the effectiveness of frost heave by limiting the annual temperature range in the underlying bedrock and by making it physically more difficult to heave.

A large area (600 x 1000 feet) of relatively boulder free, but thin (< 3 feet thick) till lies east of Camp Lake. A lower content of fines and patches of glacio-fluvial material down slope suggests that this till may have been reworked or winnowed by glacial melt waters.

When examined in pits, the till shows a graditional change in texture beginning at approximately 18 to 22 inches depth. Below this depth the till is generally more cobble rich and consequently harder to penetrate with hand tools. Fluctuations in trace metal content and size fraction sometimes correlate with the observed textural change. Possible explanations for these observed fluctuations and correlations are considered in Chapters 4 and 5.

IV SOILS

Soils have developed on till and glaciofluvial material characterized by boulder and cobble rich loamy sands and sandy loams, imperfect to very poor drainage and strong to very strongly acidic conditions with pH's averaging 4.7 to 5.6. Typical soil profiles are shown in Plates 6 to 9. At each soil sampling site, visual soil characteristics were noted and the profile was examined and classified to a sublevel of the soil classification system of the Canadian Department of Agriculture (1970). The soils were generally porous due to voids created by melting ice and brown to yellowish-brown (Munsell color 10YR 5/3 to 5/6). Occasionally they are dark brown (10YR 3/3) where the soil is coarser or grey to dark grey where the soils are gleyed. Plant roots seldom occurred below eight inches but were locally noted at depths up to 20 inches.

Brunisolic, Regosolic and Gleysolic soil orders occur but only the last two are widespread (Fig. 16). The highest degree of soil development is represented by the Brunisols, subgroups Orthic Dystric and Degraded Dystric, which are restricted to well drained coarse textured esker or outwash material. Because this parent material covers less than two percent of the land surface, Brunisols are the least common soil type. It is thought that these Brunisols are similar to Hornbrook and Allan's (1970) "Arctic Brown Soil" described at Coppermine River, N.W.T.

Elsewhere, on sites with imperfect to poor internal drainage or in areas of thin till, Regosols (Orthic, Dystric, and to a lesser extent Lithic) are the most abundant soil order comprising approximately 70 percent of the soils sampled. Gleysols (Rego and Cryic subgroups), the next

