# 3

# The Jesuit Contribution to Seismology

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## 1. Introduction

The contribution to seismology of the Society of Jesus as an institution through its colleges and universities, and through its members as individual scientists, forms an important chapter in the history of this science. This is especially so in the early years of its development. Several papers have described in part the work of Jesuits in seismology: Sánchez Navarro-Neumann (1928, 1937), Heck (1944), who limits himself to American Jesuits, and the interesting but short summaries of Linehan (1970, 1984). No recent or comprehensive work, however, exists on the topic. Recently, moreover, many Jesuit seismographic stations have been closed and the number of Jesuits actually working in seismology has been greatly reduced. To a certain extent, apart from a very few academic departments and research institutes associated with Jesuit universities, it can be said that this is a chapter which is coming to a close. The interest of Jesuits has moved in other directions and it is not likely that seismology will become again an important aspect of the work of individual Jesuits as it was in the past. For this reason we feel that it will be of interest to present an overall picture of the extent of the Jesuit involvement in seismology.

It may be intriguing to some that a religious order dedicated so much effort to a science like seismology. From the very early years of its foundation in the 16th century by Ignacio de Loyola, the Society of Jesus dedicated itself primarily to educational work through its many colleges and universities. From the beginning of these institutions, science was an important subject in the curriculum. A key figure in this development was Christopher Clavius (1537–1612), Professor of Mathematics in the Collegio Romano. Clavius was instrumental in incorporating a serious program of mathematics, astronomy, and natural sciences not only in his own college but also in all Jesuit colleges and universities (MacDonnell, 1989). Secondly, in the 17th and 18th centuries a number of astronomical observatories were established in these institutions. In a number of these, meteorological observations also were made. Finally, in a particularly notable page of this history, Jesuits were appointed Directors of the Astronomical Observatory in Beijing, China (Udías, 1994). This tradition forms the background of modern Jesuit scientific work. Since the middle of the 19th century, as many as 40 geophysical observatories were created by Jesuits around the world and in many of these seismological stations were installed (Udías and Stauder, 1991).

As a science, seismology is relatively young. Davison (1927) dates its beginning to 1750 with the Lisbon earthquake and the work of John Michell (1724–1793). Although pendulums were used to detect the ground motion due to earthquakes at the beginning of the 19th century, the earliest seismographs were those developed in Italy by Luigi Palmieri (1807–1896) in 1855 and by Timoteo Bertelli (1826–1905) in 1872. Seismographs with continuous recording were developed in Japan from 1881 to 1882 by John Milne (1850–1913) and Thomas Gray (1850–1908). One of the first studies of earthquakes is that of Robert Mallet (1810–1881), who investigated the Naples earthquake of 1857 (Davison, 1927). The first record of a long-distance earthquake is a fortuitous recording of an earthquake in Japan by pendulums set up in Potsdam in 1889 by E. A. von Reuber-Paschwitz (1861–1895). From these dates and events, seismology began to develop not only as a study of the nature of earthquakes but also, through the analysis of the seismic waves, as a method to investigate the structure of the interior of the Earth.

A series of circumstances and interests involved Jesuits in the development of this new science from its inception. This interest, certainly, was consonant with the tradition of Jesuits in science dating from the 16th century, which developed, as

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has been mentioned, out of their work in colleges and universities. The character of seismology as a public service to mitigate the destructive effects of earthquakes was another influential factor. Especially in undeveloped countries, Jesuits were in many instances the first to install seismographic stations and to carry out seismicity and seismic risk studies.

Two trends may be distinguished in this involvement of Jesuits in seismology. In the United States, emphasis was on the cooperation of Jesuit institutions in the establishment of seismographic stations organized first as the Jesuit Seismological Service and subsequently as the Jesuit Seismological Association. In other countries, especially in mission lands, the movement developed out of the activity of individual institutions in establishing seismic observatories, usually as a complement to the recording of other geophysical data.

