

Chapter 79.24 Germany

German National Report Part A. Early German Contributions to Modern Seismology

By Johannes Schweitzer
NORSAR, P. O. Box 53, N-2027 Kjeller, Norway

Contents

1	Introduction	2
2	The Beginning of Instrumental Seismology in Germany and the Appearance of the Teleseism	2
3	About the Early Roots of IASPEI in Strasbourg	6
4	The First International Conference on Seismology, Strasbourg 1901	9
5	The Second International Conference on Seismology, Strasbourg 1903	9
6	The International Seismological Association (ISA)	10
7	Emil Wiechert and the First Institute of Geophysics (1898)	12
8	Early Seismological Research in Germany	13
	8.1 Early Work About the Character of Motion of Earthquake Waves	13
	8.2 Seismic Phases	14
	8.3 Wave Propagation Studies	15
	8.4 From Travel-Time Curves to Velocity Models	15
	8.5 Estimating the Source Parameter of an Earthquake	16
	8.6 Gutenberg and the Earth's Core	17
	8.7 Surface Waves	19
	8.8 The Investigation of the Uppermost Kilometers of the Earth's Crust with Artificial Sources	20
9	Resume	22
10	Acknowledgments	22
11	References	23
12	Appendices	35
	Appendix 1. Earthquake on April 17, 1889 in Japan	35
	Appendix 2. Invitation to the Second International Conference on Seismology in Strasbourg 1903	37
13	Figures	40
14	Index	56

1 Introduction

Establishing seismology as a separate part of natural science and discovering the main structure of the Earth was a long process, to which numerous people contributed from many different countries. The most important steps towards establishing seismology and geophysics were made at the end of the 19th and the beginning of the 20th centuries. During this period, scientists working in Germany contributed significantly to the development of this new science and many of their discoveries, findings, and ideas are still worth acknowledging. In all disciplines, many ideas were developed in parallel at different places, and this also happened in geophysics. Therefore, I cannot exclude the possibility of earlier, independent discoveries in other countries of which I am unaware.

To investigate the history of our science, a lot of literature had to be read, studied, and finally weighted. The personal viewpoint of the author may not always be identical with that of the reader. However, the list of references contains original scientific publications, historical or biographical publications, and geophysical textbooks, which often contain historical information. Some references are not directly cited but were used to get a better overview and may be helpful for further studies.

A history of the earliest, non-instrumental period of German seismology can be found in Davison (1927) and in more detail in Tams (1950, 1952). The latter ended his historical study with the beginning of the 20th century, when Ernst Tams (1882 – 1963) himself became part of the seismological community. Therefore, I will start my description with the beginning of instrumental seismology during the last two decades of the 19th century. Some distance in time is needed to come to a “final” evaluation of the importance of individual contributions to our seismological knowledge. However, because numerous principal investigations in seismology were made until the end of the 1930s, I will continue the description of seismology in Germany through this time. A more detailed description of the political background of the international science relations and the political decisions in the German science community during this time can be found in Cremer (1999, 2001).

2 The Beginning of Instrumental Seismology in Germany and the Appearance of the Teleseism

The birth of modern seismology is strongly correlated with the development of instruments that were able to measure the movement of the Earth during and after an earthquake with reasonable accuracy in time and amplitude. During the 19th century many different instruments were built to record earthquakes in Europe, especially in Italy (see e.g. Dewey & Byerly, 1969; Ferrari, 1990, 1992). Because of relatively high internal friction and low amplification, these instruments were only able to record signals from earthquakes at local and near regional distances. The breakthrough came in the last decades of the 19th century, when a group of British seismologists in Japan developed different kinds of horizontal and vertical pendulums, and when Rebeur-Paschwitz built his first horizontal pendulum in Karlsruhe, Germany (**Figure 1**). A description of early instruments to observe, measure, or record seismic waves can be found e.g. in Ehlert (1898b), Berlage (1930), Dewey & Byerly (1969), or Ferrari (1990, 1992).