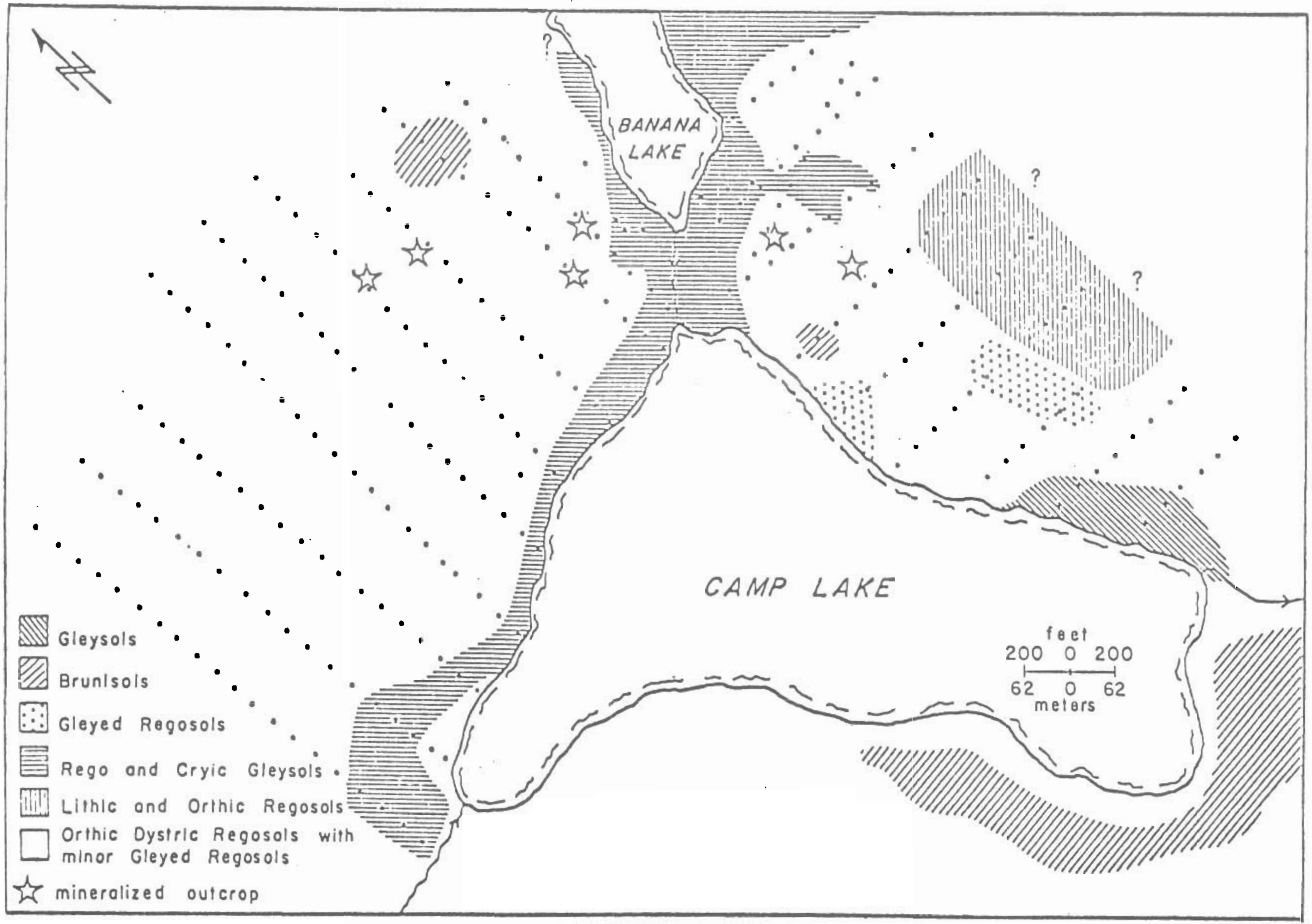


Figure 16. Generalized soil map.

most abundant order, occur on low sites adjacent to lakes or low gradient streams, topographic depressions, and at breaks-in-slope. These soils generally have a thicker organic layer or mat (L-F-H and Ah horizons) than the Regosols and are more water saturated with free water commonly occurring within 4 to 10 inches of the soil surface. Permafrost often lies relatively close to the surface beneath Gleysols because of the good insulation provided by the well developed L-F-H and Ah horizons. In fact, the active layer may be only one to two feet thick where organic cover is heavy, whereas, an average of four to six feet is common elsewhere.

Most of the study area is affected by extensive cryoturbation, manifested as numerous circles, sorted and non-sorted, which are abundant enough to impinge on one another, forming polygons and nets. Many of the circles are active as noted by vegetation-free centers, extrusion and heaving (Plates 1 to 3); whereas, others are so inactive as to be almost indistinguishable from less disturbed tundra. Inactive or dormant circles have a low, doughnut-shaped mound of vegetation with a thick Ah horizon and a central, slightly depressed, vegetated area (Plate 4). Although these two types of circles are common, most circles, in terms of cryoturbation activity, lie between these extremes.

Except in the very iron stained gossan zone west of the B-C stream, solifluction processes are not noticeable. The general lack of solifluction is probably attributable to the very gentle slopes (2 to 5 degrees) and the bouldery nature of the till (Plates 10 and 16). Where solifluction does occur it is in relatively boulder-free till and on unvegetated slopes, both factors apparently relatable to the presence of large amounts of weathering sulphides and concomitant low soil pH's. The relatively finer grain size of these soils and the lack of stabilizing vegetation probably aids solifluction processes in these areas.

In areas of intense iron staining associated with mineralization, oxidizing sulphides, particularly pyrite. give rise to extremely low pH values (≤ 4.5). Mineral grains and rock fragments are severely attacked by the acidic groundwater and coated by iron oxides and hydroxides obtained from the decomposition of pyrite. This results in the entire soil profile appearing bright orange (Munsell color 10YR 5/8). Consequently, any detailed soil profile development is obscured. Furthermore, because this intense chemical weathering results in a finer soil texture, through reduction of soil particle size and chemical precipitation of metal oxides (e.g. Fe), these areas appear to be much more susceptible to cryoturbation.

This in turn probably accelerates the weathering process. Low soil pH and active cryoturbation also inhibit vegetation and this together with the exothermic nature of sulphide oxidation, may result in a thicker active layer.

V VEGETATION AND WILDLIFE

The region is well north of the tree line and has a typical arctic tundra flora. Dwarf willow and birch and lichens cover much of the area. Grasses are dominant on wetter sites and on the more exposed hills where drainage is good.

Wildlife includes barren land grizzles, wolverines, musk oxen, ground squirrels, weasels, foxes and arctic hares. In the summer, thousands of caribou and many birds pass through the area on their annual migration.

VI GENERAL GEOLOGY OF THE PROPERTY

A. Introduction and Exploration History

Because of active exploration by several companies in areas adjacent to the Bathurst Norsemines property much of the detailed geology of the area is held as confidential by Cominco Limited; therefore, only a general picture of the geology will be presented here. Most of the data in this section has been obtained from published reports by MacNeill (1973, 1974, 1976) and from personal communications with several Cominco employees, most notably B. Mioduszewska and P. Wilton whose assistance proved invaluable.

