No. _____

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

TOPICAL REPORT NO. 69

CONTRIBUTIONS OF THE MARINE GEOLOGY UNIT OF THE GEOLOGICAL SURVEY OF CANADA TO THE POLAR CONTINENTAL SHELF PROJECT, DISTRICT OF FRANKLIN, 1962

BY

B. R. PELLETIER

OTTAWA

1963

Map of Arctic Islands. Traverses of 1960, 61, 62 shown in solid lines; Traverses of 1963 shown in dashed lines. Shaded areas indicate inshore traverses

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Introduction

The purpose of this report is to summarize the activities of that part of the marine geology group of the Geological Survey of Canada which is participating in the Polar Continental Shelf Project (Frontispiece). Programs and results of previous field seasons were reviewed earlier (Topical Report 47), and are summarized here together with current projects. Future programs for field and laboratory studies are also presented. Some conclusions and applications involving the earlier research programs are given by means of illustrations. These illustrations demonstrate the direction that certain programs in the future will take. References are made to earlier reports and to projected publications of the near future.

The Geological Survey is responsible for geological phases of the Polar Continental Shelf program. These investigations are planned in consultation with the co-ordinator of the P.C.S.P., and carried out, supervised and prepared for publication by officers of the Geological Survey. Survey officers have assumed the following responsibilities: offshore sampling in Arctic Ocean, and laboratory scheduling - B.R. Pelletier; inshore and inter-island sampling - D.R. Horn; J.I. Marlowe, and G. Vilks; faunal description - F.J.E. Wagner; chemical analyses - E.M. Cameron (spectrochemical laboratory); mechanical analysis of sediments - G. Duncan, E.F. Field, and R.G. Kelly (sedimentology laboratory); X-ray analysis for clay minerals - A.P. Sabina and R.J. Traill (X-ray diffraction laboratory); acidity and oxidation determinations - G. Bender and J.A. Maxwell (wet chemical laboratory); analysis of common metallic elements - W.H. Champ and W.F. White (spectrographic laboratory); faunal separation - A. Matte and B. Botte (palaeontological laboratory).

Previous and Current Field Programs

The marine geology unit of the Geological Survey was organized in 1959 to operate in the field within the framework of the Polar Continental Shelf Project. From this planning the first program was initiated in April, 1960, over the Arctic Ocean. This was a combined oceanographic-geological reconnaissance of the Arctic continental shelf and the adjacent seaward boundaries of the western channels of the Queen Elizabeth Islands. Later in the same spring and early part of the summer, a marine geological program commenced in the inshore waters of Deer Bay, and included the sampling of sediments from river beds and drainage basins in the adjacent areas of land. The following year geological work in the inter-island channels began together with the continuation of inshore and ocean projects. In 1962 all projects were continued, and plans have been made to extend the work into the southern waters in 1963.

Laboratory schedules were organized to maintain a continuous flow of samples to the various laboratories so that data could be interpreted without long delay (Flow Sheet). This expediency was provided for on the flow sheet which directed partial or duplicate samples to different laboratories simultaneously. As new programs are started or old ones discontinued or revised, the flow sheet will undergo revision accordingly.

1. Arctic Ocean study undertaken in April and May, 1960 to 1963, by B.R. Pelletier.

This project is a continuation of the offshore sampling program over the eastern Arctic Ocean and adjacent channels, which began in April, 1960. In 1961 the study extended across the continental shelf northwest of Meighen Island. In 1962 the continental shelf and upper part of the continental slope between Ellef Ringnes and Borden Islands were sampled by means of coring

apparatus and bottom grab-samplers. Studies of bottom topography, sediments and fauna are the chief interests of the project with a view to interpreting the physiographic history of the Arctic Islands and adjacent channels and continental shelf, to determining the conditions and products of sedimentation, and to determining environmental factors under which certain bottom fauna exist. This last point will help to establish ecological niches according to bathymetry.