Ernst von Rebeur-Paschwitz (1861 – 1895, see Davison, 1895; Eschenhagen, 1895; Gerland, 1895, 1896, 1898; Hurtig, 1981; Kertz, 2002; **Figure 2**) was educated as an astronomer at the Universities of Leipzig, Geneva, and Berlin, where he finished his studies in 1883 with a Ph.D. thesis on comets (Rebeur-Paschwitz, 1883). In 1886, he started the construction of a horizontal pendulum when he worked as an ‘Assistent’ at the astronomical observatory in Karlsruhe. His idea was to build an instrument to measure oscillations of the plumb line due to the influence of astronomical bodies. His instrument was not only sensitive for plumb line changes but also for horizontal accelerations of the ground. Recording a light

beam reflected at a moving mass of only 42 grams (the horizontal pendulum) on photographic paper, he achieved an at that time large effective amplification of up to 295 for the surface wave maximum; for comparison: Milne's pendulum installed in Shide in the late 1890s had an effective amplification of about 50 (Abe, 1994). With his pendulums Rebeur-Paschwitz was the first who continuously recorded movements of the ground on photographic paper. In 1889, he started experiments with a viscous damping of the instrument and saw the advantages of clearer recordings, but he stopped these experiments because he had problems with the selected fluid (glycerin).

In 1889, although already seriously ill with tuberculosis, Rebeur-Paschwitz installed two identical instruments in Potsdam at the astrophysical observatory of Hermann Carl Vogel (1842 – 1907) and, with support of Carl Nicolai Boergen (1843 – 1909; Kertz, 2002) and Max Eschenhagen (1851 – 1901; Kertz, 2002), at the marine observatory in Wilhelmshaven and recorded in parallel the movements of the ground. Later, he took measurements during his cure on Tenerife (1889 – 1891) and in Strasbourg, and the pendulum formerly located in Potsdam was installed by Iwan Jegorowitsch Kortazzi (1837 – 1903) at the marine observatory in Nicolajew, Russia (today Ukraine) close to the coast of the Black Sea. Rebeur-Paschwitz described in detail his experiments, the construction of the pendulums, and his interpretation of the recordings in Potsdam, Wilhelmshaven and on Tenerife in a monograph (Rebeur-Paschwitz, 1892, 1894b); a description of his instrument can also be found e.g. in Dewey & Byerly (1969).

Because of his plan to measure real or apparent Earth movements due to the influence of astronomical bodies, he was especially interested in common signals at both places (Wilhelmshaven and Potsdam). Astronomical signals should be very similar at two places about 240 km apart, but he had to rule out all other than astronomical explanations. Therefore, he consequently also looked for earthquakes as possible sources of unknown phenomena and by chance, he read a report about an earthquake in Tokyo, Japan on April 17, 1889 (Nature, 1889; see also **Appendix 1**), which had occurred just before his instruments recorded unusual signals in both Potsdam and Wilhelmshaven (**Figure 3** and **Figure 4**). Rebeur-Paschwitz quickly realized a correlation between these signals and the earthquake in Japan, and reported in a letter to Nature (Rebeur-Paschwitz, 1889) about his observation including a first estimate of a mean velocity of the seismic signal from Tokyo to Germany (2.142 km/s). With this teleseismic observation, global seismology was born as part of geophysics and as a method of studying the Earth's interior.

Today we can see his records only as figures in his publications, because as far as I know, no original registration of his instruments can be traced. However, in reading these papers, it is obvious that the records had a very low time resolution, that Rebeur-Paschwitz primarily observed surface waves, and that the wave velocity given in his Nature contribution is too small for a surface wave. Later, Rebeur-Paschwitz found himself that he made an error in calculating the travel-time from Tokyo to his stations in Germany due to his misinterpretation of the published local time in Tokyo (Rebeur-Paschwitz, 1895a). He corrected his velocity calculations to > 7 km/s for the first small onsets (presumably in modern terminology the long-period S or SKS onset) and to 3.23, 3.50, and 2.79 km/s for the different onsets in the surface-wave train. These later values are in better agreement with today's knowledge of surface-wave velocities for a continental path from Japan to Europe.

