

120789

R.e
342[REPRINTED FROM *The Geographical Review*, FEBRUARY, 1917. VOL. III.]

IS THE ATLANTIC COAST SINKING?

By DOUGLAS W. JOHNSON

More than half a century ago Professor George H. Cook, then state geologist of New Jersey, presented striking and apparently convincing evidence that the Atlantic coast of North America was gradually subsiding at the rate of two feet per century. Farm lands under cultivation fifty years before were, at the time of his investigation, covered with salt marsh grasses; old corduroy roads were encountered several feet below the surfaces of salt marshes at many points along the shore; and, within the memory of men then living, the ocean waters had risen so high upon the wheels of tidal mills that their operation had become difficult or impossible. The scientific manner in which Professor Cook presented his arguments gained for him not only the respect of geologists in all parts of the world but a very general acceptance of his interesting conclusions.

Independent investigation of the shores of England, southern Scandinavia, the Netherlands, and France convinced many geologists in those countries that the Atlantic coast of Europe was suffering a subsidence similar to that of the North American coast. On both sides of the North Atlantic, therefore, there has long existed a conviction that the land is slowly but surely sinking beneath the ocean waters. In America in particular it has been accepted as a well-established fact that a subsidence of from one to two feet per century is still in progress.

On various occasions the writer has discussed the supposed evidences of recent coastal subsidence along the Atlantic coast of the United States and southeastern Canada, and has presented reasons for believing that the so-called proofs of land sinking within historic times were open to alternative explanations, whereas the physiographic evidence could only be explained by postulating long-continued coastal stability. Studies on the eastern and southeastern coasts of England, the coast of Holland, and the coast of southern Sweden indicated that in like manner the supposed proofs of recent subsidence in those regions were open to criticism, while the physiography of the English and Swedish coasts furnished convincing evidence that the relative level of land and sea had not changed appreciably for many hundreds of years. A careful study of numerous reports by French observers detailing the evidence of a recent progressive subsidence of the western coast of France led to the conclusion that this evidence was not of such a character as to establish the subsidence theory; but the writer made no personal examination of this coast.

The apparent evidences of subsidence are so striking, and the conclusions in favor of recent coastal stability, in the localities in question, are so radically opposed to the long-held opinions of most geologists and geog-

raphers, that it will be profitable to review briefly some of the latest contributions to this interesting problem. We may mention first some foreign studies and then return to investigations of our own coast.

Professor Jules Welsch of the University of Poitiers has recently applied to the study of the western coast of France the same methods of interpretation outlined in the writer's "Fixité de la côte Atlantique de l'Amérique du Nord"¹ and has published his conclusions in a paper entitled "Fixité de la côte du Centre-Ouest de la France."² This clearly written and well-illustrated report analyzes at length the supposed proofs of recent subsidence upon which earlier investigators have placed reliance, criticizes other evidence which led certain students to infer a recent elevation of the land, and finally presents physiographic evidence of long-continued coastal stability. His conclusion is expressed in the words, "There is no proof of a submergence or an emergence of the coast since the Neolithic epoch, that is to say, during the last few thousand years."

In a paper on "Den Formodede Littorina-Saenkning i Norge"³ Professor Hans Reusch discusses supposed proofs of a late post-glacial subsidence of Norway, particularly of the southern part of the coast. The evidence is largely in the form of submerged peat deposits, such as have frequently been cited by American students as indicating recent subsidence of our own coast. Professor Reusch shows that in each case the field relations are easily susceptible of an alternative explanation.

The Report of Progress of the Ordnance Survey of Great Britain, detailing operations up to March 31, 1916, contains results of precise leveling which are pertinent to the present discussion. I quote the following from the section on geodesy: "In the year 1837-38 a line of accurate leveling was executed by Mr. Bunt, in order to compare the mean sea-level of the Bristol Channel with that of the English Channel, and also to enable subsequent leveling to determine whether there had been any vertical movements of the land surface. . . . In the year under review, 78 years after the original operation, the line was very carefully releveled. . . . The difference between the two results for the length of 58.87 miles between Perry Farm and Axmouth is 1.12 inches. . . . The probable error of the new geodetic leveling from Perry Farm to Axmouth, as calculated from the discrepancies between fore and back leveling, is 0.17 inch. The probable error of Doctor Whewell's leveling of the same line, calculated in the same way, works out at 1.88 inches. . . . The chief result of the comparison is that there is no indication that there has been any change in the relative levels of the coast lines of the Bristol Channel and English Channel during the 78 years that have elapsed since Doctor Whewell's leveling was carried out."

