REPORT OF THE ADVISORY COMMITTEE IN SEISMOLOGY[1]

The Advisory Committee in Seismology has pleasure in reporting the continued progress of its study of California earth movements during the year 1924–1925 without essential change of plan. A considerable amount of geologic work in the study of fault zones has been done during the year in the Mojave Desert and in Death Valley, the system of primary triangulation for the detection and measurement of horizontal displacements has progressed rapidly and effectively, and the development of suitable instruments for determining the two horizontal components of local earth movements has progressed to completion. Ground for a new laboratory has been purchased by the California Institute of Technology and the construction of the central station laboratory building upon it has been begun. The laboratory is expected to be occupied by Mr. H. O. Wood, Research Associate in Seismology, and his associates, about January 1, 1926. It is hoped that additional stations will also be occupied before the close of the present calendar year (1925), and that actual work in what has been happily termed the seismologic triangulation of California will be successfully inaugurated.

The destructive earthquake at Santa Barbara on June 29, 1925, has also had the effect of stimulating vigorous local co-operation throughout the region where, before the earthquake occurred, our efforts were looked upon with some indifference. Rather extensive plans are now under consideration for establishing similar stations in the San Francisco Bay region and possibly even in New England, which also was visited by an unusually severe earthquake in February last. Some details of the progress made during the year in these several directions will be presented in the paragraphs below.

1. Measurement of Surface Displacement

Heretofore we have depended upon astronomical measurements of position for indications of creep. These, to be effective, must be con-

[1] Extracted from Year Book No. 24, 1925, of the Carnegie Institution of Washington.

tinuous over long periods of time, and provision for the requisite continuity has now been assured by the U.S. Coast and Geodetic Survey through its occupation of the latitude station at Ukiah. It has been hoped that the observations at Ukiah might be supplemented by similar observations at Lick Observatory, but no appropriate instrument has yet been provided there for this work. Such observations as can be made at Lick Observatory will therefore be occasional rather than continuous and will be incidental to the regular work of the Observatory. The Committee still entertains the hope that the special instrument, for which budget provision was made several years ago, may yet be built and placed in continuous service there. It would also be most desirable, for obvious reasons, if a similar station could be established in southern California. This is a matter for future consideration, but the Mount Wilson Observatory would afford a most satisfactory location for it.

In addition to the information obtained from latitude observations the Committee reported last year definite indications of a more or less continuous displacement revealed by the primary triangulation on the west side of the San Andreas Fault. From these measurements it appears that the stations occupied by the Coast Survey on the west side of the fault between Monterey and the Santa Barbara Channel have all been moving northward, the southernmost ones showing the greatest extent of displacement. The maximum value reached in this movement, whatever its source, is about twenty-four feet at the Gaviota station, a few miles west of the city of Santa Barbara. In view of this report the first thought suggested by the earthquake in June last was that this accumulated stress had found release and was the proximate cause of the earthquake itself. A preliminary examination of the ground does not reveal any considerable earth movements, either in connection with or in consequence of this earthquake, but the Coast Survey has arranged to reoccupy the stations in the vicinity during the coming autumn in order to ascertain just how much, if any, of the indicated strain has been relaxed. These displacements may prove to be so closely associated with crustal creep that a relation of cause and effect is indicated, and the direction likely to be taken by our studies in the not distant future will be to ascertain more definitely just what this relation is.

The disturbance at Santa Barbara appears to have been caused by movement along two faults, one of which has been called the Mesa Fault, a zone of fracture which is probably not simple but which lies along the northern edge of the mesa just south of the Southern Pacific

Railway tracks immediately southwest of the City of Santa Barbara and extends west some twelve miles to Naples. This fault transmitted the principal vibrations that caused the damage in the city.

The second clearly recognized fault runs along the south side of the Santa Ynez Mountains. There was considerable disturbance along this fault to the west of Santa Barbara, but it was not active to the east of the city. It is possible that the concentration of destructive activity on State Street was due to the interference of elastic waves from these two sources. In any event this would help to explain the extraordinary diversity of intensities in that small area. Neither group of displacements appears to have extended east or northeast toward the great San Andreas Fault or to have received any impulse from it.