An open question is, which earthquake had been observed by Rebeur-Paschwitz. We know about two teleseismic observations (Potsdam and Wilhelmshaven), one newspaper report from Tokyo (as reviewed in Nature, 1889), and the description of Cargill Gilston Knott (1856 – 1922, e.g. Kertz, 2002), who personally observed the recording of this event with the seismometer of the Imperial University in Tokyo (Knott, 1889). If we read with today's knowledge of seismology this review of the Japanese newspaper report and Knott's notice, it is obvious that this earthquake did not occur in Tokyo. It was dominantly observed on the north-south component of the seismometers installed at the Seismological Observatory of the Imperial University, Tokyo with remarkably large amplitudes for periods around 7 seconds,

lasting about 10 minutes and 36 seconds. The length of this signal must be shorter, because at those times, seismometers were undamped. In addition, this earthquake was observed by periodic water-level changes for a quarter of an hour at a small pond in Tokyo, also in the north-south direction. If these were primary Rayleigh waves, the source was somewhere north or south of Tokyo. This corresponds well with an earthquake felt at several places on the Izu-Hanto peninsula and located west of Izu-Oshima (34.75 N, 139.33 E) by the Central Meteorological Observatory in Tokyo. The reported intensities for this event can be easily explained with a magnitude 6 event but not with a magnitude 7 to 7.5 event as suggested by the amplitudes observed in Potsdam. A more detailed discussion on this question can be found in Utsu (see Chapter 79.33.2 on Handbook CD #2). However, the mentioned discrepancy is maybe explainable by the presumption that this earthquake may have had abnormally high source radiation in the low frequency range, by the lack of damping of the 'Rebeur-Paschwitz pendulum', and by the known, relatively large magnitude bias (site effect) of the station in Potsdam (see Neunhöfer, 1985).

After this observation, Rebeur-Paschwitz came in contact with the British group of seismologists in Japan, further developed his pendulum, and reported with several publications in English, German, and Japanese scientific journals about his instrument and his teleseismic observations (e.g. Rebeur-Paschwitz, 1893b + c, 1894a + b). With a relatively small number of earthquake observations, Rebeur-Paschwitz realized that the teleseismic observation of earthquakes is the right method to discover the structure of the Earth, and that such investigations can only be done with international cooperation. Interpreting his data, he found that the seismic velocities increase with depth and that the observed seismic energy travels from the source to the observatories along different paths: some waves travel along the Earth's surface, and some through deeper regions of the Earth, the body waves. In 1893, he published for the first time about the possibility that surface waves can also travel the major arc of the great circle path from an event to the station (Rebeur-Paschwitz, 1893b + c).

Although he became increasingly interested in seismology, Rebeur-Paschwitz followed his idea of measuring the gravitational influence of astronomical bodies on the Earth, and he observed tides of the solid Earth for the first time (Rebeur-Paschwitz, 1892, 1893a, 1895a). However, his whole scientific career was restricted by his illness and many of his ideas could not be investigated as deeply as he wanted.

In his last published papers, Rebeur-Paschwitz proposed the installation of a worldwide network of seismic stations with a common instrumentation to monitor the seismicity of the Earth as completely as possible (Rebeur-Paschwitz, 1895a + b). Because the instrumental and macroseismic observation of local earthquakes was highly developed in Japan, he expected from Japan the best located earthquakes and proposed to use, in a first step, the data from these stations as references for teleseismic observations. Therefore, he presented a list of 10 stations distributed worldwide, deployed in known observatories, with which the seismicity of Japan would be observable up to the antipodes in equally spaced distances of about 20°. These ideas were partly realized by John Milne (1850 – 1913, see e.g. Kövesligethy, 1914; Herbert-Gustar & Nott, 1980; McCooey, 1995; Kertz, 2002), who installed a network of seismic stations with the help of the British Association for the Advancement of Science during the last years of the 19th century and the first decade of the 20th century. In addition, Rebeur-Paschwitz proposed the foundation of an international institute that should be responsible for collecting and publishing all reports about felt and/or instrumentally observed earthquakes.

