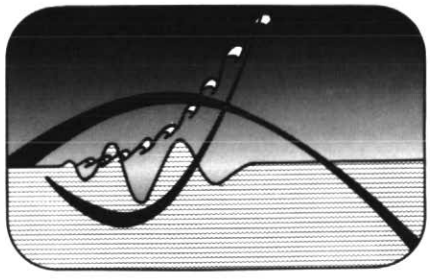
Conference Report



Workshop on Sea-Level Rise and Subsidence in the Maritimes

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Crustal contortion and ocean-level oscillation, with their manifold intervariations in terms of the apparent relative movement of land and sea over a broad region, are the subjects of a growing number of studies, the goal being to develop a theory to explain the many motions where several causes are implicated. Apparent sea-level changes as they express independent movements of land and sea, are being assessed by means of an international effort entitled "Sea-Level Changes of the last 15,000 years", a "key" project (no. 61) of the joint UNESCO-IUGS International Geological Correlation Programme. It was in the context of this newly focussed attention on the topic of sea level variation, and collaboration between geophysicists and Quaternary geologists, that David Scott and Chris Beaumont (Dalhousie Univ.) invited to a workshop in the Oceanography Department on January 10, 1977, all workers in the Atlantic region who have been studying these phenomena. The informal gathering was well attended and, from the exchange of information and ideas, progress was made toward understanding observed features in terms of modern geophysical theory.

The region is experiencing rapid vertical movement. Level lines are tilting and no longer level, there is an apparent sea-level rise of about 30 cm per century, and faulting of Late Pleistocene and Holocene age has been recognized. Applications of this knowledge range from prediction of coastal erosion (and loss of revenue) to geodetic corrections, and from quantification of mantle properties to estimates of site stability for nuclear installations.

The presentations of individual participants are treated below as they relate to "a synopsis of Quaternary crustal delevelling and sea level change" contributed by the writer. Apart from changes of sea level *per se*, a variety of mechanisms have been deforming the region. The continental margin is tilting seaward by subsiding at 5 to 10 m per million years by epeirogenic subsidence which is known from the age and depth of marker horizons in the Mesozoic-Cenozoic sedimentary wedge that forms the continental shelf. This slow sinking has been modulated by the effects of recent glaciations, both by perturbations of crustal load as glaciers moved, and by fluctuations of sea level position.

An important datum for measuring the effects of isostatic adjustment relating to the last glaciation, as well as the degree of present crustal disequilibrium, is the +2 to +6 m emerged rock bench cut as an intertidal platform probably during the last interglacial period. It has been mapped in southern Nova Scotia, around Cape Breton Island, and in southeastern Newfoundland. Except for the Mic Mac Terrace in St. Lawrence estuary, which may be a possible correlative, the feature is unknown throughout the central part of the region, and is therefore a crucial factor in any general theory of crustal warping. C. M. Tucker (McMaster Univ.) reported on his progress in differentiating this bench from similar features of glacial and post-glacial age on Burin Peninsula, southern Newfoundland. There, an excellent opportunity exists to quantify the spatial relations, and hence the subsequent deformation of sea-level stands dating from several episodes during the last 100,000 years.

Tilted shorelines up to 130 m above present sea level are the most obvious indicators of crustal delevelling. Assuming these were all formed and isostatically raised during glacial recession from only the last stadial maximum, D. Wightman (Dalhousie Univ.) presented an isopleth map of the local maxima ("marine limit") and concluded that the ice load was not attributable simply to the Laurentide Ice Sheet, but consisted of two regional ice domes having relatively little influence in central Gulf of St. Lawrence compared to that on the land masses. This agrees with Grant's hypothesis, based on independent evidence of ice limits, that Late Wisconsinan glaciers, fed from a complex of local ice caps, flowed toward the Gulf but failed to cover large areas of Cape Breton and the Magdalen Shelf, as well as high or outlying coastal parts of Newfoundland. Hence, in such areas beyond the last glacial limit, shorelines of previous postglacials (namely interstadials and interglacials) may be found. Therefore, as Wightman and Tucker stressed, it is essential to determine, if not their precise age, then at least which glaciation the shorelines belong to, so that meaningful maps of

