THE INTERNATIONAL SCIENTIFIC EXPEDITION TO THE WEST INDIES IN 1932

by

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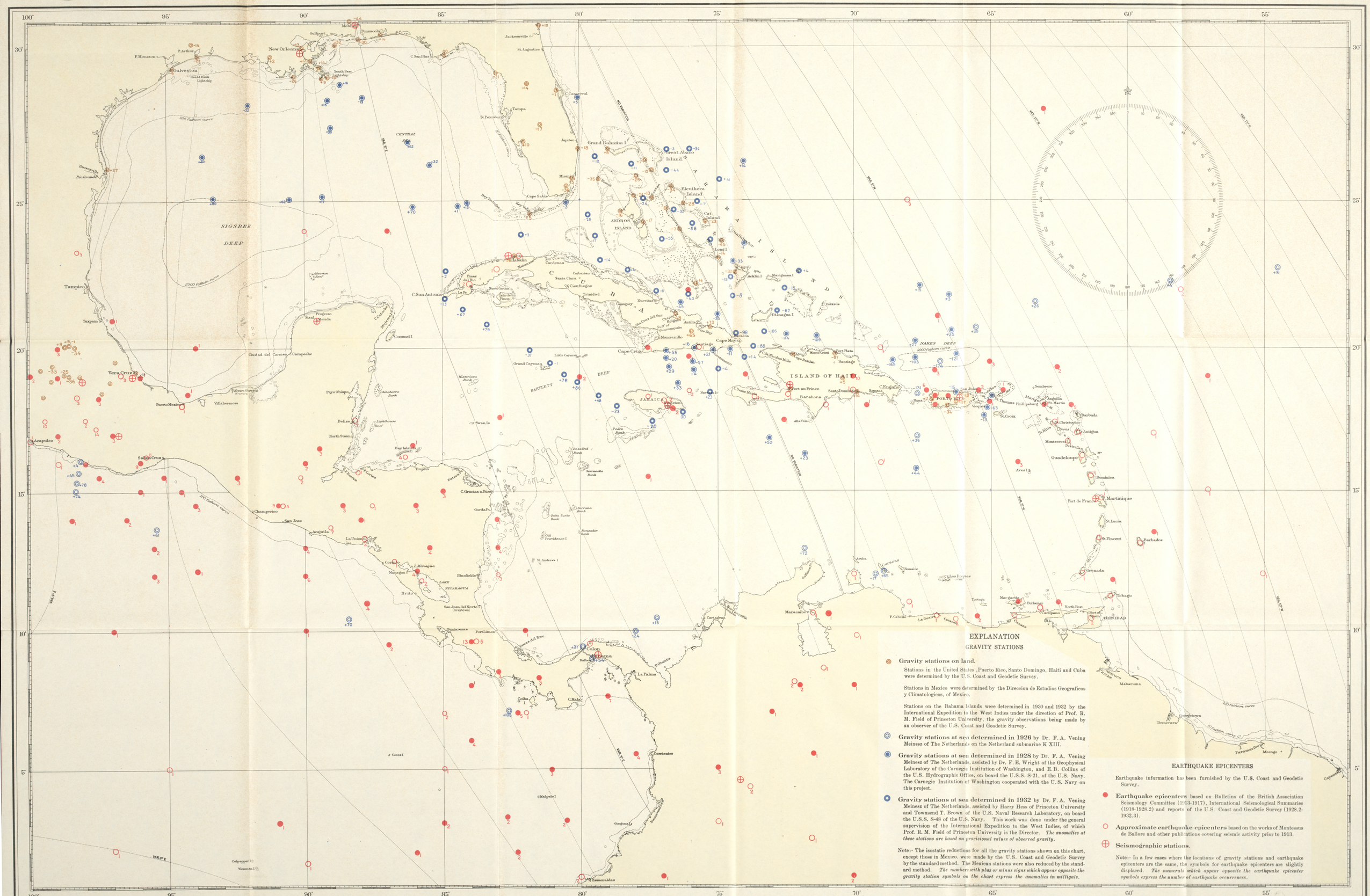
Anterior operations of the International Scientific Expedition to the West Indies had drawn attention to the archipelago of the Bahamas as a region of eminent and peculiar earth-structure. During field season in the winter of 1930 and 1931, along with the investigations of the geologists, the chemists and the biologists observations were in progress, through the cooperation of the U. S. Coast and Geodetic Survey, to measure the intensity of gravity at six selected stations. The principal facts disclosed by these measurements including the supplementary observations made at Miami in Florida, are set forth as follows:

