Current Research

The Woods Hole Oceanographic Institution - United States Geological Survey, Woods Hole, Mass.

The following account is a joint effort submitted by WHOI, and for convenience the editor has arranged the submissions according to subject matter.

General:

East Coast Continental Margin Project by Elazar Uchupi.

During 1969, members of the east coast continental margin project devoted their time to the preparation of reports for publication, the analyses of samples collected during previous years, and participation in nine cruises (see below). In 1969 the staff published 35 papers, submitted 31 others for publication, and gave 37 talks at various scientific meetings. Since the project began in the summer of 1962 the staff has published 200 papers.

The quadrangle mapping program was initiated in the summer of this year. To date several thousand kilometers of profiles using a 3.5 kc echo-sounder and a 5 cubic inch air gun seismic profiler have been recorded in the quadrangle extending from Cape Cod Bay, Massachusetts in the south to Casco, Maine in the north, and from the coast to Longitude 70° West. Other data collected within the quadrangle include bottom current measurements, several hundred bottom sediment samples, suspended sediment samples, and water samples.

In addition to sample analyses and preparation of reports, the staff participated in the following cruises:

1) R/V Atlanis II - Black Sea - interstitial water studies, sediment sampling and seismic profiling, 48 days;
2) R/V Theron - The Grand Banks of Newfoundland - coring, 20 days;
3) R/V Verrill - western Gulf of Maine (in quadrangle) - bottom samples, 2 days;
4) R/V Verrill - western Gulf of Maine (in quadrangle) - bottom samples and suspended sediment samples, 2 days;
5) R/V Asterias - Somes Sound, Mt. Desert Island, Maine - bottom samples, water samples, suspended sediment samples, bottom current studies, 5 days;
6) R/V Verrill - western Gulf of Maine (in quadrangle) - bottom currents, water samples, bottom samples, survey with a 3.5 kc echo-sounder, 2 days;
7) R/V Dolphin - western Gulf of Maine (in quadrangle) - survey with side-scanning sonar, bottom samples, suspended sediment samples, water samples, bottom photography, dredging, coring and profiling with a 3.5 kc echo-sounder, 10 days;
8) R/V Gosnold - western Gulf of Maine (in quadrangle) - survey with a 3.5 kc echo-sounder and 5 cubic inch air gun seismic profiler, 10 days;
9) R/V Atlantic II - east coast continental margin - suspended sediment samples, 26 days;
10) R/V Verrill - Cape Cod Bay - profiling with a 3.5 kc echo-sounder, 2 days.

Summary of work for 1969 by K. O. Emery.

The year has been one of conferences and writing. Most important of the conferences were the following:

Oceanology '69 Brighton, England (February) Here I gave an invited talk on placer deposits of continental shelves.

Committee of SCOR Kiel, West Germany (February) Plans were made for an international symposium on the East Atlantic Continental Margin in Cambridge, England, in March, 1970, laying the groundwork for field studies to be made in 1971-3.

Economic Commission for Asia and the Far East Bangkok and Calcutta (May) A multi-authored report on the geological structure of the East China Sea was presented (published in ECAFE Technical Bulletin). Arrangements also were made for Asian participation in a similar USN cruise to the South China Sea during May to September, and discussions were held for possible initiation of an Indian Ocean organization for shelf exploration.

Law of the Sea Rome (July) Here I presented an invited talk on "An Oceanographer's View of the Law of the Sea".

UNESCO (in association with the meeting of INQUA) Paris (September) Here I presented an invited report, "Quarternary Sediments of the Atlantic Continental Shelf of the United States".

The bulk of effort during the year was on writing the following:

Continental Rise off Eastern North America (with Uchupi, Phillips, Bowin, Bunce, and Knott) for American Association of Petroleum Geologists Bulletin of January 1970.

Structural Framework of the East China Sea and the Yellow Sea (with Wageman and Hilde) for American Association of Petroleum Geologists Bulletin of Spring, 1970.

Atlantic Continental Margin of North America This is a summary book, now about 25 percent complete, dealing with topography, stratigraphy, structure, water, sediments and life in a region of about 15 million square kilometers.

Paleontology:

Faunal Diversity in Paleoenvironmental Reconstructions by Thomas G. Gibson.

A study of diversity in different environmental settings as seen in Foraminifera off the Atlantic Coast of North America has been completed. A report on the diversity in the area from Cape Cod to Maryland has been published (Buzas and Gibson, 1969, Science, vol. 163, p. 72-75) which uses the information function as the measure of dominance diversity. The areas north into the Arctic regions and south into the Gulf of Mexico have now been investigated. The patterns of both dominance and species diversity in all the open ocean areas are similar, but some local control is observable. The importance of local control is seen especially in the marginal marine areas, or bays. Although a general increase in diversity takes place as depth increases and thus generally more open marine conditions prevail, most of the bays have their own characteristics. The bays have low diversities, both in terms of H(S)(information function) values, which generally are less than 2. 0 and commonly fall below 1. 0, and in the number of species.

The results derived from the study of living faunas have been applied to fossils formed in some of the geologic strata along the Atlantic margin. The use of diversity affords a criterion of comparison other than that between living and fossil genera and species.

