Department of the Interior

DOMINION OBSERVATORY

R. MELDRUM STEWART
Director

OTTAWA, CANADA, February 10, 1926.

MEMORANDUM:

Re. The Seismologic Problem of Quebec

The enclosed bulletins are intended to supplement an informal discussion of the above subject before the Logan Club, Victoria Museum, Wednesday afternoon, February, 10'26.

The first memorandum "Earthquake Risk in Quebec and Some Ways of Making Use of Seismologic Services", gives an outline of the topics dealt with by the author in an interview at Montreal with the officers of the Shawinigan Water and Power Co. and with members of the Quebec Running Streams Commission.

The second mimeographed article is copied from the St. Louis Post-Despatch of September 30, 1925. It outlines the research in the Ozarks, referred to in the memorandum above. It is accompanied by a photograph showing Commander Heck, Dr. Macelwane and Father Joliat (to be in charge of the St. Louis out-of-town station). These men are standing in the excavation prepared for the new vaults of this station at St. Stanislaus Academy, Florissant - about 15 miles out of St. Louis.

The third article has just been received from Science Service. It is written by Bailey Willis, who needs no introduction to geologists; it presents a well-considered statement as to the feasibility of dealing with earthquake prediction.

Further supplementing the above it may be stated that: the Shawinigan Water and Power Co. have written the Deputy Minister of the Interior, informing him of their decision to purchase, install and operate seismographs of the latest, short-period, pattern, at Shawinigan Falls and at Seven Falls on the Ste. Anne River near St. Fereol, provided they may have the cooperation of the Government in the matter of : having geodetic control stations placed about the two installations, and supervision of the seismologic work by the officers of the Government. It is essential that the cooperation of the Geologicsl Survey be obtained in this special problem. Their cooperation in a general attack on the seismicity of Quebec would be indispensable.

DOMINION OBSERVATORY, OTTAWA

February 10, 1926.

EARTHQUAKE RISK IN QUEBEC
AND
SOME PRACTICAL WAYS OF MAKING USE
OF
SEISMOLOGIC SERVICES

Ernost A. Hodgson

EARTHQUAKE RISK IN QUEBEC
by
Ernest A. Hodgson
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The following compilation of observations is not intended as a complete treatment of the subject indicated in the title. It is rather designed to call attention to the fact of a real problem facing the engineer who is engaged in planning the construction of expensive works in the seismic Quebec area. For the purpose of maintaining a definite order in the presentation of the facts they are set forth under serial numbers and sub-numbers.

I Seismology as a science secures data of value to the engineer by means of the following studies:-

1. Seismographic observations which yield information as to the frequency of earthquakes, their intensity, and their distribution in more or less well-defined areas.
2. Study of earth structure and stability in regions designated as seismic. This study is made by means of specially designed seismographs of short period. The seismologist is assisted in this field by the geologist and by the geodetic engineer. Their combined efforts produce what may be spoken of as an earthquake map.
3. Examination of the results of earthquakes upon construction with reference to the factors; proximity to the epicentre; nature of the subsoil; character of the building design and the workmanship and the quality of the materials used.

II A well-worked-out example of the above listed contribution of seismology to engineering is to be found in California. (Japan has also a fully developed seismologic service which supplies information to companies interested in construction work in that country). An outline of the progress of seismology in California may be presented as follows:-

1. Previous to 1906, the date of the San Francisco earthquake, seismographs were in operation at various points in California, notably Leland Stanford University and the University of California. These instruments were found inadequate to record any but the larger tremors but they provided a basis of observational material to enable the pioneers in seismology to deduce the frequency of shocks and to point out the more striking examples of slipping fault lines.
2. Several seismologists - Branner, Willis and Lawson - urged the necessity of systematic earthquake study.

They met with opposition from all types of business men - real estate agents, engineers, electrical development promotors, etc.

3. The San Francisco earthquake occurred, followed by the fire. Renewed efforts were made to arouse public interest in seismology but the opposition was more marked than ever. Branner and his colleagues were looked upon as a public menace. However, they succeeded in forming the Seismological Society of America.

4. The San Francisco quake was studied in detail and it was discovered that although the shock was a thing they could not have avoided, the loss would have been much less had they taken proper precautions. The city should never have been built directly on the San Andreas fault. Even though that had been done, care should have been taken to avoid areas of fill. The water conduits should have crossed as few fault lines as possible and ample storage should have been provided within the last fault crossed, to supply fire-fighting and general city requirements until a rupture in the leads could be repaired. It was actually found that the pipe lines were, in many cases, lying along a fault, crossing and recrossing the danger zone. Much was learned of the resistance of ferro-concrete construction to earthquake action.

