STRATIGRAPHY AND PETROLOGY OF THE POUCH COVE -- CAPE ST. FRANCIS AREA

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Stratigraphy and Petrology
of the
Pouch Cove - Cape St. Francis Area

by

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ABSTRACT

Detailed mapping of the Late Precambrian volcanic and sedimentary rocks of the northeasternmost tip of the Avalon Peninsula indicates that these two rock types are largely penecontemporaneous. This fact will require change or addition to the established stratigraphic column as previously determined by regional mapping. However, the studied area can be adequately described within the framework of the established Harbour Main and Conception Groups, and additional areas should be mapped in detail before new stratigraphic names are introduced.

The total thickness of sequence mapped in the Pouch Cove - Cape St. Francis area is approximately 2800 meters; its base is not exposed and its top is eroded away or removed by faulting. With the exception of minor folds, the sequence dips to the northwest and represents the northwest limb of an anticlinal zone which passes through Shoe Cove (southeast of the map area).

For descriptive purposes the sequence is divided into lower middle and upper units of volcanic and sedimentary rocks. These unit divisions have only local descriptive significance and are not proposed as formal entities of stratigraphic nomenclature. Typically the sedimentary units consist of turbidite sandstones with subordinate cherts, shales and conglomerates. Numerous acidic and basic flows and tuffs interlayered with the sediments form the volcanic units. Glacio-marine and tillite deposits within the middle sedimentary unit provide an important stratigraphic marker which is tentatively correlated with glacial deposits known within the Conception Group at several other

Avalon localities. Facies differences between correlated localities are related to the volcanic eruptions centered around the Cape St. Francis area.

Intrusions of quartz diorite, rhyolite and diabase are common in the western part of the area. The quartz diorite which occurs only in the southwestern part of the map area possibly is related to the marginal zone of the Holyrood granite batholith. The rhyolite plugs and dikes postdate the quartz diorite and thus may represent the final stage of activity of a relatively degassed granitic magma. Near Cape St. Francis one such rhyolite flow appears to unconformably overlie inclined strata of the upper sedimentary and volcanic units. If verified by further work such an unconformity would imply late Precambrian deformation, uplift and erosion, possibly related to emplacement of the Holyrood granite. This concept provides an interesting basis for further stratigraphic work in this region.

CHAPTER I

INTRODUCTION

Location and Access

The portion of the Avalon Peninsula, southeastern Newfoundland (Fig. 1), in which the Pouch Cove - Cape St. Francis Area is located has previously been referred to as the St. John's peninsula. The mapped area comprises the tip of this peninsula and is bounded partially by the coastline of Conception Bay and that of the open Atlantic. The area comprises about 60 square kilometers of land between north latitudes 47^{0} 42' and 47^{0} 51', and west longitudes 52^{0} 45' and 52^{0} 50'.

Located approximately 25 kilometers north of St. John's, the capital city of Newfoundland, the area is accessible easily on provincial highway 18, which terminates in Pouch Cove. A gravel road extends from there to Cape St. Francis, and another one, which connects Pouch Cove with Bauline, forms the southeastern boundary of the map area. During suitable weather a small boat may be launched at either Pouch Cove or Bauline, thus permitting study of the otherwise partially inaccessible coastal cliffs.

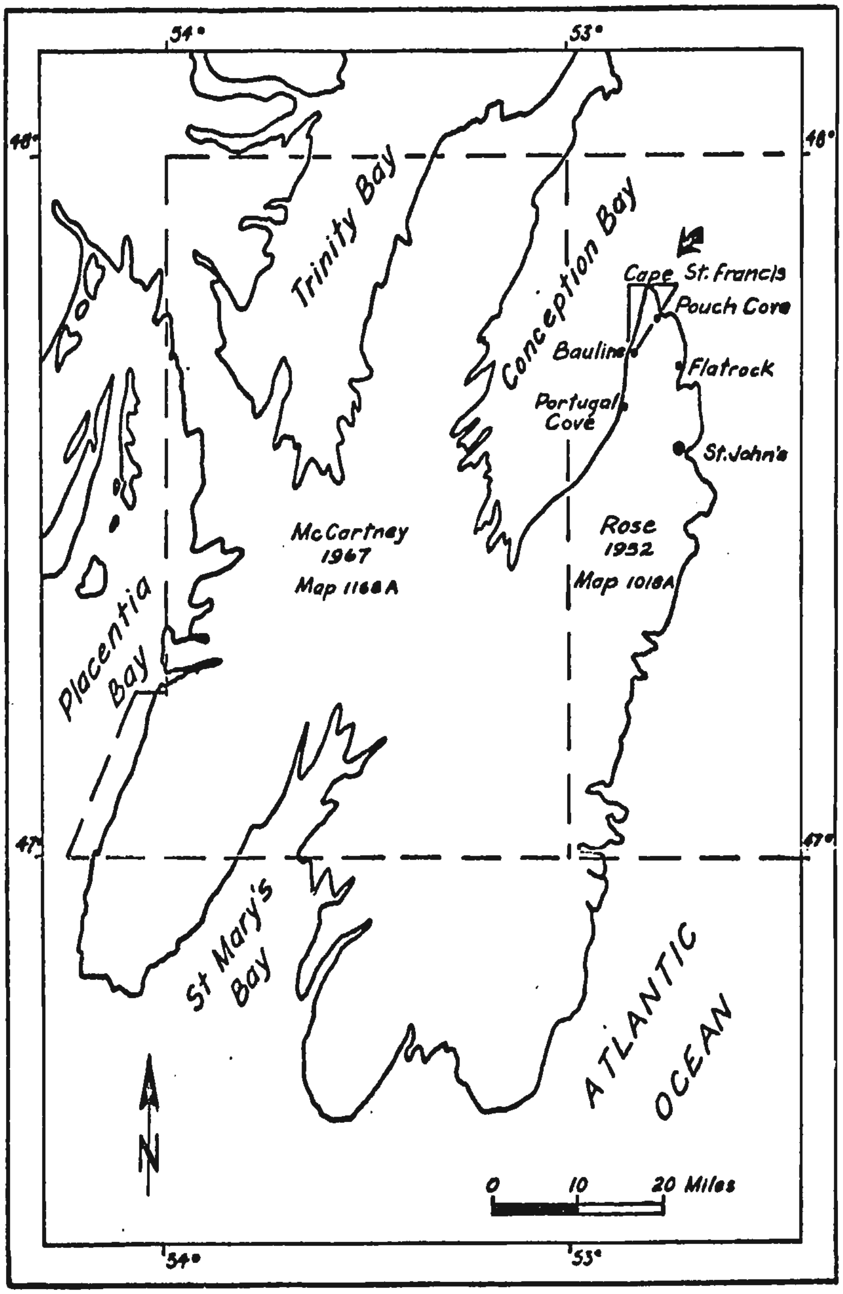


Figure 1: Map of the Avalon Peninsula of Newfoundland showing the Pouch Cove - Cape St. Francis map area in relation to regional maps of the Geological Survey of Canada by Rose and McCartney.

Previous Work

The first recorded account of the geology of the area dates back to 1843 when J.B. Jukes prepared the first geological report and map of Newfoundland. In that report he commented on the stratigraphy of Cape St. Francis, "where the slate is almost entirely concealed and supplanted by a close grained siliceous porphyry." Following Jukes, regional mapping by A. Murray and J.P. Howley resulted in publication in 1881 of the first geological map of the Avalon Peninsula. In 1899 C.D. Walcott proposed the name Avalon terrane for the "typical development of terrane on the peninsula of Avalon." He also introduced formation names. In 1919 A.F. Buddington published a paper, "The Precambrian Rocks of Southeast Newfoundland." He had not visited the Pouch Cove - Cape St. Francis area but described similar rocks from other Avalon localities. Buddington proposed the name 'Avondale volcanics' for the interbedded flows, tuffs, and sediments which he considered the basal member of the late Precambrian of eastern Newfoundland, but B.F. Howell (1925), with Buddington's approval, recommended the name 'Harbour Main Volcanics' in its place and this name is still retained today.

H.A. Baker in 1928 reinterpreted the stratigraphic sequence of the Avalon terrane, but several years later A.O. Hayes (1931) in his "Structural Geology of the Conception Bay Region" disagreed with Baker and proposed thrust faulting rather than folding as the prominent feature of Avalon geology.

In 1952, a much more comprehensive geologic map and report of the eastern Avalon Peninsula was published by E.R. Rose. He redefined the stratigraphic units of the region, clarified their mutual relationships, and pointed out those stratigraphic problems that remained to be studied. Rose's stratigraphic table for the Late Precambrian rocks shows the following sequence (details are ommitted or summarized):

Period	Formation	Lithology
Late Proterozoic ?	Cabot Group	Black slates with overlying red sandstone and conglomerates.
	Disconformity	
Mid Proterozoic ?	Holyrood Batholith	Granite and granodiorite with minor gabbro and various dikes.
	Intrusive contact	
	Conception Group	Sandstones, cherts, slates, conglomerates, tuffs and agglomerates.
	Unconformity	
Early Proterozoic ?	Harbour Main Group	Acidic and basic volcanics interbedded with cherts, slates and conglomerates.

Regarding the unconformable relationship between Harbour Main and Conception Groups, Rose stated (page 19), that "Agglomerate, tuff, and tuffaceous beds among the lower members of the Conception slate show the waning effects of volcanic activity which was probably related to that of Harbour Main time."

Such interlayering in the Conception Group, along with interlayering in the Harbour Main Group as described by W.D. McCartney (1967, 1969) for the central part of the Avalon Peninsula and by J.M. Dawson (1963) for the area south of Topsail and Foxtrap, has led C.J. Hughes (1970) and C.J. Hughes and W.D. Brückner (1971) to consider the Harbour Main and Conception Groups as formed during development of volcanic islands, possibly as a part of an island arc. Also during 1970, V.S. Papezik has published five chemical analyses of volcanic rocks from the Pouch Cove - Cape St. Francis area. His work showed the rocks to be mildly alkalic and he pointed out that such rock types are commonly associated with large scale block faulting like that of the Basin and Range Province in western United States.

At present further detailed studies on the Precambrian rocks of the Avalon Peninsula are being carried out by M.M. Anderson, W.D. Brückner, C.J. Hughes, A.F. King and V.S. Papezik, faculty members of the Department of Geology of Memorial University. Recent mineral exploration programs have been, or are presently being, carried out by the Provincial Government Mines Branch, Commodore Mining Co., Ltd., and Texas Gulf Sulfur Co., Inc. Several thesis mapping projects are also being carried out by fellow graduates and undergraduates at Memorial University.

Present Work

All previous geological work done in the Pouch Cove area was essentially of a reconnaissance nature. The most detailed map published so far (Rose, 1952) is on a scale of 1:253,400.* Mapping carried out by the writer, during the summer of 1970, was on a scale of 1:15,500 (see map in pocket). The main purpose was to clarify the relationship between the Harbour Main Group and the Conception Group, as conditions seemed to be favourable in this area for such an undertaking. As these names were found to refer to dominant facies rather than distinct stratigraphic groups their usage is restricted in this thesis. On the writer's map, all epiclastic sediments and isolated subordinate pyroclastics, most of which were sorted by water, are described as sedimentary units, whereas lava flows and major layers of pyroclastics are considered as volcanic units, without particular reference to the established group names which are not clearly adaptable to the Pouch Cove - Cape St. Francis area. Igneous rocks intruding members of both of these groups are also included in the volcanic units as they are probably related to volcanic episodes.

As an aid to detailed correlation, a continuous series of photographs was taken of the coastline from Cape St. Francis to Flat Rock (southeast of the study area) covering a stretch of approximately

*A first version of this map, in 1:63,360 has already been published earlier: Rose, E.R., 1950, Preliminary Map, Torbay, Nfld. Geol. Surv. Canada Paper 50-24.

25 kilometers. These are on file in the Geology Department at Memorial University.

Acknowledgements

The writer is particularly indebted to Professor W. D. Brückner who suggested the subject of this thesis, and provided valuable information and discussion on the geology of the study area and its regional setting. Dr. Brückner,moreover, supported the field work financially from a National Research Council Grant.

Further thanks are due to all the faculty members and staff of the Geology Department of Memorial University, for providing discussion, encouragement, and technical help during preparation of this thesis.

Geomorphology

Topography

Topographically, the Pouch Cove - Cape St. Francis area is a rough dissected plateau marked by salient hills and ridges of igneous and siliceous sedimentary rocks which have resisted erosion, while broad valleys have been carved into the less resistant types of bedrock. The coastline is rugged and precipitous except at Pouch Cove, which partly lies in a broad northeasterly trending valley. Toward the northwest prominent hills become very common as the number of intrusive rock bodies increases. Along the western shore where basic and acidic intrusive rocks predominate, elevations reach approximately 300 meters near the coastline. On hilltops the bedrock is usually exposed whereas hillsides and valleys are normally thickly wooded or bog-covered. The coastal exposures are excellent and a considerable number of good rock outcrops are present in the deforested area near Biscayne Bay, which in former days was known as the village of Cape St. Francis but at present is virtually vacated.

Effects of Pleistocene Glaciation

Features attributable to Pleistocene glaciation (Jenness,1960), aside from a general relief moulding by glacial scour, include erratics, ground moraine, striae, roches moutonnées and rebound jointing. The composition of the erratics and ground moraine is such that they may all have been derived from the bedrock of the area. Striae on bedrock inland near Bauline indicate that the glacier movement at that locality was towards Conception Bay; however, striae observed at a number of outcrops along the coast from Bauline to Cape St. Francis show trends of ice movement parallel to the present shoreline of Conception Bay. Shortly before deglaciation, the valley of Bauline thus seems to have contained a small glacier tributary to a large glacier that flowed out of Conception Bay. Roches moutonnées which concur with striae directions, and rebound jointing in sheets parallel to the striated surfaces, occur along the Conception Bay coastline.

The latest Quaternary isostatic rebound of Newfoundland is expressed by raised wave cut benches and sea caves approximately 8 to 10 meters above present sea level. These are particularly noticeable along the coast facing the Atlantic, namely at Biscayne Bay and at Bear Cave. Similar features,though less well developed, were noted at some points along the Conception Bay coastal section. According to tide gauge measurements (Jenness) the coastline of the Avalon Peninsula is presently submerging.

Drainage

Drainage is poorly developed on the rugged topography. Ponds and bogs are irregularly connected by small streams which drain toward the western and eastern coasts. Glacial drift and organic soil where present rarely form more than a thin veneer over bedrock and thus very little detritus is readily available for stream transport. Downcutting of bedrock by stream action has been negligible in post-glacial time. The only noticeable erosion in the area is mass wasting by gravity on some of the steeper slopes.

General Remarks on Structure and Stratigraphy

Any reconstruction of the stratigraphic sequence in the Pouch Cove - Cape St. Francis area is made difficult by the complex timing, sequence, and styles of deformation that have affected the area. The major fold axes generally trend northeast, and parallel to these is a set of faults which indicate thrusting. A second prominent fault set strikes northwest. The finer-grained sediments and volcanics display both flow and slip cleavages, indicating at least two periods of deformation. These have not beendated exactly, but previous workers on the Avalon Peninsula (Rose, 1952; McCartney, 1967; Brückner, 1969) have assumed that orogenic events took place in the Late Precambrian and again sometime after the Early Ordovician (Acadian orogeny?).

The writer's detailed studies, especially along the Atlantic coastline from the head of Pouch Cove to Cape St. Francis, have led him to consider the folds and faults just mentioned as subordinate complications and disruptions in a generally westward-dipping continuous stratigraphic sequence of interbedded sedimentary and volcanic rocks. This viewpoint has hence been made the basis for the description and interpretation of the individual units distinguished in the study area (see Chapters II and III). The sedimentary rocks predominantly are sandstones and siltstones. Quantitatively less important are a variety of shales, cherts and conglomerates, which contribute significantly to an environmental reconstruction. The volcanic rocks comprise basaltic and andesitic pillowed and massive flows, a variety of volcanic breccias, and aquagene tuffs. Rhyolitic flows and tuffs are also present. Associated with the volcanics, and intruding both the sedimentary and volcanic rocks are numerous dikes, sills, small stocks, and volcanic necks of basic and acidic composition.

To simplify discussion, the sedimentary and volcanic rocks of the study area are divided below into lower, middle, and upper units, on the basis of lithological changes observed in the sedimentary rocks of the sequence. Regional correlation of the units is proposed in Chapter VI.

Polished, grooved, and striated surface due to Pleistocene glaciation. Sheeting is present in dikes (dark) and sediments (light). Three kilometers south-southwest of Cape St. Francis.

Plate 2

Raised wave cut bench and sea cave at Bear Cave, two kilometers southeast of Cape St. Francis.(camera case - lower center). Cave floor is 8-10 metres above present sea level.

CHAPTER II

Sedimentary Rocks

Lower Sedimentary Unit

Distribution and Thickness

The lower sedimentary unit outcrops from Robinson's River in Pouch Cove southeastwards towards the map boundary near an anticlinal zone which strikes out to sea at Shoe Cove. Its exposures on the east side of the anticline have been studied by Keats (1968). Westward, outcrops of this unit have been noted inland for over a mile from the coast; thereit terminates against sheared volcanic rocks, presumably with a fault contact in a zone of facies change.