The investigated Pleistocene strata along the Atlantic margin from Maine to North Carolina show diversity values comparable to modern bays. In this part of the column, a cross-check of the foraminiferal and molluscan assemblages indicates similar environments of deposition.

The use of diversity in Miocene strata along the Atlantic margin indicates a series of deeper water areas separated by shallower transverse areas, closely following the basins and arches in the Coastal Plain that were previously proposed on other grounds. Further investigations of depth relations in Mesozoic and older Cenozoic strata are being undertaken, as this part of this geologic column has many fewer living genera and species and thus less control on other faunal criteria.

Ostracodes from the Atlantic Continental Shelf by Joseph E. Hazel and Page C. Valentine.

As far as the WHOI-USGS program is concerned, this past year has been spent gathering data on the distribution, abundance, and diversity of living ostracodes on the Atlantic shelf between Long Island and Cape Romain. About 150 samples collected from the R/V *Gosnold* have been processed to date. This phase of the study is nearing completion. We hope that the data gathered will allow paleoenvironmental and paleoclimatic interpretation of Pleistocene, Pliocene, and late Miocene assemblages from onshore and offshore collections.

Trace Fossils from the Deep-Sea Floor by C. D. Hollister.

The majority of bottom photographs taken on the deep-sea floor show numerous indistinct mounds and depressions, as well as occasional tracks or fecal coils produced by benthic animals. An examination of over 100,000 photographs taken in water depths over 3,000 meters has revealed many organisms producing their traces. Most walking trails composed of discrete "footprints" are produced by holothurians. Large tractor-tread trails are probably made by mud-eating asteroids and many of the grooves and furrows are chiefly echinoid traces. Rope-like fecal coils are produced by holothurians, and planispiral feces are produced by hemichordates.

Sedimentology:

Texture of Bottom Sediment on the Continental Margin off the Northeastern U. S. -- Final Report by John S. Schlee.

The Atlantic Continental Margin of northeastern United States is covered by fine- to medium-grained quartzose sand out to the shelf edge, and silt and clay on the continental slope and rise. On the glaciated part of the continental shelf (Gulf of Maine), sediment is mainly till-like mixtures of sand, gravel, silt and clay; in basins of the gulf, pelagic silty clay veneers older glacial deposits. Adjacent to the rocky shelf around Nova Scotia, coarse gravel is prevalent.

Past and present depositional agents have affected both the topography and type of sediment on the continental margin. Deposits of coarse cobbles and boulders occur mainly in the Gulf of Maine where glaciers deposit them. They are particularly well exposed as a lag on banks and ledges due mainly to winnowing of these elevated areas by bottom currents. Fine detritus from the glacial debris has settled in depressions occupied by tongues of the ice sheet to cover the glacial deposits with several meters of silty clay. The southern limit of glaciation is marked by a fringe of gravelly sand (former outwash deposits) and sandy gravel that stretches from moraines on Marthas Vineyard and Nantucket, southeastward across Nantucket Shoals and Great South Channel, and along the northern part of Georges Bank, where boreholes reveal up to 120 feet of sand with stringers of gravel. The shelf south of the glacial limit, is mainly a sand-covered plain transected by wide channels and carved by a dendritic drainage pattern southeast of New York and New Jersey; relict terraces inherited from lower stands of sea level are also prevalent in this area -- particularly on the outer shelf. Redistribution of sandy debris was so prevalent on Georges Bank and the inner shelf elsewhere, that the channel ways for glacial meltwater are now buried, though they can be detected on continuous seismic profiles.

Areas of fine-grained sediment on the shelf are confined to inshore areas such as estuaries, bays, and sounds, and to one large area on the shelf south of Rhode Island, and Cape Cod. The latter area of silty sand and sandy silt veneers older deposits of sand and probably originated through ponding of fine detritus on a shallow part of the shelf during the Holocene rise of sea level.

The bathymetric transition to the deep sea is marked by a change to finer grained sediment on the continental slope. The sand fraction lessens and changes from dominately quartz and feldspar to one mainly of planktonic foraminifera tests. Patchy reversals in the trend are due to rafting or slumping of debris down submarine canyons.

Statistical and non-statistical measures of grain-size are affected by the mixing of basic populations of gravel, sand, and silt plus clay, by one of several processes. Modes show a complex pattern on the continental shelf, in part related to transport of sand along shore during lowered stands of sea level in the Holocene. Gradients toward finer modal grain size are best developed at the shelf edge down the continental slope, where sea level stabilized during glacial stages of the Pleistocene; the gradient relates poorly to existing patterns of sediment transport on the shelf, and hence, supports the inference that much shelf sediment is relict. Grain size median is a good describer of sediment where it is fairly well sorted and unimodal. Much sediment, however, is both poorly sorted and polymodal, particularly in the Gulf of Maine. Standard deviation relates well with past and present processes that have dispersed the sediment. Till-like deposits in the gulf and sandy gravel outwash deposits around the gulf show poor sorting due to (1) an inability of the ice to sort the debris, and (2) the transport of sand and gravel by different processes. Transport mainly by a single process and of a single basic population leads toward unimodal normally distributed sediment with moderate or excellent sorting. An example would be the current-swept shoals composed of coarse to fine grained quartzose sand southeast of Nantucket.

