James B. Macelwane S.J.

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A Biographical Memoir by

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WILLIAM V. STAUDER, S.J.

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JAMES B. MACELWANE, S.J.

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BY PERRY BYERLY AND WILLIAM V. STAUDER, S.J.

THE FATHER of systematic seismology has a name spelled differently in different countries. In Germany it is spelled Wiechert. In England it is spelled Milne. In Russia, Galitzin. There is a sense in which it would be proper to say that in the United States the name is spelled Macelwane. More than any other the man whose life is here recalled contributed to establishing the science on the firm, well-established academic footing it enjoys in this country today.

James Bernard Macelwane was born on the northern shore of Sandusky Bay near Port Clinton, Ohio, on September 28, 1883. He was the second eldest in the family of nine children, five boys and four girls, born to Alexander Macelwane and Catherine Agnes Carr. Both his father and his mother were Irish and, with the pride of origin characteristic of his race and a love of paradox characteristic of the man, Father Macelwane, when questioned, used to delight in tracing his origin back to Belfast, on his father's side, and to County Longford on his mother's. While he was never one to wear his nationality on his sleeve, still a pride of ancestry such as is laudable in any man was his. It used to manifest itself in little flashes as when, with a twinkle in his eye, he would recount how as his first teaching assignment he, an Irishman, was appointed instructor of German for the high school boys of St. John's College, Toledo.

His father was both fisherman and farmer. Thus childhood days, while happy ones, were also hard ones for James and his eight brothers and sisters; the children were kept busy with such chores

as mending nets and tending gardens. As freedom from seasonal chores permitted, his early education was obtained on the benches of the Plasterbed District School about a mile and a half from his home. Back and forth to that rural school he used to trudge through summer heat and winter cold, till at the age of fifteen he left school to take a hired man's place in his father's fruit and fishing business. Family resources were meager and required what assistance young James could give.

The work of placing out the great nets and gathering them in again, and the marketing of the catch, was strenuous. It was too strenuous, perhaps, for the frame of a young boy, and he soon became thin and exhausted. But hard as it was, the work was harder still on a hope which he cherished of becoming a priest and a missionary. What time he could of an evening he devoted to study, to reading, and to writing. Finally, at sacrifices known only to his father and mother, at the age of eighteen he left home to resume his education at St. John's College in Toledo. Two years later, on August 31, 1903, he joined the Society of Jesus and after two years of study and training in the ascetic life he took his vows as a Jesuit on September 8, 1905. Thereafter he entered upon the long course of studies in the classics, science, and theology required of Jesuits who are preparing for the priesthood.

His first years of training as a Jesuit were passed in Cleveland as a member of the Buffalo Mission. The Buffalo Mission was under the auspices of the German Jesuits, and young Macelwane had joined the Mission rather than one of the American Provinces because it was his ambition to learn languages as an aid to his future work as a missionary. He would learn German readily, he thought, were he in the novitiate of the German Fathers. He learned German, right enough, and later French and Spanish and Italian, too, as well as the classical languages of Greek and Latin.

When the Buffalo Mission was dissolved in 1908, James Macelwane was assigned to the Missouri Province, and the remaining years of his training were obtained at St. Louis University. He received his

Bachelor of Arts there in 1910, a Master of Arts in 1911, and a Master of Science in 1912. In 1918 he was ordained a priest. In 1921, following upon further studies in theology and a year as an instructor of physics at St. Louis University, he went to the University of California where he studied under the late Professor Elmer E. Hall, receiving his Ph.D. in 1923.

It was upon his arrival in St. Louis that Father Macelwane's career began to turn away from that of a missionary and toward the earth sciences. Early preferences in the matter of specialized study attracted him strongly to literature and the classical languages. He also evidenced an ability and interest in mathematics and science, however, and was encouraged in that interest by his religious superiors. Eventually he was assigned to special studies in physics.

About that same time, during the scholastic year of 1910–1911, he was captivated by his first course in geology. It was an introductory course, hardly even an *aperitif,* perhaps, but that first taste of geology was cultivated when in the course of the next summer he was one of a party of seven under the direction of two Fathers, Professors at St. Louis University, on an extended field trip in the Colorado Rockies. The group spent two weeks or so in the field at each of several camping spots—Canon City, Ouray, the Wasatch Mountains of Utah, Leadville, and the vicinity of Pikes Peak. The next summer took him to Glacier National Park and Yellowstone; the following, to Arizona and to work in the Petrified Forests and the Grand Canyon, thence to the west coast and up to the Canadian Rockies. Thereby was whetted an appetite and imparted a relish for field geology which never left him. In later years trips to the field were his favorite diversion and he personally conducted a number of geology camps for students in the vicinity of Canon City in the Colorado Rockies. Such was his interest in geology that when questioned as to which science he would teach in college were his choice to be limited to one subject he would reply, "Geology, of course."

