - C. reniforme* assemblage; a *C. reniforme - C. excavatum - C. albiumbilicatum - Cibicides spp.* assemblage; a *C. reniforme* assemblage; and a *C. reniforme - C. excavatum - Cibicides reflugens* assemblage. The sequence of assemblages is believed to indicate distal glacial marine conditions before and after the formation of a Late Wisconsinan offshore ice cap. The uppermost assemblage contains both modern bank / shelf species and reworked glacial marine species, indicating post transgressive reworking and some, though not substantial, post transgressive sedimentation.

Bonifay and Piper (1988) examined seven piston cores for benthonic foraminifera from the upper continental slope on St Pierre Bank. Bonifay and Piper (1988) recognized five acoustic units on the St. Pierre slope and found a strong correlation between acoustic units and faunal assemblages. Bonifay and Piper (1988) recognized two major assemblages and two subassemblages. Assemblage 1 is a *Bulimina aculeata* - *Cassidulina laevigata* (? *C. laevigata* / ? *C. carinata* / ? *Paracassidulina neocarinata*) - *Buccella frigida* assemblage interpreted as a modern basin assemblage; and assemblage 2, a *C. reniforme* - *E. excavatum* (=*C. excavatum*) - *C. lobatalus* (= *L. lobatula*) - *Glabratella sp.* (?*Glabratellina spp.* + ? *Rotaliella chasteri*) fauna, interpreted as representing ice margin conditions. If this interpretation is correct, it implies that the ice margin extended across St. Pierre Bank / Halibut Channel to the upper continental slope on southeast St. Pierre Bank in the Late Wisconsinan.

Subsurface (borehole) studies

Most borehole samples analysed have been from northeastern Grand Bank, at the petroleum producing areas known as Hibernia and Terra Nova; in the upper 100 m sediments in the Jeanne d'Arc Basin. The remainder of the boreholes were taken along an east-west transect across a proposed pipeline route across Grand Bank.

Periera (1984) and Thomas (1987, written communication) examined 51 and 44 samples (respectively) from Grand Bank boreholes. Generally faunas are sparce to absent and those samples containing fauna show evidence of extensive reworking.

Pereira (1984) analysed samples from the 13 Mobil Oil pipeline boreholes, two long borings at the Hibernia P-15 well-site (5 samples from C-1/C-1A, 6 from W-1/W-1A) and one sample from Iceberg Scour No. 95 boring. Pereira (1984) recognized 10 foraminiferal assemblages in the 13 pipeline boreholes, where foraminifera are common. Pereira (1984) correlated the assemblages from hole to hole and interpreted the age of the assemblages. Periera interpreted four assemblages as late glacial, two as Middle Wisconsinan, one as early Pleistocene and one as Middle to Late Tertiary in age.

Thomas (1987, written communication) examined 23 samples from the P-15 boreholes (10 samples from C-1/C-1A, 5 samples from E-1/E-1A, 8 samples from W-1/W-1A), 11 from the pipe-line (Pl-1 to Pl-13) boreholes, 2 samples from Ben Nevis I-45 and 8 samples from Terra Nova K-18.

Thomas (1987, written communication) washed and cursorily examined the samples. He observed foraminifera in only 8 pipeline borehole samples. Thomas observed *E. excavatum* (=*C. excavatum*), *Elphidium spp.* (= *Cribroelphidium spp*), *B. frigida* (=*Buccella spp.*), *Islandiella spp.*, *Cibicides sp.* and *Epistominella sp.* (= *Pseudoparrella spp.*) in 7 of the 8 samples; which he interpreted as post-glacial / late glacial faunas, Pleistocene in age. In the eighth sample (Pl 2-13, 20.04 - 20.08 m) Thomas found a small number of Quaternary species and large numbers of mid-Cretaceous (Aptian-Cenomanian) foraminifera. Thomas interpreted the sample as Pleistocene in age, and the Cretaceous foraminifera he interpreted as reworked into younger sediments.

Palynology studies have also been completed on samples from the three P-15 boreholes (C-1/C-1A, E-1/E-1A, W-1/W-1A), 11 pipeline boreholes, Terra Nova K-18 and Ben Nevis I-45, (Bujak, 1981, 1986, 1987a, 1987b, 1987c, 1987d). The interpreted age of the sediments based on palynology conflicts with the age interpretation based on foraminifera. The thickness of the sections interpreted as Holocene-Pleistocene and Plio-Pleistocene vary considerably over short lateral distances. Sections interpreted as Miocene (Bujak, 1981, 1986, 1987a, 1987b, 1987c, 1987d) based on palymology contain foraminifera interpreted as Quaternary in age (Pereira, 1984; Thomas, 1987, written communication).

Bujak (1988) completed palynology studies on samples from Hibernia borehole 87400-3 (8 m in depth). Bujak (1988) analyzed five samples to which he assigned a Pleistocene—Holocene age.

On the Scotian Shelf to the south, Miller and Scott (1984), Miller (1989a, 1989b, 1993, in press) and Amos and Miller (1990) have extensively analysed foraminifera from 13 boreholes on Sable Island Bank and Banquereau. Utilizing the data of Miller (1989a, 1989b), Amos and Miller (1990) defined 9 assemblages (and 5 subassemblages) which showed strong correlation trends to lithologic changes and seismic events. Each assemblage is diagnostic of a distinct environment of deposition and is correlated with the stratigraphic members in Amos and Miller (1990).

Miller (1993) continued the western Sable Island Bank study by analysing 123 samples from an additional three boreholes drilled in 1990 (Christian and Zevenhuizen, 1990) and Miller (in press) completed the Scotian Shelf bank study by examining a further 65 samples from the 5 Banquereau boreholes, incorporating the data (30 samples) from the 1984 (Miller and Scott, 1984) study; plus 30 samples from North Eagle and 19 samples from South Sable, both southeast of Sable Island (144 samples in all). Miller recognized 16 assemblages; though correlation trends were not as strong north and south of Sable Island, or on Banquereau, where reworking is more extensive.

HALIBUT CHANNEL

Borehole locations

Four boreholes were drilled in Halibut Channel. Of these, three successfully recovered samples (Moran, 1987). Borehole (BH) 1 was located at 45° 20' 58.13" N, 55° 17' 11.78" W; in 157 m of water and drilled to a subbottom depth of 11 m, sampled to a depth of 8 metres below seafloor (mbsf). BH 2 was located at 45° 19' 21.56" N, 55° 17' 48.45" W; in 165 m of water, drilled and sampled to a depth of 75.6 mbsf. BH 4 was located at 45° 20'18.20" N, 55° 17' 19.53" W; in 167 m of water, drilled and sampled to a depth of 20 mbsf.

Seismostratigraphy

The upper 35 m of the section are interpreted from high-resolution Huntec DTS Boomer data where resolution is ca. 0.3 m (Fig. 1, front cover). Here the section mainly consists of medium to high amplitude continuous coherent reflections that are locally interdigitated with two till-tongue sequences. The two till-tongues sequences are cut by a series of channel-like features.

At the location of BH 2, the upper 35 metres of section is interpreted and subdivided into six seismostratigraphic units. The upper 0 to 11 mbsf (Unit I) shows an interval of incoherent reflection events within the channel-like feature (hereafter referred to as a channel). A narrow interval of ca. 1 m thickness (11-12 mbsf) forms the second unit (Unit II) and is represented by a series of stacked high amplitude reflection events that form the boundary zone of the channel. Unit III (12 to 14 mbsf) lies at the channel base. Unit IV (14-32 mbsf) is characterized as acoustically stratified, and exhibits three high amplitude reflection groupings interbedded with medium amplitude reflections. The lower part of the section is less coherent, and it is bounded at its base by an undulating, high amplitude reflection.

Below ca. 30 mbsf, the seismostratigraphy is interpreted using lower resolution 40 in^3 airgun data (Moran, 1987), and is subdivided into 3 seismostratigraphic units. All three units are characterized by incoherent reflections. Unit V is 16 m thick (32-48 mbsf) with an undulatory upper surface and relief of approximately 2 m. Unit VI is 27 m thick (48-75 mbsf) and its upper surface is highly undulatory with relief of 6-8 m. Unit VII is a unit of incoherent reflections 34 m thick (75-109 mbsf); the upper surface of this unit is flat with a well-defined high amplitude coherent reflection which decreases in intensity to the north, and then disappears. At the base of the section, a bedrock unit is defined by a broad regional unconformity on seaward dipping, coherent, high-intensity reflections.

In addition to the seismostratigraphic units identified at the BH 2 site, two shallow till-tongue features were targeted for borehole drilling. These do not occur at the position of BH 2 (where they were likely eroded by the channel cutting event) and were sampled in an offset borehole, BH 4. The shallowest till-tongue is identified seismostratigaphically as Unit IIIa, and the deeper as Unit IVa.

Lithology and Physical Properties

BH 1 is stratigraphically above BH 4, which in turn is stratigraphically above BH 2; they will be discussed in their stratigraphic order. Letters in brackets refer to the units, indicated on the lithologic logs (Figs. 2, 3, 4).

The lithology of BH 1 is as follows: from 0-4 m, laminated, dark olive grey fine sand of unit A with occasional coarse sand and shell debris interlamination. Drop stones occurred throughout. At 4 m, there is a gravel layer. From 4-11 m, the lithology is well sorted shelly sand of unit B. At 11 m, a gravel-shell hash was encountered, loosely packed, with an abundance of lithic fragments, unit C.

BH 4 sampled four lithologies (Fig. 3). From 0 to 3 mbsf, the litholgy is fine to medium, loose sand of unit A. From 3 to 8 mbsf, the sediment is characterized as a massive, stiff, red silty clay, unit D. At 8-11 m the clay becomes silty and slightly bioturbated. From 11-18 m gravel clasts are present in the massive clay. At 18-20 m, gravel is absent. Undrained shear strengths are uniformly low down hole, from 20 - 50 kPa, suggesting normal consolidation throughout (Moran, 1987).

BH 2 intersected and sampled most of the units identified seismostratigraphically. This borehole sampled five lithologic units (Fig. 4). At the surface, unit A (0 to 3 mbsf), a layer of loose, well sorted dark olive grey fine sand, was recovered. From 3 to 14 mbsf the borehole sampled the infilled channel complex which included an upper unsorted silty-sand deposit from 3-11 mbsf (unit B) and a similar lower deposit from 12-14 mbsf (unit B), separated by a shell hash layer at 11 mbsf (unit C). Undrained shear strengths in these units are very low, from 10-40 kPa (Moran, 1987). There is a peak in the percent water content in the upper part of unit B (Moran, 1987). The lower part of unit E (14-32 mbsf) was sampled below the channel (the upper part eroded by the channel cutting event). These sediments are a highly bioturbated clayey silt, with occasional muds clasts and dropstones. Undrained shear strengths range from 10-90 kPa, indicating normal consolidation (Moran, 1987). From 32 to 38 mbsf (unit G), the sediment is characterized as a massive brick-red silty clay, with increasing sand laminae. The physical properties (shear strength, 20-90 kPa, and bulk density 1.85-2 mg/m^3) suggest normal consolidation (Moran, 1987). The acoustic velocity is low, consistent with the other physical properties. Changes in the acoustic velocity at the upper and lower bounds of this unit result in the seismic reflections that define this interval. Unit H (38 to 48 mbsf) is a grey silty clay, lacking any sedimentary structures, that has similar physical properties to the overlying unit, except for slightly higher acoustic velocity. Again, this unit is normally-consolidated. The borehole bottoms out in unit I (48-75 mbsf), a dark grey clay with frequent dropstones, interdigitated with well sorted very fine sand at the top, laminated in sections. The amount of gravel / dropstones increases with depth. This is an overconsolidated deposit, with high shear strength (100-200 kPa) and high acoustic velocity (1650-2100 m/s). Samples taken from unit I and tested in one-dimenstional consolidation result in overconsolidation ratios of 2, confirming the interpretation of overconsolidation (Moran, 1987).

Lithostratigraphy

A lithostratigraphy has been developed for the borehole sequences, by combining the seismostratigraphy with the lithology and physical properties. This lithostratigraphy is based on the Quaternary stratigraphic framework developed by King (1970, 1980; King and Fader, 1986) for the Scotian Shelf, modified and applied to the Central Grand Banks (Fader et al., 1982; Fader and Miller, 1986b).

The lithologies and measurements of the borehole samples recovered in the upper 32 m of the section are consistent with the seismic interpretation from the Huntec profile (Fig. 1) where seismostratigraphic unit I is equivalent to lithologic units A and B; unit II is equivalent to unit C; unit III represents the lower interval of unit B; and unit IV is equivalent to unit E. Seismostratigraphic unit IIIa is equivalent to unit D, and unit IVa is equivalent to unit F. Below 32 m, the lithology and seismic interpretation based on the airgun records are used to delineate the units. Seismostratigraphic unit V corresponds to lithic units G and H, unit VI to unit I and unit VII to unit J.

The uppermost unit in BH 1 (0-4 m) is a layer of Adolphus Sand (A / I). This is a fine grained muddy sand that was deposited in the interbank channels, peripheral areas of the banks, and on the upper continental slope. It occurs below the depth of the low sea level stand and was not subject to transgressive processes. From 4-11 m is the upper channel fill (B / I) of one of the near surface / sub-surface channel complexes. At the base of the borehole is the shell hash (C / II, not shown on the log).

At the surface of BH 4 (0-3 m) is a layer of channel fill (B / I). From 3-8 m is the uppermost till-tongue (D / IIIa) of Grand Banks Drift. The Grand Banks Drift is very dark greyish brown, cohesive, poorly sorted sediment containing angular gravel to boulders (a diamict), which may at times exhibit stratification. It is interpreted as an ice-contact deposit (a primary basal till) and may also include stratified drift (subglacial to ice-marginal waterlain till) (King, 1970, 1980; Fader and Miller, 1986b), secondary till and gravity flowtill (King et al., 1991; King, 1993). From 8-11 m is a unit of Downing Silt (E / IV), separating the two till tongues. The Downing Silt is dark greyish brown, poorly sorted clayey and sandy silt, with some angular gravel (King, 1970, 1980). It is interpreted as a glacial marine deposit (King, 1970, 1980; Fader and Miller, 1986b). From 11-18 m is the lower till tongue (F / IVa) of Grand Banks Drift. At the base of the borehole (18-20 m) is Downing Silt (E / IV).

BH 2 penetrates the following sequence. From 0-3 m is a capping layer of Adolpus Sand (A / I). From 3-14 m the borehole penetrated one of the channel complexes; upper channel fill from 3-11 m (B / I) and lower channel fill from 11-14 m (B / III) separated by a shell hash (C / II) at 11 m. The channel cuts through sediments of Downing Silt (E / IV), which in the borehole occur underlying the channel, from 14-32 m.

From 35 to 48 mbsf is seismostratigraphic unit V. Lithologically, it can be subdivided into 2 units: unit G (32-38 mbsf), an upper red unit, and a grey unit, unit H (38-48 mbsf). Both units are interpreted as Downing Silt. Unit G contains more coherent reflections than unit H. The two units are separated by an erosional unconformity with 2 m of hummocky relief. Underlying this unit is a muddy diamict which may be a till, unit I / VI (48-75 mbsf). It is separated from unit H by an erosional unconformity with 6-8 m of relief. This sediment is believed to belong to the Grand Banks Drift. The third unit (J / VII, 75-109 mbsf); is interpreted as a till (Grand Banks Drift), the borehole bottomed out at the upper surface of this unit. It is interpreted as a subglacial deposit, with high shear strength and very high acoustic velocity (Moran, 1987).

The unit in which the till-tongues are rooted and the upper two till-tongues are truncated by a regional erosional unconformity (Moran, 1987).

Radiocarbon ages

Depth m	^{14}C age	Lithostratigraphic unit	Material	Laboratory No. Beta / Isotrace	ETH No.
0.21	2735	channel fill (B)	foraminifera	28274	4724
7.95	6150	channel fill (B)	shell	28275	4725
10.21	8020	channel fill (B)	shell	28276	4726
26.01	14870	Downing Silt (E)	shell	28278	4728
29.56	19120	Downing Silt (G)	shell	28229	4729
66.61	41080	Grand Banks Drift (I)	shells	28280	4730

Table 1: Compiled: depth in borehole, radiocarbon age, material dated and laboratory numbers for BH 2. These dates are uncorrected.

FORAMINIFERA

Laboratory methods

Samples of approximately 50 cm^3 were collected on site and placed in plastic vials and covered with a solution of sea water and $CaCl_2$ buffer (to balance the pH and prevent dissolution) and stored at A.G.C. until processing. All samples were then washed with 500 and 63 micron stainless steel sieves and dried overnight in a 30° C oven. When dried, the foraminifera were then concentrated by adding the sample to a 10:4 solution of bromoform and acetone (Gibson and Walker, 1967), which separated the foraminfera by flotation. The separation took place in about one minute after which the float was washed into filter paper, rinsed with acetone and dried.

Analytical methods and identification of foraminifera

Sixty-four floated samples and three whole samples (38, 41, 46) were analyzed for Quaternary benthonic and planktonic foraminifera and reworked (Cretaceous / Tertiary) foraminifera. Those samples containing abundant foraminifera were dry split with a micro-splitter. Between 300-800 Quaternary benthic specimens (when present) and the accompanying Quaternary planktonic and reworked foraminifera were subsequently identified and counted. If a counted split contained greater than 300 reworked foraminifera, but less than the appropriate numbers of Quaternary forms, additional splits were examined counting only the Quaternary (benthic and planktonic) specimens. If a 1/4 split contained less than 5 QB specimens, the sample was designated barren and no further examination completed.

The faunal reference list is given in Appendix A. Generally, all species were assumed to be Quaternary and identified by a Quaternary species name, except for those species known to have become extinct before the Quaternary. These extinct species were usually well known Cretaceous species and identified as such (i.e. species of *Heterohelix, Gavelinella, Praebuliminia* and *Pyramidina*). The only genera potentially represented in both the Quaternary and reworked fauna were rare specimens of *Gyroidina* - *Gyroidinoides* and *Lenticulina.* Specimens of *Lenticulina* are considered reworked. Small pristine specimens identified as *Gyroidinoides quinqueloba* or *Gyroidinoides nipponicus* are considered Quaternary, all other *Gyroidinas* - *Gyroidinoides* are considered reworked.

Another problem occurring throughout the literature has been the custom to employ distinct names for species found in sediments of different ages, even if the specimens appear to be identical and therefore conspecific. Both Quaternary and Cretaceous names have been used to identify the species of *Gyroidina.*

Generic classification is based on Loeblich and Tappan (1988), exceptions are given in Appendix A. Because many species formerly assigned to one genus (Loeblich and Tappan, 1964) are now assigned to (many) various genera, generic names in quotation marks (" ") are used to delineate these closely related species previously known by only one or two genus names. Species are usually identified by the most common or frequently used specific name in the reference literature, though there are some notable exceptions here. Where a specific name is not the most commonly cited (i.e. two species are considered synonymous and the more common name becomes a junior synonym), a brief note is included, and the name of the more common junior synonym.

Most reworked planktonic foraminifera are planispiral (i.e. *Globigerinoides*) biserial (i.e. *Heterohelix*) or triserial (i.e. *Gumbelitrea* and *Rectogumbelitrea*) and are easily distinguished from modern forms.

For each sample, the (sample) number, (sample) depth, size of the (sample) split, number of foraminifera in each category (QB, QP and reworked) present, relative species abundances for the QB species, and actual counts of QP and reworked specimens by species, are listed on Tables 2 (BH 1), 3 (BH 4) and 4 (BH 2). A schematic core log, the number of foraminifera in each of the three catagories, and the relative species abundances of the eight dominant species groups are plotted for each borehole on Figures 2 (BH 1), 3 (BH 4), and 4 (BH 2).

Samples are curated at G.S.C. - Atlantic, B.I.O., Dartmouth. Key slides are curated at Marine G.E.O.S.

Down hole assemblage sequences

Foraminiferal assemblages are identified and numbered based on stratigraphic position, numbering down section.

<u>BH1</u>

Downhole in BH 1 the sequence is: assemblage 1a (0- < 1 mbsf) and assemblage 3 (< 1- 7 mbsf). Data are presented on Table 2 and data for major / diagnostic species groups are illustrated on Figure 2.

<u>BH4</u>

Down hole in BH 4 sequence is: assemblage 1a (0-1 mbsf), assemblage 2 (1-3 mbsf), assemblage 4a (3-6 mbsf) and assemblage 4b (6-20 mbsf). Data are presented on Table 3 and data for major / diagnostic species groups are illustrated on Figure 3.

<u>BH 2</u>

Down hole in BH 2 the assemblage sequence is: assemblage 1b (0-1 mbsf), assemblage 2 (2-12 mbsf), assemblage 3 (12-13 mbsf), assemblage 2 (13-15 mbsf), assemblage 4b (16-17 mbsf), assemblage 2 (17-18 mbsf), assemblage 4b (18-19 mbsf), assemblage 6 (20-21 mbsf), assemblage 5 (21-23 mbsf), assemblage 7 (23-24 mbsf), assemblage 5 (24-32 mbsf), assemblage 4a (32-50 mbsf) and assemblage 4b (50-76 mbsf). Data are presented on Table 4 and data for the major / diagnostic species are presented graphically on Figure 4.

Foraminiferal assemblages

Assemblage 1a: *I. algida - I. helenae - A. angulosa - Buccella spp.*

Assemblage 1a occurs in the uppermost samples only of BH 1 and BH 4. It has high numbers of QB foraminifera. The Quaternary benthonic (QB) fauna is characterized by the dominance of *Islandiella algida* (20-30%) and the sub-dominance of *Angulogerina angulosa* (5-15%), *Buccella spp.* (ca. 10%) and *I. helenae* (5-16%). Also present are *Cribroelphidium excavatum, Cassidulina reniforme* and *Cibicides reflugens* (4 -8%). There are also low numbers of 7 agglutinated species present. There are high numbers of Quaternary planktonic

(QP) specimens, *Turborotalia pachyderma* or *Globigerinita uvula,* and no K / T specimens present.

Assemblage 1b: *C. reniforme - C. excavatum*

Assemblage 1b occurs in one sample only, at the surface of BH 2. The QB fauna is characterized by the dominance of *Cassidulina reniforme* (29.5%) and *Cribroelphidium excavatum* (16.5%). Sub-dominant are *Cribroelphidium bartletti* (5.5%), *C. albiumbilicatum* (5.5%), *Haynesina germanica* (5.5%), *Buccella spp.* (5.0%), *I. algida* (4.5%) and *I. helenae* (4.5%). There are a few specimens of agglutinated foraminifera. The numbers of QP specimens are low (compared to the number of QB) and are *Globigerina bulloides* and *Globigerinita uvula. Turborotalia pachyderma* is absent.

Assemblage 2: *C. reniforme - C. excavatum - "Cibicides"* (including *Lobatula*)*spp.*

Assemblage 2 occurs in one sample only in BH4 (1-3 mbsf) and 3 times in BH 2, from 2-12 mbsf, 13-15 mbsf and 17-18 mbsf. It is characterized by very high numbers of QB foraminifera (32,000-382,000 specimens per sample) in BH 2. It is a high diversity (QB) fauna characterized by the dominance of *C. reniforme* (36-55%). Sub-dominant are *C. excavatum* (6.5-17%),*"Cibicides" spp.* (8-25%, including *C. reflugens* and *Lobatula lobatalus*) and *Buccella spp.* (7.5%).

Present in low numbers are *Astrononion stelligerum, Cribroelphidium albiumbilicatum, "Fissurina" spp.* (including *Lagenosolenia spp. , Palliotella spp., Parafissurina spp. and Ventrostoma spp.*), *Gavelinopsis praegeri, Glabratellina spp., Haynesina orbiculare, Islandiella spp., Nonionella spp., Nonionellina labradorica, Patellina corrugata, Rosalina micens* and *Rotaliella chasteri.* There are high numbers of QP specimens (2,500-18,000 per sample). The QP fauna is dominated by *T. pachyderma* left coiled; *T. pachyderma* right coiled, *Turborotalita quinqueloba* (left and right coiled), *Neogloboquadrina dutertri, G. bulloides* and *G. uvula* are also present. There are low numbers of reworked specimens present (less than 10 specimens per split counted).

Assemblage 3: *C. excavatum - "Cibicides" spp. - "Glabratella" spp.*

Assemblage 3 occurs throughout most of BH 1 (< 0 - 7 mbsf) and in one sample only in BH 2 (12-13 mbsf). It is a lower diversity fauna, but there are high numbers of QB foraminifera present (42,000 specimens / sample). It is dominated by *C. excavatum* (48.5); subdominant are *"Cibicides" spp.* (mainly *C. reflugens* and *Lobatula lobatalus)* with percent occurrences of 24%. Also subdominant is *Rotaliella chasteri* (16%). Also present are *C. reniforme* (6%), *A. stelligerum* and *H. orbiculare.* Absent are typical shelf species. There are moderate numbers of both QP foraminifera (mostly *T. pachyderma* left and right coiled) and reworked (K / T) foraminifera present.

Assemblage 4a: Low numbers - *C. excavatum - C. reniforme - "Glabratella"* (including *Rotaliella*) *spp.* - reworked component

Assemblage 4a occurs in BH 4 from 3-6 mbsf and in BH 2 from 32-50 mbsf. There are low numbers of QB specimens (< 1,000 specimens / sample). *C. excavatum* is dominant (26.5 - 50%), *C. reniforme* is sub-dominant (14.5-32%). *Buccella spp.* (9.0%), *I. algida* (5.5-11.5%), *I. helenae* (1-5.5%) are all present.

Present in low numbers are *A. stelligerum, Bolivinella pseudopunctata, "Cibicides" spp., Cribroelphidium spp., "Fissurina" spp., Islandiella norcrossi, Patellina corrugata, Pseudopolymorphina novangliae* and *Pulleniella osloensis.* Agglutinated specimens (QB fauna) are almost absent.

In BH 2 there are moderate to high numbers of reworked (K / T) specimens; in some samples the K / T specimens out number the QB specimens (at 32, 34, 37-40, mbsf). There is a large peak of reworked foraminifera at 39 mbsf. The QB fauna is still dominated by *C. excavatum* (30-50%) and *C. reniforme* (19-32%). There are scattered occurrences of the deeper water species *Ioanella tumidula, "Epistominella" spp.* (including *Eilohedra spp.* and *Pseudoparrella spp.*) *Oridosalis umbonatus, Tosaia hanzawaia, "Uvigerina "spp.* (including *Euuvigerina brunnensis, Neouvigerina canariensis* and *Uvigerina peregrina*). There are low numbers of QP foraminifera.

Assemblage 4b: High numbers - *C. excavatum - C. reniforme - "Glabratella" spp.*- agglutinated component

Assemblage 4b occurs throughout most of BH 4 (6-20 mbsf) three times in BH 2 (16-17, 18-19 and 50-76 mbsf). There are higher total numbers than in assemblage 4a, but there is an overall decrease in the total numbers of QB specimens compared to overlying assemblages 1-3 (1,000-20,000 per sample).