Skewness and kurtosis show a very patchy areal distribution of values; scatter plots with each other and with standard deviation and median lend support to the idea that skewness and kurtosis are a partial measure of the degree of mixing between basic populations. Clustering of points in these plots is influenced by source in that the points are more tightly clustered where sedimentary formations under the shelf and coastal plain are the probable source of detritus, in comparison to those values from reworked glacial deposits in the gulf.

Analysis of the shape of grain size curves, shows that three types approximate log normal distribution and two other types are not normal. A comparison of the normal types with those from other milieus and with Passega C-M diagrams, shows that ice, tractive bottom currents, and pelagic suspensions are the main deposition agents. Most of the sands, plot as log-normal distributions with a steep slope; they show obvious similarity to current-winnowed sediment in sand waves and beaches. Deep water or sheltered water deposits of silt and clay, likewise tend to be log normally distributed though with a moderate sorting. These deposits are most similar in curve shape to gravity-settled clays from abyssal plains and sheltered bays. Poorly sorted mixtures of sand, gravel, silt, and clay from the Gulf of Maine tend to be log normal in their distribution and to show a similarity to tills deposited on land. Polymodal mixtures of sand and gravel show a non-normal step-like curve and probably reflect transport by saltation and suspension for the sand and surface creep or ice for the gravel. Most of the silty sand on the upper continental slope and on the flanks of basins in the Gulf of Maine is skewed toward the coarse fraction to give rise to an asymmetrical distribution of moderately sorted silt and clay in with fairly well sorted sand. This type sediment usually covers a transitional area between well sorted log normally distributed sand of the shelf and moderately sorted log normally distributed silty clays of deeper water areas, and hence, may reflect two processes of sedimentation, current-deposited sand and pelagic silt and clay; thorough biogenic reworking has mixed the two components.

Sediments on the Continental Margin South of Long Island by John D. Milliman.

Sediments on the continental shelf and slope south of Long Island can be classified into nine sedimentary groups:

1) Fine-grained clear arkosic to subarkosic sands and silts;
2) Iron-stained subarkosic sands;
3) Coarse to medium-grained subarkosic-orthoquartzitic sands, with less than 25% calcium carbonate;
4) Orthoquartzitic sands with 25 to 75% carbonate;
5) Carbonate-rich orthoquartzitic sands, containing large amounts of barnacle fragments, oolite, and coral reef debris;
6) Carbonate-poor slope muds;
7) Glauconitic slope sands;
8) Carbonate-rich slope muds;
9) Planktonic carbonate sands and gravels from the Blake Plateau.

From the presence of fossils within many of these sediment groups, it has been concluded that the continental shelf is generally an environment of non-deposition. Recent sedimentation is generally restricted to nearshore areas, especially near estuaries. However, during floods and storms, large quantities of sediments may be carried to the outer shelf. The fact that these sediments do not accumulate on the middle or outer shelf suggests a strong current regime in this area.

Much of the continental slope and the Blake Plateau have not accumulated sediment since the Miocene. The erosive action of the Florida Current no doubt has been responsible for most of this non-deposition. Clearly then, any sediments debouching onto the slope off Georgia or South Carolina must be swept north by the Florida Current. As such, this sediment may account for a significant sediment accumulation in the deep-sea northeast of Cape Hatteras.

Source and Dispersion of Surface Sediments in the Gulf of Maine - Georges Bank Area by David A. Ross.

A study of the mineral composition of the sand fraction (2 to 0. 62 mm) of 115 surface samples from the Gulf of Maine-Georges Bank area has defined eight provinces based mainly on heavy mineral composition. Sediments in three of these provinces, off the Penobscot, Kennebec, and Merrimack Rivers are of recent origin. The remaining five provinces are composed of relict sediments; in three of which (two in the Gulf of Maine, one off Cape Cod) they are of glacial origin. The sediments of Georges Bank are reworked Coastal Plain sediment either derived from the rocks underlying the bank or from the Gulf of Maine, in which instance they have been transported to the bank by glaciers. Fine-grained sediments have been winnowed from Georges Bank and transported into the Gulf of Maine where they have mixed with glacial sediments of that area.

Mineral composition throughout the area of study is controlled mainly by the source, though some modification has resulted from reworking. This modification is most pronounced in the high energy areas of Georges Bank and off Cape Cod, where more resistant heavy minerals predominate. The sediments in these areas are also better sorted and have lower feldspar-quartz ratios than the sediments in the low energy areas of the Gulf of Maine.

Reworking of sediment on the ridge areas of the Gulf of Maine was anticipated, but not definitely observed. This may be due to the small number of samples examined or that not enough time has elapsed for these sediments to come to equilibrium with their environment.

Sediments of the Gulf of Panama by Joseph MacIlvaine and David A. Ross.