Further direction of his career toward the earth sciences came that same year of 1910–1911. Father Frederick L. Odenbach, S.J., of John Carroll University, Cleveland, was at that time organizing the Jesuit Seismological Service as a cooperative scientific project on the part of Jesuit institutions of the United States and Canada. Fifteen horizontal component Wiechert seismographs and three vertical component Wiecherts were imported and installed at various Jesuit universities and colleges. By the beginning of 1911 the stations were in operation and sending data to the recently established International Central Station at Strassburg.

At St. Louis University the seismographic station was under the direction of Father Goesse of the physics department, who called upon the then Mr. Macelwane, along with two or three others, including Joseph S. Joliat, S.J., later of John Carroll University, to assist in the running of the station. The new Wiechert had recorded its first earthquake. But the seismograph was not operating satisfactorily and Macelwane and Joliat undertook to find out what was the matter and to put the instrument in adjustment. They took the instrument completely apart and found a kinked spring in the main hinge system. This they straightened, and then, with the parts disassembled, they began to study the theory of the seismograph as they proceeded to put it together. Out of the endeavor came Father Macelwane's first technical paper, published jointly with J. S. Joliat, "The Physics of the Seismograph." Though he did not appreciate the fact at the time, this was the beginning of his life's work.

The seismographic station at St. Louis was conducted in close association with the meteorological observatory. Interest in the one drew him into the work of the other, and among a number of short papers which followed during these years of his Jesuit training was one on the "Jordan Sunshine Recorder." His interest in meteorology, as well as in geology, is indicative of a characteristic trait of the man; his interests were always broad and enduring, and once his curiosity was aroused he continued with a gentle persistence over a period of years, gradually adding bit by bit to his knowledge, until at last his endeavors bore fruit, whether in the encouragement of others or in his own researches. Meteorology is a case in point; his later work on microseisms and with the microbarograph had its roots back in the room on the third floor of DuBourg Hall and the year 1911.

In 1912, his work toward the Master's degree completed, he began his forty-four years' association with the faculty of St. Louis University. He was appointed an instructor in physics. The next two years he held an assistant professorship in that same department, and then, in 1915, he resumed his theological studies. Much of Father Macelwane's most important work was accomplished as an administrator and educator. It is significant, therefore, to observe him in his new position as an instructor of physics supplying the lack of any suitable laboratory handbook by immediately undertaking to organize a manual of his own. In this he collaborated with James I. Shannon, S.J., then head of the department, producing a loose-leaf manual in five parts. This exercise book is a model of exactness and attention to fine details.

Meawhile he continued the interest born of Wiechert and the seismograph by wide reading of seismological literature. He had advanced himself well along in seismology by the time he arrived at the University of California in the fall of 1921 to obtain his Ph.D.

The University of California offers a geophysical library exceptional for its wealth of classical and early papers in seismology. Father Macelwane was a natural-born student and an avid reader, and so one can well imagine the zeal with which he dipped into the works of Wiechert and Zoeppritz, Galitzin, and Mohorovicic, continuing to develop his already broad background. How often even today graduate students in geophysics note his name on the pocket of almost every book or periodical printed before 1925.

But it was not the library that had influenced him in his selection of the University of California. Rather, he came to Berkeley because of the presence of Professor Elmer E. Hall on the staff of the Physics Department there. Hall was one of the very few men in the United States at the time who had measured vibrations in buildings.

From his earlier reading Father Macelwane had become much interested in the discussion in the literature concerning the relation

of the period of a seismic wave to the distance it had traveled. Larger earthquakes are recorded at greater distances and have longer periods than do smaller shocks. The process of dispersion was not well understood among seismologists until some years after this time, and there was disagreement at the time particularly as to whether or not there was a functional relation between period and distance traveled for the surface waves of an earthquake. This was the problem Macelwane chose for his dissertation.

Under Hall's direction, vibration recorders were set up a mile or so apart and the vibrations from trains were recorded. Both director and student hoped that the vibrations might present some evidence regarding change of period with distance, but this attack proved unfruitful. It was necessary to tackle the problem directly, to study the seismograms for one earthquake recorded at many distances. An earthquake off the coast of northern California in 1922 was selected and with the cooperation of Professor A. C. Lawson, Chairman of the Department of Geological Sciences, the seismograms of fifty-one stations throughout the world were borrowed.