More detailed discussions of the seismology and of the geology of the Santa Barbara shock are in preparation by Mr. Wood, Research Associate in Seismology, and Mr. Willis, of this Committee, and will presently be published in the BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA.[2]

As was stated in the report of last year, an accurate system of primary triangulation, especially placed with reference to these studies, has now been completed from Mount Lola and Mount Round Top, near Reno, Nevada, to the San Francisco Bay region, thence southward along the coast to a point near the Mexican boundary, thence eastward to American Peak in the Colorado River Valley. Supplementary to this system a spur was extended northward during the winter of 1924 and 1925 from the San Francisco Bay region in the direction of Ukiah and Point Arena, with the help of a special fund allotted for this purpose by the Carnegie Institution. Unfortunate weather conditions were encountered, and in consequence the allotment was exhausted before the end stations were reached. This work will be completed during the current year.

In establishing these triangles the alignment from Point Arena and Ukiah along the coast to the Mexican boundary follows the course of the major faulting in the west-coast region, and is therefore expected to reveal with precision any horizontal movements which take place there. The spurs to the eastward at San Francisco Bay and along the Mexican boundary provide a connection between the triangles in the

[2] Mr. Willis' contribution on this subject was published in the December, 1925, number of the BULLETIN.

unstable region and the stablest terrane available nearby. In the south the stations in the Colorado River Valley were thought to afford adequate stability as reference points. The stations on Mount Lola and Mount Round Top do not afford the same geological assurance of freedom from movement in view of the faulting in the Great Basin. Accordingly, as a further measure of precaution to secure stability in our points of reference, additional triangles will be run during the present summer eastward from Mount Lola and Mount Round Top to Carson Sink and Mount Grant. The additional triangles, at least so far as geological observation indicates, should fix the stability of these reference points beyond reasonable doubt.

The continuation of this program of triangulation as now contemplated will provide a cross link from the Nevada region, above mentioned, in a direction somewhat west of south to connect with the present system in the vicinity of Los Angeles. This line of triangles when completed will cross the supposedly active fault zones of Mono and Inyo Counties in eastern California and will afford a much-desired base from which to recognize movements in this region.

Provision for the recognition of vertical movements as a part of these studies is hardly more than begun because the major movements hitherto recognized in California have shown much greater displacement in the horizontal than in the vertical dimension and so were deemed to be the more important. Nevertheless a plan has been developed for a system of precise levels covering approximately the same ground over which the horizontal triangulation above described has been made. The first of these series of levels was run last year over the Cajon Pass along the line of the Santa Fe Railway, because on that line an earlier set of levels was in existence against which it was desirable to check and also because the line crosses several of the known faults of the south California region. The reduction of these measurements is not yet completed, but differences of the order of magnitude of one foot were found in comparison with the levels of fourteen years ago. This year the plans of the Coast Survey contemplated a similar line of levels to the top of Mount Whitney and across the fault zones which have been located to the east and west of it. The height of Mount Whitney has twice been determined with precision in earlier years so that here again it was thought that a desirable check on possible vertical movements might be obtained. Most unfortunately, however, the Survey party on reaching the 8,000-foot level found the mountain trail completely de-

stroyed so that it was not practicable to carry the survey to the top of Mount Whitney at a cost in any way commensurate with the resources available. Accordingly the levels were discontinued at the 8,000-foot bench mark.

No other lines of precise leveling are contemplated with the resources available this year, but next year it is hoped to establish other lines with particular reference to the control of vertical fault movements in southern California.

In this connection it is appropriate to mention that the appropriation available to the Coast and Geodetic Survey for triangulation and precise leveling for the determination of earth movements was cut by the last Congress from $12,000 in 1924 to $10,000 in 1925, and therefore does not permit the same extent of ground to be covered as in previous years.

2. Publications

In the Annual Report of last year record was made of a special grant of $5,000 by the Carnegie Corporation of New York for seismological publication. Of this sum there has been expended during the current year the sum of $1,235.21 for the publication of sixteen papers on seismologic subjects in volume 14 of the Bulletin of the Seismological Society of America. These articles have been printed by the Bulletin at actual page cost of printing. The remainder of the grant, amounting to $3,764.79, is available for further publications of similar work and is to remain available until expended.