## 2. Jesuit Seismographic Stations

Table 1 presents a list of 38 seismographic stations installed and maintained by Jesuits. In each case dates of the installation of different types of seismographs are given (OM indicates "own manufacture"). The distribution by continents is as follows: Europe 6, Asia 4, Africa 2, Australia 1, North America 18, and South America 7 (Fig. 1). Most of these stations were founded before 1920, and many ceased operation in the 1960s and 1970s. At present, there are only 8 functioning regularly. Initially, the preferred instruments were Wiechert and Mainka mechanical seismographs, and later, Galitzin–Wilip and Sprengnether electromagnetic instruments. In 1962, 10 Jesuit stations became part of the 125-station global World Wide Standard Seismographic Network (WWSSN) supported

**TABLE 1** Jesuit Seismographic Stations

| Station | Dates | Instruments |
|---|---|---|
| Manila, Philippines | 1868– | 1868: OM Seismoscopes Z, H<br>1882: Cecchi, Bertelli, Rossi<br>1889: Gray–Milne, Ewing<br>1911: Wiechert, NE, 1000 kg |
| Baguio | | 1911: Vicentini, Omori<br>1951: Sprengnether SP ZNE<br>1962: WWSSN |
| Guam y Butuam | | 1912: Wiechert NE 200 kg |
| Ambulong | | 1912: Vicentini, Agamennone<br>1930: Galitzin–Wilip, ZNE |
| Tagaytay | | 1930: Wiechert NE |
| Davao | | 1962: WWSSN |
| Manila | | 1962: Sprengnether SP ZNE |
| Puebla, Mexico | 1877–1914 | 1877: OM 3 H Seismoscopes |
| Tuscalano Frascati, Italy | 1888–1920 | 1888: OM Seismoscope (Egidi)<br>1908: Cancani, Agammenone |
| Tanarive, Madascar | 1899–1992 | 1899: Cecchi, Bertelli<br>1927: Mainka ZNE 460 kg |
| John Carroll, Cleveland, OH, JSA | 1900–1992 | 1900: OM Seismoscope (Odenbach)<br>1908: Wiechert NE 80 kg<br>1946: Sprengnether LP-ZNE, SP Z |
| Cartuja, Granada, Spain | 1902–1971 | 1902: Vincentini NE 305 kg, Z 245 kg; Stiattesi NE<br>1908: OM Z 208 kg, NE (Cartuja)<br>1920: OM NE 3000 kg (Cartuja)<br>1924: OM ZNE Electromag (Neumann) |
| Ebro, Tarragona, Spain | 1904– | 1904: Vicentini ZNE, Grablowitz<br>1914: Mainka Z 1500 kg, NE 300 kg<br>1965: Benioff SP ZNE<br>1969: Sprengnether LP ZNE |
| Zikawei, Shanghai, China | 1904–1949 | 1904: Omori<br>1909: Weichert NE 1200 kg<br>1913: Galitzin Z<br>1932: Galitzin–Wilip ZNE |
| Belen, Havana, Cuba | 1907–1920 | 1907: Bosch–Omori NE |
| Santa Clara, CA | 1907–1958 | 1907: OM seismograph<br>1909: Wiechert ZNE 80 kg<br>1930: Galitzin–Wilip ZNE<br>1931: Wood Anderson NE |
| Stonyhurst, Lancs., England | 1908–1947 | 1908: Milne NE<br>1924: Milne–Shaw NE |
| Mungret, Limerick, Ireland | 1908–1915 | 1908: OM (O'Leary, inv. pend.) |
| Riverview, Australia | 1909–1985 | 1909: Wiechert ZNE<br>1910: Mainka NE<br>1941: Galitzin–Wilip ZNE<br>1953: Sprengnether SP-Z<br>1962: WWSSN |
| Regis, Denver, CO, JSA | 1909–1988 | 1909: Wiechert NE 80 kg<br>1946: Sprengnether LP-NE, SP-Z<br>1962: Sprengnether SP-ZNE |
| Gonzaga, Spokane, WA, JSA | 1909–1970 | 1909: Wiechert NE 80 kg<br>1946: Wood Anderson NE |
| Holy Cross, Worcester, MA | 1909–1934 | 1909: Wiechert NE 80 kg |
| Marquette, Milwaukee, WI, JSA | 1909–1951 | 1909: Wiechert NE 80 kg |
| Georgetown, Washington, DC, JSA | 1910–1972 | 1910: Wiechert NE 80 kg<br>1912: Bosch–Omori NE 25 kg<br>1912: Bosch photog. NE 200 kg<br>1912: Wiechert ZNE 200 kg<br>1912: Mainka NE 135 kg<br>1923: Galitzin ZNE<br>1962: WWSSN |
| Canisius, Buffalo, NY, JSA | 1910– | 1910: Wiechert ZNE 80 kg<br>1932: Galitzin–Wilip Z<br>1946: Sprengnether LP-NE, SP-Z |
| Saint Louis, St. Louis, MO, JSA | 1910– | 1910: Wiechert NE 80 kg<br>1928: Wood Anderson NE |

(*continued*)