Father Macelwane's procedure was to select two waves of the maximum group (surface waves) one occurring a minute after the group commenced and one two minutes after the beginning. He measured the periods of these waves at every station and plotted the periods against the epicentral distance. He found that there was a functional relationship; the periods increased with distance. His averaged curves indicated eight seconds for the period very near the epicenter and twenty seconds a quarter of the way around the world.

Professor Lawson had been much impressed by Father Macelwane. The University's two seismographic stations had been set up in 1886–1887 in Berkeley and on Mount Hamilton. For the first two decades they had been in charge of various departments—astronomy, engineering—with no one in charge who was very much interested. Then geology had taken over. But again the supervision was bandied about in the department. In this student of seismology Lawson saw his opportunity to set seismology on a firm basis. He invited Father

Macelwane to take charge as Assistant Professor of Geology. In due time his religious superiors allowed him to take the position for two years.

The Berkeley seismographs (Bosch-Omori and Wiechert) were some fifteen years old and the new Wood-Anderson had just been invented in Pasadena. There the Carnegie Institution of Washington was starting a project long endorsed by Harry Wood, a chain of closely spaced stations in an earthquake region. Professor Bailey Willis and Father Macelwane conceived the idea of a similar chain in central and northern California. It was Macelwane who got the program started, Willis who got the first money, and the senior author of this memoir who was left to carry out the program. There are now twelve stations in the chain.

During his professorship at Berkeley, Father Macelwane wrote up the Corralitos, the Calaveras, and the Crystal Springs earthquakes, small shocks in the San Francisco Bay region. He thus set a policy which was followed for many years at the University of California, that of keeping as complete a record as possible of the moderate earthquakes of the region. This collection of field data was later taken over by the California Field Survey of the U. S. Coast and Geodetic Survey.

During the Berkeley period Father Macelwane also collected the seismograms of the south Pacific earthquake of 1924 and began to study them. The physical state of the earth's core was much debated at the time. The core was known to cast a shadow for P waves. The speed of P waves drops as they enter the core. The core acts as a huge lens with gross aberration. P is weak from 103° to 142° and then the waves which have passed through the core emerge. Efforts to find S′, or transverse waves, which have traversed the core were not so successful, and consequently the fluidity of the core was advocated by many. At first the mathematicians were horrified, for they had proven that the earth must be solid throughout. Finally they rushed to their pencils and shortly proved that the core must be liquid.

Father Macelwane was not so certain. He looked for S through the core for the South Pacific shock and debated long with himself whether or not the S′ observations were good enough. He was reluctant to speak of matter as fluid, at least as the liquid state is known at the earth's surface, under physical conditions of great heat and pressure such as exist within the core, and to the end of his life remained undecided as to the state of matter in the core.

The doctoral degree in physics with a seismological dissertation granted to him in 1923 was the first of its kind conferred in the United States. His program was an individual one, worked out with the cooperation of Hall and Lawson. One of his important contributions while he held the assistant professorship at Berkeley was to plan a better organized general program of studies. Accordingly it was he who conceived and gave the first direction to the program of graduate studies in seismology at the University of California.

In 1925 he returned to St. Louis, where he was appointed Professor of Geophysics and Director of the new Department of Geophysics at St. Louis University, a position he held for the remainder of his days. He at once set about organizing the department and developing the program of graduate studies in geophysics there, too, just as he had done at California.

Realizing from his experience on the west coast the importance of cooperation among a network of stations and the need of the establishment of a central research center, he chose as one of his first projects the revitalization of the Jesuit Seismological Service. Oddly enough, the impetus to this came not from within the circle of Jesuit institutions but from without. It was while Father Macelwane was a student at Berkeley that Harry Wood, then connected with the National Research Council in Washington, recalled to him a conversation concerning the Seismological Service which he had had with Professor H. W. Gregory of Yale University. With the encouragement of Mr. Wood and of Professor Gregory and with the active cooperation of Arthur L. Day, Chairman of the Advisory Committee on Seismology of the Carnegie Institution of Washington and Director of the Geophysical Laboratory, the merits of the project were proposed to the Jesuit Provincials and to the presidents of the institutions concerned. An organizational meeting was held in Chicago. Out of this was born the Jesuit Seismological Association, with a central station and research center in St. Louis and with member stations throughout the United States.

