PRINCIPLES OF MARINE LEVEL CORRELATION

BY

DOUGLAS JOHNSON

COLUMBIA UNIVERSITY

REPRINTED FROM

THE GEOGRAPHICAL REVIEW

VOL. XXII, No. 2, APRIL, 1932

Pp. 294–298

AMERICAN GEOGRAPHICAL SOCIETY

BROADWAY AT 156TH STREET

NEW YORK

PRINCIPLES OF MARINE LEVEL CORRELATION

Douglas Johnson
Columbia University

IN the summer of 1931 the writer undertook, with the support of the American Geographical Society, the Carnegie Institution, and Columbia University, a reconnaissance study of marine terraces and other real or supposed elevated shore features from Rhode Island down the Atlantic coast to Florida and around the Gulf coast to Texas. No attempt was made to examine all supposed marine forms now found above sea level along this extended belt of coast, but many of the best-known features were examined, often with the aid of and in company with those who had previously given them detailed study. Only a brief summary of results is presented here. For a somewhat fuller statement the reader is referred to the forthcoming *Comptes Rendus* of the International Geographical Congress held at Paris in 1931. A detailed discussion of the whole problem is in preparation for publication at a later date.

The objects of the investigation were three in number:

I. To discover the cause or causes of the widely divergent views now held with regard to marine level correlation in eastern North America.

II. To establish, if possible, some general principles of shore-line correlation which might help toward the solution of this difficult problem.

III. To give, if feasible, an answer to the question as to whether the ancient marine levels of the region investigated are horizontal or inclined.

I. Causes of Divergent Views

With respect to the first point, it appears that the existing wide differences of opinion respecting correlation of marine levels in America arise from a variety of causes, among which only a few are mentioned here.

1. *The searching for evidence in support of a single working hypothesis.* This method of investigation, always open to objection, is peculiarly dangerous when employed in the correlation of ancient marine levels. Coastal regions usually preserve so many traces of real or supposed shore lines that a sufficient number of benches, cliffs, gravel deposits, or other features may be found sufficiently near any given level to lend apparent but often fictitious support to almost any theory favored by an investigator.

2. *Using as a basis of correlation forms that are of no real significance.* It has not infrequently happened that facts observed on maps or discovered by profiles have been interpreted as indicating the existence of ancient shore lines, when they will bear equally well an alternative interpretation devoid of any special significance. An example is the citation of belts of country parallel to the shore in which the hilltop elevations are about the same as proofs of marine terracing, when the same phenomenon may characterize a normally dissected sloping coastal plain or peneplane.

3. *Using as a basis of correlation really significant features that are, however, of nonmarine origin.* Flood-plain bars, natural levees, stream-cut escarpments, faults or monoclinal warpings, partially submerged stream divides, and Indian shell mounds have all been, in one place or another, assigned a marine origin and used as a basis for fixing ancient sea levels.

4. *Failure to fix ancient water planes, with respect to real marine features of certain types, by any uniform method.* Different observers will, for example, place the water level at widely different heights with respect to an ancient offshore bar; and the same observer will place the water level at widely different parts of different bars.

5. *Fixing ancient water planes at similar parts of terraces having entirely different origins.* In the case of two terraces *A* and *B*, Figure 1, it has quite naturally hap-

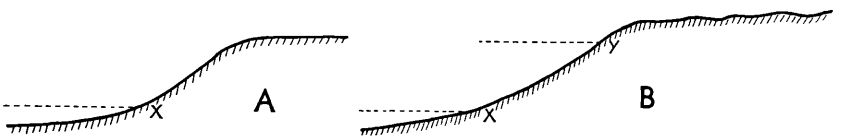

FIG. 1—Destructional terrace (*A*) and constructional terrace (*B*) compared.

pened, in view of their close resemblance, that the former water plane for each has been fixed at the level *X*. Now if *A* is a destructional terrace, formed where the waves cut into the sloping surface of the coastal plain, the water level may correctly be placed at *X*. But if *B* is a constructional terrace, built forward into the sea like Cape Canaveral or the Dungeness, the ancient water plane should be located not at *X*, but at *Y*.

