Atlantic Geology

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Volume 1, numéro 2, april 1965

URI : https://id.erudit.org/iderudit/ageo1_2rep02

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Éditeur(s)

Maritime Sediments Editorial Board

ISSN

0843-5561 (imprimé)
0843-5561 (numérique)

Découvrir la revue

Citer ce document

Blanchard, J. E., Dainty, A. M., Ewing, G. N., Keen, C. E., Keen, M. J., Moore, G. S. & Tsong, C. F. (1965). Seismic studies on the eastern seaboard of Canada. *Atlantic Geology*, *1*(2), 23–28.

GEOPHYSICS AND GEOCHEMISTRY

Seismic studies on the eastern seaboard of Canada

by: J.E. BLANCHARD, A.M. DAINTY, G.N. EWING, C.E. KEEN, M.J. KEEN, G.S. MOORE and C.F. TSONG

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Introduction

This is a resume of seismic experiments on the eastern seaboard of Canada undertaken by DALHOUSIE UNIVERSITY; those concerned with the experiments include the authors and D.L. BARRETT, I. BERGER, and R.E. MCALLISTER, who appreciate the active help and cooperation of the DEPARTMENT OF MINES AND TECHNICAL SURVEYS and the ROYAL CANADIAN NAVY. Many of the results presented are of a preliminary nature, and do not represent final, considered conclusions.

The seismic experiments are designed to make clear the structure of the crust and upper mantle and their inter-relationship, and of the nature of seismic wave propagation. In particular we are concerned with the structure of the crust and mantle beneath well-defined geological systems - the Appalachian mountain system on the one hand, with the problems of its apparent termination northeast of Newfoundland, and the continental margin on the other, with the problems which relate to the crust and upper mantle at the boundary of continent and ocean basin. A number of long seismic lines were established in 1962, 1963 and 1964 and there is now sufficient information available that a coherent picture is beginning to become clear.

Methods

Seismic lines up to 350 km long have been established by firing explosives at sea - the charge sizes ranging up to 1250 lb - and recording on land where convenient, or with sonobuoys at sea. The equipment used on land are the very-low-frequency systems manufactured by SOUTHWESTERN INDUSTRIAL ELECTRONICS and by TEXAS INSTRUMENTS, in conjunction with 2 cycle/second geophones and on occasion WILLMORE seismometers. The sonobuoys used at sea are telemetring buoys designed by E.M.I. - COSSOR, DARTMOUTH, N.S. for submarine detection, but these are being modified as self-recording buoys by addition of tape-recorders, radio receivers and chronometers. All explosives have been fired electrically, on the sea-bottom or suspended at 100 metres depth.