5. A system of education was begun, mostly through the small group of enthusiasts forming the Seismological Society of America. This led, in time, to a realization of the need for scientific investigation of the seismic possibilities and the best means of meeting them. Public opinion demanded knowledge and the protection it affords.

6. The Advisory Committee in Seismology of the Carnegie Institution of Washington was formed and began work in California in 1921. They invited and received the cooperation of Ukiah and Lick Observatories, the U.S. Coast and Geodetic Survey, the U.S. Geological Survey, the California Institute of Technology, the U.S. Bureau of Standards, the University of California, Leland Stanford University, and the United States Navy.

7. Since 1921 the cooperating bodies have:-

(a) Produced a fault map of California on a scale of 8 miles to the inch, showing all the known faults, active and passive in California or beneath the coastal waters. This map was made possible by funds subscribed by the same business men who once considered seismology a menace. The work involved considerable expense to trace fault lines indicated by the seismograph and by the studies of the geology of the region.

(b) Determined the relative shift of triangulation points in California. These show movements of the surface, in different directions at different places, ranging from two to twenty feet. A study of these shifts designates the fault lines likely to slip and indicates whether the shift taking place at the time of an earthquake has relieved the strain or whether further slips are likely.

(c) Developed a new type of seismograph which combines the advantages of small compass, relative economy of production and operation and which has proved highly successful in the study of local tremors which do not record on seismographs of the usual type. A modification of the instrument is being developed for recording distant earthquakes. Experiments, so far, have shown remarkably satisfactory results.

(d) Arranged for a thorough sub-oceanic survey which has been successful in detecting configurations of the ocean floor for areas near the coast, making possible an extension of the traces beyond the shore line for many faults known to traverse the land areas.

(e) Established special seismic observation stations, equipped with the Wood-Anderson special type seismographs, for critical study of the seismicity of the California region.

III So successful has been this work in California that it is now proposed to carry on a similar investigation in the Ozark mountains; in this case the Jesuit seismological organizations will cooperate with the U.S. Coast and Geodetic Survey, the geological surveys of the states concerned and possibly the geology department of the University of Chicago. They hope to:-

1. Throw a geodetic triangulation and precise level net over the area, as a basis of investigation at a later date to detect evidences of accumulating strain in this area which has not been relieved since the great earthquake of 1811 at New Madrid.

2. Produce a detailed topographical map of the area, based on the geodetic triangulation.

3. Study, by means of three suitably equipped seismologic stations, the present evidences of slipping fault lines, with a view to determining their laws of shock recurrence, if any.

4. Survey the area geologically to determine the angles at which the strata appear and the position of fault lines, revealed by the distribution of different kinds of rock.

5. Produce an earthquake map of the region, using the topographical map as a base and plotting on it the active and dead fault lines discovered in the seismologic and geologic surveys.

IV The activities in the United States have been outlined to show the methods which should be followed to determine the fault lines in an area known to be seismic, in which many people are called upon to live, and where considerable investments are tied up in construction of various kinds. The recent earthquake in Quebec occurred on a fault line which has long been known to seismologists as active although it was never very closely delimited. The records of the Dominion Observatory, maintained since 1906 and the investigations of the destruction last February permit us to say with respect to the location of fault lines in Quebec, that:-

1. The activity in the faults in this region was not marked previous to last February and subsequent to the beginning of the Ottawa records in 1906. A shock in from three to five years was all that was reported or registered at Ottawa and known to come from the lower St. Lawrence.

2. Other shocks were felt there but were too faint to record on the seismographs then in use at Ottawa. No observer was stationed in this locality to report the tremors. Our records of earthquake frequency are, therefore, limited.

3. The quake of February 28 occurred, in all probability on a fault line crossing the St. Lawrence near Riviere Ouelle, entering the south shore to near St. Pacome, and extending into the north shore up one or both the rivers Malbaie and Gouffre to their common source in the highlands near the eastern boundary of the Laurentides Park. It probably consisted of a sharp upward thrust on the north-east side of the fault, with possibly a strong horizontal movement toward the north-east in the case of the south-west side of the fault. The maximum movement was in the region near Riviere Ouelle on the south shore and Malbaie on the north shore, but very considerable damage was done at Quebec, and, to a lesser degree, at Shawinigan Falls and Three Rivers. These were due to the deep alluvial soil at these places or to a combination of deep soil and the location of heavy buildings on a steep slope.