3. The Development of Instruments[3]

Because of its urgency, since ordinary ball-governor driving clocks were found unduly expensive and otherwise not wholly satisfactory for our purposes, we have spent by far the greater part of the past year in experimental work to develop a method for rotating and advancing the recording drums of our local-earthquake seismometer assemblies. Our aim has been to develop and make ready for production a mechanism for driving recording drums more accurately and with less cost than previous devices commonly used for this, because we shall need a considerable number of such driving mechanisms to operate the necessary number of seismologic stations, and because our requirement in respect to accuracy and uniformity of running is more exacting than is usual

[3] Extracted from the Report of H. O. Wood, Research Associate in Seismology.

or essential in teleseismic registration. The steps and progress of this work are discussed further on.

Turning first to other work, jointly with Dr. J. A. Anderson the writer prepared for publication a paper of seventy-two pages entitled "Description and Theory of the Torsion Seismometer." This was submitted for publication to the BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA in February 1925, and appears in the March number. Great pains were taken to make the presentation simple and plain in the hope that this important theoretical matter, at best somewhat difficult in aspect to readers whose training in physics is elementary, may thus be made clearer and more serviceable to many of the routine workers in seismology.

To a greater extent than usual time has been devoted to study of our experimental seismograms in the light of important advances in seismology made during the past ten years and presented chiefly in foreign publications, some quite recent, others older, but in most cases only recently accessible. This work will not lead to immediate publication. Our seismograms present certain interesting individual characteristics which will require time and the accumulation of more data from several well-separated stations before a good understanding of their meaning will be obtained. In the case of far-distant teleseisms our records appear to agree with and strengthen the hypothesis of an earth-core at a depth of the order of 2,900 kilometers. And, in addition to peculiarities not yet well understood, we unquestionably have found on the records of many local shocks amplitude changes in the first phase conforming with the $\overline{P}$ and P phase beginnings brought to notice first by Mohorovičić.

Throughout the year seismometer "B" has been operated regularly, except for brief accidental intermissions, at the California Institute of Technology, without significant experimental changes or any results which require detailed report here.

Seismometer "D" continued in operation experimentally at the Mount Wilson Observatory Office plant until early in April, 1925, with occasional experimental changes in adjustments, constants, and the assembly of auxiliary apparatus. No detailed report upon this can be given here. All findings were in good accord with theory. As an outcome of this experimental operation the conclusion was reached that this instrument had, at all times, too high static or geometric magnification and too low damping for optimum registration of local earthquakes in the regular routine way. This is true even though a few of the shocks recorded

were too weak for good registration. There are probably many definite shocks too feeble to be registered by any instrument practical for routine use. However, for special purposes even higher static magnification is advantageous or necessary. It can easily be obtained by suitable changes in the suspended system. Also the period can be changed through a considerable range, with the damping maintained at the critical value.

Throughout the year seismometer "E," designed for teleseismic registration, has been operated continuously at the Observatory Office station with several instructive changes in adjustment and constants. Numerous teleseisms have been registered which exhibit differences due in part to the characteristics of the shocks themselves and in part to the changes in adjustment. Two may be mentioned here. [Details omitted.] . . . . Such records as these, supported by others, including our records of the Japanese shocks of September, 1923 (with local-earthquake instruments), make us well satisfied that the torsion seismometer designed for distant earthquake registration will compare favorably with the best instruments hitherto in use. For convenience of adjustment, small changes in design and construction are required. These are easy to make.