Rebeur-Paschwitz found in Georg Gerland from Strasbourg a very enthusiastic mentor and discussion partner, with whom he was in contact since about 1894 (Cremer, 1999, 2001). Gerland presented Rebeur-Paschwitz's ideas at the 6th International Geographic Conference (Gerland, 1900), which had its meeting in London from end of July to the beginning of August 1895. Here Rebeur-Paschwitz's ideas matched the suggestions of John Milne, who in January 1895 had published his 'Suggestions for a systematic observation in the northern hemisphere of earth waves and vibrations travelling great distances' (Milne, 1895). Rebeur-

Paschwitz's proposal was supported by the delegates, in a final resolution accepted, and, in a French and German version with the signatures of many scientists, widely distributed by Gerland. **Table 1** lists all the 25 supporters of this proposal.

Table 1: List of scientists supporting Rebeur-Paschwitz's proposal for international cooperation in seismology at the 6th International Geographical Congress, London, 1895 (after Gerland, 1900).

A. d'Abbadie	Prof. Dr. G. Gerland	Prof. Dr. F. Omori
Prof. G. Agamennone	Prof. Dr. F. R. Helmert	Prof. Dr. A. Penck
Prof. Dr. E. Becker	Prof. Dr. W. Kilian	Dr. E. v. Rebeur-Paschwitz
Prof. Ad. Cancani	Dr. H. Klein	Prof. A. Riccò
Prof. R. Copeland	Astronomer J. Kortazzi	Oberst R. v. Sterneck
Prof. G. H. Darwin	Prof. G. Lewitzky	Prof. Dr. A. Supan
Prof. Ch. Davison	Prof. J. Milne	Prof. P. Tacchini
Prof. Dr. M. Eschenhagen	Dr. G. v. Neumayer	Capit. J. Viniegra
Prof. Dr. F. A. Forel		

Rebeur-Paschwitz died on October 1, 1895, shortly before the resolution was printed and distributed. Charles Davison (1858 – 1940) wrote in his obituary of Rebeur-Paschwitz in the *Nature* issue of October 17, 1895: 'Dying at thirty-four, he had done work which most men of twice the age might regard with satisfaction as the fruits of a well-spent life.' (Davison, 1895; see Chapter). The influence of Rebeur-Paschwitz on modern seismology can be imagined by the fact that in 1927, more than 30 years after his death, Davison dedicated his monograph 'The Founders of Seismology' to the memory of three seismologists: John Milne, Fusakichi Omori (1868 – 1923, see Davison, 1924; Kertz, 2002), and Ernst von Rebeur-Paschwitz.

Georg Cornelius Karl Gerland (1833 – 1919, see e.g. Belar, 1903; Sapper, 1940; Angenheister, 1964; Kertz, 2002; **Figure 5**) was a talented musician and composer; educated as a philologist, he wrote his Ph.D. thesis about a grammatical problem in Ancient Greek, and was the author of poems, fairy-tales, and dramas. He worked for many years as *Gymnasiallehrer* (German grammar and high school teacher), and he published about anthropology, ethnology, geography, and geophysics. In 1875, he accepted the chair for geography at the newly founded university in Strasbourg and became increasingly interested in all fields of geophysics. In 1887, he founded a new scientific journal for this relatively young science: The 'Beiträge zur Geophysik' very soon became one of the leading international journals in geophysics and especially in seismology. After Gerland became an emeritus in 1910, this journal (starting with volume 11) was renamed in honor of its founder as 'Gerlands Beiträge zur Geophysik' and published until its 99th volume in 1990, only interrupted due to the two World Wars.

Since 1892, one of the two Rebeur-Paschwitz's pendulums was recording at the Imperial Astronomical Observatory in Strasbourg, installed and maintained by its director Ernst Becker (1843 – 1912). The results of this first, over two years long recording period in Strasbourg (April 1892 – August 1893) with the horizontal pendulum were published in the second volume of Gerland's journal together with a compilation of similar observations at other observatories (Rebeur-Paschwitz, 1895a). Also in 1892, Gerland became interested in recording seismic waves and he applied for financial support from the University in Strasbourg. In January 1894, he could contact Rebeur-Paschwitz and after some negotiations Gerland could buy the instrument installed at the Imperial Astronomical Observatory (Cremer, 1999, 2001). Later, Gerland received for his institute in Strasbourg the scientific inheritance of Rebeur-Paschwitz (Gerland, 1903a). Unfortunately, the original seismograms of Rebeur-Paschwitz and his original pendulum got lost sometime after World War I (Cara et al., 1987). In the hope that some material of and about Ernst von Rebeur-Paschwitz could have been saved, I contacted a member of the Rebeur-Paschwitz family in October 1999.