4. According to the Geological Survey there are probably many fault lines in the region of the north shore. The seismographs at Ottawa and the reports of local residents show that these are active. None have been definitely located by geological surveys. There has been no complete triangulation of the country by the Geodetic Survey. No accurate topographical or geological map of the territory north of the St. Lawrence and south of the Saguenay exists. Arguments may be advanced in favour of carrying out a programme of work similar to that done in California or that shortly to be undertaken in the Ozarks, within this area of large investments in mills and other works connected with lumbering, as well as

in water power electrical development. We may profit by the lessons learned in California by the business men of that state, to the extent that we bring ourselves to admit our problem and take steps to solve it.

5. A thorough study of the situation in this area would not yield full results at once. We would undoubtedly expect that within a year or two we would be led, in our choice between two otherwise equally suitable sites, to exhibit some degree of judgment. Later, triangulation and precise levelling, once made and repeated after an interval of, say, ten years would serve to indicate the existence or non-existence of lateral and vertical earth movements and the accumulation of strain likely to result in an earthquake. A detailed topographical map of the country, showing contours, would form a valuable asset to companies operating in the area and form a base upon which the seismologist could plot the fault lines discovered by the geologist. He could then study these in detail and a series of seismic observations with suitable apparatus would give full details as to which faults are active, and which are passive. Such work would grow in value with time. If we had these data today we could say with conviction "do not build here; there is a safer location". Unless we do this work today our tomorrow will also be comfortless in this respect. Neither ignorance of conditions nor apathy toward them can be looked upon as a comfortable condition in the face of the positive, known, fact, that the area concerned is seismic.

V Although we cannot now say exactly where most of the fault lines lie in Quebec we can point out that:-

1. No buildings should be placed on deep alluvial soil if such a location can be avoided.

2. If construction of massive type must be erected in such places then a well braced steel frame is required as the basis of the design upon which the structure is to be moulded.

3. Concrete construction having the ordinary reinforcement of rods, bars and wire network, is quite safe except for points immediately upon the fault line or where the soil is deep.

4. All concrete work should be so designed that the walls shall taper; wide at the bottom and diminishing in thickness toward the top.

5. Curtain walls are to be avoided in all cases.

6. Overhanging cornices, ornamental terra-cotta work and tile roofs are dangerous.

7. Water tanks should be built apart from and not into the frame of mills, factories, etc.

8. Massive machinery on the upper floors of buildings will result in a serious strain on the structure in the case of earthquakes.

9. Dams should be designed with a safety margin calculated to withstand surging due to earthquakes affecting the upper waters. Gate works should be placed where they will not be damaged by such surging.

10. Frame buildings must have the studding run through from sill to top plate, with ledger board construction at the second floor joists. The frame must be well braced. The chimney must be tied to the building at several points. Under no circumstances should a chimney be built on a shelf as is sometimes done in this region. Neglect of this precaution is likely to result in loss of life in the case of even a minor shock and the fire risk is greatly increased by such improper chimney construction in frame buildings from private residences to construction shanties.

11. Additions to buildings, when placed in immediate contact with the original structure, should be bonded in to the latter. Otherwise each part acts as a battering ram for the other at the time of an earthquake.

12. Brick veneer buildings are not safe on either solid or deep soil locations within a distance of the epicentre which varies with the intensity of the shock, the character of the soil and the quality of the workmanship, from twenty to a hundred miles or even more.

13. Solid brick buildings are much safer under similar conditions than are those of brick veneer but if they are on deep soil and near the epicentre they are likely to be disintegrated by the first shocks and overthrown by the secondary tremors. The same remarks apply, though perhaps to a lesser degree, to solid stone structures.

14. Dwelling houses which must be built on alluvial soil and near active fault lines should be of wood. The design should include plenty of diagonal bracing. The sheathing should be applied diagonally. The chimney should not pass up through a bedroom.

