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QUATERNARY GEOLOGY OF SOUTHEASTERN VANCOUVER ISLAND AND GULF ISLANDS (92B/5, 6, 11, 12, 13 AND 14)

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INTRODUCTION

This report presents preliminary results of the first of a two-year Quaternary geological study involving surficial mapping and a regional geologic synthesis on southeastern Vancouver Island and the Gulf Islands. The location was selected for study in response to the need for more information on land resources and geologic hazards in an area of intensive urbanization.

The study area covers the region south of latitude 49°00′ to the Juan de Fuca Strait, and from longitude 124°00′ west to the east coast of Saturna Island (*see* Figure 4-2-1).

Growing urban pressures in the southeastern Vancouver Island and Gulf Island areas are forcing marginal land areas, such as poorly drained lowlands, to be considered as future urban development sites. At the same time urban and rural parkland is being identified for green space preservation and exploration programs are being conducted for aggregate and liquid and solid waste management sites. Furthermore, southwestern British Columbia's precarious position over an active subduction zone (Rogers, 1988) requires a clear identification of potential geologic hazards such as land susceptibility to earthquake induced liquefaction or ground failure. A land use and resource evaluation conducted around the expanding urban area is the first step towards maximizing the land's potential and preventing land-use conflicts.

To evaluate the resource and land-use potential of southeastern Vancouver Island and the Gulf Islands, the regional geological history of the area must be understood. This involves study of the Quaternary sediments and landforms in the region and their stratigraphic and chronologic relationships.

This project has four main objectives:

- To construct a comprehensive surficial geology map of southeastern Vancouver Island based on air photo interpretation and field investigation with special emphasis being placed on the Saanich Peninsula, a region that has not been mapped since 1913 and which is undergoing intensive urbanization.
- To characterize surficial deposits using textural, physical and lithological data in order to elucidate the material properties for engineering projects, hazard potential and chronological correlation.
- To establish a Quaternary history by integrating stratigraphic and morphological information with absolute dating results.
- To map and input data into a geographical information system (G.I.S.) to facilitate information accessibility.

Of these four objectives the air photo and field checking were completed in 1992. The detailed Quaternary history, maps and digital information base are presently in progress.

BEDROCK GEOLOGY AND PHYSIOGRAPHY

Low-relief areas (averaging 200-300 m above sea level) are found on the eastern Vancouver Island coast and northern Saltspring Island and Gulf Islands and are underlain by a conformable sequence of marine and nonmarine sedimentary rocks of Late Cretaceous age known as the Nanaimo Group (Muller, 1980). They consist of sandstone, shale, siltstone, conglomerate and often coal (van Vliet *et al.*, 1991). Bedrock controlled north to south-striking ridges separated by narrow valleys are typical of this area. Differential erosion of weak shale and mudstone is responsible for the formation of the valleys, whereas the ridges are formed by the resistant sandstones and conglomerates.

South of Fulford Valley on Saltspring Island and southwestward toward Victoria and Sooke, the bedrock consists of Paleozoic metasediments and metavolcanics (Ryder, 1978; Muller, 1980). These more resistant metamorphic rocks form topographic highs with elevations from 600 to 900 metres above sea level (van Vliet *et al.* 1987).

Although the basic topography is controlled by bedrock formations, glacial processes have greatly altered the landscape. Thick sequences of Quaternary sediment found along the eastern coast from Ladysmith to Victoria and on James and Sidney Islands, have subdued the overall landscape. The bedrock terrain has also been reshaped by erosional glacial processes. Roche moutonnée, striated and fluted bedrock are dominant features in the landscape of southeastern Vancouver Island and on most of the Gulf Islands.

PREVIOUS WORK

Quaternary studies in British Columbia began with G.M. Dawson's general overview in 1881 and his later discovery, in 1887, of two tills separated by stratified sands and silts (Dawson, 1881, 1887). Willis' work in the Puget Lowland subdivided the Quaternary sediments into an older Admiralty glaciation, a "Puyallup" nonglacial interval and a more recent, Vashon glaciation (Willis,1898). Many studies followed but only those most relevant to southeastern Vancouver Island and the Gulf Islands are cited here.