PRINCIPAL FACTS AT GRAVITY STATIONS, BAHAMA ISLANDS (1930)

STATION.	LATITUDE LONGITUDE	ELEVATION.	THEORETICAL GRAVITY (BOWIE Formula). γ	CORRECTION FOR ELEVATION.	CORRECTION FOR TOPOGRAPHY & COMPENSATION.	COMPUTED GRAVITY. g_c	OBSERVED GRAVITY. g	ISOSTATIC ANOMALY. $g - g_c$
	° ′	Metres.	cm./sec.^{2}	cm./sec.^{2}	cm./sec.^{2}	cm./sec.^{2}	cm./sec.^{2}	cm./sec.^{2}
North Bimini	25 43.51 79 18.37	2	979.010	—0.001	+0.041	979.050	979.015	—0.035
Billy Island	24 38.95 78 30.65	1.5	978.936	0.000	+0.038	978.974	978.958	—0.016
Great Stirrup Cay	25 49.73 77 53.44	14	979.018	—0.004	+0.067	979.081	979.056	—0.025
Nicolls Town	25 08.25 78 00.32	5	978.969	—0.002	+0.054	979.021	979.000	—0.021
Mangrove Cay	24 16.00 77 40.54	1.5	978.910	0.000	+0.048	978.958	978.941	—0.017
Nassau	25 05.04 77 21.00	4	978.966	—0.001	+0.073	979.038	979.025	—0.013
Miami (Fla.)	25 42.82 80 15.12	7	979.009	—0.002	+0.032	979.039	979.034	—0.005

The most striking feature of the results in this tabulation is that the anomalies in the intensity of gravity are negative in each and every instance. The large majority of the island stations of the world which have been established in the past have shown positive anomalies. In most cases the

EARTHQUAKE EPICENTERS AND GRAVITY ANOMALIES
IN THE
GULF OF MEXICO, CARIBBEAN SEA AND ADJACENT REGIONS



EXPLANATION

GRAVITY STATIONS

Gravity stations on land.

Stations in the United States ,Puerto Rico, Santo Domingo, Haiti and Cuba were determined by the U.S. Coast and Geodetic Survey.

Stations in Mexico were determined by the Direccion de Estudios Geograficos y Climatologicos, of Mexico.

Stations on the Bahama Islands were determined in 1930 and 1932 by the International Expedition to the West Indies under the direction of Prof. R. M. Field of Princeton University, the gravity observations being made by an observer of the U.S. Coast and Geodetic Survey.

Gravity stations at sea determined in 1926 by Dr. F. A. Vening Meinesz of The Netherlands on the Netherland submarine K XIII.

Gravity stations at sea determined in 1928 by Dr. F. A. Vening Meinesz of The Netherlands, assisted by Dr. F. E. Wright of the Geophysical Laboratory of the Carnegie Institution of Washington, and E.B. Collins of the U.S. Hydrographic Office, on board the U.S.S. S-21, of the U.S. Navy. The Carnegie Institution of Washington cooperated with the U. S. Navy on this project.

Gravity stations at sea determined in 1932 by Dr. F. A. Vening Meinesz of The Netherlands, assisted by Harry Hess of Princeton University and Townsend T. Brown of the U.S. Naval Research Laboratory, on board the U.S.S. S-48 of the U.S. Navy. This work was done under the general supervision of the International Expedition to the West Indies, of which Prof. R. M. Field of Princeton University is the Director. *The anomalies at these stations are based on provisional values of observed gravity.*

Note:- The isostatic reductions for all the gravity stations shown on this chart, except those in Mexico, were made by the U.S. Coast and Geodetic Survey by the standard method. The Mexican stations were also reduced by the standard method. *The numbers with plus or minus signs which appear opposite the gravity station symbols on the chart express the anomalies in milligals.*

EARTHQUAKE EPICENTERS

Earthquake information has been furnished by the U.S. Coast and Geodetic Survey.

