Paleoseismic Tsunami Investigations, Northern Cascadia Subduction Zone: Collaborative Research (B.C. Geological Survey Branch, Geological Survey of Canada, University of British Columbia and Simon Fraser University).

Grant Number: PN6171

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NON-TECHNICAL PROJECT SUMMARY

Great earthquakes (magnitude >8) occur, on average every 500 years on the Cascadia subduction zone of western North America. Damage from the earthquakes will be widespread and will result from ground shaking, coastal subsidence, landslides, liquefaction and tsunamis. Geologic evidence for past earthquakes has been well documented in coastal marshes from northern California to Vancouver Island. The objective of this project is to determine the frequency and size of prehistoric tsunamis in Cascadia by studying their deposits in low-elevation lakes along the west coast of Vancouver Island. Cores from seven lakes and tidal inlets have been retrieved and analyzed to document late Holocene tsunami events. Deposits of one to two large tsunamis have been found in three of the lakes. The age and distribution of these deposits help elucidate the extent of the tsunami hazard in Cascadia.

ANNUAL PROJECT SUMMARY

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Program Element: I

Key Words: geology, neotectonics, paleoseismology, tsunami

Investigations Undertaken

Although no great earthquakes (moment magnitude Mw>8) have been recorded in the historic period at the Cascadia subduction zone (the interface of the Juan de Fuca and North America plates along the coasts of British Columbia and the adjacent U.S.), a variety of geological and geophysical data suggest that several great earthquakes have occurred there over the course of the late Holocene (Atwater et al. 1995). Evidence in support of this conclusion has been obtained from stratigraphic sequences in estuaries from northern California to southern Vancouver Island. In this region, geological investigations of past tsunamis have largely focused on analysis of tsunami deposits in intertidal marshes and lagoons (e.g. Long et al. 1989; Minoura and Nakaya 1991).

In contrast to the northwest coast, the coastal plain at western Vancouver Island, has undergone uplift during the late Holocene. As a result, the record of earthquakes in intertidal marshes on Vancouver Island does not extend further back in time than about 1000 years ago (Clague and Bobrowsky 1994). To document older events on Vancouver Island, we have targeted lakes near the limit of tides. In particular, lakes with low fluvial inputs, located 1-10 m above sea level and situated at the heads of narrow inlets and bays, appear to hold the greatest promise for paleotsunami investigations. Not only is the lithology of a tsunami deposit likely to be distinct from that of low-energy, autochthonous lake deposits, but marine and brackish-marine microfossils carried into the lake by a tsunami contrast sharply with the freshwater taxa native to the lake. Moreover, a tsunami deposit has a much higher probability of burial and preservation in a lake than in the neighbouring forest. Recent work by Hutchinson et al. (1996) confirm the premise that some coastal lakes on Vancouver Island contain evidence for late Holocene tsunami inundation.

We have investigated seven sites (five lakes and two tidal inlets) on the west coast of Vancouver Island (Figure 1). Six of the sites are northwest of Tofino and one is directly west of Victoria (Table 1). The lakes and inlets were accessed by truck, boat and helicopter. The sampled lakes range in size from approximately 0.1 to 1.2 km^2, are from about 100 m to 5 km from the coast and range in elevation from 0 to 6 m. This range in lake attributes is important as it provides a diverse suite of potential catchment basins where tsunami sediments may be preserved and provides constraints on tsunami run-up and size.

A floating, portable coring system was constructed specifically for this study using two Quicksilver 3.5 m long inflatable boats, separated by bumpers and covered with a folding plywood platform. Cores were recovered from the lakes using a standard Livingstone corer or a percussion corer (cf. Reasoner 1986, 1993). Maximum solid core length using the above systems is about 3 m.

Results

Cores from all seven sites have been split and logged. Organic samples have been removed and submitted for radiocarbon dating. Preliminary diatom analysis has been conducted on one of the cores from Deserted Lake (see below), and detailed sub-sampling for diatom and pollen is currently underway and will be completed during the winter months. We describe here present preliminary results from Deserted Lake.