Preliminary field and laboratory observations indicate the following: 1) the Arctic continental shelf is fairly uniform in relief, except for small local knolls and depressions. The depth of the shelf varies from 400 metres 30 to 40 kilometres off shore, to about 600 metres at the seaward edge where the slope breaks about 150 to 160 kilometres from the northwestern tips of Ellef Ringnes and Borden Islands. The sequence of events involving the Quaternary physiographic history of the continental shelf and adjacent channels appears to have commenced with valley glaciation of pre-glacial river systems which occupied the present inter-island areas. This glaciation presumably extended some distance seaward, and took place when the land was at a higher elevation relative to sea level. This event was followed by submergence, and it is thought that shallower features near shore are due to submergence of old land features. 2) The sediments consist, generally, of light brown mud and silt, with 10 to 25 per cent sand. However, in the drowned areas near shore at the seaward tips of the islands, the sand content exceeds 75 per cent. Much of the fine material appears to be derived directly from the adjacent islands to the east, based on the fact that the upper layer increases in thickness in that direction. Pebbles and cobbles occur over all areas of the continental shelf and are presumably ice-rafted. 3) A study of bottom fauna obtained from depths ranging between 180 and 1,200 metres indicates that a definite zonation based on bathymetry does exist, but that this zonation

appears prominent only when a difference in depth of at least a few hundred metres is considered (Fig. 1).

2. Peary Channel study which took place from March to August 1961, and was carried out by D.R. Horn. This project consisted of a study of sediments and bottom topography beneath the inshore and channel waters adjacent to eastern Ellef Ringnes Island, northern Amund Ringnes Island, southwestern Axel Heiberg Island, and the southern parts of Meighen Island. Geological formations underlying the main drainage areas, as well as the drainage areas themselves, were sampled in order to study source material and its alteration during sedimentary transport. Sediments and conditions at the site of deposition were investigated for the purpose of making environmental studies. Soundings were taken to establish further the submarine topography and the physiographic history of the Arctic islands and channels.

Preliminary observations on soundings indicate the presence of submerged glacial valleys. The evidence for such features includes U-shaped valleys, hanging tributaries below sea level, hummocky terrain and gravel deposits which may be of glacial origin, and the presence of glaciers at the headward portion of some of the U-shaped troughs. The sequence of events appears to be as follows: normal fluvial erosion in pre-glacial time when the land stood higher relative to sea level; then, valley glaciation followed by submergence of the river valleys and parts of the present day islands. On the floor of Peary Channel a medial rise occurs which appears to have been an interfluvial area. Several submarine prominences which formerly separated river valleys leading into Peary Channel before the land was submerged also occur but are now under several hundred feet of water.

Sediments at the headwaters are coarse, and such coarse material occurs along the river beds to a point downstream where an abrupt lowering of the gradient occurs. From this point to the coast, rivers carry mainly coarse sands and finer material, and the grain size decreases with distance of sedimentary transport. Sedimentation in marine waters appears to be most intense in areas offshore from river mouths. In such areas the texture is coarsest. Here rivers are the greatest contributors of sediments and, to a lesser extent, wind and ice. Most bottom cores exhibit two layers consisting of light brown silt in the upper or modern layer, and dark greyish brown silt and mud in the lower layer. The demarcation between the layers is sharp, and is similar to that found in cores recovered from Prince Gustaf Adolf Sea and the Arctic Ocean over the adjacent continental shelf. The bottom fauna appear to be more abundant in the upper layer than in the lower one. This together with the marked change in colour indicates a widespread change in conditions of sedimentation all over this part of the Arctic waters which may be related to a change in ocean climate.

3. Prince Gustaf Adolf Sea and MacLean Strait study which took place from early May until late July, 1962. The sampling program in the channel was carried out by J.I. Marlowe, and the inshore program in Deer Bay and the adjacent coast line of Ellef Ringnes Island was undertaken by G. Vilks. The overall project was designed to provide information on the total sedimentary environment. To do this, samples were collected from outcrops and stream beds, as well as from the nearshore and offshore bottom zones.

Bathymetric data indicate strongly that the channels occupy a drowned area of terrestrial drainage. Submarine river valleys, with a local relief of 200 to 300 metres, trend along the axes of the channels. Some shoal

features appear to be seaward extensions of presently emerged islands.