The exploration history of the Bathurst Norsemines property began in 1962 with reconnaissance scale mapping of the area by the Geological Survey of Canada (Fraser, 1964). In 1965 Rio Tinto Exploration Company Limited presumably attracted by the obvious gossans of the area, inspected the Main Zone at Camp Lake. Limited trenching revealed disseminated copper minerals and pyrite in siliceous zones but interest was insufficient to warrant further investigation. Following claim staking in 1966 and 1967, limited work was carried out in 1968 by Bathurst Inlet Mining Corporation, Norsemines Limited., and Atlin Yukon Limited. These companies merged in 1969 to form Bathurst Norsemines Limited., present owners of the 901 claims. Geological work that year involved more mapping, electromagnetic surveys, and 13 shallow drill holes totalling 2900 feet.

Cominco Limited optioned the property in 1970 and since that time all exploration work has been carried out by them. Work has included helicopter-borne electromagnetic and magnetometer surveys, ground electromagnetic and gravity surveys and geochemical sampling. Diamond drilling, consisting of 93 holes totalling 40,106 feet, has indicated three major ore bodies, the East Cleaver Lake, Boot Lake and Main or "A" Zones. Published data (MacNeil op. cit.) give a combined total of over 13 million tons of ore averaging approximately 0.40% Cu, 1.2% Pb, 7.5% Zn, 7.0 oz./ton Ag and 0.07 oz./ton Au. In addition, an equivalent tonnage of substantially lower grade ore has been indicated. Furthermore, at two other locations, Finger Lake and Jo Zone (Fig. 17), intersections of sulphides have also been encountered.

B. Regional Geology

A simplified picture of the somewhat complex regional geology, with location of ore bodies and significant mineralized zones, is shown in Figure 17. The Bathurst Norsemines property is underlain by a broad, northwest trending assemblage of metasedimentary and metavolcanic rocks, assumed to be Archean (Frith and Hill, 1975) and belonging to the Yellowknife Group. These rocks have been subjected to three, or possibly four, phases of deformation and metamorphism which approached upper amphibolite facies grade but later retrograded (Wilton, pers. comm.). These rocks form a belt up to 12