VI Research in seismology is constantly discovering facts which are of importance to the engineer, in whatever field he may be working. Papers appear from time to time, containing information likely to interest the builder, the oil surveyor, the insurance agent, the investment companies, manufacturers of building products, etc. etc. Many of these papers appear in the Bulletin of the Seismological Society of America. For example they have been running a series of articles on "Earthquake Risk in California". These touch on many points in engineering. Articles of a similar type appear in other journals as well. Some are in foreign languages. The Japanese have, for many years, carried on, along with their other seismologic activities, research work in engineering design for earthquake areas. Most of this is published in English in the beautifully printed and illustrated reports of the Imperial Earthquake Commission. Recently a committee of engineers has been appointed in the United States to study and report on "The Effects of Earthquakes on Engineering Structure with Special Reference to the Japanese Earthquake of September 1, 1923." Several preliminary reports have been published by the Dominion Observatory, dealing with the observed conditions in the St. Lawrence region after the February earthquake. The final report which will appear as one of the regular official series "Publications of the Dominion Observatory" is now nearing completion.

VII Within the past month steps have been taken to form an Eastern Section of the Seismological Society of America. The proposed activities of this section are of interest to engineers. They include the following:-

1. Formation of a membership list, divided into two classes - full and associate.

2. Arrangements for fees - full members pay the regular three dollar dues for membership in the parent society and also a one dollar fee toward the maintenance of the Eastern Section. Associate members pay only the latter.

3. Benefits distributed - full members receive the quarterly Bulletin of the Seismological Society of America and also all the circulars, memoranda, reports of meetings, abstracts of papers given before the Eastern Section, etc. Associate members receive all except the Bulletin.

4. The first meeting of the Eastern Section is to be held in Washington, sometime in April. The keynote of this meeting will be "A Review of the Past; an Outlook to the Future". Following out this idea, papers will be given by those in a position to deal with their own respective fields, treating in detail the seismologic services of such bodies as - the Jesuits of the United States and Canada: the United States Government services: The Canadian Government services: the work of the geologist. Papers may also be given treating the subject from the standpoint of the insurance companies and of those interested in the lessening of earthquake hazard. These papers will be abstracted and published in mimeographed form to all members of the Eastern Section.

5. It is proposed to issue quarterly a list of all articles on pure and applied seismology which appear in book

form or in technical journals. This list will be divided into sections for the convenience of those receiving it. The sections will give, respectively, a bibliography of those articles of particular interest to - seismologists only: construction engineers: oil-field workers: insurance companies: manufacturers of building material: and geologists. If an article would be of interest in more than one of these fields it will be entered in all the sections with which it is concerned. The complete list, in mimeographed form, will be sent, each quarter, to all members of the Eastern Section. It will probably appear also in the Bulletin.

This service will keep posted those individuals and firms joining the section, with regard to those matters which should interest all who are concerned with the lessening of earthquake hazard and its attendant dangers of fire and flood, the fixing of adequate insurance premiums whether from the standpoint of the insurer or the insured, the evolving of well-planned structural design, the development of natural resources, or the stability of investments in those areas which are definitely seismic.

The dangers which surround all activities in such areas may be reduced to a very low percentage by precautions, revealed as wise by the light of accurate knowledge and requiring, in most cases, no greater first cost than their dangerous alternatives, followed in the past through ignorance of conditions.

Dominion Observatory,
Ottawa, Canada.

January 16'26.

MEMORANDUM
SOME PRACTICAL WAYS OF MAKING USE OF
SEISMOLOGIC SERVICES

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1 Some person should be appointed in each organization interested, whose responsibility it shall be to receive the quarterly bibliography of seismologic publications sent out by the Eastern Section of the Seismological Society of America; to secure copies of those articles and books reported as being of interest in the field concerned; and to maintain a section of the company files or library for such literature. In this way it would be certain that everything in seismology, of value for the work of the organization would be brought to the attention of those officers who were in a position to profit by the information.

2 Before we can determine much about the seismicity of a region it is necessary that we know the positions of the fault lines. If there are many they must be plotted on a good topographical map. Thus, in general, the geodetic engineer and the geologist must perform their work before the seismologist can hope to do his. When their part is finished a complete seismic survey of a region can be made by means of three seismographic installations.

3 In some cases a fault line is known and important works are already constructed there or there is no other place for proposed installations to be set. It then becomes desirable to know whether strains are accumulating in that area which are liable to be relieved by an earthquake. Evidences of these strains may be detected by reoccupying, after a lapse of years, geodetic triangulation points from which first-order observations were made. Steps should be taken to have a first-order triangulation net placed over the suspected area at once, to form the basis of future investigation for the detection of slow creep.

4 If there are slight shocks from time to time on a fault line known to exist, they are evidence that the fault is active. From observations with a seismograph alone it is not possible to determine just what is happening. Strain may be accumulating which is being continuously relieved by the slip: or the strain may be increasing at a rate faster than that for which the slippages would be sufficient to completely compensate. The record of slight shocks would be a positive proof of activity; their absence would **not** be complete proof of stability.