C. excavatum is dominant (25-50%), sub-dominant is *C. reniforme* (13-36.5%). In BH 2 there is an increase in the occurrence of *"Glabratella" spp.* (including *Glabratellina spp., Rotaliella chasteri* and *Trichohyalus bartletti*, 2-23%). Consistently present in slightly higher numbers than seen previously are *H. orbiculare, I. algida, I. helenae,* and *R. chasteri* (up to 16%). Consistently present but in lower numbers are *Buccella spp.* and *C. reflugens.* There is a noticeable component of agglutinated foraminifera, the most common species are *Hemisphaerammina bradyi, Psammosphaera fusca* and *Rhumblerella humbolti;* there are also specimens of *"Trochammina" spp.* (including *Lepidoeuterammina spp. and Lepidoparatrochammina spp.*), "*Reophax " spp.* (including *Cuneata arctica, Reophanus guttifer* and *Rephax fusiformis*) and *Spiroplectammina spp.* present. There are low to moderate numbers of QP specimens, still dominated by *T. pachyderma* left but with an increase in diversity. There are low to moderate numbers of K / T specimens present, higher numbers than seen previously, with a marked peak in all numbers (QB, QP, K / T) in one sample at 25 mbsf.

Assemblage 5: *C. excavatum - C. reniforme - "Glabratella" spp. - I. helenae* - agglutinated component.

Assemblage 5 occurs twice in BH 2 only, from 21-23 and 24-32 mbsf. There are low total numbers of QB specimens present (1,700-3,000 specimens / sample) except for 3 samples. The fauna is characterized by *C. excavatum* (28-50%), *C. reniforme* (13-35%), "*Glabratella" spp.* (6-21%) and is distinguished by the slight increase in per cent occurrence of *I. helenae* (2-13.5%) with the maximum present at 27 mbsf. There is also a noticeable agglutinated component present, with 25% of the fauna agglutinated species at 22 mbsf. There are moderate numbers of QP, and low numbers of K / T specimens present.

Assemblage 6: *C. excavatum - C. albiumbilicatum - "Glabratella" spp.*

Assemblage 6 occurs in one sample only from (20-21 mbsf). *C. excavatum* is the dominant species (43.5%); however, there is a marked increase in the occurrence of *C. albiumbilicatum* (23.5%). There is also an increase in the occurrences of *H. orbiculare* (7.0%) and *I. helenae* (7.0%) and a corresponding decrease in the presence of *C. reniforme* (9.5%). There are 3 species of *Glabratellina* present (*G. lauriei, G. wrightii, G. sp. 1*) and *Trichohylus bartletti* is present. There is a decrease in the occurrence of *R. chasteri* (X %). *Cribroelphidium spp.* (*C. asklundi, C. bartletti, C. frigidum* and *C. subarcticum*) are also present. Absent are *A. stelligerum* , *"Epistominella" spp., Rosalina spp.* There are very low numbers of QP (dominated by *T. pachyderma* left) and K / T.

Assemblage 7: Low number - *C. reniforme* - *"Fursenkoina " spp.* - *"Glabratella" spp.*

Assemblage 7 occurs in one sample only in BH 2, sample 26 at 23 mbsf. It is characterized by a marked decrease in the percent occurrence of *C. excavatum* (5.5%) and a marked increase in the occurrence of *"Fursenkoina" spp.* (*F. fusiformis, F. pauciloculata, F. rotundata and Stainforthia concava*) to 16%. *C. reniforme* (25%) is dominant and *"Glabratella" spp.* is also sub-dominant (10%). *I. helenae* is also present (5.5%) and there is a slight increase in the occurrence of *Rosalina micens* (4.5%) and *"Nonionella" spp.* (4%).

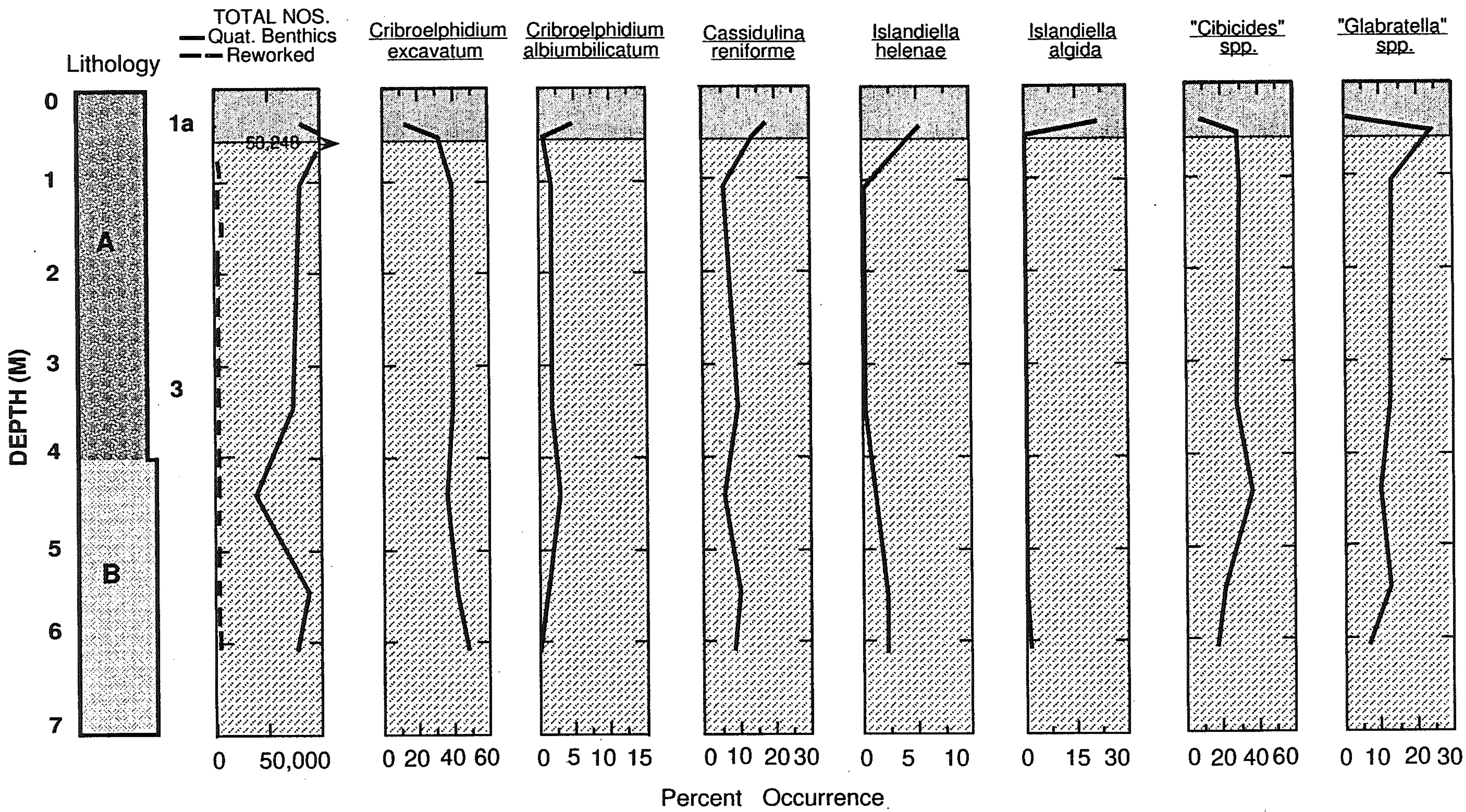

Figure 2: Foraminiferal abundances and percentage occurences of key QB species downhole in BH 1. Letters shown in the "Lithology" column and numbers to the right of the "Lithology" column correspond to sediment units and the foraminiferal QB assemblages (respectively) as described in the text.

SAMPLE NUMBER	1	2	3	4	5	6	7
DEPTH (M)	0.4	0.53	1.06	3.46	4.42	5.46	6.1
TOTAL NOS. QUATERNARY BENTHICS	42,069	53,248	41,344	37,056	19,712	44,928	39,040
SPLIT COUNTED	(3/256)	(1/128)	(1/128)	(1/64)	(1/64)	(1/128)	(1/128)
Agglutinated foraminifera							
Adercotryma glomerata	X						
Recurvoides contortus	X						
"Eggerella" group							
Rhumblerella humbolti	X						
"Saccammina" group							
Lagenammina atlantica	X						
"Spiroplectammina" group							
Spiroplectammina biformis	X						
Spirplectammina earlandi	X						
"Trochammina" group							
Lepidodeuterammina ochracea	X						
Calcareous foraminifera							
Angulogerina angulosa	5.0			X		X	
Patellina corrugata		X					
"Bolivina" group							
Bolivinella pseudopunctata	X						
"Buccella" group							
Buccella frigida				X			
Buccella vicksburgensis	9.5	2.0	1.0	2.0		4.0	2.0
Buccella sp. 2		1.0		X	X		
"Bulimina" group							
Bulimina marginata					X		
"Cassidulina - Islandiella" group							
Cassidulina reniforme	18.0	14.0	5.5	9.5	6.0	10.0	8.5
Islandiella algida	21.5	X		X		X	1.0
Islandiella helenae	5.0		X	X		2.0	2.0
"Cibicides" group							
Cibicides reflugens	7.5	2.0	1.0	4.5	14.5	11.5	18.0
Heterolepa subhaidingerii		X					
Lobatula lobatalus	1.0	26.5	29.5	23.5	23.0	10.5	9.5
"Discorbis - Rosalina" group							
Gavelinopsis praegeri						X	1.0
Rosalina micens		X			X	X	
Rotorbis auberii		X					
"Elphidium" group							
Cribroelphidium albiumbilicatum	5.0	1.0	2.0	2.0	3.0	1.5	
Cribroelphidium asklundi		10.0	1.0	X			
Cribroelphidium bartletti	1.0						
Cribroelphidium excavatum	13.5	32.5	40.0	40.0	36.5	42.0	49.0
Cribroelphidium subarcticum		X					
"Eoeponidella" group							
Eoeponidella pulchella	X	X			X	X	
"Epistominella" group							
Pseudoparrella takayanagii	2.0	X			X	X	X
"Fissurina" group							
Fissurina circularis	X						
Fissurina marginata		X					
Fissurina stewartii	X		X	X			
"Fursenkoina" group							
Fursenkoina fusiformis	2.0					X	
Fursenkoina rotundata	X	X					

Table 2: Foraminiferal data, BH 1, Halibut Channel. Data for the Quaternary benthic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X< 1%.

SAMPLE NUMBER	1	2	3	4	5	6	7
"Glabratella" group							
Glabratella lauriei			X			1.0	X
Glabratella wrightii		1.0	X	X	X	1.0	1.5
Glabratella sp. 1	X	21.0	12.0	11.5	8.5	10.0	4.5
Rotaliella chasteri		1.0				X	
"Miliolinella" group							
Miliolinella chukchiensis			X		1.0		
Miliolinella circularis		X		X			
Miliolinella subrotunda							
Triloculinella tegminus			X				
"Nonion" group							
Astrononion stelligerum	1.0	2.0	1.0	1.5	1.5	2.5	1.0
Haynesina orbiculare	X	1.5	4.5	2.0	1.5	2.0	2.0
Melonis barleeanus					X		
Nonionellina labradorica	2.0	X					
"Oolina" group							
Favulina melo	X						
Homeohedra acuticostata	X		X	X			
"Quinqueloculina" group							
Axiopolina parva					1.0		
Quinqueloculina seminula	X			X	X	X	
Siphonaperta aspera	X						
"Uvigerina" group							
Uvigerina peregrina				X			
QUATERNARY PLANKTONICS							
TOTAL NO. SPECIMENS	768	896	640	192	448	640	256
SPLIT COUNTED	(3/256)	(1/128)	(1/128)	(1/32)	(1/64)	(1/128)	(1/128)
Globigerina bulloides						256	
Globogerinita uvula	768						128
Globorotalia inflata							
Neogloboquadrina dutertri							
Turborotalia pachyderma-left		640	128	160		256	128
-right		128	512	32			
Turborotalita quinqueloba-left						128	
-right		128					
REWORKED							
TOTAL NO. SPECIMENS	/	768	128	96	192	512	384
SPLIT COUNTED		(1/128)	(1/128)	(1/32)	(1/64)	(1/128)	(1/128)
Gavelinella monterelensis		128					
Gyroidinoides depressa				32			
Praebulimina carseyae		128					
Praebulimina reussi		384					
Globorotalites michelinianus							256
Heterohelix globulosa		128			128	128	128
Heterohelix pulchra					64		
planktonics			128	64		384	

Table 2: Foraminiferal data, BH 1, Halibut Channel. Data for the Quaternary benthic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X< 1%.

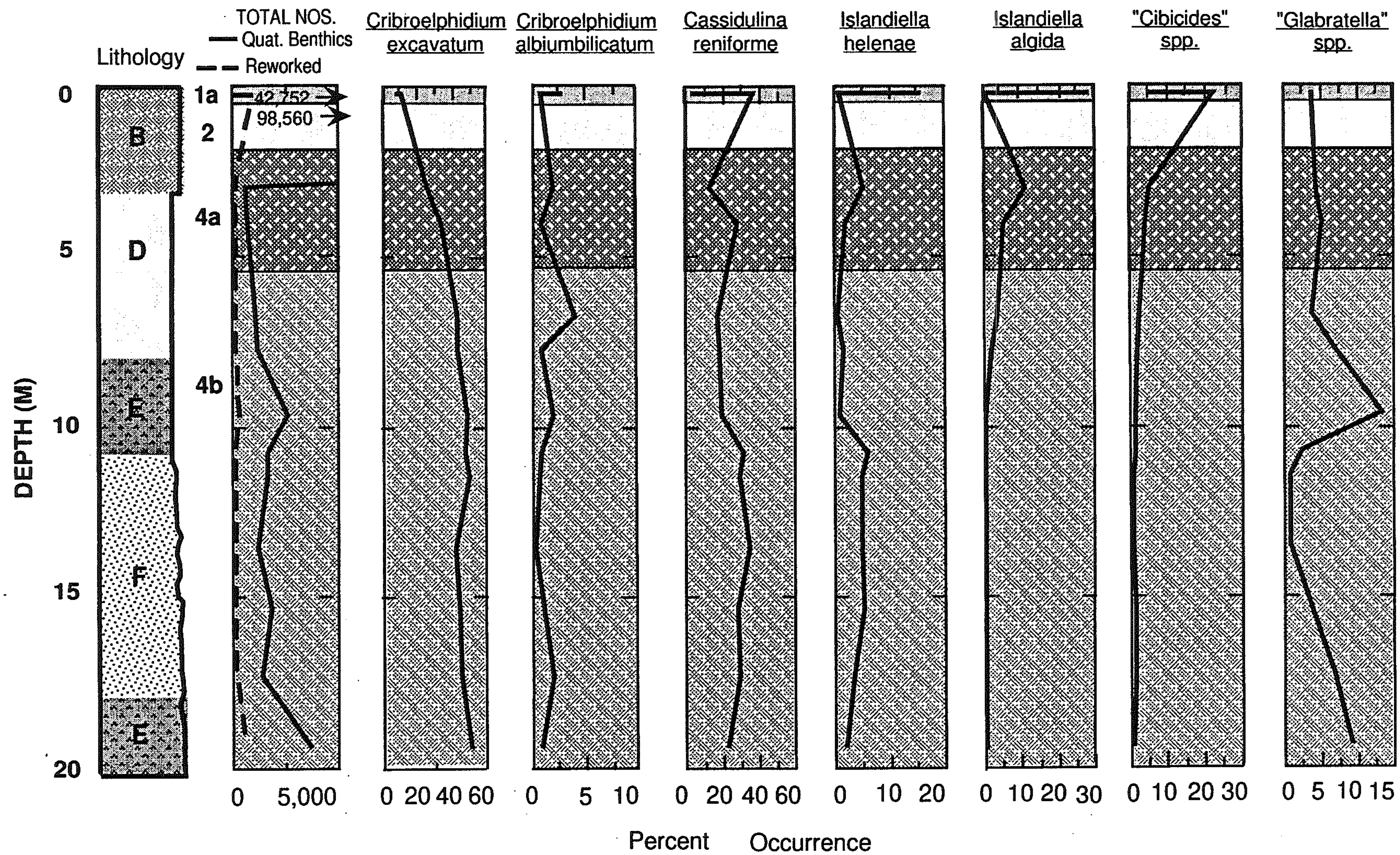

Figure 3: Foraminiferal abundances and percentage occurences of key QB species downhole in BH 4. Letters shown in the "Lithology" column and numbers to the right of the "Lithology" column correspond to sediment units and the foraminiferal QB assemblages (respectively) as described in the text.

SAMPLE NUMBER	63	62	64	65	66	67	69	70	71	72	73	74	76
DEPTH (M)	0.23	0.25	3.01	4.05	6.73	7.72	9.66	10.77	11.49	13.6	15.32	17.29	19.4
TOTAL NOS. QUATERNARY BENTHICS	42,752	98,560	736	757	1,140	1,212	2,640	1,700	1,755	1,256	1,920	1,428	3,776
SPLIT COUNTED	(1/128)	(1/256)	(1/2)	(9/16)	(1/4)	(1/4)	(1/8)	(1/4)	(3/16)	(1/4)	(3/16)	(1/4)	(1/8)
Agglutinated foraminifera													
Hemispherammina bradyi					1.0	X							
Psammosphaera fusca						X							
"Cribrostomoides" group													
Veleroninoides jeffreysii			X										
"Eggerella" group													
Rhumblerella humbolti						X	3.0			X			1.0
"Reophax" group													
Reophanus guttifer	X												
Reophax fusiformis		X											
"Spiroplectammina" group													
Spiroplectammina biformis	X										X		
"Trochammina" group													
Lepidodeuterammina ochracea						X							
Lepidodeuterammina ochracea sinuosa		X											
Calcareous foraminifera													
Angulogerina angulosa	14.0	X	4.5	1.0						X	1.0	X	
Aubignyana perlucida								X	X				
Patellina corrugata		1.0	X	1.0	X				X				
Rotorbis auberi												X	
Valvulineria minuta				X									
"Bolivina" group													
Aphenophragmina britannica												X	
Aphenphragmina spathulata							X				X		
Bolivina mexicana			X				X						
Bolivinella pseudopunctata		X	X	1.0	X	X							
"Bucella" group													
Buccella depressa		1.0		X	X			X				2.0	X
Buccella frigida													
Buccella hannai			X				X					X	
Buccella vicksburgensis	10.5	7.5	9.5	9.0	8.5	5.0	4.0	1.0	1.5	2.0	1.5	1.0	2.0
Buccella sp. 2			2.0	1.0	1.5	2.0	2.0	1.0	X		1.0		1.0
"Bulimina" group													
Bulimina marginata				X									
Buliminella tenuis	X		X								X		
Globobulimina auriculata		X								X			
"Cassidulina - Islandiella" group													
Cassidulina carinata			X										
Cassidulina reniforme	5.0	38.5	14.5	30.5	19.0	20.0	21.5	33.5	31.5	36.5	30.0	31.0	24.5
Islandiella algida	29.0	X	11.5	5.5	3.5	2.0	X	X		X	X		X
Islandiella helenae	16.0	1.0	5.5	2.0	X	1.5	1.0	6.0	5.0	5.0	5.5	3.5	2.0
Islandiella norcrossi	1.0	X	X	X	X	X		X		X			
Paracassidulina neocarinata			X							X			
"Cibicides" group													
Cibicides corpulentus			2.0			X	X						
Cibicides reflugens	4.0	20.5	2.0	3.0	2.0	1.0	1.0	X	X	X	X	X	X
Lobatula lobatalus	1.0	2.0	1.0	X		X		X			X	X	
Planulina retia		X		X								X	
"Cornuspira" group													
Cornuspira borealis				X			X		X				
Cornuspira planorbis													X
"Discorbis - Rosalina" group													
Discorbinella bertheloti				X									
Gavelinopsis praegeri		X				X							X
Lamarkina haliotedea					X				X				X
Neodiscorbinella plana			X	X		X	X			X			X
Rosalina globularis		X			X		X						
Rosalina micens		1.5	X	1.0	X	X	X		X		X		X
"Elphidium" group													
Cribroelphidium albiumbilicatum	3.0	1.0	2.0	1.0	4.0	1.0	2.0	1.0		X		2.0	1.0
Cribroelphidium asklundi		X	X	X	X	X	X	1.0	X	X			
Cribroelphidium bartletti	1.5		X	X	X		X	X	1.0		X	X	
Cribroelphidium excavatum	9.5	12.5	26.5	34.0	43.0	43.0	48.0	47.5	49.0	41.5	43.5	45.0	50.5
Elphidiella hannai									X				
Elphidiella rolfi													X
"Eoeponidella" group													
Altastellerella riveroae			X										X
Eoeponidella pulchella	X		X		X		1.5	1.0		1.5	X	X	
"Epistominella" group													
Epistominella exigua				3.0	2.0	3.0	3.0				X	X	2.0

Table 3: Foraminiferal data, BH 4, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	63	62	64	65	66	67	69	70	71	72	73	74	76
Pseudoparrella subperuviana			1.0							X			X
Pseudoparrella takayanagii	X					X	X		X			X	
"Fissurina" group													
Fissurina aequilabialis		X											
Fissurina anapectebasilaris								X				X	
Fissurina annectans				X	X								
Fissurina cucurbitasema								X					
Fissurina lucida												X	
Fissurina marginata								X	X	X		X	
Fissurina pseudoglobosa							X					X	
Fissurina pseudoglobosa pseudoglobosa			1.0					X	X		X	X	
Fissurina stewartii			X				X			X			
Fissurina sp. 1 (sensu Jones)	X												
Lagenosolenia inflataperforata					X	X							
Lagenosolenia lagenoides		X											
Palliotella orbignyana							X	X					
Parafissurina arata												X	
Parafissurina himatiostoma			X										
Parafissurina magnilabiata							X						
Ventrostoma fovigera				X									
"Fursenkoina" group													
Fursenkoina fusiformis		X	1.0	X	X					X			
Fursenkoina pauciloculata						X	X		X				
Fursenkoina rotundata	X		X	X		X							
Stainforthia concava										X			
"Glabratella" group													
Conorbella pulvinata										X			
Glabratellina lauriei		X	X			X	X			X	X		
Glabratellina wrightii		1.0		X	1.0		X			X	X	1.0	X
Glabratellina sp. 1		X	1.0	1.0	1.0	3.0	7.5	1.0	X		X	2.5	6.0
Heronallenina parva		X											
Rotaliella chasteri		2.0	1.0	3.0	X	3.5	3.0	X			1.0	1.0	2.0
Trichohyalus bartletti												X	
"Gyroidina" group													
Gyroidinoides nipponicus			X										
Gyroidinoides quinqueloba													
"Lagena" group													
Lagena semilineata			X										
Procerolagena gracilis							X						
"Miliolinella" group													
Adelosina sp. 1							X						
Miliolinella chukchiensis							X	X					X
Miliolinella circularis				X		X	X	X					
Miliolinella subrotunda													X
Triloculina dissidens								X			X		
Triloculina tricarinata										X		X	
"Nonion" group													
Astrononion stelligerum		2.0	X	X	X	1.0	X	X	X		X		X
Haynesina germanica				X						X			
Haynesina orbiculare	2.0	1.0	3.5	2.0	3.0	1.5	4.5	3.0	3.5	3.0	4.5	4.5	4.0
Laminononion stellatum						X							
Nonionella lobsannensis		X											
Nonionella stella							X						
Nonionellina labradorica	1.0	4.0	3.0	2.0	1.0	1.0	X	2.0	3.5	1.0	5.5	2.0	X
Nonionoides grateloupi		X											
Pulleniella osloensis			X	1.0		X					X		
"Oolina" group													
Favulina melo			X									X	X
Homeohedra acuticostata			X										
"Polymorphina" group													
Svenia sidebottomi						X							
"Quinqueloculina" group													
Axiopolina parva					X						X	X	
Quinqueloculina arctica	X					X					X		
Quinqueloculina crassiciarinata								X					
Quinqueloculina patagonica													X
Quinqueloculina seminula					X								X
"Uvigerina" group													
Euuvigerina brunnensis					X								

Table 3: Foraminiferal data, BH 4, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	63	62	64	65	66	67	69	70	71	72	73	74	76
QUATERNARY PLANKTONICS													
TOTAL NO. SPECIMENS	384	8,192	18	7	24	48	112	36	43	60	21	56	392
SPLIT COUNTED	(1/128)	(1/256)	(1/2)	(9/16)	(1/4)	(1/4)	(1/8)	(1/4)	(3/16)	(1/4)	(3/16)	(1/4)	(1/8)
Globigerina bulloides		512			4	4		8					16
Globogerinita uvula		512	4		4			4		8	5	8	
Globorotalia inflata		256											
Turborotalia pachyderma - sinistral	256	4,096	4	3	8	28	80	16	43	40	11	36	336
- dextral	128	1,536	6	2		4	8	4		4		4	32
Turborotalita quinqueloba - sinistral		256	2			8	8	4		8			
- dextral		768		2		4	8				5	8	8
Neogloboquadrina dutertrei		256	2		8		8						
REWORKED													
TOTAL NO. SPECIMENS	/	768	14	11	52	64	208	28	48	60	53	56	464
SPLIT COUNTED		(1/256)	(1/2)	(9/16)	(1/4)	(1/4)	(1/8)	(1/4)	(3/16)	(1/4)	(3/16)	(1/4)	(1/8)
Agglutinated foraminifera													
Verneuilina muensteri					4								
Calcareous foraminifera													
Bulimina fabilis							8						
Dentalina solvata			2										
Ellipsonodosaria exilis													
Eouvigerina americana					4		8						32
Gavelinella monterelensis							8						
Gavelinella nelsoni									5			8	8
Gavelinella sandidgei						4							
Gyroidinoides depressus									5				
Gyroidinoides nitidus													8
Lagena globosa						4							
Neobulimina canadiensis							8						
Nonionella robusta							8						
Osangularia cordierana					4		8						
Praebulimina reussi			2	2	4	12	24	4	5	8	5		40
Pyramidina referrata			2										
Pyramidina triangularis												4	
Rotalipora appennenica							8						
Globorotalites michelinianus						4	8						8
Globorotalites subconicus											5		
Gumbelitrea cretacea											6		
Heterohelix globulosa		512	2	2		16	72	24	11	36	32	28	192
Heterohelix pulchra		256											8
planktonics			6	7	36	24	40		22	16	5	16	168

Table 3: Foraminiferal data, BH 4, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

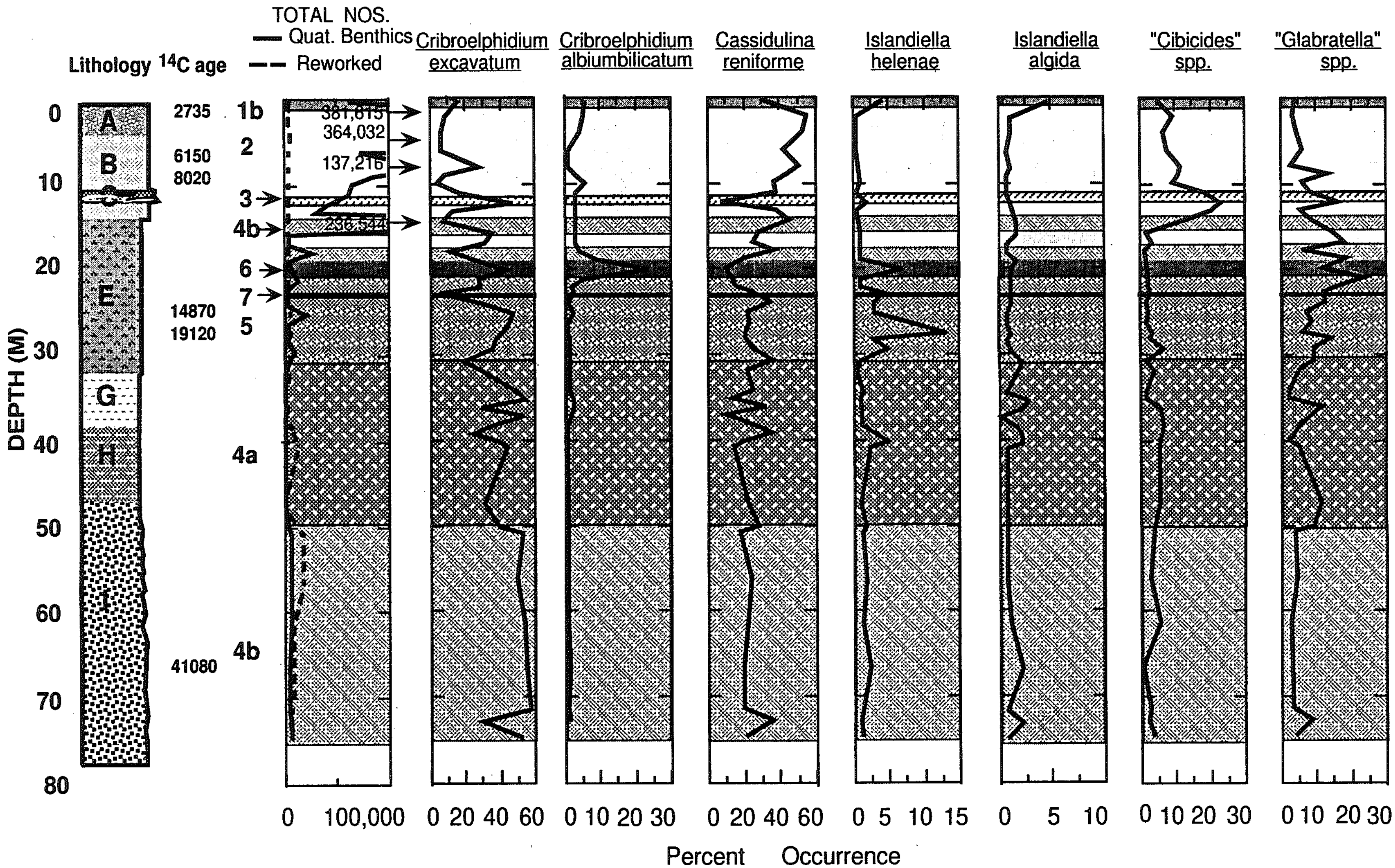

Figure 4: Foraminiferal abundances and percentage occurences of key QB species downhole in BH 2. Letters shown in the "Lithology" column and numbers to the right of the "Lithology" column correspond to sediment units and the foraminiferal QB assemblages (respectively) as described in the text.