Deserted Lake lies at an elevation of about 3 m asl in a small, steep-sided valley situated between the head of Hisnit Inlet and the upper reaches of Tlupana Inlet, both of which are tributary fjords in the Nootka Sound fjord complex (Figure 2). The 1:50,000 maps of the area show two outlet streams from Deserted Lake, one draining south to Hisnit Inlet, the other to the east to Tlupana Inlet (Figure 3). The elevation of the lake is bedrock-controlled; the outlet stream to Hisnit Inlet is incised some 1 - 2 m into bedrock. This channel provides a shorter, more direct route for tsunami access to the lake basin, and our cores were consequently taken in the vicinity of the outlet.

We established two coring stations during our reconnaissance visit: DL-1 located ca. 250 m from the outlet in 20 m of water; DL-2 ca. 80 m from the outlet in 10.5 m of water. Soundings between these two stations indicated that the water depth increases to ca. 20 m about 100 m from the outlet.

Stratigraphic logs of the two cores are shown in Figure 4. Both cores consist predominantly of massive and laminated gyttja (organic mud and silty organic mud). In DL-2 the gyttja overlies a basal layer of gravelly sand and mussel (Mytilus sp.) shell hash. Twenty samples of gyttja and one sample of the basal gravelly sand were removed from core DL-2 for preliminary diatom analysis. Qualitative assessment of the diatom assemblages in these samples (Figure 5), provides some insight into the evolution of the lake. The history of this basin, like that of other, low-elevation lakes along the coastal plain of western Vancouver Island, appears to have been governed by relative sea-level fall during the late Holocene.

The basal unit of gravelly sand and shell hash contains a diverse assemblage of marine diatoms and likely records a time when the lake basin was part of a marine inlet subject to strong tidal action. The transition to the overlying gyttja marks a change to a sheltered lagoonal environment, presumably as a result of the emergence of the basin. The diatom assemblages in the gyttja overlying the basal marine unit record progressive freshening of the lagoon. Tidal penetration into the Deserted Lake basin was gradually reduced with time until the lagoon transformed into a freshwater lake. This transition is marked by the disappearance of brackish diatoms in gyttja deposits above approximately 1.2 m in the core (Figure 5).

Coarser-textured beds are present within the gyttja sequence in both DL-1 and DL-2. An upper coarser-textured unit in DL-1 (0.26-0.28 m depth) consists of a 1 cm thick layer of clean fine sand with a sharp lower contact, overlain by a thin layer of woody plant detritus (Figure 4). A single sample of material has been submitted from this unit for AMS radiocarbon dating.

This upper coarse-textured unit in DL-1 may correlate with a more complex series of coarse-textured beds and plant detritus at a depth of 0.80-1.10 m in DL-2 (Figure 4). The base of this unit consists of five thin (1- 5 cm thick) layers of sand or muddy sand with variable amounts of plant detritus. These clastic beds are separated by thin layers of woody detritus containing minor amounts of sand. Two sub-samples of this organic material have been submitted for AMS dating.

The diatom assemblages of these layers were determined from five samples. The diatoms are dominantly freshwater species, but include species with brackish-water affinities, notably Navicula peregrina. This species is a common member of brackish marsh and mudflat communities. The composition and stratification of the deposit, and the contrast between the associated diatom flora and that of the enclosing freshwater gyttja leads us to infer that these beds may have been deposited by multiple waves or phases of a tsunami wave train. The tsunami waves appear to have transported material from the lake bed (the mud and freshwater diatom components), the foreshore of Hisnit Inlet and the intertidal channel of the outlet stream (the sand and brackish-water diatoms), and the intervening forest (the woody detritus).

Above this sequence is a 1 cm thick mud layer which is overlain at 0.80-0.91 m depth, by a layer of clean, weakly graded, fine sand. This sand layer is capped by a thin bed of plant detritus. The sand layer is much thicker than the sandy-forest detritus layers beneath it, and contains a distinctive diatom microflora. Although three of the four diatom samples from the sand layer were barren of diatoms, the basal sample yielded a brackish diatom assemblage dominated by Navicula digitoradiata. This species is a common member of moderately saline mudflat communities. The sand may have been deposited by a belated, but very large wave in the tsunami wave-train that deposited the underlying sands, or by a tsunami that entered the Deserted Lake basin some years or decades afterwards. A single AMS sample from the bed of plant detritus capping this unit may clarify the chronology of these events. For the moment, we have chosen to lump these units together as a deposit of a single tsunami event (Figure 5).