Father Macelwane was elected president of the Association, an office to which he was reelected annually for thirty years, and an agreement was concluded between the Association, Science Service, and the United States Coast and Geodetic Survey. Science Service would finance telegraphic reports of earthquake data from a select network of stations; the data was to be sent to the Central Station and to the Coast and Geodetic Survey. Independent location of epicenters for each large earthquake, in turn, was to be made by the Central Station and the Survey and the results telegraphed to Science Service. Location of epicenters remained one of the routine services of the Association. A *Preliminary Bulletin* is published, and a summary of the determinations is usually published in the *Transactions* of the American Geophysical Union.

The Eastern Section of the Seismological Society of America was also formed in 1925. Father Macelwane was one of the moving spirits behind its organization and always remained an active participant in the projects of the Section.

At his own Central Station he busied himself with the improvement and expansion of the station facilities. A first-class station was installed at Florissant and a new vault and new equipment added to the University facilities during the construction of the University gymnasium. Eventually two other stations, one at Cape Girardeau and one at Little Rock, were added to the St. Louis group.

St. Louis is not located in an area of frequent seismic activity. Recurring small earthquakes do occur, however, and in 1811 and 1812 three of the greatest earthquakes in North American history centered at New Madrid, Missouri, not too far from St. Louis. A study of the seismicity of the area has been one of the activities of the station as well as detailed studies of the individual earthquakes

which occur in the Missouri area. In this the data from the St. Louis University group of stations has been of great practical value.

Shortly after his return to St. Louis, in addition to his direction of the Department of Geophysics and of the Central Station, he was appointed Dean of the Graduate School. In this post, which he held from 1927 to 1933, he contributed most importantly to the University. The University was at a critical stage of its development. Father Macelwane's policies left a deep organizational imprint on the Graduate School and influenced to a profound degree the scholarly heritage it bears today. He played a similar role in the organization of the program of studies to be pursued within his Order; for several years he was the chairman of the Inter-Province Commission on Higher Studies. He was also, in addition to his numerous other committee duties, chairman of the University Committee on Academic Rank and Tenure and for some years a member of the University Board of Trustees. In 1944 he established the Institute of Technology, the University's school of earth sciences and engineering, and became its first Dean.

His memory will long be held in honor at St. Louis by reason of his contribution to these important academic developments and services. Undoubtedly, however, these duties took time from the hours he would have preferred to spend in teaching and in research. True, he always managed to reserve time to teach at least one course, generally two, and he carried on his research in geophysics continuously. But perforce his research was conducted predominantly through his students.

Under his direction, beginning in 1928, a long series of doctor's theses on geophysical subjects began to appear from the Department of Geophysics. The first of these was that of William C. Repetti, S.J., later Chief of the Division of Seismology and Terrestrial Magnetism in the Philippine Weather Bureau. The problem of the variation of the speed of compressional (P) waves with depth had been studied by Wiechert and his students at Göttingen. Father Repetti reinvestigated the problem.

The consideration is an arduous one, for the only data available to seismologists are the arrival times of seismic energy at stations on the earth's surface. A ray arriving at any particular point on the earth's surface follows a curved path from the source to the point of observation. A travel time curve expresses graphically the relation between the time of arrival and the epicentral distance, and, if the slope of the curve be taken as the parameter of the ray arriving at a particular epicentral distance, wave theory readily permits the derivation of an integral equation for the epicentral distance as a function of the parameter. However, if any knowledge of the actual path of the ray, and hence knowledge of the earth's interior is to be obtained, what is needed is not an expression for the travel time arrivals at the surface but the variation of velocity with depth of penetration. The problem is solved by means of a transformation devised by Herglotz which results in an integral equation capable of graphical integration. The equation is integrated for a specific epicentral distance, yielding a specific value of the velocity of propagation of P waves at a particular depth. Successive integrations at corresponding epicentral distances yield the velocity of propagation at all depths. In addition to second order discontinuities at several depths similar to those found by the Göttingen group, Repetti found a new second order discontinuity at a depth of 950 kms. which he thought sharp enough to reflect seismic waves.

In 1934 Cornelius Dahm continued the same line of investigation in the vicinity of the core. His researches presented evidence for a thin layer of transition just outside the core. Recent publications of Inge Lehmann in which she finds P out to 135° in some earthquakes require the existence of this Dahm layer if the old core is to be preserved. Dahm found the cutoff for P (the beginning of the core's shadow) at an epicentral distance of 102.5°, indicating a core depth of some 2780 kms. Beyond this depth the conditions for applying the integral equation of Herglotz were not verified. However, using reflection equations, Dahm found that the P waves reflected at the core boundary indicated that the actual boundary of the core was at a depth of 3000 kms., somewhat deeper than the 2900 kms. of Gutenberg. Dahm concluded that there is a transition layer some 220 kms. thick where the velocity is constant and somewhat less than that above it.