Christian Malte von Rebeur-Paschwitz informed me that all old private documents of his family were lost in Berlin by fire after bombing during World War II.

3 About the Early Roots of IASPEI in Strasbourg

After the early death of Rebeur-Paschwitz in 1895, Gerland promoted the idea of an international bureau to collect seismic observations worldwide, and the idea of an international society as a discussion forum and to coordinate all seismological research. Gerland was also interested in establishing Strasbourg as the center for seismology in Germany. One of his students, Reinhold Ehlert (1871 – 1899, see Gerland, 1899a + b; **Figure 6**) began a new observing period with horizontal pendulums in Strasbourg, improved the ‘Rebeur-Paschwitz horizontal pendulum’ in many details, and built an instrument with three equal pendulums arranged with an angle of 120° between (Ehlert, 1898a). This was done to solve the ambiguity in determination of the principle direction of the particle motion. The time and amplitude resolution of the seismograms at that time was so low that the direction of the principle particle motion was calculated from the relative amplitude ratio of the two horizontal components without any polarity information (i.e. from envelopes) which results in an ambiguity for the direction of the particle motion. In case of three instruments arranged with an angle of 120° between, this ambiguity can be solved without knowing anything about the polarity of the single cycle of ground motion. The configuration with three sensors in the horizontal plane was invented some years earlier.

For example, August Schmidt (1840 – 1929; **Figure 7**), Professor in Stuttgart, built a seismometer with four sensors before 1883, three to measure the horizontal and one the vertical movements of the Earth (Mack, 1927; Schick & Wielandt, 1994, Wielandt & Schick, 1997). Later Schmidt built one of the worldwide first gravimeters, the so-called ‘Trifilargravimeter’, which was in operation for many years at the observatory in Hohenheim, near Stuttgart (Schmidt, 1900; Mack, 1927; Dewey & Byerly, 1969).

Ehlert’s instrument became known as the ‘Rebeur-Ehlert pendulum’ and was installed at many observatories worldwide (**Figure 8**). The seismometers were built by the factory ‘J. und A. Bosch’ in Strasbourg (later in Hechingen, near Tübingen), which had problems producing and delivering all the requested instruments around 1900 (Germann, 1981), because Gerland successfully promoted the usage of this instrument. Later, this factory also became known as the designer and manufacturer of the worldwide installed ‘Bosch-Omori seismometers’, also known as ‘Strassburger Horizontalschwerpendel’, and of the ‘Mainka pendulum’ (see e.g. Berlage, 1930). However, the further development of the ‘Rebeur-Ehlert’ type of seismic instrument ended abruptly when Ehlert died on January 1, 1899 in a snow-avalanche accident in the Alps. Newer instruments, as developed by Emil Wiechert from Göttingen, by Carl Mainka (1873 – 1943, see Anonymous, 1944; Kertz, 2002) from Strasbourg, or by the Russian Prince Boris Borisovič Galitzin (1862 – 1916, also written Golitsyn; see e.g. Schmidt, 1979; Kertz, 2002) did not have the mechanical problem of abrasion in the hanging mechanism of the moving mass. In addition, the ‘Rebeur-Ehlert pendulum’ had a non-linear effect in the seismometer’s transfer function: the eigenperiod of the instrument depended on the observed amplitudes as was known since the experiments of Rebeur-Paschwitz with this kind of pendulum (Rebeur-Paschwitz 1892, 1895a; see also Galitzin, 1914).