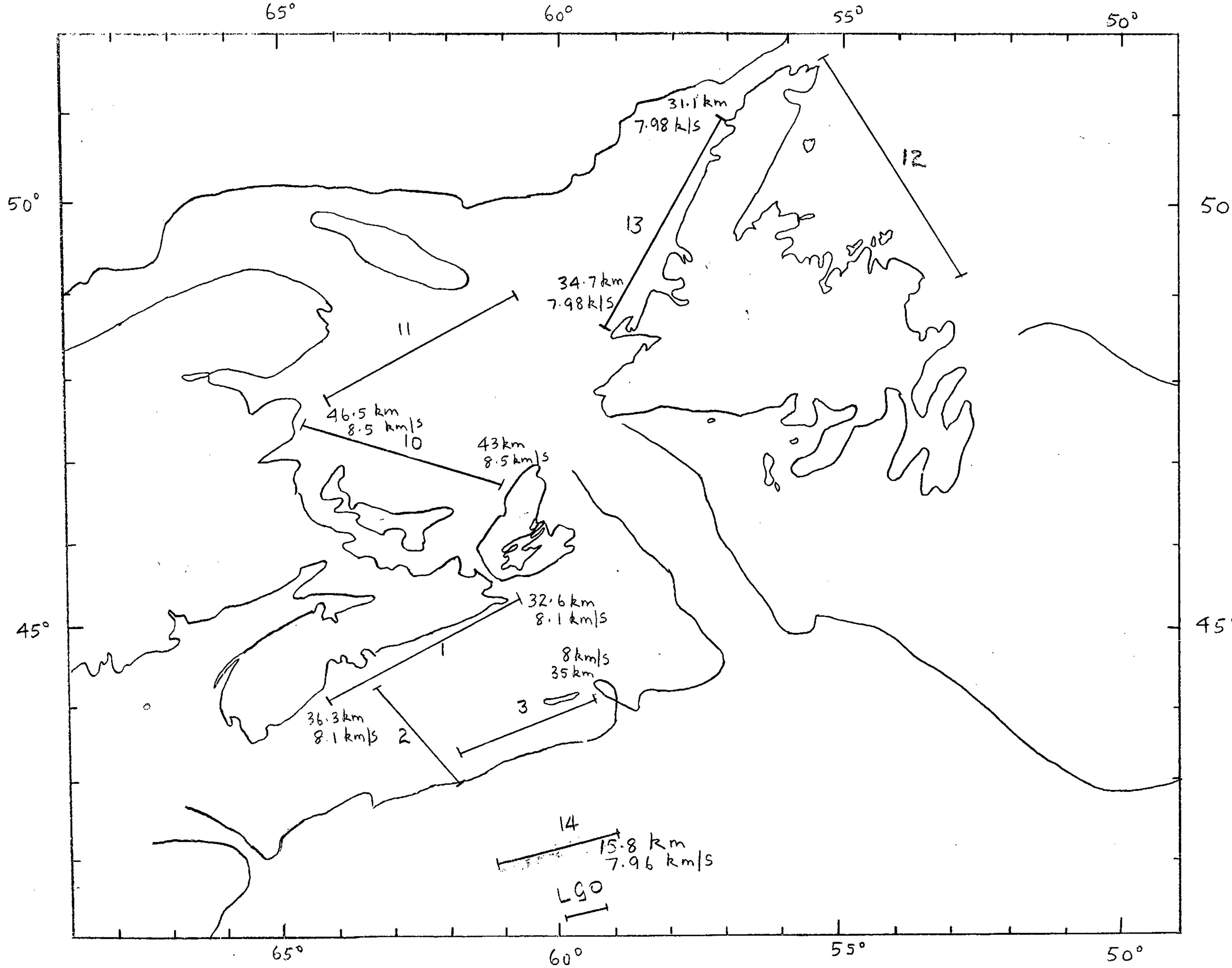


FIGURE 1

Seismic refraction profiles on the eastern seaboard

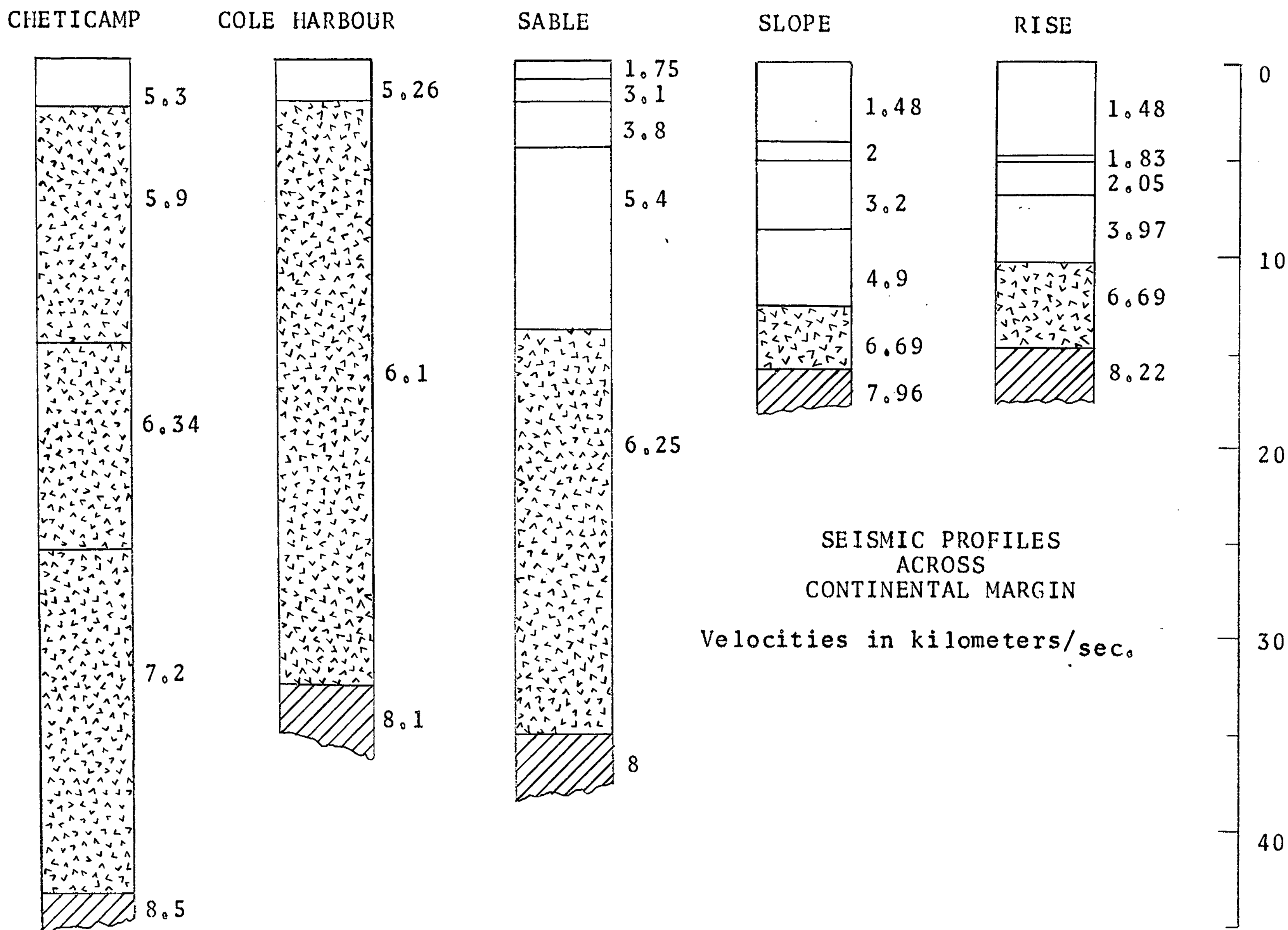

CHETICAMP
5.3
5.9
6.34
7.2
8.5
COLE HARBOUR
5.26
6.1
8.1
SABLE
1.75
3.1
3.8
5.4
6.25
8
SLOPE
1.48
2
3.2
4.9
6.69
7.96
RISE
1.48
1.83
2.05
3.97
6.69
8.22
0
10
20
30
40
SEISMIC PROFILES
ACROSS
CONTINENTAL MARGIN
Velocities in kilometers/sec.

FIGURE 2

Location of experiments

The location of the seismic lines are shown in Fig. 1. These were alined so far as possible in directions parallel to the predominent geological strike; clearly, in the Gulf of St. Lawrence this is not a well-defined direction, and northeast of Newfoundland the land for recording sites is not situated conveniently. In so far as the major problems of interpretation arise on the seismic lines in these areas the original principle seems good, but if the problems generated have solutions then more information is gained by siting the lines across the strike. Experiments along the Atlantic Coast of Nova Scotia have been repeated several times, because the structure of the crust there seems simple, and the area suitable for rather specific experiments.

