thrust faults. Possibly both the subaerial and the submerged troughs were deepened by vertical movements later than the folding, probably of the same age as the movements that produced the high-angle normal faults at the edge of the Trois Rivières Valley trough. This narrow trough would be a striking feature if submerged, but such troughs bounded by normal faults are unusual in the Republic.

EARTHQUAKES.

By Wendell P. Woodring.

Records Available.

Earthquakes are frequent in the Republic, as in other parts of the Tertiary equatorial geosyncline. During the history of the colony and of the Republic disastrous earthquakes have at times almost or completely destroyed Port-au-Prince, Cap-Haïtien, and other cities. Different parts of the Republic have had distinct seismic histories, and an attempt is here made to correlate the seismic phenomena with the known tectonic features. The information on which this attempt is based was obtained from records and accounts published by Rev. J. Scherer, Directeur de l'Observatoire Météorologique du Séminaire-Collège St.-Martial, Port-au-Prince. M. Scherer deserves the highest praise for his patience in collecting records and for his striking accounts of the disastrous shocks and of their relation to the surface and to the geologic features. His publications are as follows:

Les grands tremblements de terre dans l'île d'Haïti: Observatoire Météorologique du Séminaire-Collège St.-Martial Bull. semest., July-Dec., 1911, pp. 153-162, 1912. An English translation of this article was published in the Bulletin of the Seismological Society of America, vol. 2, pp. 161-180, map, 1912.

Les tremblements de Terre de l'île d'Haïti dans leurs rapports avec le relief du sol et les fosses maritimes qui l'entourent: Observatoire Météorologique du Séminaire-Collège St.-Martial Bull. semest., July-Dec., 1912, pp. 132-139, 1913.

Catalogue chronologique des tremblements de terre ressentis dans l'île d'Haïti de 1551 à 1900: Observatoire Météorologique du Séminaire-Collège St.-Martial Bull. semest., July-Dec., 1913, pp. 147-151, 1914. This catalogue is based principally on the following two catalogues: Poey y Aguirre, Andrès, Catalogue chronologique des tremblements de terre ressentis dans les Indies Occidentals de 1530 a 1858; suivi d'une bibliographie séismique concernant les travaux relatifs au tremblements de terre des Antilles: (Extrait de l'annuaire de la Société Météorologique de France, tome 5, p. 75, séance du 12 Mai, 1857) 76 pp., Versailles, 1858; and Tippenhauer, L. Gentil, Liste der Erdbeben auf Haiti: Die Insel Haiti, pp. 170-175, Leipzig, 1893.

Tremblements de terre observés en Haïti de l'année 1901-1910: Observatoire Météorologique du Séminaire-Collège St.-Martial Bull. ann., année 1920, pp. 100-104, 1921.

In addition to these accounts and catalogues, M. Scherer has published records of shocks in the Bulletins of the Observatoire. The Bulletins appeared semiannually from the last half of 1909 to the end of 1916, and

annually since 1917. The records are based on observations made by M. Scherer in Port-au-Prince and by correspondents at twenty-three other localities, namely: Cap-Haïtien, Borgne, Port-de-Paix, Bassin-Bleu, Gros-Morne, Môle St.-Nicolas, St.-Michel de l'Atalaye, Pilate, Gonaïves, Mirebalais, St.-Marc, Thomazeau, Gantier, Fond-Verrettes, Petionville, Furcy, Petit-Goave, Anse-à-Veau, Jérémie, Tiburon, Cayes, Bainet and Jacmel.

This list is based on the list of stations published in the bulletin for 1921, which is the latest bulletin now available. At times records were kept at Grande-Rivière du Nord, Bahon, Dondon, Bayeux, l'Arcahaie, Miragoâne, Dame-Marie, and Chardonnières.

Beginning with the bulletin of July-December, 1911, the records of a seismograph installed at the Observatoire have been published. The seismograph is the Omori-Bosch horizontal pendulum type, recording southeast-northwest and southwest-northeast movements magnified 40 times. This instrument is very useful in registering distant shocks, but it is useless for determining the direction and amplitude of local shocks. There is an immediate need in Haiti for instruments designed to register local shocks. Such instruments should be installed first at Port-au-Prince and Cape-Haïtien, and later at other places, particularly Môle St.-Nicolas and Anse-à-Veau.