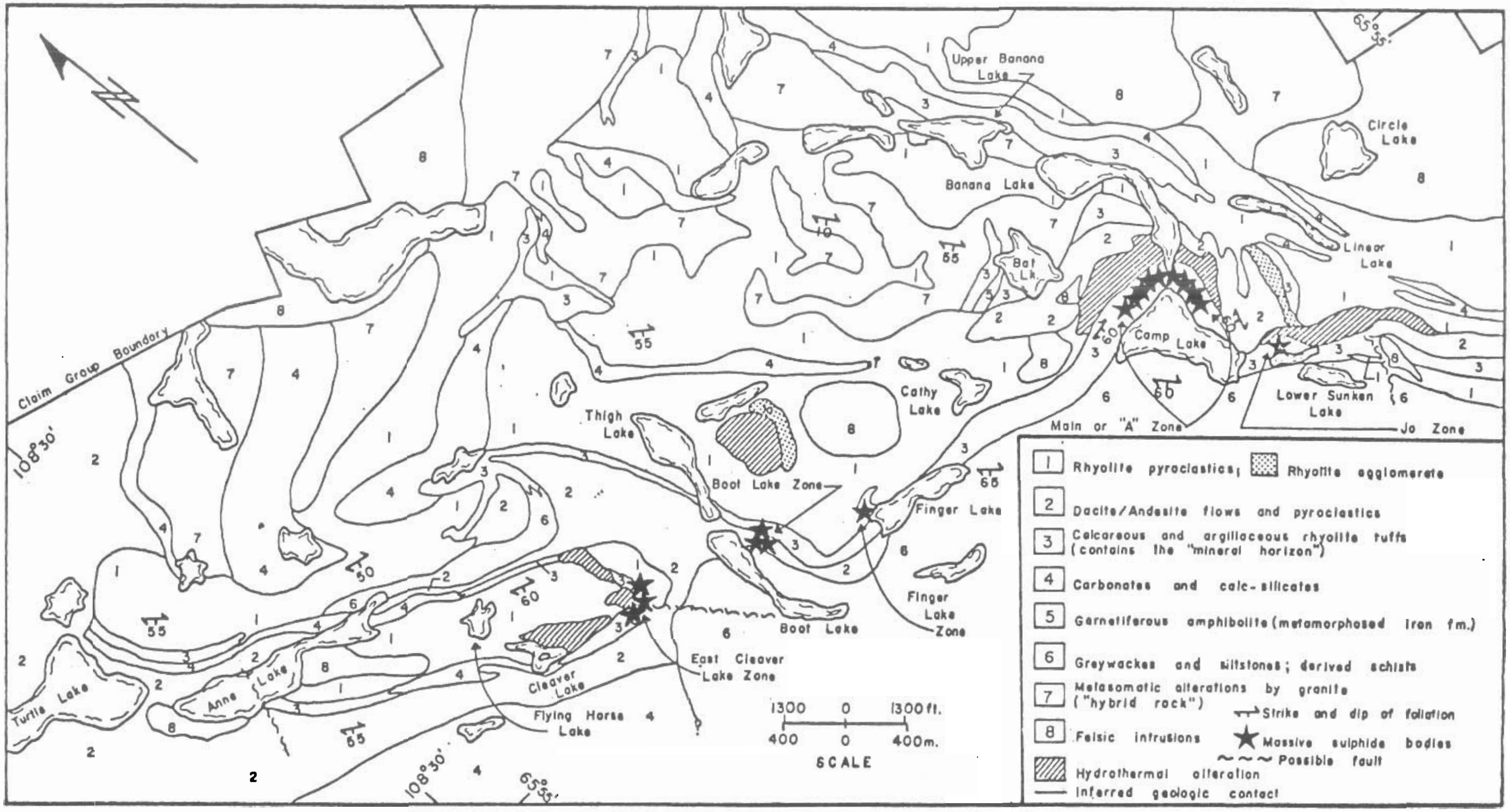


Figure 17. Regional geology map of the study area (map compiled by Cominco geologists).

miles wide and 25 miles long which occurs as an inlier or synclinal remnant in granitic terrain. Rocks within the belt are steeply overturned, dip 50 to 70 degrees to the southwest, and plunge to the southeast. Within the map area (Fig. 17) the surrounding granitic rocks appear to be contemporaneous or slightly younger, as shown by an extensive zone of "hybrid rocks" formed from volcanic and sedimentary rocks which have undergone metasomatic alteration during emplacement of the granite. A large fault system, the Hackett River Fault, lies several miles south of the ore bodies, paralleling the axial trace of the synclinorium (synclinal remnant).

Ore bodies and mineralized zones developed within a thick sequence of andesites and rhyolites (flows, tuffs and breccias) which were deposited, often explosively, in an eugeosynclinal environment. Mineralization occurred during the late or waning stages of rhyolitic volcanism in conjunction with fumarolic activity centered on the Main and Jo Zones. At the same time a wide variety of mixed rock types were forming including argillaceous tuffites, cherts, greywackes, ironstones, and tuffaceous limestones. This assemblage implies the presence of more quiescent conditions with chemical precipitates and, to some extent, epiclastic rocks becoming dominant. This group of rocks is quite variable, depending upon proximity to a vent, in composition, thickness and extent. Part of this assemblage, comprising rhyolite tuffs, calcareous tuffite and limestone is known as the "mineral horizon" and is the host for the ore bodies.

Overlying this relatively thin assemblage is either a thick (5000 feet), mainly epiclastic, sequence of metamorphosed argillites, greywackes, siltstones and impure sandstones (turbidites?) with minor tuff bands (Main, Jo and Boot Lake Zones), or a series of andesite-dacite flows followed by carbonate units (Anne Lake "mineral horizon" and East Cleaver Lake Zone). This overall sequence of rocks combined with the association of mineralized zones with a late stage, and often explosive phase, of submarine volcanism is consistent with the classification of these deposits as volcanogenic (cf. Fryer and Hutchinson, 1976; Sangster, 1972).

C. Detailed Geology of Camp Lake

The geology at Camp Lake is thought to form part of a continuous sequence proceeding from moderate rhyolitic submarine volcanism, through an episode of explosive cyclic andesite-dacite to rhyolite activity, to a much more quiescent period involving intermixed volcanic and sedimentary phases. Regional metamorphism has deformed the rocks producing a steeply dipping, (approximately 60 degrees) large, closed and moderately southeast plunging syncline (Fig. 18).