This section, to the west of the anticlinal zone, is approximately 500 meters thick. This figure is less than the 800 meter estimate of Keats (1968) for the east flank of the anticlinal zone. The difference in thickness may in part be real and in part due to the arbitrary placement of the upper boundary at Robinson's River; however a significant change in sedimentary rock type does occur there, and the section is also broken by a fault. The beds strike from SE to NE and their dips vary from 10^0 to 65^0 N. A few very minor folds cause some southeasterly dips.

Lithology

The unit is composed mainly of gray green laminated arkoses which weather to a rusty green. Minor interbeds of light gray arkose weather to a white gray. Individual arkose beds are from 5 centimeters to 2 meters in thickness, but those of light gray color do not exceed 15 centimeters. The arkose beds are usually separated by dark green shaly layers which are less than 3 centimeters thick.

Seven thin sections show that the gray-green arkoses are composed of generally angular to subangular grains of plagioclase (average 33%), quartz (average 32%), rock fragments (average 5%) and fine-grained matrix (average 30%). Only a small percentage of the grains is rounded. On the basis of its refractive index the plagioclase is albite and oligoclase, but a few grains with weak zoned extinction may have more calcic cores. The plagioclase grains commonly show simple albite twinning and are often completely free of inclusions. Inclusions, if present, have high relief but could not be identified specifically. The quartz grains may be single crystals or composite. Many of the single crystals contain minute inclusions of columnar apatite crystals. The rare composite grains are well rounded and texturally resemble vein quartz. The extinction pattern in the quartz grains is typically undulose and deformation lamellae are common. Rock fragment grains are composed of very fine-grained quartzo-feldspathic material exhibiting felsitic texture. Occasional flakes of muscovite and chlorite and well rounded grains of epidote and sphene are also present. As far as recognizable the matrix is composed of very fine material of the same nature as the larger grains, and of secondary chlorite, sericite, and pyrite. Authigenic overgrowth is noticeable on grains of quartz and sphene.

The light gray arkoses have detrital material similar to that of the gray-green beds, but contain conspicuously less matrix. Calcite is a common secondary mineral forming concretionary patches, filling micro-fractures, and replacing grains and matrix. Authigenic albite and quartz are prominent whereas chlorite, sphene and pyrite are subordinate.

The thin shale interbeds were not studied microscopically.

Structures and Textures

The prominent gray-green arkoses are usually thick-bedded. Their maximum grain size does not exceed 0.3 mm., the average sand size being 0.15 mm. Tabular or elongate grains have a preferred orientation sub-parallel to the bedding planes. Two types of sedimentary structures were observed. Most prominent are laminae of finer, coarser and variously sorted material which normally are parallel with the major bedding planes. Ripple lamination is also present and indicates a consistent current direction from the north-east. Grading, which is one of the most common features in the sedimentary units, is not present in these sandstones. Considering the high percentage (~30%) of fine-grained material present in these beds, they are poorly sorted. Due to the laminations these beds appear similar to the interval Tb of the turbidites belonging to the middle sedimentary unit described below.

The thin interbeds of light gray arkose also have a maximum grain size of 0.3 millimeters but the average is 0.25 millimeters. In contrast to the thick-bedded arkoses these sandstones are comparatively well sorted. In these beds no laminations were seen and grading is not evident. These light gray arkoses are similar to the thicker massive arkoses of the middle and upper sedimentary units. In these thicker beds of arkose (1 or 2 meters rather than 10 or 20 centimeters) weak grading is present and large sedimentary clasts are found. In spite of these differences, arkoses from all localities are indistinguishable in thin section. An important feature of the total coastal sequence is the general increase in the thickness and quantity of thick massive arkose beds which occurs upward in the total stratigraphic succession.

The shale layers separating the sandstone beds of the lower unit are always less than 2 centimeters thick, and have fairly sharp boundaries with both the overlying and underlying sandstone. This is in contrast to the ideal turbidite style of bed seen in the middle unit where sandstone grades upward into a shale interval. A strong slaty cleavage in the thin shale layers of the lower unit masks any sedimentary features which these shales may contain.

Middle Sedimentary Unit

Distribution and Thickness

The middle sedimentary unit overlies the lower unit at a fault contact at the mouth of Robinson's River and it extends northward to a faulted upper contact near the lowest horizon of pillow lava in the coastal sequence, which crops out approximately 4 kilometers north of Pouch Cove; to the southwest the unit extends along strike to Bauline. On the east coast, the section is approximately 1500 meters thick. This figure is an estimate as the section is interrupted by thrusts which eliminate portions of the sequence and cause a repetition of other parts. There is no individual bed within the sequence suitable for use as a marker horizon, however correlation is possible by means of a chert member some 30 meters thick, which crops out predominantly in the northeastern, central and southwestern parts of the area. At most localities a thick persistent conglomeratic member is present in the strata underlying the chert member. Exact correlation along strike is complicated by low angle thrusts parallel to the strike and by faults approximately normal to the strike which displace the sequence laterally.

Lithology

The middle unit consists mainly of green to gray sandstones and siltstones which weather various shades from rusty gray-green to light gray. Pale green cherty beds are common and also form the thick sequence used as a stratigraphic marker. Other interbedded rock types include red and gray shales, red cherts and conglomeratic beds. Intercalated throughout the sedimentary sequence are pyroclastics and lava flows of rhyolitic, andesitic and basaltic compositions (Chapter III). These volcanic rocks are more common in the lower portion of the middle unit, where the conglomeratic and reddish sediments are prominent. In the upper portion of the unit graded sandstones, siltstones and green cherts contain noticeably fewer volcanic intercalations.

The sandstones range in composition from arkose to graywacke. Modal analyses of thin sections of typical end members, excluding matrix, show the following compositions.

	Arkose	Graywacke
Quartz Grains	45%	11%
Feldspar Grains	40%	13%
Rock Fragment Grains	5%	76%

The matrix content of these sandstones ranges from 5% to 60%. In general the sand size grains are angular or subangular, but occasionally sandstones consisting mainly of well rounded volcanic rock fragments are present (Plate 12).

The feldspar grains in the sandstone are albite and oligoclase, and commonly show albite twinning; grains with no twinning, with simple twinning in two directions, or with pericline twinning show a bluish iridescence. Deer, Howie and Zussman (1963) describe such iridescence as common in peristerites.

Six thin sections and four rock slabs from the sandstones were studied for the presence of potassium feldspar by application of sodium cobaltinitrite, following Van der Plas (1966). The arkoses, generally devoid of lithic grains, did not absorb the stain; however, the stain was absorbed by most of the lithic grains in the graywackes. It must be stated that the staining only affected the fine-grained matrix of the volcanic lithic fragments and not individual feldspar crystals which these fragments sometimes contain. Following this the samples were treated with barium rhodizonate to check for plagioclase using the method of Bailey and Stevens (1960). In this case, the individual feldspar grains became stained and the lithic fragments absorbed the stain in areas which had not stained with sodium cobaltinitrite. The lithic grains then appear as a mottled intergrowth of sodium and potassium feldspar.

No chemical analyses are available to show the ratio of potassium to sodium,or variation in the alkali content, in either these sediments or in the interlayered volcanic rocks. Thus it appears from these specimens that the alkali distribution is simply the result of devitrification, which commonly affects fine-grained acid volcanic rocks. More information on staining is presented in the discussion of conglomeratic rocks on page 20.

Quartz grains in the sandstones generally have undulose extinction and often show deformation lamellae. Occasionally, these grains are round and show embayments similar to those shown by resorbed crystals in acid volcanic rocks. The preservation of such features indicates these grains were subjected to little erosional wear prior to their deposition.

Rock fragment grains vary in lithology and may be rhyolitic, andesitic, basaltic, or sedimentary. Most of the rhyolitic fragments have a eutaxitic texture and are rich in quartz and albite phenocrysts. Many of the basic fragments are pilotaxitic and some contain abundant disseminated magnetite. The sedimentary grains, which are rare, are derived from fine-grained siltstones and shales. Possibly genetically related to these grains are larger sediment fragments, which appear to be derived from penecontemporaneous detrital rocks. These larger clasts are more fully discussed as a feature of the turbidites in the following section on texture below.

The matrix and finer-grained portions of the sandstone beds are composed mainly of fine-grained material similar to the coarser grains. Secondary minerals in the sandstones include quartz, albite, chlorite, sphene and an unidentified micaceous mineral. Quartz and albite overgrowth is prominent in those arkoses that contain little matrix, whereas the graywackes and arkoses rich in matrix contain considerable amounts of secondary chloritic and micaceous material but do not show extensive authigenic quartz and albite.

The shaly beds, now commonly slates, are reddish gray to grayish green and are generally laminated and fissile. These beds are not to be confused with the uppermost fine-grained shaly (slaty) portions of graded sandstones. The shales under present discussion may be up to several meters in thickness, and do not appear to be associated with any coarser siltstone or sandstone bed intervals. Locally, the shales include concentrations of boulders, pebbles, and sand of volcanic and sedimentary derivation. Normally the shale laminae are continuous, but where coarser components are present the larger fragments (up to 3 meters in diameter) have in places disrupted the laminae. Two distinct types of coarser fragments are present: igneous fragments, which have maintained their original shape, and fine-grained sedimentary fragments, which are flattened and stretched due to tectonic events.

Associated with the shales in the lower portion of the middle unit are several conglomeratic layers. Some are intraformational conglomerates and breccias while others like the shale with megaclasts described above are true interbeds within the shale sequence. The most significant interbedded conglomerate is best exposed south of Herring Cove Pond. At this locality the conglomerates have an observed thickness of 65 meters and contain clasts of volcanic and sedimentary derivation, ranging from sand to boulder size, set in a silty matrix. Interpretations for this conglomerate and the shale with megaclasts are further discussed in the following section on textures. An additional type of conglomerate is present as a thin layer at several exposures just west of the Pouch Cove - Bauline road. It contains subrounded and angular volcanic clasts in a water laid volcanic ash. This layer is interpreted as a slightly reworked volcanic agglomerate.

One sample from each of the last two types of conglomerate mentioned above were stained for potassium feldspar and plagioclase. In these rocks, lithic fragments and matrix absorbed the stains characteristic for the two feldspars in the same manner as did the graywacke discussed earlier. At the same time, microveins and incipient cleavage planes stained for potassium feldspar. The presence of these stains indicates potassium migration in the rocks and may point to a need for detailed chemical analyses to study possible alkali metasomatism in the thesis area.

Layers of green or red chert together make up several hundred feet of the middle unit. The beds of red chert are rare and found associated with red shales and conglomerates. Green chert beds form thicker sequences than the red cherts, and they are stratigraphically higher in the unit commonly interbedded with arkoses and graywackes. Intricate laminations present in these green cherts, which often show syn-sedimentary deformation features, are emphasized on surfaces that have weathered a creamy-white. The most significant petrographic feature of many of the chert beds is the presence of quartz and feldspar crystal fragments. These may form very prominent horizons or be scattered at random throughout a bed. No other significant microscopic features were seen in the fine-grained material making up most of the cherty beds. However, at other localities on the Avalon Peninsula where similar cherty beds occur, Dr. C.J. Hughes has recognized shard fragments in some of the beds (personal communication). Thus it seems likely that the cherts are of pyroclastic origin.

Early fractures in the chert beds are filled by albite and chlorite and these are crosscut by later veins of quartz. Like the potassium feldspar in the graywackes and conglomerates, the vein albite in the cherts points to migration of alkalies. In contrast to the potassium feldspar which commonly contains irregular plagioclase inclusions, these albite veinlets consist of clear crystals that display albite and pericline twinning.

Structures and Textures

The middle unit, especially in the lower portion, contains several hundred feet of sandstone similar to that in the lower sedimentary unit. These are thick laminated beds of arkose which are separated by very thin shale layers. Lamination is developed throughout the beds and grading is not apparent. In the upper portion of this unit are graded sandstones of the type commonly found at many localities on the Avalon Peninsula where the Conception Group is exposed. Individual sandstone beds of the middle unit maintain constant thickness in any one exposure, while successive beds at any one locality vary from less than a centimeter to three meters in thickness. Characteristic sedimentary structures of these sandstones are graded bedding, cross ripple lamination, convolute lamination, slump structures and 'soft-sediment' clasts. Many sandstone beds represent a complete or incomplete sequence of the kind considered typical of turbidity current deposits by Bouma (1962) and others.

That is: Top Te: pelitic interval,
Td: upper interval of parallel lamination,
Tc: interval of current ripple lamination,
Tb: lower interval of parallel lamination,
Bottom Ta: graded interval.

Layers with the characteristics of all Bouma intervals have been observed in the middle unit and, not uncommonly, complete sequences are present in a single bed. The thickest beds either contain all the units or are top truncated. Beds without the basal graded interval (Ta) are conspicuously thinner than the others and many are only six to ten centimeters thick. Grading in the turbidite beds may be distinctly visible, or discernible only in thin sections. Most beds show a grain size decrease from bottom to top irrespective of the number of intervals (Ta - Te) present. The largest grains observed in a very thick sandstone bed were about 5 millimeters across. Normally however, the coarsest sand grains do not exceed 1 millimeter and the middle to upper parts of the graded interval (Tc - Te) are silty to shaly. The average sand grain diameter in the graded and lower laminated intervals (Ta and Tb) is approximately 0.3 millimeters.

The thick graded beds frequently contain megaclasts of shale and siltstone. They are present at various levels in the graded interval but are most frequent immediately below the lower interval of parallel lamination (Tb); clasts were not found in Tb or any higher intervals. These clasts vary in maximum diameter from a fraction of a centimeter to half a meter. They are usually platy or disc-like and their greatest axis is generally parallel to the bedding planes. That these fragments were parts of semi-consolidated layers that were disrupted is shown by their tattered edges and deformed internal laminations. Their presence only in the massive graded interval of turbidite beds indicates that the conditions of transport and deposition of this interval differed significantly from the conditions that developed traction structures, without megaclasts, in the overlying finer grained intervals. The angularity and sometimes irregular orientation of the clasts in interval Ta point to rapid transport and deposition. This of course agrees with the turbidite theory elucidated by Kuenen and Migliorini (1950). Further aspects of clast dispersal are discussed in the description of the upper Conception unit, below. An unusual texture was noted in some thick beds of graded sandstone from the upper portion of the middle unit: coarse (up to 5 millimeters), well rounded sand appears as lenses in an otherwise typical sandstone as seen in turbidite interval Ta. Interstitial to the well rounded volcanic lithic grains are finer subangular quartz and feldspar grains like those in the remainder of the bed. The exposures of this feature are poor and the exact relationship of these lenses to the enclosing bed could not be determined. The mode of emplacement for these coarse sand grain lenses is uncertain. They may have either been deposited in the bed by rafting, and thus are glacio-marine, or they may have been included in the sandstone by turbidity current erosion and slumping of a pre-existing sandstone layer. In this latter case these beds would be fluxoturbidites (Dzulynski, Ksiazkiewicz and Kuenen, 1959; Stanley, 1963; Walker, 1970).

The lower interval of parallel lamination (Tb) usually consists of fairly thick laminae (approximately 1 centimeter) developed at the top of the graded interval. These laminae are conspicuously thicker than those in intervals Tc and Td. The boundary between such intervals is not always clear and thus cross ripple lamination typical of interval Tc sometimes appears to belong to the Tb portion of the bed.

In interval Tc cross ripple lamination is typical but in many beds convolute lamination appears to be superimposed on the cross ripples and thus much of their value as current indicators has been destroyed. Directional readings were obtained on foreset laminations at only six localities and these indicate a northeasterly current source for these beds.

Intervals Td and Te represent the finest material deposited by the turbidity currents. Td typically shows fine lamination in the shaly portions of graded beds and Te is structureless.

Other sedimentary structures noted in the succession and not related to deposition of sediment from turbidity currents are described below.

Soft sediment deformation is attributable to loading where sand deposits overlying silty material show bulbous load casts into the fine material, which at the same time has been injected upward in the form of flame structures. Slump folds are recognized as thin horizons of chaotic and tightly folded beds which occur in an otherwise normally bedded sequence. At most localities the geometric pattern of the slump folds is disordered but in one occurrence at the coast in Pouch Cove, a series of isoclinal folds indicates that slumping was directed toward the southwest.

Spherical and lenticular concretions are present in many beds. Most of these are calcareous, some are cherty, and some have cherty cores and calcareous outer shells. In the thick graded sandstones these concretions have developed parallel to the bedding. Those in the fine-grained silts and cherts however, are oriented parallel to the slaty cleavage direction. It is uncertain whether these concretions have been tectonically rotated to this position or whether they have developed later than the diastrophic event that produced the cleavage.