6. *Using a range of terrace level nearly as great as, or even greater than, the inter-terrace range.* If the range of one supposed dissected terrace is given as 180–220 feet, and of the next higher as 280–340, it is evident that we must expect, on analyzing maps or profiles, to find that in one case nearly half, in the other case more than half the hilltop elevations will fall within the supposed terrace belt, parallel to the sea, even if we are dealing with a simple, unterraced upland sloping toward the shore.

7. *Failure of authors to state the precise significance of the figures given for terraces described by them.* When it is merely stated that there is a terrace with an elevation of from 190 to 240 meters, this may mean a variety of things. Attempts to correlate terraces when the true significance of the available figures is unknown must lead to confusion.

8. *Employing the elevation of nonsignificant parts of terraces.* If an ancient wave-cut cliff (*A*, Fig. 2) is elevated above the sea, and waves of a new sea level

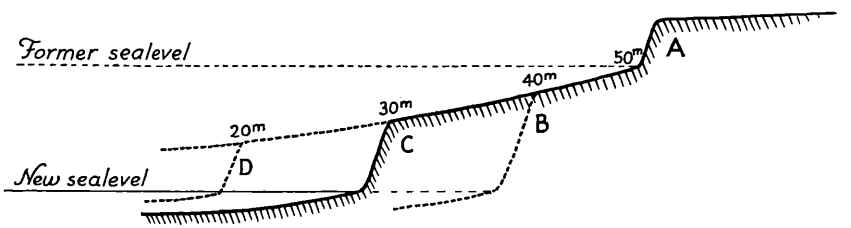

FIG. 2—Erosion terrace cut in former sea floor.

later cut a new cliff (*C*) into the sloping ancient sea bottom, we have a terrace, *CA*, on which it is quite useless to give the elevation (say 30 meters) of the front margin at *C;* for obviously the height of the front margin is fortuitous. Had the sea cut in less (*D*) it would be but 20 meters; had it cut in more (*B*) it would be 40 meters. The only figure worth recording, the only significant figure, is the elevation of the rear margin of the terrace, at the base of the ancient cliff, in this case say 50 meters.

9. *Failure to record all of the terraces or other marine features in a given area.* If the investigator who believes in the existence of a 100-meter terrace and a 200-

meter terrace emphasizes only the terraces having approximately those elevations, the case (Fig. 3) may appear very strong for eustatic changes of sea level, or for uniform uplift of the land, even if some of the terrace areas are weakly developed. But when all terrace remnants for each locality are fully represented, the case for tilting of the land may appear as strong or even stronger (Fig. 4).

10. *Attempting correlation on the basis of the degree of stream dissection.* Time and altitude are not the only factors that determine degree of dissection. Nearness

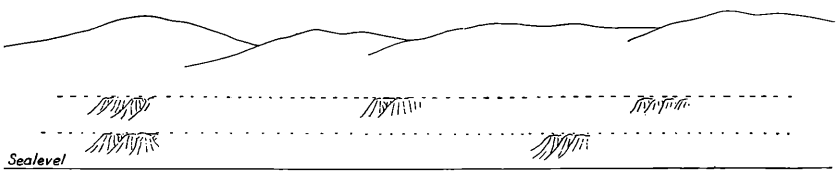

FIG. 3—Correlation of only part of the evidence of ancient marine levels here permits the inference that there are remnants of two horizontal elevated shore lines. Compare with Figure 4.