SAMPLE NUMBER	8	9	10	11	12	13	14	15
DEPTH (M)	0.45	2.43	4.26	6.29	8.3	9.17	10.08	11.21
TOTAL NOS. QUATERNARY BENTHICS	63,104	381,615	364,032	73,536	137,216	86,016	65,664	62,080
SPLIT COUNTED	(1/128)	(1/512)	(1/512)	(1/64)	(1/256)	(1/128)	(1/128)	(1/64)
Agglutinated foraminifera								
Adercotryma glomerata								
Hemispherammina bradyi								
Psammosphaera fusca								
Recurvoides contortus								
"Cribrostomoides" group								
Veleroninoides crassimargo								
"Eggerella" group								
Rhumblerella humbolti	X				X		X	
"Reophax" group								
Cuneata arctica								
"Saccammina" group								
Lagenammina atlantica	X							
Saccammina sphaerica								
"Spiroplectammina" group								
Spiroplectammina biformis								
Spiroplectammina nitens	X						X	
"Trochammina" group								
Lepidodeuterammina ochracea	1.0	X	1.0	X	X		1.0	
Lepidodeuterammina ochracea sinuosa								
Lepidoparatrochammina haynesi	X					X	X	
Lepidoparatrochammina lepida								X
Calcareous foraminifera								
Allomorphina fragilis								
Angulogerina angulosa	3.5	X	X	X	X	X	X	X
Aubignyana perlucida	X			X			X	
Patellina corrugata	2.0	X	1.5	X	1.0	1.0	1.0	X
Sphaeroidina bulloides								
Tosaia hanzawaia								
Valvulineria minuta		X	1.0	X				X
"Bolivina" group								
Aphenophragmina britannica				X				
Aphenophragmina spathulata		X	X	X	X	X	1.0	
Bolivina aenariensis			X	X	X			
Bolivina decussata								
Bolivina mexicana								
Bolivina vadescens								
Bolivinella pseudopunctata	X	X	X	X	X	X	X	X
"Buccella" group								
Buccella depressa								X
Buccella frigida						2.0		
Buccella hannai	2.5		1.0		X	X	5.5	X
Buccella mansfieldi	1.0							
Buccella vicksburgensis	2.5	4.5	2.5	5.0	7.5		X	4.5
Buccella sp. 2	3.5	2.0	1.0	2.5	1.0	3.5	X	2.5
"Bulimina" group								
Bulimina marginata				1.0			X	
Buliminella tenuis		X						
Floresina milletti							X	
Globobulimina auriculata	1.5					X		X
"Cassidulina - Islandiella" group								
Cassidulina carinata				X				
Cassidulina laevigata							X	
Cassidulina reniforme	29.5	55.0	53.0	41.5	50.5	44.0	36.5	38.0
Cassidulina teretis								
Islandiella algida	4.5	1.0	1.0	X	1.0	X	X	X
Islandiella helenae	4.5	X		X			1.0	X
Islandiella norcrossi	X	X	X	X				
Paracassidulina neocarinata		X			X	X	X	
"Cibicides" group								
Cibicides corpulentus		X					X	
Cibicdes grossa								
Cibicides robertsonianus								
Cibicides reflugens	3.5	9.0	6.5	8.0	X	11.0	9.5	5.0
Heterolepa subhaidingerii								
Lobatula lobatalus	2.0		X		11.0	X	X	13.5
Planulina retia		X		1.0	X	X	2.0	

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	8	9	10	11	12	13	14	15
"Cornuspira" group								
Cornuspira involvens								
Cornuspira planorbis								
"Discorbis - Rosalina" group								
Discorbinella bertheloti	X		1.0	X				
Gavelinopsis praegeri				X				X
Lamarkina haliotedia			X					
Neodiscorbinella bradyi							X	
Neodiscorbinella plana	X	X	1.0	1.0				
Orbitina williamsoni		X	X		2.0			
Rosalina globularis		X	X					
Rosalina micens	X		1.0	1.0		1.0	X	X
"Elphidium" group								
Cribroelphidium albiumbilicatum	5.5	5.0	4.0	X	2.5	3.0	5.5	2.5
Cribroelphidium asklundi				X				X
Cribroelphidium bartletti	5.5							
Cribroelphidium excavatum	16.5	8.5	6.5	7.0	18.5	8.5	4.0	17.0
Cribroelphidium frigidum								
Cribroelphidium subarcticum				X				
Elphidiella groenlandicum								
"Eoeponidella" group								
Altastellerella riveroae								
Eoeponidella pulchella		X	1.0	X	X	X	X	
"Epistominella" group								
Eilohedra arctica								
Eilohedra levicula				X			X	
Pseudoparrella exigua			1.0		1.0			X
Pseudoparrella subperuviana	1.0		X		X	X		
Pseudoparrella takayanagii		X	X	X	X	X		
"Eponides" group								
Eponides pusillus								
Ioanella tumidula								
Nuttalides bradyi								
Oridosalis umbonatus								
"Fissurina" group								
Fissurina aequilabialis				X		X		
Fissurina annectans		X	X	X			X	
Fissurina circularis								
Fissurina cucurbitasema			X					
Fissurina dancia								
Fissurina fasciata						X		X
Fissurina fimbriata								
Fissurina latistoma				X				
Fissurina lucida								
Fissurina marginata			X	X	X			X
Fissurina paula							X	
Fissurina polita								
Fissurina pseudoglobosa								X
Fissurina pseudoglobosa pseudoglobosa		X		1.5				X
Fissurina stewartii								
Fissurina subchasteri								
Fissurina tricarinata			X				X	
Fissurina sp. 1 (sensu Jones)								
Galwayella subangulosa				X				
Lagenasolenia infltaperforata								
Lagenosolenia lagenoides			X	X				
Parafissurina arata				X				
Parafissurina carinata		1.5						
Parafissurina exiguiformis								
Parafissurina fornasini								X
Parafissurina himatiostoma								
Parafissurina magnilabiata								
Parafissurina obsoleta								
Parafissurina ovata								
Parafissurina subquadrata			X					
Parafissurina tectulostoma							X	
Pseudoolina fissurinea					X			
Ventrostoma depressiformis				X				
Ventrostoma foevigera			X				X	
Ventrostoma mitrata	X							
"Fursenkoina" group								
Fursenkoina fusiformis		X	1.5	7.5		2.5	10.5	X

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	8	9	10	11	12	13	14	15
Fursenkoina pauciloculata	X							
Fursenkoina rotundata		X	1.0	3.0	X	1.0	1.0	X
Rutherfordoides mexicana								
Stainforthia concava		X						
"Glabratella" group								
Conorbella pulvinata								
Glabratellina arcuata								
Glabratellina lauriei							X	X
Glabratellina wrightii			X	X				X
Glabratellina sp. 1								X
Heronallenina parva				X				
Rotaliella chasteri	1.0	2.0	3.5	3.5	2.5	10.0	5.5	4.5
Trichohyalus bartletti								
"Gyroidina" group								
Gyroidinoides nipponicus				X				
Gyroidinoides quinqueloba								
"Lagena" group								
Hyalinonetrion distoma								
Lagena substriata		X						
Procerlagena gracilis						X		
"Miliolinella" group								
Miliolinella chukchiensis							X	
Miliolinella circularis				X			X	
Miliolinella subrotunda								
Pyrgo oblonga				X				
Triloculina dissidens						X	X	X
Triloculina tricarinata								
Triloculina trihedra				X				
Triloculinella differens								
Triloculinella tegminus								
"Nonion" group								
Astrononion stelligerum	2.0	2.0			1.5	X	2.5	X
Haynesina depressula								
Haynesina germanica	5.5			1.5			1.0	X
Haynesina orbiculare			X	2.0				X
Laminononion stellatum								
Melonis barleeanus	X		X	X			1.0	
Nonionella lobsannensis				X				X
Nonionella stella				X			X	
Nonionellina labradorica	3.5	1.0	1.5	1.5	1.0	5.5	4.5	2.0
Nonionoides grateloupi			X	X			X	
Pulleniella osloensis		X	1.0	1.5	X	X	2.0	
"Oolina" group								
Cushmanina striatopunctata	X	X						
Favulina hexagona				X				
Favulina melo		X						
Oolina lineata								
"Polymorphina" group								
Entomorphinoides inalienata								
Globulina minuta								
Globulina priscea								
Globotuboides decora								
Metapolymorphina ligua								
Pseudopolymorphina novangliae				X				
"Quinqueloculina" group								
Axiopolina parva				X				X
Quinqueloculina akerniana								
Quinqueloculina arctica								
Quinqueloculina crassicarinata								
Quinqueloculina patagonica								
Quinqueloculina seminula					X			
"Uvigerina" group								
Euuvigerina brunnensis								
Neouvigerina canariensis								
Uvigerina peregrina								

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	8	9	10	11	12	13	14	15
QUATERNARY PLANKTONICS								
TOTAL NO. SPECIMENS	768	17,408	21,504	6,592	2,560	7,296	12,800	5,952
SPLIT COUNTED	(1/128)	(1/512)	(1/512)	(1/64)	(1/256)	(1/128)	(1/128)	(1/64)
Globigerina bulloides	512	512	1,536	192			128	384
Globogerinita uvula	256	3,072	1,536	320	512	512	2,176	256
Globorotalia inflata								
Neogloboquadrina deutertri		512						
Turborotalia pachyderma - sinistral		9,216	12,288	2,560	1,028	2,816	6,016	2,816
-dextral		3,072	4,096	1,600	256	1,408	3,456	832
Turborotalita quinqueloba - sinistral		512	512	640	256	640	768	896
- dextral		512	1,536	1,280	256	1,920	256	768
REWORKED								
TOTAL NO. SPECIMENS	128	/	1,024	384	/	512	640	448
SPLIT COUNTED	(1/128)		(1/512)	(1/64)		(1/128)	(1/128)	(1/64)
Agglutinated foraminifera								
Arenobulimina americana								
Dorothia bulleta								
Pseudotextulariella cretacea								
Spiroplectammina laevis								
Tritaxia pyramidata								
Tritaxia singularis								
Trochammina texana								
Verneuilina muensteri								
Calcareous foraminifera								
Alabamina wilcoxensis								
Allomorphina trochoides								
Anomalinoides harperi								
Astacolus dissonus								
Bandyana greatvalleyensis								
Bolivinita eleyi								
Bolivinopsis papillata								
Brizalina decorrata delicatula								
Brizalina decurrens								
Brizalina incrassata								
Brizalina velascoensis								
Brizalina watersi								
Bulimina fabilis								
Cassidella navarroana								
Cassidella tegulata								
Cibicides concentricus								
Cibicides constrictus								
Cibicides subcarinatus								
Dentalina basiplanata								
Dentalina consobrina								
Dentalina crinita								
Dentalina gracilis								
Dentalina lornieana								
Dentalina megalopolitana								
Ellipsonodosaria exilis								
Eouvigerina americana	128							
Eouvigerina austinana								
Eouvigerina excavata								
Eouvigerina subsculptura								
Eponides haidingerii								
Gavelinella clemintiana						128		
Gavelinella henbesti								
Gavelinella intermedia								
Gavelinella monterelensis								
Gavelinella nelsoni				192			256	
Gavelinella pertusa								
Gavelinella rubinosa								
Gavelinella sandidgei				128				128
Gavelinella tennesseensis								
Gavelinella velascoensis								
Gyroidinoides depressus						128		
Gyroidinoides giradianus								
Gyroidinoides globosa								
Gyroidinoides nitidus								
Hanzawaia producta								
Lagena apiculeata								

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	8	9	10	11	12	13	14	15
Lenticulina navicula								
Lenticulina nuda								
Lenticulina rotulata								64
Lenticulina subalata								
Lenticulina williamsoni								
Marginulina recta								
Marginulina stephensoni								
Nodosaria affinis								
Osangularia cordierana								
Osangularia navarroana								
Planularia gemmata								
Pleurostomella austiniana								
Pleurostomella subnodosa								
Praebulimina carseyae								
Praebulimina kickapooensis								
Praebulimina reussi						128		64
Pseudouvigerina cretacea								
Pseudouvigerina seligi								
Pullenia quaternaria								
Pyrulina fusiformis								
Pyramidina referrata							128	
Pyramidina rudita								
Pyramidina triangularis								
Reusella szajnochae								
Rotalipora appennenica								
Siphonina prima								
Stetsioeina pommerana								
Valvulineria allomorphoides								
Valvulineria cretacea								
Valvulineria umbilicatula								
Globorotalites michelinianus								
Globorotalites subconicus								
Gumbelina glabrans								
Gumbelitrea cretacea								
Heterohelix globulosa			1,024	64			128	192
Heterohelix pulchra								
Heterohelix striata								
Planoglobulina taylorana								
Rectogumbelina cretacea								
Rectogumbelina hispida								
planktonics						128	128	

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	16	17	18	19	20	21	22	23	24	25
DEPTH (M)	12.32	13.25	14.56	15.8	17.02	17.92	18.94	20.17	21.4	22.29
TOTAL NOS. QUATERNARY BENTHICS	41,984	31,317	236,544	3,584	3,157	25,088	4,171	6,480	13,080	1,723
SPLIT COUNTED	(1/128)	(3/256)	(1/512)	(3/32)	(3/32)	(1/64)	(3/32)	(1/16)	(1/8)	(3/16)
Agglutinated foraminifera										
Adercotryma glomerata							1.0			
Hemispherammina bradyi				X	5.0				X	11.5
Psammosphaera fusca				2.5	2.0	2.5			5.0	13.0
Recurvoides contortus							X			X
"Cribrostomoides" group										
Veleroninoides crassimargo										
"Eggerella" group										
Rhumblerella humbolti							2.0		1.5	X
"Reophax" group										
Cuneata arctica										
"Saccammina" group										
Lagenammina atlantica										
Saccammina sphaerica							X			
"Spiroplectammina" group										
Spiroplectammina biformis				X			X			
Spiroplectammina nitens										
"Trochammina" group										
Lepidodeuterammina ochracea		2.5	1.0			4.0	1.0			
Lepidodeuterammina ochracea sinuosa	X									
Lepidoparatrochammina haynesi							X		X	
Lepidoparatrochammina lepida		2.0	X		X		X			
Calcareous foraminifera										
Allomorphina fragilis										
Angulogerina angulosa			X	1.0	X	X	1.0	X	X	
Aubignyana perlucida										
Patellina corrugata			X				X			
Sphaeroidina bulloides									X	
Tosaia hanzawaia										
Valvulineria minuta		X				X	X		X	
"Bolivina" group										
Aphenophragmina britannica										
Aphenophragmina spathulata			X	X	X					
Bolivina aenariensis										
Bolivina decussata				X						
Bolivina mexicana										
Bolivina vadescens					X					
Bolivinella pseudopunctata			X			X	X			
"Buccella" group										
Buccella depressa									X	
Buccella frigida										
Buccella hannai		X	X							
Buccella mansfieldi							X			
Buccella vicksburgensis	X	3.5	5.0	1.0	X	4.5	1.5	X	1.5	1.0
Buccella sp. 2	1.0	X	3.5	4.5	5.0	4.5	2.5	1.0	1.5	3.0
"Bulimina" group										
Bulimina marginata			2.0				X	X		
Buliminella tenuis										
Floresina milletti										
Globobulimina auriculata		X		X						
"Cassidulina - Islandiella" group										
Cassidulina carinata										
Cassidulina laevigata								X		
Cassidulina reniforme	6.0	37.5	45.5	28.0	24.5	36.0	19.5	9.5	13.0	15.5
Cassidulina teretis							X			
Islandiella algida	1.0		1.5	1.5	X	X	1.5	1.0	1.0	
Islandiella helenae	2.0	X		1.0			1.0	7.0	1.0	1.0
Islandiella norcrossi										
Paracassidulina neocarinata										
"Cibicides" group										
Cibicides corpulentus	2.0						1.0			
Cibicdes grossa										
Cibicides robertsonianus										
Cibicides reflugens	3.5	17.0	12.0	2.0	4.0	10.0		2.0	3.0	3.0
Heterolepa subhaidingerii										
Lobatula lobatalus	18.0	3.5	X			X				
Planulina retia	X	1.0	X		X	X				

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	16	17	18	19	20	21	22	23	24	25
"Cornuspira" group										
Cornuspira involvens										
Cornuspira planorbis										
"Discorbis - Rosalina" group										
Discorbinella bertheloti							X			
Gavelinopsis praegeri		X					X			
Lamarkina haliotedia			X							
Neodiscorbinella bradyi										
Neodiscorbinella plana			X		X	X	X			
Orbitina williamsoni										
Rosalina globularis				X			1.5			
Rosalina micens		X	1.5	X	X	X		X	X	
"Elphidium" group										
Cribroelphidium albiumbilicatum		3.0	2.5	2.5	3.0	4.0	8.5	23.5	5.0	1.5
Cribroelphidium asklundi	X					1.0		3.0	2.0	
Cribroelphidium bartletti								X		
Cribroelphidium excavatum	48.5	13.0	8.0	35.5	32.0	12.5	25.5	43.5	28.0	30.0
Cribroelphidium frigidum								X		
Cribroelphidium subarcticum						X		X		
Elphidiella groenlandicum										
"Eoeponidella" group										
Altastellerella riveroae			X	X			X	X	X	
Eoeponidella pulchella					X	X	X		X	X
"Epistominella" group										
Eilohedra arctica										
Eilohedra levicula										
Pseudoparrella exigua		X	X	X	X	X			1.0	X
Pseudoparrella subperuviana						X	X		X	
Pseudoparrella takayanagii		X		1.5	1.5	X	1.0			
"Eponides" group										
Eponides pusillus										
Ioanella tumidula										
Nuttalides bradyi										
Oridosalis umbonatus										
"Fissurina" group										
Fissurina aequilabialis		X								
Fissurina annectans		X								
Fissurina circularis					X	X				X
Fissurina cucurbitasema										
Fissurina dancia										
Fissurina fasciata		X								X
Fissurina fimbriata										
Fissurina latistoma										X
Fissurina lucida										
Fissurina marginata								X	X	
Fissurina paula						X				
Fissurina polita										
Fissurina pseudoglobosa				X						
Fissurina pseudoglobosa pseudoglobosa										
Fissurina stewartii									X	
Fissurina subchasteri										X
Fissurina tricarinata			X							
Fissurina sp. 1 (sensu Jones)										
Galwayella subangulosa										
Lagenasolenia infltaperforata			X							
Lagenosolenia lagenoides										
Parafissurina arata										
Parafissurina carinata										
Parafissurina exiguiformis										
Parafissurina fornasini										
Parafissurina himatiostoma			X							
Parafissurina magnilabiata										
Parafissurina obsoleta										
Parafissurina ovata						X				
Parafissurina subquadrata										
Parafissurina tectulostoma										
Pseudoolina fissurinea										
Ventrostoma depressiformis										
Ventrostoma foevigera										
Ventrostoma mitrata										
"Fursenkoina" group										
Fursenkoina fusiformis		X	2.5	X	1.0	1.0	X		X	

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	16	17	18	19	20	21	22	23	24	25
Fursenkoina pauciloculata					X		1.0			
Fursenkoina rotundata		1.0	X		X	1.0	1.0	X		
Rutherfordoides mexicana										
Stainforthia concava										
"Glabratella" group										
Conorbella pulvinata									X	
Glabratellina arcuata										
Glabratellina lauriei		X	X			X		1.5	5.0	X
Glabratellina wrightii					X	X		1.5	1.0	1.0
Glabratellina sp. 1		1.5	1.5		5.0	1.0	X	6.5	14.0	9.0
Heronallenina parva										
Rotaliella chasteri	16.0	3.5	4.0	11.0	8.0	4.0	16.0	X	1.0	3.5
Trichohyalus bartletti								1.5	1.0	
"Gyroidina" group										
Gyroidinoides nipponicus					X		X			
Gyroidinoides quinqueloba					X					
"Lagena" group										
Hyalinonetrion distoma										
Lagena substriata										
Procerlagena gracilis										
"Miliolinella" group										
Miliolinella chukchiensis										
Miliolinella circularis		X		X	X	X	X			
Miliolinella subrotunda					X			X		X
Pyrgo oblonga										
Triloculina dissidens		X				X	X			
Triloculina tricarinata		X								
Triloculina trihedra										
Triloculinella differens										
Triloculinella tegminus									X	
"Nonion" group										
Astrononion stelligerum		X	1.5	X		1.0	X	X		
Haynesina depressula							X			
Haynesina germanica		X	1.5	X		X				1.0
Haynesina orbiculare	1.0			1.5	1.0		1.0	7.0	3.0	X
Laminononion stellatum										
Melonis barleeanus			X				X			
Nonionella lobsannensis						X				
Nonionella stella										
Nonionellina labradorica		4.0	X	X		3.5		X	1.0	1.0
Nonionoides grateloupi			X							
Pulleniella osloensis			X	X		1.0			X	
"Oolina" group										
Cushmanina striatopunctata										
Favulina hexagona										
Favulina melo										
Oolina lineata										
"Polymorphina" group										
Entomorphinoides inalienata										
Globulina minuta										
Globulina priscea		X								
Globotuboides decora							X			
Metapolymorphina ligua										
Pseudopolymorphina novangliae										
"Quinqueloculina" group										
Axiopolina parva					X		X			X
Quinqueloculina akerniana	X									
Quinqueloculina arctica										X
Quinqueloculina crassicarinata										X
Quinqueloculina patagonica				X						
Quinqueloculina seminula	X							X	X	
"Uvigerina" group										
Euuvigerina brunnensis										
Neouvigerina canariensis										
Uvigerina peregrina										

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	16	17	18	19	20	21	22	23	24	25
QUATERNARY PLANKTONICS										
TOTAL NO. SPECIMENS	512	3,584	17,920	96	117	1,856	277	176	184	91
SPLIT COUNTED	(1/128)	(3/256)	(1/512)	(3/32)	(3/32)	(1/64)	(3/32)	(1/16)	(1/8)	(3/16)
Globigerina bulloides	128	170	1,024			64				
Globogerinita uvula		86	1,536				11			
Globorotalia inflata										
Neogloboquadrina deutertri				32			11			5
Turborotalia pachyderma - sinistral	384	1,280	8,192	53	64	1,344	180	144	96	81
-dextral		1,280	3,072	11	53	256	53	32	80	5
Turborotalita quinqueloba - sinistral		256	1,024			192	11		8	
- dextral		512	3,072				11			
REWORKED										
TOTAL NO. SPECIMENS	384	170	512	587	267	192	299	176	24	91
SPLIT COUNTED	(1/128)	(3/256)	(1/512)	(3/32)	(3/32)	(1/64)	(3/32)	(1/16)	(1/8)	(3/16)
Agglutinated foraminifera										
Arenobulimina americana										
Dorothia bulleta										
Pseudotextulariella cretacea										
Spiroplectammina laevis										
Tritaxia pyramidata										
Tritaxia singularis										
Trochammina texana										
Verneuilina muensteri										
Calcareous foraminifera										
Alabamina wilcoxensis										
Allomorphina trochoides										
Anomalinoides harperi										
Astacolus dissonus										
Bandyana greatvalleyensis										
Bolivinita eleyi										
Bolivinopsis papillata										
Brizalina decorrata delicatula										
Brizalina decurrens										
Brizalina incrassata										
Brizalina velascoensis							11			
Brizalina watersi										
Bulimina fabilis										
Cassidella navarroana										5
Cassidella tegulata				11						
Cibicides concentricus										
Cibicides constrictus										
Cibicides subcarinatus										
Dentalina basiplanata										
Dentalina consobrina										
Dentalina crinita										
Dentalina gracilis										
Dentalina lornieana										
Dentalina megalopolitana										
Ellipsonodosaria exilis										
Eouvigerina americana				11						
Eouvigerina austinana										
Eouvigerina excavata					11			32		5
Eouvigerina subsculptura										
Eponides haidingerii										
Gavelinella clemintiana										
Gavelinella henbesti										
Gavelinella intermedia										
Gavelinella monterelensis										
Gavelinella nelsoni				11						
Gavelinella pertusa										
Gavelinella rubinosa										
Gavelinella sandidgei				11						
Gavelinella tennesseensis										
Gavelinella velascoensis	128									
Gyroidinoides depressus										
Gyroidinoides giradianus										
Gyroidinoides globosa										
Gyroidinoides nitidus				64			11		8	
Hanzawaia producta										
Lagena apiculeata										

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	16	17	18	19	20	21	22	23	24	25
Lenticulina navicula										
Lenticulina nuda										
Lenticulina rotulata				11						
Lenticulina subalata										
Lenticulina williamsoni										
Marginulina recta										
Marginulina stephensoni							11			
Nodosaria affinis										
Osangularia cordierana										
Osangularia navarroana				11						
Planularia gemmata										
Pleurostomella austiniana										
Pleurostomella subnodosa										
Praebulimina carseyae							43			
Praebulimina kickapooensis								16		
Praebulimina reussi					32	64	21	32		
Pseudouvigerina cretacea	128									
Pseudouvigerina seligi										
Pullenia quaternaria										
Pyrulina fusiformis										
Pyramidina referrata				21						
Pyramidina rudita										
Pyramidina triangularis					11					
Reusella szajnochae								16		
Rotalipora appennenica										
Siphonina prima										
Stetsioeina pommerana										5
Valvulineria allomorphoides										
Valvulineria cretacea										
Valvulineria umbilicatula										
Globorotalites michelinianus				11						5
Globorotalites subconicus										
Gumbelina glabrans										
Gumbelitrea cretacea				11						
Heterohelix globulosa		85	512	160	181	64	117	16	16	50
Heterohelix pulchra		85								
Heterohelix striata					11					
Planoglobulina taylorana										
Rectogumbelina cretacea										
Rectogumbelina hispida										
planktonics	128			256	21	64	85	64		21