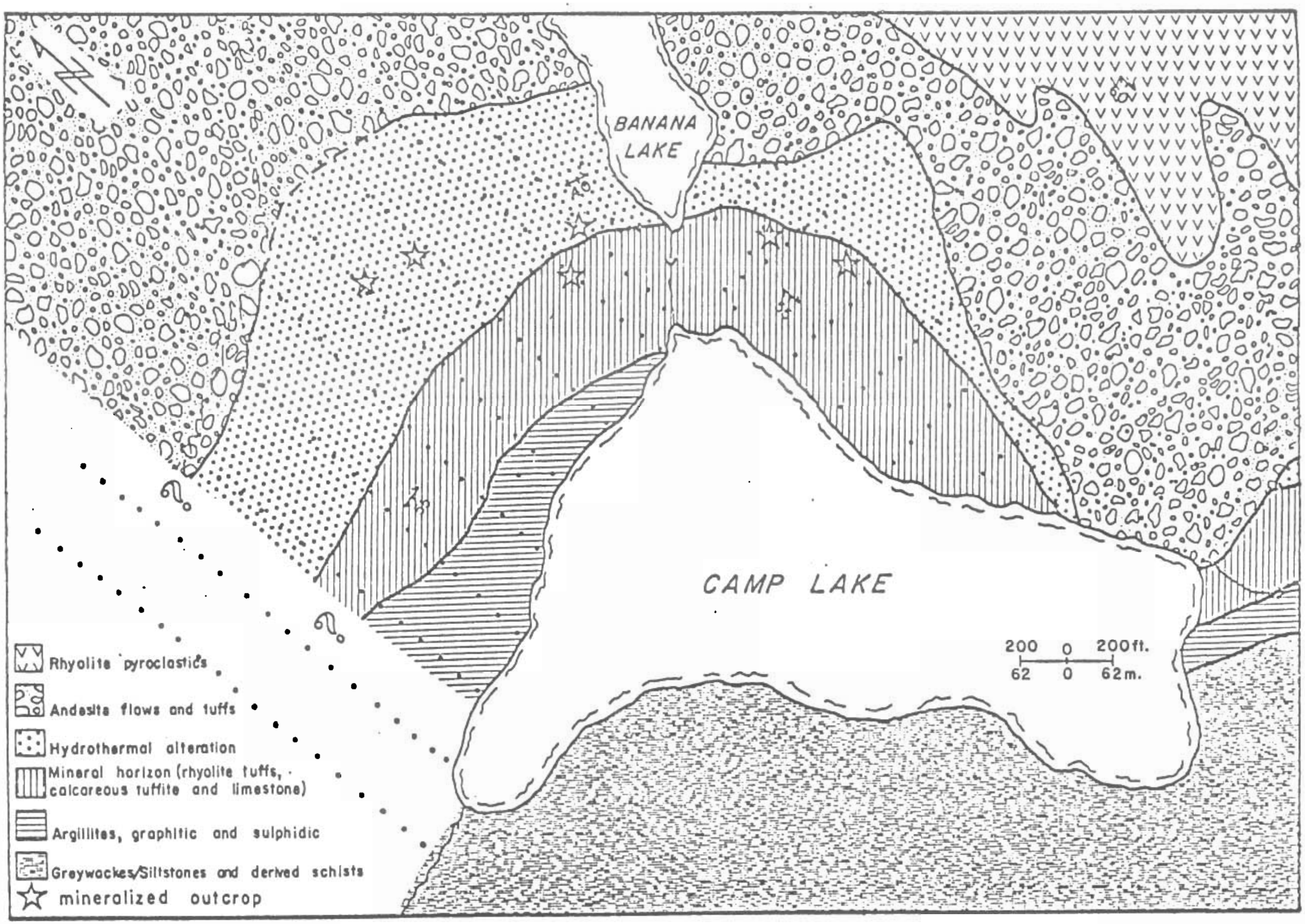


Figure 18. Simplified geologic map of Camp Lake.

In terms of exploration geochemistry, the most important features are the mineralized outcrops and the trace of the "mineral horizon" which marks the boundary between the underlying volcanic rocks and the overlying sedimentary rocks. Directly beneath the "mineral horizon" is an irregular layer of andesite tuff agglomerate (mill rock of Sangster, 1972) which is generally a few hundred feet or less thick and extends for approximately 3000 feet along strike. The upper part of the agglomerate, and the lower part of the "mineral horizon", has experienced moderate hydrothermal alteration and silicification. Within this alteration zone the identification of agglomerate is difficult. Contained in the alteration zone and cross cutting the volcanics, are several slightly sinuous conduit pipes where intense hydrothermal alteration (leaching) and silicification has occurred. It is thought that the majority of the mineralizing fluids ascended through these pipe-like zones. Beneath the alteration zone and the agglomerate lies a quartz-eye rhyolite tuff. Above the "mineral horizon" is a 5000 foot thick sequence of metamorphosed sedimentary rocks, possibly turbidities, the lower 150 to 200 feet of which are graphitic and sulphidic possibly as a result of late stage vent emanations.

CHAPTER 3

SAMPLE COLLECTION, PREPARATION AND ANALYSIS

I GENERAL INTRODUCTION

Samples were collected in the summers of 1974 and 1975. Table 2 summarizes the types and numbers of samples collected. Soil sample location was controlled through the use of chain and compass. Lake water and sediment samples were located on detailed maps at 1 inch to 200 feet. A regional lake water and sediment survey had been planned but was not implimented due to difficulties with the helicopter.