A second possible tsunami deposit in DL-1 consists of a layer of granules (1.89 - 1.96 m depth) mixed with, and capped by, woody detritus. The corer bottomed-out in this unit, revealing silty organic mud in the core catcher just below the granule layer. Material for AMS dating was collected at 1.92 m depth. This unit may correlate with sands and sandy muds at 1.53 - 1.95 m in DL-2. Two thin sand beds at the base of the unit are separated by a thin layer of sandy gyttja and are overlain by a poorly stratified bed of sandy mud intermingled with woody detritus that extends from 1.53 to 1.89 m. The age of this unit will be determined from AMS samples taken at the upper and lower contacts. Diatom assemblages in this deposit are similar to those in the enclosing brackish lagoon deposits. These sands and sandy muds may represent the deposits of an earlier tsunami wave train.

The only other unusual unit in DL-2 is a thin bed of clayey silt at 2.54 m depth. This bed is barren of diatoms. This unit may represent the distal facies of a river flood or a debris flow deposit.

Reports Published

Results of work at Kanim Lake (Figure 1) have been accepted for publication and will be published in 1997 (Hutchinson et al. 1997). We will publish results from Catala and Deserted lakes after analyses are completed.

Availability of Data

Field notes and core logs are available in paper format from any of the investigators. Microfossil and radiocarbon results are pending, but will also be available from the investigators. No instrumental data were collected during this study.

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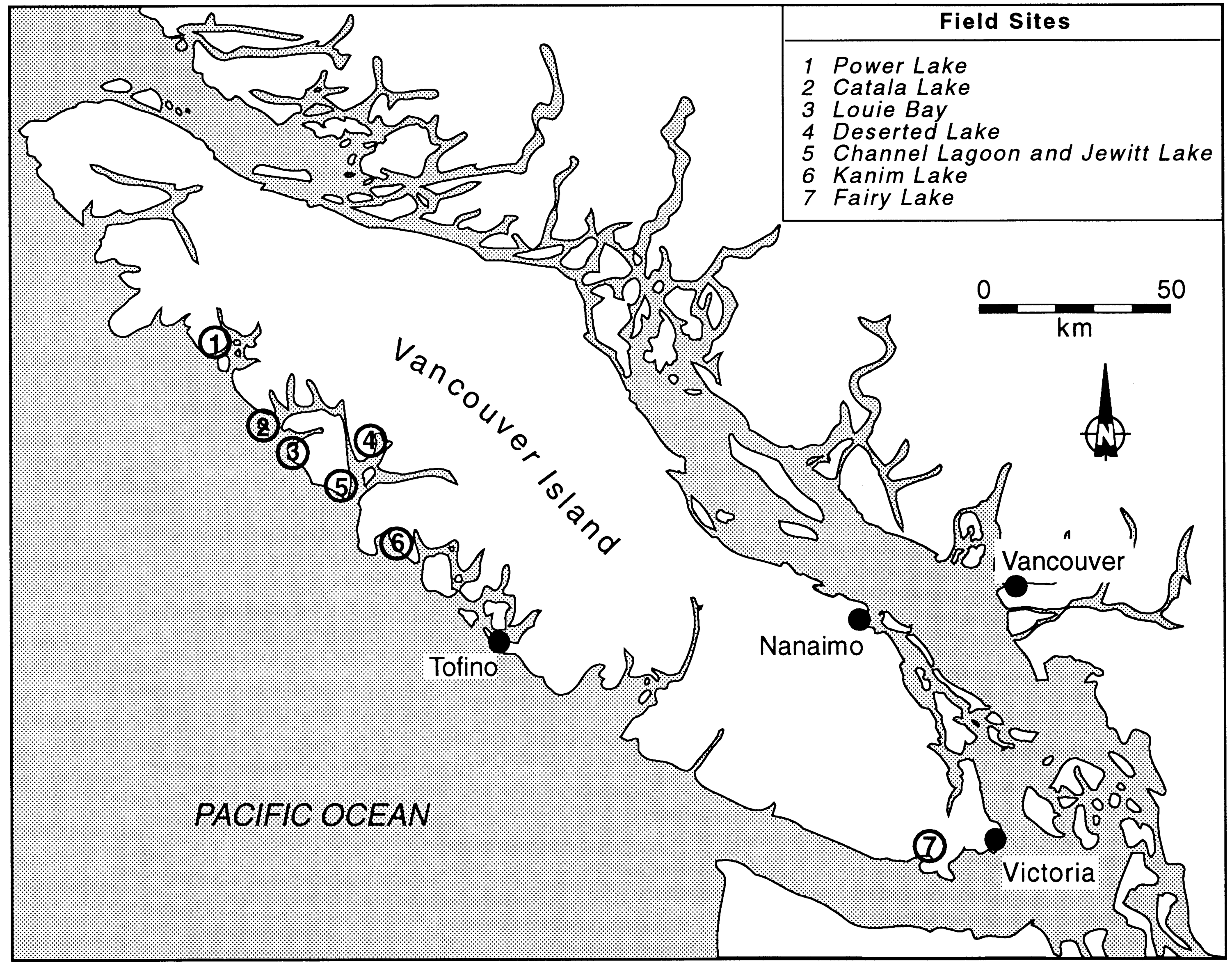
Figure 1. Location map of seven study sites on western Vancouver Island, British Columbia.