The dominant texture of the conglomeratic members is that of megaclasts in a fine-grained matrix. The shale with clasts cropping out between Old Pond and Pouch Cove N.W. Pond has a primary laminated structure and the laminae are bent around the megaclasts. In several instances the laminae beneath the clasts were observed to be penetrated by the clasts whereas the laminae above them lose their upward curvature parallel to the clast surface within several centimeters or so upward in the profile. Since many of the clasts are well rounded cobbles, this precludes a pyroclastic origin (Plate 4B). These structural features are known to be characteristic of deposits containing rafted clasts (Ovenshire,1970; Hardy and Legget,1960). Lenses of sediment which have also been incorporated in the shaly matrix, though in an apparently still poorly consolidated state at the time of deposition, possibly were pebbles of ice-rafted till like those described by Ovenshire (1970), that is "small pellets of till that were originally sediment filling the spaces between clear ice crystals"(Plate 4A). In addition to these features, the irregular distribution and size of the megaclasts, the variety of their lithologies (basalt, andesite, rhyolite, siltstone, pellets of till), and the considerable lateral extent (approximately 10 kilometers) of the conglomeratic member, all correspond to glacio-marine deposits (Harland, Herod and Krinsley, 1966).

The conglomerate of the type well exposed south of Herring Cove Pond is composed of clasts similar to those in the glacio-marine deposits but in this conglomerate the matrix is silty to sandy and lamination is absent. The great density of clasts, the absence of a laminated matrix, and the association with glacio-marine beds points to this conglomerate as being a fossil till.

These conglomeratic deposits have intercalations of volcanic origin, particularly basic pillowed flows and rhyolite ash flows. Near Pouch Cove N.W. Pond, pillows, semi-isolated from their main lava-flow unit, are surrounded by fine-grained sediment with clasts. Similarly, portions of shaly material are seen to be surrounded by basalt. Apparently the lava flowed over unconsolidated sediment with a mélange developing at the nose of the advancing flow.

As described in the chapter on structural features, the stratigraphic sequence of the middle unit is discontinuous in the eastern part of the map area due to several thrusts located near the base of the chert sequence immediately north of Pouch Cove. These faults appear to have resulted in considerable movement of the chert sequence towards the southeast, so that it now covers the area where the conglomeratic beds would otherwise crop out. Thus the increased thickness of the overlying cherty beds in the coastal section is merely an apparent one and the glacio-marine strata and their volcanic intercalations are hidden from view.

Upper Sedimentary Unit

Distribution and Thickness

The upper sedimentary unit outcrops from the major horizon of basaltic pillow lava near Bear Cave on the eastern coast north and west to the coastline of Conception Bay. The unit is continuous along strike until it is largely replaced by intrusive rocks and cut off by the 'Topsail fault zone' (Brückner, 1969), which runs parallel to the coastline from Topsail to Cape St.

Francis.

Light gray massive arkoses are the dominant rock type in the area of Cape St. Francis, but inland, graywackes, shales and volcanic tuffs are prominent indicating a change in sediment distribution. Interbedded with the sediments are extensive subaqueous volcanic flows, breccias and tuffs, which are described in Chapter III.

This unit is approximately 800 meters thick. According to Hayes (1931) the sequence from Bear Cave to Cape St. Francis is repeated by isoclinal folding so that the northwesternmost portion is an overturned limb. The writer, however, could not confirm any major overturning in this area. Only a small syncline along the extreme northern shore of Biscayne Bay causes overturning but an adjacent anticlinal fold quickly returns the beds to their regional upright attitude. Thus most of the west-dipping sandstones in Biscayne Bay, and all in the small Cove immediately west of Cape St. Francis, in Big Cove, and in Cripple Cove are upright and not overturned. This conclusion is supported by numerous observations of sedimentary structures such as grading, distribution of included sedimentary rock clasts, and sequence of turbidite subdivisions.

The upper unit is cut by many faults one of which, running from Biscayne Bay southwestwards, forms part of the boundary between the Harbour Main and Conception Groups on Rose's map (1952). Hayes (1931) interpreted that particular fault as a major fracture bringing the Harbour Main volcanics on its northwest side upwards by a considerable amount. In the same paper he considers the Topsail fault, less than one kilometer to the west, to have downfaulted the volcanic rocks on its west side by some 2600 meters. According to his interpretation, there would hence be a narrow horst between these two faults, raised some 2600 meters above the blocks to the east and west. However the similarity of lithologies and structures on both sides of the fault at Biscayne Bay is evidence in opposition to a major displacement.

Lithology

Nine thin sections show the massive light gray arkoses cropping out near Cape St. Francis to be composed of quartz (approximately 50%), plagioclase (approximately 40%), and rock fragments (1 to 5%). The remainder (5 - 9%) is matrix, which is dominantly chlorite. The rock fragments and matrix together may increase to about 30% in some more poorly sorted beds which are, in fact, graywackes very similar to those of the middle sedimentary unit. Typically the maximum grain size is about 0.3 mm. The quartz, feldspar and rock fragments are similar in composition to those present in the middle unit. In these massive beds, however, authigenic overgrowth of quartz and feldspar is extensive. The sandstone beds are separated by shaly layers less than an inch in thickness, and only occasionally are thicker horizons of laminated shale and siltstone present. Aside from major volcanic intercalations, several thin horizons of pale green water-laid tuff occur. Two thin sections show the shale and siltstone to be composed of grains compositionally similar to the sands but of a finer grain size. The generally fine-grained tuffs contain scattered crystal and rock fragments. In several intervening beds unusual bimodal sandstones were seen, which are basically arkose with lenses of coarse, well rounded sand grains like those seen locally in the middle unit. The graywackes exposed inland are composed dominantly of volcanic rock fragments of rhyolitic, andesitic, and basaltic composition. The fragments display eutaxitic or pilotaxitic textures. These rocks have components with a maximum grain size of about 3.0 mm., show poor sorting, and some have over 50% matrix. Interbedded with these are fine-grained volcanic tuffs. These tuffs are similar to those interlayered with the arkose described above.

Pigeon Island, off the coast of Biscayne Bay, presents a lithology of its own. Angular blocks of volcanic rocks form a sequence about 50 feet thick. The blocks vary in texture from fine-grained to porphyritic to vesicular, and in color from red to black, but all seem andesitic and/or basaltic in composition. Sedimentary material forms the matrix, as portions of sandstone appear squeezed between the volcanic blocks. The irregularly shaped sedimentary portions may be up to one meter in diameter, larger than the volcanic fragments most of which are less than 0.3 meters across. The interstitial sedimentary material is similar to that of the arkose and siltstone beds along the adjacent main coastal section. Smaller islands further offshore are composed of basic flows including fragments or arkosic sandstone.

Structures and Textures

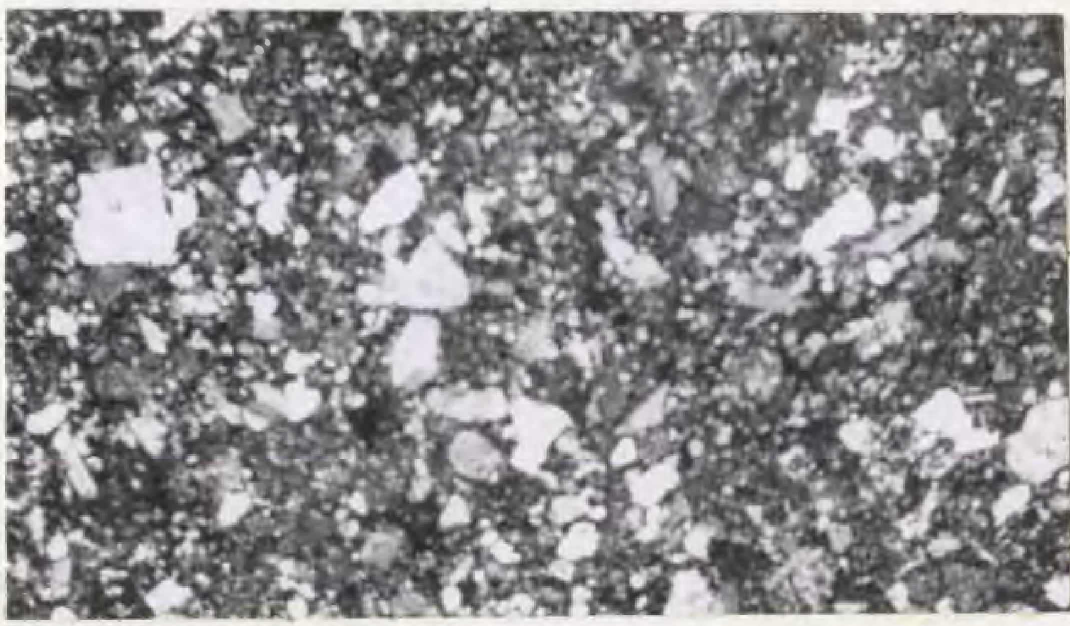
The light gray arkose and greenish gray graywacke are typically thick-bedded (0.5 to 1.5 meters). Most beds are massive, but grading and parallel lamination are sometimes developed. The most conspicuous feature is the abundance of sedimentary fragments contained in the beds. Bent and broken fragments of pre-existing though presumably penecontemporaneous shale, siltstone and chert can be found in nearly every bed. The pieces range up to one foot in diameter. They occur at all levels throughout the massive beds, but are most commonly dispersed in the upper portions. The shale pieces are extremely angular and may not show any distinct orientation except that their largest planar surface is usually parallel to the bedding planes. In many beds where a number of elongate fragments are exposed an alignment subparallel to the northeast-southwest direction was measured. Marschalko (1970), who studied similar inclusions in Carpathian turbidites, found that such fragments had no preferred orientation and reasoned that deposition from a turbidity current could not be expected to align the fragments. Bagnold (1956) reckoned that mudstone fragments in a layer undergoing grain flow should develop an orientation parallel to the flow direction and this seems to be the case in the rocks presently under discussion. No direction sole marks were recorded in the study area, but the alignment of mud fragments does agree with the northeasterly trend of foreset ripple laminae which are present in some of the laminated beds.

Textural evidence of a source direction for the volcanic graywackes is lacking. Two or three tuffaceous shaly clasts were seen at isolated outcrops; however, no prominent preferred orientation of clasts was recorded. A northeasterly source is improbable as these graywackes are scarce in the exposures along the northeastern coast. Furthermore the graywackes are coarser-grained than the arkoses yet farther from a northeastern supply. These volcanic sandstones may hence be derived from a volcanic source in close proximity possibly associated with the numerous volcanic intercalations.

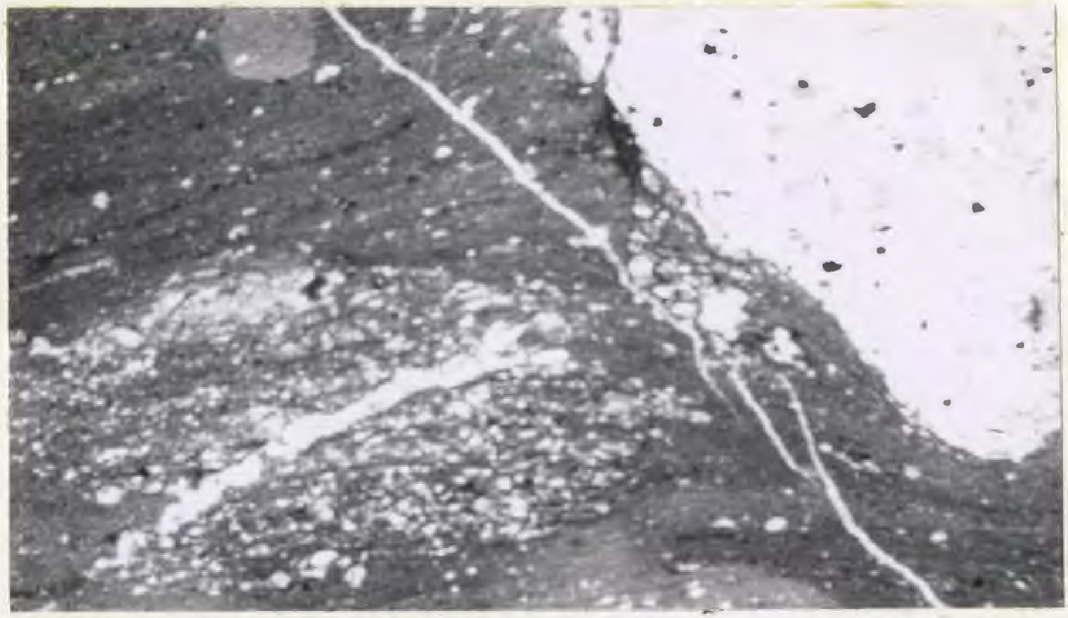
The massive volcanic breccia of Pigeon Island texturally resembles a mud flow deposit. The angular volcanic fragments appear to have been deposited rapidly and sunk into unconsolidated massive and laminated sand, following which the whole mass possibly slumped or moved as a mud flow to its present stratigraphic position. This breccia may be a lahar which blended with silty and sandy sediment before final emplacement.

Photomicrographs of parts of a three feet thick bed of graded graywacke from west shore of Pouch Cove. X-nicols. 12X.

A. Fine-grained upper part with siltstone clast.



B. Coarser-grained basal part.



A. Photomicrograph of fine-grained laminated shale from tillite horizon (south of Pouch Cove N.W. Pond) showing a slightly coarser 'till pellet' and a volcanic rock clast. 12X.

B. Rounded clasts in tillite (northwest of Old Pond).

One of several thrust faults cutting middle-unit sediments exposed on the Atlantic coast approximately 1 km. north of Pouch Cove. Hanging wall is displaced towards the left (southeast).

SE ←

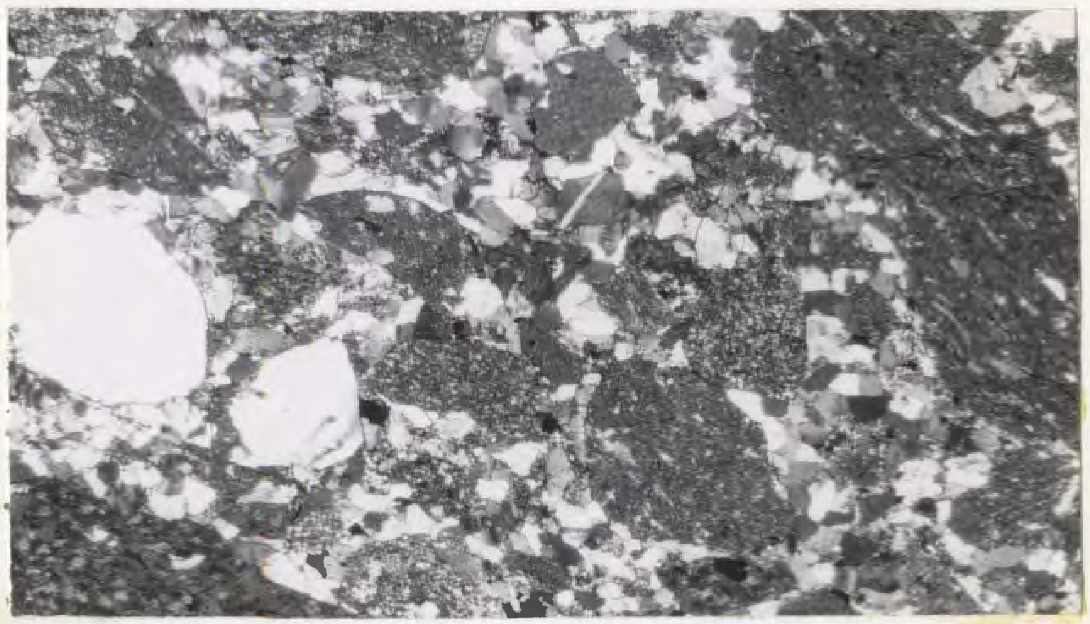
Overfold associated with a thrust south of that shown in Plate 5.

Early deformation fold cut by later northwesterly trending normal fault. Atlantic coast about 2 km. north of Pouch Cove.

Photomicrograph of the dominant axial planar cleavage (diagonally crossing this photo), cut by a later strain slip fabric (approximately horizontal). X-nicols. 12X.

Plate 9

One of the many diabase dikes (dark rock) which intrude the sedimentary strata (light rock) throughout the map area. Atlantic coast 3.2 km. north of Pouch Cove.



Photomicrograph of one of the rare bimodal sandstones which occur in middle and upper sedimentary units. X-nicols. 12X.

Siltstone and shale fragments, near the top of a coarse grained turbidite bed at Biscayne Bay, showing preferred orientation (current effect). The largest fragment shown is approximately 3 cm. in length.

CHAPTER III

Volcanic and Intrusive Rocks

Introduction

The igneous rocks described in this chapter are placed in three divisions: the lower, middle and upper volcanic units, which correspond respectively with the lower, middle and upper sedimentary units with which they are interlayered.

It is not suggested that these units correspond to older and younger members of the Harbour Main Group described elsewhere (McCartney, 1967; Rose, 1952; and others) although some correlation may eventually be achieved.

Lower Volcanic Unit

Discussion

The lower volcanic unit does not outcrop in the thesis map area. The unit consists of a series of basaltic pillowed flows and tuffaceous rhyolites which crop out southeast of the Bauline - Pouch Cove road. The mineralogy of these acid volcanics is significant in that quartz and plagioclase form phenocrysts in quantities (quartz 46%, plagioclase 54%) which correlate closely to the proportion of detrital quartz and feldspar grains in many of the arkoses. The compositions and textures of these mineral grains also correspond.

Although these lower unit volcanics lie along strike from the lower unit sediments, the stratigraphic and structural relationship has yet to be studied. There may be significant faulting so that the sediments and volcanics are not closely related. However, some of the lower unit sandstones may overlie the rhyolites and basalts which hence may have existed as a topographic volcanic high during sedimentation of some and perhaps even the oldest beds of the lower sedimentary unit.