The analysis of the seismic phenomena is divided into two parts, as the records gathered from different parts of the Republic by M. Scherer since 1909 are much more detailed than the records before 1909. Shocks that originated in the Dominican Republic or elsewhere are not considered.

Disastrous Earthquakes from 1551 to 1908.

During the early colonial period (1630-1750), after the French and English buccaneers had driven out the first Spanish settlers, the principal towns were on Tortue Island, along the north coast, at Petit-Goave, near the present site of Léogane (founded in 1712), and at St.-Louis du Sud. During the late colonial period (1750-1803), Cap-Haïtien was the largest city, but Port-au-Prince was already established and the present cities and towns grew gradually.

During the colonial period and the early period of the Republic only earthquakes that affected the administration of the government or the means of livelihood of the people were recorded. Even in such records only the destruction in the larger cities would be noted. Masonry and brick buildings, whose destruction during earthquake shocks causes the greatest havoc, are most numerous in the cities, and many of the larger cities are built wholly or in part on alluvium, which is more susceptible to the effect of shocks than bed rock or residual soil, particularly where ground water is near the surface. For these reasons, as Scherer has pointed out, records of the effects produced in the cities and in the more thickly populated alluvial plains, where the destruction was greatest, are the only

records that have come down to us. Little is known of the intensity of even the most disastrous shocks in the hilly country districts. But as cities were widely distributed even in the late colonial period, the intensity of disastrous earthquakes as indicated by their effects in the cities may be safely used in determining their origin. Moreover, the results of a study of the records of the disastrous shocks from 1551 to 1908 agree closely with the results of a study of the more complete records from 1909 to 1922.

From 1551 to 1908 there were seven disastrous earthquakes that apparently originated in the Republic of Haiti or under the sea near its shores. Many less severe shocks were recorded, most of them in the large cities, particularly in Port-au-Prince, but the records are of no value in determining the places of their origin.

On May 7, 1842, Cap-Haïtien, Port-de-Paix, and Môle St.-Nicolas were completely destroyed by the most disastrous earthquake recorded along the north coast. Cap-Haïtien was then and had been during the colonial period the most beautiful city in the Republic, and the accounts of the destruction there are most complete. It is estimated that 5,000 people were killed at the Cap out of a total population of 10,000. Most of the city stood on alluvium close to its contact with bed rock. The only record of a sea wave is that the sea dashed against the buildings along the quay. At Port-de-Paix not a single building remained standing after the shock. The sea withdrew 200 feet and then returned, covering the city with more than 15 feet of water. Probably most of the city stood on alluvium. Môle St.-Nicolas was an important military post, but the shock ruined the warehouses, forts, church, and aqueducts. There seems to be no definite record of a sea wave here, although in his catalogue Scherer records a wave along the entire Atlantic coast. Probably the entire town, except the fortifications, was built on alluvium. The destruction was great in the area extending eastward along the North Plain to and beyond the Dominican border. At Gonaïves and St.-Marc the shock was much less severe, although several houses fell. In the Southern Peninsula the shock was slight.

These records show that the shock was most severe along the north coast from Môle St.-Nicolas eastward to Cap-Haïtien. The recording of the sea wave only at Port-de-Paix may indicate that Port-de-Paix is near the place of origin, or the records may be deficient. The Bartlett Deep, as limited by the 1,000 fathom line, begins north of the Northwest Peninsula of the Republic and plunges sharply southwestward, parallel to the similarly plunging anticlinal crest of the Northwest Peninsula. It has been suggested on page 337 that the Bartlett Deep and other submerged deeps of the West Indies are synclinal troughs bounded by zones of high-angle thrust faults. The earthquake of May 7, 1842, was probably due to almost vertical displacement of the sea bottom along the fault zone at the south edge of the Bartlett Deep off the coast of the Northwest Peninsula.

This interpretation has already been given by Taber,[1] who claims, however, that the Bartlett Deep is a downfaulted block, bounded by normal faults. There is no evidence to substantiate the claim made by both Scherer and Taber that a prolongation of the Bartlett Deep extends along the channel south of Tortue Island and thence southeastward across the Cibao Valley of the Dominican Republic.