**TABLE 1** (*continued*)

| Station | Dates | Instruments |
|---|---|---|
| | | 1946: Sprengnether LP-NE, SP-Z |
| | | 1960: Benioff SP-Z |
| | | 1963: Sprengnether LP ZNE, Benioff SP N |
| Florissant | 1928–1974 | 1928: Galitzin ZNE |
| | | 1928: Wood Anderson NE |
| | | 1962: WWSSN |
| French Village | 1974– | 1972: WWSSN |
| Cape Girardeau, MO | 1938– | 1938: Wood Anderson NE |
| | | 1980: Benioff SP-ZNE |
| Little Rock, AR | 1930–1958 | 1930: Wood Anderson NE |
| Cathedral Cave, Onandago State Pk | 1991– | 1991: IRIS Station |
| Saint Boniface, Manitoba, Canada | 1910–1922 | 1910: Wiechert NE 80 kg |
| Fordham, New York, NY, JSA | 1910–1977 | 1910: Wiechert NE 80 kg |
| | | 1924: Milne–Shaw NE |
| | | 1927: Galitzin–Wilip ZNE |
| | | 1932: Wood Anderson NE |
| | | 1936: Benioff SP-Z |
| | | 1950: Sprengnether SP-ZNE |
| Loyola, New Orleans, LA, JSA | 1910–1960 | 1910: Wiechert NE 80 kg |
| | | 1946: Sprengnether LP-NE, SP-Z |
| Spring Hill, Mobile, AL, JSA | 1910–1989 | 1910: Wiechert NE 80 kg |
| | | 1941: McComb–Romberg NE |
| | | 1962: WWSSN |
| Ksara, Bekka, Lebanon | 1910–1979 | 1910: Mainka NE 135 kg |
| | | 1921: Mainka NE 460 kg |
| | | 1933: Galitzin–Wilip ZNE |
| | | 1957: APX SP-ZNE (Grenet Coulomb) |
| Loyola, Chicago, IL, JSA | 1913–1960 | 1912: Wiechert NE 80 kg |
| | | 1957: Sprengnether ZNE |
| | | 1983: Kinemetrics SP-Z |
| San Calixto, La Paz, Bolivia | 1913– | 1913: OM Z 1500 kg, NE 2000 kg |
| | | 1930: Galitzin–Wilip ZNE |
| | | 1962: WWSSN |
| | | 1972: HGLP-ASRO |
| Sucre, Bolivia | 1915–1948 | 1915: OM Z 1500 kg, NE 3000 kg |
| Rathfarnham Castle, Ireland | 1916–1961 | 1916: OM Z (O'Leary) 1500 kg |
| | | 1932: Milne–Shaw NE |
| San Bartolome, Bogotá, Colombia | 1923–1940 | 1923: OM NE 2000 kg (Cartuja) |
| | | 1926: Wiechert NE 2000 kg |
| | | 1930: OM NE 1000 kg (Cartuja) |
| Xavier, Cincinnati, OH, JSA | 1927–1986 | 1927: Galitzin–Wilip ZNE |
| | | 1949: OM ZNE (electromag) |
| Weston, Boston, MA, JSA | 1928– | 1930: Bosch–Omori NE |
| | | 1934: Wiechert NE 2000 kg |
| | | 1936: Benioff SP-ZNE |
| | | 1962: WWSSN |
| Saint Louis, Island of Jersey | 1936–1979 | 1936: Mainka NE 1000 kg |
| Saint George's, Kingston, Jamaica | 1940–1975 | 1940: |
| Instituto Geofísico, Bogotá, Colombia | 1941– | 1941: Benioff SP-Z |
| | | 1943: Wiechert NE |
| | | 1946: Sprengnether NE |
| | | 1962: WWSSN |
| | | 1973: ASRO |
| Galerazamba | | 1949: Sprengnether ZNE |
| Chinchina | | 1949: Sprengnether ZNE |
| San Luis, Antofagasto, Chile | 1949–1965 | 1949: Bosch Omori |
| | | 1960: Wilson–Lamison |
| San Francisco, CA | 1950–1964 | 1960: Sprengnether LP-NE, SP-Z |
| S. Jean de Brébeuf, Montreal, Canada | 1952– | 1952: Wilmore |
| | | 1952: Benioff SP-ZNE |
| | | 1961: Press–Ewing LP-ZNE |
| | | 1961: Geotech SP-Z |
| Addis Ababa, Ethiopia | 1957–1978 | 1957: |
| | | 1962: WWSSN |

by the US Government. Of these two, one in Colombia and the other in Bolivia, were later upgraded to become Seismological Research Observatory (SRO) and High Gain Long Period-Adapted Seismological Research Observatory (HGLP-ASRO) stations, respectively.