¹ *Annal. de Géogr.*, Vol. 21, 1912, pp. 193-212.

² *Annal. de Géogr.*, Vol. 23, 1914, pp. 193-218.

³ *Norges Geol. Undersøk. Aarbok*, 1915, Art. 4, 19 pp.

In the Summary Report of the Geological Survey of Canada for the year 1914, published in 1916, there is a synopsis of the results secured by Professor J. W. Goldthwait in his physiographic work in Nova Scotia. From this it appears that Professor Goldthwait examined the old fortress at Louisburg, the position of which is so often asserted to prove a recent sinking of the land. The present writer had previously secured a report upon this locality through an assistant, Dr. Donald Barton, who was unable to find any evidence of a change of level in the vicinity of the fort. Professor Goldthwait reaches the conclusion that "there has been no sinking or rising of the coast at this place during the last two centuries."

Dr. D. S. McIntosh, professor of geology in Dalhousie University, Halifax, has just published an interesting article entitled "A Study of the Cow Bay Beaches."⁴ A number of drumlins near Halifax have been eroded by the sea, and with portions of the erosion products the waves have constructed a series of beach ridges. Examination of the rings of growth of stumps on the oldest ridge fixes its minimum age at about 150 years. Inasmuch as the crest of the oldest beach ridge has about the same altitude as that of the modern ridge, the author concludes that "these beaches are the effect of waves upon a stationary coast—one which has remained so for at least a hundred and fifty years."

A paper by Dr. J. W. Spencer on "Postglacial Earth-Movements about Lake Ontario and the Saint Lawrence River"⁵ contains a section on the "present stability of the lake region," in which occurs a table of the mean differences of level between two permanent benchmarks at Port Colborne and Cleveland, 160 miles apart, as deduced from the daily records of lake-level for a period of 57 years. Such a table is of interest because of the possibility, or even probability, that any subsidence or elevation of the land would be accompanied by a warping which would be revealed by a change in the relative levels of two points so far apart. No such change is apparent. Doctor Spencer concludes: "From a full study it is apparent that there has been no change of level in 57 years. . . . These results disprove my original suggestion (1894) that the Niagara discharge would be turned into the Mississippi in the not distant future. This idea was expanded into a monograph on earth-movements by Dr. G. K. Gilbert, who used the fluctuations of the lakes; but in so doing he took the levels of a few isolated days, irregularly selected. The erroneous results derived therefrom have been widely quoted, but the table given above contains the proof of the present stability of the lake region."

In connection with his study of the New Jersey coast, the present writer desired to ascertain whether there had been any warping or tilting of the state, such as might be expected to accompany the rapid subsidence generally believed to be in progress all along the New Jersey shores. He accord-

⁴ *Trans. Nova Scotian Inst. of Sci.*, Vol. 14, 1916, Part I, pp. 109-119.

⁵ *Bull. Geol. Soc. of Amer.*, Vol. 24, 1913, pp. 217-228.

ingly suggested to the state geologist the desirability of re-surveying certain lines of precise level in the southern part of the state, where the supposed evidence of subsidence was most striking, in order to determine whether the relative elevations of Atlantic City, Vineland, and Cape May Court House, three points of a triangle 30 miles on a side, had undergone any change since the important surveys of 1886. The leveling was done in 1911, and the results published the following year.⁶ In the accompanying table the essential facts are made clear:

Place	Elevations in feet above sea-level		
	1886	1911	Difference
Cape May Court House.....	19.498	(19.498)	0.0
Vineland.....	108.100	108.082	-0.018
Atlantic City.....	8.954	8.931	-0.023

The agreement between the levels of 1886 and those of 1911 is extremely close and is well within the limits of the probable error of the observations. It is clear, therefore, that there has been no warping or tilting in the southern New Jersey region during the last quarter of a century.