5 For a complete analysis we must arrange for the accurate geodetic survey, follow it with some years of observations with a short period seismograph properly placed and well attended, repeat the triangulation, and thus determine which of four cases represents our conditions, namely:

(a) There is a steady creep with no slight shocks tending to relieve the strain. There is then grave reason to expect an earthquake.

(b) There is a steady creep with some slight shocks but not enough to relieve the accumulating strain completely. There is reason to expect an earthquake, especially after a period of no disturbance, or after a series of slightly more severe shocks than usual at a somewhat greater interval in time.

(c) There is no indicated creep after a period of, say, ten years. Slight shocks are registered. We may suppose that the shocks are taking care of the creep and that there is not very much likelihood of a severe earthquake.

(d) There are no evidences of creep and no local tremors are recorded. The fault is, more than likely, a dead one and no apprehension need be felt.

Dominion Observatory,
Ottawa, Canada.

January 19, 1926.

Heck. Macelwane. Joliat.

EARTHQUAKE SURVEY OF OZARK REGION PROPOSED BY ST. LOUIS SCIENTIST

SMALL SHOCKS ARE FREQUENT, AND IF A BIG ONE IS COMING WE OUGHT TO KNOW IT, SAYS THE REV. DR. JAS. B. MACELWANE OF ST. LOUIS UNIVERSITY

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One of the most interesting investigations in the history of Missouri and adjoining states is proposed by a St. Louis scientist. The information assembled during the investigation would be set forth on a map of the region - a map of a sort never before made in this part of the United States.

The scientist is the Rev. Dr. James B. Macelwane, S. J., who is the seismologist or earthquake expert, at St. Louis University. The inquiry which Dr. Macelwane has initiated would answer the following questions.

Do the small shocks frequently felt in this region of late have a sinister meaning which should be heeded?

If what seismologists call a catastrophic earthquake is on the way, what point or points in the area are threatened?

Accurate, well-founded answers to these questions would not be useless information. True it is that if a disastrous earthquake is brewing in nature's mighty laboratory, the quake will come just the same. It cannot be prevented nor delayed. But with ample warning of such an impending peril, there are some very practical things which can be done to minimize the damage.

"The Ozark region is seismic; that is subject to quakes of the earth's crust." said Dr. Macelwane. "A great many small shocks occur in all the States on the flanks of the Ozarks. Missouri had one of the greatest earthquakes known at New Madrid and vicinity in December 1811, and January 1812. We had a shock in St. Louis only a few weeks ago which was felt by a good many people, although it did no harm.

Small Quakes are Frequent

"There are frequent small quakes on all sides of us - in Oklahoma, Arkansas, Kentucky and Tennessee. The Ozark region is not only an area which has been seismic in the past, but one which is active now.

"Certainly it is not my wish to alarm people. But if we are in danger of an earthquake we ought to know it and take measures in advance to protect ourselves. With proper measures for safeguarding a community from earthquake danger, that danger can be reduced to a minimum. This applies not only to human lives, but to buildings and other property.

"Let me repeat, a great many small shocks occur in all the States on the flanks of the Ozarks. At present we have no facilities for observing and studying those quakes, which are noticed by residents, and the still greater number of quakes which nobody feels.

"In the case of shocks strong enough to be felt by people in the vicinity, we have no means of locating the center of the disturbance accurately. Our seismograph at St. Louis University was designed for distant and not local earthquakes. But instruments may be obtained which render perfectly satisfactory service in recording local earthquakes.

"The essential part of our program will be to find out beforehand just what rock strain has accumulated in the region and where it is greatest. If there has been a movement of rock strata which will produce a dangerous strain or stress in the rock, we ought to know it.

"This condition can be ascertained by scientific means.

Three Stations Needed

"The first thing to do is to get one seismological station with latest equipment for recording earthquakes in operation, preferably at St. Louis. Then at least two other similar stations should be established on the flanks of the Ozarks. These three stations would form the points of a great triangle and the data from them would be compared and co-ordinated. In this way we should obtain a true record of all the shocks in the region and their points of origin - not a distorted picture but a general picture of the whole area.

"In addition to ascertaining the amount of strain which has accumulated, we should find out in what degree this strain is being relieved by small shocks, and the relation of the small shocks to the places of greatest strain.

"The progress of an earthquake might be compared to the collapse of a big wooden beam in a building. The beam does not go all at once. The collapse is preceded by the cracking of the outer fibers of the beam. Just so, the first break of the rocks in a catastrophic earthquake is known to be preceded by a large number of small shocks.