The first seismographic station installed by Jesuits was about 1868 in the Observatory of Manila. This consisted of two pendulums, one vertical the other horizontal, and were what we would today call seismoscopes. They were designed by Juan Ricart, Professor of Sciences at the Manila Jesuit College. They functioned intermittently until 1877 when regular, continuous-recording instruments were installed. After the Manila earthquakes of 1880, which were recorded on the old seismographs and studied by Federico Faura (1847–1897), the station was better equipped with Cecchi, Bertelli, and Rossi seismographs made in Italy. Additional stations were installed at other points of the Philippines, namely at Baguio, Ambulong, Butuam, Tagaytay, and the island of Guam (Saderra-Masó, 1895, 1915; Su, 1988). Unfortunately, all seismographic records were lost in the destruction of the observatory during World War II. The continuous catalog of Philippine earthquakes, however, was salvaged and was published shortly after the war by Repetti (1946). After the war, new seismographs were installed in Manila, Baguio, and Davao. The last two sites became WWSSN stations in 1962.

The first seismograph installed by Jesuits in Europe was a seismoscope made by Giovanni Egidi (1835–1897) and installed in the meteorological observatory in Tuscolano, Frascati, Italy, founded in 1868 (Egidi, 1888). An important station was installed in 1902 in Granada, the most seismically active region of Spain. Due to a lack of funds most seismographs were made patiently under the direction of Manuel

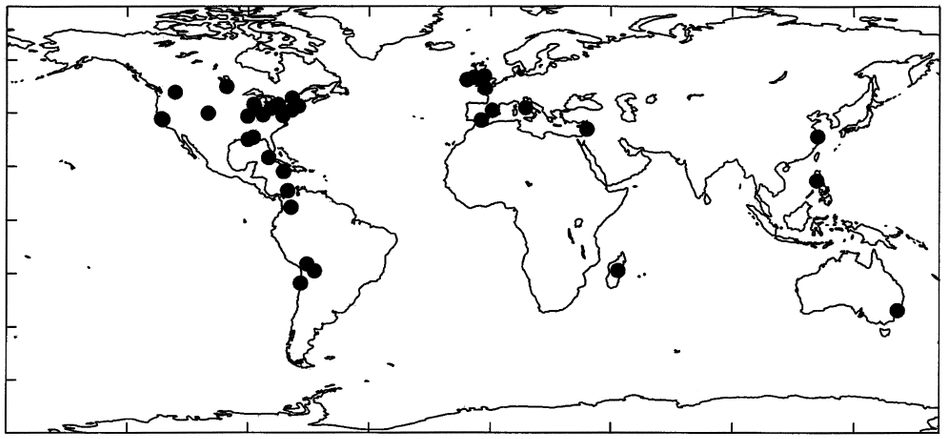

**FIGURE 1** Map showing the location of Jesuit seismographic stations.

Sánchez Navarro-Neumann (1867–1941), who reproduced with some improvements the Omori, Wiechert, and Galitzin seismographs (Sánchez Navarro-Neumann, 1928). In Ireland, William J. O'Leary installed the first seismograph, also of local design, at Mungret College in 1908. In 1916 it was moved to Rathfarnham Castle, where it was in operation until 1961. This was an inverted pendulum suspended by steel wires with a mass of 600 kg recording on smoked paper on two drums (Murphy, 1995). In the Ebro Observatory, Spain, a seismological station has functioned continuously from 1904 to the present. At Stonyhurst, England, the station operated from 1908 to 1947. A seismographic station was also established by Jesuits on the Island of Jersey, operating from 1936 to 1979.

Very early, in 1899, Jesuits installed a seismographic station in Madagascar using instruments of Italian design. In 1927 a three-component Mainka seismograph was installed. This station operated under Jesuit supervision until 1967 and may have been one of the earliest seismographic stations in Africa. In 1904 Jesuits installed an Omori seismograph donated by the Japanese government in the observatory of Zikawei. This may have been the first such station in China. Updated with Wiechert and Galitzin–Wilip instruments in 1909 and 1932, respectively, Zikawei continued as a first-class station up to the time the Jesuits were expelled from China in 1949 (Gherzi, 1950). In Ksara, Lebanon, seismographs were installed in 1910. This was an important station due to lack of stations in the Middle East. It operated uninterruptedly until 1979 with Wiechert instruments. In Australia, the Jesuit seismographic station of Riverview was initiated in 1909 with Wiechert instruments. In 1962 it became a WWSSN station and operated until 1985. For many years this was the best known and best equipped station in Australia (Drake, 1980; Doyle and Underwood, 1965).