A preliminary examination of samples taken from detailed traverses across the sub-littoral zone of the west coast of Ellef Ringnes Island indicates that the sediments of that area are texturally complex, a characteristic which suggests that ice was a dominant agent of sedimentary transport and erosion in that area. A distinctive extremely cold-water fauna is present in the nearshore samples so far examined. Core samples from the channels west and south of Ellef Ringnes Island consist of mud and, commonly, numerous pebbles. A light-coloured upper layer overlies a darker layer in most of the cores and probably represents a drastic change in conditions of sedimentation. Analysis may relate this change to climatological events in the Pleistocene.

4. Foxe Basin, Foxe Channel, and Hudson Strait.

This was an oceanographic program carried out in 1959 by the Atlantic Oceanographic Group of Fisheries Research Board of Canada in collaboration with the P.C.S.P. It was supported also by the Ontario Department of Lands and Forests, and was carried out by A.E. Collin now of the Marine Sciences Branch. The bottom samples obtained on this project were prepared for faunal and sedimentary analyses in the Geological Survey laboratories. These analyses were undertaken as a joint study by F.J.E. Wagner and B.R. Pelletier. The purpose of the study is to investigate the relationship of bottom sediments to the contained fauna.

It was found that the same species of bottom fauna occur in areas covered with pebbles as in areas covered with sand and silt. The primary relationship of bottom fauna to sediments does not appear to exist and, at best, is only secondary. This secondary relationship was further established from the standpoint of bathymetry in view of the fact that depths from which the

samples were taken are fairly uniform - 18 to 27 metres. It is thought that nature of the bottom is not a critical primary factor which establishes the important environmental condition under which bottom fauna live, but rather the more important factors are oceanographic and include the following: depth, currents, salinity, temperature, geography, and food supply all of which presumably form an interplay of influences. The relative importance of each factor is not known but the present studies will serve as one contribution to the larger, more complex problems of ecological niches and speciation.

Future Field Programs

Field programs for 1963 will include a continuation of work done in previous years but the surveys will move further to the south and southwest. The offshore program will be undertaken by B.R. Pelletier and will take place over the continental shelf of the eastern Arctic Ocean northwest of Borden and Brock Islands. It will be reconnaissance in scope and will consist of a sampling program based on a 10 to 15 mile grid extending perpendicular to the general northwesterly trending coast of the Arctic Ocean. An attempt to obtain longer cores below deeper parts of the ocean is planned. This sampling will take place mainly on the continental slope.

The channel program under J.I. Marlowe will cover the western part of Prince Gustaf Adolf Sea and the adjacent waters to the south. This project will essentially involve the recovery of long cores, although in shallower areas where sand predominates it may be feasible to obtain only bottom grabs. This project will have the same purpose as the 1962 project which took place in the eastern part of the sea.

The inshore program will be carried out by G. Vilks who will operate in the large bay on the eastern extremity of Mackenzie King Island. The project will be concerned with the detailed sedimentology and palaeontology, and most of the material will be obtained by means of bottom snapper samplers. In addition, the adjacent drainage basin will be sampled at the outcrop and along the river channels to determine more effectively the alteration of detritus from its source to its dite of deposition.

Continuing Laboratory Studies and Results

For the purpose of a convenient reference to the flow sheet, these continuing laboratory programs have been placed in three specific categories: 1) the mechanical analyses of sediments, 2) the analyses of bottom faunas, and 3) the chemical analyses of sediments. The following account gives further subdivisions and summarizes some of these researches verbally and graphically. This is done not only for explanatory purposes but to keep on file a record of the working methods which will serve as a guide for future projects of a similar nature.