Figure 2. Location of Deserted Lake in relation to Hisnit, Tlupana and Muchalat inlets within the Nootka Sound region of British Columbia.

Figure 3. Detailed map of Deserted Lake showing location of two core sites.

Figure 4. Lithostratigraphic logs for the two cores from Deserted Lake.

Figure 5. Lithostratigraphy, biostratigraphy and interpreted depositional environments for core DL-2 from Deserted Lake.



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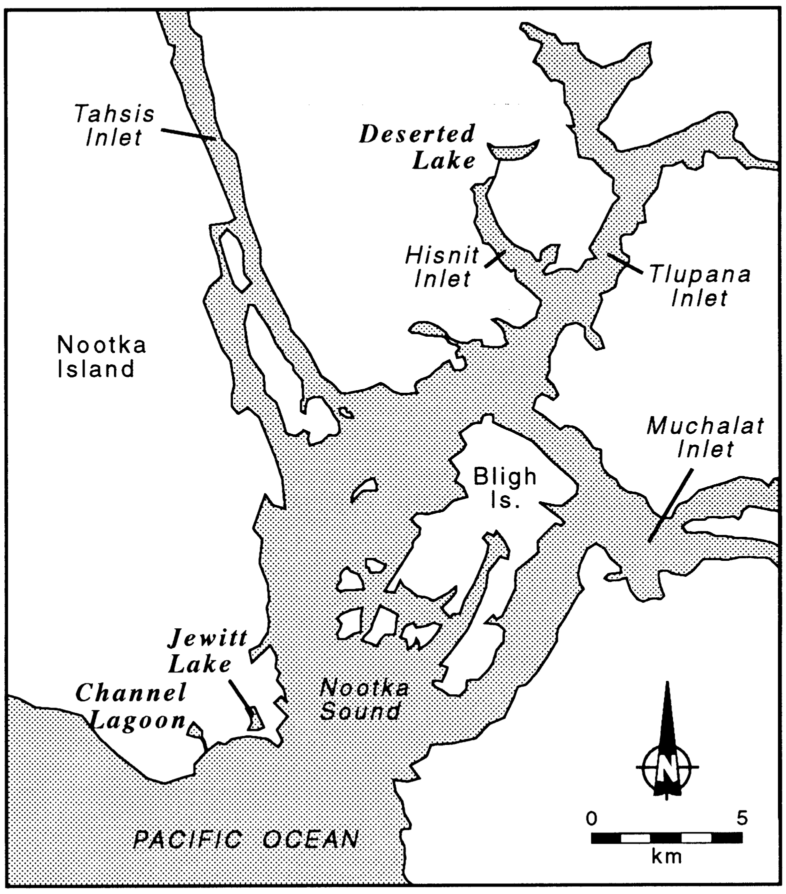