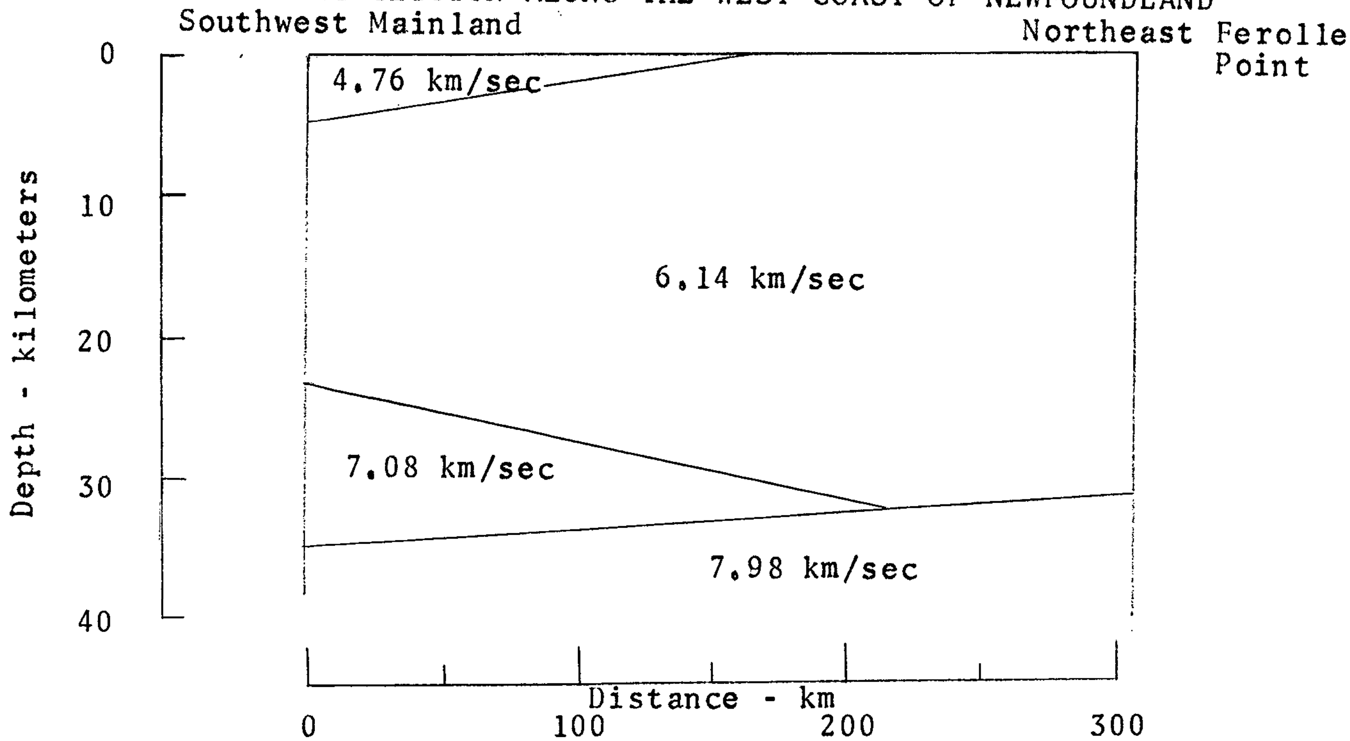
The crust and upper mantle

The interpretation of the time-distance data has initially been in the conventional manner, as for example has been described by Mota; the principal assumption of concern here is that boundaries between layers are plane.