Clapp (1912, 1913 and 1917) not only expanded the known stratigraphy of southeastern Vancouver Island, by subdividing the Puyallup interglacial into the Maywood (marine) clays and the Cordova sands and gravels, he also

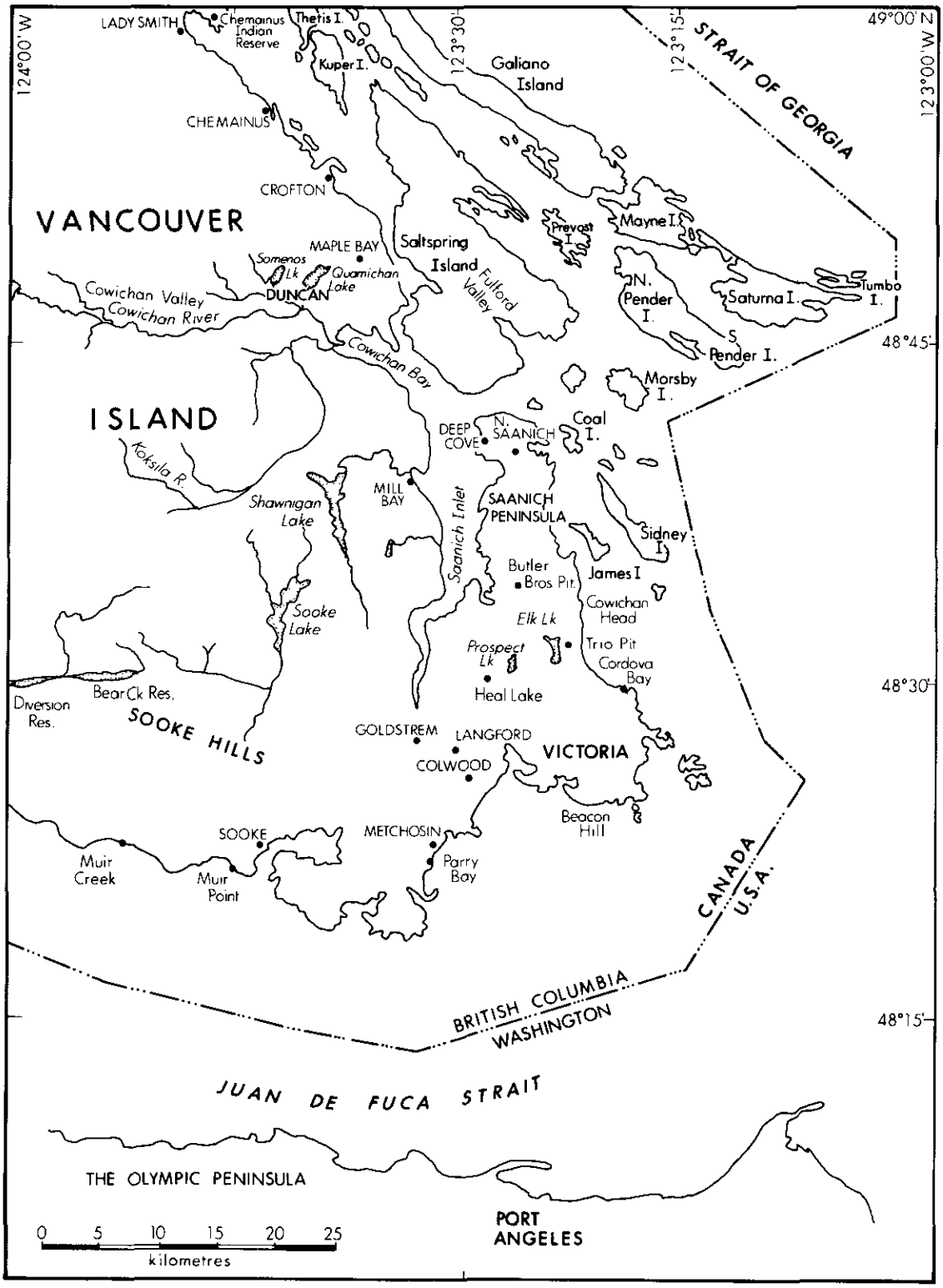

Figure 4-2-1. Map of study area and section locations.