"If such shocks are accumulating in the Ozark area we ought to know it, and know just where they are originating. This can be done by installing special instruments for the observation of local earthquakes. And the whole program for investigating the earthquake possibilities of the Ozark region can be carried out at an expense less than the money loss involved in the destruction of a single first-class building by earthquake.

"Eventually we should have enough information, assembled in this way, to be able to give the earthquake risk at any point in the Ozark area."

The Ozark Seismic Area

Dr. Macelwane defined the Ozark seismic area as including nearly all of Missouri, Western Kentucky, Western Tennessee, a bit of North-western Mississippi, Northern Arkansas, Northeastern Oklahoma and Eastern Kansas.

"There is a large number of small earthquakes in the history of this region", he continued, "besides the catastrophic shocks which occurred at New Madrid. We have not enough strictly scientific data about the New Madrid disaster to say that it was the most terrible earthquake which ever occurred in the United States. But probably it was.

"There are some indications at present, in the reports which we receive, that there are more small earthquakes in this area at present than in the past. But we can't tell whether this is true until we get suitable instruments. There is a probability, although this is in doubt, of an accumulating rock strain in the region. We shall not know until an investigation has been made. There may be a catastrophic earthquake brewing for the Ozark seismic area. Forewarned, the threatened points could get ready for it in various ways.

"In california an investigation of this kind has been in progress this year. Some very definite results have been obtained, although they are not yet at the end of the program, to ascertain what localities are in danger and the best ways to minimize the damage when the quakes come. The major part of the work in California has been done since 1921. In the last few years they have gotten very splendid results.

"I have been brought here by St. Louis University to inaugurate the progress of such an investigation. Recently I made a trip to Washington and asked officials of the Coast and Geodetic Survey if they would give assistance here as they are giving it in the similar investigation in Southern California. I found them very willing to co-operate with our work as far as funds are available. The machinery is at hand, in the Temple Act passed by the last Congress, which provides that the topographical map of the United States shall be completed within the next 20 years.

"A prerequisite to this mapping is an accurate survey which will determine the key points of the region. In order to get the points necessary we need to have the Coast and Geodetic Survey run a system of triangulation across the Ozarks. This same triangulation will help us determine the strains in the rock strata as it has done in California.

Importance of Task

"It seems to me that solving a problem like this of possible earthquake danger, will be of high economic importance. In a clearly recognized seismic region like the Ozark area, we face a situation something like that of storm risk. We protect ourselves against the danger of damage from high winds for example, by building against the winds. When there is potential danger of any kind, we should take precautions. Danger of the destruction of St. Louis, for example, by an earthquake probably is extremely small. But whether such a danger impends, where and when and to what extent should be ascertained.

"Our investigation may show that St. Louis and environs are not in for any earthquake catastrophe but that a rock strain is accumulating elsewhere in the Ozark seismic region. To ascertain that danger and to warn the people there, so that they may protect themselves, would show our concern for the welfare of our fellow citizens. It would be an achievement in which all St. Louisans who had assisted, financially or otherwise, might well take pride."

Dr. Macelwane explained that an earthquake-proof type of building construction has been evolved. Properly applied in the design and erection of a building, it will save that building from destruction, even from minor damage. Which, of course, means safety for the occupants and no downpour of bricks, stones, etc., upon people in the street.

Building Against Quakes

"This type of construction," he said, "provides for flexibility with strength, proper distribution of load and good workmanship throughout a building which is a unit and acts as a unit is the best for an earthquake area. Frame buildings generally are regarded as safer in an earthquake as far as the shock is concerned, but they are more liable to damage by fire which usually follows the quake. Even greater resistance to shock can be gotten with steel and concrete. The earthquake building is so designed that it will vibrate as a unit. The walls should be anchored firmly, tied to the framework, and the natural period of vibration of the various materials used in a building should be the same. This is a matter of lengths and weights and elasticity, and 'constants' well-known to engineers.

"Furthermore, water mains can be laid in such a way as to minimize the danger that they will be broken during an earthquake. Many times fire and lack of water have caused greater havoc than the quake itself.

Dr. Macelwane is planning for an underground station in the county, protected not only from storm disturbances but from the rumble of street cars, heavy trucks and other features of city life which cause local, artificial tremors. There a seismograph of the latest improved type will keep a log, as it were of all earthquake disturbances in the Ozark region. Two more stations at other points of a great triangle across the region, will be established, he hopes. Study of all the data obtained will yield information as to any earthquake "danger spots" which exist in the region.