Middle Volcanic Unit

Distribution

The middle volcanic unit comprises those volcanics that are conformably interlayered with the middle sedimentary unit in the central part of the map area.

As was the case for the middle unit sediments, exact correlation of individual volcanic members (especially the abundant basalts and andesites) is made difficult by lack of outcrop continuity. However, rhyolite tuffs crop out consistently at the same stratigraphic level, from the southern boundary of the map area to a point just southeast of Old Pond (a distance of approximately 7 kilometers) where they are thought to be obscured beneath the thrusts seen in the eastern coastal section.

Two plugs of fine-grained rhyolite and related dikes which intrude the middle unit are discussed later with similar 'late-stage' rhyolites of the upper volcanic unit.

Lithology

Rhyolite

The middle unit volcanics include light to dark gray rhyolitic tuffs which weather beige and white. A major and several minor tuff layers were mapped. These are essentially crystal tuffs containing albite and quartz phenocrysts in a fine-grained matrix. The phenocrysts constitute from 5% to 60% of the rock. The crystals may be unbroken and subhedral, or broken and partly angular, and they range in diameter from 0.5 to 2.0 millimeters. The subhedral forms commonly show embayments and rounding due to magmatic corrosion. The feldspar crystals commonly show finely divided albite twin lamellae, which is also a feature of the detrital feldspar grains in the interlayered sediments. The quartz crystals are commonly fractured and have strongly undulose extinction and deformation lamellae which are probably due to tectonic events. The matrix is recrystallized to a fine-grained schistose assemblage of quartz, feldspar and mica. Upon application of sodium cobaltinitrite the matrix stained slightly, hence it may contain some potassium feldspar although no individual crystals of potassium feldspar were seen.

Tuffs in which the matrix has a laminated appearance may be water-laid; however, the tuffs at other outcrops are much denser and appear welded. In these welded tuffs (Plate 15B), shard fragments are apparent. These shards stained where treated with sodium cobaltinitrite and might hence consist of potassium feldspar and silica like those described by Ross and Smith (1961).

Lithic fragments less than two centimeters in length were recognized, but are uncommon. Besides the frequent albite and quartz phenocrysts, epidote-chlorite pseudomorphs are enclosed here and there in the flow-textured matrix. Scattered small zircon crystals and widely disseminated magnetite are minor primary minerals whereas chlorite, mica, epidote, and pyrite appear to be secondary.

Basalt and Andesite

The basalts and andesites of the middle unit are gray-green to black in color and commonly weather to a rusty brown. These basic volcanic rocks (as well as those in the upper volcanic unit) are difficult to classify petrographically as they have some features which are characteristic of spilites. In this thesis the author does not wish to discuss the controversial spilite problem, thus these rocks are referred to as andesites and basalts. Exact petrographic nomenclature is further hampered by the variety of lithologies which appear to form a complete range from basalt to andesite. This range in composition is reflected in color index figures which vary from 20 to 45, thus indicating transition across all andesite-basalt divisions which have been proposed in this respect: Kuno 35-37 (1950), Rittmann40 (1962), Moorhouse 27 (1959). The color index of the rocks is largely an indicator of the amount of pyroxene present.

The basalts and andesites of this unit are described only briefly as they generally appear to be similar to those of the upper unit where good field exposures permitted more selective sampling. The basalts are composed of albite, augite, chlorite and opaques with minor epidote, sphene, quartz, pyrite and calcite. In any particular flow, either one or both of albite and augite may be partially altered to a fine-grained intergrowth of chlorite, epidote and sericite. Chlorite is the most common amygdaloidal mineral and is ubiquitous in the matrix where it may represent devitrified glass. Where vesicles are filled with several minerals, the order of filling from the outer edge of the vesicle to the center is as follows: epidote, chlorite, albite, quartz, and calcite.

In the lighter colored andesitic rocks, augite is reduced in quantity while albite is more abundant. In one andesite sample amphibole (hornblende?) was the prime mafic mineral.

An interesting feature concerning the time of secondary mineralization was seen in one thin section from a volcanic conglomerate. A boulder of fine-grained variolitic basalt is cut by small veinlets of quartz and albite, which do not seem to affect the surrounding matrix. This may indicate that at least this particular mineralization occurred before the fragment was eroded and deposited.

Primary Structures and Textures

Rhyolite

The rhyolite tuffs are generally thick crystal-rich layers. Lithic varieties are rarely exposed and no conspicuous vertical textural variations were noticed. The boundaries of the main tuff horizons are not exposed, but several small horizons 1 to 2 meters thick were seen to conform to the normal sedimentary stratification. Although these rocks are commonly sheared, shards are locally preserved, especially in the lee of crystal fragments. A eutaxitic texture is imparted to the rock where shards are compacted between crystal grains. The shards have a homogeneous, fine-grained appearance in which axiolitic textures were not seen. On the basis of their stratified nature, great lateral extent, and eutaxitic textures, these rhyolitic rocks are presumably ash flow tuffs.

Their interbedding with marine sediments indicates deposition below sea level; however, welding and the reddish color of some associated sediments seem to point to very rapid emplacement at shallow depths, or else such effects of volcanic heat would not have developed. The lack of lithic fragments may have resulted from sorting, all pieces of pumice having remained afloat to be carried away by currents.

Basalt and Andesite

Most of the basaltic and andesitic rocks, which are interlayered with the sediments (Plate 15A) and rhyolites, are pillowed flows. Extensive pyroclastic deposits such as are present in the upper volcanic unit were not seen. The pillows are up to 2 meters in diameter with the interstices filled by fine-grained tuffaceous material and less commonly by disrupted sedimentary material from the underlying beds. Although the mineral assemblage is largely spilitic, petrographic textures typical of fresh basalts and andesites are well preserved. The flows are either aphanitic or porphyritic with albite phenocrysts up to 1 centimeter in length and augite phenocrysts up to 0.5 centimeters in diameter. Glomeroporphyritic, pilotaxitic and variolitic textures are common. Generally feldspar laths are acicular and some have feathered ends indicative of quenching. Some of the less basic flows have orthophyric texture as is commonly seen in andesite.

Upper Volcanic Unit

Distribution and Interrelationship of Rock Types

The upper volcanic unit is generally defined by the same boundaries as the upper sedimentary unit with which it is interbedded. Basalts, andesites and their pyroclastic equivalents are conformably interlayered with the sediments that have been described in Chapter II. Included with these youngest volcanics of the study area are the fine-grained and in some cases porphyritic rhyolites that intrude the middle unit near Pouch Cove and thoroughly pervade the middle and upper units near Bauline and along the Conception Bay coastline. These 'late-stage' rhyolites commonly show intrusive relationships and are then interpreted to be plugs and dikes. However, near the road 1.5 kilometers south of Cape St. Francis a flow-like body has developed in connection with one of the larger rhyolite dikes.

Quartz diorite and gabbro are common in the map area and were seen to intrude sediments and volcanics of both middle and upper units. Most frequent in the southern portion of the map area, the quartz diorite appears as small discontinuous dike-like bodies, but occasionally it outcrops continuously for about 50 meters with contacts unexposed. Several prominent hills in the area are composed largely of gabbro. No observations were made as to the relationship that may exist between the quartz diorite and the gabbro.

A final phase of igneous activity is represented by diabase dikes which intrude all the above mentioned rock types (Plate 9).

Many of the contact exposures in the upper unit are difficult to interpret due to the development of cleavage and micro-faulting, which is often intensified at contacts. Hence only a few contacts show decisive evidence, the conclusions from which were extrapolated for the interpretation of other occurrences.

Lithology

Basalt and Andesite

The basalts and andesites range in color from black to gray-green and generally weather to a rusty brown. The weathering colors vary greatly around minor faults where intense reds, greens or blacks may be developed. The basic volcanic rocks of the upper unit, studied in eighteen thin sections, are composed of albite (An 6-8) and augite ($2V=43^{0}$) set in a dominantly chloritic matrix containing disseminated magnetite (Plates19A, 19B). Epidote, pyrite, sphene, calcite and quartz are minor secondary minerals, which are dispersed throughout the rocks, most commonly in veinlets and as vesicle fillings.

The albite crystals generally are laths showing albite twinning and often appear fresh although in several flows they are intensely saussuritized. The crystals are not noticeably zoned and no remnants of more calcic feldspars were seen in any of them. In the coarser porphyritic flows, individual phenocrysts of albite may exceed one centimeter in length and make up 5% to 30% of the rock.

Augite is present in most flows but varies in quantity from 5% in some andesites to about 35% in basalts. Individual phenocrysts rarely reach 0.5 centimeters in length. The augite is colorless and non-pleochroic, and its phenocrysts, where present, are smaller and less frequent than those of albite. The augite phenocrysts are euhedral to subhedral, occasionally zoned and often twinned along (100) to produce twin seams. Embayments and rounding indicate reaction of augite with the magma.

The chlorite, which commonly forms the mesostasis between feldspar and pyroxene phenocrysts and microlites, probably represents altered glass which was undoubtedly present initially in these rapidly chilled pillow lavas.

Fragments of congealed lava embedded in autobrecciated flows are enriched in disseminated opaques and contrast sharply with the less oxidized green flow rock which is interstitial to the fragments. A similar contrast exists in pyroclastic breccias, where the fragments are more oxidized than the tuffaceous matrix.

Eight thin sections of basic sills and dikes indicate that these are of similar mineralogical composition to the lavas described above.

Rhyolite

The frequent fine-grained rhyolite plugs and dikes are gray to black in color but weather to cream or white. Eleven thin sections showed they are composed of albite phenocrysts and microlites in a matrix of silica, with finely disseminated chlorite and occasional small patches of epidote. Mineralogically these rocks seem to have some features of quartz-keratophyres; however, as previously mentioned the author does not intend to deal with the spilite - keratophyre problem and hence these rocks are simply referred to as rhyolites. The albite phenocrysts seldom exceed 0.5 millimeters in diameter and are often equant in dimensions. Numerous fine albite twin lamellae such as are common in the basalts, andesites and tuffaceous rhyolites previously described are not present in the feldspars of these 'late stage' rhyolites. The albites usually contain only one or two twin lamellae in two directions normal to one another thus dividing the phenocryst sections into quadrants (Plate 20A). V.S. Papezik (1970) has chemically analyzed two of these fine-grained rocks which he calls soda rhyolites.

Where shearing is prominent along the Conception Bay coastline, recrystallization of the rhyolite appears to have produced small elongated patches enriched in very fine-grained albite, which is best observed after staining with barium rhodizonate.

Quartz Diorite

The quartz diorite which crops out in the central and southern portions of the map area is composed mainly of albite, quartz and amphibole (hornblende?). Quartz and albite are present in approximately equal amounts, whereas amphibole may make up a considerable percentage (20%) of the rock or be almost entirely absent. The quartz and feldspar grains include small euhedral apatite crystals. Some of the amphibole is altered to chlorite with associated epidote and calcite. Sphene, subhedral to anhedral in form, is present in minor quantities.

At contacts of the quartz diorite and country rock, epidote is often extensively developed. At one such contact, between quartz diorite and diabase, contact veinlets are filled with epidote and garnet (Plate 20B).

Gabbro

Gabbroic rocks, studied in three thin sections, are composed of plagioclase and clinopyroxene. The pyroxene is relatively unaltered, has a 2V around 40^{0} and seems to be augite similar to that in the basaltic flows. The plagioclase is commonly saussuritized but refractive index measurements on less altered feldspars indicate it is albite. Chlorite is ubiquitous in these rocks, and pyrite is a very common secondary mineral.

Primary Structures and Textures

Basalt and Andesite

The upper volcanic unit affords excellent exposures of basic lava flows with associated pyroclastic breccias. Pillowed and unpillowed flows frequently are overlain by pyroclastic deposits containing isolated pillows, fragments of broken pillows, and assorted fine-grained tuffaceous material. The stratification and textures of these deposits are very similar to those described by Carlisle (1963) and thus his nomenclature is used in describing the stratified pyroclastic breccias.

The base of any single pyroclastic unit is composed of pillowed and/or unpillowed flows. Individual massive flows do not exceed 3 meters in thickness. Close-packed pillows (Plate 17) range from 0.5 meters to 3 meters in length and have typical ellipsoidal shapes. Interstices between pillows are filled with tuff, jasper and epidote, or near the bottom of the flow with sandstone and siltstone from the underlying sedimentary beds (Plate 17). Occasionally large lenses of sandstone have become incorporated in the flows. The pillows have a chilled rim 1 or 2 centimeters thick and usually exhibit radial and concentric joints.

Isolated-pillow breccia gradationally overlies close-packed pillows at several localities. This breccia (Plate 22A) consists of ellipsoidal and irregular-shaped pillows and fragments of pillows dispersed throughout a tuffaceous matrix which makes up about 40 percent of the rock. Some pillows have spectacularly irregular shapes. One of these is over two meters long but only 10 to 15 centimeters thick. 'Mini-pillows' only 10 to 20 centimeters in diameter are also common. The tuffaceous matrix shows slight lamination due to sorting, presumably by water currents.

Transition from isolated-pillow breccia to broken-pillow breccia is also gradational. In this layer complete pillows are not present. The breccia fragments are generally vesicular and they have only partially chilled or unchilled margins indicating their derivation from whole pillows by rapid disintegration (Plate 21). Tuffaceous matrix usually makes up 50% or more of this breccia type. Sorting, which has produced layers enriched in either coarser or finer breccia fragments, is presumably caused by thermal and mechanical density currents, which would undoubtedly develop at the site of a submarine eruption.

The aquagene tuff which gradationally overlies the broken-pillow breccia consists of very angular grains of basalt and crystal fragments in a very fine-grained (almost glassy) matrix (Plate 22B). The lithic fragments have a texture similar to that of the underlying basalt flows. Also present in these tuffs are individual grains and lenses of sediment similar to underlying sandstones. No distinct shards or globules were recognized in the altered fine-grained matrix. Bedding or lamination is less obvious in this tuff layer than in the lower breccia layers;

however, the admixture of sedimentary material is probably due to turbulent erosion and mixing of unconsolidated sediment with tuff.

Volcanic horizons as described above vary in thickness from tens to hundreds of meters, with close-packed pillows making up the greater part of any sequence. Several horizons distinctly wedge out toward the southwest thus indicating a vent to the northeast, presently beneath sea level. No well defined vent was mapped in the area; however, at two localities where larger diabase dikes cut through the sequence, they appear to be connected with overlying flows.

Not all the basic volcanic rocks fit the description of layered pyroclastics as described above. Autobrecciated basalt flows have a very similar field appearance to broken-pillow breccia but the microscopic textures are considerably different. Other breccias, which occur at various localities, were simply considered as agglomerates if they did not show definite genetic features. Many of these are probably volcanic mud flows (lahars), which would probably be frequent in a submarine volcanic environment. One such breccia (Plate 13) has been previously described in Chapter II.

Two kilometers south of Cape St. Francis, one of the larger sill-dike bodies, approximately 20 meters thick, shows a distinct banding on weathered surfaces. The banding is expressed by light colored resistant, and darker less resistant layers which vary in thickness from 1 to 2 centimeters near the sill contacts to 10 or

15 centimeters internally. The layers are parallel to the sill contacts. On fresh surfaces and microscopically the bands are much less distinct. The prominent constituents are plagioclase, clinopyroxene, chlorite, and an opaque mineral (Magnetite?). The darker less resistant bands are slightly enriched in chlorite and magnetite (?). Clinopyroxene was more abundant in a sample from the centre of the sill than in a sample from the lower contact, however no noticeable quantitative variation in augite was apparent in the adjacent light and dark bands from either sample. The plagioclase laths generally have a preferred orientation parallel to the banding. In two of the five thin sections studied the plagioclase orientation was not consistent but varied in thin layers several millimeters in width. It is not certain if this is a primary fabric or a tectonic one due to incipient kinking. Extensive sampling and chemical analyses appear necessary to specify the rather subtle compositional variation throughout the fine-grained sill.

The basalts and andesites present a rather typical spilitic mineral assemblage composed of albite, augite, chlorite and magnetite. Certain microscopic textures indicate that the mineral assemblage is a primary magmatic one, while other features indicate that at least part of the mineral association has developed after solidification of the lavas. Feathered and swallow-tail features are common in the albite laths. These effects of quenching appear to be primary having formed at the time of lava solidification. Also curved albite phenocrysts, which were presumably bent before the lava consolidated, show no release of strain as would be expected during recrystallization of a more calcic plagioclase to albite. The above textures, following Battey (1956) and Donnelly (1963), are considered to point to these crystals being of a primary magmatic origin. However, at the same time, vesicles filled with albite are evidence that at least some albite is related to late magmatic fluids or even later metasomatism.

Normal basaltic and andesitic textures are common in the lavas (Plates 19A, 19B). If the chlorite is considered as devitrified basaltic glass, intersertal and hyalopilitic textures are common, while the coarser rock types are subophitic and pilotaxitic. In the finest grained lavas, especially in pillow selvages, plagioclase is variolitic in the devitrified glass matrix. The basalts and andesites are amygdaloidal to varying degrees. In pillows large round amygdales occur centrally while those in or near the selvage are flattened coplanar to the chilled margin. In cross sections of some pillows a central portion, representing about 10% of the pillow, is highly vesicular to an extent that hardly anything but amygdaloidal minerals is present. At three localities massive and pillowed flows contained amygdales which ranged in diameter up to ten centimeters.

