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CLIMATIC EVIDENCE FROM SEA-LEVEL FLUCTUATIONS

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Introduction

The ecological changes that result from coastal changes brought about by sea-level fluctuations will not be discussed. Some of these are reasonably self evident, for example the severance of once continuous land into islands during rising sea level. On the other hand, the part played by sea-level change in the production of coastal dunes is not so clear. Such changes together with alterations in coastal currents may be ecologically important but they affect only small coastal areas.

It is generally agreed that sea level has been at least 200–300 ft. lower and higher than the present at different times during the Quaternary, and that these large eustatic changes have been due to major advances and retreats of ice sheets. For example, during glaciation much water, normally returned to the oceans, is locked on land as ice and as a result sea level falls. As we are discussing postglacial climatic changes within New Zealand the major changes in sea level are less important than the superimposed minor changes. Do these have any significant meaning for local climatic changes? First of all we must examine the reliability of the postglacial sea levels.

Postglacial Eustatism

The study of sea-level change is complicated by: local crustal movements; tidal changes, if there has been major coastal change; changes in coastal profiles and regimes; compaction of sediments; and reliability of radiocarbon dates. All agree, however, that since 10,000 years ago ocean levels rose approximately 100 ft., reaching about the present level at some time between 3000 to 6000 years ago; and that sea level is rising now. With these few facts all agreement ceases.

The main point at issue is whether there was a postglacial period when sea level was up to 10 ft. higher than the present. This is still widely accepted, the more active proponents being those who also believe in minor fluctuations of sea level. For instance, Fairbridge (1961a) has massed world-wide data along an impressive sea-level curve (Fig. 1), but he has been often uncritical of the evidence. After examining and culling his evidence (Schofield, in press) insufficient is left statistically to bolster some of

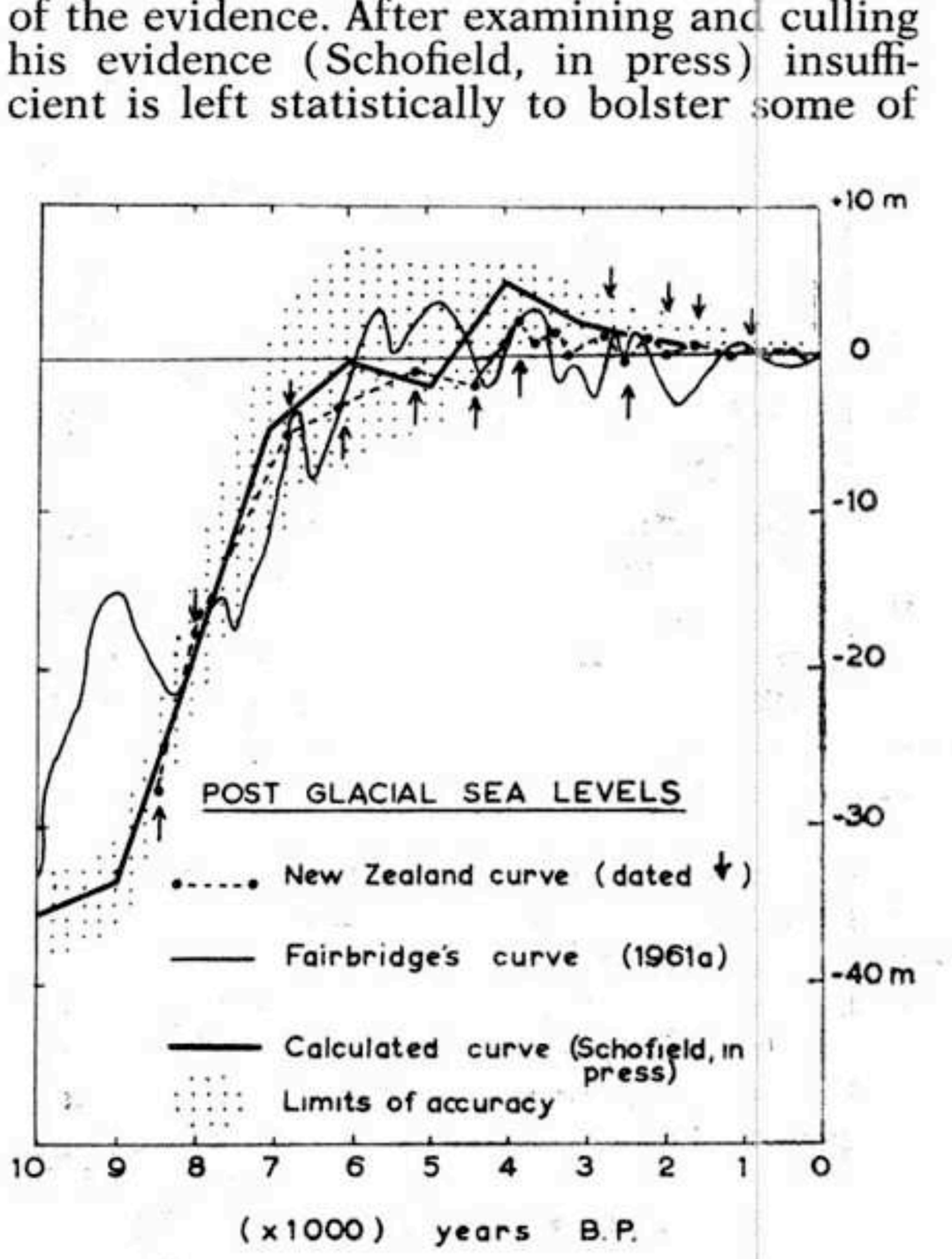

FIGURE 1. *Postglacial sea levels, after Fairbridge (1961a) and Schofield (in press).*