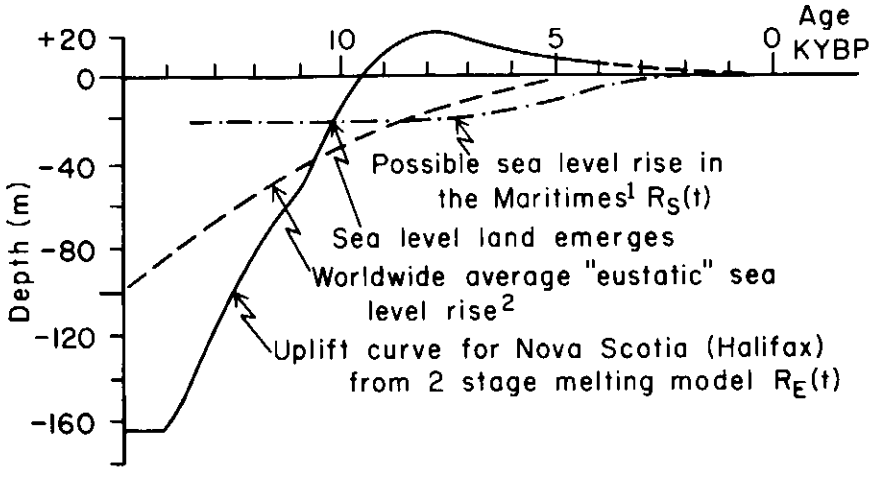
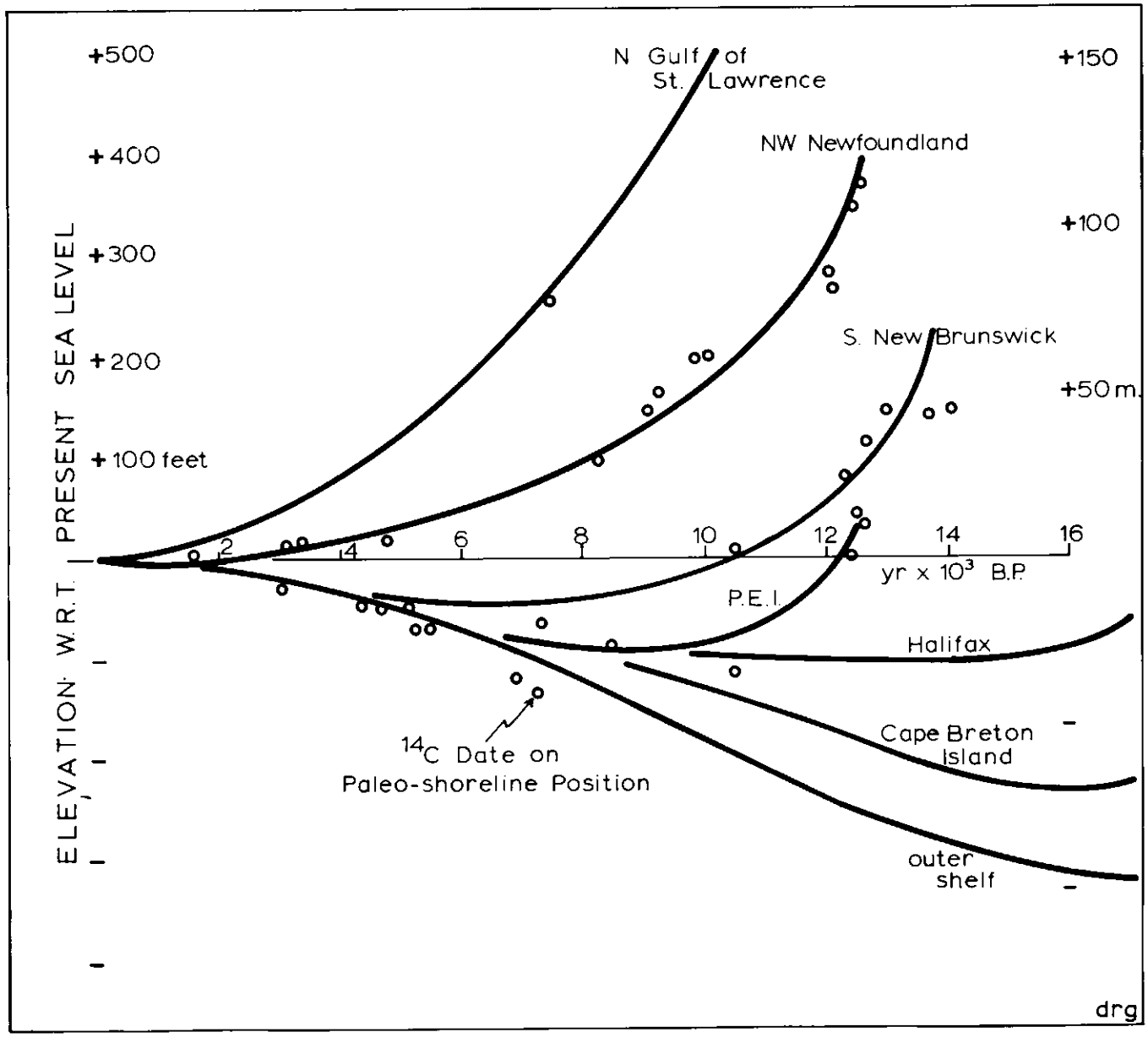


Figure 1
Diagrammatic Post-Glacial rebound and sea level rise for Halifax (C Beaumont)

Figure 2
Local variations of relative sea-level change, illustrating the interplay of eustatic recovery, subsidence and isostatic rebound (D R Grant)



post-glacial delevelling can be constructed.