produced surficial geologic maps for the Victoria, Saanich, Sooke and Duncan map areas. Fyles (1963) presented evidence from central Vancouver Island for two major glaciations and three nonglacial intervals. In the Fraser Lowlands an evolution of stratigraphic sequences was developed by Armstrong (1956, 1957, 1960, 1961, 1965, 1975a, 1975b) and Armstrong *et al.* (1965). Revisional works by Armstrong and Hicock (1975, 1976), Hicock (1976) and Arm-

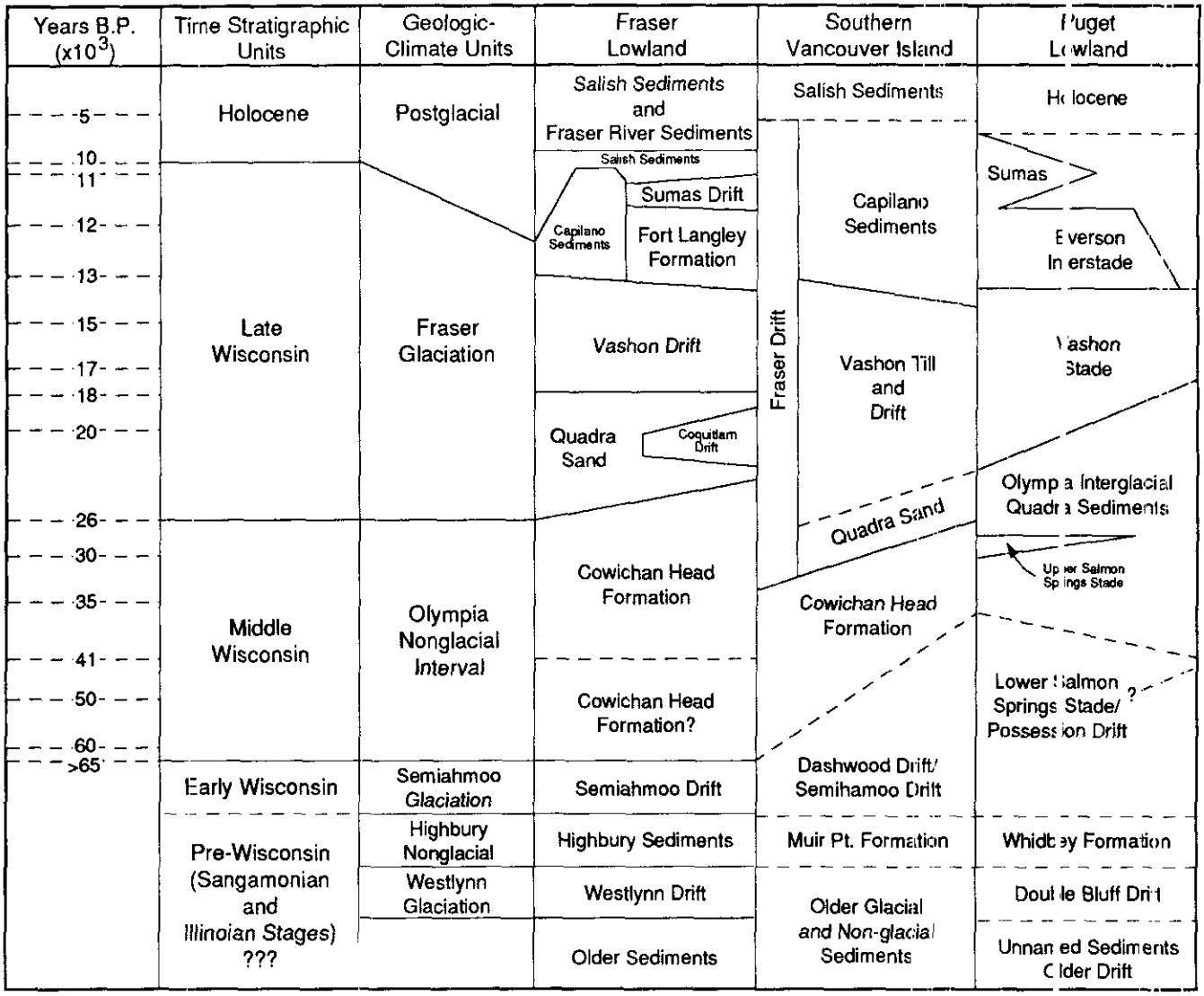

Figure 4-2-2. The Quaternary stratigraphic sequences in southwestern British Columbia and northwestern Washington (After: Fyles, 1963; Armstrong and Clague, 1977; Alley, 1979; Armstrong, 1981; Hicock and Armstrong, 1983; and Alley and Hicock, 1986).

strong (1981) established three major glacial events: the Westlynn, Semiahmoo and Fraser glaciations; and four major interglaciations. Meanwhile, Armstrong and Clague(1977), Clague (1976, 1977) and Alley (1979) worked to define the interglacial Cowichan Head Formation using stratigraphic and palynological investigation. Using Fyles' (1963) research as a framework, Hicock *et al.* (1979) compiled a summary of the Quaternary stratigraphy on southeastern Vancouver Island that included the detailed works of Clague (1977), Alley (1979) and his own research. Some of the most detailed work on pre-Fraser Pleistocene stratigraphy, geochronology and paleoecology to encompass Vancouver Island and the Fraser and Puget lowlands was completed by Hicock (1980). Alley and Hicock (1986) presented a review of the Quaternary history and stratigraphy of Vancouver Island, the Fraser lowlands and the Puget lowlands as did Hicock and Armstrong (1981,1983, 1985) and Hicock (1990). A compilation of established Quaternary stratigraphic sequences for southern Vancouver Island, the Fraser and Puget lowlands is presented in Figure 4-2-2.