On September 23, 1887, another severe earthquake shook the same region. The destruction was greatest at Môle St.-Nicolas, where nearly all the houses were ruined. The sea withdrew a great distance and in returning augmented the disaster. At Port-de-Paix the recently erected church was destroyed. Farther east and south the destruction was not so great, but the sea wave was recorded as far west as Jérémie and Anse d'Hainault. The intensity of the shock and the size of the great sea wave at Môle St.-Nicolas indicate that this earthquake was due to almost vertical displacement along the south edge of the Bartlett Deep, probably farther southwest than the displacement that caused the earthquake of 1842, as Taber [2] has suggested.

No disastrous shocks are recorded in the central part of the Republic between 1551 and 1908. During the colonial period and the early years of the Republic the Central Plain and adjoining parts of the Massif du Nord belonged to the Spanish colony.

During the same period (1551 to 1908) there were several severe earthquakes in the southern part of the Republic, most of them centering near Port-au-Prince. The earliest shock occurred on November 9, 1701, when houses on the Léogane Plain were destroyed. The road from Léogane to Petit-Goave sank into the sea at places, but this movement may have been due to slumping. The records are too meager to show the place of origin of this shock. Port-au-Prince had not been founded at that time and the neighboring regions were thinly populated.

On November 21, 1751, Port-au-Prince suffered one of its greatest disasters from an earthquake. The newly founded capital then consisted of about 100 buildings, most of which were constructed of masonry. It is said that only one building was left standing after the shock and that it was destroyed by equally severe shocks on the following day. There were numerous aftershocks, and the people lived in tents until December 8. Probably all the buildings at that time, except the fortifications, stood on the low alluvial ground near the shore. In the Cul-de-Sac Plain, which is almost wholly covered with alluvium, many plantation buildings were laid in ruins. The shocks were felt at Léogane, St.-Marc, Gonaïves, and the Cap, but apparently the destruction was confined to Port-au-Prince

[1] Taber, Stephen, The great fault troughs of the Antilles: Jour. Geology, vol. 30, p. 102, 1922. Since this account was written Prof. Taber has published another paper describing the disastrous earthquakes of the Republic (The seismic belt in the Greater Antilles: Seismological Soc. America Bull., vol. 12, pp. 199-219, pl. 7, 1922). The conclusions regarding the origin of these shocks are the same as those given in the earlier paper.

[2] Idem.

and the Cul-de-Sac Plain. The field work done during the reconnaissance revealed a zone of imbricated high-angle thrust faults along the south side of the Cul-de-Sac trough. Some of these faults are well exposed on the Grande-Rivière du Cul-de-Sac above Bassin Général. Overturned folds, some of which are ruptured along high-angle thrust faults, were discovered closer to Port-au-Prince (see p. 130). The probable westward prolongation of this zone of overturned folds and faults is concealed near Port-au-Prince by nonmarine conglomerates, probably of Pleistocene age. Most of the folding and presumably of the thrust faulting took place at the end of Miocene and during Pliocene time. The region was mobile even later, as the Cul-de-Sac trough was completely submerged in Quaternary time. The earthquake of 1751, which was so disastrous to Port-au-Prince, was probably due to movements along one of the fractures in this fault zone. If the shocks were due to vertical or nearly vertical submarine movements, as the earthquakes of 1842 and 1887 were supposed to be, there would surely be some record of a sea wave, as the coast from the site of the city northward along the Cul-de-Sac Plain is very low.