Rhyolite

The fine-grained rhyolites, which form 'late-stage' dikes, plugs, and flow-like bodies, are texturally fragmented or flow banded. Fragmentation is well developed especially at or near the contacts of the rhyolite bodies. A typical plug and columnar jointing, which is a common feature of the rhyolites, are shown in Plates 23 and 24.

At plug contacts the brecciated material consists of rounded fragments of rhyolite up to 25 centimeters in diameter enclosed in a tuffaceous matrix. The rounding of fragments is possibly due to abrasion during intrusion. Alignment of the rhyolite fragments imparts a flow orientation to the rock (Plate 25A). Microscopically the tuffaceous matrix also shows a fluidal arrangement of crystal and lithic fragments which are interstitial to the larger rounded breccia fragments. Usually this contact breccia has sharp boundaries with the country rock, but at one outcrop in Big Cove the rhyolite appears to have partly been remobilized and mixed with basaltic country rock. At another outcrop, also in Big Cove, the country rock appeared to be folded upward next to the intruding rhyolite indicating forceful intrusion.

The flow-oriented breccia grades inward over a distance of one or two meters into an angular unoriented rhyolite breccia (Plate 25B). Such an unoriented breccia is also typically developed at the contacts of the smaller rhyolite dikes and at the base of the flow-like body south of Cape St. Francis. The lack of fluidal orientation and particle abrasion indicates that much less differential movement has occurred in these breccias than at the plug contacts.

In the upper portion of the flow-like body and in the central portion of the larger plugs the unoriented breccia grades into flow-banded rhyolite. The gradation may be over a distance of centimeters or over many meters with an extremely coarse breccia developed in the flow-banded material.

Flow-banding and brecciation are features associated with high viscosity and indicate that the rhyolites were partly congealed before flow movement ceased. However, the abraded contact breccias with their rounded fragments and flow texture appear to have been less viscous and possibly somewhat fluidized. Although the contact breccia is quantitatively small, it may have played an important role during intrusion by providing a small amount of fluidization (Reynolds, 1954) at the contact, which operated in conjunction with forceful intrusion.

The 'flow-like rhyolite body', which has been referred to, has a fragmented basal layer and an upper flow-banded layer. Any upper contact which may have existed has been removed by erosion. This body is in near proximity to a small plug with divergent flow-banding from which it is probably derived. Exposures do not permit decisive interpretation as either an extrusive flow or an intrusive sill. If it were a flow, its basal contact would be an angular unconformity and thus deformation and much erosion would have to be invoked preceding the emplacement of this rhyolite.

At several scattered localities, roof pendants of silicified basaltic tuff rest on top of rhyolite exposures, indicating these intrusive rhyolites did not reach the surface.

Microscopically these rhyolites consist of scattered albite phenocrysts in a hypocrystalline matrix of silica, albite and chlorite. Occasionally the lath-like albite microlites show a fluidal or pilotaxitic arrangement. Due to the fine-grained siliceous composition, these rocks have a conchoidal fracture pattern.

The rhyolites described above are most common toward Conception Bay, and many outcrops at that coast are intensely sheared and partly recrystallized.

Quartz Diorite

Quartz diorite shows complex field relationships, but microscopically has a fairly uniform hypidiomorphic-granular texture. At exposures on the Bauline road where the quartz diorite is finer-grained than usual, the amphibole has in part overgrown the plagioclase in a way resembling ophitic texture. The time of emplacement of the quartz diorite is limited by the fine-grained 'late-stage' rhyolite dikes which cross-cut it.

The actual emplacement of the quartz diorite appears complex and further study is required, however the following field relationships exist:

1. Just north of the Pouch Cove - Bauline road small quartz diorite veinlets cross-cut shales and tuffs of the middle sedimentary unit. At nearby exposures quartz diorite crops out continuously for 50 meters and adjacent outcrops are of sedimentary strata, thus an intrusive relationship is implied.
2. At several localities between Trout Pond and Bauline, quartz diorite pods seem to be xenolithic in diabase dikes as the dike rock appears chilled against the quartz diorite. The relationship is complicated by a foliation and secondary mineralization of the contact. As some diabase dikes post-date the quartz diorite, xenoliths of quartz diorite may be expected in them.
3. In Bauline, quartz diorite appears to have developed at the expense of diabase or basalt, possibly by metasomatism. In these exposures the quartz diorite grades into diabase over a short distance (fraction of a meter).

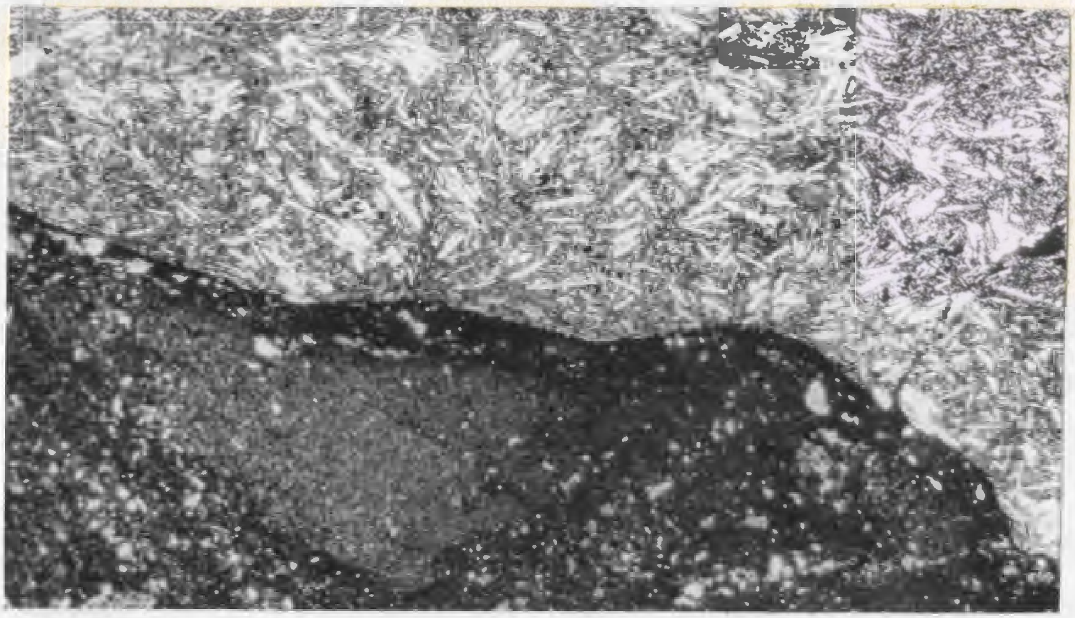
It is of interest to note that in addition to these occurrences of quartz diorite near the Conception Bay coastline the only other known occurrence in the region is the quartz diorite which forms a hybrid marginal zone to the Holyrood granite (Barning, 1965).

Gabbro

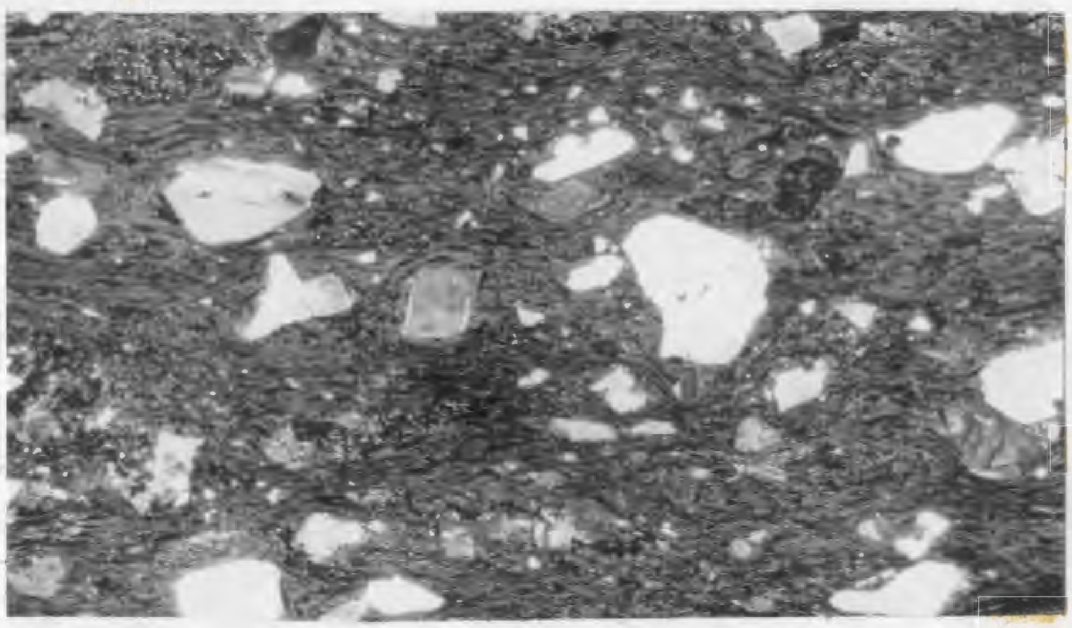
The small gabbroic bodies which intrude the upper and middle units were not seen in contact with the 'late-stage' rhyolites and thus their time of intrusion could not be fixed in that respect. Texturally the gabbros are hypidiomorphic-granular but in some places approach diabase in texture and the clinopyroxene becomes ophitic and intersertal in habit.

Like the gabbro, most of the diabase dikes could not be assigned a relative age. Some feed basic flows while others cut the youngest rocks in the sequence; however, the remainder of the observed dikes (which are a majority) could not be assigned to a particular period of igneous activity.

Photomicrographs. X-nicols. 12X

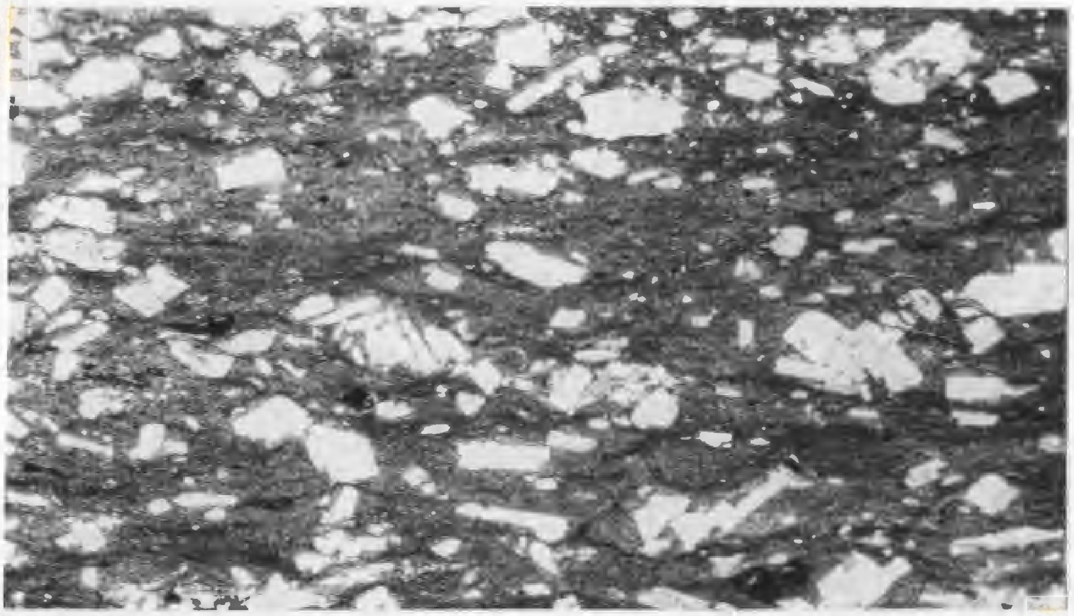


A. Contact of fine-grained subvariolitic basalt (top) with siltstone including a shaly portion (bottom), one kilometer southwest of Old Pond.



B. Rhyolitic ash flow tuff showing eutaxitic texture. One half kilometer southeast of Herring Cove Pond.

Photomicrographs of volcanic rocks of the middle volcanic unit. X-nicols. 12X.



A. Orthophyric andesite.

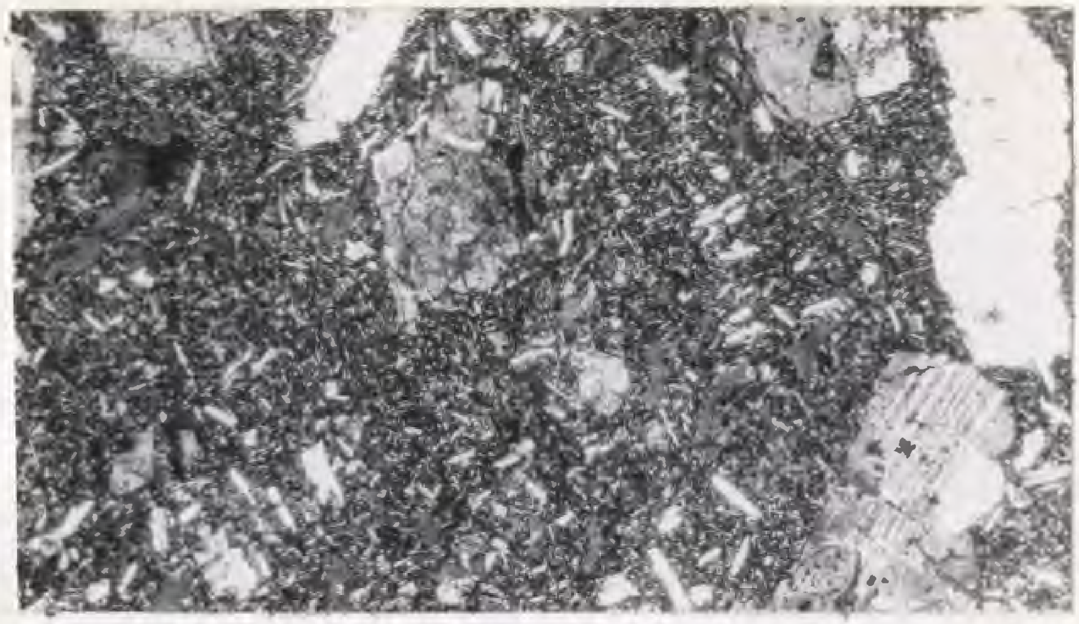
B. Glomeroporphyritic basalt.

Typical base of a subaqueous basalt flow where pillows came to rest in unconsolidated arkose, that now fills the interstices. Photo covers an area of approximately 1.0 m. x 0.7 m.

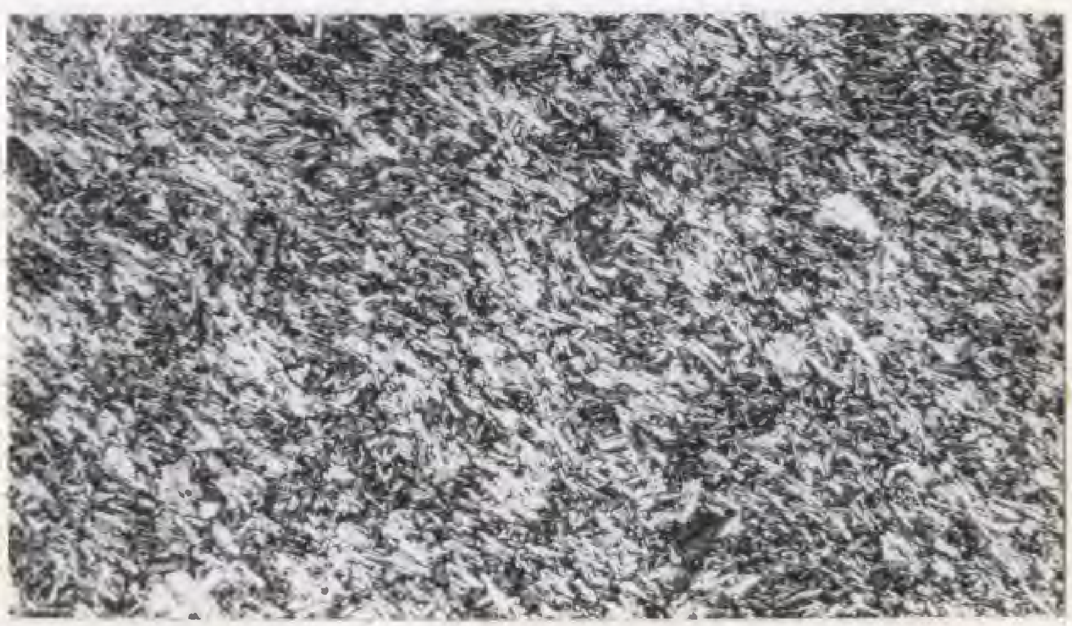
Plate 18

Beds of arkose and graywacke conformably overlying pillowed basalts 250 meters northwest of Bear Cave.