During the last years of the 19th century, numerous seismic stations were installed worldwide, and in 1899, Gerland succeeded in setting up the first central seismological institute for Germany in Strasbourg (**Figure 9** and **Figure 10**). He managed to get the institute jointly financed by the Reichsland Elsass-Lothringen and the German Empire and became the first director of this institute, officially called ‘Kaiserliche Hauptstation für Erdbebenforschung’ (Imperial Central Station for Earthquake research). The institute became responsible for the organization of the planned homogenization and extension of the German seismological network. In addition, it became the central address in Germany for collecting

all earthquake observations and for recording the seismicity of the Earth with all the important seismic instruments (Gerland, 1900; Cara et al. 1987; Cara, 1990).

However, Gerland's other important plan was to initiate the international cooperation of seismologists as proposed in the London resolution and to found an international center for seismology in Strasbourg. Therefore, he prepared, together with some German colleagues, a second resolution for the 7th International Geographic Conference in Berlin 1899, in which he proposed the foundation of an international seismological society with the following objectives (Gerland, 1900; Rothé, 1981; Cremer, 1999, 2001): The society should

- as far as possible promote a systematic macroseismic investigation of all countries, especially of those without seismic stations and therefore with relatively unknown seismicity,
- as far as possible organize a homogeneous microseismic observation system,
- concentrate its publications which should be published as independent supplements to 'Beiträge zur Geophysik'.

This international society was planned as a union of seismic institutes and stations from all states in which seismicity is observed. Each of these institutes (or, in some cases, states) would send one delegate to annual meetings. The general meetings of the international society were planned together with the International Geographic Conferences. The members would pay a yearly fee and should receive the publications of the association.

The 7th International Geographic Conference supported this proposal and an 'International Permanent Commission for Earthquake Research' was spontaneously founded. As far as I know, this is the first international organization of seismologists. As of September 1900, this commission had 54 members, which are listed in **Table 2**.

Table 2: List of members of the Permanent Commission for Earthquake Research (September 1900) after Gerland (1900) with additions and corrections; the listed association between persons and states follows Gerland's list.

State	Name	City, Function, Remarks
Belgian	Prof. E. Lagrange	Brussels
Brasilia	Director L. Cruls	Rio de Janeiro
Denmark	Dr. Th. Thoroddsen	Copenhagen
Germany	Prof. Dr. C. Boergen	Wilhelmshaven
	Prof. Dr. H. Credner	Leipzig
	Prof. Dr. G. Gerland	Strassburg (Strasbourg)
	Prof. Dr. S. Günther	München
	Prof. Dr. F. R. Helmert	Potsdam
	Prof. Dr. K. Mack	Hohenheim near Stuttgart
	Director G. v. Neumayer	Hamburg
	Prof. Freiherr F. v. Richthofen	Berlin
	Prof. Dr. A. Schmidt	Stuttgart
	Dr. R. Schütt	Hamburg
	Prof. Dr. R. Straubel	Jena
	Prof. Dr. A. Supan	Gotha
	Prof. Dr. W. Valentiner	Heidelberg
England	Prof. G. H. Darwin	Cambridge
	H. Darwin	Cambridge (brother of G. H. Darwin)