Later Father Macelwane advised Otto Nuttli in a somewhat similar study. Using the data of large magnitude earthquakes occurring in the years 1950–1952 for which P was recorded at stations more distant than 100°, Nuttli discovered a surprising result in the travel times for P. The plotted points appeared to define two straight lines diverging with increasing epicentral distance. The point of bifurcation occurred at an arcual distance of approximately 90°. Nuttli used the symbols P and P_2 to refer to the waves corresponding to the first and second P curves, respectively, and suggested that the travel times obtained by Dahm did not correspond to the actual P wave but rather to P_2. From the slope of the earlier portion of the P curve the depth to the core was found to be 2900 kms.; the later P wave, Nuttli suggested, may be one which has traveled to a depth of only 2700 kms.

Work of the nature just described depends much on the accuracy of the available travel time tables, and the improvement of the tables has always been one of the tasks of seismologists. The tables must be kept up to date with improved techniques and with improved knowledge of travel times. This is a routine phase of seismological research, and in this, too, Macelwane has played his part. He published his first set of tables while yet at California, and periodically throughout the early years at St. Louis revisions and refinements of the tables were issued.

In connection with this routine work of the station, another very useful project evolved. That some earthquakes have a source deep within the earth had only recently been recognized. When such deep-focus shocks occur, the travel times of the various phases are quite at variance with the travel time curves for earthquakes with a focus near the surface. George J. Brunner, S.J., studied these deep-focus shocks, and in 1935 he and Macelwane published a Focal Depth-Time-Distance Chart which provides a very convenient graphical method for the simultaneous determination of focal depth, epicentral distance, and focal time of an earthquake from the records of a single station.

Aside from the vibrations which arise from earthquakes, there are additional small earth motions which are called microseisms. Microseisms occur more or less continuously. They are of interest to the seismologist for they are the "noise level" which bars him from making his seismograph more sensitive. In one sense, their presence is, therefore, a nuisance, for they may easily obscure the beginning or complicate the interpretation of a weak phase. But certain microseisms are also related to features of the earth's surface and to regional atmospheric conditions. After 1935 the investigation of this relation preoccupied the attention of Father Macelwane.

Microseisms occur within almost any range of frequencies. Some of these are definitely local phenomena, associated with man-made vibrations or local wind effects. These are not of interest. But the microseisms in the range 4–10 seconds have intrigued seismologists since the science began.

These microseisms may persist for many hours at a time and show features which are very similar on records traced at stations distributed over a wide area. They were early recognized as connected with meteorological conditions, for they are much heavier in fall and winter than in spring and summer, and seem to be related to storms at sea. Are they standing or traveling waves? What is their origin? Both questions long awaited an answer, and a great discussion arose as to whether great oceanic storms are able to put microseisms into the earth through the deep water or whether this energy was imparted to the land only by the breaking of surf on beaches.

A great contribution toward the solution of the problem was Father Macelwane's idea of the tripartite system. Working with J. E. Ramirez, S.J., he set up three seismographic stations at the corners of an isosceles right triangle, the legs of which were arranged in an approximately E-W and N-S orientation. The length of each side was of the order of a quarter to half a wave length of the micro-

seisms under consideration—close enough together so that the wave form of the microseisms changes very little from station to station, but far enough apart that the direction of travel across the net can be determined. The project proved successful, for it was definitely possible to trace the progress of a given train of waves across the net and to determine the direction from which the waves proceeded.

The results demonstrated that microseisms are traveling and not stationary waves. The same waves were identified at each of the stations of the net and also at Florissant, 21.8 kms. distant from St. Louis University. A study of the nature of the waves from the three Galitzin-Wilip components at the Florissant station revealed in the waves many of the characteristics of Rayleigh waves, that is, that the particles of the earth's surface move in retrograde elliptical orbits as the microseismic waves pass.

A specially designed microbarograph was set up and observations made over a period of a year or more in order to detect any correlation between microseisms and local microbarometric oscillations. No direct relationship between the two phenomena in wave form, group form, period, or duration of storms was observable. The source of microseisms is not over land. On the other hand, all the determined directions of incoming microseisms at St. Louis were found to point to a deep barometric low over the ocean, the amplitudes depending only upon the intensity and widespread character of the barometric laws. For a number of hurricanes off the Atlantic seaboard Ramirez was able to show that the direction of approach of microseisms pointed to the storm center at sea. Whatever the mechanism by which barometric lows over ocean water result in the production of microseisms, the important point was that large microseisms were shown to be produced without any indication of surf near the coasts.