Surficial mapping and geomorphic studies in the study area have been presented by Bretz (1920), Halstead (1968), Senyk (1972), Foster (1972) and Energy, Mines and Resources Canada (1981). Soils and surficial materials of the Gulf Islands were reviewed by van Vliet *et al.* (1987, 1991). General Quaternary overviews of the Cordilleran ice sheet were compiled by Ryder *et al.* (1991), Ryder and Clague (1989), Booth (1987, 1991) and Clague (1985).

Other research on specific Quaternary subjects includes: the sea level history has been developed by Clague and Bobrowsky (1990) and Clague *et al.* (1991); improvements in chronological control have been made by Clague (1981), Easterbrook and Rutter (1982), Hicock and Rutter (1986) and most recently, in Washington State, by Easterbrook (1986, 1992). Paleoclimatic studies have been undertaken by Clague (1978), Alley and Hicock (1986) and Alley and Chatwin (1979).

METHODS

A preliminary air photo interpretation of the surficial geology was conducted at a scale of 1:50 000 on NTS map sheets 92B/ 5, 6, 11, 12, 13 and 14 prior to fieldwork. More than 400 field sites were visited in order to check the accuracy of mapping and to describe stratigraphic and sedimentological features of Quaternary exposures. Section descriptions include field characteristics such as: colour, texture, unit thickness, large clast (≥pebble) lithology, clast and matrix mineralogy, primary and secondary structures such as bedding and fabric, and unit contact descriptions. Unit provenance will be determined later by interpreting section descriptions and matching information to possible source localities or correlative units.

Samples for age determination were taken and will be analyzed in the manner most suitable for the material found. For example, amino acid analysis of shells will be used to provide relative dating control; radiocarbon analysis of organic matter will be used for absolute dating control; and tephrochronological methods will be used to identify and date samples of volcanic ash.

A geographical information system (TerraSoft) will be used to combine areal and point-form data with stratigraphic information to produce a three dimensional map of the study area.