1. Mechanical Analyses of Sediments.

Mechanical analyses were carried out on sediments from many environments which include the following: lake, river, delta, protected bay, channel, and open ocean. The results have been elaborated in earlier reports and are illustrated here in Figures 4, 5, 6, and 7. The salient features are: 1) in fluvial and inshore deposits there is a direct relationship of decrease in size of detritus with distance of sedimentary transport together with a reduction in the percentage frequency, mean size and number of heavy mineral species (Fig. 4). Directly offshore in deltaic samples the size decrease is

exponential with distance; therefore, to reduce the number of samples necessary to demonstrate this principle as well as maintain an overall economy in sampling, the interval between sampling stations was set up on a logarithmic basis (Fig. 5 and 7). This also provided for the maximum of sampling near shore where progressive variation in texture is greatest. Departure of observations from the size-distance curve (Fig. 5) may be due to the inclusion of anomalous data on coarser ice-rafted material, or similarily to the inclusion of data on wind-blown sediments from the nearby areas of land. These results can be applied to studies of correlation, sedimentary transport, and palaeogeography. 2) Offshore in areas of drifting ice, the latter of which contributes sediments to the sea floor, no progressive variation in texture from station to station occurs. However, where currents are known to exist, such as in the open ocean and mid-channel areas, the sediment is sorted to a better degree than in areas where currents are extremely slow or absent. This gives rise to an apparently anomalous distribution of sediments in which the bulk of a bottom sample near shore consists of fine material whereas offshore on the continental shelf and mid-channel areas, the coarser material occupies a greater percentage of the sample (Fig. 6). 3) The contours, or isopleths, of a sand-mud lithofacies map of the submarine portion of a delta are distorted characteristically so that instead of concentric arcs, the contours are skewed in the direction of longshore currents (Fig. 7). Silting of the bay should be pronounced in that direction. The general protruding pattern of isopleths superposed over the depth contours indicates the prograding of clastic sediments due to a relative marine regression, or rise of land. By constructing such maps from data obtained from the analyses of the underlying layers, it should be possible to establish some earlier rises and falls of sea level.

2. Analyses of Bottom Faunas.

Faunal studies undertaken by F.J.E. Wagner will continue on sediments obtained from wide regions of the Arctic Ocean, island channels, and various nearshore waters. The collections are representative of certain depths down to 1,300 metres below sea level. It is significant that a change in faunal suites can be indicated bathymetrically providing the difference in depth which accompanies the faunal change is in the order of a few hundred metres (Fig. 1). Other environmental studies involving sediments and oceanographic factors (Fig. 2) will continue, and will be used in an attempt to establish more data on the problematical aspects of ecology and speciation.

G. Vilks also commenced a faunal study which will be restricted to material obtained from protected bays and interisland channels. The combined studies of Wagner and Vilks on the modern sedimentary surface will be useful in establishing a framework of biostratigraphy in the Arctic environment involving the examination of cores from different marine areas of the Arctic. Eventually these results will be correlated with similar results from other marine areas of Canada. At present both Wagner and Vilks have noted, independently, the occurrence of an Atlantic fauna only from depths ~~less~~ greater than 200 metres. It is this type of study applied to stratigraphy which should lead to the unravelling of physical and biological events in the marine areas of Canada.

3. Chemical analyses of Sediments

Chemical analyses of sediments have been proceeding along two major lines: 1) X-ray analysis to determine the groups or families of clay minerals occurring in the Arctic environment; 2) spectrochemical analysis

of sediments to determine the chemical composition of the sediments with reference to certain elements. The results of the X-ray analyses indicate that clay minerals occur in groups which are related to the geological formations in the immediate vicinity of the drainage basin (Fig. 3). This further indicated that clay minerals, in the Arctic environment at least, are detrital in nature and hence can be used as tracers for the purpose of establishing routes of sedimentary transport and eventually, the source area contributing the sediments.

Preliminary results from the emission spectrograph indicate that certain elements occur in an abundance which appears to be related directly to the geological formations underlying the drainage basins. This further indicated that certain elements, depending upon the composition of the source rock, could be used as tracers in order to establish routes of sedimentary transport.

Another research problem involving spectrochemical techniques deals with the determination of chemical activity in Arctic sediments at the site of deposition. The spectrographic results indicated the virtual absence of such activity, but due to the range of the instrument only a semi-quantitative statement could be prepared. However, with the new spectrochemical apparatus - the quantograph - now installed in the Geological Survey, a more rapid and refined determination of given elements can be made. The results of these analyses can be phrased in terms of unstable versus stable oxides for the purpose of comparing geological material from the source area with that from the depositional site. By means of a selection of suitable compounds that will yield a ratio of these unstable and stable oxides, it may be possible to determine quantitatively the amount of unstable material lost through weathering

or marine diagenesis. These studies can also lead to considerations of past climatic regimes of ocean and land as certain mineral formations, such as the deposition of Ca CO_3, are related to temperature belts.