The work attracted the attention of the United States Navy. Very shortly, with Macelwane as adviser and with M. H. Gilmore in charge of the project, a number of tripartite stations were established in the West Indies for the early detection and tracking of storms.

Gilmore used the system with some degree of success in tracking hurricanes originating in that area. Consequently, it was with considerable optimism that tripartite networks were established in the Pacific with the hope of detecting and tracking the devastating tropical storms which arise over those so inaccessible seas. Not all storms were traceable, and others, while they sent out their telltale trains of microseisms for two or three days, soon very artfully covered their traces with a confusion of signals originating, seemingly, from the swell near island shores. Hence the old problem once again as to just what is the origin of microseisms. Quite evidently there is truth in both propositions: microseisms originate in part in areas of barometric lows over ocean deeps and in part by the swell near coasts. The dual character of the micro-oscillations and their failure to signal in all instances the raising of storm warnings has proved them an unreliable detection system and the project has since been abandoned by the Navy. The researches were fruitful, nonetheless, in shedding light upon many of the mysteries of microseisms.

An outgrowth of the work on microseisms of the 4–10 second range just mentioned was a further investigation of microseisms of yet shorter period, the group in the .3–.5 second range. It was mentioned that Ramirez found no relation between microseisms of the longer period and regional or local changing meteorological conditions. The microbarograph did show, however, that there are rapid oscillations in atmospheric pressure associated with barometric changes. Local storms brought a literal clutter of such micro-oscillations, and with them a similar storm of microseisms of the shorter period. Is there a genetic relation? What understanding can the micro-oscillations, whether in the earth or in the air, contribute to the science of weather formative processes or weather forecasting? This is the turn which the investigation of microseisms took in Father Macelwane's last years.

A miniature tripartite system was set up at Florissant and new techniques of instrumentation were devised for this new study. The short periods required a much accelerated paper speed on the recording drums as well as facilities for processing the long lengths of photosensitive paper used in routine daily observations. The amount of data accumulated is vast and its interpretation difficult. Progress reports have been forthcoming from time to time and papers have been presented, but the work is not yet in any definitive form.

Mention should here be made of Father Macelwane's intimate connection with the senior and the younger Sprengnether. Almost from the beginning of his years in St. Louis he worked with the Sprengnether Company in the development of the various Sprengnether seismographs; especially in the work on microseisms did he cooperate with them in the development of instruments for use in microseismic work.

Another chapter in the life of James Macelwane is that of his interest in geophysical methods of prospecting for oil. When he came to the University of California, surface geological methods were the only known means of estimating subsurface structure favorable to the accumulation of petroleum. Such methods are applicable only to a limited depth and many of the oil fields thus discoverable had already been found. Geophysical prospecting, on the other hand, made detection thousands of feet underground possible. Father Macelwane saw its possibility and contributed toward developing it in a practical way. In 1924 he became consultant in seismic prospecting for the Reiber Exploration Company. He also served as consultant to the old General Geophysical Company owned by M. J. Connolly from 1927 to 1929, and as a seismological consultant to the Root Petroleum Company. More important still, in his work as an educator he trained men who now serve in high positions on the geophysical staffs of several oil companies. This was, in fact, one of the foremost purposes he had in mind when in 1944 he established the Institute of Geophysical Technology at St. Louis University, the training of competent personnel for the exploration programs of the oil companies.

The graduates of the school meet a very real need and the school has proved a valuable asset to the industry. One small evidence of the well-planned character of the academic program of the Institute and of the enthusiasm which he was able to convey to the students manifests itself in the active and spirited participation of the students in the St. Louis student chapters of both the SEG and the AIME. Father Macelwane pioneered in the forming of student chapters, and those at St. Louis remain among the most cooperative and vigorous of their respective organizations.

Curiously, the development of the geophysical methods which have proved so successful, particularly refraction methods, began somewhat under a cloud. Refraction techniques utilize energy refracted along the underside of a boundary or discontinuity. The ray paths of such waves follow a non-optical path. They have been treated theoretically by Jeffreys, by Muskat, by Cagniard and others, but only recently yet another student of Macelwane's, Patrick A. Heelan, S.J., developed a very satisfactory theory for the ray paths and their energy content.