Bottom sediments from the shelf of the Gulf of Panama were studied to determine their source and history of deposition. The center of the shelf is covered by a relict sand deposited during the Holocene transgression, and is characterized by coarse texture, iron staining, abundance of foram tests, shell fragments, and glauconite grains. Around the margins of the shelf a nearshore clay facies is being deposited and is prograding over the transgressive sand. Heavy mineral ($\geq$ 2. 9 g/cc) assemblages in the sand-sized fraction indicate three parental populations. These mineral assemblages originate in Bahia San Miguel in the east, Bahia Chame in the west, and from the Las Perlas Archipelago in the center of the Gulf. The light fraction of the sand supports the distinction between the populations. The heavy mineral data were subjected to a vector analysis reduction which confirms the above pattern. The distribution of the mineral assemblages suggests that the drainage across the shelf during the Pleistocene low stand of sea level was different from that indicated by present bathymetry.

The Transaural Sediments in Cape Cod Bay by C. D. Hollister.

During the summer of 1969, with equipment provided through the courtesy of Ocean Research Equipment and with ship-time donated by A. T. & T. , a distinctive layer of fine mud was mapped over much of the Western Gulf of Maine. A correlation between sedimentary type and its acoustic nature as recorded by a 3. 5 kc profiler system, has been established. Forty to fifty meters of apparent penetration is recorded in clay and silt. In silty-sand, penetration on the order of five to ten meters was noted. No penetration could be obtained in material coarser than gravel. Patterns of acousitc penetrability correlate well with the surface sediment types determined from numerous samples and cores.

Atlantic Continental Shelf and Slopes of the United States Texture of Surface Sediments, New Jersey to Southern Florida by C. D. Hollister.

Bottom currents on the continental margin play a major role in governing textural parameters. Bottom currents have re-worked sediment on the continental shelf and Blake Plateau in such a fashion that many of the surface samples from these two distinct physiographic provinces are texturally similar. The continental slope off Florida is covered with a prograding accumulation of poorly-sorted clayey-silt deposited beneath the Gulf Stream Counter Current. A distinctive accumulation of silty-sand on the southern margin of the Blake Plateau is probably winnowed pelagic ooze transported from the eastern Blake Plateau by the Antilles Current. Well-sorted sand is found beneath the axis of the Gulf Stream in the Florida Straits and on the Blake Plateau. North of the Blake Plateau, where the Gulf Stream touches the bottom in deeper water, a marked increase in silt and sand is found.

The clayey, hemipelagic silt found on the continental slope north of Cape Hatteras was deposited beneath the sluggish, southerly-moving Slope Water. The silty-clay on the upper continental rise off Maryland and New Jersey accumulates in the relatively tranquil region that lies between the Slope Water and the deeper more vigorous Western Boundary Undercurrent.

Submarine Lithification by John D. Milliman.

In the past several years the concept that sediments lithify only with exposure to meteoric waters or to great temperatures and pressures has been disproved. Carbonate sediments can lithify in the oceans, in the deep-sea as well as in the intertidal zone. Several types of deep-sea limestones are recognized. In areas of non-deposition, such as the tops of sea mounts, the slopes of islands, or the Blake Plateau, large fragments of lithified planktonic ooze are found. Although the planktonic organisms are generally unaltered, the limestones are nearly always in equilibrium with the ambient waters, suggesting in situ precipitation of the matrix and cement. The cement can be micritic or blocky. Younger limestones are always magnesium calcite, usually about 12 mole percent $MgCO_3$, while older limestones (Miocene and older) are generally low magnesium calcite, thus implying an inversion of the metastable magnesium calcite with time.

Limestones found in the vicinity of volcanoes are believed to have been "baked" during volcanism, although it is equally possible that lithification, in some instances, may have been connected with submarine weathering of volcanic tuffs. These volcanic limestones are generally out of isotopic equilibrium with their ambient waters, and are relatively pure calcite. Minor and trace elements are seldom present in concentrations greater than 0.15 percent.

In restricted saline oceanic basins such as the Red Sea and the eastern Mediterranean, layers of limestone are found in deep-water. In the Red Sea, aragonitic and magnesium calcite lithic layers compose roughly 20 percent of the sediment obtained by piston cores. In addition, roughly 50 percent of the deep-sea lutite is magnesium calcite, with identical properties to the magnesium calcite in the lithic fragments, suggesting inorganic precipitation. During extremely high salinities, aragonite has been precipitated; at present only magnesium calcite is being precipitated. In the eastern Mediterranean most of the deep-sea sediment is calcitic Globigerina and coccolith ooze. However there are discret layers of small limestone fragments contained in a matrix of magnesium calcite lutite. The process of the lithification of the fragments and precipitation of the lutite is presently under investigation.

Contour Currents, Microtopography and Sediment Transportation in the Deep Sea by C. D. Hollister.

An examination of precision echograms, seismic reflection profiles, bottom photographs and sediment cores from the Labrador Sea and the western North Atlantic has revealed sedimentary features within the upper few kilometers of the sea floor which were formed through sediment transport and deposition by the Western Boundary Undercurrent, a deep current associated with the thermohaline circulation of the Atlantic.

Longitudinal zones of hyperbolic and prolonged echoes determined from precision echograms taken on the continental rise correlate with the axis of the Western Boundary Undercurrent as determined from the distribution of near-bottom potential temperature and density.

Sub-bottom horizons seen on seismic reflection profiles have the following characteristics: (1) They are horizontal beneath abyssal plains; (2) They form wedges that thin seaward beneath the continental rise; and (3) They commonly outcrop on the continental slope. The thickest portion of the wedges on the continental rise lies near the axis of the Western Boundary Undercurrent.