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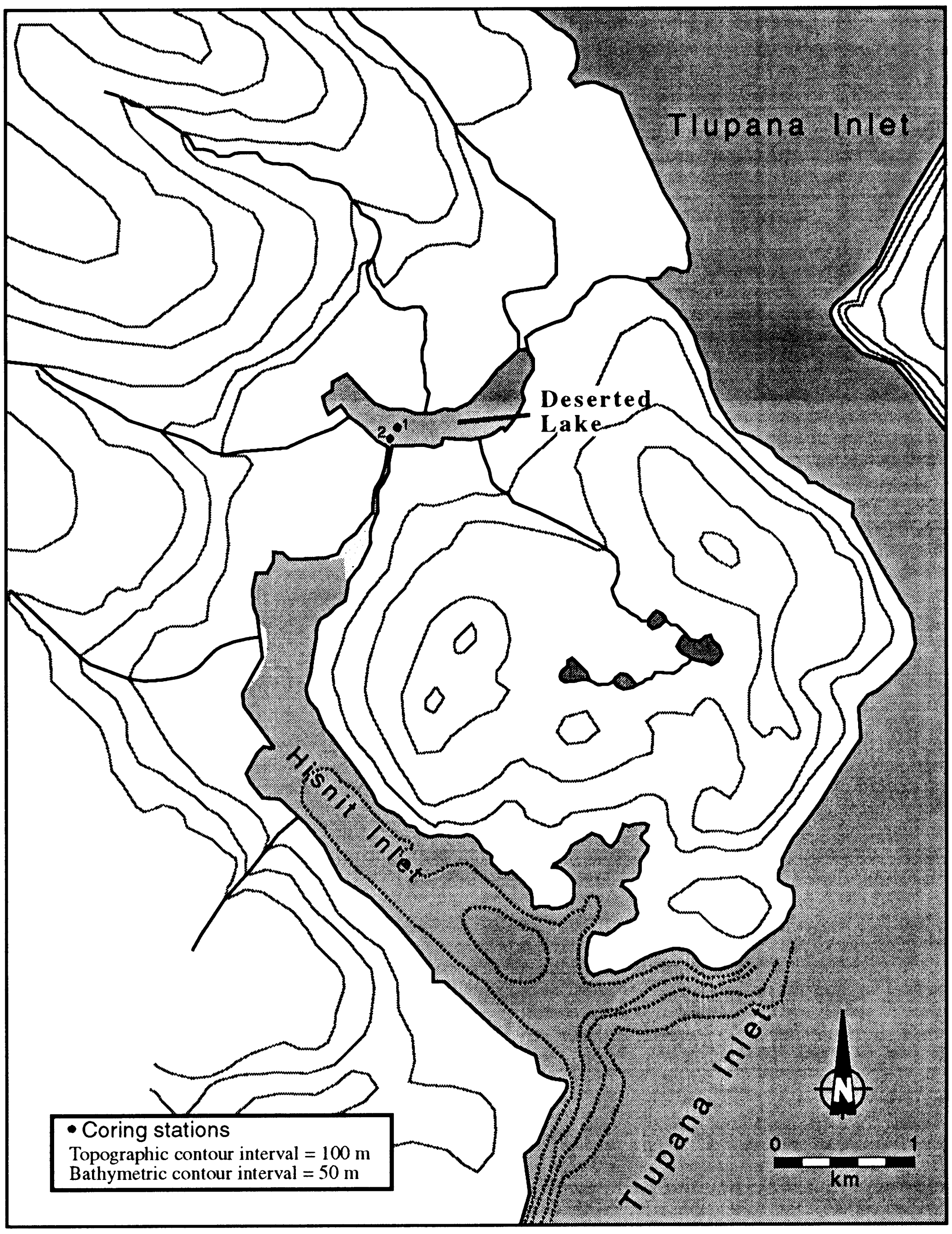