Not long after his return to St. Louis University from the University of California, Father Macelwane was appointed chairman of a committee of the National Research Council to bring out a book on seismology as a part of the "Physics of the Earth" series. The book appeared in 1933. He was also one of the authors of the very successful book, *Internal Constitution of the Earth,* which appeared in 1939. In 1936 he published his *Introduction to Theoretical Seismology, Part I, Geodynamics.* The book is a detailed exposition of the theory of elastic waves and of the application of the theory to seismology. It is a good text, bridging the chasm between Love's more abstruse *Theory of Elasticity* and the grasp of the average student. These and other works have helped to extend his influence as a teacher and educator outside the circle of his own students or the walls of his own classroom. In 1947 he published a popular non-mathematical book on earthquakes, *When the Earth Quakes,* which manifests his desire that everyone, layman as well as specialist, understand something of earthquakes and of the mysteries of the planet on which we live.

The name of James B. Macelwane has also figured in the national and the international scene, and perhaps it is his contributions here that did most to win for him the renown and respect which he enjoyed. He was a tireless promoter of any activity for the advancement of the geophysical sciences. He belonged to numerous scientific societies and his membership in each was ever of an active sort. His sympathetic interests and cooperative spirit were common knowledge and consequently his services were in frequent demand. No picture of the man and of his work would be complete without at least a summary treatment of this phase of his activity.

Mention already has been made of his cooperation with the National Research Council in sponsoring the "Physics of the Earth" series. In this connection he held the post of Chairman of the Subsidiary Committee on Seismology of the Committee on the Physics of the Earth from 1926 to 1933 and drew with him into the project J. A. Anderson, P. Byerly, H. F. Reid, and H. O. Wood. Following the completion of this work he served the National Research Council for the next two years as Chairman of the Committee on Pacific Seismology, and again from 1947 to 1950 as Member-at-Large of the Division of Geology and Geography.

In the two societies most intimately connected with his field, the Seismological Society of America and the American Geophysical Union, he held a life membership in the first and a membership from the year 1925 in the second. He was also a Director of the seismological Society from 1925 to his death, member of the Scientific Committee from 1926 to 1930, Chairman of the Eastern Section 1926 to 1928, President 1928 to 1929, Scientific Councilor for five different terms, and a member of the Editorial Committee from 1932 onward. Within the American Geophysical Union he was elected to serve in similar offices: Vice-Chairman of the Section on Seismology, 1935 to 1938, Section President, 1938 to 1941, and a member of the Executive Committee of the Section on Seismology, 1947. In 1953 he was elected President of the Union and was serving the third year of his term at the time of his death. He was a participant in all the triennial assemblies of the International Union of Geodesy and Geophysics, of which the AGU is the organ in the United States. In 1954 he was chosen by the State Department to head the American delegation at the International Congress in Rome.

There was, too, the Jesuit Seismological Association. His role in its formation, his work as its President and as Director of the Central Station has been related above.

From 1947 he was connected with the Research and Development Board of the Department of Defense; two years later, he was appointed to the Scientific Advisory Board of the United States Air Force. In 1952 he received appointment to the Committee on Institutional Research Policy of the American Council on Education, and in 1955 was invited by the National Education Association to participate in the Association for Higher Education. President Eisenhower appointed him to membership on the National Science Board of the National Science Foundation in 1954. And, finally, because of his prestige and experience he was asked to serve as Chairman of the United States Technical Panel on Seismology and Gravity for the International Geophysical Year.

Closer to home, Father Macelwane was always a genial and welcome participant in the activities of the Academy of Science of St. Louis, of which he was first Vice-President, then President, in the years 1935 to 1937. He encouraged the common projects and common interests among the other schools within the State of Missouri, and was one of the sponsors and a charter member in the formation of the Missouri Academy of Science. Of this, too, he served as president and vice-president.

The growth and development of the Department of Geophysics and later of the Institute of Technology brought him into close contact with several professional societies. The bond was more than one of membership, for it was founded on common problems and interests and cemented by a friendly and valuable cooperation on both sides. Particularly in relation to the problems of geophysical education is this true, for he served on the Committees of Education of both the Society of Exploration Geophysicists and the American

Institute of Mining and Metallurgical Engineers. That each of these societies should honor him with its highest award, the SEG with an Honorary Life Membership and the AIME with the Jackling Lecturer award, attests their appreciation of his devotedness and service to the cause of geophysics. He was also a member of the American Meteorological Society from 1934, a professional member from 1945, and honored as a Councilor from 1953.