At the 2nd General Assembly of the International Seismological Association, Manchester, 1911, a resolution was passed recommending that the Jesuits install a seismic station in the central part of South America. In response to this recommendation, a seismological station was installed in 1913 at La Paz, Bolivia, with the name of Observatory de S. Calixto, by Pierre M. Descotes (1877–1964), with instruments of local design. In 1930, the station was upgraded with Galitzin–Wilip seismographs. From 1964 to 1993, the station was directed by Ramón Cabré. The Observatory of S. Calixto has been one of the most reliable stations in South America (Cabré, 1988; Coenraads, 1993). The first seismograph in Colombia was installed by Jesuits in 1923 in Bogotá. In 1941 the Instituto Geofísico de los Andes Colombianos (today the Instituto Geofísico, Universidad Javeriana) was founded by Jesus E. Ramirez (1904–1983). This soon became one of the best seismological research institutions in South America (Ramirez, 1977; Goberna, 1988). In 1962, the stations of La Paz and Bogotá became WWSSN stations. Later La Paz became an HGLP-ASRO station (1972) and Bogotá became an SRO station (1973). This upgrade is a clear recognition of the work done by Jesuits in these two stations.

Other Jesuit seismographic stations in Cuba and Chile functioned only a few years. In 1940 a seismographic station was installed in St. George's College, Kingston, Jamaica, dependent on Weston Observatory. In Montreal, Canada, a seismographic station was installed in 1952 (Buist, 1983). The Montreal station was a modern station with WWSSN-type instruments. It was the last new station installed under direct Jesuit auspices. Maurice Buist was its director for 31 y until his retirement in 1983. In Ethiopia, Haile Salassie invited the Jesuits to undertake the administration of the National University in Addis Ababa. Although not a Jesuit station in the strict sense, the associated Geophysical Observatory of Addis Ababa was directed by the Canadian Jesuit Pierre Gouin from 1957 to 1978. In 1962, a WWSSN seismographic station was installed.

## 3. The Jesuit Seismological Association

The history of the work of Jesuits in seismology in the United States is linked to the Jesuit Seismological Association (Macelwane, 1926, 1950). The first Jesuit to install a seismograph in the United States was Frederik L. Odenbach (1857–1933) in 1900 at John Carroll University, Cleveland, Ohio, with two seismoscopes of his own design. In 1908 Odenbach conceived the notion that the system of Jesuit colleges and universities distributed throughout the United States offered an opportunity to establish a network of similar seismographic stations. In 1906 the International Seismological Center had been established in Strasbourg, France, where data were centrally reported and epicenters determined. Odenbach envisioned a network of Jesuit stations that could contribute significant data to this international enterprise.

Odenbach sold the presidents of the colleges and universities and the American Jesuit Provincial Superiors on the idea. In 1909 sixteen identical horizontal Wiechert seismographs of 80 kg mass were purchased in Germany and were distributed to 15 colleges in the United States and one in Canada. A typical station was that of Georgetown (Fig. 2). These stations formed the Jesuit Seismological Service. Individual stations were to process their own seismograms and send the readings to the Central Station in Cleveland. The data would then be collated and forwarded to the International Seismological Center in Strasbourg. These stations, in effect, constituted the first seismological network of continental scale with uniform instrumentation.

Many of the first stations, for a variety of reasons, foundered early, and the cooperative effort was never fully established. In 1925 James B. Macelwane (1883–1956) returned to Saint Louis University after completing his doctoral studies at the University of California. One of Macelwane's early efforts was to revitalize the Jesuit seismographic network. The impetus to this came not only from his own interest but also from the urging of scientists of the National Research Council and the Carnegie Institution in Washington, and with the further encouragement of Sánchez Navarro-Neumann of the Spanish Observatory at Cartuja.

Thus, in the summer of 1925 the stations were reorganized into the Jesuit Seismological Association. The 14 member stations are indicated as JSA in Table 1. The Presidents of the Association have been J.B. Macelwane of Saint Louis University, 1925–1956; J.J. Lynch of Fordham University, 1957–1970; and D. Linehan of Weston Observatory, 1970–1986. W. Stauder of Saint Louis University has been President from 1986 to the present.

Saint Louis University became the Central Station in 1925. Through its recently established Department of Geophysics it became a resource for graduate education in seismology for a number of Jesuits who then returned as directors to their own institutions. The Central Station assumed as well the responsibility on behalf of the JSA of collecting data from member stations and from other stations around the world and of locating earthquake epicenters and publishing these to the worldwide seismological community. The Central Station continued this service until the early 1960s when, with the advent of computer determination of epicenters, it was discontinued as an unnecessary duplication of the determinations by the US Coast and Geodetic Survey (later by the US Geological Survey) in the United States and by other international agencies.