In April, 1925, seismometer "D" was replaced by seismometer "F," with a static magnification of about 1,400 and a proper period of about 0.9 second when undamped. At first this was tried with slight overdamping, which was afterward reduced to about $h=0.9$ ($h=0$=no damping, $h=1$=critical damping, following Galitzin's notation $h^2=1-\mu^2$). After a little over two-months use we conclude that the static magnification of this instrument is still a little higher than is best for routine operation, but not greatly so, since many shocks now well recorded would not be well registered with a much lower magnification. However, for shocks perceptible at the station a considerably lower static magnification, and perhaps also an instrument of lower sensitivity, is necessary for good registration. Strong shocks, and great shocks, require still less sensitive instruments and still lower magnifications, so far as it may be possible to register such shocks at all. Registration of the shocks of the Santa Barbara earthquake beginning June 29, 1925, demonstrated this well. In this case a few of the aftershocks were barely registered at Pasadena by instrument "F," many were well registered, some were too strong for excellent registration but were usefully recorded, and some, including the chief shocks, were not usefully re-

corded. There is not space here for further discussion of this shock. It will be discussed at length in the proper place.

The design of a vertical component seismometer with a period longer than 0.4 to 0.5 second offers difficulties which may be overcome in several ways, none of which, however, have been found quite satisfactory. A great deal of consideration has been given to this problem and further experiments will be made at the earliest opportunity. There is, of course, no difficulty in designing vertical instruments along the lines of those hitherto in use, and with short periods the torsion instrument can be used directly, but there is hope of obtaining an instrument superior in principle to previous models for this direction of motion.

We have experimented further with the piezo-electric principle, utilizing a resistance coupled amplifier. This principle is sure to prove useful with rapid feeble vibrations, but, with electron tubes now available, there are difficulties when slow vibrations are the subject of study. With electrostatic apparatus, of very high impedance tubes, the principle will yet be utilized to measure slower vibrations.

Extended consideration has been given to the experimental work which should be taken up after the successful development of the driving mechanism, which is now apparently near a practical solution. Following after the earliest practical accomplishment of this, experimental work should be continued as opportunity allows to effect its improvement in all practicable ways.

First, however, attention should be given to a method for making time marks upon all the seismograms at all the stations of the system by special minute-to-minute radio time-signals, thus eliminating from our seismograms all *relative* time errors. It is hoped that this may be accomplished without undue delay—otherwise excellent time-marking chronometers, and means for frequent determination of their corrections, will be required at each station; and in addition to this costly equipment, much valuable time will have to be spent in determining the time error for each station on all the seismograms on which earthquakes are registered. This labor will be saved if radio timing is successfully developed.

A method of driving drums for teleseismic assemblies has been considered which should prove adequate for this, and be much less costly to construct and operate than the drive necessary for local-shock instruments. This will require some development.

A seismometer designed to record the *energy* of the shock at the station, rather than its acceleration or other physical magnitude, should

prove of great use in checking the determination of phase-beginnings and in clarifying the interpretation of the interior conditions. It seems possible that such an instrument can be developed without encountering serious obstacles. If successful its records would probably afford the solution of many vexing problems. A scheme for such a seismometer has been considered at length. Its development should be attempted.

There is need of a visible-writing seismograph whose record can be consulted at any time. It will be of great advantage if it can also be an instrument of reasonable precision and not a mere indicator. There is hope that a useful instrument for this can be developed along new lines. Visible-writing seismographs of the older kind will not meet all of the needs. A better type should be sought.

Returning to our work on the recorder driving mechanism—early in the year we received from England a tuning-fork synchronous-motor assembly which runs very accurately. We hoped this would provide a ready-made solution of our problem. However, upon trial it did not work efficiently enough, and when periods of operation of several days' duration were attempted it was found wanting in reliability, though doubtless it ran very accurately while it continued running. Nevertheless it conclusively demonstrated the suitability of the synchronous-motor principle for the driving of our drums.

To get rid of the difficulties encountered with the electric contact points of the tuning fork we then constructed an electron-tube oscillator with its oscillations controlled by a capacity and an inductance, the latter in the earlier models constructed with an iron core. By amplifying this oscillatory current it was made to operate a contact-making relay which then took the place of the tuning fork. First and last a considerable number of relays were tried out, but at length a very satisfactory type was found, a telegraph relay recently developed for continuous commercial service. To secure efficiency a special reaction machine, or simple impulse synchronous motor, was constructed, to run with a very small current working through the relay. At a very early stage in this work it was obvious that the electron-tube oscillator could be made reliable and sufficiently accurate—even very accurate—and that we were making progress along a useful route, but many theoretical and practical obstacles were encountered which had to be eliminated one by one, and considerable time elapsed before a well-balanced assembly was obtained, so that the motor could be run both reliably and efficiently by the relay in synchronism with the oscillator.