Photomicrographs of upper unit volcanics. X-nicols. 12X

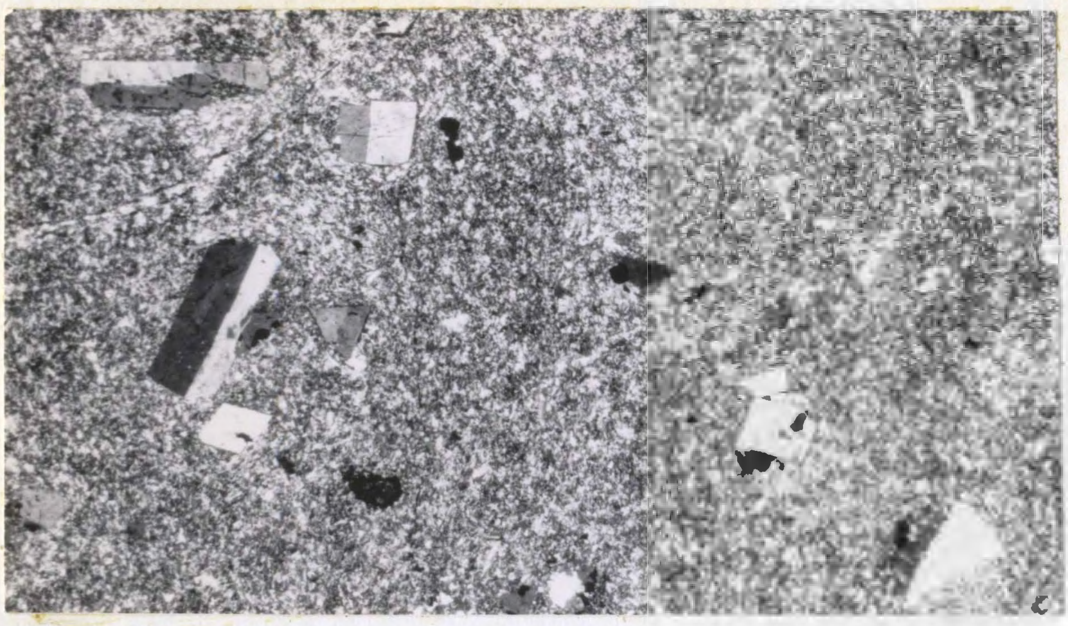


A. Amygdaloidal pillow basalt with phenocrysts of albite and augite sampled 2 km. south of Cape St. Francis.

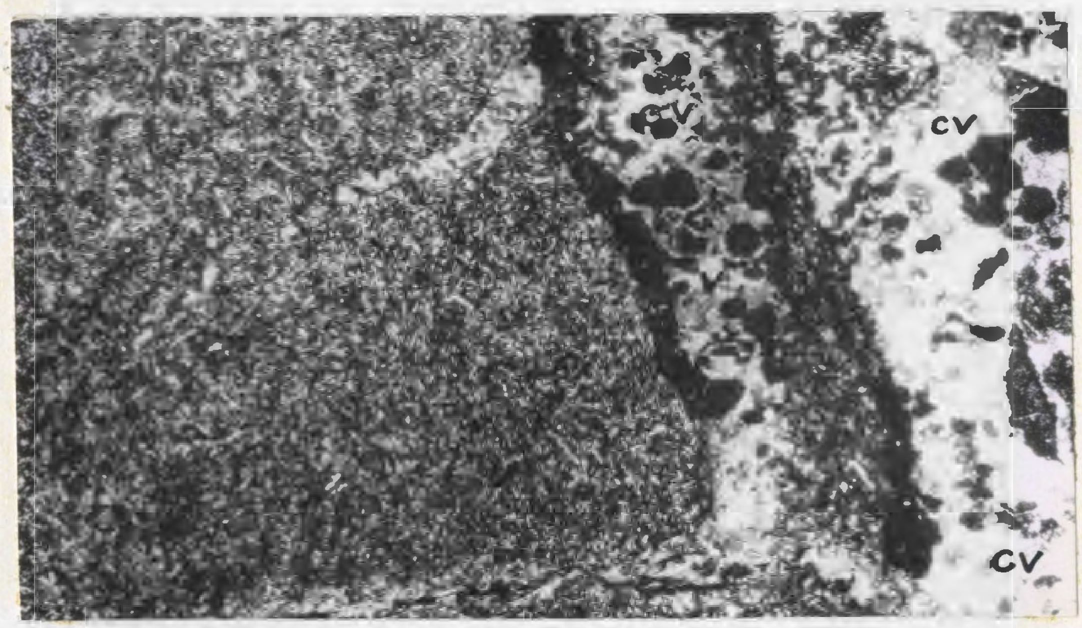


B. Pilotaxitic andesite sampled 3 km. south-southwest of Cape St. Francis.

Photomicrographs. X-nicols. 12X.

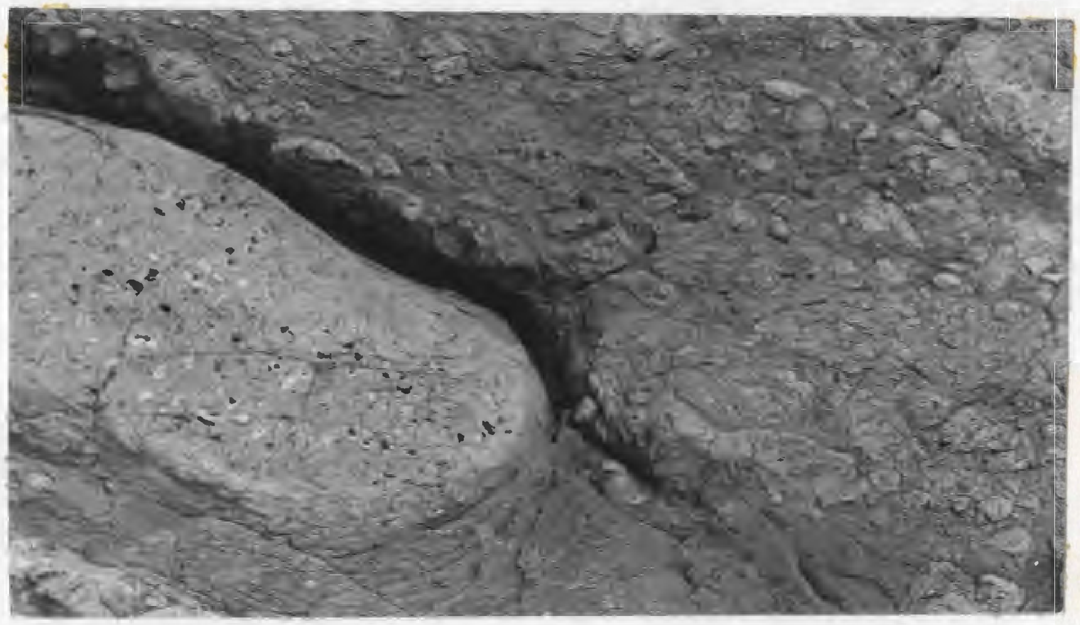


A. Fine-grained porphyritic rhyolite with albite phenocrysts sampled 1.7 km. south of Cape St. Francis.

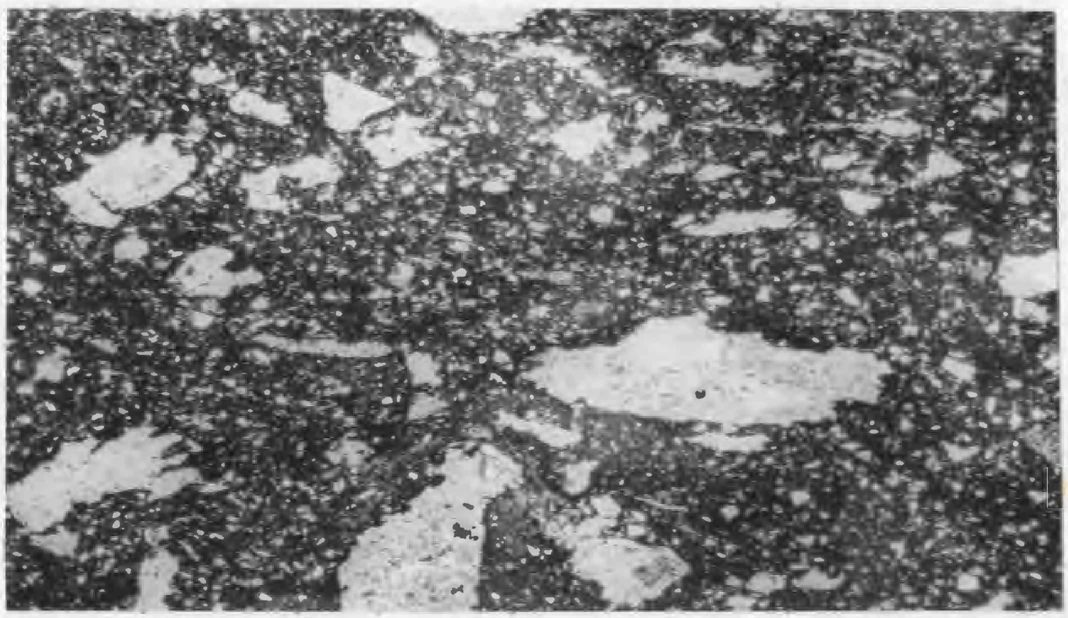


B. Contact veinlets (cv) between diabase (left) and quartz diorite (not shown) are filled with epidote and garnet. Sampled 1 km. south of Herring Cove Pond.

Breccia composed of broken pillow fragments. Eastern shore of Big Cove.



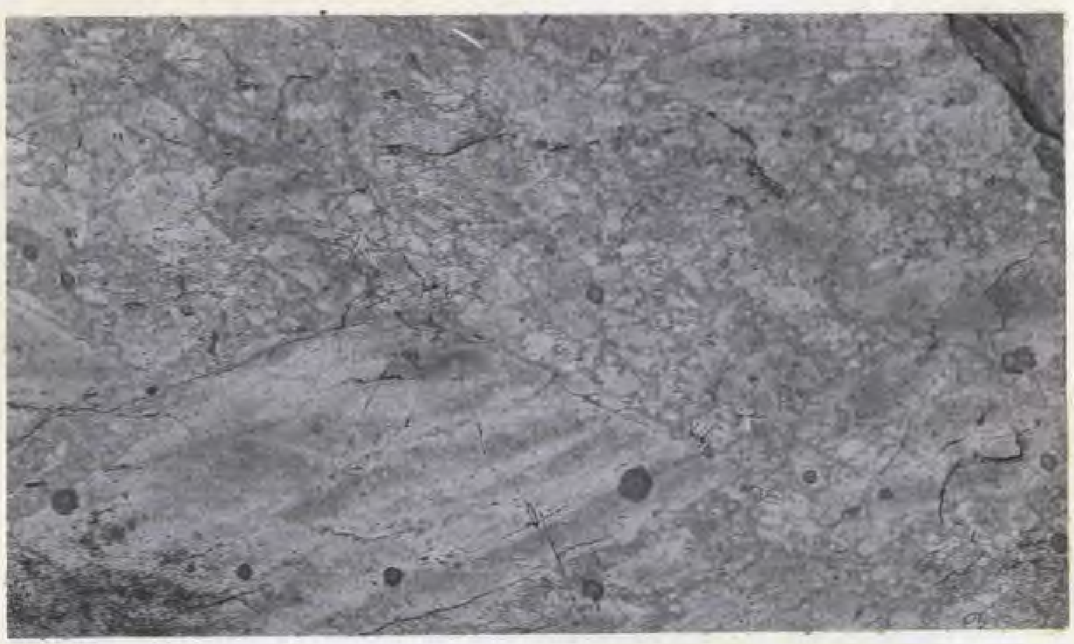
A. Basaltic breccia composed of pillow fragments and a few isolated unbroken pillows. Cripple Cove.



B. Photomicrograph of aquagene basaltic tuff. X-nicols. 12X. South shore of Big Cove.

Columnar jointing in the rhyolite plug
shown in plate 23.

A. Breccia composed of subrounded rhyolite fragments developed at the contact of rhyolite plug (Plate 23) with tuffaceous basaltic rocks.



B. Breccia composed of angular rhyolite fragments developed inside the contact zone shown in Plate 25A.

CHAPTER IV

Synopsis of Stratigraphy and Paleogeographic Implications

It is apparent from the descriptions in Chapters II and III that the volcanic and sedimentary rocks of the Pouch Cove - Cape St. Francis area are penecontemporaneous facies, and that the respective terms Harbour Main Group and Conception Group can only be used here to distinguish between these two facies.

As the base of the total Harbour Main - Conception sequence is nowhere seen nor has it been explored by geophysical means, the stratigraphic record of the area begins with strata of unknown level in the total sequence and the distinction of lower, middle, and upper units has hence no absolute significance.

The oldest sediments exposed and described above as the lower sedimentary unit, contain no volcanic intercalations but most or all of their constituent grains are derived from acid volcanic rocks and attest to a source area of that composition having been eroded at the time. The fact that matrix-rich volcanic rock fragments, sensitive to erosion, are scarce in the lower unit sediments is considered proof for concentration of the more resistant grains during erosion and transport, and this together with relatively good sorting would seem to indicate that the source area was some considerable distance away. The sedimentary structures of this unit do not permit a simple interpretation to be given with regard to the conditions of deposition. The thick though laminated sandstone beds separated at sharp contacts by thin shaly layers may be the result of a complex interaction of transport agents. The thickness of the sandstone beds and the angularity of their sand grains indicate ample sediment supply and relatively rapid transport without much wear, while at the same time the more transport-sensitive lithic fragments have been eliminated. Thus following initial rock break-down and erosion, transport may have taken place first in rivers and then by tidal and bottom currents which account for the laminations which are present throughout the sandstone beds. The shale layers represent breaks between periods of rapid sand transport and would correspond to time when only silt and clay were supplied from the source area. The occasional thin beds of massive light gray arkose must represent periods when quantities of well sorted sand were deposited over the area in too rapid a manner to permit traction features to develop. These sands may have been emplaced as dense sand slurries which acquired their initial sorting by river and tidal action.

If the small number of observations of current directions are considered meaningful, the sands of the lower sedimentary unit were deposited by currents from the northeast. This conclusion is supported by observations near Shoe Cove (W.D. Brückner, personal communication). It is hence possible, but of course by no means certain, that the source area lay somewhere in the northeast.

The middle sedimentary unit differs from the lower in several ways but most significantly by its interlayering with volcanic rocks. These volcanic intercalations are reflected in the sediments by an abundance of volcanic lithic grains. In the lower portion of the unit rhyolitic ash flow tuffs are associated with volcanic graywackes containing rhyolitic fragments. Several interbedded layers of red and gray shales may be related to voluminous ash eruptions or they may indicate periods without energetic rock-forming events. These rhyolite tuffs that are partially welded indicate that the water depth probably was not great; however, shallow water sedimentary features were not observed in the associated sandstones. Occasionally interbedded with the rhyolites but more abundant higher in the unit are basaltic and andesitic massive and pillowed flows. These volcanics are also reflected in the penecontemporaneous graywackes, as basic volcanic lithic grains are present in them.

The glacio-marine and tillite member of the middle unit probably is the most interesting paleogeographic feature. These deposits are found interbedded with the shales mentioned above. Their presence in the study area is stratigraphically important as Brückner and Anderson (1971) have found glacio-marine strata and tillite in Conception Group sequences at several other Avalon localities. These peculiar rocks are indicators of an ice age and hence may be used as a means of correlation within the sedimentary sequences, which lacks other reliable marker horizons, as well as on a global scale (Harland, 1964, 1965).

A thick series of green cherty beds, which occurs approximately halfway up the middle unit, may also be useful in correlation with adjacent areas, though hardly over the entire Avalon Peninsula. Slump folds, the noses of which all point to the southwest, were seen in sandstones which underlie the thick series of cherty beds. This suggests a paleoslope towards the southwest as does the average of a limited number of current direction readings that were made in the middle unit.

The uppermost portion of the middle unit is composed of graywackes and arkoses of turbidite origin. During their sedimentation volcanic activity in the immediate area was temporarily reduced, however abundant volcanic material was available in the source area. An important aspect of these turbidites is that toward the northeast they contain coarser material than toward the southwest; that is, the graded interval Ta forms a prominent portion of any individual bed in the northeast while in the southwest part of the study area it is greatly reduced in thickness or absent.

Somewhat similar to the middle unit the upper sedimentary unit shows periods of sedimentation alternating with constructional volcanic activity. Dominant in the northeast are thick-bedded, graded arkoses petrographically very similar to the thinner arkose beds in the lower and middle units. Their coarse grain size and the lack of laminations in most of them may indicate that these beds were deposited more proximal to a coast than the sandstones of the underlying units. This is also borne out by the observation that the number and thickness of arkose beds in the map area increase toward the northeast, hence strengthening the case in favor of a source area in that direction. However, the graywackes of the upper unit cropping out to the southwest of the arkoses do not fit into the pattern of transport from the northeast. These graywacke beds contain coarser debris than the arkoses, are more poorly sorted, and seem to wedge out toward the northeast as there are none to be seen on the northeastern coast. Obviously these graywackes are derived from a volcanic source that lay in a different direction, possibly to the northwest. Unfortunately no current indicators were observed in the graywackes to support this view.

Some of the subaqueous basalt layers thicken toward the northeast, which may indicate a vent in that direction. Other basaltic volcanic layers have probably had a vent source within the map area itself as they appear to be connected with some of the larger dikes.