Abundant ripples and scour marks seen in sea-floor photographs on the continental shelf are the result of tidal and wind-driven currents. Occasional current markings seen in photographs on the continental slope appear to result from scour by Slope Water. Current lineations observed in oriented bottom photographs taken on the continental rise indicate that sediment is being transported and deposited parallel to bathymetric contours. Bottom current directions inferred from the orientation of current lineations correlate with the spreading direction of the Western Boundary Undercurrent. Evidence of currents is rarely seen in photographs of abyssal plains.

An examination of over 300 deep-sea sediment cores has revealed a distribution of red-colored lutite that indicated sediment transport toward the southwest parallel to bathymetric contours on the continental rise from Cabot Strait to the Blake-Bahama Outer Ridge, a distance of nearly 3000 km.

A detailed study of primary structures in over 2000 clastic beds from over 100 continental rise and abyssal plain cores and petrographic analysis of more than 50 thin sections from selected layers show that thick, massive and muddy sands are typically found on abyssal plains. These graywacke and sub-graywacke type sands may exceed 50 cm in thickness, and as a rule they rarely exceed 50 in number per 100 m of core. Continental rise sediment, on the other hand, typically contains as many as 500, then (< 1 cm), well-sorted silt lamina per 10 m of core. These relatively mud-free silts usually contain cross-beds accentuated by heavy mineral placers.

Both downslope and across-slope transport of clastic material on the continental rise can be inferred from patterns of proportional similarity, obtained through vector analysis, of heavy mineral suites which consist predominately of hornblende, garnet and pyroxene.

The seaward-thinning wedges of sediment that comprise the continental rise appear to have been constructed of: (1) Material injected laterally into low velocity (< 50 cm/sec) contour-following bottom currents by high velocity (> 100 cm/sec) turbidity currents flowing down slope; and (2) Material transported in suspension through the water column from sediment sources on the continental shelf and subsequently transported and deposited by contour currents.

Contour Currents in the Weddell Sea by C. D. Hollister.

The Antarctic Bottom Current flows parallel to bathymetric contours of the Antarctic continental margin in the Weddell Sea. This contour current is presently transporting sediment from the Weddell Sea, around the South Sandwich Arc and into the South Atlantic. As the southerly-flowing Western Boundary Undercurrent smooths and shapes the large sediment accumulations in the North Atlantic, so must the Antarctic Bottom Current smooth and shape the sea floor of the Weddell Sea.

Geomorphology and Structure:

Structural Setting of the Black Sea by David A. Ross, Elazar Uchupi, and Kenneth E. Prada.

In the spring of 1969 a geological and geophysical study of the Black Sea was made by the Woods Hole Oceanographic Institution. Echo sounding profiles taken during the expedition supplemented by published information indicate that the continental shelf has its greatest development south of Odessa where it is over 200 km in width. Elsewhere the shelf is less than 20 km wide. The continental slopes are about 1800 meters high, and are deeply entrenched by submarine canyons, except for the slope seaward of the Danube which is only about 1000 meters high and is relatively smooth. Seaward, the Danube Fan has buried most of this slope and has prograded across the abyssal plain that occupies the central part of the Black Sea.

Continuous seismic profiles across the continental slopes generally show extensions of land structure. This is especially so along the east coast where ridges possibly related to the Caucasus Mountains trend across the shelf and slope. Some diapirs were observed off the Russian coast. Records from the abyssal plain generally showed it to be featureless, except near the continental slopes where considerable evidence of faulting and slumping was evident.

Geomorphology and Structure by Elazar Uchupi, J. D. Phillips, R. D. Ballard, and K. E. Prada.

Geomorphic and structural studies during 1969 consisted of a compilation of a bathymetric chart of the continental shelf in the Gulf Coast of the United States, a seismic profiler study of the New England Seamount Chain and the western Gulf of Maine (quadrangle mapping program - see R. N. Oldale, Elazar Uchupi, and K. E. Prada). The chart of the Gulf

Coast continental shelf was compiled from soundings from the U. S. Coast and Geodetic Survey hydrographic surveys. The prominent shorelines displayed by this chart at 160 meters and 60 meters depths appear to be related to the Holocene transgression. Landward of the 40 meter contour, the topography of the shelf is quite complex. This irregular topography is believed to have been produced by the rising sea during the Holocene and deposition since sea level reached its present position several thousand years ago.

Seismic and magnetic data suggest that the New England Seamount Chain, a 1200 km volcanic belt extending from the upper continental rise to the Bermuda Rise, is located along a fracture zone formed by a discontinuity of sea-floor spreading pattern. The discontinuity probably resulted from a simple transform fault that may have opened progressively along its length or opened at one time as a result of change in spreading direction. This opening of the fault may have begun during the Triassic and continued to the Cretaceous.

Geophysical Investigations in the Jeffreys Quadrangle, Western Gulf of Maine by R. N. Oldale, B. E. Tucholke, Elazar Uchupi, C. D. Hollister, and K. E. Prada.