Only 19 years later, on June 3, 1770, Port-au-Prince and the Cul-de-Sac Plain suffered another disaster, caused by one of the most severe earthquakes that has occurred since the island was settled by Europeans. The region of greatest destruction extended from Croix-des-Bouquets westward through the Cul-de-Sac Plain to Port-au-Prince and thence westward along the coast through Léogane and Petit-Goave to Miragoâne. Two hundred people were killed in the capital. Léogane was destroyed and only one building remained standing in Petit-Goave. The houses between Petit-Goave and Étang de Miragoâne were thrown down in ruins, even those that had been built on other than alluvial ground. The shock was felt all over the colony. Southey [1] states that the sea rose a league and a half up into the island, but this exaggerated report is not confirmed in contemporary accounts. At Grand-Goave part of the foot of a hill called La Saline was submerged, and " something similar happened in part of l'Arcahaie.[2] " This movement may have been due to slumping. If there had been a great sea wave it would be recorded, for all the towns destroyed along the coast were so situated that they would have been at least partly inundated. In the absence of authentic reports of a sea wave it seems reasonable to believe that this disastrous shock also had its origin in the fault zone along the south side of the Cul-de-Sac trough. Its intensity was apparently greater than that of the shock of 1751 and the area of destruction was greater along the thickly populated coast west of Port-au-Prince.

The coast from Petit-Goave to Anse-à-Veau had a moderately severe shock on April 8, 1860. At Anse-à-Veau the people sought refuge in La

[1] Southey, Captain Thomas, Chronological history of the West Indies, vol. 2, p. 407, London, 1827.

[2] Scherer, J., Les grands tremblements de terre dans l'Ile d'Haïti: Observatoire Météorologique du Séminaire-College St.-Martial Bull. semest., July-Dec., 1911, p. 161, 1912.

Haute Ville, the eastern part of the town, which stands on a Quaternary reef cap about 10 meters higher than La Basse Ville, the western part, which is built on alluvium. The sea withdrew and then broke on the shore with a crash. The shock did some damage as far west as Baradères, but was only slight at Jérémie. It was pronounced on the south coast at Aquin and Les Cayes, and even at Port-Salut. The damage in Port-au-Prince was only slight. The sea wave was not a prominent feature, as no wave is recorded at coast towns other than Anse-à-Veau. Moreover, the shock was much stronger on the south coast than on the north coast. Although the evidence is conflicting it seems that this shock originated in the Southern Peninsula. The tectonic features of the Asile Valley are not fully known, but the abrupt mountain slope along the south side of the valley seems to be a fault scarp, along which the principal movement took place after the close of Miocene time. (See Fig. 20, *A*, p. 322.) Con-

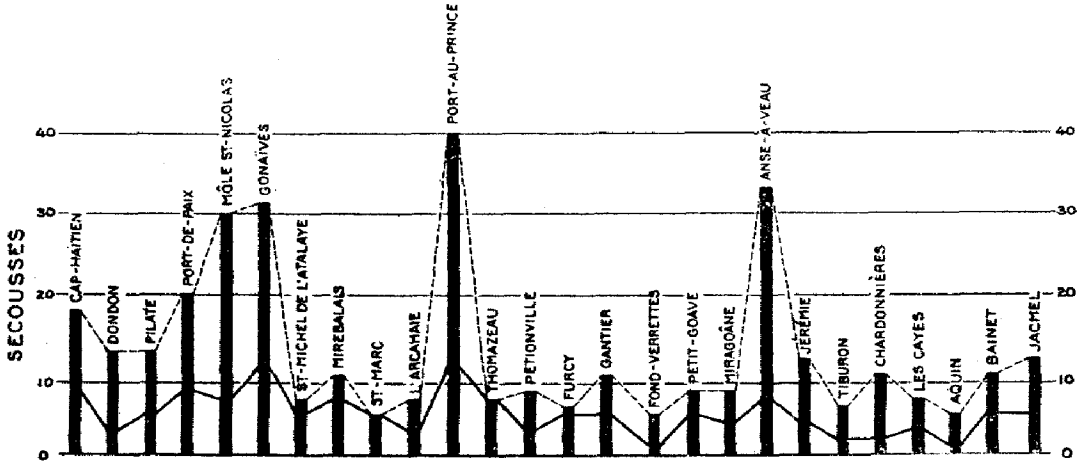

FIGURE 22.—Graph showing the number of earthquakes recorded at different stations from 1909 to 1922.

Lower curve (solid) represents general earthquakes felt in almost the entire country.

tinued movements along this supposed fault may account for the shock of 1860 and many later less serious shocks.