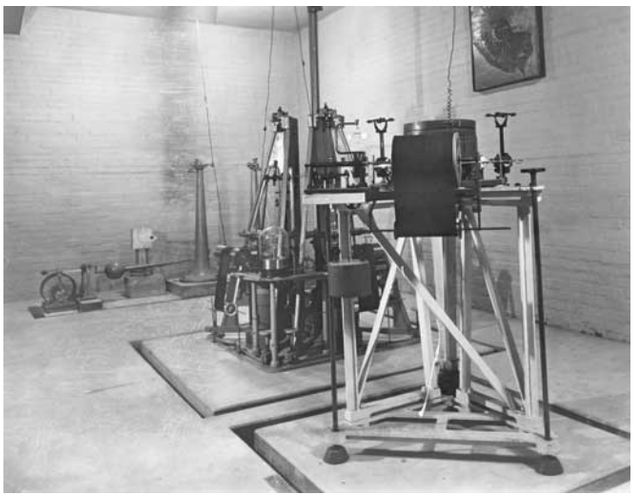

**FIGURE 2** Instruments of the Georgetown seismographic station, about 1920. The Wiechert is on the far right.

Most of the JSA seismographic stations continued in regular operation until relatively recent time. Florissant (Saint Louis), Weston, Georgetown, and Spring Hill became WWSSN stations in 1962. At present only Saint Louis and Weston continue as seismological research institutes. Both conduct active research programs and operate regional networks, and are members of IRIS, the Incorporated Research Institutes for Seismology. Saint Louis has installed a broadband station of the IRIS system at Cathedral Cave, Missouri and is deploying other similar broadband stations in the Midwest.

## 4. Jesuit Seismologists

From 1868, the approximate date of the installation of the first seismograph by the Jesuits in Manila, to the present, many members of this religious order have dedicated their time and efforts to seismology. In this short article it is hardly possible to do more than mention even the most important of them. However, a few words must be said about those that occupy an important place in the history of seismology. We will mention

only the work of past Jesuits, although at present there are still Jesuits actively working in seismology (e.g., L. Drake, presently at La Paz, P. Gouin in Montreal, W. Stauder in St. Louis, S. Su in Manila, R. Van Hissenhoven in Bogotá, and A. Udías in Madrid).

The first Jesuit to be mentioned is Federico Faura, who published a study about the destructive Manila earthquakes of 1880 (Faura, 1880). In the paper he reproduced the records obtained by the instruments (seismoscopes) in the Observatory of Manila. Faura continued his interest in seismology, improving the seismological instrumentation of the Observatory and publishing a seismological bulletin. Beginning in 1877, Giovanni Egidi, director of the Observatory Tuscolano in Italy, collaborated with M.S. De Rossi in the seismological observations that were published in *Bullettino del Vulcanismo Italiano* (Davison, 1927, p. 100).

Two Jesuits contributed very early to the study of the seismicity and seismotectonics of the Philippines and Spain. Manuel Saderra-Masó dedicated himself to the study of the seismicity of the Philippines, interpreting it in terms of seismotectonic lines and relating it to the geological structure of the archipelago in a very early work of this type (Saderra-Masó, 1895; Saderra-Masó and Smith, 1913). M. Sánchez Navarro-Neumann, Director of the Observatory of Cartuja, Spain, compiled the first modern earthquake catalogue of Spain and published numerous studies on the seismicity of that region (Sánchez Navarro-Neumann, 1919). He also published an early paper on the energy in earthquakes (Sánchez Navarro-Neumann, 1915).

The most renowned Jesuit seismologist was without doubt James B. Macelwane (Fig. 3) (Byerly and Stauder, 1958). Macelwane obtained his doctoral degree at the University of California, Berkeley, in 1923, with the first dissertation on a seismological topic in the United States. In 1925 he became the first Director of the Department of Geophysics at Saint Louis University and reorganized the Jesuit Seismological Association. Travel times of seismic waves, the constitution of the interior of the earth, and the nature of microseisms and their relation to atmospheric storms were a few of the topics of his research papers (e.g., Macelwane and Dahm, 1937; Macelwane, 1939, 1946). In 1936 he published the first textbook on seismology in America (Macelwane, 1936). In 1928–29 he was President of the Seismological Society of America and in 1953–56 of the American Geophysical Union. In 1944 he was elected to the National Academy of Sciences. Throughout his career Macelwane took an active part in the committees and commissions of these societies, as well as in projects of the National Research Council and the International Union of Geodesy and Geophysics. He was also always interested in promoting educational programs and in encouraging young geophysicists. For the latter reason, in 1962 the American Geophysical Union created a medal in his honor for recognition of significant contribution to the geophysical sciences by a young scientist of outstanding ability.