Earthquake epicenters based on Bulletins of the British Association Seismology Committee (1913-1917), International Seismological Summaries (1918-1928.2) and reports of the U.S. Coast and Geodetic Survey (1928.2-1932.3).

Approximate earthquake epicenters based on the works of Montessus de Ballore and other publications covering seismic activity prior to 1913.

Seismographic stations.

Note:- In a few cases where the locations of gravity stations and earthquake epicenters are the same, the symbols for earthquake epicenters are slightly displaced. *The numerals which appear opposite the earthquake epicenter symbols express the number of earthquake occurrences.*

Small corrections from Notices to Mariners; from other sources:

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ocean islands are of igneous origin, and, for this reason, positive anomalies of gravity at island stations have been attributed to vulcanism.

In making the isostatic reduction at a gravity station, the effect of the topographic masses on gravity at the station is computed and there is also computed the effect of the isostatic compensation of the topography. The topography is the mass of materials that is above sea level and the deficiency of mass in the ocean waters. Necessarily, in computing the attractive effect of the topography, values must be assigned to the densities of the topographic material. The material above sea level is given a density of 2.67. This is the density used also for computing the deficiency of density that extends from sea level to the deepest parts of the ocean. The topography for the ocean areas is the difference between a mass of rock of 2.67 density equal in volume to the water and the water, which has a density of about 1.01. The compensation, as is well known, is the deficiency of mass under land areas and the excess of material under water areas, which, if isostasy is perfect, exactly balances the topography above. The compensation extends to a depth of approximately 60 miles below sea level. The depth of compensation used in the isostatic reduction for the Bahama and Florida stations was 113.7 kms., approximately 70 miles, but the anomalies would be changed only slightly if 60 miles were used instead.

The values of the anomalies vary from −0.13 dyne, at Nassau, to −0.035 dyne at North Bimini. The other values lie between these two. The station which should be most characteristic for the Great Bahama Bank is Billy Island which lies almost in the center of the bank. It will be noticed that it has a negative value of 0.016 dyne. One can readily visualise what an anomaly of a certain sign signifies if it be kept in mind that a disk of material with a density of about 2.7 which is 30 feet in thickness and of indefinite horizontal extent will have an attraction of 0.001 dyne on a unit mass. Therefore, the −0.016 dyne at Billy Island could be caused by a deficiency of 30 times 16 or 480 feet of rock immediately below the station.

It seemed to be reasonably certain from the evidence thus made available that the Bahamas were not built by igneous action. Knowledge as to just what the structure is remained dependent on additional evidence.

Giving the stations on the Bahamas equal weight, it was found the average is −0.021 dyne. This is equivalent to the attraction, in a negative sense, of a disk rock about 630 feet in thickness and of 2.67 density. Even though this average negative anomaly might indicate a lack of isostatic equilibrium for the Bahama Bank region, yet, even so, the negative mass which could cause this average anomaly is comparatively small.

In making the reductions, of course, account was taken of the great depth of water in the Tongue of the Ocean and in the Northeast Providence Channel. In the latter there are depths of more than 2000 fathoms. The depths of the water in the Straits of Florida are as great as 500 fathoms.

The necessity thus confronting the Expedition of discovering the distribution of the intensity of gravity in the deep channels running through the Bahama archipelago and in the bordering high seas of the West Indies brought an emissary of Princeton University, the American sponsor of the Interna-

tional Scientific Expedition to the West Indies, to the Navy Department in Washington. Since measurements of the intensity of gravity require the ascertainment of the time of oscillation of a pendulum and since such a measurement on the sea can only be made in a vessel fitted to be submerged below the zone of agitation that characterizes the surface of the sea, to surmount the barriers to progress encountered by the Expedition necessitated coming to the door of some Navy, because it is only in the naval services of nations that submarine vessels are maintained.