Taber[1] believed that the shocks of 1701, 1751, 1770, and 1860 were due to movements of the sea bottom off the north coast of the Southern Peninsula along a supposed fault zone extending westward from the Cul-de-Sac trough. The description on pages 397-398 clearly shows that the submerged prolongation of the Cul-de-Sac trough bends northwestward into the St.-Marc Canal. Although the off-shore slope along the western half of the Southern Peninsula is very steep there is hardly enough evidence to warrant the supposition of faulting, and the seismic phenomena can be interpreted otherwise.

EARTHQUAKES FROM 1909 TO 1922.

Figure 22 graphically shows the number of shocks recorded by Scherer and his correspondents from 1909 to May 4, 1922, inclusive. This graph

[1] Op. cit., pp. 94-98, 1922.

can not be rigidly used to show the frequency of earthquakes in different parts of the Republic, for the records of the observations on which it is based were furnished by as many different persons as there are localities. At some of the stations, Aquin for example, records were not kept continuously during the period covered. The completeness of the record at Port-au-Prince, which includes a large number of shocks, is probably due in part to the unfailing energy of M. Scherer. The lower line of the graph, representing the number of general shocks, would be smoother in some parts if all the general shocks were accurately recorded during the entire period at the different stations. The shocks considered general were recorded at five or more stations, but some of them were general only in parts of the Republic. Some of the general shocks—for example, that of the Porto Rico earthquake of October 11, 1918—were of distant origin and were felt in virtually all the Republic. Clearly recognizable aftershocks were not included in the total number of shocks. The location of the stations also affects the graph. Some of them are on alluvial ground, others are on bed rock or on residual soil.

In view of the facts just stated the graph may not seem to be very useful, yet it shows clearly the relative frequency of earthquakes in some parts of the Republic. The large number of shocks recorded in the Northwest Peninsula, at Port-au-Prince, and at Anse-à-Veau indicate that they are the regions of highest seismicity. Moreover, this indication agrees with the results of a study of the disastrous shocks from 1551 to 1908.

The numerous shocks recorded at Môle St.-Nicolas, Gonaïves, Port-de-Paix, and Cap-Haïtien probably originated along the fault zone at the south side of the Bartlett Deep, as did the disastrous shocks of 1842 and 1887. Sea waves are not recorded for any of the shocks from 1908 to 1922, which may therefore have involved small vertical displacement. The largest number of shocks were recorded at Gonaïves and Môle St.-Nicolas, which are closest to the place of supposed origin. Most of the shocks have an intensity of II to IV (Rossi-Forel scale), but a few are as high as V and VI. Some of the shocks—for example, that of February 4, 1918—were relatively strong at Môle St.-Nicolas (IV-V) but were not recorded elsewhere. The earthquake of March 20, 1910, is typical of the minor shocks felt in the northern part of the Republic, particularly in the Northwest Peninsula. It was recorded at Môle St.-Nicolas, Gonaïves, Port-de-Paix, Bassin Bleu (on Les Trois Rivières between Gros-Morne and Port-de-Paix), Cap-Haïtien, Grande-Rivière du Nord, Dondon, and Bahon. A shock that occurred on August 21, 1911, was recorded at Môle St.-Nicolas (IV-V), Gonaïves (V), Gros-Morne (V-VI), Port-de-Paix (V), Pilate (V), Cap-Haïtien, St.-Michel de l'Atalaye, Hinche, St.-Marc (IV), Port-au-Prince (III), Furcy (III), Petit-Goave (II), Anse-à-Veau (III-IV), and Cayes. It is remarkable that this shock was not recorded at Pétionville, for at Furcy, farther from the place of its origin,

it had an intensity of III. Both stations are on bedrock or on residual soil close to bedrock. Scherer remarks that this is not the first time that a general shock was not felt at Pétionville. The highest intensity in the Southern Peninsula was at Anse-à-Veau, and Les Cayes was the only locality on the south coast where the shock was felt.

The earthquake of September 6-7, 1912, apparently had its origin in the interior of the Massif du Nord, as it was strongest at Plaisance (VII), Limbe (VII), Grande-Rivière du Nord (VII), and St.-Michel de l'Atalaye (VII). At Port-au-Prince the intensity was IV-V. The shock was felt at all the stations except Tiburon, Aquin, and Les Cayes.