He was a Fellow of the Geological Society of America of the American Association for the Advancement of Science, of the American Physical Society, and of the American Geographical Society. And he held membership in numerous other societies: the Optical Society of America, the American Society for Engineering Education, the Catholic Committee on Intellectual and Cultural Affairs, the Society of Rheology, the American Society for Testing Materials, and the American Association of Petroleum Geologists. He was a member of the California and later of the Saint Louis University chapter of the Society of Sigma Xi.

In his association with the many above-mentioned learned and professional societies Father Macelwane was frequently called upon to serve as chairman in discussion committees and in other official capacities. As discussion leader he was ever at pains, sometimes to the point of boredom to his more impatient colleagues, to see to it that everyone had an opportunity to express his views. No one left a meeting feeling he had been cut off or not given a fair hearing.

Foremost among the honors conferred upon Father Macelwane was his election, in 1944, to the National Academy of Sciences. He was also National Lecturer, Sigma Xi, in 1945, and received the Bowie Medal of the American Geophysical Union in 1948. Villanova University conferred its Mendel Medal upon him in 1955. The Honorary Life Membership in the Society of Exploration Geophysicists and the Jackling Lecturer Award (given posthumously) have been already mentioned. Honorary doctoral degrees were awarded him by Saint Norbert's College, Washington University, John Carroll University, and Marquette University.

Death came to Father Macelwane just as he was at the zenith of a long and richly rewarding career. He was hospitalized on November 21, 1955, because of general fatigue and intestinal disturbances. He underwent surgery on December 19, rallied from its effects, and then relapsed after five weeks or so of promising recuperation. He died peacefully on February 15, 1956, in the seventy-third year of his life.

Father Macelwane was remarkable for his enthusiasm, for his optimism, and for his dogged persistence. This last sometimes became almost a fault, for he was adamant once he set a course of action for himself or for a project under his direction and would brook no exception. His students will remember him for the exacting discipline he demanded of them, which they often resented at the time but later deeply appreciated. They show, one and all, a deep loyalty to him and to a marked degree mirror his own virtues as a student. He, in turn, felt a deep, sometimes unsuspected affection for his students. With pride he used to follow their careers and delight in the joys of their families. The junior author of this memoir has spent many hours listening to Father Macelwane's account of old graduates he had visited on his frequent trips or in glancing with him through the albums in which he kept the snapshots which he took to preserve the memory of those reunions.

He used to delight in little paradoxes, and there were many of these about the man himself. He was reserved, in a way, and not always one with whom it was easy to converse. Yet he was most affable, simple and easy of approach to all—a truly humble man. Once rapport had been established, those who made the effort found the experience rewarding and worth while. His was a genial personality, such as elicited spontaneously the cooperation he habitually received and so generously gave. And not the least of his virtues, nor the least factor of his genial character, was his charity; he had those who violently opposed not a few of his projects, but never did he complain or criticize.

In conclusion, while not the greatest of his honors, one award might be singled out for special comment. It is for those of its members whose lives represent an extraordinary exemplification of the two things for which the American Geophysical Union stands, research in the Earth Sciences and cooperative effort in its prosecution, that the Union reserves its William Bowie Medal. Its motto is "Unselfish Cooperation." In 1948 this medal was conferred upon the Rev. James B. Macelwane, S.J. While the Bowie Medal was only one of the many honors Father Macelwane received, the thoughts which his memory calls forth in the minds of his friends and colleagues throughout the world are a tribute to the singular fitness of that award. The man himself and his accomplishments will be always cherished by his religious community and by all who knew him.

KEY TO ABBREVIATIONS

Bull. Amer. Meteor. Soc. = Bulletin of the American Meterological Society
Bull. Geol. Soc. Amer. = Bulletin of the Geological Society of America
Bull. Nat. Res. Coun. = Bulletin of the National Research Council
Bull. Seis. Soc. Amer. = Bulletin of the Seismological Society of America
Bull. St. Louis Univ. = Bulletin of St. Louis University
Eng. News Rec. = Engineering News Record
Jesuit Educ. Assoc. = Jesuit Educational Association
J. Appl. Phys. = Journal of Applied Physics
Phys. Bull. = Physics Bulletin
Phys. Rev. = Physical Review
Proc. Amer. Phil. Soc. = Proceedings of the American Philosophical Society
Sci. Mech. = Science and Mechanics
Sci. Mo. = Scientific Monthly
Tech. Pub. Amer. Inst. Min. Met. Engr. = Technical Publications, American Institute of Mining and Metallurgical Engineers
Trans. Amer. Geophys. Union = Transactions of the American Geophysical Union
Univ. Calif. Pub. Bull. Seis. Sta. = University of California Publications, Bulletin of the Seismological Station

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