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	26	27	28	29	30	31	32	33	34	36	37
DEPTH (M)	23.01	24.21	25.22	26.43	27.55	28.41	29.46	30.95	32.04	34.4	35.32
TOTAL NOS. QUATERNARY BENTHICS	1,092	2,656	19,712	1,717	5,504	2,064	8,640	2,816	606	262	137
SPLIT COUNTED	(1/4)	(1/8)	(1/64)	(3/16)	(1/16)	(3/16)	(1/32)	(1/8)	(1/2)	/	/
Agglutinated foraminifera											
Adercotryma glomerata											
Hemispherammina bradyi			2.0					1.0	14.0		
Psammosphaera fusca	6.0	X				5.0			3.5		
Recurvoides contortus			X								
"Cribrostomoides" group											
Veleroninoides crassimargo								X			
"Eggerella" group											
Rhumblerella humbolti		X		X		X					
"Reophax" group											
Cuneata arctica										X	
"Saccammina" group											
Lagenammina atlantica											
Saccammina sphaerica											
"Spiroplectammina" group											
Spiroplectammina biformis	X										
Spiroplectammina nitens											
"Trochammina" group											
Lepidodeuterammina ochracea	1.0	1.0			X						
Lepidodeuterammina ochracea sinuosa				X							
Lepidoparatrochammina haynesi			X								
Lepidoparatrochammina lepida						X			X		
Calcareous foraminifera											
Allomorphina fragilis	X										1.0
Angulogerina angulosa							1.0		X	X	
Aubignyana perlucida				X							
Patellina corrugata	2.0	1.0						X	X		1.0
Sphaeroidina bulloides											
Tosaia hanzawaia											1.0
Valvulineria minuta	X	X		X					X		
"Bolivina" group											
Aphenophragmina britannica								X			
Aphenophragmina spathulata	X	X									
Bolivina aenariensis											
Bolivina decussata											
Bolivina mexicana				X				X			
Bolivina vadescens											
Bolivinella pseudopunctata	X	X									
"Buccella" group											
Buccella depressa				1.0				X			1.5
Buccella frigida											
Buccella hannai										X	
Buccella mansfieldi											
Buccella vicksburgensis	1.0	2.0	2.0	1.0	X	2.0	2.0	3.0	1.0	3.5	1.5
Buccella sp. 2	2.0	2.0	3.0	1.0	X	2.0	2.0	2.0	1.5	2.0	1.0
"Bulimina" group											
Bulimina marginata	X								X	X	1.5
Buliminella tenuis								X			
Floresina milletti	X										
Globobulimina auriculata											1.0
"Cassidulina - Islandiella" group											
Cassidulina carinata											
Cassidulina laevigata											
Cassidulina reniforme	25.0	34.0	22.0	23.0	20.5	20.5	24.5	35.5	21.0	24.5	13.0
Cassidulina teretis						X			X		
Islandiella algida	1.0	1.0	X	X	1.0	X	1.0	2.0		X	2.5
Islandiella helenae	4.5	3.0	3.0	2.0	13.5	3.0	5.0	1.0	X	1.5	1.0
Islandiella norcrossi							1.5		X	1.0	
Paracassidulina neocarinata											
"Cibicides" group											
Cibicides corpulentus						3.0	X				
Cibicdes grossa											
Cibicides robertsonianus					X						
Cibicides reflugens	3.0	2.0	3.0	2.0	4.0	2.0	6.5	2.0	4.5	2.0	1.0
Heterolepa subhaidingerii										3.5	
Lobatula lobatalus	X				4.0						1.0
Planulina retia										X	

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	26	27	28	29	30	31	32	33	34	36	37
"Cornuspira" group											
Cornuspira involvens					X						
Cornuspira planorbis				X							
"Discorbis - Rosalina" group											
Discorbinella bertheloti				X							
Gavelinopsis praegeri			X	X							
Lamarkina haliotedia		X									
Neodiscorbinella bradyi											
Neodiscorbinella plana	X		X							X	1.0
Orbitina williamsoni											
Rosalina globularis											
Rosalina micens	4.5	4.0		X	1.5			1.0	1.0	X	2.5
"Elphidium" group											
Cribroelphidium albiumbilicatum	2.0	X	2.0	X	X	1.0	1.0	1.0		1.0	2.0
Cribroelphidium asklundi		X			X	2.0	2.0		2.0		
Cribroelphidium bartletti											
Cribroelphidium excavatum	5.5	29.5	48.5	45.5	41.5	38.5	36.0	20.0	30.5	50.0	55.0
Cribroelphidium frigidum											
Cribroelphidium subarcticum						1.0					
Elphidiella groenlandicum											
"Eoeponidella" group											
Altastellerella riveroae	X	1.0		X		1.0		X	X		
Eoeponidella pulchella	1.0			2.0				X	X		1.5
"Epistominella" group											
Eilohedra arctica	1.0								X		
Eilohedra levicula	X										
Pseudoparrella exigua		X	1.0	X				X			1.0
Pseudoparrella subperuviana					X						
Pseudoparrella takayanagii	2.0		1.0	2.5	X	X	1.5	10.0	4.5	X	
"Eponides" group											
Eponides pusillus											
Ioanella tumidula											
Nuttalides bradyi											
Oridosalis umbonatus											
"Fissurina" group											
Fissurina aequilabialis											
Fissurina annectans											
Fissurina circularis	X										
Fissurina cucurbitasema											
Fissurina dancia											
Fissurina fasciata					X						
Fissurina fimbriata								X			
Fissurina latistoma		X									
Fissurina lucida				X				X			
Fissurina marginata										X	
Fissurina paula											
Fissurina polita											
Fissurina pseudoglobosa								X			
Fissurina pseudoglobosa pseudoglobosa											
Fissurina stewartii											
Fissurina subchasteri											
Fissurina tricarinata											
Fissurina sp. 1 (sensu Jones)											
Galwayella subangulosa											
Lagenasolenia infltaperforata											
Lagenosolenia lagenoides											
Parafissurina arata											
Parafissurina carinata											
Parafissurina exiguiformis											1.0
Parafissurina fornasini											
Parafissurina himatiostoma											
Parafissurina magnilabiata											
Parafissurina obsoleta								X			
Parafissurina ovata											
Parafissurina subquadrata											
Parafissurina tectulostoma											
Pseudoolina fissurinea											
Ventrostoma depressiformis											
Ventrostoma foevigera											
Ventrostoma mitrata											
"Fursenkoina" group											
Fursenkoina fusiformis	7.5	X							X	X	

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	26	27	28	29	30	31	32	33	34	36	37
Fursenkoina pauciloculata	5.5								X		
Fursenkoina rotundata	3.0		X					X	X		
Rutherfordoides mexicana											
Stainforthia concava								X		X	
"Glabratella" group											
Conorbella pulvinata											
Glabratellina arcuata								X	X		
Glabratellina lauriei	X				X	5.0	8.0	2.0			
Glabratellina wrightii	X				1.0	1.0				X	
Glabratellina sp. 1			2.5	2.5		1.5		1.0	X		
Heronallenina parva											
Rotaliella chasteri	10.0	11.0	2.0	6.0	4.5	5.0		5.0	3.5	X	1.5
Trichohyalus bartletti											
"Gyroidina" group											
Gyroidinoides nipponicus											
Gyroidinoides quinqueloba	X							X			1.0
"Lagena" group											
Hyalinonetrion distoma	X										
Lagena substriata											
Procerlagena gracilis											
"Miliolinella" group											
Miliolinella chukchiensis											
Miliolinella circularis			X		X	X					
Miliolinella subrotunda				X							
Pyrgo oblonga								X	X		
Triloculina dissidens											
Triloculina tricarinata											
Triloculina trihedra			X								
Triloculinella differens											
Triloculinella tegminus	X						X		X		
"Nonion" group											
Astrononion stelligerum	1.0					X	2.0	X			
Haynesina depressula				X							
Haynesina germanica			X	2.5		1.0		3.5			
Haynesina orbiculare	1.0	2.0	2.5		4.5	3.0	2.0	X	X	4.0	1.5
Laminononion stellatum							2.0	X	X		
Melonis barleeanus		X									
Nonionella lobsannensis	X								X		
Nonionella stella	X										
Nonionellina labradorica	3.0	X	1.0	X	1.0	X		1.0	5.0	X	3.5
Nonionoides grateloupi											
Pulleniella osloensis	1.0	1.0						X		X	
"Oolina" group											
Cushmanina striatopunctata											
Favulina hexagona											
Favulina melo											
Oolina lineata											1.0
"Polymorphina" group											
Entomorphinoides inalienata											
Globulina minuta											
Globulina priscea											
Globotuboides decora											
Metapolymorphina ligua											
Pseudopolymorphina novangliae											
"Quinqueloculina" group											
Axiopolina parva											1.0
Quinqueloculina akerniana											
Quinqueloculina arctica	1.0	X				X					
Quinqueloculina crassicarinata											
Quinqueloculina patagonica							X				
Quinqueloculina seminula							X				
"Uvigerina" group											
Euuvigerina brunnensis											
Neouvigerina canariensis											
Uvigerina peregrina											

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	26	27	28	29	30	31	32	33	34	36	37
QUATERNARY PLANKTONICS											
TOTAL NO. SPECIMENS	80	280	1,536	208	368	112	448	208	40	4	9
SPLIT COUNTED	(1/4)	(1/8)	(1/64)	(3/16)	(1/16)	(3/16)	(1/32)	(1/8)	(1/2)	/	/
Globigerina bulloides							64	8	4		
Globogerinita uvula	36	40	64	9		5	32	32			
Globorotalia inflata											
Neogloboquadrina deutertri						5	32	24	2		1
Turborotalia pachyderma - sinistral	16	216	1,408	148	288	70	224	88	10	2	4
-dextral	24	16	64	46	80	16	96	48	12	1	4
Turborotalita quinqueloba - sinistral	4	8		5		11		8		1	
- dextral						5			4		
REWORKED											
TOTAL NO. SPECIMENS	260	112	2,176	251	352	181	3,136	912	830	851	860
SPLIT COUNTED	(1/4)	(1/8)	(1/64)	(3/16)	(1/16)	(3/16)	(1/32)	(1/8)	(1/2)	/	(1/2)
Agglutinated foraminifera											
Arenobulimina americana											
Dorothia bulleta							32				
Pseudotextulariella cretacea											
Spiroplectammina laevis										1	
Tritaxia pyramidata										2	
Tritaxia singularis										1	
Trochammina texana											
Verneuilina muensteri										1	6
Calcareous foraminifera											
Alabamina wilcoxensis											
Allomorphina trochoides											2
Anomalinoides harperi											
Astacolus dissonus											
Bandyana greatvalleyensis											
Bolivinita eleyi											
Bolivinopsis papillata											
Brizalina decorrata delicatula	4									1	2
Brizalina decurrens											
Brizalina incrassata										1	
Brizalina velascoensis											
Brizalina watersi											2
Bulimina fabilis											
Cassidella navarroana											
Cassidella tegulata											
Cibicides concentricus											
Cibicides constrictus											4
Cibicides subcarinatus		8								1	
Dentalina basiplanata											
Dentalina consobrina										2	
Dentalina crinita							32				
Dentalina gracilis									2		
Dentalina lornieana								8		2	
Dentalina megalopolitana											
Ellipsonodosaria exilis											
Eouvigerina americana				5		5		24	2	20	20
Eouvigerina austinana											
Eouvigerina excavata			64							2	
Eouvigerina subsculptura										2	
Eponides haidingerii	4					12					
Gavelinella clemintiana	12										14
Gavelinella henbesti											2
Gavelinella intermedia											
Gavelinella monterelensis				16			64	8		18	40
Gavelinella nelsoni	4							16			
Gavelinella pertusa										15	10
Gavelinella rubinosa										1	
Gavelinella sandidgei	8	8	64					16			2
Gavelinella tennesseensis										3	
Gavelinella velascoensis							64				
Gyroidinoides depressus	16			9	16	21	128	8	2		12
Gyroidinoides giradianus											
Gyroidinoides globosa											4
Gyroidinoides nitidus			128	5						16	4
Hanzawaia producta											
Lagena apiculeata										1	

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	26	27	28	29	30	31	32	33	34	36	37
Lenticulina navicula											
Lenticulina nuda											
Lenticulina rotulata									4	1	
Lenticulina subalata											
Lenticulina williamsoni											
Marginulina recta											
Marginulina stephensoni											
Nodosaria affinis										1	2
Osangularia cordierana										2	2
Osangularia navarroana									2	11	
Planularia gemmata											2
Pleurostomella austiniana											
Pleurostomella subnodosa											
Praebulimina carseyae						21					
Praebulimina kickapooensis											
Praebulimina reussi	12	8	448	16	48	5	160	72	14	57	36
Pseudouvigerina cretacea											
Pseudouvigerina seligi											
Pullenia quaternaria											
Pyrulina fusiformis											
Pyramidina referrata						5		24			
Pyramidina rudita											
Pyramidina triangularis				5			64				
Reusella szajnochae							32			2	2
Rotalipora appennenica											
Siphonina prima											
Stetsioeina pommerana										4	
Valvulineria allomorphoides											2
Valvulineria cretacea											
Valvulineria umbilicatula										6	
Globorotalites michelinianus					16	11	64	8	6	8	30
Globorotalites subconicus											
Gumbelina glabrans											
Gumbelitrea cretacea	4				16			24			
Heterohelix globulosa	96	40	768	92	112	48	384	440	68	323	226
Heterohelix pulchra	4	8							2	9	8
Heterohelix striata	4									1	10
Planoglobulina taylorana											4
Rectogumbelina cretacea											
Rectogumbelina hispida										7	4
planktonics	92	40	704	103	144	53	544	264	122	330	402

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	38	39	40	41	42	43	44	45	46	47	48
DEPTH (M)	36.17	37.31	38.44	39.34	40.29	41.02	42.69	44.23	47.51	49.12	50.24
TOTAL NOS. QUATERNARY BENTHICS	989	11	233	63	280	827	676	870	129	782	4,192
SPLIT COUNTED	(5/8)	/	/	/	/	(3/8)	(1/2)	(1/2)	/	(1/2)	(3/32)
Agglutinated foraminifera											
Adercotryma glomerata											
Hemispherammina bradyi											
Psammosphaera fusca											
Recurvoides contortus											
"Cribrostomoides" group											
Veleroninoides crassimargo											
"Eggerella" group											
Rhumblerella humbolti											
"Reophax" group											
Cuneata arctica											
"Saccammina" group											
Lagenammina atlantica											
Saccammina sphaerica						2.0					
"Spiroplectammina" group											
Spiroplectammina biformis								X			
Spiroplectammina nitens								X			
"Trochammina" group											
Lepidodeuterammina ochracea			1.0				1.0		1.0	1.0	X
Lepidodeuterammina ochracea sinuosa	X										
Lepidoparatrochammina haynesi											
Lepidoparatrochammina lepida											
Calcareous foraminifera											
Allomorphina fragilis						X					
Angulogerina angulosa	X										X
Aubignyana perlucida											
Patellina corrugata	X		1.5			X	X	X			
Sphaeroidina bulloides											
Tosaia hanzawaia							1.0	X			
Valvulineria minuta											
"Bolivina" group											
Aphenophragmina britannica											
Aphenophragmina spathulata	X				X		X	X			
Bolivina aenariensis											
Bolivina decussata			X								
Bolivina mexicana											
Bolivina vadescens										X	
Bolivinella pseudopunctata	X				1.0	X		1.0	1.0		
"Buccella" group											
Buccella depressa			1.0		X						X
Buccella frigida											
Buccella hannai											
Buccella mansfieldi			1.0								
Buccella vicksburgensis	2.0			P	1.5	1.5	3.0	6.0	5.0	3.5	2.0
Buccella sp. 2	X		2.0	P	X	2.0		2.0		1.0	2.5
"Bulimina" group											
Bulimina marginata					X	1.0		1.0		X	1.0
Buliminella tenuis						X				X	
Floresina milletti											
Globobulimina auriculata											
"Cassidulina - Islandiella" group											
Cassidulina carinata											
Cassidulina laevigata											
Cassidulina reniforme	32.0		25.0	D	20.5	14.0	23.0	25.0	22.0	24.0	28.0
Cassidulina teretis						X					
Islandiella algida	2.0		1.5	P	2.0	X	1.0	1.0		X	2.0
Islandiella helenae			1.5		5.0	2.5	1.0	X	1.0	2.5	2.0
Islandiella norcrossi	X		1.0		1.0	X	1.0	X			X
Paracassidulina neocarinata	X										
"Cibicides" group											
Cibicides corpulentus											
Cibicdes grossa						X					
Cibicides robertsonianus											
Cibicides refulgens	6.0		7.0	P	5.5	5.5	3.5	3.0	6.0	3.5	4.0
Heterolepa subhaidingerii				P	X		2.5	X		X	
Lobatula lobatalus					X						X
Planulina retia											

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	38	39	40	41	42	43	44	45	46	47	48
"Cornuspira" group											
Cornuspira involvens											
Cornuspira planorbis											
"Discorbis - Rosalina" group											
Discorbinella bertheloti						X					
Gavelinopsis praegeri		P						1.0		X	
Lamarkina haliotedia											X
Neodiscorbinella bradyi											
Neodiscorbinella plana								X			
Orbitina williamsoni											
Rosalina globularis			X		X	1.0	1.0			X	
Rosalina micens			1.5	P	2.0	1.5	1.0	1.5	3.0	X	2.5
"Elphidium" group											
Cribroelphidium albiumbilicatum	2.0		X			X	X	X			
Cribroelphidium asklundi	X				X	X			1.0		X
Cribroelphidium bartletti											
Cribroelphidium excavatum	30.0	D	36.0	C	40.0	44.5	42.0	23.0	31.5	37.5	40.5
Cribroelphidium frigidum											
Cribroelphidium subarcticum	1.0										
Elphidiella groenlandicum											X
"Eoeponidella" group											
Altastellerella riveroae											X
Eoeponidella pulchella					X		1.0		3.0	X	X
"Epistominella" group											
Eilohedra arctica					X			X			
Eilohedra levicula			X					X			
Pseudoparrella exigua	1.0		2.0	P	X	1.0		2.5			
Pseudoparrella subperuviana											X
Pseudoparrella takayanagii	X		2.0		2.0	X	9.0	6.0	3.5	12.0	2.5
"Eponides" group											
Eponides pusillus								X			
Ioanella tumidula			1.0		X	X	1.5	2.0		1.0	
Nuttalides bradyi			X								
Oridosalis umbonatus								X		X	
"Fissurina" group											
Fissurina aequilabialis											X
Fissurina annectans											
Fissurina circularis					X	X					
Fissurina cucurbitasema			X			X					
Fissurina dancia											
Fissurina fasciata											
Fissurina fimbriata											
Fissurina latistoma						X					
Fissurina lucida											
Fissurina marginata				P	X						
Fissurina paula											
Fissurina polita											
Fissurina pseudoglobosa	X							X			
Fissurina pseudoglobosa pseudoglobosa											
Fissurina stewartii					X					1.0	
Fissurina subchasteri											
Fissurina tricarinata											
Fissurina sp. 1 (sensu Jones)	X										
Galwayella subangulosa											
Lagenasolenia infltaperforata											
Lagenosolenia lagenoides											
Parafissurina arata											
Parafissurina carinata											
Parafissurina exiguiformis											
Parafissurina fornasini											
Parafissurina himatiostoma					X	X					
Parafissurina magnilabiata											
Parafissurina obsoleta											
Parafissurina ovata											
Parafissurina subquadrata	X										
Parafissurina tectulostoma					X						
Pseudoolina fissurinea											
Ventrostoma depressiformis											
Ventrostoma foevigera									1.0		
Ventrostoma mitrata											
"Fursenkoina" group											
Fursenkoina fusiformis			2.0		X	X		3.0	1.0	X	X

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	38	39	40	41	42	43	44	45	46	47	48
Fursenkoina pauciloculata											
Fursenkoina rotundata	X				1.0	1.0		1.0	1.0	X	
Rutherfordoides mexicana						X					
Stainforthia concava										X	
"Glabratella" group											
Conorbella pulvinata											
Glabratellina arcuata											X
Glabratellina lauriei	X				X				6.0		
Glabratellina wrightii	1.0		1.0								
Glabratellina sp. 1	6.0		1.0					1.5			1.0
Heronallenina parva											
Rotaliella chasteri	4.0		2.0	P	2.0	3.5	X	3.0	6.0	2.0	6.5
Trichohyalus bartletti											
"Gyroidina" group											
Gyroidinoides nipponicus			1.5			X	1.5	1.0		1.0	
Gyroidinoides quinqueloba	X	P			X		2.0	1.0	1.0	1.5	X
"Lagena" group											
Hyalinonetrion distoma											
Lagena substriata	X										
Procerlagena gracilis											
"Miliolinella" group											
Miliolinella chukchiensis											
Miliolinella circularis							X	X			
Miliolinella subrotunda						X					
Pyrgo oblonga											
Triloculina dissidens								X			
Triloculina tricarinata											
Triloculina trihedra											
Triloculinella differens											
Triloculinella tegminus											
"Nonion" group											
Astrononion stelligerum	X				X	1.0	X	1.0			
Haynesina depressula											
Haynesina germanica							1.0				
Haynesina orbiculare	1.0		5.0	P	3.0	1.0	1.0	1.0	1.0	2.5	1.0
Laminononion stellatum	X										
Melonis barleeanus						X			1.0		X
Nonionella lobsannensis											
Nonionella stella											
Nonionellina labradorica	3.0		2.5	P	2.0	2.0	1.0	3.5	4.0	X	X
Nonionoides grateloupi											
Pulleniella osloensis			1.5		1.5	1.0	1.0	2.0		1.0	X
"Oolina" group											
Cushmanina striatopunctata											
Favulina hexagona											
Favulina melo											
Oolina lineata											
"Polymorphina" group											
Entomorphinoides inalienata								X			
Globulina minuta							X				
Globulina priscea											
Globotuboides decora											
Metapolymorphina ligua					X						
Pseudopolymorphina novangliae											
"Quinqueloculina" group											
Axiopolina parva										X	X
Quinqueloculina akerniana											
Quinqueloculina arctica											
Quinqueloculina crassicarinata											
Quinqueloculina patagonica											
Quinqueloculina seminula											
"Uvigerina" group											
Euuvigerina brunnensis											
Neouvigerina canariensis						X					
Uvigerina peregrina					X		X				

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	38	39	40	41	42	43	44	45	46	47	48
QUATERNARY PLANKTONICS											
TOTAL NO. SPECIMENS	16	1	16	3	22	83	28	64	11	46	352
SPLIT COUNTED	(5/8)	/	/	/	/	(3/8)	(1/2)	(1/2)	/	(1/2)	(1/16)
Globigerina bulloides	5				1	4		6	1	2	
Globogerinita uvula			1			6		22	1	10	
Globorotalia inflata											
Neogloboquadrina deutertri	1		1		7	20		8			64
Turborotalia pachyderma - sinistral	8		8	1	6	20	14	22	7	24	192
-dextral	1	1	4	1	8	24	6	18	2	6	80
Turborotalita quinqueloba - sinistral			1			4	2	4			16
- dextral	1		1	1		3	6	2		4	
REWORKED											
TOTAL NO. SPECIMENS	131	80	7,200	109	3,344	12,144	8,624	5,376	71	4,520	13,024
SPLIT COUNTED	(5/8)	/	(1/16)	/	(1/16)	(1/16)	(1/16)	(1/16)	/	(1/8)	(1/16)
Agglutinated foraminifera											
Arenobulimina americana											
Dorothia bulleta											
Pseudotextulariella cretacea	2										16
Spiroplectammina laevis											
Tritaxia pyramidata						16		16			48
Tritaxia singularis	2										
Trochammina texana			16								
Verneuilina muensteri	2				16	32	96	96			48
Calcareous foraminifera											
Alabamina wilcoxensis		1									
Allomorphina trochoides							16				
Anomalinoides harperi											
Astacolus dissonus			16								
Bandyana greatvalleyensis										8	
Bolivinita eleyi											
Bolivinopsis papillata						16					
Brizalina decorrata delicatula			32			16					32
Brizalina decurrens											16
Brizalina incrassata								16			16
Brizalina velascoensis											
Brizalina watersi											
Bulimina fabilis										8	
Cassidella navarroana											
Cassidella tegulata			32		16		16			8	16
Cibicides concentricus										40	
Cibicides constrictus						16					
Cibicides subcarinatus			16								
Dentalina basiplanata											
Dentalina consobrina											
Dentalina crinita											
Dentalina gracilis						16					
Dentalina lornieana											
Dentalina megalopolitana							16				
Ellipsonodosaria exilis											
Eouvigerina americana	2	1	48	2	128	288	128	96	1	88	640
Eouvigerina austinana			16								
Eouvigerina excavata											
Eouvigerina subsculptura			16								
Eponides haidingerii											16
Gavelinella clemintiana	5	1		4		32		48	1		32
Gavelinella henbesti						48		16			48
Gavelinella intermedia											
Gavelinella monterelensis	3	5	48	2		80	48	32	4		48
Gavelinella nelsoni					32	48			1	48	16
Gavelinella pertusa					16		48			8	112
Gavelinella rubinosa											
Gavelinella sandidgei			160		16	64	80			16	48
Gavelinella tennesseensis			16						1		
Gavelinella velascoensis											
Gyroidinoides depressus		2		3	112	208	160	112	2	88	112
Gyroidinoides giradianus				1			16				
Gyroidinoides globosa								32	1		
Gyroidinoides nitidus			208		32	80	80	80	1		160
Hanzawaia producta		1									
Lagena apiculeata											

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	38	39	40	41	42	43	44	45	46	47	48
Lenticulina navicula											16
Lenticulina nuda				2							
Lenticulina rotulata	2										32
Lenticulina subalata											
Lenticulina williamsoni				1							
Marginulina recta						16					
Marginulina stephensoni											
Nodosaria affinis											
Osangularia cordierana		1		1	32	48					16
Osangularia navarroana			32						1		
Planularia gemmata											
Pleurostomella austiniana											
Pleurostomella subnodosa											
Praebulimina carseyae											16
Praebulimina kickapooensis	2										
Praebulimina reussi	5	7	336	8	16	624	400	432	6	312	752
Pseudouvigerina cretacea											
Pseudouvigerina seligi										8	
Pullenia quaternaria											16
Pyrulina fusiformis						16					
Pyramidina referrata	2			2		128	80	16		64	16
Pyramidina rudita				1							48
Pyramidina triangularis		2									16
Reusella szajnochae								16	1		16
Rotalipora appennenica						48		16			16
Siphonina prima											
Stetsioeina pommerana							16			24	32
Valvulineria allomorphoides											
Valvulineria cretacea		1									
Valvulineria umbilicatula	6										
Globorotalites michelinianus	3	6	80	11	16	144	128		2	72	160
Globorotalites subconicus											
Gumbelina glabrans											
Gumbelitrea cretacea		1					16			40	
Heterohelix globulosa	40	21	2,752	27	1,408	4,526	2,256	1,808	28	1,680	4,784
Heterohelix pulchra	2		192		112	2,032	1,120	32		72	192
Heterohelix striata				1		176				32	16
Planoglobulina taylorana											16
Rectogumbelina cretacea				1							
Rectogumbelina hispida			32			16	80	16		16	64
planktonics	51	30	6,880	43	1,392	5,024	3,824	2,496	16	1,888	5,376