Similar lines of level were run in the northern part of New Jersey in 1915, and the results are summarized in the Annual Report of the State Geologist, published the following year. The important conclusion so far as the present discussion is concerned occurs in the statement: "During the period of about 30 years intervening between the several series of levels, there has been no appreciable change in relative elevations at the seashore and in Sussex and Warren Counties (points from 40 to 50 miles apart), due to tilting of the earth's crust."

Special importance attaches to the results of precise leveling prosecuted under the direction of the Chief Engineer of the City of New York in recent years, because the results obtained enable one to determine not only whether there has been any warping or tilting of the land in the vicinity of New York, but also, with equal certainty, whether or not the land mass as a whole has subsided. The data summarized below are taken from the report on "Precise Leveling in New York City," by Frederick W. Koop, published in 1915.

In 1887 a bench-mark on a monument at Perth Amboy was found to be 18.5763 meters above mean sea-level at Sandy Hook, and in that same year a bench-mark on a sea wall at Willets Point, 33 miles distant to the north-east, was determined as 4.3083 meters above the same datum plane. In 1911 Mr. Koop connected these points by a line of precise levels which showed that the relative positions of the two bench-marks had changed by an apparent amount of but 1.2 millimeters, or .004 feet. The slight apparent difference is less than the probable error of the earlier survey and proves that on a line 33 miles long no warping or tilting has occurred in the last quarter of a century.

Absolute elevation or subsidence of the land would be detected by com-

⁶ Report on Leveling, *Geol. Survey of New Jersey Bull.* 6, pp. 18-21, 1912.

paring the absolute elevations of certain bench-marks in 1887 with the absolute elevations of those same bench-marks in 1911. It is not possible to make such comparisons with sea-level at the same point, because the tide gage at Sandy Hook, which furnished the datum plane in 1887, is no longer operating; while the tide gage at Fort Hamilton, which has been used to determine the modern datum plane, was not operating in 1887. Careful studies have, however, convinced Mr. Koop that mean sea-level has the same elevation both at Sandy Hook and Fort Hamilton, so that comparison between the two surveys can be made with accurate results. The following table gives the apparent differences in elevation of certain bench-marks after a lapse of 24 years, together with the differences which ought to exist if the land had been sinking at the rate of 1 foot or 2 feet per century, as commonly supposed. All differences are expressed in millimeters.

<i>Bench-mark at</i>	<i>Apparent difference in 24 years mm.</i>	<i>Expectable difference, assuming 1 foot subsidence per century mm.</i>	<i>Expectable difference, assuming 2 feet subsidence per century mm.</i>
Bay Ridge, Brooklyn.....	-0.5	78.0	146.0
Bath Beach, Brooklyn.....	-1.2		
East 84th Street, Manhattan....	-0.7		
Willels Point, Long Island.....	-1.2		
College Point, Long Island.....	+3.7		

When one considers that the probable error in determining mean sea-level at Sandy Hook was ± 9.1 millimeters, it is seen that all the apparent differences are well within the limits of error of observation; whereas the expectable differences according to the subsidence theory are so great that no errors of observation could obscure the subsidence, were it really in progress.

If the reader will pardon the personal reference, I will quote Mr. Koop's final conclusions verbatim: "From the determinations above noted, which are the result of spirit leveling of unquestioned accuracy, it is clear that from the standpoint of the geodesist or engineer there is no reliable evidence to show a general progressive subsidence of the Atlantic coast in New York City and vicinity. On the contrary, all the evidence is in favor of stability. The work of the writer on the Board of Estimate leveling must be construed as a striking confirmation of Professor Johnson's theory of coastal stability as set forth in the preceding paragraphs. It is of especial interest because it is a proof based on engineering methods of the absolute stability during the last quarter of a century of the very part of the coast which is generally supposed to be undergoing most rapid subsidence at the present time."