Several cruises were made in the Jeffreys quadrangle this past summer for the purpose of geologic mapping. The R/V A. E. Verrill and the R/V Dolphin were used for 3. 5 kc echo-sounding surveys, and the R/V Gosnold was used for a seismic profiler survey (using a 5 cubic inch air gun as a sound source), 3. 5 kc echo-sounding, and magnetic studies.

The Jeffreys quadrangle can be divided into several topographic provinces. To the south is the smooth-floored Cape Cod Bay separated from the open sea by the Cape Cod peninsula; north of Cape Cod Bay near the coast is a rocky zone about 25 km wide flanked on the seaward side by a chain of relatively flat-bottomed basins more than 160 meters wide. Beyond these basins are the flat-top topographic highs, Stellwagen Bank and Jeffreys Ledge with their tops being less than 60 meters deep. East of the banks are Murray and Wilkinson basins having depths in excess of 280 meters.

In the rocky zone west of Jeffreys ledge the 3. 5 kc echo-sounding recordings show closely spaced bedrock (basement composed of Paleozoic igneous and metamorphic rocks) out-crops, having as much as 40 meters of sediment in deep depressions cut into the basement by glacial erosion, possibly along pre-glacial fluvial valleys. Seaward of this rocky zone, within the discontinuous basins, the bottom is smooth since the sediment has completely covered the basement. In some places the sediment cover exceeds 40 meters, it is not thick enough to completely mask the gross morphology of the basement. No penetration was observed on Jeffreys Ledge and Stellwagen Bank. Seaward of these topographic highs, within Murray and Wilkinson basins, the 3. 5 kc echo-sounding traces show a penetration of several meters above a sub-bottom that does not appear to be basement. In Cape Cod Bay, penetration of a few meters to a smooth sub-bottom was common. Comparison of a sediment map from the southern part of the quadrangle with a contour map of the amount of penetration with a 3. 5 kc echo-sounder indicates a close correlation with sediment types. Maximum penetration occurs in areas of silt and clay, intermediate values in areas of fine sand, as in Cape Cod Bay, and little or no penetration in areas of sand and gravel.

Preliminary examination of the seismic profiler information and existing bathymetric data suggests that Jeffreys Ledge and possibly the upper part of Stellwagen Bank may represent a submerged late Pleistocene end moraine with several interlobate angles. The fine-grained sediments landward of these features, which in places exceed 40 meters in thickness, may in part represent glaciomarine sediments deposited during the Holocene submergence, or glacio-lacustrine sediments deposited in lakes dammed by the moraine.

Summary of Geological Activities 1969-70 of the Mineral Resources Branch of the New Brunswick Department of Natural Resources, Fredericton, New Brunswick.

Geochemistry:

Victorio Austria Jr. is currently working on reconnaissance geochemical prospecting in southwestern New Brunswick. This work includes stream sediment sampling and trace element studies of the St. Stephen granite. He is also studying aspects of uranium distribution in

Carboniferous rocks of the province. "The Cu, Pb, Zn, Mn, and Mo contents of stream and spring sediments in parts of southwestern New Brunswick" is in progress and will be published by the Mineral Resources Branch in 1970.

J. L. Davies is working on geological and geochemical problems of Ordovician volcanic rocks of the Tetagouche Group in northeastern New Brunswick, with particular reference to the Brunswick 6 and 12 ore bodies. Parts of this work will be used to complete requirements for the doctoral program at Carleton University and will be available in thesis form in 1970. His most recent publication is "Geological map of northeastern New Brunswick" in "Geological investigations in New Brunswick": New Brunswick Dept. Natural Resources, Mineral Resources Branch, Information Circular 68-1, p. 17-18.

Economic Geology:

J. B. Hamilton continues his province-wide studies of non-metallic industrial mineral resources with the initiation of a two-year project on sand and gravel deposits of New Brunswick. This study will be particularly concerned with the economic potential of glacial deposits of the province. "Gypsum in New Brunswick" is in preparation and will be published by the Mineral Resources Branch in 1970.

A. A. Ruitenberg continues work on fundamental geological problems related to economic mineral development in southern New Brunswick. His most recent publication is "Mineral deposits in granitic intrusions and related metamorphic aureoles in parts of Welsford, Loch Alva, Musquash and Pennfield areas": New Brunswick Dept. Natural Resources, Mineral Resources Branch, Rept. Investigation No. 9, published in 1969.

Sedimentology and Stratigraphy:

Terence Hamilton-Smith is working on sedimentological and stratigraphic problems of Ordovician and Silurian rocks of western and northwestern New Brunswick. "Stratigraphy and structure of Ordovician and Silurian rocks of the Siegas area, New Brunswick" is in progress and will be published by the Mineral Resources Branch in 1970. "Transgressive-regressive turbidite sequence and a possible submarine channel in the early Llandovery of northwestern New Brunswick" and "Paleography of northwestern New Brunswick during the early Llandovery: a study of the provenance and facies of the Siegas Formation" are in progress and will be published in 1970 or 1971.

Walter van de Poll is on a one-year leave of absence of the University of Wales, Swansea College, where he is completing work on a doctorate program. His thesis and recent work is concerned with the stratigraphy, sedimentation and paleocurrents of the Carboniferous rocks of New Brunswick. His most recent publication is "Pennsylvanian sedimentation in the Central Basin of New Brunswick" in "Geological Investigations in New Brunswick": New Brunswick Dept. Natural Resources, Mineral Resources Branch, Information Circular 68-1, 11-14.