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	49	51	52	53	54	55	56
DEPTH (M)	50.91	56.31	61.53	66.76	71.53	73.02	74.87
TOTAL NOS. QUATERNARY BENTHICS	4,928	5,728	4,688	4,464	4,528	5,773	4,915
SPLIT COUNTED	(1/16)	(1/16)	(1/16)	(1/16)	(1/16)	(5/64)	(5/64)
Agglutinated foraminifera							
Adercotryma glomerata							
Hemispherammina bradyi							
Psammosphaera fusca							
Recurvoides contortus							
"Cribrostomoides" group							
Veleroninoides crassimargo							
"Eggerella" group							
Rhumblerella humbolti							
"Reophax" group							
Cuneata arctica							
"Saccammina" group							
Lagenammina atlantica							
Saccammina sphaerica							
"Spiroplectammina" group							
Spiroplectammina biformis							
Spiroplectammina nitens							
"Trochammina" group							
Lepidodeuterammina ochracea							X
Lepidodeuterammina ochracea sinuosa							
Lepidoparatrochammina haynesi							
Lepidoparatrochammina lepida				X			
Calcareous foraminifera							
Allomorphina fragilis							
Angulogerina angulosa	X						
Aubignyana perlucida						X	
Patellina corrugata		1.0		1.0	X		1.0
Sphaeroidina bulloides							
Tosaia hanzawaia							
Valvulineria minuta		X			X		
"Bolivina" group							
Aphenophragmina britannica							
Aphenophragmina spathulata		X	X			X	X
Bolivina aenariensis							
Bolivina decussata							
Bolivina mexicana							
Bolivina vadescens							
Bolivinella pseudopunctata	X			1.0	X	X	
"Buccella" group							
Buccella depressa		X				X	X
Buccella frigida							
Buccella hannai				X		1.0	X
Buccella mansfieldi					X		1.0
Buccella vicksburgensis	1.5	1.5	2.0	2.0	1.5	2.5	2.0
Buccella sp. 2	1.0	1.0	1.0	3.0	X	3.0	1.0
"Bulimina" group							
Bulimina marginata	X		X	X	X	X	X
Buliminella tenuis						X	
Floresina milletti							
Globobulimina auriculata							
"Cassidulina - Islandiella" group							
Cassidulina carinata				X			
Cassidulina laevigata				X			
Cassidulina reniforme	17.0	24.0	22.0	19.0	19.0	35.5	20.0
Cassidulina teretis							
Islandiella algida	X	X	1.0	2.0	X	2.0	X
Islandiella helenae	1.5	2.0	1.5	2.5	1.5	1.0	1.5
Islandiella norcrossi		X	X		2.0	X	
Paracassidulina neocarinata							
"Cibicides" group							
Cibicides corpulentus				1.0			
Cibicdes grossa							
Cibicides robertsonianus							
Cibicides reflugens	4.5	3.0	5.0	1.0	3.5	3.0	4.5
Heterolepa subhaidingerii				1.0			
Lobatula lobatalus		X	1.0				
Planulina retia							

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	49	51	52	53	54	55	56
"Cornuspira" group							
Cornuspira involvens							
Cornuspira planorbis							
"Discorbis - Rosalina" group							
Discorbinella bertheloti							
Gavelinopsis praegeri						X	
Lamarkina haliotedia							X
Neodiscorbinella bradyi							
Neodiscorbinella plana	X	X				X	
Orbitina williamsoni							
Rosalina globularis							
Rosalina micens	X	1.0	X	1.0	1.0	2.0	
"Elphidium" group							
Cribroelphidium albiumbilicatum	X	X	X	1.0	X	1.0	
Cribroelphidium asklundi		1.5	1.0		X	X	1.5
Cribroelphidium bartletti					X		
Cribroelphidium excavatum	54.0	50.0	54.5	56.0	57.5	31.0	53.5
Cribroelphidium frigidum							
Cribroelphidium subarcticum							
Elphidiella groenlandicum	X	X					
"Eoeponidella" group							
Altastellerella riveroae							
Eoeponidella pulchella	X	1.0	X		X	1.0	
"Epistominella" group							
Eilohedra arctica							
Eilohedra levicula							
Pseudoparrella exigua	X		X	X		X	
Pseudoparrella subperuviana				X			
Pseudoparrella takayanagii	2.0		1.5	2.0	1.5	1.0	1.5
"Eponides" group							
Eponides pusillus							
Ioanella tumidula			1.0				X
Nuttalides bradyi							X
Oridosalis umbonatus							
"Fissurina" group							
Fissurina aequilabialis		X	X			X	
Fissurina annectans							
Fissurina circularis						X	
Fissurina cucurbitasema							
Fissurina dancia				X			
Fissurina fasciata							
Fissurina fimbriata							
Fissurina latistoma							
Fissurina lucida							
Fissurina marginata							
Fissurina paula							
Fissurina polita				1.0			
Fissurina pseudoglobosa							
Fissurina pseudoglobosa pseudoglobosa							X
Fissurina stewartii	X						
Fissurina subchasteri							
Fissurina tricarinata							
Fissurina sp. 1 (sensu Jones)							
Galwayella subangulosa							
Lagenasolenia infltaperforata							
Lagenosolenia lagenoides							
Parafissurina arata							
Parafissurina carinata		X					
Parafissurina exiguiformis							
Parafissurina fornasini							
Parafissurina himatiostoma						X	
Parafissurina magnilabiata						X	
Parafissurina obsoleta							
Parafissurina ovata							
Parafissurina subquadrata							
Parafissurina tectulostoma							
Pseudoolina fissurinea							
Ventrostoma depressiformis							
Ventrostoma foevigera				X	X		
Ventrostoma mitrata							
"Fursenkoina" group							
Fursenkoina fusiformis			X			1.0	

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	49	51	52	53	54	55	56
Fursenkoina pauciloculata							
Fursenkoina rotundata	X	X				X	
Rutherfordoides mexicana							
Stainforthia concava		X					
"Glabratella" group							
Conorbella pulvinata							
Glabratellina arcuata							
Glabratellina lauriei			1.0		X		
Glabratellina wrightii					1.0		
Glabratellina sp. 1	1.0		1.0	3.0		1.5	
Heronallenina parva							
Rotaliella chasteri	2.5	4.0	1.0		2.0	5.0	3.0
Trichohyalus bartletti							
"Gyroidina" group							
Gyroidinoides nipponicus							
Gyroidinoides quinqueloba		X	1.0				
"Lagena" group							
Hyalinonetrion distoma							
Lagena substriata							
Procerlagena gracilis							
"Miliolinella" group							
Miliolinella chukchiensis							
Miliolinella circularis							
Miliolinella subrotunda							
Pyrgo oblonga							
Triloculina dissidens							
Triloculina tricarinata							
Triloculina trihedra							
Triloculinella differens					X		
Triloculinella tegminus							
"Nonion" group							
Astrononion stelligerum	1.0		X	1.0	X	2.0	1.0
Haynesina depressula							
Haynesina germanica						X	
Haynesina orbiculare	4.0	3.5	1.5	1.0	1.0	X	2.0
Laminononion stellatum							
Melonis barleeanus		X					X
Nonionella lobsannensis							
Nonionella stella							
Nonionellina labradorica	2.0	1.5	1.0	2.0	1.0	2.0	1.5
Nonionoides grateloupi							
Pulleniella osloensis				1.0	X		
"Oolina" group							
Cushmanina striatopunctata							
Favulina hexagona							
Favulina melo							
Oolina lineata							
"Polymorphina" group							
Entomorphinoides inalienata							
Globulina minuta							
Globulina priscea							
Globotuboides decora							
Metapolymorphina ligua							
Pseudopolymorphina novangliae							
"Quinqueloculina" group							
Axiopolina parva				X			
Quinqueloculina akerniana							
Quinqueloculina arctica							
Quinqueloculina crassicarinata							
Quinqueloculina patagonica							
Quinqueloculina seminula							X
"Uvigerina" group							
Euuvigerina brunnensis							
Neouvigerina canariensis							
Uvigerina peregrina							

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	49	51	52	53	54	55	56
QUATERNARY PLANKTONICS							
TOTAL NO. SPECIMENS	1,280	96	144	32	240	180	64
SPLIT COUNTED	(1/64)	(1/16)	(1/16)	(1/16)	(1/16)	(5/64)	(5/64)
Globigerina bulloides	64						
Globogerinita uvula	128	16			16	26	14
Globorotalia inflata					16		
Neogloboquadrina deutertri	192		48	16	64		
Turborotalia pachyderma - sinistral	576	64	32		64	90	26
-dextral	320	16	48	16	48	51	26
Turborotalita quinqueloba - sinistral			16		16	13	
- dextral					16		
REWORKED							
TOTAL NO. SPECIMENS	19,008	18,048	9,632	8,592	7,616	4,774	9,312
SPLIT COUNTED	(1/64)	(1/32)	(1/16)	(1/16)	(1/32)	(5/64)	(1/32)
Agglutinated foraminifera							
Arenobulimina americana			16			13	
Dorothia bulleta							
Pseudotextulariella cretacea			16				
Spiroplectammina laevis							
Tritaxia pyramidata	128	32	32		32	38	64
Tritaxia singularis							
Trochammina texana							
Verneuilina muensteri	256	128	160		32	38	32
Calcareous foraminifera							
Alabamina wilcoxensis							
Allomorphina trochoides							
Anomalinoides harperi		32				13	
Astacolus dissonus							
Bandyana greatvalleyensis							
Bolivinita eleyi	64					13	
Bolivinopsis papillata							
Brizalina decorrata delicatula	64			16	32		
Brizalina decurrens							
Brizalina incrassata				16			
Brizalina velascoensis							
Brizalina watersi							
Bulimina fabilis							
Cassidella navarroana							
Cassidella tegulata		64	32	16			
Cibicides concentricus							
Cibicides constrictus							
Cibicides subcarinatus				32			
Dentalina basiplanata		32					
Dentalina consobrina		32					
Dentalina crinita							
Dentalina gracilis							
Dentalina lornieana			16				
Dentalina megalopolitana							
Ellipsonodosaria exilis				16			
Eouvigerina americana	320	352	240	192	224	128	160
Eouvigerina austinana							
Eouvigerina excavata	128						
Eouvigerina subsculptura				64			
Eponides haidingerii		96					
Gavelinella clemintiana	128	64	16	16	96	13	
Gavelinella henbesti						102	
Gavelinella intermedia						13	
Gavelinella monterelensis	128	64	32	272	258	38	192
Gavelinella nelsoni	64	32			128		96
Gavelinella pertusa		32	64	32			64
Gavelinella rubinosa				16			
Gavelinella sandidgei		32	64				64
Gavelinella tennesseensis							
Gavelinella velascoensis							
Gyroidinoides depressus	192	32	64	96	160	77	768
Gyroidinoides giradianus							
Gyroidinoides globosa							
Gyroidinoides nitidus	256	352	240	96	64	77	64
Hanzawaia producta							
Lagena apiculeata							

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

SAMPLE NUMBER	49	51	52	53	54	55	56
Lenticulina navicula							
Lenticulina nuda							
Lenticulina rotulata					32		
Lenticulina subalata	64						
Lenticulina williamsoni							
Marginulina recta							
Marginulina stephensoni	64	96				13	
Nodosaria affinis							
Osangularia cordierana		96	160				
Osangularia navarroana				96			
Planularia gemmata							
Pleurostomella austiniana			16				
Pleurostomella subnodosa				16			
Praebulimina carseyae						26	
Praebulimina kickapooensis							
Praebulimina reussi	1,792	1,152	768	288	288	346	544
Pseudouvigerina cretacea		32					
Pseudouvigerina seligi				16			
Pullenia quaternaria							
Pyrulina fusiformis							
Pyramidina referrata	192	96	48	16	32		32
Pyramidina rudita			48				
Pyramidina triangularis		64				13	
Reusella szajnochae	64					13	
Rotalipora appennenica	64	32	16			64	
Siphonina prima				32			
Stetsioeina pommerana	128	96	16				
Valvulineria allomorphoides				16			
Valvulineria cretacea							
Valvulineria umbilicatula							
Globorotalites michelinianus		480	80	96	128	102	64
Globorotalites subconicus			192	96			288
Gumbelina glabrans						13	
Gumbelitrea cretacea	64	96	16	16	32	13	
Heterohelix globulosa	7,168	6,176	3,424	2,860	2,912	1,702	3,616
Heterohelix pulchra	192	352	112	112	160	77	128
Heterohelix striata		32		48	96	26	
Planoglobulina taylorana			16		32		32
Rectogumbelina cretacea							
Rectogumbelina hispida	192		64	16	32	51	
planktonics	7,232	7,840	3,664	3,910	2,848	1,754	3,488

Table 4: Foraminiferal data, BH 2, Halibut Channel. Data for the Quaternary benthonic species reported as percent occurrence, actual numbers given for the Quaternary planktonic and reworked species. X < 1%.

Foraminiferal results

Foraminfera in modern glacial marine environments

Both *C. excavatum* and *C. reniforme* dominated faunas are present in modern ice-marginal to ice-proximal glacial regimes and the occurrences of each need to be clearly distinguished. The crucial factor may be the mixing of melt- and oceanic waters. *C. reniforme* is reported in modern ice-marginal to ice-proximal glacial regimes, accompanied by an agglutinated fauna (Elverhøi et al., 1980; Schafer and Cole, 1986) in environments where there is deeper water, high SPM, salinities > 33 $^{o}/_{oo}$ and mixing of melt- and oceanic waters. Ice-distally *C. reniforme* may be replaced by *L. lobatalus*, particularily if the substrate becomes coarser, water shallower, current strength increases and SPM decreases (Nagy, 1965; Schafer and Cole, 1986; Hald et al., 1994; Jennings and Helgadóttir, 1995; Haynes et al., 1995). *C. reniforme* is found in modern environments, as dominant component in benthic assemblages, on the Norwegian Slope, in water depths of 700-1200 m, and salinities of 34-35 $^{o}/_{oo}$, in an area of homohaline deepwater of the Norwegian Sea (Sejrup et al., 1981). *C. excavatum* is reported dominating ice-marginal, ice-proximal and ice-distal glacial marine environments; it appears to dominate in very shallow water, in salinities < 33 $^{o}/_{oo}$ and where there is no mixing of melt- and oceanic waters (Nagy, 1965; Hansen and Knudsen, 1992; Hald et al., 1994). Miller et al. (1995b) have suggested that *C. excavatum* dominated assemblages can represent ice-distal (*C. excavatum* percent occurrence 25-60%), ice-proximal (60-88%) and possibly ice-marginal / floating glacier-tongue front (88-94%) environments in isolated basins (i.e. Emerald Basin, Scotian Shelf) where there is no mixing of melt- and oceanic waters; and if there is high SPM and salinities < 33 $^{o}/_{oo}$. Long et al. (1986), Hald and Vorren (1987), Sejrup et al. (1987), Hald et al. (1994) and Haynes et al. (1995) all suggest a dominance of *C. excavatum* indicates meltwater events. Seidenkrantz and Knudsen (1993) suggest that the morphology of *C . excavatum* may be a salinity (and meltwater) indicator. Other evidence suggests that *C. albiumbilicatum* represents significant meltwater influxes (Weiss, 1954; Mangerud et al., 1981; Knudsen, 1982; Bergsten and Denngård, 1988; Guilbault, 1989, 1993) particularily in channelized areas (Knudsen, 1978, 1993; Jensen and Knudsen, 1988; Miller, 1989a, 1989b, 1993; Knudsen and Sejrup, 1993).

Foraminifera: environmental interpretation and correlation to the lithostratigraphy

Assemblage 1a in BH 4 is dominated by *I. algida.* Sen Gupta and McMullen (1969) and Sen Gupta (1971) have found this species the most common species on the sandy areas of the Tail of the Grand Banks and Miller (in prep.) has found it on Grand Bank. Williamson (1983) and Williamson et al. (1984) reported an assemblage completely dominated by this species (their assemblage 7) prevailent on isolated outer banks and isolated depressions on the Scotian Shelf, where it replaces a *Cibicides* assemblage (their assemblage 2). Williamson et al. (1984) attribute this replacement with conditions of higher salinity and an increase in the percent gravel. It also dominates raised interstadial assemblages found in the eastern Canadian Arctic (Feyling-Hanssen, 1976a, 1980a,1980b) and has been found as common in the near surface of the Celtic Sea (Scourse et al., 1990). Assemblage 1a is found in the Adolphus Sand, (A / I) a fine-grained sand with a mud component, found in water depths below the base of the transgression and subject to post transgressive oceanographic processes. The source sediment is Downing Silt and Grand Banks Drift.

Assemblage 1b (Adolphus Sand, BH 2) is marked by an increase in the percent occurrence of *"Cibicides" spp.*, in particular *C. corpulentus, C. reflugens* and *L. lobatalus;* these species are interpreted as indigenous. Sen Gupta and McMullen (1969) found *L. lobatalus (sensu lato)* at 90% of the stations on the Tail of the Bank with a mean percent occurrence of 12.5%. Williamson (1983) and Williamson et al. (1984), found a *Cibicides lobatalus (=C. reflugens)* assemblage patchily distributed on the outer banks of the Scotian Shelf - including Banquereau. Substrate type: coarse sands, bedrock and boulders; and high hydraulic energy (strong bottom currents) appears to be the controlling distribution factor (Phleger and Parker, 1951; Parker, 1952; Sen Gupta and McMullen, 1969; Sen Gupta, 1971; Murray, 1971, 1991; Østby and Nagy, 1981, 1982; Sejrup et al., 1981; Sturrock and Murray, 1981; Murray et al., 1982; Thomas and Schafer, 1982; Hald and Vorren, 1984, 1987; Hald et al., 1991; Hald and Steinsund, 1992; Seidenkrantz, 1993c; Austin and Sejrup, 1994). In the modern glacial marine environment *L. lobatalus* has been found ice-proximal in Baffin Island and Greenland fjords (Schafer and Cole, 1986; Jennings and Helgadóttir, 1994) and ice-distal in Spitsbergen (Nagy, 1965). The increase in the percent occurrence of *"Cibicides" spp.* is taken to indicate a period of shallower, stronger bank conditions.

The presence of *C. excavatum* and *C. reniforme* in assemblage (1b), here in the Adolphus Sand, is interpreted as relict (penecontemporaneous, reworked *in situ* and transported), present in the surface sediments due to strong currents and low sediment accumulation rates. Williamson (1983) and Williamson et al. (1984) observed *C. excavatum* the dominant species in their factor assemblage 8 on the Scotian Shelf (generally in the Sambro Sand, facies equivalent of the Adolphus Sand, Fader and Miller, 1986a); and concluded, as a result of living - total foraminiferal distribution studies; that the presence of *C. excavatum* on the Scotian Shelf was largely relict, and not in equilibrium with modern hydrographic conditions. Sen Gupta and McMullen (1969) found a very high diversity fauna, with *C. excavatum* present in the total population only, at 80% of the stations, to a percent occurrence of 59%, on the Tail of the Bank. The presence of this relict assemblage confirms that the Adolphus Sand is a product of reworking, and that glacial marine sediment served as the source.

The assemblage 1 (1a and 1b) auxillary species, *C. albiumbilicatum, C. bartletti, H. germanica, I. algida* and *I. helenae* are all known to inhabit cold, slightly hyposaline, (often) inner shelf environments around eastern North America (i.e. Loeblich and Tappan, 1953; Vilks, 1969, 1980; Poag et al., 1980; Williamson, 1983; Williamson et al., 1984; Mudie et al., 1984; Vilks and Deonarine; 1988) and around Europe (i.e. Sejrup et al., 1981; Van Weering and Qvale, 1983; Hald and Vorren, 1984; Vorren et al., 1984; Austin and Sejrup, 1994).

Assemblage 3, the high number - *C. excavatum* - *"Cibicides" spp.* - *"Glabratella" spp.* fauna is present in the shell-hash layer (C / III) found within the channel in BH 2. Two species have been identified as *Glabratellina lauriei* and *G. wrightii,* another *Glabratellina* species has been identified only to genera (*G. sp. 1*) and is included in this group. Murray (1973) describes *Glabratella* as typical of the normal marine inner shelf. Only Schafer and Cole (1978; Cole, 1984, oral communication) have found it dominant in assemblages; in assemblages from the north shore of the Bay of Chaleur. Cole (1984, oral communication) suggests that this is a shallow intertidal to subtidal (shallow shelf) species, that it prefers a very sandy - gravelly substrate and very turbulent water. This is often an attached genera and it seems to replace *L. lobatalus* in some environments, particularily when there is no plant life (seaweed, algae, etc.) (Cole, 1984, oral communication). Murray (1991) attributes these species to a high energy environment. Østby and Nagy (1981, 1982) describe a *Cibicides - Rosalina* assemblage (which is very similar to assemblage 3), where these two genera are diagnostic, though not dominant. They illustrate specimens (1982) of *Rosalina* and *Glabratella* which include the species referred to here as *G. lauriei, G. wrightii, R. micens* and *Rotaliella chasteri,* they describe the environment as one of an open bank. The shell hash probably formed by channelized high-energy meltwater flow. *C. excavatum* in assemblage 3 is interpreted as largely indigenous, based on the absence / low numbers of *C. reniforme* in this assemblage (see below).

Assemblages 2, 4a, 4b, 5, 6 and 7 are dominated by *C. excavatum / C. reniforme;* species generally thought to be indicative of glacial or near glacial environments or substantial reworking of glacial marine sediments. Assemblages strongly dominated by *C. excavatum* and *C. reniforme* and with low species diversity don't appear to be living in modern temperate to arctic shelf environments.

In assemblage 2, *C. reniforme* is the dominant (35-60%) species. Elverhoi et al. (1980) found *C. reniforme* (38-66%) accompanied by agglutinated species and *C. excavatum,* ice-marginal to ice-proximal in Konsfjorden, Spitsbergen (a fjord with a marine ending tidewater glacier). Schafer and Cole (1986) found *C. reniforme* and *L. lobatalus* the dominant calcareous species in some Baffin Island shallow nearshore fjord environments. Schafer and Cole (1986) suggest that the dominance of *C. reniforme* over *L. lobatalus* may be related to its tolerance of high concentrations of suspended particulate matter (SPM). In both instances the occurrence of *C. reniforme* is attributed to direct influence of North Atlantic waters and salinities of > 33 ‰. Korsun et al. (1995) have also found it dominant in some fjord samples. Nagy (1965), Hansen and Knudsen (1992), Jennings and Helgadótttir (1994) have all found *C. reniforme* present with similar numbers in these same modern glacial environments. Jennings and Helgadóttir (1994) relate its occurrence to the presence of Atlantic (vs. polar) waters in Greenland fjords.

Bonifay and Piper (1988) infer that they found a *C. reniforme* dominated assemblage; they list their assemblage as a *C. reniforme - C. excavatum - Cibicides lobatalus - Glabratella spp.* assemblage which they subdivide into 2 sub-assemblages. Assemblage 2 (this study) plus assemblage 4 (this study) would correlate to their assemblage IIb (IIa characterized by > 30% *C. lobatalus* plus *Glabratella spp.;* IIb characterized by < 30% of these species groups).

Vilks et al. (1989) find a *C. reniforme* dominated assemblage in zone D, which occurs as a surface layer in both inner and outer Hudson Strait and in zone B of cores taken in Hudson Strait. *F. fusiformis* is an auxillary species in Hudson Strait. Vilks et al. (1989) interpret this subsurface occurrence to indicate a proximal glacial marine environment.

Osterman and Andrews (1983), Osterman (1984), and Osterman and Nelson (1989) have documented a *C. excavatum - C. reniforme - I. helenae* sequence in three cores along a Frobisher Bay transect, which they interpret as the transition of proximal to extreme distal glacial marine regimes; with the *C. reniforme* zone representing a distal glacial marine environment.

Knudsen (1992) found *C. reniforme* as 40-60% of the total benthic fauna (*C. excavatum* as 20-40%) occurring in sediments dated at isotopic stages 5c, 5b and 5a - the Weichselian intermediate, in north Denmark; Feyling-Hanssen (1980b) found it to be dominant in his zones D and E of raised Quaternary deposits on Baffin Island. Other occurrences of a glacigenic sequence dominated by *C. reniforme* have been reported (Buzas, 1965; Elverhøi and Solheim, 1983; Vorren et al., 1983b; Feyling-Hanssen and Ulleberg, 1984; Sejrup, 1987; Sejrup et al., 1989). Based on the modern distribution of *C. reniforme* dominated assemblages, and the reported occurrences in glacigenic sequences, this assemblage is interpreted as indicative of a drop in sea water temperatures and an increase in water depth in an ice-marginal to ice-proximal environments. It also implies circulation with ocean waters and salinities of ca. 33^{o}/oo. It is consistent to find this assemblage in the channel fill deposits, sediments interpreted as being deposited in channels previously scoured out or formed by subglacial meltwater. They are loose, coarse grained deposits which have not seen significant reworking. The bulk density and water content support this interpretation. The *C. reniforme* dominated assemblage indicates this channel was infilled relatively soon after glacial retreat, while there was still a substantial meltwater influence and an ice-marginal to ice-proximal environment. Specimens of *C. excavatum* and *C. reniforme* are probably both indigenous and reworked. The increased numbers of *Cibicides spp.* are interpreted as indigenous. *Cibicides* is consistent with strong bottom currents and a coarse sand or gravel substrate. The faunas are generally well-preserved; which indicates that they probably have not been subjected to severe reworking. The very high numbers of QB specimens is attributed to current winnowing / low sedimentation rates.

Bonifay and Piper (1988) comment that their assemblage IIa (=assemblage 2, this study) contains very high foraminiferal concentrations and occurs in highly stratified sediment; and conclude that their assemblage IIa is reworked. They also point out that these high numbers might result from high nutrient supply associated with the upwelling of slope water, or upwelling associated with subglacial meltwater discharge. Alternatively, the high numbers might result from transport of the silt fraction by sediment transport. In all probability, some winnowing is occurring, but a conclusion that the assemblage is reworked is not supported here.

The channel in BH 2 cuts through the Downing Silt (unit E / IV); Downing Silt occurs underlying the channel from 14 to 32 m. These glacial marine sediments are normally consolidated and contain foraminiferal faunas 5, 6 and 7. Assemblage 5 occurs throughout this Downing Silt unit; assemblages 6 and 7 appear as thin bands, each interpreted as representing a brief time period / event within this unit.

Assemblage 5 is distinguished by the slight percent occurrence increase in *I. helenae*. *I. helenae* is found living today: in deep outer estuaries of eastern Canada (Schafer and Cole, 1978), the Gulf of St. Lawrence (Rodrigues and Hooper, 1982) and on the Labrador Shelf in salinities of 32.5 ^{o}/oo to 33.5 ^{o}/oo (Vilk et al., 1982; Vilks and Deonarine, 1988; Vilks er al., 1989). In the Gulf of St. Lawrence it is found in the intermediate water depths of ca. 70-140 m (Rodrigues and Hooper, 1982). It is also common in Beafort Shelf (western Canadian Arctic) sediments (Vilks et al., 1979) and is the dominant species in Frobisher Bay and on the southern Baffin Shelf (Osterman, 1982). It is also a minor component in modern glacial marine environments (Jennings and Helgadóttir, 1994; Korsun et al., 1995).