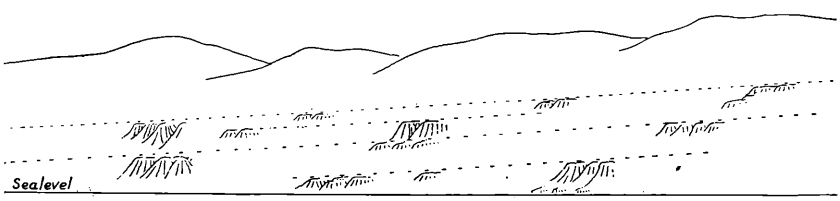

FIG. 4—This figure reproduces the data shown in Figure 3 but with additional data indicating the existence of a greater number of inclined shore lines.

to streams, character of subsoil, quality and quantity of vegetation, amount of precipitation—these are some of the other factors entering into the problem.

11. *Attempting correlation on the basis of the degree of weathering of soils or gravels.* Here again the question of many variable factors enters, and the method of correlation seems unsafe.

12. *Basing correlations on barometric determinations of altitude.* A very faint slope, not determinable by barometric methods, may be significant of the origin of a terrace. In Connecticut certain terraces thought to be quite horizontal on the basis of barometric readings, and therefore assigned to a glacio-lacustrine origin, were by our surveys shown to be uniformly inclined toward the south.

13. *Attempting correlations on the basis of marine levels reported in the literature.* Studies of ancient marine levels have not yet reached the degree of precision and uniformity in methods of investigating and reporting field phenomena that makes dependence on the literature a safe basis of correlation.

There are other causes of differences in opinion regarding correlation of former marine levels, in addition to the thirteen cited above. But these are sufficient to make clear the great difficulty of the problem.

II. Principles of Marine Level Correlation

With respect to the second object of our reconnaissance, I am not so presumptuous as to imagine that we can, at this early stage of our studies, lay down a set of principles that will adequately suffice for all studies of marine level correlation. I can, however, suggest some principles that are being employed to guide our investigations. These are gladly submitted to the criticism of our colleagues engaged in similar studies.

1. *Recognize fully the extreme difficulty of the problem.* The geomorphologist who fails to realize the intricacy of the problem of correlating ancient marine levels, and who therefore fails to proceed with the caution requisite to the extraction of truth from a maze of conflicting and often dubious evidence, is sure to go astray.

2. *Admit on absolutely equal footing these four working hypotheses:* (*a*) The ancient levels result from eustatic drops of sea level. (*b*) The ancient levels result from uniform uplift of a large block of the earth's crust. (*c*) The ancient water

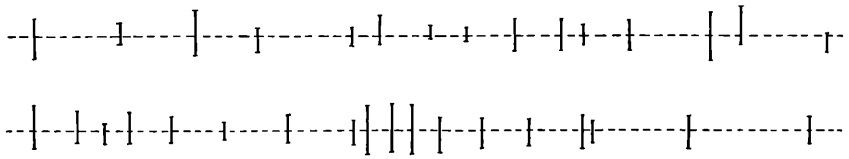

FIG. 5—Correlation of maximum possible ranges (heavy vertical lines) of ancient water planes for different marine features, suggesting eustatic lowerings of sea level or uniform uplifts of a large crustal block.

In Figures 5, 6, and 7, the heavy vertical lines show possible vertical ranges of water planes for different observed marine features (terraces, bars, cliffs, etc.). The horizontal (Fig. 5) or inclined (Figs. 6 and 7) dashed lines show assumed correlations of these ranges.

levels may be due to differential warping of the earth's crust. (*d*) The ancient levels may result from a combination of two, or even of all three of the above-mentioned causes.

3. *Eliminate from consideration all but undoubted marine forms.* The inclusion in the evidence of doubtful features that happen to "fall in line" with previously determined levels gives a false appearance of strength to a theory which may lead the investigator far in the wrong direction.

4. *Determine by accurate instrumental methods the true elevation of each undoubted marine feature at the greatest possible number of points.* A basis of accurately determined facts is essential to the solution of the problem. Slight differences in elevation may be of critical value in determining the true history of shore forms.

5. *From the data thus secured determine the full possible range of the water plane for every marine feature at each individual locality,* absolutely without regard to other localities and without regard to any presupposed altitudes of such water planes.