This problem bears especially on the interpretation of submerged shorelines, such as those discussed in Northumberland Strait by K. Kranck (Atlantic Oceanographic Lab.). There, several well-developed (intertidal?) marine planation surfaces at about 20 m, 27 m, 37 m, 50 m, and 70 m below sea level, for which a few radiocarbon dates on covering sediments are available, appear to reveal uplift with tilting up to the northwest, succeeded by subsidence during the last 7000 years. However, the older or deeper two of the series are found only in the eastern approaches to the strait off Cape Breton, and hence may lie beyond the limit of Late Wisconsin glaciers. These are not dated, and may therefore mark either relative sea-level stands of the last stadial or eustatic maxima of former interstadials.

Any analysis of crustal warping based on displaced shorelines depends mainly on dating of organic material that is known to have formed contemporaneously with the feature for which the paleo-sea-level position is known. John Armon (McMaster Univ.) dealt with the various ways by which spurious datings of both emerged and submerged strandlines result from redeposition of older shell material into *bona fide* littoral sediments. Clearly the best data for paleo-sea-level study will come from beach deposits containing a fossil molluscan fauna in growth position. Such conditions rarely prevail except for example in the offlap sequence of western Newfoundland where, because of the carbonate terrane, Pleistocene shells are abundant and well preserved, and the collector is thus able to be very discriminating.

During most of the Holocene the early postglacial uplift and emergence has been offset by subsidence and submergence. The resulting transgression has, over the past several millenia, caused thick estuarine wedges of salt-marsh mud to accumulate over forest remains. A chronology of rising sea level was thus produced by D. R. Grant from datings of the submerged tree stumps. Recently, other techniques are being employed to extend and refine the chronology. A. Palmer (Environment Canada) described his work on diatom stratigraphy and dating of lagoonal deposits created behind a barrier at Basin Head, P.E.I. that had prograded, and been built upward 11 m during the last 4000 years. D. Scott (Dalhousie Univ.) explained his improved method of recognizing former tide levels - that of dating narrow horizons in salt-marsh sediments whose precise relationship to sea level is recognized from foraminiferal assemblages unique to specific tidal levels. In this way Scott has derived different subsidence rates for several Nova Scotian localities.

The submergence is not everywhere due entirely to subsidence, however. From the sedimentology and chronology of corings through Minas Basin intertidal muds, C. Amos (Atlantic Geoscience Centre) found that currents increased markedly after 5000 years B.P. probably due to greater tidal range, thus supporting an earlier hypothesis that Holocene sea level rise in Bay of Fundy was largely due to tidal amplification following submergence of Georges Bank.

Perhaps the most significant contribution was that by C. Beaumont (Dalhousie Univ.) who presented a geophysical model of postglacial isostatic response, which incorporated the recent concepts that eustatic recovery is non-uniform and largely reflects geoidal configuration, and that the rate of postglacial crustal recovery depends on the subcrustal viscosity profile. Solving his equation relating uplift to glacial retreat, local meltwater accession, and gravitational attraction (Fig. 1) he found that Halifax for example would rise for 6000 years then subside for the last 8000 years.

In summary, the region was differentially affected by the variables determining the postglacial recovery of sea level and crustal equilibrium, namely the distance behind or beyond the glacier margin, and the date and rate of retreat. To illustrate the local character of crustal response as expressed by change of relative sea level, a family of curves extrapolated from numerous dated shorelines is presented (Fig. 2). Areas well beyond the ice margin, like the outer shelf, have had a submergence owing to eustatic rise and forebulge collapse. Areas near the ice margin like Prince Edward Island, and southern parts of Newfoundland and New Brunswick first emerged until isostatic uplift waned and then subsided and submerged for the last 7000 years. Farther north, western Newfoundland and probably also Gaspé (judging by its distance from the ice margin) emerged until recent centuries when the approaching forebulge brought stability or slight submergence. The northern Gulf is just now completing the uplift phase.

Recent advances in the concepts of isostasy and eustasy, new notions of glacial limits in the region, and the results of this workshop in particular make possible now a more enlightened approach to field studies aimed at gathering the most relevant data bearing most directly on the manifold aspects of crustal and sea-level adjustment in the region.

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