The present seismograph at St. Louis University, installed in 1909 and typical of the instruments for long-distance earthquake observation, is a big pendulum upside down. The pendulum action is obtained by having it a little off vertical, and balancing the pull of gravity on the 175-pound bob against two springs. Attached to the bob are two levers which rest upon the frame of the instrument and are brought together in front of a revolving chart of smoked paper, on which they make the record with aluminum bristles. The framework is vibrated by the earth tremors, while the inverted pendulum is held theoretically still by the inertia of its 175 pounds.

Kinds of Earth Waves

Dr. Macelwane explained that there are several kinds of earth waves which radiate out from a quake and which are recorded by a seismograph. One type is longitudinal, like a sound wave. One is transverse, like a light wave. The one which travels through the earth most rapidly is the one like a sound wave.

"These two types of waves start together," said Dr. Macelwane. "The distance by which the more rapid type leaves the other type behind is a measure of the distance traveled. The farther behind the transverse wave is, the more distant the center of the earthquake. There also are surface waves which travel around the outside of the earth, and they also may be used in estimating distance."

Dr. Macelwane was graduated from St. Louis University in 1910 and received his M. A. in 1911 and his M. S. in 1912. The University of California, at Berkeley, conferred on him the degree of Ph. D. in 1923. For the last two years he has been assistant professor of geology at the University of California and in charge of the seismograph station there. He supervised the publication of seismograph records for the University of California and for Lick Observatory.

Brother George Rueppel, who has been temporarily in charge of the St. Louis University seismograph station, will be assistant director of the new department of geophysics and seismology, besides carrying on his meteorological work and directing station WEW the university's broadcasting plant.

THE SCIENCE NEWS-LETTER

A Weekly Summary of Current Science

EDITED BY WATSON DAVIS

ISSUED BY
SCIENCE SERVICE
B and 21st Streets
WASHINGTON, D. C.

EDWIN E. SLOSSON, Director
WATSON DAVIS, Managing Editor

SUBSCRIPTION: $5 A YEAR, POSTPAID

Vol. VIII, No. 252 Saturday, Feb. 6, 1926

CAN WE PREDICT EARTHQUAKES?

(This is an unsensational statement on the earthquake problem by one of America's leading seismologists. Is there danger of earthquake in California, New England, and elsewhere in the United States? Dr. Willis states the facts and the reader can draw his own conclusions.)

By Dr. Bailey Willis

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"All I know is what I read in newspapers", as Will Rogers says. At least that is true as regards "predicting" earthquakes. Prediction connotes precision and precision spices news. Hence news predicts precisely. There will be a destructive earthquake shock in Wall Street in two years, two months, and a day. That, telegraphed by an irresponsible reporter is news, though not true. There have been severe earthquake shocks in New England. They are sure to occur again sooner or later. Common sense demands that we take precautions against disaster. That is not news, though true.

Earthquake news, served up as a kind of side dish, is overspiced. It is time for seismologists to give the public plain food. Certain facts we know; others we think we know; still others we infer confidently; others doubtfully; then we guess. The prediction of an earthquake is a guess, which I prefer to call a forecast.

We know that earthquakes are natural phenomena, which have occurred from time to time, at longer or shorter intervals, with greater or less violence, but unequally as regards time-intervals and intensities in different countries.

If earthquakes were like comets they would return at definite intervals, But they do not resemble comets in any respect whatever. Rather are they like storms, an effect of concentrated energy; gathered in the one case in the air and reaching a crisis at frequent intervals; in the other case gathered in the earth's crust and rising to a critical state at longer intervals. That much we know regarding their periodicity and we can say with confidence that the farther we are from the last great shock, the nearer we are to the next one.

We know that sometimes, but not always, earthquakes group themselves in a district in a brief sequence of years. We recognize in those cases what we call fore-shocks, a relieving shock, and after-shocks. When we have a full series there is no difficulty in distinguishing the several parts of the sequence. The fore-shocks are moderately severe and limited in their effects to a small area. The relieving shock is one of great intensity and large area. The after-shocks gradually diminish in intensity and frequency. In case of a moderately severe earthquake, however, such as the Santa Barbara incident, we cannot know definitely to what extent it may have served as a relieving shock for that locality or in what manner it may have relieved adjacent districts of strain, or have increased the strain upon them. Here we begin to guess.