6. *In making the foregoing determination of possible ranges of water planes, give full consideration to every marine feature, whether weakly or strongly developed.* Omission of any feature deemed unimportant by the investigator introduces into the analysis the personal and subjective element, prejudges the conclusion, and is almost sure to falsify the result. It is well known that the same shore feature may be poorly developed in one place and strongly developed in another.

7. *Correlate the ranges of water planes thus determined,* rather than the elevations of the terraces and other marine forms. Unless the possible ranges of water planes, rather than the actual elevations of marine features, are correlated, the result will not represent full consideration of all the possibilities of the case and may seriously falsify the conclusions.

8. *The correlation of water planes envisaged above is to be made on any one of several principles:*

(*a*) Continuity of planes. Unfortunately, except in special cases or for limited areas, a given water plane cannot be continuously traced for great distances, because the marine features from which the range of the water plane is calculated are themselves fragmentary and widely dispersed.

(*b*) Identity of elevations. If the possible ranges of water planes appear substantially identical over a great expanse of territory, as shown in Figure 5, differential warping would appear to be eliminated and the probable interpretations reduced

to two: eustatic changes in sea level or uniform movement of a large block of the earth's crust.

(*c*) Regularity of spacing. The possible ranges of water planes may show regularity of spacing, involving identity of spacing without identity of elevation,

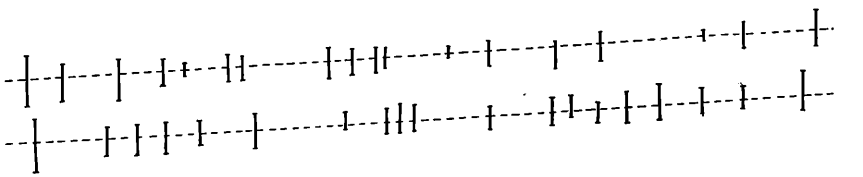

FIG. 6—Correlation of ranges of water planes suggesting eustatic drop of sea level followed by upwarping of the land.

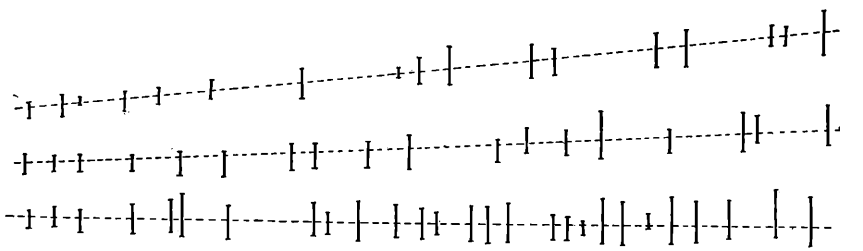

FIG. 7—Correlation of ranges of water planes suggesting differential upwarpings of the land without evidence of eustatic changes of sea level.

as in Figure 6. In this case differential warping would appear to be demonstrated, preceded by eustatic shifts of sea level or the uniform movement of a large crustal block.

On the other hand, the regularity of spacing may occur without either identity of spacing or identity of elevation, as shown in Figure 7. In this case eustatic shifts of sea level would appear to be eliminated or rendered indeterminate, while differential warping would be demonstrated.

(*d*) Irregularity of spacing, defying analysis, may be the ultimate result. In this case it will be difficult to eliminate with certainty any one of the four working hypotheses mentioned above, yet equally difficult to prove the validity of any one.

III. Attitude of Ancient Shore Lines

With respect to the third and incidental object of the reconnaissance, it is too early as yet to give an answer to the disputed question as to the attitude, horizontal or inclined, of the ancient shore lines found along the Atlantic coast of North America. At present all that can be said with assurance is that the studies thus far made by different observers do not appear to us conclusive as to the validity of any theory respecting correlation and attitude of ancient marine levels in America. In our opinion the question is still an open one.