St.-Marc is strikingly free from frequent shocks, the only shocks recorded there being general shocks originating at some distant locality. The records at St.-Michel de l'Atalaye and Mirebalais show similar features, indicating that the central part of the Republic has fewer earthquakes than the northern and southern parts. The serious earthquake of October 6, 1911, seems to have originated along the southern border of the Massif du Nord, or of its prolongation the Cordillera Central of the Dominican Republic, as Scherer has suggested. The greatest intensity was at San Juan de la Maguana (IX-X) in the Dominican Republic. It was felt at Cerca-la-Source (IX), Hinche (VII-IX), Vallière (VI), Cap-Haïtien (VI-VII), Mirebalais (VI-VII), St.-Marc (VI), Gonaïves (VI), Port-de-Paix (IV-V), Port-au-Prince (VI), and throughout the Republic, the intensity diminishing in all directions from Cerca-la-Source and San Juan de la Maguana. The destruction was not very great, as the region where the intensity was highest is thinly populated and most of the houses are built of wood. The great scarp overlooking Cerca-la-Source from the south may be a fault scarp. (See p. 334 and Pl. XXV, *A*.) If it is a fault it was active at the close of Miocene time, and if it is still active it may account for this earthquake. At Port-au-Prince this shock was the strongest recorded since September 23, 1887, the time of one of the disastrous earthquakes in the northern part of the Republic. Seven aftershocks of intensity II and III were felt at Port-au-Prince.

More earthquakes have been reported at Port-au-Prince that at any other station. Many of them are supposed to be due to movement of the rocks along the fault zone at the south side of he Cul-de-Sac Plain, such as produced the disastrous shocks of 1751 and 1770. If this supposition is correct it is surprising that so few of the shocks were recorded at Gantier, Pétionville, and Thomazeau. Gantier and Pétionville are on bedrock or residual soil, but Thomazeau stands on alluvium. A pronounced vertical movement was felt during many shocks that apparently originated near Port-au-Prince. On July 31, 1914, a shock lasting 40 to 50 seconds at Port-au-Prince had an intensity of V. All of the movement seemed to be vertical. Despite its intensity the shock was purely local and was not felt farther than Pétionville, Furcy, and Léogane. The earth-

quake of July 26, 1917, was the most recent pronounced shock apparently originating near Port-au-Prince, where it had an intensity of VI. The intensity in general decreased away from Port-au-Prince, but it was unusually high at Cap-Haïtien (VI) and Limonade (V-VI). Although the shock was felt throughout the Cul-de-Sac Plain and at Gantier (V), it was not felt at Pétionville and Furcy. Most of the shocks recorded at Pétionville, Gantier, and Thomazeau were felt at Port-au-Prince and generally with greater intensity there.

The most striking feature of the Southern Peninsula is the large number of shocks of low intensity (II-III) recorded at Anse-à-Veau. Probably most of them originated along the south side of the Asile Valley, as suggested for the earthquake of April 8, 1860, but on this supposition more of them should be felt at Aquin and Les Cayes.

The earthquake of August 3, 1910, seems to have been most severe at Jérémie (VII). It was felt over virtually the entire Republic and had an intensity of V at Port-au-Prince and Cap-Haïtien. At many stations a strong vertical movement was noted. An observer on the south coast of Gonave Island felt the shock, but states that the sea was as calm as a lake. The origin of this earthquake is not so clear as for some other shocks, although it is supposed that a fault, active since Miocene time, extends along the north edge of the interior lowland south of Jérémie. (See pp. 226-227 and Fig. 7, p. 137.)

The most recent pronounced shock was on January 15, 1922. The intensity was greatest at Les Cayes (V-VI), where houses even of reinforced concrete were cracked. It was felt all along the south coast as far east as Jacmel (IV), along the north coast of the Southern Peninsula from Jérémie (IV-V) to Port-au-Prince (IV-V), and as far north as Gonaïves (III) and St.-Michel de l'Atalaye (II). In the absence of adequate information it may be suggested that this earthquake had its origin either along the supposed fault at the south edge of the Asile Valley or along the scarp between the Port-Salut Peninsula and the Cayes Plain. This scarp has the appearance of a fault scarp. (See p. 135.)