Graduate Studies in the Earth Sciences, Dalhousie University, Halifax, Nova Scotia.

This account has been produced by the Department of Geology as a guide to prospective students who wish to know what programmes there are in earth sciences at Dalhousie University.

Introduction:

The study of the earth involves many disciplines and its successful pursuit demands avoidance of unduly rigid departmental boundaries. Consequently, contributions to earth sciences come from all Dalhousie's Science departments -- Geology, Physics, the Institute of Oceanography, Biology and Chemistry. Many aspects of the study of the earth now require sophisticated facilities which no one department or institution can hope to have. Accordingly, many departments work together in a study of the earth, as indeed do numbers of institutions, although they are not linked at all in any formal way. Locally these institutions include Dalhousie University, Bedford Institute, Nova Scotia Department of Mines, Nova Scotia

Technical College and the Nova Scotia Research Foundation. It is this interlocking network of people, disciplines and institutions which makes graduate work in many aspects of the study of the earth especially rewarding at Dalhousie.

Dalhousie University:

Dalhousie University was founded in 1818. The campus is on the peninsula of Halifax proper, close to the North-West Arm. Other scientific institutions are nearby. The Atlantic Regional Laboratory of the National Research Council is on campus. Bedford Institute and the Nova Scotia Research Foundation are in Dartmouth, a few miles away, across Halifax Harbour. The Departments of Geology and Physics are housed in the Sir James Dunn Science Building, opened in 1960. The Department of Biology and the Institute of Oceanography are at present in an old building, but move to the new Life Sciences Centre in the summer of 1971. Special salt-water facilities, known as the Aquatron, will be built in this centre. The Killam Memorial Library and the Computer Centre are all within a hundred yards or so of each department. There are six faculties: Arts and Science, Law, Medicine, Dentistry, Health Professions and Graduate Studies, with a total enrollment approaching 5000. Degrees in engineering are awarded in conjunction with Nova Scotia Technical College, which has a formal association with Dalhousie University.

Further information about Dalhousie will be found in an information bulletin and in the calendars of the Faculty of Arts and Science, and Graduate Studies. These can be obtained from the Deputy Registrar.

Institutions with Informal Associations with Dalhousie

Bedford Institute:

This is a Federal Government Laboratory, housing scientists from the Marine Sciences Branch of the Department of Energy, Mines and Resources, and the Fisheries Research Board. It is responsible for a major part of the Federal Government's oceanographic work; construction of hydrographic charts, marine geophysical surveys, marine geological research, tidal prediction, ice and current surveys, marine ecology and physical oceanography are all within its domain. Several vessels are based at Bedford Institute, and the fleet includes C. S. S. HUDSON, one of the world's latest and best oceanographic ships. Graduate students with marine interests are likely to spend part of their time working from Bedford's ships, or engaged in work with Bedford's scientists. Many undergraduates find summer employment there.

Department of Mines, Province of Nova Scotia:

This is a Provincial Government organization responsible for, among other things, the geological investigations normally conducted by a provincial or state geological survey. Joint projects with the Department of Mines include, for example, the measurement of heat flow by Dalhousie in holes which the Department of Mines has drilled for stratigraphic reasons. Students interested in hydrogeology may find themselves working with the Department's Ground-water Section. For many years a program of geological mapping has been carried out by Dalhousie staff and students for the Department of Mines. This programme involves many aspects of geology.

Nova Scotia Research Foundation:

The Nova Scotia Research Foundation is a Provincial Government organization which undertakes research and development in a number of applied sciences of interest to the Province. They are responsible for Provincially organized applied geophysics, and in this, often work in co-operation with Dalhousie so far as teaching and research are concerned.

Dalhousie University Staff and their Research Interests

Geology Department:

H. B. S. Cooke - Pleistocene studies: vertebrate palaeontology
C. G. I. Friedlaender - Petrology and mineralogy
R. A. Gees - Modern sediments; the Bermuda Rise

M. R. Gregory - Sedimentology; flysch sequences; Palaeoecology; Foraminifera
M. J. Keen - Geophysical studies of the continental margin
F. Medioli - Micropalaeontology
G. C. Milligan - Economic and structural geology
P. E. Schenk - Turbidites and carbonates from the Appalachians
A. Volborth - Geochemistry; granites; mineralogy

Physics Department:

R. Ravindra - Theoretical seismology
R. J. Reynolds - Leads isotopes: abundance and distribution

Institute of Oceanography:

R. D. Hyndman - Heat flow, magnetotellurics
P. J. Wangersky - Chemical oceanography and geochemistry

Biology Department:

E. S. Deevey - Palaeolimnology; ecology
F. R. Hayes - Limnology; ecology
J. G. Ogden - Palynology
J. C. Ritchie - Palaeolimnology

Staff at Government Institutions with Appointments at Dalhousie

Bedford Institute, Dartmouth, Nova Scotia:

L. H. King - Regional marine geology; for example the Scotian Shelf
B. D. Loncarevic - Marine geophysics
D. H. Loring - Inorganic geochemistry
J. I. Marlowe - Physical marine geology
B. R. Pelletier - Sedimentology

Nova Scotia Department of Mines, Halifax, Nova Scotia:

J. F. Jones - Hydrogeology

Nova Scotia Research Foundation, Dartmouth, Nova Scotia:

J. E. Blanchard - Applied geophysics

Current Research

Appalachians:

Palaeocurrents and depositional basins of the Meguma Group and the Appalachian continental margin.
Palaeogeography and palaeoecology of the Windsor - Mississippian carbonates.
Geology and geochemistry of Nova Scotia granites.
Petrology and mineralogy of Nova Scotia basalts.