In order to obtain a synchronous motor which would be self-starting and rotate in one direction only, we had recourse to a three-phase field winding with a soft iron rotor. This necessitated three-phase current with constant frequency. An early solution of this requirement was the design and construction of a three-phase electron-tube oscillator, which worked excellently. But it was soon found possible to obtain three-phase pulsating direct current (which served quite well enough) more simply and much more cheaply by driving a three-phase commutator or distributor by means of the ordinary impulse motor controlled by an oscillator of the ordinary kind. A reasonably efficient three-phase motor was obtained by re-winding an ordinary 1/20th-horsepower 50-cycle single-phase induction motor for three-phase current, 5 cycles at 32 volts. We hope to obtain a still more efficient motor by similar suitable changes in a smaller commercial motor. But also, in an endeavor to secure still greater efficiency, a three-phase motor of special design was constructed. If a modified commercial motor of suitable efficiency is not found this design can be refined and developed successfully, but such motors will have to be constructed in small numbers and it is desirable to avoid this expense if possible. However, efficiency is essential since we must operate from a storage battery which must be large enough to render the station independent, for a day or two at least, of the commercial current supply. Hence the current draft must be kept as small as is practicable.

In the meantime it was recognized that an oscillator controlled by an air-core inductance would be more accurate and more uniformly reliable in our assembly than one with an iron-core inductance. This was tried and the two were compared, after a period of balancing and readjustment, both with and without thermostatic temperature control. As a result it was clear that the air-core assembly was as good, nearly, without temperature control as the iron-core assembly with temperature control. But both behave better in an even temperature than in a variable one. However, the air-core inductance has still more significant advantages.

From time to time during the development, doubt arose as to the advisability of trusting a system in which contact-making relays form an essential part. Consequently there was designed and constructed an oscillator-amplifier assembly terminating with a 5-watt electron tube which provides an output capable of operating a small synchronous motor directly without intervening mechanical parts, ... and with

some modifications and a second 5-watt tube an output capable of operating several motors can be obtained. A similar assembly ending with a 50-watt electron tube was designed but has not yet been constructed. In principle this method of running the necessary number of synchronous motors is superior to any of the others, but it is not yet certain that such assemblies can be constructed and operated at sufficiently low cost. If it is found possible to do this, this method should later supplant the system which is now regarded as the immediately practical solution upon which attention is now concentrated. The direct tube-drive should be developed further at a later stage. It will afford a practically perfect method for driving recording drums if a low cost assembly can be worked out.

However, success at relatively low cost appears to be in sight with an assembly consisting of an oscillator-amplifier with an air-core inductance held at even temperature working an excellent relay which controls and operates a simple impulse synchronous motor. The motor in turn drives a three-phase distributor which supplies three-phase pulsating direct current from a 32-volt storage battery of adequate ampere-hour capacity to a number of 3-phase 5-cycle synchronous motors, sufficient to operate all the recording drums at a given station. Each of these synchronous motors drives the gear-work which rotates and advances one of the recording drums, with an accuracy directly referable to the behavior of the oscillator. The oscillators already constructed appear to perform better than most good clocks, excluding clocks of the highest precision.

The reliability of such a driving assembly will be considerably increased if the oscillator is made to operate two relays (instead of one) which in turn furnish current to a quarter-phase impulse-actuated synchronous motor. A motor thus served and controlled will be self-starting, unless overloaded, and it will rotate in only one direction. This improvement is still under development.

If the present oscillator can be replaced, without sacrifice of reliability and accuracy, by an oscillator operating on the heterodyne principle, the assembly will be simplified considerably and it can then be regulated much more easily and finely. Such an oscillator is being developed.

Moreover, if it is found practicable to substitute for the inductance-capacity element a simple temperature-compensated vibrating spring or reed a much further simplified system of still greater precision and ease of adjustment should result. This is under experiment.