Conclusions Regarding Frequency of Shocks in Different Parts of the Republic.

An analysis of the disastrous shocks from 1551 to 1908 and of the more detailed records of shocks from 1909 to 1922 indicate that the Northwest Peninsula, the region near Port-au-Prince, and the region near Anse-à-Veau are the areas where earthquakes are most frequent.

The frequency of earthquakes in the Northwest Peninsula agrees with the evidence derived from its geologic features. It is the most mobile region in the Republic, as Quaternary reef caps there have an altitude of 400 to 450 meters above sea level and are more numerous than elsewhere. The elevation of these reef caps is clearly due to the emergence of the

southwestward plunging crest of the Northwest Peninsula anticline. This continued rapid emergence causes strains in the rocks that are relieved by fracturing along the submerged northwest flank of the anticline where it plunges into the remarkable depths of the Bartlett Deep, or by slipping along former fractures at the same place. The strains would be relieved principally by vertical or almost vertical fracturing or slipping. The vertical movements transmitted through the elastic rocks cause the vibrations. If this explanation is correct the serious shocks should cause sea waves. The observer at Môle St.-Nicolas, the station nearest to the supposed place of origin, should record any indications of a sea wave.

Only one earthquake (September 6-7, 1912) seems to have originated in the interior western part of the Massif du Nord. There is a fault of considerable displacement on the south slope of Mont Puilboreau near its crest (see Fig. 18, *C*, p. 311), but it probably was active at the end of Eocene time and there is no other evidence that it is still active. The interior eastern part of the Massif du Nord, which is a great batholith of quartz diorite, is probably the most stable area in the Republic. This supposition could be verified by obtaining records at Vallière. The southern border of the massif is relatively stable, although one shock of high intensity (October 6, 1911), originated near Cerca-la-Source.

Thrust faults along the southwest edge of the Central Plain, active at the end of Miocene time, seem to be no longer active, but this region is thinly populated, and minor shocks originating there might not be recorded.

No shocks seem to have originated near St.-Marc or in the Artibonite Valley. On both sides of St.-Marc there are plunging anticlines bearing Quaternary reef caps resembling in miniature those of the Northwest Peninsula. It might be supposed that the emergence of these reef caps would produce strains; if so, they have not caused rupturing of the rocks during the time since the region was colonized. The thrust faults along the southwest flank of the Chaîne des Mateux near the Arcahaie and the Cul-de-Sac plains (see Fig. 5, p. 128 and Fig. 21, p. 335) are evidently no longer active, as no shocks have originated near l'Arcahaie.

If the interpretation of the numerous shocks at Port-au-Prince given on page 342 is correct the thrust faults along the south edge of the Cul-de-Sac Plain have been active during historic time, and there is no indication that their activity has ceased. Many of the shocks seem to be due to vertical or almost vertical displacement indicating corresponding movements along the high-angle thrust faults. The cause of the strains thus relieved is not known but may be related to the emergence of the Cul-de-Sac Plain, which was submerged early in Quaternary time.

It is hoped that M. Scherer can find a correspondent at l'Asile. If the unusually numerous shocks recorded at Anse-à-Veau are due to displacement along the south side of the Asile Valley the shocks should be

of higher intensity at l'Asile. A correspondent at Baradères could furnish records that would be valuable in fixing the limits of this highly seismic area. The rest of the Southern Peninsula seems to be fairly stable, although one shock (August 3, 1910) seems to have originated near Jérémie, and the most recent widespread shock (January 15, 1922) had its origin near Les Cayes. The central basalt in the Massif de la Selle is limited on at least the north side by faults, which apparently are no longer active.

M. Scherer should enjoin his correspondents at all stations on the coast to collect faithfully any information concerning sea waves, particularly during shocks of high intensity.