Bermuda Rise:

The structural relationships between the basalts and the overlying aeolianites.
The age and geochemistry of the basalts.

Continental margin of eastern Canada: geophysical studies:

Seismic studies on the shelf and slope.
Magnetic and gravity field on the margin.
Structure of the Labrador Shelf.
Heat flow on land, in lakes and at sea.

Electrical conductivity beneath the margin.

Economic studies:

Wall rock alteration associated with sulphides in pre-Mississippian rocks of Cape Breton, as well as their structural history.
Conditions of formation of barite deposits in Cape Breton.
Structural and metamorphic studies of Labrador iron ranges in vicinity of Grenville Front.

Geochemistry:

Investigations of stoichiometry of oxygen and fluorine in minerals.
Geochemistry of granites in Nova Scotia.
The effect of pressure on the dissolution of carbonates in sea-water; a laboratory approach.
Analytical investigations in salt-water systems.
Organic - inorganic interactions in deep sea sediment deposition.

Hydrogeology:

Unconfined flow of groundwater in near surface aquifers and changes in geochemistry between aquifers of contrasting permeabilities.
Prediction of digital modelling of drawdown in a groundwater reservoir after specified periods of pumping.
The determination of the groundwater component of stream-flow during flood stage.
Hydrogeology of various watersheds in Nova Scotia.

Micropalaeontology:

Microfauna and sediments of Halifax Harbour.
Nannoplankton and Foraminifera of the eastern seaboard; Foraminifera of the McKenzie River delta.

Mid-Atlantic Ridge:

Magnetic and gravity fields over the Ridge at 45° North - Application of information theory - Sediments in the basins of the crestal mountains - Studies of cores and seismic reflection profiles

Modern Sediments:

The surface textures and shapes of beach, dune and river sand grains.
Transport of sediments in the surf zone.
Sediments of the Scotian Shelf.

Pleistocene studies:

Pleistocene deposits in Nova Scotia, and their relation to the sediments of the shelf.

The earth's interior:

Elastic properties of the earth's interior.
Deep reflections.
Deformation of the earth - a study of solid earth tides, and loading by ocean tides.

Facilities

Computers:

An IBM 360 Model 50 is installed in the University's computer centre. Other computers to which access can sometimes be arranged include: Bedford Institute - CDC 3100; Institute of Oceanography - Linc 8; Biophysics - Sigma 5.

Earthquake Seismology:

One of the Stations of the Dominion Observatory's network is on campus.

Electron Microprobe:

Nova Scotia Technical College has an electron beam microprobe, a Phillips AMR - 3.

Exploration Geophysics:

Gamma ray spectrometer for field estimation of U, Th, K.
Access to proton magnetometers, gravity meters and other exploration equipment through Nova Scotia Research Foundation.

Geochemistry:

A computerised fast-neutron activation and X-ray fluorescent laboratory supported by atomic absorption, optical emission spectrographic, flame spectrophotometric and classical silicate analysis facilities. Gas chromatography for the detection of organic compounds and high pressure equipment for simulation of deep ocean environment.

Geological Sample Preparation:

The Geology Department has a well-equipped sample preparation laboratory, and facilities for providing thin sections and polished sections.

Geophysics:

Equipment for measurement of heat flow on land, in lakes and at sea; seismic refraction and reflection units; air gun and sparker; three - component magnetometer.

Hydrogeology:

Field equipment for most hydrogeological investigations is available through the Groundwater Section, Department of Mines. Data of other hydrogeological interest can be obtained from the Water Survey of Canada, Inland Waters Branch, Department of Energy, Mines and Resources.

Salt Water laboratory facilities:

A 50 metre diameter tank for large scale experiments; a 10 metre high tank for pressure experiments; sundry flume tanks; rooms with constant light and constant temperature. These facilities will be housed in the new Life Sciences Building, to be completed in 1971.

Scanning Electron Microscope:

Access to a scanning electron microscope is available through the Department of Anatomy, Dalhousie University and through Bedford Institute.

Sedimentology:

A modern sedimentology laboratory is located in the Geology Department. Other facilities will be available in the new Life Sciences Building.

Ships:

Ship time is arranged through the Institute of Oceanography on a number of oceanographic vessels, which include HUDSON, BAFFIN, KAPUSKASING, DAWSON, MAXWELL and SACKVILLE. They are owned by the Department of Energy, Mines and Resources or the Fisheries Research Board, and operate from Bedford Institute.

Technical Services:

A technical services group provides instrumentation service for staff in Geology, Physics, Engineering-Physics, and Oceanography. The Physics Department has a well-equipped machine shop.