II SOIL

A. Collection and Preparation

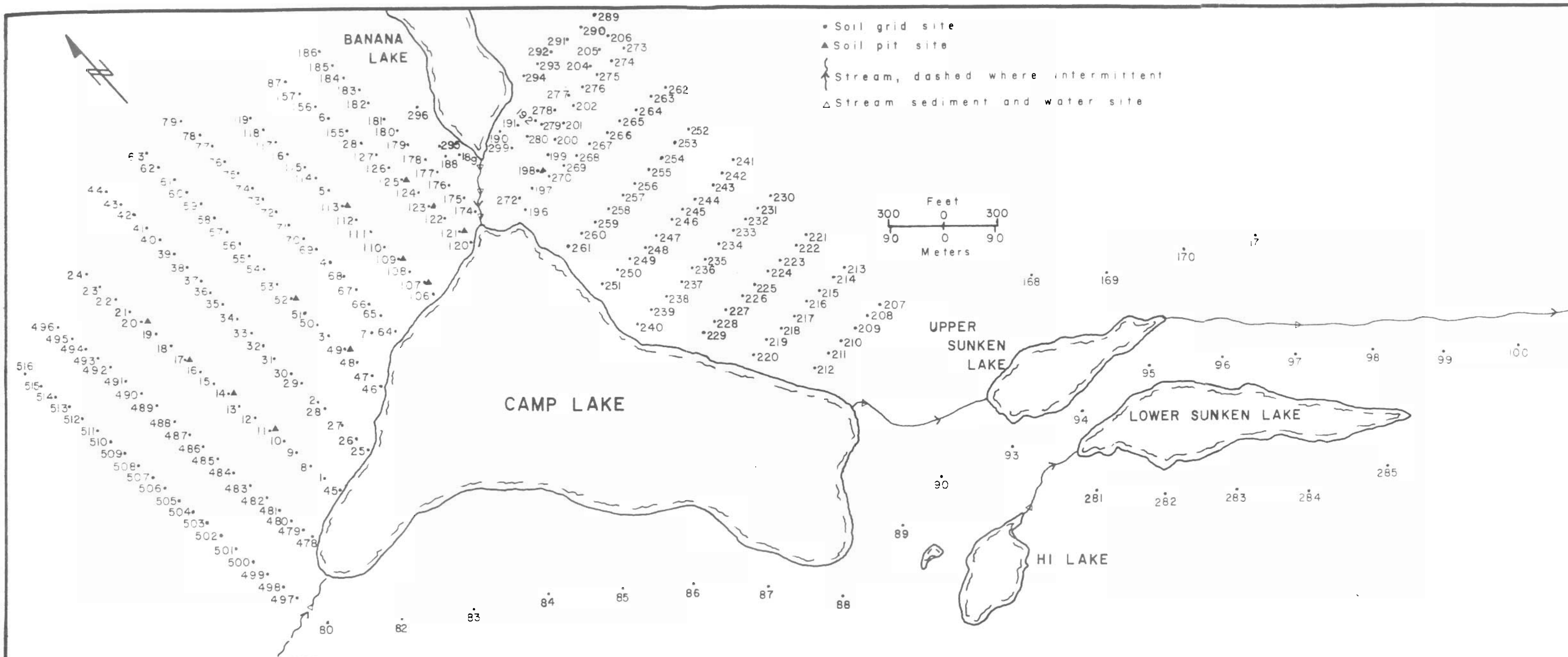
Soil samples were collected by hand digging to a depth of 15 to 40 inches. Sampling depth was limited by stones and cobbles and by slumping of the pit walls at relatively shallow depths in the wet soil. At each station the site, soil profile, and the parent material and vegetation were recorded; channel samples were taken from one face of the pit. Location, site number and sample type are shown in Figures 19 and B1.