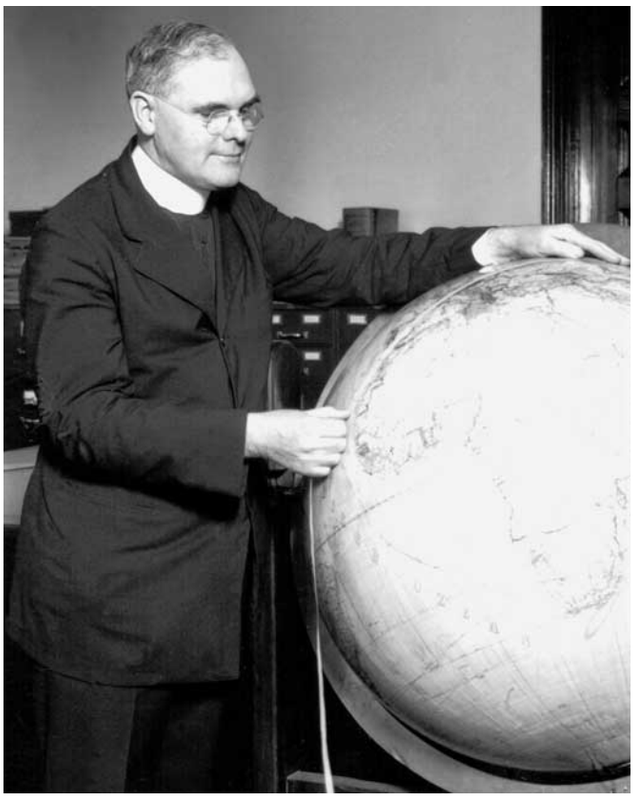

**FIGURE 3** James B. Macelwane, S.J.

Two Jesuit students of Macelwane deserve to be mentioned. William C. Repetti (1884–1966) studied the interior of the Earth from the travel times of body waves, inferring the existence of several discontinuities in its interior. In 1928 he joined the staff of the Manila Observatory, where he assumed charge of the seismological section. Among other contributions he compiled a catalog of earthquakes of the Philippines (Repetti, 1946). Jesus E. Ramirez (1904–1983) worked on the problem of microseisms and storms, designing a tripartite station system to track the center of tropical hurricanes. In 1941 he founded in Bogotá the Instituto Geofísico de los Andes Colombianos, where he conducted and published a large number of studies of Colombian seismicity (Ramirez, 1967). He was a leading figure in the seismicity of South America.

J. Joseph Lynch (1894–1987) became Director of the Seismographic Station of Fordham University in 1920. This was the beginning of a long career as a seismologist that led to a variety of seismological studies, among them a field study of the Dominican Republic earthquake of 1946. He has left us a lively account of his involvement in seismology over a period of 50 y (Lynch, 1970). Daniel Linehan (1904–1987) was Professor of Geophysics and Director of Weston Observatory for 32 y. A prolific writer in many aspects of seismology, he dedicated himself especially to seismic exploration. In 1950 he carried out, accompanied by Lynch, a shallow

seismic exploration survey under St. Peter's Basilica in Rome for archeological purposes. He participated in three expeditions to the Antarctic, one to the Arctic, and several UNESCO seismological missions in Africa, Asia, and South America. Two other Jesuits participated in separate expeditions to the Antarctic during the International Geophysical Year: Edward Bradley of Xavier University, Cincinnati, and Henry Birkenhauer of John Carroll University, Cleveland.

Of European Jesuit seismologists, Richard E. Ingram (1916–1967), Director of Rathfarnham Castle, Ireland merits mention for his theoretical papers (Ingram, 1963).

Among the different topics in seismology, the study of microseisms attracted the special interest of Jesuit seismologists. We have already mentioned the work of Macelwane and Ramirez, with a first paper in 1935. Probably the first suggestion of the relation between microseisms and storms was made by José Algue (1859–1930), Director of Manila Observatory, as early as 1894 in his study of Philippine Islands typhoons (Deppermann, 1951). Ernesto Gherzi (1886–1976), Director of Zikawei Observatory, published several papers on the relation between microseisms and atmospheric conditions (Gherzi, 1924). In 1952 a seminar was organized by the Pontifical Academy of Sciences on the problem of microseisms in which Gherzi, Macelwane, and Due-Rojo (Cartuja) participated, along with a select group of other specialists.