It will be apparent that this comprehensive attempt to develop a driving mechanism has involved much thought and experimentation with many groupings and assemblies of apparatus and modifications too numerous to report in detail. Numerous problems as to theory have been encountered in the work of planning experiments and designing apparatus. Altogether this work has made large demands on time and energy. So it is gratifying to report that it already gives definite promise of success, and, further, that the continuation of the development, after a first practicable assembly is thoroughly proved, appears certain to lead to significant simplifications and refinements, and very probably further reductions in cost.

In the course of the year eighteen recording drums with bases, supporting brackets, and leveling screws were built for us by Mr. F. C. Henson. These are completed and ready to be equipped with gear-work and synchronous motors when the driving mechanism has reached the stage of production.

4. Observation Stations

During the past year an arrangement has been entered into with the California Institute of Technology whereby the Institute will build upon appropriate ground in the City of Pasadena a seismological laboratory, which is to serve as the central station for research work in seismology of the Carnegie Institution of Washington and also as the central unit in a group of observation stations through which will be undertaken the systematic study of local earth movements in the southern California region. The research work of the station will be conducted by the Advisory Committee in Seismology under the immediate supervision of Mr. H. O. Wood, Research Associate in Seismology, and Dr. J. A. Anderson of this Committee, with competent assistants.

On the other hand, the station will be enrolled in the newly established Department of Geology of the California Institute of Technology and will afford such opportunity for advanced students in geology to share in the conduct of research problems in seismology as the character of the problems and the capacity of the laboratory may permit.

In pursuit of this plan a tract of three acres located on a granite hillside just west of the City of Pasadena has been purchased and ground broken for a laboratory building which is already in process of construction and is expected to be occupied soon after January 1, 1926.

The ground floor will provide a seismograph room with six piers

built directly upon the underlying granite, a small laboratory room with two additional piers for experimental purposes, a photographic room, a radio room, and a large storage and file room. At the back of the building two tunnels will be driven into the granite rock composing the hillside, one to a depth of thirty-six feet, the other thirty feet. The two tunnels will enter from opposite ends of the building and will be connected by a covered passage the entire length of the building (78 feet). This passageway with tunnels at right angles to it at each end will afford excellent opportunity for tilt experiments in two dimensions which have long formed a part of the Committee's plan.

On the second floor are two laboratories, four offices, a large drafting and measuring room, and an attractive lobby at the main entrance, which is on this floor.

The entire building is of concrete, about seventy-eight by forty feet in floor area exclusive of tunnels and passageway, has a tile roof, and is of nearly earthquake-proof construction.

The first of the branch stations will be located at the Scripps Oceanographic Laboratory of the University of California at La Jolla. In the basement of the main building of this station a room has been set aside and equipped with piers ready to receive instruments as soon as the latter are ready. This station is located directly on the beach of the Pacific Ocean and will afford excellent opportunity to study the effect upon sensitive instruments of the pounding of sea-waves, concerning which there has always been some controversy because of their possible relation to microseisms.

The second of the branch stations will be located at Riverside, approximately eastward from the central station in Pasadena. A contract for this station has been entered into with the municipal government of Riverside which will provide the building and an attendant to care for the instruments and change the seismograph sheets daily. The contract will run for five years and the building is designated for the exclusive use of the Carnegie Institution of Washington for this purpose. Construction is to be begun at once.

The third branch station will be established on Mount Wilson as a part of the Mount Wilson Solar Observatory.

Negotiations are proceeding with San Diego County for a station at Fall Brook and with the owners of Catalina Island in the hope that we may be enabled to complete a group of five branch stations about the central laboratory at Pasadena.

In view of the recent earth movements at Santa Barbara, which have resulted in the partial destruction of the business portion of that city, and the further fact that the primary triangulation by the Coast Survey has revealed a displacement or creep in this region amounting to as much as twenty-four feet, it is earnestly recommended that a further triangle be set up to the north and west of the Pasadena station so as to include this seismically active region. A station near Santa Barbara and a second to the north of San Bernardino would serve this purpose.