We may be guided in guessing by related facts and may feel more or less justified accordingly. Thus the historical record shows that southern California is a province which has been shaken from time to time by earthquakes of a general character. In 1857 the disturbance was strong over an area of some 250,000 square miles. That is, it compared in extent with the earthquake of February 28, 1925 in the eastern States, but it was much more violent. The Santa Barbara shock, by contrast, shook an area that did not exceed 3000 square miles and points of high intensity were curiously limited and sporadic. The energy released in the latter case was not more than one percent., very likely not one tenth of one percent. of that set free in 1857. The 1857 shock was a relieving shock. It was followed by a long interval of quiet. I would not feel safe in guessing that the Santa Barbara incident would have a like effect.

During the last seven years there have been four incidents of the Santa Barbara kind in southern California. We do not know that they are fore-shocks. We cannot know until the relieving shock shall have shown that they are. But we are on the safe side in guessing that they will prove to have been fore-shocks.

We think we know that earthquakes are produced by pressure which distorts the elastic rocks, so that when they slip they vibrate. It has been found by the Coast Survey that the mountains in California are on the move, so to speak; that is, they are pushed out of place, and we connect their movements with the pressure to which we attribute earthquakes. In southern California certain mountain peaks not far from Santa Barbara have moved northward, in the direction in which the earthquake pressure should push them, as we understand it. In northern California other mountain peaks moved northward until after the earthquake of 1906, but they then began to slide back southward. The shock of 1906 was a relieving shock for the north and we guess that it took off the pressure. The mountains in the south have not begun to slide back, so we think that the pressure has not been relieved, and this confirms our guess that the relieving shock is ahead of us.

Until recently we have had to depend upon our senses for evidence of nearby earthquake activity and we have been aware that their capacity to detect vibrations is limited to the greater ones. Thousands of minor shocks or micro-tremors occur daily and they would give us an index of the elastic strain in the rocks not unlike the significance of a barometer in weather observations, if we could but register them constantly. We have had instruments, it is true, that would record the occurrence of a great shock a thousand miles away, but they are not tuned to the more rapid waves of a local tremor. Through the researches of the Carnegie Institution of Washington, we now have available the Wood-Anderson seismometer, a simple, but very sensitive little instrument, which can be tuned to record elastic waves of any length, and we are thus in a position to know what the actual condition of the earthquake strain is in any district where the seismometers may be installed. We shall then guess more certainly, but we have to wait until the value of that information is appreciated in San Francisco, New York, Boston, and elsewhere, at least to the degree that business interests will provide the instruments as a measure of self-protection.

In the mean time the seismometers have been made and tested at Pasadena, where they have proved their efficiency by registering as many as two hundred micro-tremors a year. This state of activity is not what we would expect during a period of quiet. It might occur before a relieving shock or soon after one, but in the latter case the great shock must have occurred recently, and that is not the fact.

To sum up for southern California: Sixty-eight years have passed since the last general earthquake; severe strain is indicated by local shocks, displacements of mountains, and seismometric records; in 1852 a disturbance similar to that of 1925 preceded the relieving earthquake of 1857. Will history repeat?

For northern California the facts are: It is only 16 years since the greatest relieving shock recorded in that province; slight, though sensible tremors occur from time to time; they are not as strong as we would expect fore-shocks to be; the pressure which moved mountains has been relaxed. The best guess seems to be that the strain has begun to re-accumulate, but is not likely to reach a critical condition for two or three decades.

As regards New England we know that the conditions are very different from those in California. Intervals between relieving shocks are much longer; distinct fore-shocks have not been recognized; movements of mountain peaks may have occurred, but are unknown; seismometric records of micro-tremors are lacking. The St. Lawrence earthquake of February 28, 1925, no doubt relieved the strain within a considerable area. Does that area include New England? I do not know. Does it include New York? I cannot guess! The poverty of information is lamentable. We face two possibilities, as far apart as the poles: (1) the strain is relieved; we need not expect another severe shock in a century or two. Or (2) the strain is not relieved; it has been increased by the failure of one part of the continental structure, which brings the pressure to bear on another; if so, we may expect renewed activity soon. No light leads in either direction.

New York, Philadelphia, Washington are in a seismic belt where shocks have been so rare and so slight that we hardly expect them. It may be a safe guess that no earthquake of any severity will ever affect those cities. And yet - there was the Charleston earthquake of 1886! A great shock, its intrusion upon our fancied security gives one pause. I wish seismometers had been longer in use, that they were more generally installed today.