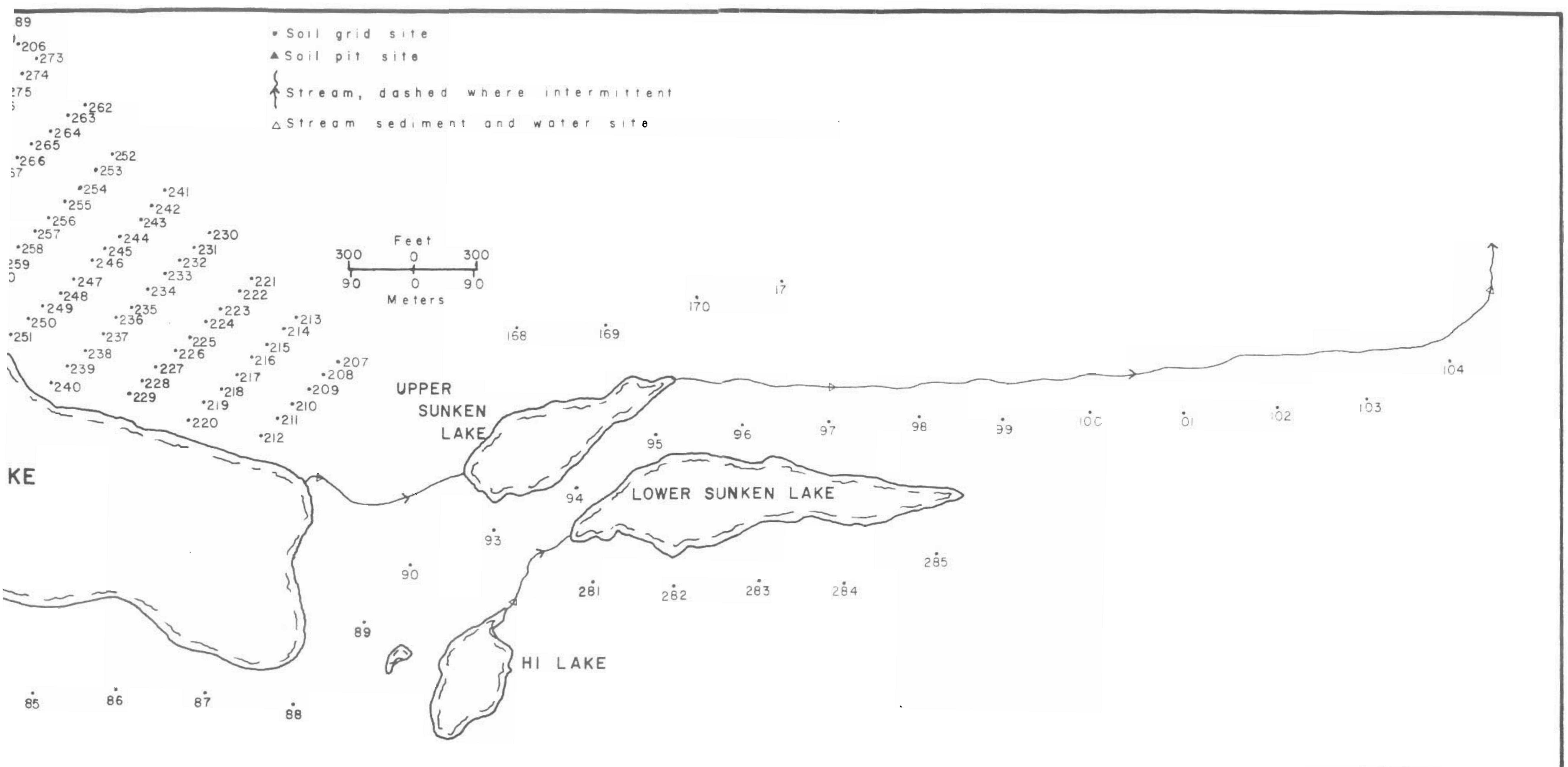
Initially an attempt was made to sample soil horizons but, except for the shallow (generally less than three inches) organic-rich surface horizon (L-F-H), this was not possible

Table 2. Summary of sampling at Camp and Anne-Cleaver Lakes

Medium	Number of Samples Camp Lake	Anne-Cleaver Lakes
(1) <u>Soil</u>		
L-F-H horizon	271	139
0-14 in. (0-10 in.)[1] layer	280	152
14-25 in. (10-20 in.) layer	157	49
>25 in. (>20 in.) depths	10	3
Pit profiles	300	52
(2) <u>Waters</u>		
Surface seepage	22	16
Snow-melt runoff	63	15
Pit seepage	13	2
Lake	21	12
Stream	19	10
(3) <u>Sediments</u>		
Lake bottom	50	25
Lake suspended	16	4
Stream	6	14

1: ( ) designates sampling intervals at Anne-Cleaver Lakes.


BANANA LAKE
CAMP LAKE
UPPER SUNKEN LAKE
LOWER SUNKEN LAKE
HI LAKE
• Soil grid site
▲ Soil pit site
Stream, dashed where intermittent
△ Stream sediment and water site
Feet
300 0 300
90 0 90
Meters



• Soil grid site
▲ Soil pit site
Stream, dashed where intermittent
△ Stream sediment and water site
Feet
300 0 300
90 0 90
Meters
UPPER SUNKEN LAKE
LOWER SUNKEN LAKE
HI LAKE
KE

because of poor soil profile development. Consequently, for routine mineral soil sampling several arbitrary depth intervals were chosen (0 to 14 inch, 14 to 25 inch, 25 to 36 inch and 36 to 45 inch). However, except for soil profile studies, the lower density distribution of $\geq$25 inch depth samples over the soil grid does not allow effective contouring of metal values. Table 2 summarizes geochemical sampling at Camp and Anne-Cleaver Lakes.

Detailed soil profile information was obtained from the excavation of 16 deep pits (usually $\geq$50 inches depth). Digging was limited by soil flowage and occasionally boulders. In no case was permafrost a limiting factor. The frost table, however, was encountered at several sites early in the season but thawing was rapid and this barrier, after a few days exposure, quickly receded. Attempts were made to excavate deep pits and cross-section sample active circles but this proved impossible due to continuously flowing soil. A Copco Soil Sampler[1] also proved ineffective because stones either prevented penetration or plugged the sampling tube. Consequently, most pits were sited in areas of relatively undisturbed till or in dormant circles.