5. Related Activities

The Advisory Committee in Seismology was constituted to "advise with the president regarding the initiation and development of research in the field of seismology"; it therefore appears pertinent to include in this report brief mention of two activities which have been inaugurated during the present year in which this Committee has had no official part but indirectly has given such aid and counsel as it could.

During the past summer the Jesuit students of seismology representing such important stations as Georgetown University (Washington), Fordham University (New York), St. Ignatius College (Cleveland), St. Louis University (St. Louis), and many others, met in Chicago to arrange for a co-operative organization with two important purposes (among others): (1) To provide for uniform standards of measurement and interpretation of seismograph records, (2) to encourage seismologic research. A tentative organization was perfected for the first year which has been designated the "Jesuit Seismological Association," with Professor J. B. Macelwane of St. Louis as organizing officer and director of the central station. In view of the fact that the Jesuit order maintains seismologic stations all over the world and has always taken a leading part in the development and prosecution of seismologic studies, and the further fact that Professor Macelwane is himself one of the foremost students of seismology in this country, very much may be expected of this new organization.

Under the leadership of a member of the Advisory Committee in Seismology, Mr. Willis, an effective beginning has been made in the study of safe building construction and proper insurance against the earthquake risk.

The Committee on Building for Safety against Earthquakes, organized by the Seismological Society of America in co-operation with the Society of American Civil Engineers, the American Institute of

Architects, the National Board of Fire Underwriters, and several other organizations, has carried on its work throughout the year, investigating the actual conditions of building and seeking practical methods of improving them at reasonable cost. Reports have been prepared in preliminary form and discussed among the members of the Committee with a view to revision and expansion for the final report. Mr. Willis drew up an analysis of earthquake forces in relation to engineering problems, which was published in part in the BULLETIN OF THE SEISMOLOGICAL SOCIETY, in one of the papers on "Earthquake Risk in California." Mr. Dewell, the representative of the Committee of the Society of American Civil Engineers, has prepared a report on the character and magnitude of strains set up by earthquake shock in frame structures, and this is now in press in the forthcoming number of the BULLETIN. Mr. Hunt, representative of the American Institute of Architects, is preparing a report on the construction of walls, panel walls, roofs, and floors, in which he will point out the peculiar weaknesses of modern practice and suggest better methods. A report on foundations by Mr. McIntosh, representative of the Bureau of Engineering of the City of San Francisco, is expected before the end of the year. In matters relating to insurance and public safety Mr. Andrews of the National Board of Fire Underwriters, and Mr. Manwaring, representing the Committee on Safety of the City of Los Angeles, have been active in studying the relation of earthquake damage to the fire hazard. Mr. Andrews has prepared a preliminary report which is to be enlarged before publication. Mr. Manwaring has written a statement on panic and its prevention, which will shortly be published in the BULLETIN.

The work of this Committee has been extended to the consideration of practical methods of enforcing better construction. It having been ascertained that building codes take no account of the stresses which may be set up by an earthquake, it appeared desirable to take steps toward introducing such provisions into the codes of the Pacific Coast cities and elsewhere. To this end a general statement regarding the magnitude of the stresses, the conditions governing their intensity, and the general features of design necessary to resist them, was drawn up by Mr. Willis in co-operation with Professors C. D. Marx and C. B. Wing of Stanford University, and steps are now being taken to have detailed specifications written in accordance with these general provisions. It is anticipated that with the aid of the National Board of Fire Underwriters a uniform code of provisions against earthquake stresses

may thus be developed and placed at the service of all cities where there is earthquake risk.

The co-operative work of the Seismological Society is thus reaching out into fields of practical application and is drawing into the effort toward greater security through better building the interests which are behind insurance, banking, engineering, and municipal control.

6. Recommendations

It is recommended that provision be made:

1. For further experimental work on vertical-component instruments for the stations already designated.

2. For the further study of minute-to-minute time signals for simultaneous record at all of the stations.

3. For further experimental work in the study of cumulative stresses (tilt mechanism).

4. For two additional branch stations at appropriate points north and west of Pasadena.

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