The major part of the results is shown in Figs. 2, 3 and 4; note that one line labelled LGO and RISE is one published by LAMONT GEOLOGICAL OBSERVATORY. These figures illustrate two major conclusions. First, the change in thickness of the crust is abrupt at the continental margin - it appears to change from 16 km to 35 km thickness in about 100 km, from the seismic data alone, and in some tens of kilometres according to interpretations of gravity data in the same area obtained by B.D. LONCAREVIC. This structural picture may be as well-defined as the techniques will allow; the interpretation is critically dependent upon the depth to M beneath Sable Island, and whilst the data there were of poor quality because of recording conditions upon the Island, a check is provided by the seismic line perpendicular to the coast of Nova Scotia, off Halifax. And the quality of the data of this line is high. Also, one interpretation of the gravity measurements suggests that at some depth below M the density beneath the continent must be greater than that beneath the ocean basin. Second, the thickness and structure of the crust across the Appalachian system reflects the surface geology; the thickness changes from about 35 km beneath the Atlantic Coast of Nova Scotian and west Newfoundland, to about 45 km beneath the Gulf of St. Lawrence and beneath the central part of the Appalachian system northeast of Newfoundland. Moreover, there appears to be an "intermediate" layer of considerable thickness beneath the Gulf and northeast Newfoundland. Such a structural picture corresponds to the concept of a two-sided, symmetrical geosyncline developed by H. WILLIAMS of the GEOLOGICAL SURVEY OF CANADA; the seismic line west of Newfoundland is largely on the flanks of the geosyncline, and the line northeast of Newfoundland within this central mobile belt.