All samples were placed in high wet strength Kraft paper envelopes and dried at ambient temperatures for two or more

1: The Copco Soil Sampler is a gasoline driven percussion sampler which drives a one inch diameter rod and sample tube into the soil.

days before shipping to the Department of Geological Sciences, University of British Columbia. Samples were then disaggregated with the aid of a rubber mallet and a portion was sieved through an 80-mesh nylon screen (177 microns). The minus 80-mesh material, usually amounting to 10 to 20 g, and the plus 80-mesh fractions were stored separately.

B. Decomposition

1. Nitric-perchloric digestion (total attack)

0.5 g of minus 80-mesh material was transferred to a test tube, 2 ml of a 4:1 mixture of nitric-perchloric acids added and then evaporated to dryness overnight on a hot air bath. The residue was redissolved in 2.5 ml of warm 6 M hydrochloric acid, diluted with distilled water to 10 ml, and analyzed by atomic absorption spectrophotometry using standards prepared in 1.5 M hydrochloric acid. Where necessary additional dilutions were made with 1.5 M hydrochloric acid using an automatic dilutor.

2. Partial extraction procedures

Partial attacks using cold 1.0 M hydroxylamine hydrochloride acetic acid, 1.0M hydrochloric acid and 0.05M EDTA (ethylenediamine tetraacetate) were carried out on various size fractions. For each partial attack the procedure was as follows: a 0.5 g sample was transferred to a test tube and 10.0 ml of one of the three reagents added. This mixture was mechanically shaken for 14 hours and then the solutions allowed to settle for at least a day before being analyzed by atomic absorption spectrophotometry. Standards were prepared in 1.5 M hydrochloric acid for the 1.0 M hydrochloric acid and 0.05 M EDTA extractions, and in 1.0 M hydroxylamine hydrochloride-acetic acid for the 1.0 M hydroxylamine hydrochloride-acetic acid attack.

III SEDIMENTS: COLLECTION, PREPARATION AND DIGESTION

Samples of the upper zero to four inches of sediment were collected from Turtle, Anne, Banana, Camp, Upper and Lower Sunken Lakes using a mud snapper[1]. Additional samples were collected from Camp and Banana Lakes using a modified Phleger coring device which retrieved short four to twelve inch cores. This device causes some compaction of the sediment. Sample locations are shown in Figures 102 to 107 and 122. Immediately upon retrieval the cores were sealed inside their plastic liners so that, on arrival at the University of British Columbia, several weeks later,

1: Manufactured by Kahl Scientific Instruments, California.

the cores were still moist and fresh in appearance. After removal from their liners the cores were split lengthwise and divided into short homogeneous segments on the basis of visual sedimentological and chemical characteristics. Segments were placed in paper coin envelopes and dried in an oven at 80°C for one to two days before disaggregating with the aid of a mortar and pestle. Due to the fine nature (silt-clay grain size) of the cores sieving to minus 80-mesh was unnecessary in most cases.

Stream sediments (Figs. 19 and B1) were collected from several square feet of stream bed as near mid-stream as possible taking care to avoid bank and colluvial material. After drying at ambient temperatures, stream sediment pretreatment was similar to that described for soils (page 60) except that a porcelain mortar and pestle were required for complete disaggregation.

IV WATER

A. Collection and Preservation

Near-surface water samples were collected close to the centers of streams (Figs. 19, B38 and B39) and at the surface, halfway to the bottom and near the bottom of lakes at several locations within the lake. Surface seepages (Figs. 97 and B38) were sampled wherever encountered along the soil grids; generally they were small pools in topographic depressions or breaks-in-slope, or small rivulets found after the snow melted in June. In mid to late June, snow-melt runoff was sampled from ice-water pools and small temporary streams with undefined channelways (Figs. 98 and B39). Where possible, water was also collected from soil-grid sites one to two days after excavation (Figs. 97 and B38).

All water samples, except for lake water samples which were collected using a Van Dorn Sampler[1] and four liter polyethylene jugs, were collected in 500 ml acid washed, distilled water rinsed polyethylene bottles. Samples taken during the day were filtered each evening using Sartorius filters and 0.45μ millipore membranes. Passage of water through the filter was accelerated by pressure from a small nitrogen tank. A 250 ml portion of the filtrate was acidified with 2 ml of 6 M hydrochloric acid and placed in an acid washed 250 ml polyethylene bottle for subsequent analysis. Analysis was by atomic absorption spectrophotometry, without pre-concentration.

B. Field Analysis

Aliquots of filtered water were analyzed for alkalinity, chloride (both by titration) and sulphate (by turbidity) using Hach kits. Conductivity was measured using a Hach 2510 Conductivity Meter.

1: Kahl Scientific Instruments, California.