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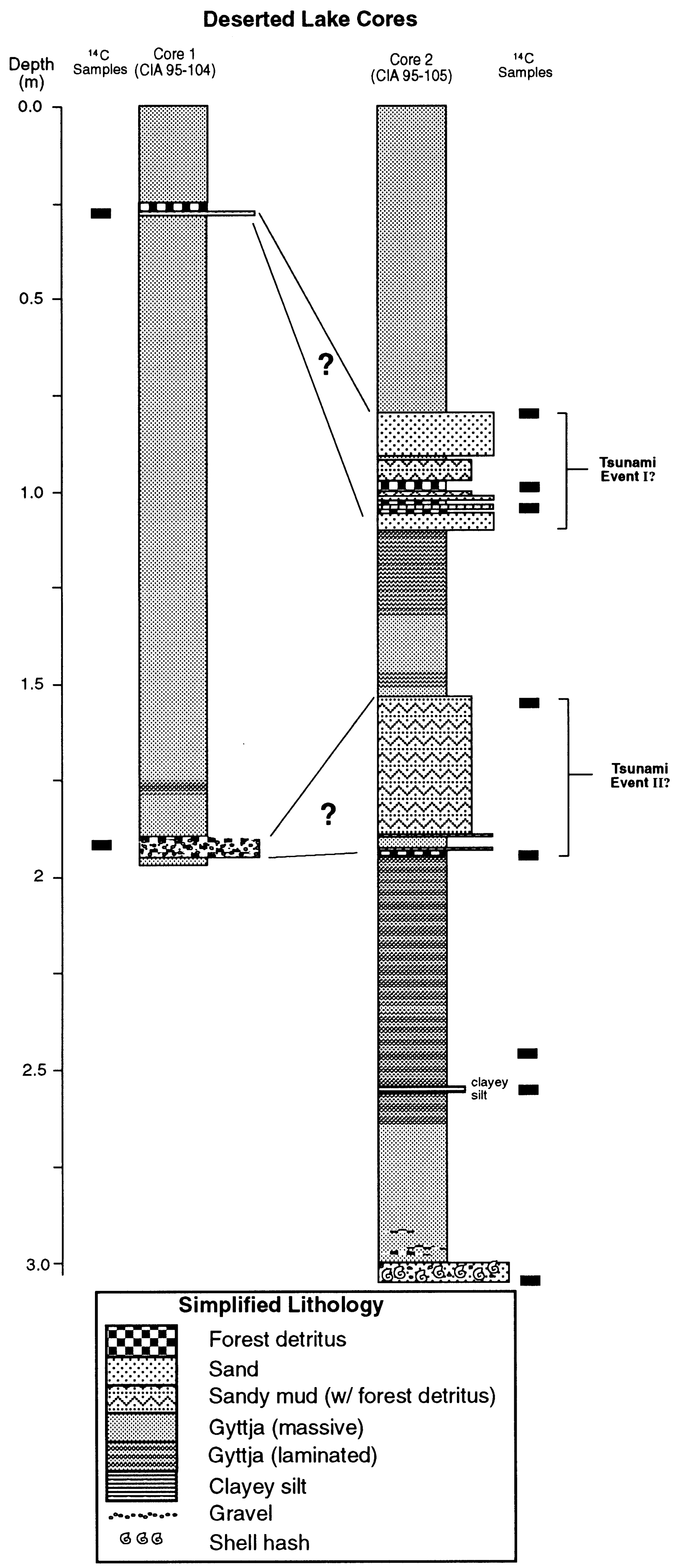