Publications and Reports

Three papers covering similar aspects of the above work are now in preparation. 1) Horn, D.R. (1963), Marine Geology, Peary Channel, Polar Continental Shelf Project, District of Franklin, Geological Survey of Canada, Paper Series. 2) Marlowe, J.I. and Vilks, G. (1963), Marine Geology, Eastern Portion of Prince Gustaf Adolf Sea, Polar Continental Shelf Project, District of Franklin, Geological Survey of Canada, Paper Series. 3) Pelletier, B.R. and Wagner, F.J.E. (1963), Marine Geology, Arctic Ocean adjacent to Ellef Ringnes and Borden Islands, Polar Continental Shelf Project, District of Franklin, Geological Survey of Canada, Paper Series.

Three reports have been published. 1) Pelletier, B.R. (1961), Progress Report of the Submarine Geology Unit, Polar Continental Shelf Project, Western Queen Elizabeth Islands, District of Franklin, 1961, Geological Survey of Canada, Topical Report No. 47. 2) Pelletier, B.R. (1961), Submarine Geology Program, Polar Continental Shelf Project, Isachsen, District of Franklin, Geological Survey of Canada, Paper 61-21. 3) Wagner, F.J.E. (1961), Faunal Report - Submarine Geology Program - Polar Continental Shelf Project, Isachsen, District of Franklin, Geological Survey of Canada, Paper 61-27.

Two unpublished reports under the 1961 titles were submitted earlier to the office of the P.C.S.P.

1) P.C.S.P. Paper No.35 (1960) by B.R. Pelletier
2) P.C.S.P. Paper No.36 (1960) by F.J.E. Wagner

Very brief accounts of the activities of the marine geology group have been submitted to the Information Circular and Annual Report of the Geological Survey of Canada for 1961 and 1962, and to the Division of Oceanographic Research of the Marine Sciences Branch.

On behalf of the Department, talks and informal visits concerning the above projects were given at the following:

Lamont Geological Laboratories, New York.
Woods Hole Oceanographic Institute, Massachusetts.
Dalhousie Institute of Oceanography, Halifax.
Carleton University, Ottawa, Ontario.
University of Ottawa, Ottawa, Ontario.
Queen's University, Kingston, Ontario.
The Bedford Institute of Oceanography, Dartmouth.
McMaster University, Hamilton, Ontario.

In the near future a seminar will be given to the geology department of Dalhousie University, Halifax.

Appendix

Naming key for species, indicated by letters, in Figures 1 and 2.

Species A Alveolophragmium crassimargo (Norman)

B Alveolophragmium jeffreysi (Williamson)

C Astrononion gallowayi Loeblich and Tappan

D Bucella frigida (Cushman)

E Cassidulina islandica Norvang

F Cassidulina laevigata d'Orbigny

G Cassidulina norcrossi Cushman

H Cassidulina teretis Tappan

Species I *Cibicides lobatulus* (Walker and Jacob)

J *Elphidiella arctica* (Parker and Jones)

K *Elphidium bartletti* Cushman

L *Elphidium clavatum* Cushman

M *Elphidium frigidum* Cushman

N *Guttulina* sp.

O *Nonion labradoricum* (Dawson)

P *Nonionella auricula* Heron-Allen and Earland

Q *Oolina costata* (Williamson)

R *Protelphidium orbiculaire* (Brady)

S *Pyrgo williamsoni* (Silvestri)

T *Quinqueloculina seminula* (Linne)

U *Cibicides wuellerstorfi* (Schwager)

V *Eponides tener* (Brady)