FIGURE 4

A SEISMIC SECTION ALONG THE WEST COAST OF NEWFOUNDLAND



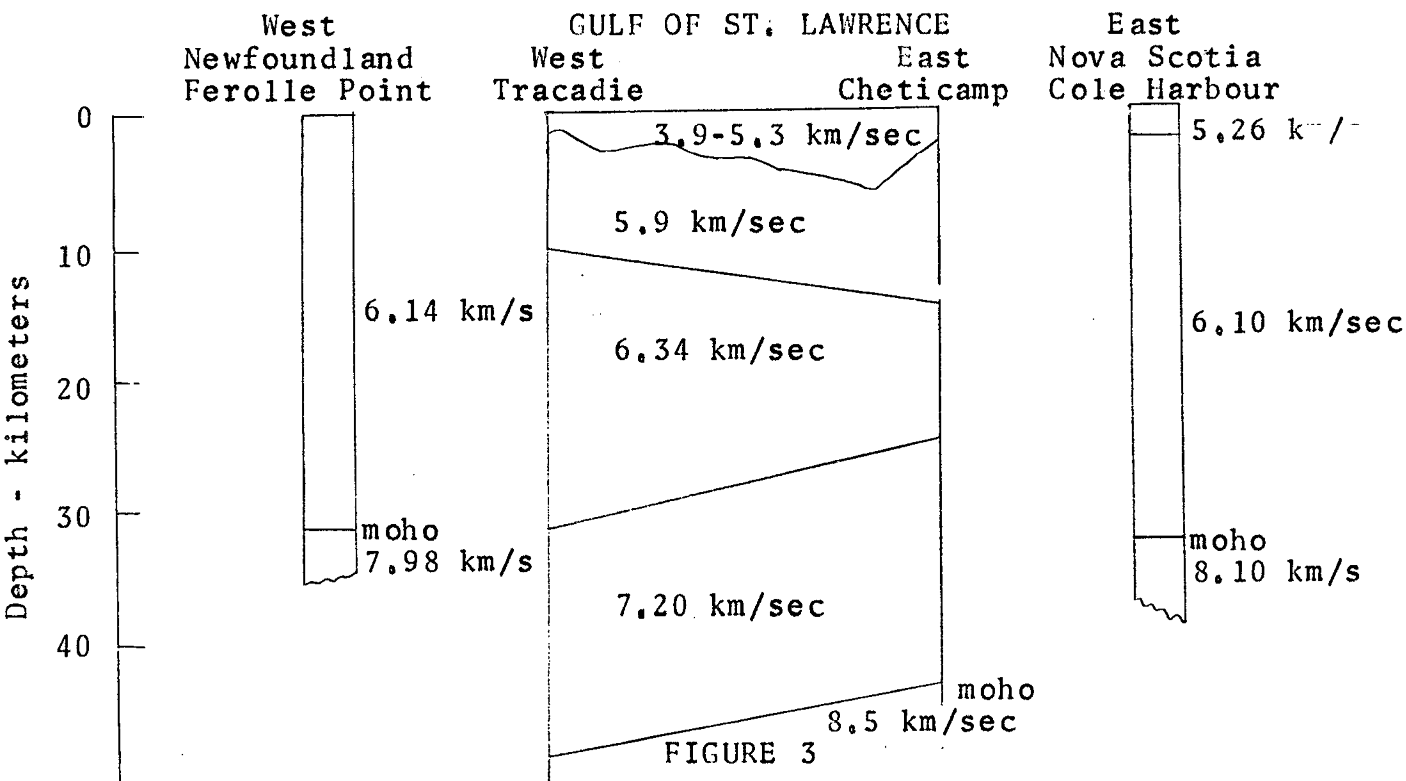


FIGURE 3

A SEISMIC SECTION THROUGH THE APPALACHIAN MOUNTAIN SYSTEM IN EASTERN CANADA

The "Logan Line", which divides the strongly deformed part of the geosyncline from the less deformed part deposited on the stable foreland formed by the Shield is seen just south of Anticosti Island (line 11, Fig. 1), and the change in thickness and structure of the crust must be abrupt in this region. The compressional wave velocity associated with the rocks of the upper part of the mantle beneath the Gulf and also beneath northeast Newfoundland is higher than one might anticipate - 8.5 km/sec and 8.7 km/sec. Here the problem of the assumption of plain layers rears its head, on which two comments may be appropriate. WILLMORE and SCHEIDEGGER observed a high apparent veolcity in their experiments in the Gulf of St. Lawrence, and further, if the true velocity is 8.1 km/sec then the crust must be thicker than the 45 km deduced from the values of 8.5 and 8.7 km/sec. To resolve this difficulty - an abnormally thick crust or an abnormal mantle - we hope to set up an experiment in and northeast of Newfoundland, parallel to the major northeasterly strike. However, if the mantle is abnormally dense beneath the thick crust of the central part of the Appalachian system, this could correspond to the results of interpretations of the gravity observations across the continental margin, which most reasonably demand, given our seismic control, a mantle more dense at depth beneath the continent than beneath the ocean basin.

Wave propagation, reflections and attenuation

Measurement of the amplitudes and frequencies of events which correspond in time to reflections from the M discontinuity have suggested to us that the discontinuity must be sharp - of the order of a few hundreds of metres in thickness. These suggestions have led to concern over the shape of the signals recorded as a seismogram. That attenuation of seismic waves increases with frequency is well-known, and this leads to broadening of the initial pulse recorded as the first event, for example, on the seismogram. This phenomenon can be quantitatively described, and leads to the suggestion that some of the rocks beneath the Gulf of St. Lawrence and beneath the Atlantic Coast of Nova Scotia may be different, even though their compressional wave velocities are approximately the same - in the neighbourhood of 6 km/sec.

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C.D. Hobson, Geological Survey of Canada, conducted refraction seismic studies of the sedimentary section off the west coast of Newfoundland. Two profiles were shot: 1) between Bonne Bay and St. Mary Island; 2) between Red Island and East Point, Anticosti Island.

The following studies are reported by the GEOLOGICAL SURVEY OF CANADA in Paper 65-1, Report of Activities: Field, 1964, published in 1965:

ANDERSON, D.T., Aeromagnetic-Photogeologic study of the Coulonge River (31K E1/2) Area: p. 113

BOYLE, R.W., Geochemical studies, Bathurst-Newcastle mineral belt: p. 123

The Shell Structure and Composition of Recent Molluscs from the Atlantic Coasts

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Although there has been considerable research on the shell morphology of recent and fossil molluscs, little attention has been given to the shell structure and composition. Shell material is an important source of sediment, and it has been suggested that it may be a useful source of palaeoecologic data. Previous authors have correlated shell structure and composition with genetic, ontogenetic and ecologic factors, especially temperature and salinity. Some of the conclusions are conflicting, and the analytical techniques that have been used are inadequate.

A project was initiated at SWANSEA UNIVERSITY, Great Britain in 1960 to study a number of recent species which were collected,