I. helenae is considered a marker species and paleosalinity indicator (32 - 33.5‰) indicating extreme distal glacial marine / early post-glacial conditions and an influx of meltwater on eastern North American margins (Vilks et al., 1974, 1984, 1987, 1989; Feyling-Hanssen, 1976a, 1976b, 1976c, 1980a, 1980b; Vilks and Rashid, 1976; Osterman and Andrews, 1983; Vilks and Mudie, 1983; Osterman, 1982, 1984; Mudie et al., 1984; Scott et al., 1984; Miller et al., 1985, 1995a, 1995b, submitted; Miller 1988, 1989a, 1989b, 1993, in press; Guilbault, 1989, 1993; Osterman and Nelson, 1989; Amos and Miller, 1990; Rodrigues et al., 1993). It is interesting to note that it has seldom been reported from similar environments on the western North Atlantic margin (exceptions: Mangerud et al., 1981; Scourse et al., 1990).

Assemblage 6 shows a marked increase in the occurrence of *C. albiumbilicatum.* Rottgardt (1952), Haake (1962), Lutze (1965, 1974) and Wiegank (1972) report the species as common in recent boreal shallow water, and that it tolerates very low salinities and large fluctuations in temperature. Risdal (1964) reported it as dominant in water depths < 6 m in the arms of Oslofjord. Austin and Sejrup (1995) also report it as common today on the western Norwegian Shelf, in water depths > 39 m, temperatures ca. 3° C and salinities ca. 32 ‰. *C. albiumbilicatum* was originally described by Weiss (1954) from the interglacial Gardiners Clay, New York, where he describes it as common. Weiss (1954) interprets the environment of deposition as shallow, brackish water in a bay or lagoonal area protected by an offshore bar. Miller has found Late Quaternary assemblages where *C. albiumbilicatum* becomes co-dominant near surface on Sable Island Bank and Banquereau (Miller 1989b, 1993, in press) and dominant (Miller, in press) near surface on Banquereau (Miller, in press) and interpreted the environment as very shallow water / estuarine / quiet water with hyposaline conditions.

Knudsen (1978) found an *C. albiumbilicatum* zone (up to 60%) in Late Quaternary raised marine deposits in northern Denmark. *C. excavatum* is co-dominant and *Cassidulina crassa* (=*C. reniforme*) is also consistently present. Generally, this assemblage occurs in an infilled meltwater channel, in sandy sediments, probably indicative of shallower water, higher current velocity, lower temperatures and lower salinities than a *C. excavatum* assemblage. Knudsen (1978) believes these sediments were deposited as channel fill; either subglacially or by meltwater streams during deglaciation. Knudsen (1993) also found a *C. albiumbilicatum* zone in burried tunnel valleys in NW Germany. Mangerud et al. (1981) found a *C. albiumbilicatum* zone in gravel deposits (abundance ca. 45%), correlated it to the end of the Eemian interglacial; and estimated the paleo- water depth at 0-10 m.

Similar occurrences in late glacial sediments have been reported (Andersen, 1971; Feyling-Hanssen, 1981; Knudsen, 1985; Bergsten and Denngård, 1988; Jensen and Knudsen, 1988; Guilbault, 1989, 1993; Peacock et al., 1992; Knudsen and Sejrup, 1993). Eiríksson et al. (1992) have found it in a raised Pliocene section in Iceland.

Assemblage 7 is characterized by a brief interval with 16% *"Fursenkoina "spp.*, another marker genera believed to have paleo-environmental significance. *Fursenkoina spp.*, in particular *F. fusiformis*, is well known in modern environments.

Recent studies relate the common (modern) occurrence of *F. fusiformis* to anoxic conditions initiated by human induced environmental alterations (urban / organic pollution) (Alve, 1990, 1991, 1994, 1995; Alve and Murray, 1995). It can tolerate low dissolved oxygen levels (< 2ml / l) and salinities > 30 ‰ (Alve, 1990) and can survive brief periods of anoxia (Alve, 1994). Where pollution has been monitored and steps taken to reduce urban waste *F. fusiformis* is an opportunitistic species, the first and most successful to recolonize (Alve, 1995; Alve and Murray, 1995). It is also found presently in modern glacial marine environments (Nagy, 1965; Elverhøi et al., 1980). It is considered an indicator species in deep estuarine environments of eastern Canada (Schafer and Cole, 1978; Scott et al., 1980; Miller et al., 1982a) where salinities are generally 30-33 ‰. It is common in surface assemblages on the Labrador Shelf (Vilks et al., 1984) and in surface sediments in the Candian Arctic (MacLean et al., 1989) where it directly overlies the *C. excavatum* fauna. It is dominant (Murray, 1985, 1991, 1992) in surface assemblages in the North Sea. It was reported as very abundant in Gullmar fjord and the Skagerrak (Höglund, 1947); and common at water depths of 40-145 m in the southern Kattegat (Conradsen, 1993; Conradsen et al., 1994). It is associated with muddy sediments of high organic content and oxygen depletion (Sturrock and Murray, 1981; Conradsen, 1993; Conradsen et al., 1994). Hald et al. (1994) looked at its distribution in the Skagerrak and correlated it to salinities > 30 ‰ and a very fine sand substrate.

Fursenkoina spp. often is a minor to common component in the *I. helenae* extreme distal glacial marine / postglacial assemblage (Vilks et al., 1974, Vilks and Rashid, 1976; Scott et al., 1984). Miller and Fader (1995a, 1995b) and Miller et al. (1995b) find its highest percent occurrence peak within the *I. helenae* zone, following the maximum occurrence of *I. helenae.* The same trend is observed here in Halibut Channel. Coincident with the occurrence of *Fursenkoina* there is a marked decrease in the occurrence of *C. excavatum,* in both Halibut Channel and Emerald Basin (Scott et al., 1984; Miller et al., 1995b). *Fursenkoina spp.* has been found in late glacial sediments with variable percent occurrence frequencies and variable species associations; consequently its presence has been interpreted as indicating: an ice-shelf environment (Scott et al., 1984), proximal glacial marine (Osterman, 1982, 1984, Osterman and Andrews, 1983; Osterman and Nelson, 1989), distal glacial marine (Vilks et al., 1974; Vilks and Rashid, 1976; Scott et al., 1994) or extreme distal glacial marine / postglacial (Miller and Fader, 1995a, 1995b; Miller et al., 1995b) environments.

All three of these assemblages indicate that deglaciation, of both Newfoundland centred ice and the Laurentide ice sheet, was occurring, during the time period ca. 15-12 ka. Based on modern analogues, *I. helenae* (assemblage 5) indicates that the water depth was probably in the range of 70-140 m and salinities ca. 32-34 ‰, and meltwater and oceanic waters were well mixed. The *Fursenkoina* interval (assemblage 7) is believed to indicate a decrease in salinity (to 30-33 ‰), possibly coupled with a decrease in dissolved oxygen content. This may have been triggered by zones of upwelling (common in the distal glacial marine environment, on the outer continental shelf; Boulton, 1990), sustaining high rates of biological productivity and rich benthonic and planktonic faunas, which in turn deplete the dissolved oxygen supply.

Towards the end of this interval, the late ice surge in Halibut Channel commenced. Sea level was rising and the ice surge must have been short-lived.

The *C. albiumbilicatum* interval (assemblage 6) is believed to indicate a strong meltwater influence, decreasing the salinity and decreasing the mixing with oceanic waters; possibly the initiation of meltwater flow that eroded and formed the overlying channels.

Assemblage 4 (a and b) is the *C. excavatum - C. reniforme* assemblage, characterized by 30-60% *C. excavatum* and 20-30% *C. reniforme* with auxillary species *C. albiumbilicatum* and *I. helenae.* (There is no known unambiguous modern analogue of this assemblage.) It has consistently been interpreted as indicative of a proximal to distal glacial marine regime. Miller et al. (1982b) compiled reported modern occurrences of *E. excavatum* (= *C. excavatum*) including *C. excavatum* forma *clavata* (Cushman), the small, orange-brown disc-shaped transluscent ecophenotype,with a smooth periperal outline and lacking papillae in the sutures and umbilical region (Miller et al., 1982b); and stated that it occurs today as a minor constituent in high diversity arctic shelf faunas. Hald et al. (1994) have also recently looked at the recent and Late Quaternary distribution of *C. excavatum* forma *clavatum.* They concluded that three oceanographic parmeters directly influence its occurrence: fluctuating sailinty and slightly hyposaline conditions, turbidity / SPM, and seasonal ice cover. They also believe that it is a meltwater indicator; its percent occurrence in assemblages increases at a point stratigraphically that correlates to the first meltwater pulse from the Barents and Fennoscandian ice sheets (Jones and Keigwin, 1988; Sarnthein et al., 1992).

Nagy (1965), Hansen and Knudsen (1992), Hald et al. (1994), Jennings and Helgadóttir (1994), and Korsun et al. (1995) report it as common to dominant in the inner fjord ice-marginal to ice-proximal glacial regime (particularily in very shallow water); often occurring with *H. orbiculare* and *Cibicides spp.* This assemblage is ubiquitous in near surface and subsurface glacigenic (Late Wisconsinan) sediments throughout the Eastern Canadian Margin: on the Scotian Shelf (Vilks et al., 1974; Vilks and Rashid, 1976; Scott et al., 1984; Miller, 1989a, 1989b, 1993, in press; Amos and Miller, 1990; Miller et al., 1995b), in the Champlain Sea sediments (Cronin, 1976, 1979; Rodrigues and Richard, 1986; Guilbault, 1989, 1993) on Northeast Newfoundland Shelf (Scott et al., 1984; Miller et al., 1985; Miller, 1988; Miller et al., 1995a, submitted), on the Labrador Shelf (Vilks and Mudie, 1978; Vilks, 1980, 1981; Vilks et al., 1984; Vilks and Deonarine, 1988), in Hudson Strait (MacLean et al., 1989; Vilks et al., 1989), in Hudson Bay (Bilodeau et al., 1990) and in the Arctic (Feyling-Hanssen 1976a, 1976b, 1976c, 1980a, 1980b, 1985; Vilks et al., 1979; Osterman, 1982, 1984; Osterman and Andrews, 1983; Osterman and Nelson, 1989). Foraminiferal faunas dominated by *C. excavatum* have also been found Late Weichselian and older glacignenic sediments along the Scandinavian margin and in the North Sea; and the sediments of the U.K. continental shelves (e.g., Feyling-Hanssen, 1964, 1971, 1981,1982, 1990; Andersen 1971; Jørgensen 1971; Knudsen 1971a, 1973, 1976, 1977, 1978, 1984, 1985, 1986, 1992; Haynes et al., 1977, 1995; Hughes et al., 1977; Gregory and Harland, 1978; Nagy and Ofstad, 1980; Østby and Nagy, 1981, 1982; Vilks, 1981; Elverhøi and Solheim, 1983; Andersen et al., 1983; Feyling-Hanssen et al. 1983; Skinner and Gregory, 1983; Vorren et al., 1983a, 1984; Feyling-Hanssen and Ulleberg, 1984; Nagy, 1984; Feyling-Hanssen and Knudsen, 1986; Long et al., 1986; Sejrup, 1987; Sejrup et al., 1987, 1989; Hald and Vorren 1987; Bergsten and Dennård, 1988; Jensen and Knudsen, 1988; Stoker, 1988; Hald et al., 1989, 1990; Lykke-Andersen, 1990; Haflidason et al.1991; Knudsen and Asbjörnsdóttir

1991; Poole et al., 1991, 1994; Ausin and McCarroll, 1992; Eiríksson et al. 1992; Hald and Steinsund 1992; Peacock et al., 1992; Knudsen and Sejrup 1993; Seidenkrantz 1993a, 1993b, 1993c; Seidenkrantz and Knudsen, 1993; Stoker et al., 1994; and Laban, 1995).

Assemblage 4a has much lower numbers of QB specimens, compared to assemblage 4b, both assemblages are also distinguished by the very high numbers of reworked Quaternary and pre-Quaternary foraminifera.

Fauna 4a occurs in BH 4 in the upper till tongue (D / IIIa), and in the unit of Downing Silt (red unit G / V and grey unit H / V) in BH 2, from 32-48 m. The geotechnical properties of these units include normal consolidation (Moran, 1987) suggesting rapid sedimentation with no loading of ice on the sea-floor. There are very low numbers of QB specimens, consistent with high sedimentation rates. Agglutinated forms are absent, because levels of SPM are believed to have been high. Assemblage 4a also has scattered occurrences of deeper water species, i.e. *Eilohedra levicula, Ioanella tumidula, Oridosalis umbonatus, Pseudoparrella subperuviana, Tosaia hanzawaia* and species of *"Uvigerina"*. These are all Q / T outer shelf and slope species (Cole, 1981; Poag, 1981; Williamson, 1983; Williamson et al., 1984; Scott, 1987). These are believed to be be 'environmental erratics', penecontemporaneous, transported reworked. The pre-Quaternary forms and the environmental eratics are interpreted as having been incorporated in the ice mass from the K / T bedrock (some of it is distinctively red coloured) exposed in Placentia Bay, on the bank areas and in inner Halibut Channel (Fader et al., 1982; King et al., 1986) and transported east / west or south as the ice advanced. This is strongly substantiated by the direct correlation between assemblage 4a and the red coloured sediments of the upper till-tongue (unit D) and unit G of the Downing Silt. The most likely depositional environment is either rainout and suspension from a grounded, calving ice front or a grounded margin with a floating tongue front; or local slumping / debris flows ice-marginal to ice-proximal of the grounding zone.

Assemblage 4b also has a noticeable agglutinated component. Agglutinated species such as these are found ice-marginal to ice-proximal in modern glacial marine fjord environments (Nagy, 1965; Elverhøi et al., 1980; Schafer and Cole, 1986, 1988; Jennings and Helgadóttir, 1994; Korsun et al., 1995), usually in *C. reniforme* dominated assemblages. These species are also those typical of species found in surface samples on the Scotian (Williamson, 1983; Williamson et al., 1984) and Labrador (Vilks, 1980; Mudie et al., 1984; Scott et al., 1984; Vilks et al., 1984) shelves and on Grand Bank (McMullen and Sen Gupta, 1969; Sen Gupta, 1971; Miller, in prep.) all waters influenced by the present day Inner Labrador Current (Lazier, 1982). Based on modern occurrences, the foraminifera indicate assemblage 4b were deposited in ice-marginal to ice-proximal glacial marine environments.

Assemblage 4b occurs in BH 4 in the encapsulated Downing Silt (E / IV) and lower till-tongue (F / IVa). In BH 4, the Downing Silt and lower till-tongue can not be differentiated based on faunal content; this till-tongue appears to be largely reworked glacial marine sediment. An increase in acoustic velocity and coarsening differentiate the till-tongues from the encapsulating glacial marine sediment. Assemblage 4b occurs in BH 2 at the very base of the channel-fill deposit (B / III), underlying the channel deposit in the Downing Silt (E / IV) and in the Grand Banks Drift (unit I / VI). The uppermost occurrence of assemblage 4b in

BH 2 is an encapsulated deposit within assemblage 2 at the very base of the channel deposit and interpreted as entirely reworked. Its source may have been be a remnant of the upper till-tongue, or the underlying Downing Silt. The interpretation of the lower most occurrence of assemblage 4b in BH 2 is different. This was originally deposited as a glacial marine sediment. The geotechnical properties show that this unit (I / VI) is overconsolidated, compare to the overlying units above (Moran, 1987). The acoustic velocity and shear strength increase across the unit boundary remain high. Subsequent to deposition of this unit, and prior to deposition of the overlying units, this sediment was overconsolidated, the mechanism is interpreted as ice loading by a subsequent ice advance. An estimate of the minimum ice thickness, based on shear strength, is 430 m (Moran, 1987).

Significance of the foraminiferal faunas

The foraminiferal analyses and interpreted environments of deposition inferred from the foraminiferal assemblages enhances the information acquired from the seismostratigraphic interpretation and lithologic characteristics. The uniformity and character of assemblage 4b throughout the Grand Banks Drift (unit I / VI, BH 2) indicates that this unit was originally deposited as a glacial marine sediment, and not as a basal till; and has been remoulded and resedimented during ice-loading. Assemblage 4b shows uniformity throughout the lower till-tongue (unit F / IVa, BH 4) and overlying Downing Silt (E / IV, BH 4), indicating that regardless of the depositional mechanism the till-tongue was formed of reworked glacial marine sediment. The characteristics and uniformity of assemblage 4a, the low numbers of QB specimens and the high numbers of pre-Q specimens, in the Downing Silt (unit H / V, BH 2) support the theory of rainout and suspension from calving, melting ice. The variations in percent occurrence within assemblage 4a in unit G / V and upper till-tongue (unit D / IIIa, BH 4) suggest local slumping / debris flows may have played a role in deposition. The dominance of *C. excavatum* in assemblage 4 (a and b) indicates low salinities, high SPM, and an absence of melt- and oceanic waters mixing. The occurrence of assemblage 5 (*I. helenae*) throughout the uppermost Downing Silt (E / IV, BH 2) indicates deglaciation was occurrring along the whole southeastern Laurentide / Newfoundland centred ice margins. Assemblages 6 and 7 within this unit indicate the presence of meltwater (6) and possibly anoxic conditions (7). The occurrence of a *C. reniforme* dominated assemblage in the channel-fill sequence indicates submarine infilling, salinities > 33 $^{o}/_{oo}$, deeper waters, mixing of melt- and oceanic waters and possibly sustained meltwater influence along this southern Newfoundlland margin. The presence of assemblage 3 (*"Cibicides" spp.* and *"Glabratella" spp.*) in the shell hash layer (BH 2) confirms that high-energy channelized flow was occurrring at that time. The presence of relict *C. excavatum* and *C. reniforme* in assemblage 1 (a and b) indicates the substantial role of reworking in the formation of the modern surficial Adolphus Sand.

Chronology of events

The lithostratigraphy and environments of deposition (as interpreted from the foraminiferal assemblages), coupled with age control based on AMS ^{14}C dating (Table 1, Figure 3); allows a chronology of events, as reflected in the preserved sedimentary sequence for the Halibut Channel area, to be constructed. A broad unconformity on bedrock (Carboniferous and Tertiary) was developed by glacial erosion, previous to 41 ka BP. Prior to 41 ka BP a basal till (J / VII) was deposited immediately overlying the bedrock surface and ice had retreated from the area. Though it may be older than Wisconsinan in age; it may be Middle Wisconsinan (stage 4) when the most extensive Wisconsinan glaciation of the Atlantic provinces took place (Grant, 1989) and ice extended across the continental shelf (Fader et al., 1982; Fader and Miller, 1986b; Piper, in Piper et al., 1990). The direction of ice movement is not known, though it probably advanced southward as an extension of Newfoundland centred ice. This till in outer Halibut Channel may correlate with the till which overlies bedrock in inner Halibut Channel and Placentia Bay to the north.

During stages 4 / 3 (ca 50-30 ka BP), glacial marine sediment (I / VI) was deposited over the basal till, either during retreat of the ice which deposited unit J or in front of the ice of the next advance; or both. These glacial marine sediments were subsequently loaded by another ice advance, probably the Late Wisconsinan advance, by ice estimated to be over 400 m in thickness; this unit (I / VI) became a deformation (secondary) till (sensu the INQUA commission, Dreimanis, 1989). This ice loading was prior to the deposition of the overlying units (which do not show ice loading effects) and therefore well prior to 20 ka. Based on the regional seismic interpretation, which show facies equivalents of glacial marine sediments to the north (indicating Placentia Bay was ice-free at this time); the most feasable cause of this ice loading is that ice caps developed on the exposed banks (St. Pierre / Green) and advanced west / east over Halibut Channel.

The ice loading was followed by retreat and the deposition of glacial marine sediment, Downing Silt (H and G / V). Acoustically this unit is incoherent and difficult to interpret because it is at the limit of Huntec acoustic penetration. Lithologically it is a stiff, silty clay and consists of at least two distinct depositional events from possibly two different source areas. It is interpreted as ice-proximal to ice-distal glacial marine.

This was followed beginning at ca. 20 ka BP by the deposition of another unit of Downing Silt (E / IV). Deglaciation of the entire margin was well underway, as indicated by the *I. helenae* assemblage. The numerous foraminiferal assemblages within this unit indicate that the depositional environments were undergoing substantial rapid change, probably accompanied by periods of extensive reworking. Sea level was believed to be at a minimum soon after deposition of unit E / VI (BH 2) commenced. The thin band of *Fursenkoina spp.* indicates a period of reduced salinity, or a reduction in dissolved oxygen in the water mass. The band of *C. albiumbilicatum* represents a period when salinities dropped suddenly, perhaps because of stratified meltwater, and the waters were cold, shallow and not mixing with the open ocean.

At this time the third ice advance occurred, probably ca. 13-11 ka BP. Associated with this ice advance is the formation of the two till-tongues, representing minor oscillations of the ice margin grounding line. The lower till tongue (F / IVa) can't be distinguished based on foraminifera and physical properties, from the overlying Downing Silt (E / IV) in BH 4, these data suggest that it was not ice loaded. Likely depositional mechanisms include: rainout and suspension from a grounded, calving ice front or a grounded margin with a floating-tongue front; or local slumping / debris flows ice-marginal to ice-proximal of the grounding zone; or subglacial deposition over water saturated sediment. The foraminiferal are consistent with all three possible interpretations. There was a local retreat of the grounding line as evidenced by the deposition of Downing Silt (E / IV) in BH 4. This was followed by another advance forming the upper till-tongue (D / IIIa). Strongly correlating with the red units (D and G) is foraminiferal assemblage 4a (low total numbers, no agglutinated species, presence of environmental erratics and pre-Quaternary forms). Again the physical properties do not suggest ice loading and the unit is interpreted to have formed by a local slumping / debris flow mechanism ice-proximal to the grounding line, or by rainout and suspension by calving ice or a grounded margin with a floating ice-tongue.

At this time (ca. 12-10 ka BP) sea level had reached its low stand minimum and was rising (due to eustatic rising and isostatic rebound) and the glacial regime changed. Subglacial meltwater channels formed. After ice retreat these channels were subsequently infilled. The foraminfera at the base of the channel in BH 2 are remnants of glacial marine faunas (4b) and shallow bank / ice-distal faunas (3) and ice-proximal glacial marine (2) assemblages. Assemblage 4b indicates a thin band of the lower till-tongue or Downing Silt, and the shallow bank / ice-distal assemblage (3) coincides with the shell hash. A ^{14}C age on shell material from this layer indicates its formation ca. 8 ka BP. Assemblage 2 is dominated by *C. reniforme* and marked by a decrease in *C. excavatum*, and increase in *Cibicides spp.*, it indicates ice-proximal environments, with water depth increasing, salinities of at least 33 $^{o}/_{oo}$ and mixing with oceanic waters. The presence of this fauna, rather than a shelf fauna, indicates the infilling commenced soon after formation of these channels, while the influence of the glacial marine environment was still felt and salinities still reduced.

Subsequent to the deposition of the upper till-tongue, either prior to or subsequent to the channel formation, a significant erosional event occurred across outer Halibut Channel.

Variations in glacial regimes and associated depositional mechanisms and facies.

The sequence in Halibut Channel is interpreted as containing sediments indicative of three glacial advances, each producing and preserving very different facies attributable to variations in ice sheet dynamics, glacial regime and sea level.

Overconsolidation is the main criteria utilized here for distinguishing the action of grounded ice; and the resultant deposit is either a basal till (if the overconsolidation occurred during primary deposition) or a deformation (secondary) till (sensu the INQUA commission, Dreimanis, 1989) if it was subsequently ice / sediment loaded and now exhibits similar lithologic characteristics and physical properties as a (primary) basal till. High shear strengths, high accoustic velocity, incoherent accoustic character and the foraminiferal faunas recorded for the two basal units in BH 2 are the main criteria employed here in making the interpretation that unit J / VII is a basal till, and unit I / VI is a glacial marine sediment that was subsequently ice loaded. The distinct differences of these units implies different glacial regimes and different source areas.

The basal till sits directly on bedrock and is probably the product of bedrock erosion. If this is a lodgement till, both net-freezing and net-melting have occurred; freezing incorporating debris into the ice mass (marginally) and melting releasing it (from the basal core). Alternatively, this could be a melt-out till, formed during deglaciation.

The overlying unit is interpreted as having been has been overridden by cold, dry-based ice. The source material is the glacial marine sediment, remoulded into a deformation till (Boulton, 1990). This unit may have been resedimented by mechanisms analagous to those proposed by Austin and McCarroll (1992) for the section at Aberdaron, North Wales. Deformation and remoulding have remixed the faunas to the extent that any evidence of a proximal to distal, or distal to proximal environmental transition has been destroyed. If this interpretation is correct, the sediments have been deformed by both fracture and flow, masses of sediment have been plucked from the bed without disaggregation, sediment is incorporated in the ice several metres above the bed and ice below this sediment did not form from subglacial water (Boulton, 1979). However, basal freeze-on should also be considered. Sættem (1990) suggested that excess pore water may be removed from an ice-loaded fine grained substratum by freezing onto the base of the grounded ice instead of being drained downward or laterally into permeable strata. The frozen glacier-bed contact impedes the flow of subglacial meltwater, elevating subglacial pore pressure (Weertman, 1961; Moran et al., 1980). Frozen sediments have a higher strength than glacier ice, and thus may be transported and remain relatively intact. Such a local pore water sink may allow the total thickness of ice (both above and below sea level) to effectively load the sediments, because the pore pressure of the loaded sediment does not communicate with sea level (Sættem et al., 1992b).

The absence of tunnel valleys / subglacial channels suggests that there was not an appreciable amount of meltwater at the glacier sole during deposition of unit J, or the ice loading of unit I. For any large glacier undergoing large scale basal melting, subglacial channels must exist to drain the excess water, and permit stable deformation of the sediments (Boulton and Hindmarsh, 1987). Alternatively, meltwater had to drain into a substantial underlying aquifer (Boulton and Jones, 1979; Boulton and Hindmarsh, 1987); in this instance the physical properties indicate these two units could not act as such an aquifer.

Two possible depositional mechanisms are suggested for Units H and G / V and the upper till-tongue (D / IIIa). They are normally consolidated, which suggests they were not ice-loaded. They could be the result of ice-proximal to ice-distal glacial marine sedimentation by rainout and suspension settling (from a grounded calving front or grounded ice sheet with a floating tongue front); the other is that they are the result of local slumping or debris flows (down the bank slopes / channel flanks) triggered by large volumes of sediment being released quickly, (resulting in high sedimentation rates) by the retreating ice margin. The fluctuations in specific foraminiferal percent occurrences in unit G suggests discrete shortlived depositional events, rather than continuous sedimentation. Discrete events from different source areas / material, may be reponsible for the distinct lithologies of, and distinct boundary between, units G and H. The source area of these red sediments (G) is different from the underlying material and is probably the same source as that of the red sediments seen in BH 4 (unit D). Brick red sediments have been attributed by others to meltwater plumes from the Gulf of St. Lawrence (Conolly et al., 1967; Loring and Nota, 1973; Bond and Lotti, 1995); this may be the source of these red sediments in Halibut Channel. The hummocky 2 m of relief of the surface separating the two may indicate a period of ice berg groundings / turbation.