Remembering that the interpretation of evidences respecting submarine configuration and earth structure in the West Indies had been elucidated by the employment, in 1928, of a submarine vessel of the United States Navy to conduct sea-observations of the intensity of gravity, at the request of the Carnegie Institution of Washington, the interest of the Hydrographic Office was attracted to the problems of the International Scientific Expedition to the West Indies, with a view of obtaining the assignment of a suitably attended submarine vessel of the United States Navy to operate for the determination of the distribution of the intensity of gravity at selected stations in the waters surroundings Jamaica and Cuba and in the channels running through the Bahama archipelago as well as in the bordering high seas.

The misfortune which resulted in the destruction of the non-magnetic ship *Carnegie* at Samoa in 1929 involved the loss of the specially designed pendulum apparatus which had been brought from Holland for the observation of the intensity of gravity at sea. This loss has since become the means of illustrating the international nature of the Navy-Princeton expedition to the West Indies, for Dr. F. A. VENING-MEINESZ of the Netherlands Geodetic Commission, distinguished for his achievements in gravity observations in the United States submarine *S-21* in the West Indies expedition of 1928 and in the Royal Dutch submarines of the Netherlands Navy in world-encircling cruises, joined the present Expedition at the instance of Princeton University, in January of this year, bringing with him from Holland the multiple-pendulum apparatus of his invention for the purpose of completing the instrumental installations for accomplishing the desired results in the United States submarine *S-48*.

Embarked in this submarine vessel and in the United States submarine rescue ship *Chewink*, the Expedition enveloped the Island of Cuba during the month of February, proceeding through the waters south of Jamaica and around the western end of Cuba and returning to the point of departure at the Guantanamo Naval Station. In the course of this circuit, of 2.000 miles in length, 27 gravity-at-sea stations were occupied, and continuous profiles of the conformation of the bottom of the sea along the route leading from one to another of the stations were delineated by means of closely spaced echo-soundings.

The Expedition passed to the Bahama region toward the close of February, and the month of March was devoted to the delineation, through the waters of that archipelago, of profiles aggregating 2,300 miles in length, and to the determination of the intensity of gravity at 27 sea stations, to complement

and complete the gravimetric survey of the Bahama archipelago, which was meanwhile proceeding by the occupation of pendulum stations on the islands by the United States Coast and Geodetic Survey.

The prime desideratum in pendulum observations of supplying means to ascertain the exact duration of the counted total of oscillations of the pendulum was met by the Naval Observatory whence special time signals were sent to the Expedition throughout the term of its operations, which included the periods of calibration of the multiple-pendulum apparatus at the base-gravity station established at the Naval Research Laboratory by connection with the world-base at Potsdam, Germany.

Four charts have been drawn up (*) to show, in a distinctive manner, as large a proportion as the scale of construction would admit of the echo-soundings taken by the U. S. S. *S-48* and the U. S. S. *Chewink*, moving in parallel courses at a distance apart no less than two miles throughout the route of the Expedition. As registered in these charts the values of the depths have been uniformly derived by considering 800 fathoms per second to be the velocity of sound in sea-water.

A fifth chart has also been printed (**) by the Hydrographic Office containing the values of the anomalies of gravity at the stations occupied by the International Scientific Expedition to the West Indies derived from the provisional computations that have been made pending the final reduction of the values of the intensity of gravity, together with the anomalies resulting from other gravity-at-sea expeditions in the West Indian region and from stations occupied on land in the United States, Puerto Rico, Santo Domingo, Haiti, Cuba and Mexico, besides the distribution of the epicenters of earthquakes recorded within these geographical limits.

(*) U. S. H. O. Charts N° 373, 944, 948 & 2145.

(**) H. O. Miscel. Chart N° 7941 - Earthquake Epicenters and Gravity Anomalies in the Gulf of Mexico, Caribbean Sea and adjacent regions - 1st edition, June 1932 (preliminary).