the minor fluctuations shown. Nevertheless, work on the beach-ridge system within the Firth of Thames (Schofield 1960 and in press) shows that Fairbridge may be right in concept if not necessarily in detail. The Firth of Thames area warrants further study, its advantages being that: each sea level is generally based on three lines of evidence, and that there is a reasonably complete sequence of events preserved in the one area. The latter may not at first appear significant but it is far easier to deal with '*x*' bedevilments at one locality than with '*xy*' bedevilments at '*y*' localities. The investigations at the Firth of Thames show that sea level was 7 ft. above the present nearly 4000 years ago and that several minor fluctuations have been superimposed upon the fall to the present-day level.

The other school of workers (*e.g.*, McFarlan 1961, Shepard 1961, Newell 1961) thinks that sea level was never higher than the present within postglacial times. Their evidence is mainly drawn from probably the two most thoroughly investigated areas on the globe, the Mississippi Delta region and the coast of Holland. However, these same workers freely admit that both these areas are subsiding due to local instability of the crust. A subsiding crust produces a local relative rise in sea level, and although allowances can be made it is difficult to understand how antagonists to a formerly high sea level can maintain their position.

It is important to know which is correct, for if there was no postglacial sea level higher than the present that could be correlated with a "world-wide, postglacial climatic optimum", then a knowledge of minor fluctuations in sea level may be useless for climatic studies.

There is one other field of evidence for a postglacial maximum in sea level, arising from the well-studied, raised strandlines of Scandinavia. These raised coastlines owe their present position to sea-level fluctuations and a rapidly rising earth-crust brought about by isostatic rebound; but these two factors have been separated by Dr H. R. Thompson of the Applied Mathematics Laboratory, N.Z. D.S.I.R. (Schofield, in press). Not only does the resultant isostatic-rebound curve make sense but the sea-level curve makes sense in showing a high sea level about 4000 years ago as well as being close to all other New Zealand eustatic data (Fig. 1). Thus, although possibly still biased, I believe that an objective appraisal of the present evidence suggests that there has been a postglacial high sea level. Once this is accepted then the minor fluctuations that succeeded it may also be acceptable.

RELATION OF CLIMATE TO MINOR SEA-LEVEL FLUCTUATIONS

The study of the relation, if any, of climate to minor sea-level fluctuations raises two questions. Are minor sea-level fluctuations climatically controlled, and if so, can sea-level changes be interpreted in terms of local climatic changes?

Climate probably does control minor sea-level fluctuations on two counts. Increased temperatures, and/or a decrease in precipitation in their source areas, cause glaciers to retreat and the water so released is added to the oceans causing a rise in level. There is a good correlation between present sea-level rise and retreat of the majority of the world's glaciers (Thorarinsson 1940). At the same time increased air temperature over the oceans would increase their temperatures and make them expand. Brooks (1950) calculated that an average rise of 5°F. in ocean temperature would raise sea level by 5 ft.

With our present knowledge, minor sea-level changes can apparently not be related to minor *local* climatic changes. A climatic optimum has been demonstrated in many parts of the earth's surface: for instance, in Sweden 6000 years ago (Fries 1951); Alaska 5400 years ago (Karlstrom 1961); West U.S.A., 3000–8500 years ago (Heusser 1961); Hudson Bay, 5000–6000 years ago (Flint 1956); New Zealand, 2500–6500 years ago (Harris 1963); and in South America, climatic phases including the optimum are considered synchronous with those in Europe (Hammen and Gonzalez 1960). Although there has probably been a climatic optimum in postglacial times throughout

the world, it is another matter whether or not it reached a peak, or ranged over a lengthy period of time, or if it was perfectly synchronous, but this matters little at the moment for we are uncertain of the time or duration of the sea-level maximum of about the same period. Fairbridge's (1961a) sea-level curve shows several peaks at about plus 10 ft. within the period of 3750–5750 years ago, and Godwin (1961) suggests that postglacial transgression of the sea ceased between 3600 to 5000 years ago. New Zealand eustatic data and the sea-level curve calculated from Scandinavian data show one single peak about 4000 years ago. Thus, although both the climatic and sea-level maxima appear of about the same age, much more needs to be known about the reliability of the ages and of the actual sea levels before we can be certain of the exact relationships.

The present rise in sea level coincides with the retreat of most of the world's glaciers, but up to at least 1938 (Thorarinsson 1940) some European glaciers were at the same time advancing and hence the rise in sea level cannot be directly related to purely local climatic changes. More strikingly, Calder (1961) shows that the mean annual temperature during 1940–50 dropped a maximum of 4°F. in North Siberia, but elsewhere rose 1°F. and more. The latter includes most of Europe and the U.S.A., but over the bulk of the earth's surface, including most of the ocean space, temperatures fell during this period.

Nevertheless, agreement that minor sea-level fluctuations are due to an aggregate effect of changes in climate throughout the world, forms a basis for ultimate determination of local climatic changes. This, however, requires a detailed knowledge of climatic-pattern changes wrought by any alteration in climate. Some progress towards this end is being made (*e.g.*, Willett 1949, Schove 1961, Fairbridge 1961b) but it may be some time before there can be a satisfactory correlation of minor sea-level fluctuations with minor local changes in climate.

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