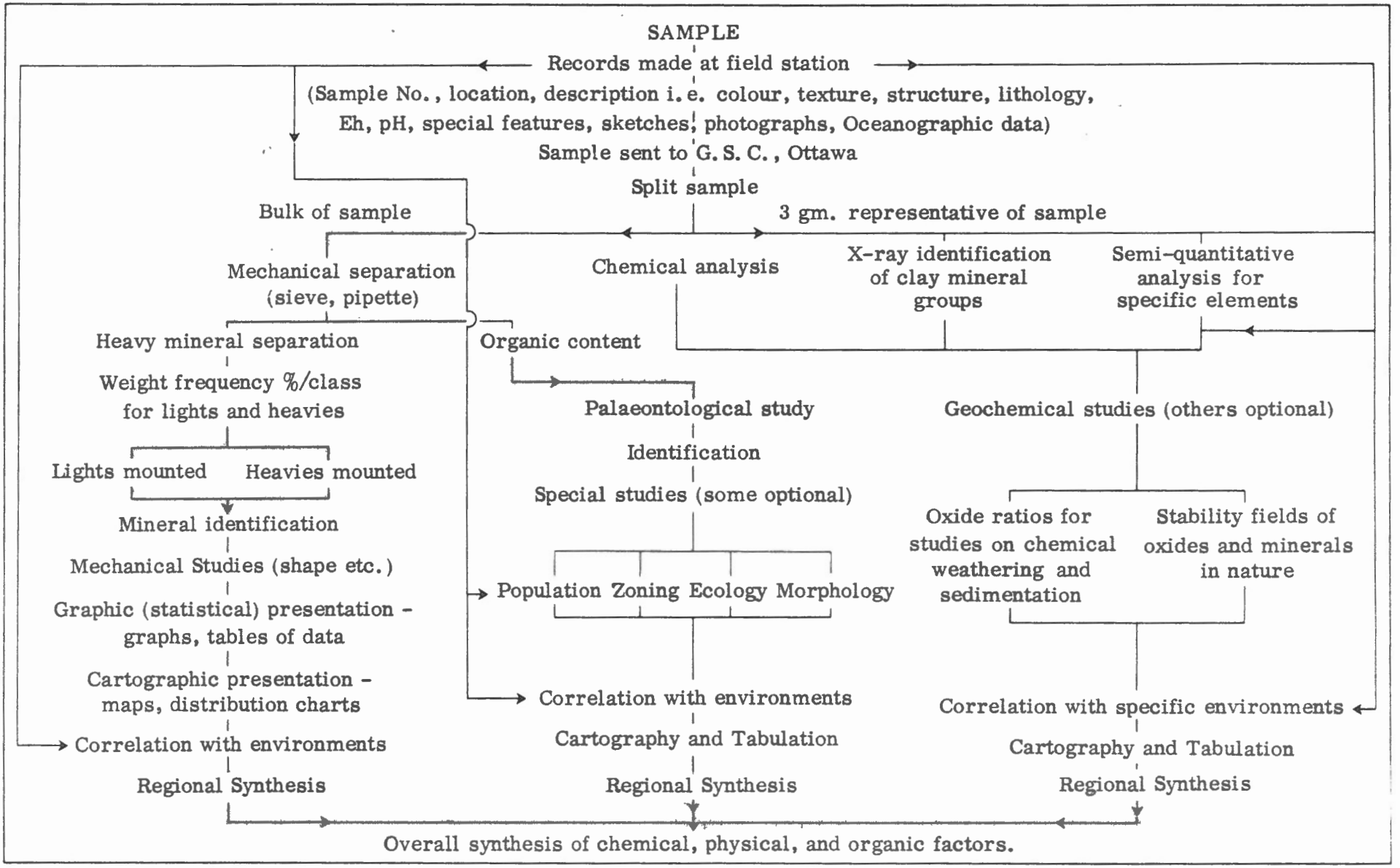
W *Nummoloculina* sp.

X *Quinqueloculina arctica* Cushman

Y *Quinqueloculina* sp. (? = *Q.* sp. of Green)

Z *Valvulineria horvathi* Green

This list is part of a faunal list drawn from studies by F.J.E. Wagner on fauna from Hudson Strait and the Arctic Ocean. The purpose of the list is to aid the comparative studies of species from different areas, and thus supply some of the facts on oceanographic and biologic history.



Flow sheet for processing data and samples.