	Prof. C. Davison	Birmingham
France	Prof. Dr. W. Kilian	Grenoble
	Prof. A. de Lapparent	Paris
Greece	Prof. Dr. D. Eginitis	Director of the Astronomical Observatory Athens
Japan	Prof. Dr. F. Omori	Tokyo
	Prof. N. Yamasaki	Tokyo
India	Director Moos	Bombay
Italy	Prof. L. Palazzo	Director of Uffic. Centr. di Meteor. e di Geodinamica, Roma
	Prof. G. Vincentini	Padua
	Prof. A. Riccò	Director of R. Osservatorio di Catania ed Etneo
	Director Cav. C. Guzzanti	Mineo, Sicily
Netherlands	Dr. J. P. van der Stok	De Bilt near Utrecht
	Director Dr. S. Figee	Batavia (Jakarta)
Norway	Prof. H. H. Reusch	Kristiania (Oslo)
	Dr. C. F. Kolderup	Bergen
New Zealand	G. Hogben	Secretary of the Seismological Society, Wellington
Austria-Hungary	Bergrath E. v. Mojsisovics	Vienna
	Colonel R. v. Sterneck	Vienna
	Prof. R. Hoernes	Graz
	Prof. A. Belar	Laibach (Ljubljana)
	Prof. E. Mazelle	Triest (Trieste)
	Prof. Dr. W. Láska	Lemberg (Lwów)
	Dr. F. Schafarzík	President of the Hungarian Earthquake Commission, Budapest
Romania	St. C. Hepites	Director of the Meteorological Institute, Bucharest
Portugal	F. A. Chaves	Director of Meteorological Observatory Ponta Delgada, St. Miguel, Azores
Russia	Director von Hlasek	Tiflis (Tbilissi)
	I. J. Kortazzi	Astronomer in Nicolajew (Ukraine)
	Prof. Dr. G. V. Lewitzky	Jurjew, Dorpat (Tartu)
	Prof. Dr. E. E. Leyst	Moscow
	Prof. I. V. Mušketov	St. Petersburg
	General H. Pomerantzeff	St. Petersburg
Sweden	E. Svedmark	Stockholm
Switzerland	Prof. Dr. F. A. Forel	Morges
	Prof. Dr. A. Riggenbach-Burckhardt	Basel
Siberia	Director A. W. Wosnessensky	Director of the Meteorological and Magnetic Observatory in Irkutsk
United States	Dr. L. A. Bauer	Washington

4 The First International Conference on Seismology, Strasbourg 1901

With support by the German foreign office and the organization of the International Geographic Congresses, Gerland could issue invitations to the First International Conference on Seismology in Strasbourg (April 11 – 13, 1901) with the objective of a vote for the foundation of an international seismological society (**Figure 11**). Official delegates came from Belgium, Germany, Japan, Italy, Austria, Hungary, Russia, and Switzerland, in addition to numerous individuals, mostly members of the International Permanent Commission founded in Berlin (Gerland, 1903a, 1905a; Sieberg, 1904; Rothé, 1981; Cremer 1999, 2001; Kozák, 2001). Instead of a society of individuals, as planned by Gerland, and especially because of requests from the delegates of Japan and Russia, the conference proposed an International Association of States with the following structural elements: a Permanent Commission, a General Assembly, and a Central Bureau; a structure similar to the International Geodetic Association.

However, it became clear that the foundation of such an international association would take some time and therefore it was of interest to establish a provisional structure. The non-German delegates asked the conference for a vote to install a preliminary Central Bureau at Gerland's 'Hauptstation für Erdbebenforschung' in Strasbourg, which was accepted. To support the work of the Central Bureau all participants obliged themselves to send their earthquake observations to Strasbourg. Emil Rudolph (1854 – 1915, see Sapper, 1915 and **Figure 12**), of Strasbourg, a fellow of Gerland's institute, was nominated as secretary of the conference, and he received the duty of publishing the proceedings of the conference. In 1902, the whole proceedings were published as 'I. Ergänzungsband der Beiträge zur Geophysik' in parallel in French and German (Rudolph, 1902).

With this result from the 'First International Conference on Seismology', the International Permanent Commission for Earthquake Research founded two years earlier in Berlin could be dissolved, but a smaller commission was formed with Francois Alphonse Forel (1841 – 1912), Gerland, Friedrich Robert Helmert (1843 – 1917; Kertz, 2002), Radó von Kövesligethy (1862 – 1934), Grigory Vasiloevic Lewitzky (1852 – 1917, also written Grigori Vassiljevitch Levitski), Edmund von Mojsvá Mojsisovics (1839 – 1907; see Kozák & Plešinger), and Luigi Palazzo (1861 – 1933) as members. This commission should act as liaison with the Congress of Geography.