There are so many faults in Haiti that any shock originating on the land could plausibly be considered the result of movements along some fault, but it is difficult actually to prove that any fault is still active. The only faults that have been regarded as probable places of origin of earthquakes have been active since Miocene time. Surface indications of recent activity are usually soon obliterated, and even immediately after they are formed a careful search generally is required to reveal them. No surface indications were seen during the reconnaissance. The only way actually to prove, for example, that the numerous shocks at Port-au-Prince are due to movements along the faults at the south edge of the Cul-de-Sac Plain would be to determine the region of highest intensity after a serious shock and then search for signs of a recently active fault.

Precautions Against Damage.

Earthquakes have been very frequent in Haiti, particularly in the Northwest Peninsula, at Port-au-Prince, and at Anse-à-Veau. At times they have been disastrous. Shocks may be expected to continue at frequent intervals and some of them may devastate the most thickly populated parts of the Republic. No one can predict when the shocks will come or at how frequent intervals they will be disastrous. Port-au-Prince was almost or completely destroyed twice within the period of 19 years from 1751 to 1770, but disastrous shocks are usually not so frequent. In such a region disaster is invited unless precautions are taken. The earthquakes can not be warded off, but buildings and other structures can be so located and constructed that they will most successfully stand the shocks. The following precautions are taken from the account of Professors Reid and Taber, who investigated the Porto Rico earthquake of October 11, 1918.[1] Methods of building construction in Porto Rico are very similar to those used in the Republic.

Shocks are more severe on alluvial soils, especially soils that are saturated with ground water, than on bedrock or on residual soils. Most of

[1] Reid, Harry Fielding, and Taber, Stephen, The Porto Rico earthquake of 1918, with descriptions of earlier earthquakes: 66th Congress, 1st Session, House of Representatives Document 269, 74 pp., 6 figs., 1919 (see pp. 69-74); The Porto Rico earthquakes of October-November, 1918: Seismol. Soc. America Bull., vol. 4, pp. 95-127, pls. 7-14, 1919.

the large cities and towns in Haiti stand along the coast and are built wholly or in part on alluvium. The location of many city buildings on alluvium is therefore unavoidable. The possibility of damage is diminished by extending the foundations to bedrock, if possible. Virtually the same result is obtained by building on a thick reinforced concrete plate, which causes the building to move as a whole. Contacts of alluvium with bed rock, escarpments, and river banks are especially dangerous locations.

Buildings and other structures should be either so elastic that they yield without breaking or so strong that the shocks can not seriously injure them. Wooden buildings are one type of elastic structures. They should be well braced and the joints should be strong enough to resist pulling apart. For some time after the earthquake of June 3, 1770, the colonial authorities permitted only wooden buildings to be built in Port-au-Prince. The chief objection to the use of wooden buildings in the tropics is that they rapidly deteriorate through rotting and the attacks of termites and other insects. The common type of houses in the country districts and in the city districts where the poorer classes live are virtually immune from damage. They consist of wooden frames, usually lashed together with fiber thongs, and the walls are made of wicker, which is sometimes covered with plaster or adobe. Steel-frame buildings, such as the market at Port-au-Prince, are also strong, elastic structures.

Buildings constructed of rigid material, such as brick, building stone, and concrete, should be strong enough to resist injury. Many of the dwellings and public buildings show an inferior type of masonry construction, consisting of stones of irregular size and shape embedded in a poor lime mortar. The soft Quaternary coralliferous limestone is frequently used. The lime used in the mortar is often incompletely burned and imperfectly slacked, and the sand contains many impurities. Several such buildings were being built in Port-au-Prince during our stay there. Buildings of this kind would be the first to fall during a shock of high intensity, and their construction should be prohibited.

Brick buildings will resist any but the strongest shocks if a good mortar is used and the bricks are properly crossed. Clean sand should be used for mortar in both brick and masonry work. The only known large deposits of quartz sand relatively free from impurities are on the North Plain. The binding power of lime mortar is improved by adding cement.

First-class concrete made with clean sand and sufficient cement is fairly strong. Concrete strengthened with steel reinforcements is believed to be the strongest material available.

Heavy roofs, parapet walls around roofs, and overhanging cornices should be avoided. Solid partition walls should be firmly tied to the outer walls. Floor and roof joists should pass through the supporting wall, or at least half a meter beyond the inner face of the wall. They should be entirely free to slide in their recesses or should be firmly attached to the walls with iron plates.