SURFICIAL GEOLOGY

The majority of surficial materials in the study area were deposited during the last glaciation (the Vashon Stage of the Fraser Glaciation) between 25 000 and 15 000 years ago (Easterbrook, 1992; van Vliet *et al.*, 1987). Low-lying coastal areas in the southeastern Vancouver Island region are covered by glaciomarine drift, beach materials, till and/or glaciofluvial/fluvial sand and gravel. Higher elevations (*i.e.*, from 600 to 900 m above sea level) are covered by till or colluviated till, glaciofluvial sand and gravel and more recent colluvium.

Diamicton Deposits

Much of the low-lying coastal areas, including Ladysmith, Chemainus, Victoria, the Saanich Peninsula and James and Sidney islands are draped by 1 to 2 metres of silty diamicton. In places it directly overlies bedrock; in low-lying areas it is found directly over a silty clay unit; and in upland areas it is found over what appears to be glaciofluvial sand and gravel.

In low-lying areas (less than 175 m above sea level) this diamicton is characterized by: high percentages of clay and silt (10-40 and 40-50 % respectively); approximately 10 to 15 per cent fine to medium sand and less than 5 per cent course sand. Clast content ranges from 5 per cent at the base to 30 per cent at the top and maximum clast size ranges from 0.1 to 1.0 metre in diameter. The diamicton is generally well indurated and a grey to dark greyish brown colour (Munsell code 2.5Y 4/2, moist). The dominant lithologies of the clasts are, in order of abundance: plagioclase porphyry, granite, quartzite, sandstone, siltstone and basalt (*i.e.*, mostly local and Coast Mountain lithologies).

The diamicton is interpreted to be a basal till deposited by ice that overrode and incorporated subaqueous silts and clays. From lithological and striae data it appears to have Cowichan Valley and/or Coast Mountain sources.

In the Ladysmith area, up to 12 metres of massive, very indurated, clay-rich diamicton occurs at surface. It contains 25 to 30 per cent clasts, 5 to 10 per cent clay, approximately 40 per cent silt, approximately 40 per cent fine sand and approximately 5 per cent medium to coarse sand. It differs slightly from diamictons in the Victoria area in both colour (*i.e.*, grey, Munsell code 5Y 5/1, moist) and lithology: plagioclase porphyry, diorite, fine-grained mafic volcanics and siltstone compose the majority of the clasts. Locally this diamicton shows signs of colluviation in the form of decreased clay content and rare bedding planes. This deposit is very similar to the surficial diamictons found in Deep Cove and Chemainus.

A diamicton with similar texture and colour characteristics as that in the Ladysmith area occurs near Shawnigan Lake. However, the abundance of basalt and fine-grained volcanic, sandstone and siltstone clasts in the diamicton denotes a more local source.

Throughout lowland regions, from Ladysmith to Victoria and in parts of Metchosin, outcrops of an unconsolidated, sandy, poorly bedded diamicton occur sporadically. Good examples can be found in sea cliffs in Beacon Hill Park and at the tops of sections at Parry Bay, Cordova Bay, the Trio gravel pit and the Butler Brother's gravel pit (Figure 4-2-1). Due to the low elevation of each of these sections (none above 90 m above sea level and all below the late glacial marine high stance of 175 metres (Ryder, 1978), poor sorting, the presence of bedding and the sandy texture of the diamicton, they are tentatively interpreted as subaqueous debris-flow deposits, most likely derived from a proglacial environment.

Sand And Gravel Deposits

Surface concentrations of sand and gravel exist in the Metchosin, Langford and Goldstream areas 15 kilometres west of Victoria, in an area just northwest of Muir Creek about 20 kilometres west of Sooke, along the Chemainus river approximately 21 kilometres west of Chemainus and throughout the lower and upper Cowichan Valley (Figure 4-2-1). They are thick, aggradational sequences of steeply dipping (25-28°) sands and gravels overlain by channelled, cut-and-fill sands and gravels resembling those of glaciofluvial deltaic and braided stream environments, respectively. They were most likely deposited in the recessional phase of the last glaciation.

Not all sand and gravel deposits in the field area are attributable to glaciofluvial processes, some appear to have originated in ice-contact environments. Convoluted, interbedded sand, gravel and diamicton combined with pitted, kame and kettle topography just south of Duncan, provides evidence for ice stagnation and downwasting in the area. Halstead (1966) attributes this to ice stagnation of a partially grounded Cowichan Valley glacier.