Jesuits participated in the early stages of the organization of seismological associations. R. Cirera (1864–1932), first Director of Ebro Observatory, represented Spain as one of two delegates in the second meeting of the International Seismological Conference in 1903 in Strasbourg (Rothé, 1981). Three Jesuits, Berloty (Ksara), Sánchez Navarro-Neumann (Cartuja) and Stein (Vatican) were present at the first General Assembly of the International Association of Seismology in the Hague in 1907. Jesuits have participated actively in the International Association of Seismology and the Physics of the Earth's Interior since its establishment in 1922 as part of the International Union of Geodesy and Geophysics (IUGG).

Jesuits have had a special relation with the Seismological Society of America. One of the 13 participants at the first meeting for its founding in 1906 was Jerome S. Ricard (1850–1930), Director of Santa Clara Observatory, who was elected

**FIGURE 4** Participants in the joint meeting of the Eastern Section of the Seismological Society of America and the Jesuit Seismological Association held in St. Louis, 1937. *First row (l to r)*: Anthony J, Westland, S.J., Archie Blake, Ernest A. Hodgson, Capt. Nicholas H. Heck, James B. Macelwane, S.J., J. Joseph Lynch, S.J. *Second row (l to r)*: J. Emilio Ramirez, S.J., Alphonse R. Schmitt, S.J., Louis B. Schlichter, Alton C. Chick. *Third row (l to r)*: H.M. Rutherford, Florence Robertson, Paul Weaver, —?, Victor G. Stechschulte, S.J., Theodore Zegers, S.J. *Fourth row (l to r)*: Daniel Linehan, S.J., Albert J. Frank, Arthur C. Ruge, Msgr. Joseph A. Murray, John P. Delaney, S.J., Ross Heinrich.

a member of the first Board of Directors (Byerly, 1964). J.B. Macelwane also served on the Board from 1925 to 1956 and was elected President of the Society in 1928. W. Stauder served on the Board from 1962 to 1967 and was President in 1966. Several Jesuits have been Chairman of the Eastern Section of the Seismological Society of America: J.B. Macelwane, 1926 (first Chairman); J.J. Lynch, 1930; V.C. Stechschulte, 1933; D. Linehan, 1954; V. Blum, 1955; H. Birkenhauer, 1956; and W. Stauder, 1963. For many years the Jesuit Seismological Association met jointly with the Eastern Section. In 1937, for example, at the joint meeting in St. Louis, of 22 participants 9 were Jesuits (Fig. 4); in 1948 at the meeting in Cleveland, of 29 participants 8 were Jesuits; and in 1961 at the joint meeting in Cincinnati, of more than 80 participants 9 were Jesuits.

## 5. Conclusion

As we have seen, Jesuits contributed to organizational, experimental, and theoretical aspects of seismology. Their principal contribution has been providing seismological data for research into the constitution of the Earth and the processes of generation of earthquakes. To accomplish this more effectively, Jesuit stations regularly endeavored to update the quality of their instrumentation (Table 1). This was particularly of significance in the early times, between 1910 and 1960, when the number and quality of seismological stations worldwide was rather limited. Jesuit stations in South America, Africa, and Asia were particularly important in those early times. In some instances, they were the only reliable stations in a region for many years. Establishment of modern national seismological networks and research institutions has made their work no longer necessary and explains the closing of many Jesuit stations.

The reporting of data has been a service of Jesuit observatories. Although many of the stations have been closed, those still active keep up this tradition. More and more, though, the contributions of Jesuits to this now very modern and developed science are through the research centers, principally Saint Louis University, Weston Observatory, Instituto Geofísico (Bogotá), Observatorio de S. Calixto (La Paz), and Manila Observatory. There are also contributions by individual Jesuits associated with Jesuit stations or working in or with other institutions or associations. They have continued to play an important part in the development of the theory of plate tectonics, in the study of the deep constitution of the Earth and of the mechanism of earthquakes, and in the earthquake hazard reduction programs of their various national efforts and cooperative international initiatives. They do indeed stand even today in the tradition of the early Jesuit pioneers.

In order to preserve a recognition of the contribution of Jesuits to this science, in 1989 the Jesuit Seismological Association approached the Eastern Section of the Seismological Society of America with the offer to fund the establishment of an award to honor an individual who has contributed notably to observational seismology. The Eastern Section accepted the proposal in 1991. The award is now conferred annually and bears with it a plaque and a small monetary prize.

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## Editor's Note

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