Following sedimentation and volcanism, granitic, rhyolitic and diabase intrusions have pervaded much of the area. The small quartz diorite bodies are the oldest of these intrusions and, although no data are available to relate these to the Holyrood granite, it is tempting to assume such a relationship, as the granite may well have been emplaced prior to the 'late-stage' rhyolites. From the presence of an angular unconformity as suggested for the base of the rhyolite near Biscayne Bay, a period of uplift and erosion might be inferred to have preceded emplacement of the rhyolite and in fact to have coincided with the granite intrusion. Small diabase dikes, which cut all other rock types represent the final igneous activity in the study area.

CHAPTER V

Structural Features of Diastrophic Origin

In this chapter observations on diastrophic structures are related, which the author was able to make beside his stratigraphically oriented field studies. As these structures were not studied in great detail and the total structural history of the Avalon Peninsula is by no means completely understood, the conclusions drawn must be considered tentative.

Cleavage and Foliation

The most widespread structural feature in the rocks of the map area is a prominent slaty cleavage which has affected the shales and tuffs and some of the fine-grained siltstones but is rarely observed in the more competent rock types of the area. This cleavage is associated with parallel arrangement of fine-grained platy minerals, mostly chlorite and sericite,and locally grades into foliation. Also vesicles in some lava flows, and clasts in some conglomeratic beds have been flattened and stretched parallel to the cleavage planes. The maximum elongation of these stretched bodies is approximately normal to the cleavage-bedding intersections. The cleavage generally strikes north-northeast and dips steeply to the west. It is possible that this widely developed cleavage is axial planar with respect to the major anticlinal zone which Rose (1952) has shown to pass through Shoe Cove; however, the author has not studied cleavage-bedding relationships outside the thesis area.

Superimposed on the slaty cleavage is an incipient strain-slip cleavage and a probably associated set of kink bands. This second cleavage is best observed in tuffs of the middle volcanic and sedimentary units, where it appears to strike northwest and dip steeply to the south. On the planes of the second cleavage minor recrystallization of quartz and sericite has taken place (Plate 8). The kink bands were best observed in shaly rocks of the middle and upper sedimentary units. The kinks range in amplitude from less than a millimeter to approximately a centimeter. They cause a northwesterly plunging lineation on the planes of slaty cleavage.

At many localities along the Conception Bay shoreline, from Bauline to Cape St. Francis, the rocks are also affected by a closely spaced fracture cleavage which strikes approximately north and has a vertical dip. The author had the impression that it cuts the primary slaty cleavage at a small angle; thus it appears to be younger; however, this relationship requires verification by further study. Small amounts of displacement are apparent along the fracture cleavage planes, which locally disrupt laminations and bedding planes to such an extent that individual strata may be difficult to follow across outcrops. The more massive igneous rocks present at these localities have acquired a sheared texture which appears to be parallel to the fracture cleavage. This cleavage might be a feature of the disturbed belt called the "Topsail fault zone" by Brückner (1969), which runs parallel to the southeastern shoreline of Conception Bay.

Folds

As stated earlier the sequence of rocks in the study area essentially forms the west flank of a major anticlinal zone, the axis of which lies near Shoe Cove to the east of the area mapped (Rose, 1952; Keats, 1968). Hence only small-scale folds are described here.

Minor folds, with amplitudes up to 30 meters are well exposed in the Atlantic coastal section. Their axes trend approximately northeast and their axial planes dip steeply northwest. The folds are of the similar type with thickening of beds in the hinges and thinning on the limbs. Locally the primary slaty cleavage is parallel to the axial planes of the minor folds. The southeastern limbs of the folds are commonly overturned and thrust faults were seen to cut through these lower limbs causing the upper limbs and the overlying sequence to be displaced toward the southeast (Plates 5 and 6). Other minor folding of beds was recorded around small intrusive bodies, in which cases the sediments dip away from the center of intrusion.

Faults

Faults are numerous throughout the area but only the more prominent ones are shown on the accompanying map.

Immediately north of Pouch Cove are several low angle thrust faults as already mentioned above in connection with minor folds (Plates 5 and 6). These thrusts together are thought to account for several hundred meters of displacement.

The largest fault in the general area is clearly the Topsail fault which lies parallel to the coastline a short distance offshore beneath Conception Bay (Hayes, 1931; Rose, 1952). Hayes has calculated that the Harbour Main and Conception rocks to the east of the fault, in the vicinity of Bauline, have been upthrown some 2300 meters.

At a small horizontal angle to the Topsail fault are strike faults trending northeast across the map area. Where these intersect the Atlantic coastline large ravines have been eroded but there is no clear evidence of significant movement along the fault planes.

A number of normal faults strike northwest and dip south. Where determinable the displacement of these is no more than several meters. Plate 7 shows one such fault which has displaced an earlier minor fold.

Source Area Deformation

In two graywacke samples of the upper sedimentary unit, a few grains of volcanic rock fragments were seen which exhibit an incipient strain-slip cleavage. The majority of the associated eutaxitic or pilotaxitic grains do not show this cleavage. Hence the possibility exists that the cleavage in these clasts formed before erosion and deposition of the grains, implying that their source area must have been subjected at least locally to diastrophic deformation.

Discussion

Further detailed studies of the many diastrophic features observed in the study area are necessary before a complete picture of the structural pattern and history can be presented.

The cleavages may be most useful in this respect especially if they can be traced to the southern portion of Conception Bay where Paleozoic strata unconformably overlie the Precambrian rocks, thus possibly permitting one to distinguish between cleavages of Precambrian age from those formed later.

The only dated structural event of the area is the latest major movement on the Topsail fault, as it can be seen to cut off and deform Cambrian strata to the north of Topsail and can be inferred to also cut off lower Ordovician sediments farther north. Thus the fracture cleavage developed along the Conception coast-line, if related to the latest movement along this fault, may also be post-Ordovician in age. The author's impression that this fracture cleavage post-dates the slaty cleavage and foliation indicates a pre-Cambro-Ordovician (presumably Late Precambrian) origin for the latter. However, there does not appear to be any other evidence suitable for an age determination of the slaty cleavage. The time of formation of the strain-slip cleavage is also open to discussion as it is only known to post-date the primary slaty cleavage. Aside from the Topsail fault, the faults in the area do not appear to have caused any major displacement in the sequence.

A late Precambrian deformation resulting from east-west compression might be inferred from the possible angular unconformity below the 'late-stage' rhyolites described in Chapter III. Although further folding has probably occurred at a later time, possibly with a similar stress pattern, the nature of such folding is not apparent in the map area.

CHAPTER VI

Correlation

At the present time sufficient detailed sedimentary studies have not been made in the Conception Group that might permit the establishment of an extensive basinal correlation, nor has the sequence of volcanic events in the Harbour Main Group been established except locally and in a general way.

However, the recent discovery of a fauna in the Conception Group (Anderson and Misra, 1968; Misra, 1969) and the identification of tillites and glacio-marine deposits in this group (Brückner and Anderson, 1971) may lead to the establishment of important stratigraphic marker horizons for the whole of the Avalon Peninsula.

With respect to correlation of the three sedimentary units distinguished in the Pouch Cove - Cape St. Francis map area it is useful to consider the geographic distribution of localities where similar rocks are known to occur.

Laminated sandstones like those described as lower sedimentary unit crop out in the anticlinal zone at Shoe Cove and also are exposed in the area of Red Head north of Flat Rock where they are in complex contact with rocks of the Cabot Group. Laminated sandstone, moreover, crops out in Middle Cove, Torbay Bight (Cull, 1968), and for some distance along the highway from Torbay to St. John's (W.D. Brückner, personal communication). The author has observed similar looking sandstones also in a rock quarry adjacent to the northeastern boundary of St. John's airport.

The graded sandstones, cherty beds and intercalated tuffs described as middle sedimentary unit seem to be the most widespread rock types of the Conception Group in northeastern Avalon (W. D. Brückner, personal communication). The glacial deposits in the middle unit probably correspond with those described by Brückner and Anderson (1971). Particularly their find in the Flat Rock area appears to have a similar stratigraphic position as the glacial deposits west of Pouch Cove, as at both localities they are underlain by laminated sandstones and overlain by graded sandstones with cherty beds. However, in the Pouch Cove area volcanic intercalations (flows and tuffs) are prominent at this stratigraphic level, whereas at Flat Rock only minor interbeds of tuff are present. This difference in volcanic intercalations must be accounted for by assuming a center of contemporaneous volcanic activity closer to the Pouch Cove area than to Flat Rock. A direct correlation with other tillite localities of Brückner and Anderson is not possible at this time; however, future mapping in the area between Bauline and Portugal Cove may show a continuation of the glacial deposits along strike between these localities, excluding for the moment structural complications.

Thick bedded arkoses as described for the upper sedimentary unit are not known to occur at any other localities on the north-eastern Avalon Peninsula, and facies equivalents are not recognized. The geographic restriction of these arkoses to the northeasternmost tip of the Avalon Peninsula is important evidence in favor of their derivation from a northeastern source.

The volcanic intercalations in the map area cannot be correlated either in detail or even in general with Harbour Main Group rocks exposed in other parts of the Avalon Peninsula (Rose, 1952; Hutchinson, 1953; Dawson, 1963; McCartney, 1967; Papezik, 1969). Neither is the complex sequence of volcanic events sufficiently understood even locally nor is there enough continuity of exposure for any detailed comparison. The small bodies of quartz diorite might be related to the Holyrood granite but further exposures south of the map area must still be mapped to show their overall distribution and their regional relationships to the granite and other rocks.

In summary, based on correlation of the sediments with those in adjacent areas, the writer asserts that volcanic activity persisted in the Pouch Cove - Cape St. Francis area during deposition of a major portion of the Conception Group. If the volcanic rocks of this area are actually part of the Harbour Main Group as previously mapped it must be concluded that these two Groups are largely penecontemporaneous.

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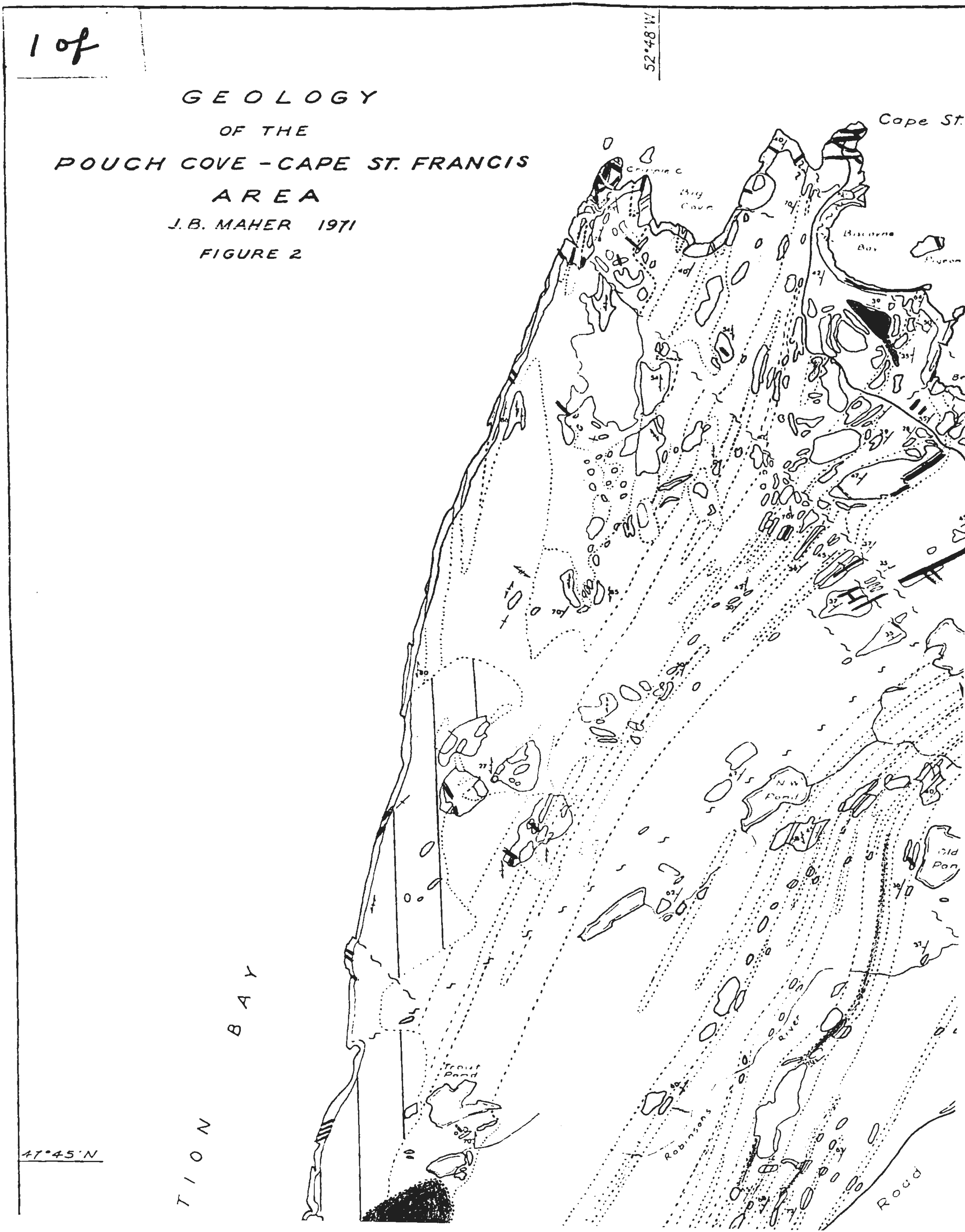
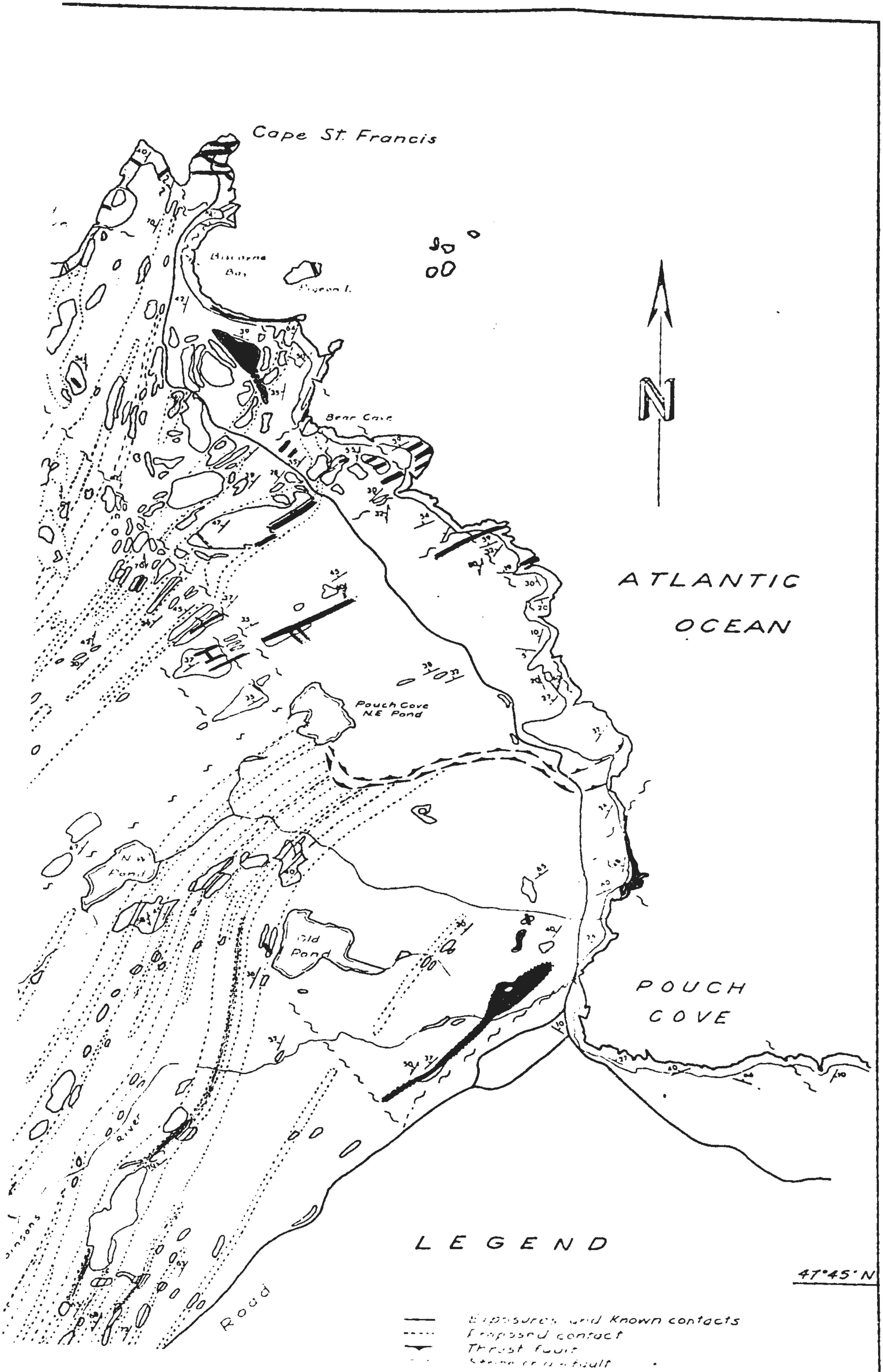
C.1