The economic viability of these aggregate deposits has been established in Metchosin, Langford, Goldstream, Dun-

can and in parts of the Cowichan Valley. Further study may also prove the Muir Creek and Chemainus sites to be of economic significance.

Upland Colluvial And Related Deposits

The mountainous inland areas of southeastern Vancouver Island appear to have been completely covered by ice during the last glaciation. The surficial materials in this part of southeastern Vancouver Island consist of colluviated diamicton over bedrock. Exposures of well indurated, clay-rich diamicton or sandy diamicton can sometimes be found around valley basins such as in the Sooke Lake region. However, these diamictons are most often overlain by recent fluvial sands, gravels and lacustrine silts and clays.

STRATIGRAPHIC HISTORY OF SOUTHERN VANCOUVER ISLAND AND THE GULF ISLANDS

The following is a chronological interpretation of the most complete Quaternary sections on southeastern Vancouver Island. No reference will be made to either time or geologic-climatic units as these have yet to be accurately established. Without the results of chronologic analysis, there is little evidence to alter the Quaternary history established by Alley and Hicock (1986).

The Quaternary history of southeastern Vancouver Island and the Gulf Islands begins with what may have been an extensive glaciation. It is evidenced by diamicton deposits interpreted as till that occur at or near sea level in the bases of the Parry Bay, Cordova Bay and Muir Point sections. A period of interglaciation followed in the coastal areas with a sequence of erosion and possible subaqueous deposition of clay and beach lag deposits. A coarsening upward sequence of fine sands and gravels, inferred to be subaerial fluvial and alluvial deposits, indicates isostatic rebound and/or eustatic sea level rise associated with deglaciation. Overlying deposits of strongly oxidized, thinly crossbedded and laminated sands with syndepositional, interbedded silts and organic sediments indicate climatic warming comparable to the area's present climate (R. Hebda, personal communication, 1992; Hicock, 1980). Decreasing organics in the overlying silt and sand units appears to indicate a cooling climatic trend. This is followed by deposition of proglacial sands and gravels that are evident throughout the southeastern Vancouver Island area. They are directly overlain by a thick unit of diamicton, interpreted to be till and glacial debris-flow deposits associated with the last major glaciation. The uppermost units in the sequence vary with topography and elevation and consist mainly of sands and gravels deposited during ice recession. Holocene organic deposits found in the Heal Lake section on the Saanich Peninsula show a distinct climatic warming, prior to and after the deposition of the 6800 B.P. (Clague, 1990) Mazama ash marker.

CONCLUSIONS

Preliminary evidence from the 1992 field season confirms the existence of two glacial and three interglacial periods during the Quaternary on southeastern Vancouver Island and the Gulf Islands. The longest Quaternary records in the area (the Parry Bay, Muir Point, Cowichan Head and Cordova Bay sections) begin with a sequence of pre-Sangamon diamicton overlain by pre-Wisconsinan or pre-Sangamon interglacial sediments (Alley and Hicock, 1986) belonging to the Muir Point Formation. These are overlain in turn by late glacial and proglacial sands and gravels which are most likely part of the Cowichan Head Formation. The upper units are composed mostly of till and outwash associated with the Late Wisconsinan Fraser glaciation. Late Wisconsinan and Holocene interglacial deposits dominate the modern landscape. Thick deposits of silt, sand, gravel and diamicton are found in valley bottoms and coastal areas; upland areas are veneered with colluvium and modern fluvial sand and gravel.

Fyles (1963) found evidence from central Vancouver Island for a mid-Wisconsinan glaciation known as the Dashwood. We have, at this stage of the project, found no evidence for this advance. More detailed chronological and paleoclimatic control should elucidate the issue of mid-Wisconsinan geologic history.

With the completion of this project we hope to resolve:

- The distribution of surficial and stratigraphic materials.
- The extent of surficial resources and geologic hazards.
- How the Dashwood drift is represented in this area.
- Where the effects of valley glaciation end and Cordilleran glaciation begin.

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