The till-tongue deposition is believed to coincide with the late advance documented by Brookes (1977a) and Grant (1992, 1994), and the marine limit documented by Brookes et al. (1985), for the west coast of Newfoundland; the ice surge which reached the continental slope off St Pierre Bank (Bonifay and Piper, 1988); and possibly part of the Younger Dryas advance recognized in Atlantic Canada (Mott et al., 1986; Amos and Miller, 1990; Miller, 1993, in press; Levesque et al., 1993; Mayle et al., 1993a, 1993b; Anderson and Macpherson, 1994; King, 1994, 1966; Mott, 1994; NASP members, 1994; Mayle and Cwynar, 1995a, 1995b). This advance may be attributable to the offshore ice cap(s) believed to have existed about this time (Grant, 1971, 1975; Stehman, 1976; Tucker and McCann, 1980; Miller and Fader, 1995a, 1995b). Based on the facies relationships interpreted from the regional seismic interpretation small (residual) ice centres (that had developed from the mechanical breakup of the larger caps, during the main phase of deglaciation) expanded / new local caps formed. This scenario is analagous to the numerous caps forming along the south coast and on the Avalon Peninsula at that time (Catto et al., 1995). These caps would also have formed on the exposed banks (St. Pierre / Green) and advanced west / east over Halibut Channel.

The lower till-tongue (F / IVa) exhibits low shear strengths, interpreted as negative evidence for subglacial deposition or subsequent ice loading. However, Sættem et al. (1992a) have suggested that buried normally consolidated sediments in outer Bjørnøyrenna were overrun by grounded ice and unable to compact due to constrained drainage conditions. A similar scenario had previously suggested by Solheim et al. (1990) for sediments in an adjacent area; and by Scourse et al. (1990) for sediments in the Celtic Sea. There are examples that subglacially deposited till and ice covered sediments can be quite soft (Boulton, 1979; Boulton and Jones, 1979; Rokonegen et al., 1979b; Orheim and Elverhøi, 1981; Clarke et al., 1984; Blankenship et al., 1986, 1987; Alley et al., 1987, 1989; Rooney et al., 1987; Vorren et al., 1989, 1990a); the result of retarded porewater drainage during deposition, possibly by a net melting base of a grounded ice sheet (Sættem et al., 1992a). This depositional mechanism is compatable with the inferred glacial regime at the time of till-tongue deposition. Fine-grained sediments, however, even under restricted drainage conditions, will consolidate with time. If drainage is limited and the sediments remain soft and normally consolidated; it implies rapid movement of the ice sheet (Boulton and Jones, 1979; Boulton and Hindmarsh, 1987; Alley et al., 1989) and sedimentation processes similar to debris flow deposition.

The subglacial meltwater channels are indicative of temperate, wet-based ice (Boulton and Jones, 1979), a tidewater front (Powell, 1984; Pfirman and Solheim, 1989) and a water depth of less than 75 m (King et al., 1991; King, 1993). The channels are not believed to be tunnel valleys. These channels occurr on a much smaller scale, comparable to those seen in the subsurface seismic units on Sable Island Bank (King, 1993, Fig. 5), where they are referred to as subglacial meltwater channels. In addition, they do not appear accoustically to have the massive basal chaotic infill some others have reported for tunnel valleys and megachannels based on seismic (Cameron et al., 1987; Wingfield, 1990; Laban, 1995) and lithologic (Eyles, 1987; Eyles and McCabe, 1989; Eyles and Lagoe, 1990; Lagoe et al., 1994) evidence. They are believed to have been formed by deglacial processes at or near the rapidly retreating calving tidewater margin (Boulton and Hindmarsh, 1987); the ice sheet margin decoupled from the bed in response to advancing into deeper water, or to marine transgression after glacial isostatic loading (depression) and rebound. Most of the south coast of Newfoundland exhibited this same deglacial response (Catto, 1992; Liverman, 1994; Liverman and Batterson, 1995). Hughes (1987) and Alley et al. (1989) has shown that rapidly calving ice margins are associated with fast flowing ice streams, that, in turn, rapidly drain the interior of an ice sheet, resulting in its collapse. Powell (1984), Eyles and McCabe (1989) and Syvitski (1993) postulated this mechanical trigger and feedback loop (rather than a climatically induced one) as the agent responsible for ice sheet collapse. Alley (1991) has modelled sedimentary processes as another mechanical trigger of rapid, marginal retreat of temperate, tidewater glaciers.

The presence of subglacial meltwater channels superimposed on these till-tongues strongly suggests that the till-tongues also formed under the same glacial regime as the meltwater channels; that is, subglacially beneath temperate wet-based ice which did not load and overconsolidate these sediments; in contrast to the inferred glacial regimes of the two previous advances recorded in the Halibut Channel glacigenic sequence. This supports the theories of King and Fader (1986) and King et al. (1991) that till-tongues are largely subglacial features deposited beneath temerate wet-based ice, and that local slumping / debris flows contribute to the deposition.

It is difficult to determine how much sediment has been eroded by the regional unconformity ocurring at or near the seabed; but the nature of the unconformity, bevelled across seaward dipping reflections, indicates that perhaps as much as 10 to 15 m of sediment has been removed. If the erosion occurred prior to channel fomation, it must the result of grounded ice. Alternatively, the erosion may be the result of bottom current scouring. A series of mud buried, large relict sandwaves occur north of the till tongues in Halibut Channel (Fader, 1986) and attest to strong currents in the recent past. These currents reworked the exposed Downing Silt and Grand Banks Drift and formed the Adolphus Sand unit, with its mixed (indigeous and reworked) foraminiferal faunas (assemblages 1a and 1b).

Halibut Channel's latest Pleistocene - early Holocene sea level history may be complex, due to the combined isostatic adjustments resulting from: the adjacent margins of Laurentide and Newfoundland centred ice, the late glacial re-advance, and the formation of numerous local ice domes, both along the southern Newfoundland coast and in the southern offshore regions, during deglaciation. The sea level curve may show significant deviations from the predicted model if the eustatic and isostatic components were out of phase with one another (Boulton, 1990) due to either limited glaciation / early deglaciation of Newfoundland centred ice (compared to Laurentide ice); or the Younger Dryas advance (the extent of which is still unknown) throughout the Maritimes. Halibut Channel may have been significantly glacio-isostatically depressed and undergone strong postglacial uplift (initial uplift rates immediately following deglaciation are often rapid, Andrews, 1978). During early Holocene times, Halibut Channel would have behaved as a conduit for meltwater from Newfoundland and the inner shelf (the bank areas were still subaerially exposed until ca. 8 ka BP) and bottom currents would have produced this truncation by erosion.

CONCLUSIONS

Seismostratigraphic, lithostratigraphic and physical property data are in good agreement with the interpretation of depositional environments, based on foraminifera, in glacigenic sequenc in Halibut Channel. The foraminiferal and physical property data greatly enhance the interpretation that can be made based on the acoustic and lithogic data alone. This lends creedence to the value of high-resolution seismic reflection data in making regional correlations and interpretations; provided there is adequate, careful, detailed analyses of strategic / representative sites.

The glacigenic sequence in Halibut Channel is believed to represent the preserved sedimentary sequence of three glacial advances. Halibut Channel appears to have behaved as a fjord, the preserved sequences of each advance are thin and fragmented because most sediments were removed during each successive advance and bulldozed to the edge of the continental shelf and the slope (Andrews, 1990). The first advance was pre-Middle Wisconsinan (pre 41ka BP), extensive, eroded bedrock and deposited a basal till on the bedrock surface across the entire shelf to the shelf edge. It is believed to have originated as Newfoundland centred ice and advanced to the south. The glacier was believed to be wet-based, with both freezing and melting occurring. Freezing incorporated glacial debris into the ice mass, melting released it.

The second advance is interpreted to have been by cold dry-based ice, loading and remoulding glacial marine sediment into a deformation till. Again, this advance appears to have been extensive, at least 400 m thick, and it may have originated offshore and not as Newfoundland centred ice. It occurred between 40 and 20 ka BP, and may correspond to the Late Wisconsinan advance.

The third advance, a very late Wisconsinan advance, may correlate to the Younger Dryas advance seen elsewhere in the Maritimes. It is believed to have been thin, temperate, wet-based ice, was short lived due to sea level constraints and formed the two till-tongues and subglacial meltwater channels. The transport and depositional mechanism for the lower till-tongue is believed to have been subglacial, over saturated sediment; for the upper till-tongue slumping and debris flow deposition are believed to have played a role.

A major erosional event, as evidenced by a major unconformity occurs at or near the sea bed. This unconformity may have been formed by grounded ice; but a more likely scenario is strong bottom currents carrying meltwater south in early Holocene times, when Halibut Channel behaved as a conduit between the subaerially exposed banks.

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APPENDIX A

Faunal Reference List

This is not a taxonomic report and lengthy synonymies will not be given here. However, it is important that an unambiguous concept of each species be conveyed to the reader; to that end the following references are given which contain an illustration and (in most cases) a synonymy of each species. Where the name of the species referred to is not the same as the one used in this report, the name in square brackets is the one used in the reference given. Species are listed in alphabetical order by species group, first agglutinated, then calcareous.

Suprageneric classification for the Quaternary foraminifera is in accordance with Lee (1990) and generic classification is in accordance with Loeblich and Tappan (1988) with the following exceptions (listed in the same order as presented in the text):

Family ADERCOTRYMIDAE, Brönnimann and Whittaker (1987), emended Brönnimann and Whittaker (1990).

Genus *Cribrostomoides* Cushman (1910), emended Jones et al. (1993), also implications for *Veleroninoides.*

Family TROCHAMMINIDAE Schwager (1877), emended Brönnimann and Whittaker (1990). Subgenus *Paratrochammina (Lepidoparatrochammina),* erected Brönnimann and Whittaker (1986). Subgenus *Deuterammina (Deuterammina)* Brönnimann (1976).

Genus *Brizalina* (and therefore *Bolivina*) emended Sgarrella (1992); and *Aphenophragmina* errected Loeblich and Tappan (1994).

Genus *Floresina* errected by Revets (1990) and placed in the Family TURRILINIDAE. Placed in the Family ORTHOPLECTIDAE by Loeblich and Tappan (1994).

Genus *Pulleniella* Ujiié (1995).

Generic classification for the reworked foraminifera is in accordance with Loeblich and Tappan (1964).

Faunal Reference List
Quaternary benthic agglutinated foraminifera

Adercotryma glomerata (Brady), VILKS, 1989, p. 530, pl. 21-I: 16-17.
Hemisphaerammina bradyi Loeblich and Tappan, SCOTT and MEDIOLI, 1980, p. 40, pl. 1: 4-5.
Psammosphaera fusca Schultze, COLE, 1981, p. 12, pl. 3: 4.
Recurvoides contortus Earland, LOEBLICH and TAPPAN, 1994, p. 18, pl. 12: 1-14 (previously referred to as *Recurvoides turbinatus* (Brady)).

"Cribrostomoides" group

Veleroninoides crassimargo (Norman), [*Cribrostomoides crassimargo* (Norman)], VILKS, 1989, p. 530-531, pl. 21-I: 18-19.
Veleroninoides jeffreysii (Williamson), [*Cribrostomoides jeffreysii* (Williamson)], VILKS, 1989, p. 531, pl. 21-I: 20-21.

***"Eggerella"* group**
Rhumblerella humbolti (Todd and Brönnimann), LOEBLICH and TAPPAN, 1994, p. 22, pl. 20: 1-7 (previously included in *Eggerella advena* Cushman).

***"Reophax"* group**
Cuneata arctica (Brady), LOEBLICH and TAPPAN, 1988, p. 59, pl. 45: 7-9 (previously referred to as *Reophax arctica*).
Reophanus guttifer (Brady), [*Reophax guttifer* BRADY], SCHRÖDER, 1986, p. 44, pl. 15: 12-13.
Reophax fusiformis (Williamson), LOEBLICH and TAPPAN, 1955, p. 8-9, pl. 1: 2-3.

***"Saccammina"* group**
Lagenammina atlantica (Cushman), [*Saccammina atlantica* (Cushman)], VILKS, 1989, p. 527, pl. 21-I: 6.
Saccammina sphaerica Brady, VILKS, 1989, p. 528, pl. 21-I: 7.

***"Spiroplectammina"* group**
Spiroplectammina biformis (Parker and Jones), VILKS, 1989, p. 532, pl. 21-II: 5-6.
Spiroplectammina earlandi (Parker), [*Textularia earlandi* Parker], VILKS, 1989, p. 533, pl. 21-II: 7.
Spiroplectammina nitens, EARLAND, 1933, p. 98, pl. 3: 31-35 (includes junior subjective synonym *Textularia torquata* Parker].

***"Trochammina"* group**
Lepidodeuterammina ochracea (Williamson), [*Deuterammina (Lepidodeuterammina) ochracea* (Williamson)], BRÖNNIMANN and WHITTAKER, 1983, p. 233-234, figs. 1-10 (previously referred to as *Trochammina ochracea*).
Lepidodeuterammina ochracea (Williamson) *sinuosa* (Brönnimann), BRÖNNIMANN and WHITTAKER, 1990, p.116-117, pl. 1: 9-12.
Paratrochammina (Lepidoparatrochammina) haynesi (Atkinson), BRÖNNIMANN and WHITTAKER, 1990, p. 112, pl. 1: 5-8 (previously included in *Trochamminna squamata* Parker and Jones).
Paratrochammina (Lepidoparatrochammina) lepida, BRÖNNIMANN and WHITTAKER, 1986, p. 118-119, pl. 1: A-L (previously included in *Trochammina squamata* Parker and Jones).

Calcareous Foraminifera
Allomorphina fragilis Hofker, KNUDSEN, 1971b, p. 250, pl. 8: 7-9.
Angulogerina angulosa (Williamson), LOEBLICH and TAPPAN, 1988, p. 525, pl. 574: 5-9 (includes junior subjective synonym *Angulogerina fluens* Todd).
Aubignyna perlucida (Heron-Allen and Earland), KNUDSEN, 1993, p. 87, pl. 1: 5-10.
Patellina corrugata Williamson, SCHRÖDER-ADAMS ET AL., 1990, p. 34, pl. 3: 25-26.
Rotorbis auberii (d'Orbigny), HANSEN and REVETS, 1992, p. 175, pl. 3: 1-3. 7.
Sphaeroidina bulloides d'Orbigny, LOEBLICH and TAPPAN, 1988, p. 564-565, pl. 617: 1-6.
Tosaia hanzawaia Takayanaki, LOEBLICH and TAPPAN, 1988, p. 513, pl: 564: 8-12.

Valvulineria minuta (d'Orbigny), LOEBLICH and TAPPAN, 1994, p. 135, pl. 268: 4-9.

"*Bolivina*" group

Aphelophragmina brittanica (Macfadyen), LOEBLICH and TAPPAN, 1994, p. 110, pl. 214: 13-24 (includes junior subjective synonym *Bolivina pacifica* Cushman and McCulloch).
Aphelophragmina spathulata (Williamson), [*Bolivina spathulata* (Williamson)], BARKER, 1960, p. 106, pl. 52: 20-21(includes junior subjective synonym *Bolivina ordinaria* Phleger and Parker).
Bolivina aenariensis (Costa), [*Brizalina aenariensis* Costa], LOEBLICH and TAPPAN, 1988, p. 498, pl. 548: 9-12 (includes junior subjective synonyms *Bolivina subaenariensis* Cushman and *Bolivina fragilis* Phleger and Parker).
Bolivina decussata Brady, PATTERSON ET AL., 1990, p. 11, fig. 17.1, 17.2 (includes junior subjective synonym *Bolivina pseudoplicata* Heron-Allen and Earland).
(?) *Bolivina mexicana* (Cushman), [*Bolivina subaenariensis mexicana* Cushman], POAG, 1981, p. 48, pl. 25: 1, pl. 26: 1a-c.
Bolivina vadescens Cushman, LOEBLICH and TAPPAN, 1994, p. 111, pl. 214: 1-4, 7-12 (includes junior subjective synonym *Bolivina lowmani* Phleger and Parker).
Bolivinella pseudopunctata (Höglund), [*Brizalina pseudopunctata* Höglund], MILLER ET AL., 1982a, p. 2364, pl. 2: 21 (includes junior subjective synonym *Brizalina transluscens* Phleger and Parker).

"Buccella" group

Buccella depressa ANDERSEN, 1952, p. 145, Figs. 7a-8.
Buccella frigida (Cushman), MILLER ET AL., 1982a, p. 2364, pl. 2: 9-10.
Buccella hannai (Phleger and Parker), [*Eponides hannai*], PHLEGER and PARKER, 1951, p. 21, pl. 10: 11a-14b.
Buccella mansfieldi (Cushman), ANDERSEN, 1952, p. 148-149, Figs. 12a-13c (includes junior subjective synonyms *Buccella inusitata* Andersen and *Buccella tenerrima* Bandy).
Buccella vicksburgensis (Cushman and Ellisor), ANDERSEN, 1952, p. 150-151, Figs. 1a-2c (includes junior subjective synonym*Buccella arctica* Voloshinova).
Buccella sp. 2, [*Glabratella wrightii* (Brady)], MILLER ET AL., 1982a (part, non *Discorbina wrightii* Brady, 1881), p. 2364, pl. 2: 16-17.
Trichohyalus bartletti (Cushman), LOEBLICH and TAPPAN, 1988, p. 644, pl. 727: 1-10.

"Bulimina" group

Bulimina marginata d'Orbigny, LOEBLICH and TAPPAN, 1988, p. 521, pl. 571: 1-3.
Buliminella tenuis Cushman and McCulloch, [*Buliminella* cf. *tenuis* Cushman and McCulloch], LOEBLICH and TAPPAN, 1994, p. 126, pl. 246: 1-4 (previously referred to as, and includes junior subjective synonym *Bulminella borealis* Haynes).
Floresina cf. *milletti* (Cushman), [*Buliminella milletti* Cushman], SEIGLIE, 1970, p. 114, text-figs. 8-12.
Globobulimina auriculata (Bailey), LOEBLICH and TAPPAN, 1988, p. 521, pl. 571: 4-7.

***"Cassidulina - Islandiella"* group**

Cassidulina carinata Silvestri, LOEBLICH and TAPPAN, 1994, p. 114, pl. 220: 7-12.

Cassidulina laevigata d'Orbigny, FEYLING-HANSSEN, 1990a, p. 20-22, pl. 4: 1-3.

Cassidulina teretis Tappan, MACKENSEN and HALD, 1988, p. 17, pl. 1: 8-15.

Cassidulina reniforme Nørvang, FEYLING-HANSSEN, 1990a, p. 22, pl. 4: 4-9.

Islandiella algida (Cushman), MILLER ET AL., 1996, p. 303-305, pl. 1: 1a-5.

Islandiella helenae Feyling-Hanssen and Buzas, VILKS ET AL., 1982, p. 226, pl. 1: 14.

Islandiella norcrossi (Cushman), VILKS, 1989, p. 538, pl. 21-IV: 5-6.

Paracassidulina neocarinata Thalmann, LOEBLICH and TAPPAN, 1994, p. 116-117, pl. 227: 1-15.

"Cibicides" group

Cibicides corpulentus Phelger and Parker, [*Cibicidoides corpulentus* (Phleger and Parker)], POAG, 1981, p. 52-53, pl. 31: 1; pl. 32: 1a-b.

Cibicides grossa Ten Dam and Reinhold, FEYLING-HANSSEN, 1990a, p. 24, pl. 4: 24-26.

Cibicides reflugens de Montfort, LOEBLICH and TAPPAN, 1994, p. 149, pl. 318: 7-9.

Cibicides robertsonianus (Brady), [*Cibicidoides robertsonianus* (Brady)], POAG, 1981, p. 54-55, pl. 5: 1, pl. 6: 1a-b.

Heterolepa subhaidingerii (Parr), LOEBLICH and TAPPAN, 1994, p. 163, pl. 359: 1-13 (includes junior subjective synonym *Cibicides umbonatus* Phleger and Parker).

Lobatula lobatalus (Walker and Jacob), LOEBLICH and TAPPAN, 1994, p. 150, pl. 316: 8-11; pl. 319: 1-7 (previously referrred to as *Cibicides lobatalus*).

Planulina retia Belford, LOEBLICH and TAPPAN, 1994, p. 149, pl. 315: 1-11; pl. 316: 4-7 (previously referred to as *Rosalina araucana* d'Orbigny).

"Cornuspira" group

Cornuspira borealis Cole, [New species of Cyclogyrae], SCHRÖDER-ADAMS ET AL., 1990, pl. 5: 3-4.

Cornuspira involvens (Reuss), LOEBLICH and TAPPAN, 1994, p. 36-37, pl. 56: 14-15.

Cornuspira planorbis Schlutze, LOEBLICH and TAPPAN, 1994, p. 37, pl. 56: 1-7.

"Discorbis - Rosalina" group

Discorbinella bertheloti (d'Orbigny), LOEBLICH and TAPPAN, 1994, p. 147-148, pl. 309: 13-15.

Gavelinopsis praegeri (Heron-Allen and Earland), HANSEN and REVETS, 1992, p. 177, pl. 6: 1-3, 6, 7.

Lamarkina haliotidea (Heron-Allen and Earland), OSTBY and NAGY, 1982, p. 85, pl. 1: 15.

Neodiscorbinella bradyi (Cushman), [*Rosalina globularis* d'Orbigny var. *bradyi*], CUSHMAN, 1915, p. 13-14, pl. 8: 1.

Neodiscorbinella plana (Heron-Allen and Earland), [*Discorbis plana*], HERON-ALLEN and EARLAND, 1932, p. 413, pl. 14: 9-12.

Orbitina williamsoni (Chapman and Parr), [*Rosalina williamsoni* (Chapman and Parr)], HAYNES, 1973, p. 162-164, pl. 17: 13-15, text-fig. 31: 1-4 (includes junior subjective synonym *Discorbis floridensis* (Cushman)).
Rosalina globularis (d'Orbigny), HANSEN and REVETS, 1992, p. 177, pl. 6: 4-6, 9.
Rosalina micens (Cushman), LOEBLICH and TAPPAN, 1994, p. 140, pl. 286: 1-3 (includes junior subjective synonym *Discorbis squamata* Parker).

"Elphidium" group

Cribroelphidium albiumbilicatum (Weiss), [*Elphidium albiumbilicatum* (Weiss)], FEYLING-HANSSEN, 1990a, p. 28, pl. 5: 14-15.
Cribroelphidium asklundi (Brotzen), [*Elphidium asklundi* Brotzen], FEYLING-HANSSEN, 1990a, p. 28, pl. 5: 16-17.
Cribroelphidium bartletti (Cusjman), [*Elphidium bartletti* Cushman], FEYLING-HANSSEN, 1980b, p. 179, pl. VI: 17-18.
Cribroelphidium excavatum (Terquem), [*Elphidium excavatum* (Terquem) formae], MILLER ET AL., 1982b, p. 116-144, pls. 1-6.
Cribroelphidium frigidum Cushman, [*Cribrononion frigidum* (Cushman)], SCOTT ET AL., 1980, p. 228, pl. 2: 8.
Cribroelphidium subarcticum Cushman, [*Elphidium subarcticum* Cushman], FEYLING-HANSSEN, 1980b, p. 179, pl. VI: 11-12.
Elphidiella groenlandicum (Cushman), [*Elphidium groenlandicum* Cushman], FEYLING-HANSSEN, 1990a, p. 29, pl. 6: 9-10.
Elphidiella cf. *hannai* (Cushman and Grant), [*Elphidium hannai* Cushman and Grant], FEYLING-HANSSEN, 1990a, p. 29-30, pl. 7: 1-7.
Elphidiella rolfi Gudina and Polovova, FEYLING-HANSSEN, 1990a, p. 30, pl. 7: 8-13.

"Eoeponidella" group

Altastellerella riveroae Seiglie, LOEBLICH and TAPPAN, 1988, p. 605, pl. 605, pl. 674: 1-3 (previouslly included with *Eoeponidella pulchella* (Parker)).
Eoeponidella pulchella (Parker), VILKS, 1989, p. 540, pl. 21-IV: 13-15.

"Epistominella" group

(?) *Eilohedra arctica* Green [*Stetsonia horvathi* (Green)], SCOTT, 1987 (non *S. hovathi* Green), p. 329, pl. 2:1- 2.
Eilohedra levicula (Resig), LOEBLICH and TAPPAN, 1994, p. 145, pl. 303: 1-13 (previously misidentified as *Epistominella exigua* (Brady)).
Pseudoparrella exigua (Brady), LOEBLICH and TAPPAN, 1994, p. 146, pl. 307: 1-7 (includes junior subjective synonyms *Epistominella vitrea* Parker and *Epistominella sandiegoensis* Uchio).
Pseudoparrella cf. *subperuviana* (Cushman), [*Pseudoparella subperuviana* (Cushman)], LOEBLICH and TAPPAN, 1988, p. 575, pl. 627, 19-21 (previously misidentified as *Epistominella vitrea* Parker and *Epistominella sandiegoensis* Uchio).
Pseudoparrella takayanagi (Iwasa), MATOBA ET AL., 1990, pl. 8: 2a-c.

"Eponides" group

Eponides pusillus Parr, LOEBLICH and TAPPAN, 1994, p. 135-136, pl. 270: 1-10.
Ioanella tumidula (Brady), UJIIÉ, 1995, p. 66, pl. 8: 5a-c (previously referred to as *Eponides tumidulus* (Brady)).
Nuttalides bradyi (Earland), LOEBLICH and TAPPAN, 1988, p. 603, pl. 669: 17-27 (includes junior subjective synonym *Pulvinulinella bradyanus* Cushman).
Oridosalis umbonatus (Reuss), SCOTT and VILKS, 1991, p. 32, pl. 2: 15-16; pl. 4: 4-5.

"Fissurina" group

Fissurina aequilabialis (Buchner), SCHNITKER, 1970, p. 40-41, pl. 2: 8a-c.
Fissurina anapetebasilaris PATTERSON and BURBIDGE, 1995, p. 647, fig. 6: 8-10.
Fissurina annectans (Burrows and Holland), [*Lagena annectans* Burrows and Holland], HERON-ALLEN and EARLAND, 1932, p. 374, pl. 10: 40-44.
Fissurina circularis Todd, LOEBLICH and TAPPAN, 1994, p. 88, pl. 154: 143-18.
Fissurina cucurbitasema Loeblich and Tappan, RODRIGUES and RICHARD, 1986, p. 20, pl. 3: 8.
Fissurina dancia (Madsen), KNUDSEN, 1971b, p. 228, pl. 6: 6-7; pl. 18: 3.
Fissurina fasciata (Egger), [*Fissurina* cf. *fasciata* (Egger)], FEYLING-HANSSEN, 1964, p. 313-314, pl. 15: 15-16.
Fissurina cf. *F. fimbriata* (Brady), [*Fissurina fimbriata fimbriata* (Brady)], JONES, 1984, p. 109, pl. 3: 3-4.
Fissurina latiostoma Seguenza, [*Fissurina latiostoma* Seguenza, subsp. *imperfecta*] JONES, 1984, p. 109, pl. 3: 6-7 (includes *Fissurina reniformis* (Sidebottom) of some authors (*non* Sidebottom); and *Fissurina britannica* Jones).
Fissurina lucida (Williamson), MURRAY, 1971, p. 97, pl. 39: 1-3.
Fissurina marginata (Walker and Boys), LOEBLICH and TAPPAN, 1988, p. 428, pl. 465: 5-7.
Fissurina paula McCulloch, LOEBLICH and TAPPAN, 1994, p. 90, pl. 155: 11-12.
Fissurina polita (Chapman and Parr), LOEBLICH and TAPPAN, 1994, p. 90, pl. 156: 14-15.
Fissurina pseudoglobosa (Buchner), SCHNITKER, 1970, p. 44, pl. 3: 1a-c.
Fissurina pseudoglobosa pseudoglobosa (Buchner), JONES, 1984, p. 110, pl. 3: 10.
Fissurina stewartii (Wright), SCHNITKER, 1971, p. 200, pl. 4: 16a-b.
Fissurina subchasteri McCULLOCH, 1977, p. 132, pl. 57: 13a-b.
Fissurina tricarinata PARR, 1950, p. 319-320, pl. 10: 16-18.
Fissurina sp. 1 , JONES, 1984, p. 116, pl. 4: 4.
Galwayella subangulosa (McCulloch), [*Lagena subangulosa*], McCULLOCH, 1977, p. 47, pl. 60: 25a-b, 27a-b.
Lagenosolenia inflatiperforata McCulloch, LOEBLICH and TAPPAN, 1994, p. 92, pl. 159: 1-11.
Lagenosolenia lagenoides (Williamson), [*Fissurina lagenoides* (Williamson)], UJIIÉ ET AL., 1983, p. 55, pl.2: 27-28 (includes junior subjective synonym*Fissurina serrata* (Schlumberger)).
Palliolatella orbignyana Seguenza, [*Fissurina orbignyana* Seguenza], MURRAY, 1971, p. 99, pl. 40: 1-5.
Parafissurina arata (Buchner), SCHNITKER, 1970, p. 45-46, pl. 3: 2a-b.