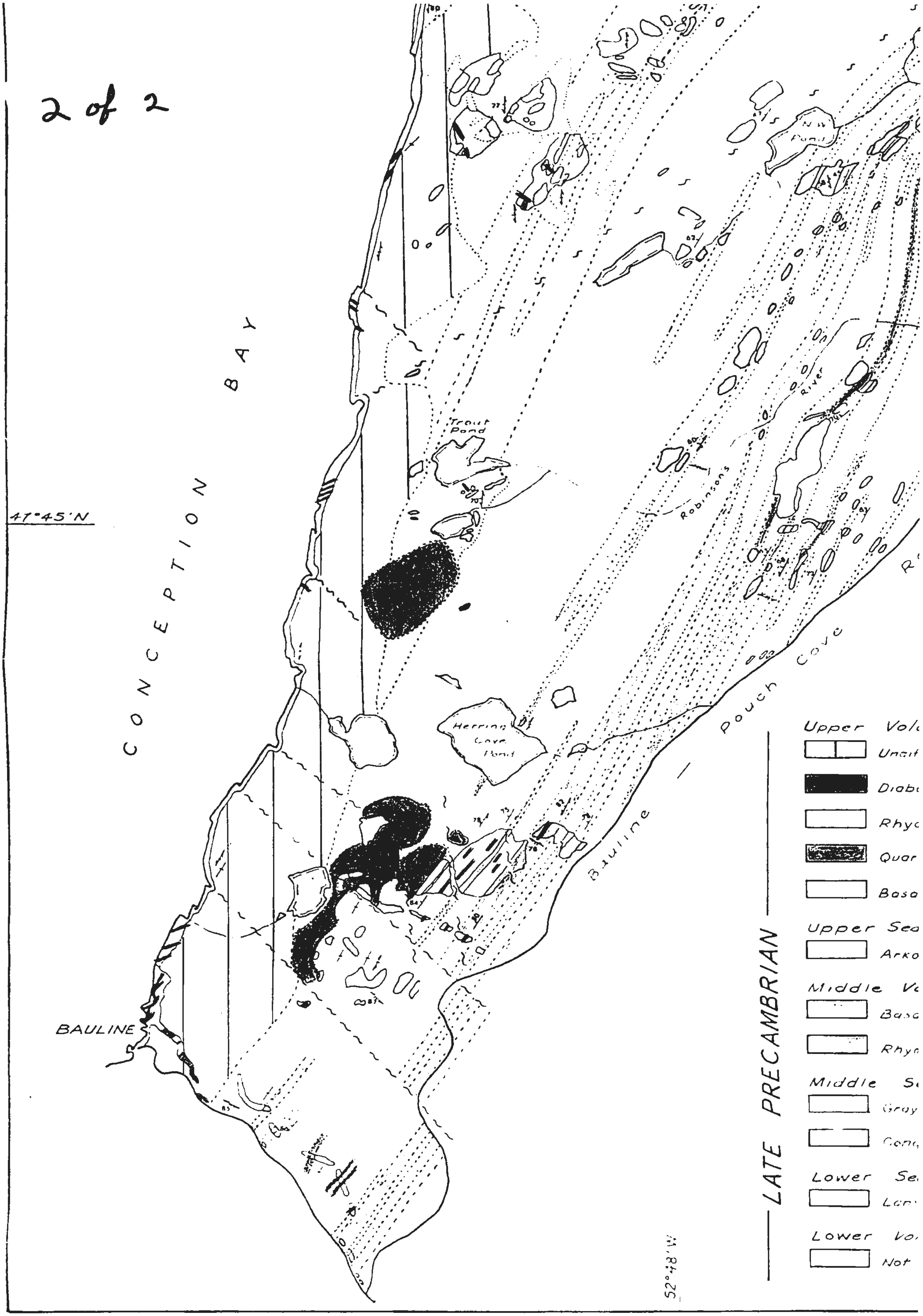
GEOLOGY OF THE POUCH COVE - CAPE ST. FRANCIS AREA

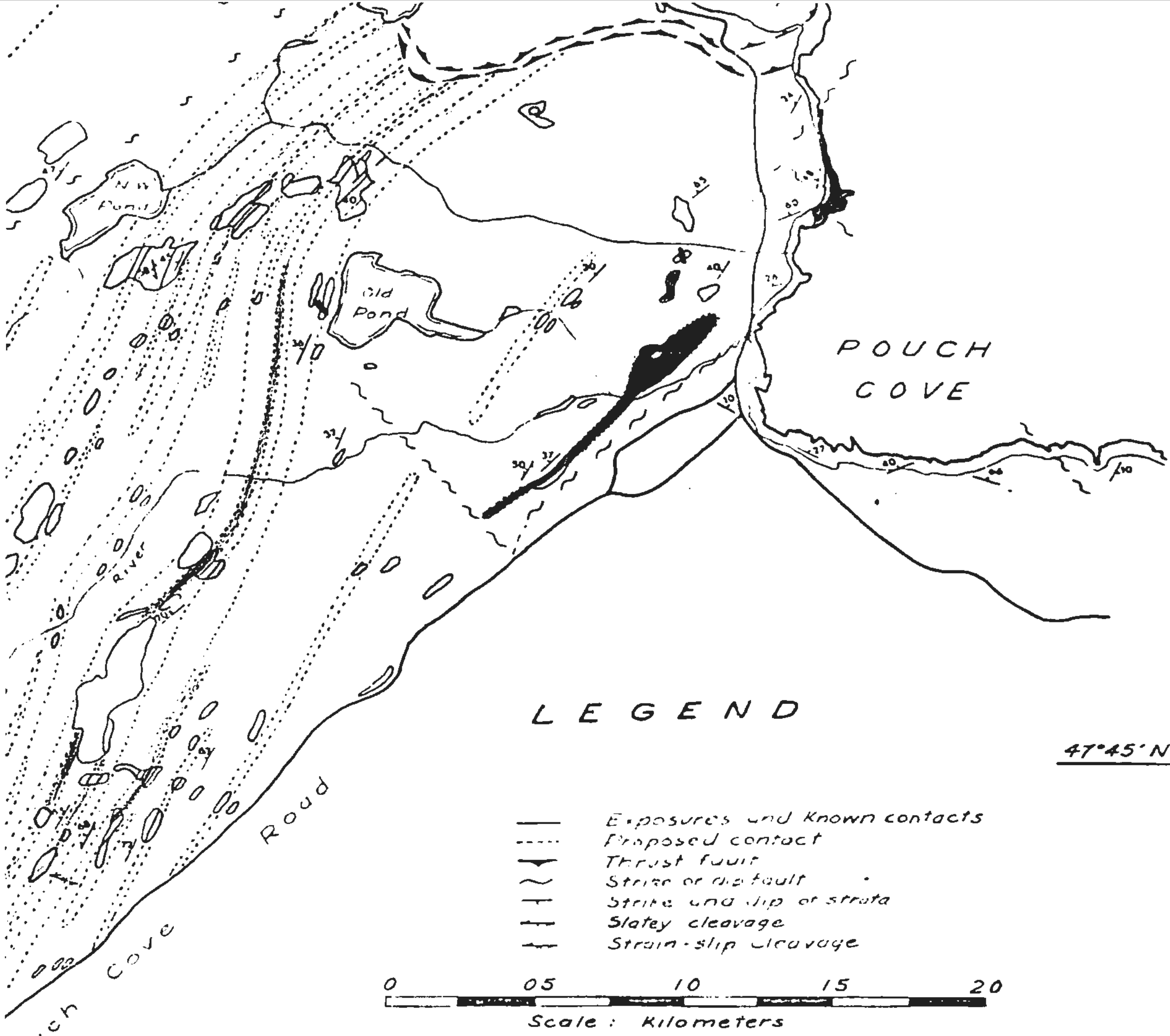
J.B. MAHER 1971

FIGURE 2




Cape St. Francis
Biscayne Bay
Pigeon I.
Bear Cove
N
ATLANTIC OCEAN
Pouch Cove N.E. Pond
Old Pond
POUCH COVE
River
Road
LEGEND
47°45'N
Exposures and known contacts
Thrust fault


CONCEPTION BAY
47°45'N
52°48'W
BAULINE
Trout Pond
Herring Cove Pond
N.W. Pond
Robinsons
River
Bauline — Pouch Cove
LATE PRECAMBRIAN
Upper Vol
Diab
Rhyo
Quar
Basa
Upper Sea
Arko
Middle Vo
Basa
Rhyo
Middle Se
Gray
Cong
Lower Se
Lower Vo
Not



LATE PRECAMBRIAN

Upper Volcanic Unit

- Undifferentiated sediments and volcanics pervaded by dikes
- Diabase and gabbro
- Rhyolite
- Quartz diorite
- Basalt and andesite

Upper Sedimentary Unit

- Arkose, graywacke, siltstone and shale.

Middle Volcanic Unit

- Basalt and andesite.
- Rhyolite tuff

Middle Sedimentary Unit

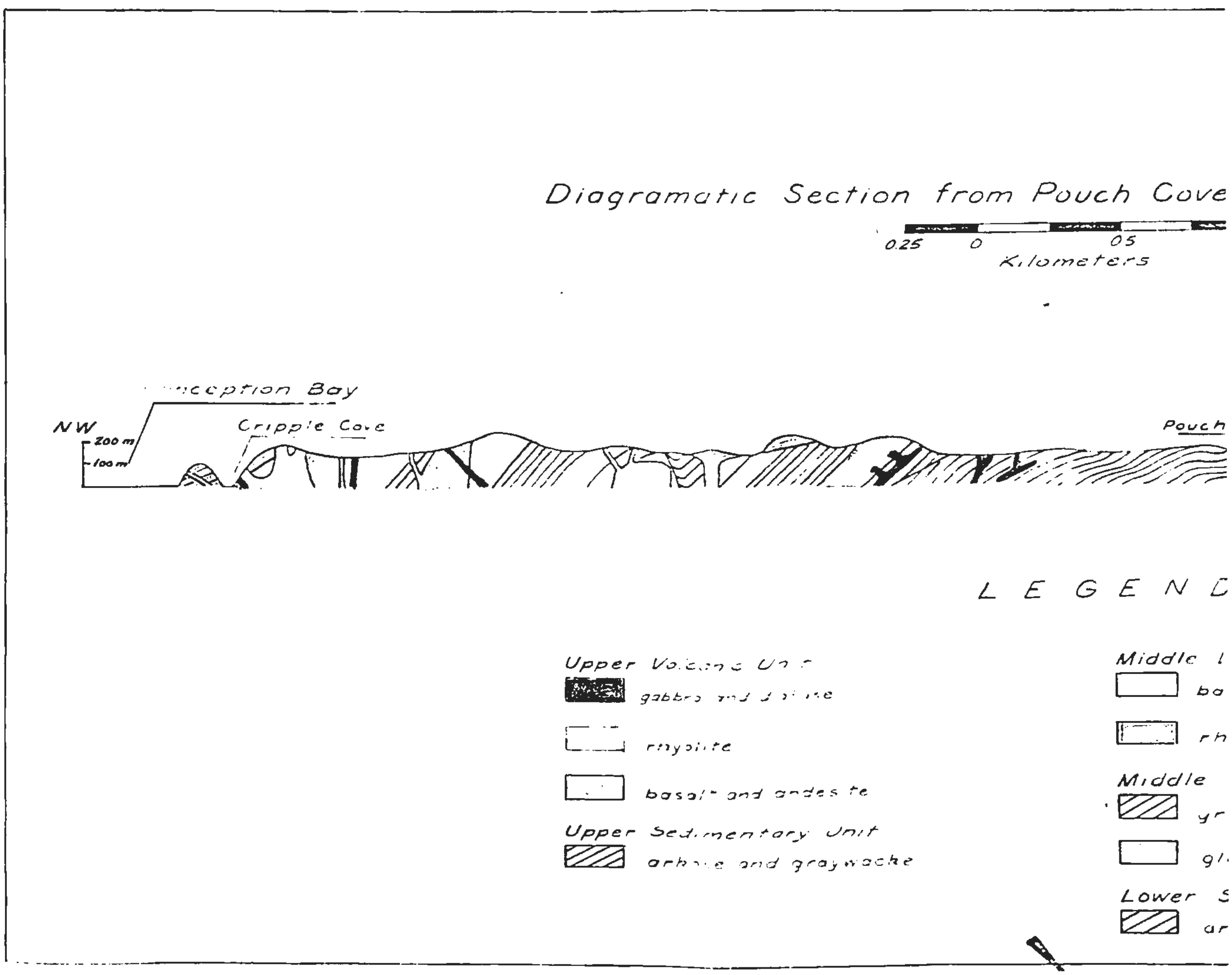
- Graywacke, arkose, chert, siltstone, shale and minor conglomerate.
- Conglomeratic glacial deposits.

Lower Sedimentary Unit

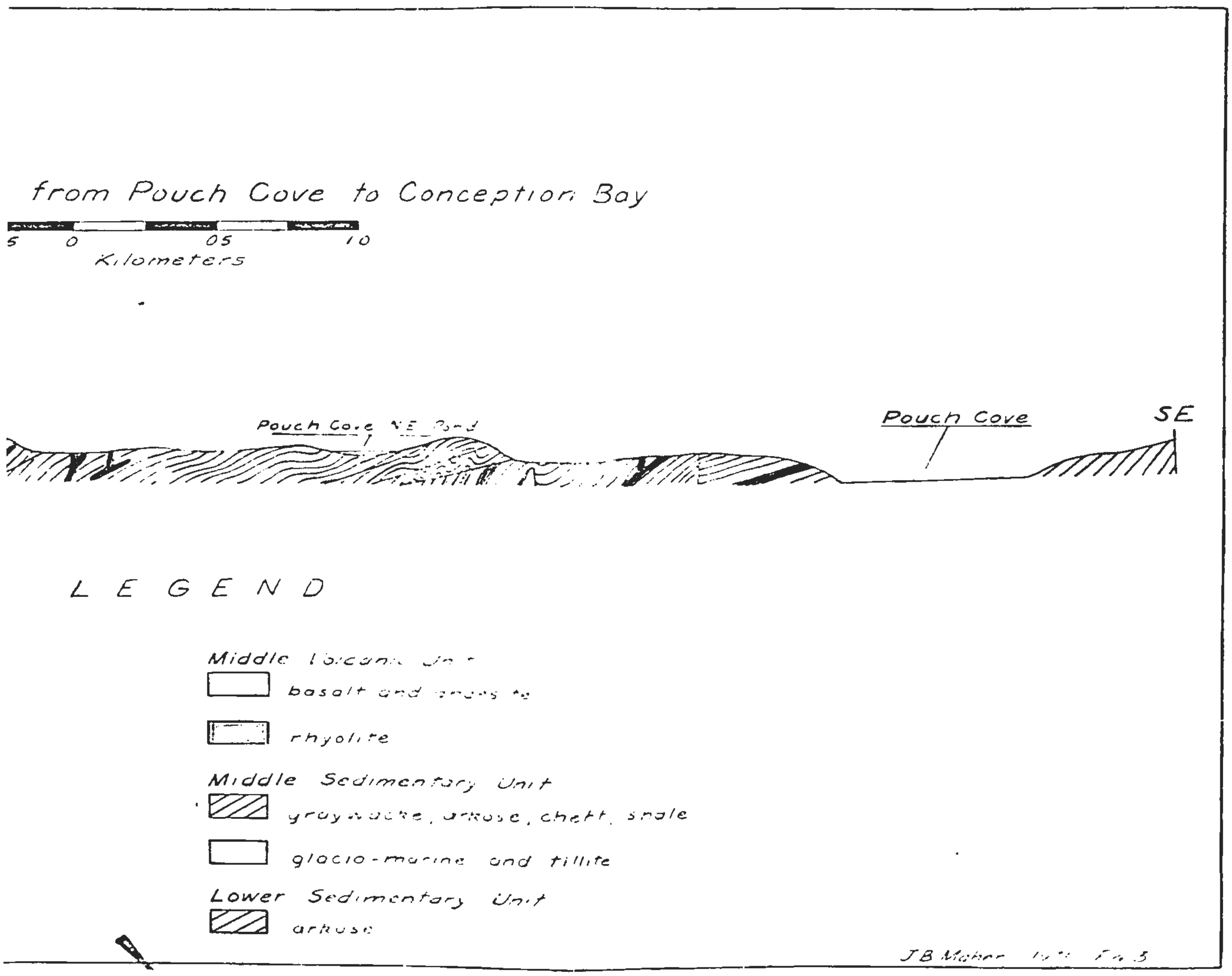
- Laminated arkose with minor shaly interbeds

Lower Volcanic Unit

- Not shown. Outcropping to SE of map area



Diagramatic Section from Pouch Cove
0.25
0
05
Kilometers
NW
200 m
100 m
Cripple Cove
Pouch
Upper Sedimentary Unit
Middle
Lower


from Pouch Cove to Conception Bay
5 0 05 10
Kilometers
Pouch Cove
SE
Pouch Cove
L E G E N D
Middle
basalt and
rhyolite
Middle Sedimentary Unit
chert, shale
glacio-marine and tillite
Lower Sedimentary Unit
J.B. Maher