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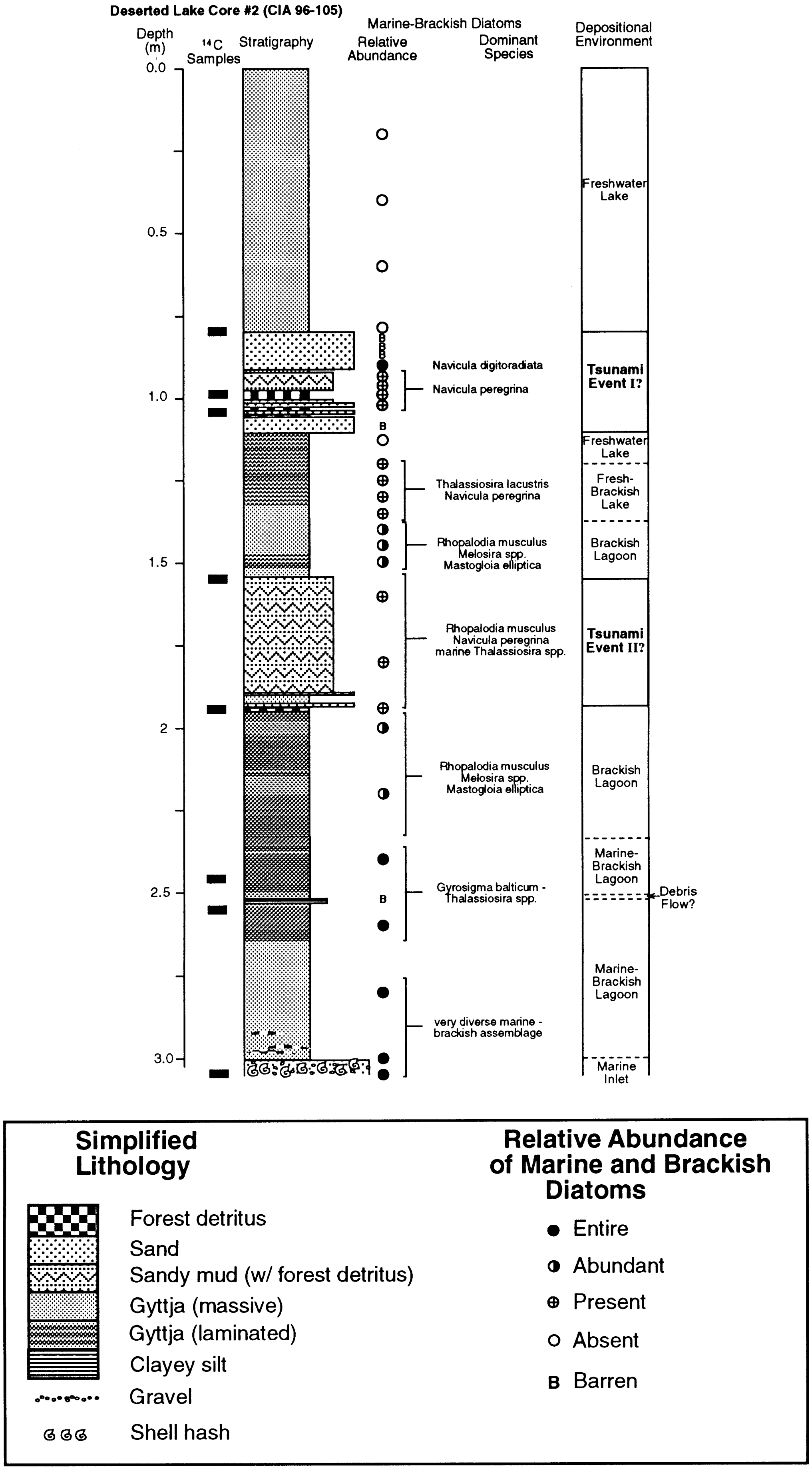

Table 1. Field site descriptive parameters for paleo-tsunami study.

SITE (Fig 1)	LAT/LONG.	ELEV.	AREA	DIST-SHORE
1. Power Lake	50°12'N, 127°29'W	ca. 3 m	ca. 0.6 km^2	0.8 km
2. Catala Lake	49°50'N, 127°03'W	ca. 1 m	ca. 0.1 km^2	0.5 km
3. Louie Bay	49°44'N, 126°56'W	0 m	ca. 0.4 km^2	0.6 km
4. Deserted Lake	49°46'N, 126°30'W	3 m	ca. 0.5 km^2	0.6 km
5. Channel Lagoon	49°36'N, 126°40'W	0 m	ca. 0.2 km^2	0.6 km
5. Jewitt Lake	49°36'N, 126°38'W	ca. 3 m	ca. 0.4 km^2	0.1 km
6. Kanim Lake	49°24'N, 126°20'W	6 m	ca. 1.2 km^2	0.7 km
7. Fairy Lake	48°35'N, 124°21'W	ca. 4 m	ca. 0.4 km^2	5 km