Parafissurina carinata (Buchner), [*Parafissurina lateralis* (Cushman) forma *carinata* (Buchner)], KNUDSEN, 1971b, p. 233, pl. 6: 12-13.
Parafissurina exiguformis McCULLOCH, 1977, p. 145, pl. 71: 22.
Parafissurina fornasini Buchner, UJIIÉ, 1990, p. 27, pl. 9: 8a-b.
Parafissurina himatiostoma Loeblich and Tappan, JONES, 1984, p.127-128, pl. 6: 9-10.
Parafissurina magnilabiata PARR, 1950, p. 316, pl. 9: 18.
Parafissurina obsoleta McCULLOCH, 1977, p. 152, pl. 71: 1a, 1c.
Parafissurina ovata (Wiesner), PARR, 1950, p. 316, pl. 10: 4.
Parafissurina subquadrata (Parr), LOEBLICH and TAPPAN, 1994, p. 94, pl. 165: 1-5.
Parafissurina tectulostoma Loeblich and Tappan, JONES, 1984, p.128, pl. 6: 13-14.
Pseudoolina fissurinea Jones, LOEBLICH and TAPPAN, 1988, p. 429, pl. 465: 3-4.
Ventrostoma depressiformis (McCulloch), [*Parafissurina depressiformis*] McCULLOCH, 1977, p. 151, pl. 70: 8-9.
Ventrostoma fovigera (Buchner), LOEBLICH and TAPPAN, 1988, p. 430, pl. 466: 15-19.
Ventrostoma mitrata (McCulloch), [*Parafissurina mitrata*], McCULLOCH, 1977, p. 151, pl. 70: 15.

"Fursenkoina" group
Fursenkoina fusiformis (Williamson), [*Stainforthia fusiformis* (Williamson)], KNUDSEN and SEIDENKRANTZ, 1994, p. 5-13, pl.3: 1-7, 16-17.
Fursenkoina pauciloculata (Brady), LOEBLICH and TAPPAN, 1994, p. 131, pl. 256: 1-5 (includes junior subjective synonyms *Fursenkoina pontoni* (Cushman) and *Stainforthia feylingi* Knudsen and Seidenkrantz (part)).
Fursenkoina rotundata (Parr), LOEBLICH and TAPPAN, 1994, p.131, pl. 256: 6-13 (includes junior subjective synonym *Stainforthia feylingi* Knudsen and Seidenkrantz (part)).
Rutherfordoides mexicana (Cushman), LOEBLICH and TAPPAN, 1994, p. 131-132, pl. 257: 13-15.
Stainforthia concava (Höglund), KNUDSEN and SEIDENKRANTZ, 1994, p. 5-13, pl. 3: 12-13.

"Glabratella" group
Conorbella pulvinata (Brady), LOEBLICH and TAPPAN, 1988, p. 565-566, pl. 618: 4-6.
(?) *Glabratellina arcuata* Seiglie and Bermúdez, LOEBLICH and TAPPAN, 1994, p. 567, pl. 619: 7-9.
(?) *Glabratellina lauriei* (Heron-Alllen and Earland), [*Glabratella lauriei* (Heron-Allen and Earland)], SCHNITKER, 1971, p. 200, pl. 6: 7a-c.
(?) *Glabratellina wrightii* (Brady), [*Glabratella wrightii* (Brady)], FEYLING-HANSSEN, 1990b, p. 104, pl. 2: 6-8.
(?) *Glabratellina sp. 1.*
Heronallenina parva Parr, LOEBLICH and TAPPAN, 1994, p. 143, pl. 296: 1-12.
Rotaliella chasteri (Heron-Allen and Earland), PAWLOWSKI ET AL., 1992, p. 129, pl. 1: 1a-2 (also includes junior subjective synonyms *Rotaliella heronallenia* Paawlowski, Zaninetti, Whittaker, and Lee; and *Glabratella arctica* Scott and Vilks).

"Gyroidina" group
Gyroidinoides nipponicus (Ishizaki), UJIIÉ, 1990, p. 47, pl. 27: 1a-c.
Gyroidinoides quinqueloba (Uchio), [*Gyroidina quinqueloba*], UCHIO, 1960, p. 66-67, pl. 8: 22-25.

"Lagena" group
Hyalinonetrion distoma (Parker and Jones), [*Lagena distoma* Parker and Jones], UJIIÉ ET AL., 1983, p.54, pl. 1: 22.
Lagena semilineata Wright, LOEBLICH and TAPPAN, 1953, p. 65-66, pl. 11: 14-22.
Lagena substriata Williamson, UJIIÉ, 1990, p. 19, pl. 5: 7-8.
Procerolagena gracilis (Williamson), [*Lagena mollis* Cushman,] LOEBLICH and TAPPAN, 1953, p. 63-64, pl. 11: 25-27.

"Miliolinella" group
Adelosina sp. 1.
Miliolinella chukchiensis Loeblich and Tappan, SCHRÖDER-ADAMS ET AL., 1990, p. 34, pl. 5: 10.
Miliolinella circularis (Bornemann), COLE, 1981, p. 56, pl. 13: 10.
Miliolinella subrotunda (Montagu), LOEBLICH and TAPPAN, 1994, p. 340, pl. 350: 1-14.
Pyrgo oblonga (d'Orbigny), LOEBLICH and TAPPAN, 1988, p. 343, pl. 351: 11-13.
Triloculina dissidens McCuLLOCH, 1977, p. 554, pl. 210: 9-11.
Triloculina tricarinata d'Orbigny, LOEBLICH and TAPPAN, 1994, p. 56, pl. 96: 1-7.
Triloculina trihedra LOEBLICH and TAPPAN, 1953, p. 45, pl. 4: 10.
Triloculinella differens [*Massilina* (?) *differens*], McCULLOCH, 1977, p. 516, pl. 216: 16 (includes junior subjective synonym *Triloculinella chiatocytis* Loeblich and Tappan).
Triloculinella tegminus (Loeblich and Tappan), LOEBLICH and TAPPAN, 1988, p. 344-345, pl. 353: 1-3.

"Nonion" group
Astrononion stelligerum (d'Orbigny), LOEBLICH and TAPPAN, 1988, p. 619, pl. 694: 1-2, 20-21.
Haynesina depressula (Walker and Jacob), BANNER and CULVER, 1978, p. 200-201, pl. 10: 1-8.
Haynesina germanica (Ehrenberg), SCHRÖDER-ADAMS ET AL., 1990, p.34, pl. 8: 7-8.
Haynesina orbiculare (Brady), [*Nonion orbiculare* (Brady)], FEYLING-HANSSEN, 1990a, p. 26, pl. 5: 9-10.
Laminononion stellatum (Cushman and Edwards), LOEBLICH and TAPPAN, 1988, p. 620, pl. 694: 3-4 (also includes junior subjective synonyms *Astrononion gallowayi* Loeblich and Tappan, and *Astrononion hamadaense* Asano, and previously misidentified as such; also previously included *Astrononion stelligerum* (d'Orbigny)).
Melonis barleeanus (Williamson), [*Nonion barleeanum* (Williamson)], SCOTT and VILKS, 1991, p. 30, pl. 2: 9; pl. 4: 6-7.

Nonionella lobsannensis (Andreae), FEYLING-HANSSEN, 1990a, p. 26-28, pl. 5: 11-13 (previously misidentified as *Nonionella atlantica* Cushman).
Nonionella stella Cushman and Moyer, [*Nonionella* cf.*opima* Cushman], SAUNDERS and MÜLLER-MERZ, 1982, p. 272, pl. 3: 26-29.
Nonionellina labradorica (Dawson), VILKS, 1989, p. 545-546, pl. 21-IV: 9-10.
Nonionoides grateloupi (d'Orbigny), LOEBLICH and TAPPAN, 1988, p. 618, pl. 692: 7-14.
Pulleniella osloensis (Feyling-Hanssen), [*Pullenia osloensis* Feyling-Hanssen], FEYLING-HANSSEN, 1964, p. 334, pl. 18: 5-6 (includes junior subjective synonym *Pulleniella asymmetrica* Ujiié).

"Oolina" group
Cushmanina striatopunctata (Parker and Jones), PATTERSON and RICHARDSON, 1987, p. 217, pl. 1: 2-6 (previously referred to as *Oolina striatopunctata*).
Favulina hexagona (Williamson), [*Oolina hexagona* (Williamson)], FEYLING-HANSSEN, 1990a, p. 20, pl. 3: 23.
Favulina melo (d'Orbigny), [*Oolina melo* d'Orbigny], RODRIGUES and RICHARD, 1986, p. 20, pl. 1: 6.
Homeohedra acuticostata (Reuss), [*Oolina acuticostata* (Reuss)], RODRIGUES and RICHARD, 1986, p. 21, pl. 1: 7; also includes junior subjective synonym *Lagena apiopleura* Loeblich and Tappan).
Oolina lineata (Williamson), LOEBLICH and TAPPAN, 1988, p. 427, pl. 463: 8-11.

"Polymorphina" group
Entomorphinoides inalienata McCULLOCH, 1977, p. 211, pl. 92: 20-23, 26-27.
Globulina minuta (Roemer), FEYLING-HANSSEN, 1990a, p. 18, pl. 3: 10-13.
Globulina prisca Reuss, CUSHMAN and OZAWA, 1930, p. 73, pl. 12: 6a-c.
(?)*Globulotuboides decora* (Reuss) [*Pseudopolymorphina decora* (Reuss)], FEYLING-HANSSEN, 1990a, p. 20, pl. 3: 14-15 (includes junior subjective synonym *Globulotuboides orbicula* McCulloch).
Metapolymorphina ligua (Roemer), [*Pseudopolymorphina ligua* (Roemer)], CUSHMAN and OZAWA, 1930, p. 89-90, pl. 22: 5-6 (includes junior subjective synonym *Polymorphina charlottensis* Cushman).
Pseudopolymorphina novangliae (Cushman), KNUDSEN, 1971b, p. 271, pl. 5: 5-6.
Svenia sidebottomi (Cushman), [*Laevidentalina sidebottomi* (Cushman)], LOEBLICH and TAPPAN, 1994, p. 65, pl. 113: 13-19 (previously referred to as, and includes junior subjective synonym, *Dentalina ittai* Loeblich and Tappan).

"Quinqueloculina" group
Axiopolina parvula Schlumberger, [*Quinqueloculina parvula* Schlumberger], LE CALVEZ and LE CALVEZ, 1958, p. 184-185, pl. 11: 131-133 (includes junior subjecticve synonyms *Quinqueloculina stalkeri* Loeblich and Tappan and *Quinqueloculina tipsworli* Andersen).
Quinqueloculina cf. *Q. akneriana* d'Orbigny, [*Quinqueloculina* cf. *akneriana* d'Orbigny], McCULLOCH, 1977, p. 479, pl. 212: 11.
Quinqueloculina arctica Cushman, SCHRÖDER-ADAMS ET AL., 1990, p. 35, pl. 5: 14.

Quinqueloculina crassicarinata Collins, LOEBLICH and TAPPAN, 1994, p. 48, pl. 77: 4-12.
Quinqueloculina patagonica d'Orbigny, BOLTOVSKOY ET AL., 1980, p. 46-47, pl. 28: 18-21.
Quinqueloculina seminula (Linné), VILKS, 1989, p. 536, pl. 21-III: 14.
(?)*Siphonaperta aspera* (d'Orbigny), HAYNES, 1973, p. 63, pl. 7: 1-3; pl. 8: 2; pl. 31: 1-5, text-fig. 15: 1-4 (includes junior subjective synonym *Quinqueloculina agglutinata* Cushman of some authors, non *Q. agglutinata* Cushman).

"Uvigerina" group
(?) *Euuvigerina brunnensis* (Karrer), [*Uvigerina brunnensis* Karrer], BARKER, 1960, p. 156, pl. 75: 4-5.
(?) *Neouvigerina canariensis* (d'Orbigny), [*Uvigerina canariensis* d'Orbigny], UJIIÉ, 1995, p. 63, pl. 6: 7a-b.
Uvigerina peregrina Cushman, LOEBLICH and TAPPAN, 1988, p. 525, pl. 573: 24-28.

Quaternary planktonic foraminifera
Globigerina bulloides d'Orbigny, LOEBLICH and TAPPAN, 1994, p. 105-106, pl. 197: 1-9.
Globigerinita uvula (Ehrenberg), LOEBLICH and TAPPAN, 1994, p. 104, pl. 191: 7-12.
Globorotalia inflata (d'Orbigny), SAITO ET AL., 1981, p. 124-126, pl. 41: 1a-d; pl. 56: 5.
Neogloboquadrina dutertrei (d'Orbigny), LOEBLICH and TAPPAN, 1988, p. 476, pl. 514: 12-14; pl. 515: 1-3.
Turborotalia pachyderma (Ehrenberg), [*Neogloboquadrina pachyderma* (Ehrenberg)], VILKS, 1989, p. 543, pl. 21-VII: 1a-3b, 21-VIII: 1a-3b, 21-IX: 1a-3b.
Turborotalita quinqueloba (Natland), [*Globigerina quinqueloba* Natland], SAITO ET AL., 1981, p. 48, pl. 10: 1a-2d.

Reworked benthonic foraminifera
Arenobulimina americana Cushman, CUSHMAN, 1946, p. 42-43, pl. 12: 1.
Dorothia bulleta (Carsey), [*Dorothia* cf. *D. bulleta* (Carsey)], McNEIL and CALDWELL, 1981, p. 184-185, pl. 15: 7a-b.
Pseudotextulariella cretosa (Cushman), HART ET AL., 1989, p. 318, pl. 7.2: 11-12.
Spiroplectammina laevis (Roemer), CUSHMAN, 1946, p. 27-28, pl. 6: 1-3.
Tritaxia pyramidata Reuss, HART ET AL., 1989, p. 320, pl. 7.3: 2-3.
Tritaxia singularis Magniez-Jannin, HART ET AL., 1989, p. 320, pl. 7.3: 4.
Trochammina texana Cushman and Waters, CUSHMAN, 1946, p. 50, pl. 1: 4-5.
Vernuilina muensteri Reuss, HART ET AL., 1989, p. 320, pl. 7.3: 7-8.
Alabamina wilcoxensis Loeblich and Tappan, LOEBLICH and TAPPAN, 1964, p. C748-C750, Fig. 614: 1a-c.
Allomorphina rochoides (Reuss), NYONG and OLSSON, 1984, p. 450, pl. 4: 15-16.
Anamalinoides harperi (Sandidge), McNEIL and CALDWELL, 1981, p. 283-284, pl. 24: 4a-c.

Astacolus dissonus Plummer, [*Planularia dissonus* (Plummer)], CUSHMAN, 1946, p. 57, pl. 19: 11-18.
Bandyana greatvalleyensis (Trujillo), McNEIL and CALDWELL, 1981, p. 270-271, pl. 22: 10.
Bolivinita eleyi Cushman, CUSHMAN, 1946, p. 114, pl. 48: 18-20.
Bolivinopsis papillata (Cushman), CUSHMAN, 1946, p. 102, pl. 44: 9.
Brizalina decoratus delicatula Cushman, [*Bolivinoides decorata* (Jones) var. *delicatula* Cushman], CUSHMAN, 1946, p. 113, pl. 48: 10-14.
Brizalina decurrens (Ehrenberg), [*Bolivina decurrens* (Ehrenberg)], HART ET AL., 1989, p. 322, pl. 7.4: 6-7.
Brizalina incrassata (Reuss), [*Bolivina incrassata* Reuss], HART ET AL., 1989, p. 322, pl. 7.4: 8-9.
Brizalina velascoensis (Cushman), [*Bolivinoides velascoensis* (Cushman)], CUSHMAN, 1946, p. 114, pl. 48: 16a-b.
Brizalina watersi (Cushman), [*Bolivinoides watersi* (Cushman)], CUSHMAN, 1946,
p. 128, pl. 53: 18.
Buliminella fabilis (Cushman and Parker), [*Buliminella* cf. *B. fabilis* (Cushman and Parker)], McNEIL and CALDWELL, 1981, p. 218, pl. 18: 13.
Cassidella navarroana (Cushman), [*Virgulina navarroana* Cushman], CUSHMAN, 1946, p. 126-127, pl. 53: 5-7.
Cassidella tegulata (Reuss), McNEIL and CALDWELL, 1981, p. 271-272, pl. 22: 11-12.
Cibicides constrictus (Hagenow), CUSHMAN, 1946, p. 160, pl. 65: 13.
Cibicides subcarinatus Cushman and Deaderick, CUSHMAN, 1946, p. 159, pl. 65: 8-11.
Dentalina basiplanata Cushman, McNEIL and CALDWELL, 1981, p. 190-192, pl. 15: 16-17.
Dentalina consobrina d'Orbigny, [*D.* cf. *cosobrina* d'Orbigny], CUSHMAN, 1946, p. 69, pl. 24: 23-27.
Dentalina crinita Plummer, CUSHMAN, 1946, p. 69, pl. 24: 29-30.
Dentalina gracilis d'Orbigny, CUSHMAN, 1946, p. 65, pl. 23: 3-6.
Dentalina lorneiana d'Orbigny, CUSHMAN, 1946, p. 65-66, pl. 23: 7-11.
Dentalina megalopolitiana Reuss, CUSHMAN, 1946, p. 67, pl. 23: 24-26.
Dentalina solvata (Cushman), NYONG and OLSSON,1984, p. 451, pl. 5: 17-18.
Ellipsonodosaria exilis Cushman, CUSHMAN, 1946, p. 135, pl. 56: 10-11.
Eouvigerina americana Cushman, CUSHMAN, 1946, p. 115, pl. 49: 4-5.

McNeil and Caldwell (1981) point out that the name *"E. aculeata"* Cushman is a junior secondary homonym of *E. aculeata* Ehrenberg and errected a new name, *E. subsculptura*. However, the species they illustrate (pl. 18: 20-21) is much more similar to *E. americana* Cushman (CUSHMAN, 1946, p. 115, pl. 49: 4-5), than to *E. aculeata* Cushman (CUSHMAN, 1946, p. 115, pl. 49: 13a-b). Consequently the name *"E. subsculptura"* is used for specimens resembling *E. aculeata* Cushman sensu Cushman, 1946; and the name *"E. americana"* (Cushman) for specimens resembling *E. subsculptura* McNeil and Caldwell (1981, p. 231-232, pl. 18: 20-21).

Eouvigerina austinana Cushman, CUSHMAN, 1946, p. 116, pl. 49: 9.
Eouvigerina excavata, CUSHMAN,1940, p. 66, pl. 11: 18.
Eouvigerina subsculptura McNeil and Caldwell, [*Eouvigerina aculeata* Cushman], CUSHMAN, 1946, p. 115, pl. 49: 13a-b.

Eponides haidigerii (d'Orbigny), CUSHMAN, 1946, p. 142, pl. 57: 13-14.
Gavelinella clementiana (d'Orbigny), HART ET AL., 1989, p. 336, pl. 7.11: 1-3.
Gavelinella henbesti (Plummer), McNEIL and CALDWELL, 1981, p. 284-285, pl. 24: 5a-6c.
Gavelinella intermedia (Berthelin), HART ET AL., 1989, p. 338, pl. 7.12: 1-3.
Gavelinella nelsoni (Berry), [*Anomalina nelsoni* Berry], CUSHMAN, 1946, p. 154, pl. 63: 8-9.
Gavelinella pertusa Marrson, McNEIL and CALDWELL, 1981, p. 286-288, pl. 25: 1a-c, 2a-c.
Gavelinella rubiginosa Cushman, [*Anomalina rubingosa* Cushman], PERLMUTTER and TODD, 1965, p. I19-I20, pl. 6: 19-21.
Gavelinella sandidgei (Brotzen), McNEIL and CALDWELL, 1981, p. 288, pl. 27: 7a-c, 8a-c.
Gavelinella tennesseensis (Berry), [*Anomalina tennesseensis* Berry], CUSHMAN, 1946, p. 155, pl. 64: 3.
Gavelinella velascoensis (Cushman), [*Anomalina velascoensis* Cushman], CUSHMAN, 1946, p. 156, pl. 64: 7.
Gyroidinoides depressus (Alth), [*Gyroidinoides depressa* (Alth)], CUSHMAN, 1946, p. 139-140, pl.58: 1-4.
Gyroidinoides girardanus (Reuss), McNEIL and CALDWELL, 1981, p. 280-281, pl. 24: 1.
Gyroidinoides globosa (Hagenow), CUSHMAN, 1946, p. 140, pl. 58: 6-8.
Gyroidinoides nitidus (Reuss), McNEIL and CALDWELL, 1981, p. 281-283, pl. 24: 2a-13.
Hanzawaia producta (Terquem), MURRAY ET AL., 1989, p. 522, pl. 10.7: 4-6.
Lagena apiculata (Reuss), [*Lagena apiculata apiculata* (Reuss)], McNEIL and CALDWELL, 1981, p. 199-200, pl. 16: 7.
Lagena globosa Montagu, [*Lagena* cf. *L. globosa* Montagu], CUSHMAN, 1946, p. 95, pl. 39: 26.
Lenticulina navicula (d'Orbigny),CUSHMAN, 1946, p. 56, pl. 18: 16.
Lenticulina nuda (Reuss), McNEIL and CALDWELL, 1981, p. 203, pl. 16: 15a-b.
Lenticulina rotulata (Lamarck), McNEIL and CALDWELL, 1981, p. 203, pl. 16: 14a-b.
Lenticulina subalata (Reuss), CUSHMAN, 1946, p. 55, pl. 18: 7-8
Lenticulina williamsoni (Reuss), [*Robulus williamsoni* (Reuss)], CUSHMAN, 1946, p. 54, pl. 18: 2-3.
Marginulina recta (d'Orbigny), [*Marginulina* cf. *M. recta* (d'Orbigny)], CUSHMAN, 1946, p. 60, pl. 21: 4-5.
Marginulina stephensoni Cushman, CUSHMAN, 1946, p. 59-60, pl. 20: 25-26.
Neobulimina canadiensis Cushman and Wickenden, CUSHMAN, 1946, p. 125, pl. 52: 11-12.
Nodosaria affinis Reuss, CUSHMAN, 1946, p. 70-71, pl. 25: 8-23.
Nonionella robusta Plummer, [*Nonionella* cf. *N. robusta* Plummer], McBETH and SCHMIDT, 1973, p. 1058-1059, pl. 1: 37-38.
Osangularia cordierana (d'Orbigny), HART ET AL., 1989, p. 354, pl. 7.20: 4-6.
Osangularia navarroana Cushman, McNEIL and CALDWELL, 1981, p. 275-277, pl. 23: 6a-c.
Planularia gemmata (Brady), BARKER, 1960, p. 148, pl. 71: 6-7.
Pleurostomella austinana Cushman, CUSHMAN, 1946, p. 131-132, pl. 54: 19-21.

Pleurostomella subnodosa Reuss, CUSHMAN, 1946, p. 132, pl. 55: 1-9.
Praebulimina carseyae (Plummer), McNEIL and CALDWELL, 1981, p.222-223, pl. 18: 9.
Praebulimina kickapooensis (Cole), McNEIL and CALDWELL, 1981, p. 225-226, pl. 18: 10-11.
Praebulimina reussi (Morrow), McNEIL and CALDWELL, 1981, p. 225-226, pl. 18: 12.
Pseudouvigerina cretacea Cushman, CUSHMAN, 1946, p. 117, pl. 49: 17-20.
Pseudouvigerina seligi (Cushman), OLSSON, 1960, p. 30, pl. 4: 23.
Pullenia quaternaria (Reuss), HART ET AL., 1989, p. 358, pl. 7.22: 3.
Pyramidina referrata (Jennings), [*Bulimina referrata* Jennings], OLSSON, 1960, p. 32, pl. 5: 3-4.
Pyramidina rudita (Cushman and Parker), [*Bulimina rudita* Cushman and Parker], FRIZZEL, 1954, p. 116, pl. 17, figs. 6a-b.
Pyramidina triangularis (Cushman and Parker) [*Bulimina triangularis* Cushman and Parker], FRIZZEL, 1954, p. 116, pl. 17: 9a-b.
Pyrulina fusiformis (Roemer), BARKER, 1960, p. 148, 150, pl. 71: 17-19; pl. 72: 4.
Reusella szjinochae (Grzybowski), [*Reussella szjinochae szjinochae* (Grzybowski)], HART ET AL., 1989, p. 360, pl. 7.23: 8.
Rotalipora appenninica (Renz), HART ET AL., 1989, p. 360, pl. 7.23: 9-11.
Siphomina prima Plummer, CUSHMAN, 1946, p. 142, pl. 59: 3-5.
Stetsoieina pommerana Brotzen, HART ET AL., 1989, p. 362, pl. 7.24: 10-12.
Valvulineria allomorphoides (Reuss), OLSSON, 1960, p. 25, pl. 6: 1.
Valvulineria cretacea (Carsey), CUSHMAN, 1946, p. 138-139, pl. 57: 8.
Valvulineria umbilicatula (d'Orbigny), [*Valvulineria* cf. *V. umbilicatula*], CUSHMAN, 1946, p. 139, pl. 57: 9-12.

Reworked planktonic foraminifera

Globorotalites michelinianus (d'Orbigny), McNEIL and CALDWELL, 1981, p. 277-278, pl. 23: 5a-c.
Globoratalites cretacea Cushman, SMITH and PESSAGNO, 1973, p. 15-16, pl. 1: 1-8.
Gumbelitrea glabrans Cushman, CUSHMAN, 1946, p. 109, pl. 46: 17-18.
Heterohelix globulosa (Ehrenberg), McNEIL and CALDWELL, 1981, p. 234-239, pl. 19: 1-2.
Heterohelix pulchra (Brotzen), McNEIL and CALDWELL, 1981, p. 239-241, pl. 19: 3.
Heterohelix striata (Ehrenberg), McNEIL and CALDWELL, 1981, p. 241-243, pl. 19: 4.
Planoglobulina taylorana Cushman, CUSHMAN, 1946, p. 110-111, pl. 47: 10-11.
Rectogumbelina cretacea Cushman, CUSHMAN, 1946, p. 110, pl. 47: 2-3.
Rectogumbelina hispidula Cushman, CUSHMAN, 1946, p. 109, pl. 46: 22-24.