5 The Second International Conference on Seismology, Strasbourg 1903

The Second International Seismological Conference (see **Appendix 2**) also met in Strasbourg (July 24 – 28, 1903) and the proceedings were again published in German and French (Rudolph, 1904). This time, 19 states were officially represented with delegates in Strasbourg: Argentina, Austria, Belgium, Bulgaria, Chile, Congo, Germany, Great Britain, Hungary, Italy, Japan, Mexico, Netherlands, Portugal, Romania, Russia, Spain, Sweden, Switzerland, and the United States of America. The delegate of Serbia was named but could not personally participate. In addition, numerous individuals interested in seismology came to Strasbourg, especially from Germany. During the conference, the statute of an International Seismological Association of States with its structure was defined: The association should have a Permanent Commission, a General Assembly, which should meet every four years, and a Central Bureau. The statute became part of the draft for an international convention to be signed by the states. This convention was intended to take effect on April 1, 1904 and should be valid at least for the next 12 years (i.e. March 31, 1916). It was planned to locate the main office of the Central Bureau in Strasbourg with Gerland as its director. The main duty of the Central Bureau should be collecting and editing of all microseismic and macroseismic observations. The Central Bureau should publish the bulletins and the minutes and proceedings of meetings.

This was the point that John Milne opposed (Milne & Darwin, 1904), and he argued against such a Central Bureau because he was ‘afraid also that the Central Bureau might have powers which would impinge upon national undertakings’ (Rothé, 1981). Some of this reaction is understandable, if we take into account that Milne had already installed, with the help of the British Association for the Advancement of Science, a network of seismic stations equipped with his seismometer, and that he started to publish his own seismic bulletin (the so-called Shide Circulars) for earthquake observations since 1899. In addition, this time was full of national resentments and perhaps Milne feared that Germany might dominate the Association by hosting the Central Bureau; the foundation of the Association itself was a good example of the political and management capabilities of Gerland. However, following Rothé (1981), ‘Milne’s attitude in 1903 was to be a burden on the whole future development of the Association’.

6 The International Seismological Association (ISA)

The International Seismological Association (ISA) was founded by the signing of the convention before April 1, 1904 by the following 18 states: Belgium, Bulgaria, Chile, Congo, Germany, Greece, Hungary, Italy, Japan, Mexico, Netherlands, Norway, Portugal, Romania, Russia, Spain, Switzerland, and the United States of America. However, Argentina, Austria, Denmark, France, Great Britain, Serbia, and Sweden supported the Association only in principle, but could not agree with four articles of the convention. These articles were changed in their favor at the Third International Conference on Seismology in Berlin on August 15, 1905. At the same conference, the first Permanent Commission was formed and Professor Palazzo from Rome was elected as its first president.

During the following years, many different meetings of the Permanent Commission took place, and the first General Assembly (**Figure 13**) of the ISA was organized in The Hague (September 21 – 25, 1907). During this assembly, the Permanent Commission also had a meeting and could add as new members the delegates of the states which had signed the convention after 1904: Canada, France, Great Britain, and Serbia; with this, the ISA now had 22 state members. The Central Bureau in Strasbourg published the results of its bulletin work and single investigations about specific scientific questions, as requested by the Permanent Commission. For instance, the Central Bureau organized and evaluated a concourse on seismographs for the meeting in The Hague. For such work, international guests came to Strasbourg and supported the permanent employees of the Central Bureau and the ‘Hauptstation für Erdbebenforschung’. If one reads the yearly reports about the work in Strasbourg as published in ‘Beiträge zur Geophysik’, one gets the impression that the Central Bureau and the ‘Hauptstation für Erdbebenforschung’ were a common institution using the same resources, but officially, they were separate organizations.

Gerland was the Director of the Central Bureau until his retirement as Professor of the University in 1910. Then Oskar August Ernst Hecker (1864 – 1938; **Figure 14**) became Director of the ‘Hauptstation für Erdbebenforschung’, and in parallel Director of the Central Bureau of the ISA (Cremer, 1999, 2001). The most important duty of the Central Bureau in Strasbourg was to publish compilations of seismic observations: Rudolph was able to compile a first bulletin with associated observations from several stations for the years 1895 – 1897 (Rudolph, 1903a + b). The next worldwide catalogue was compiled for the year 1903 (Rudolph, 1905). Then it was Elmar Rosenthal (1873 – 1919, see Cederberg & Tarvel, 1926-1929), who published the first international bulletin in the name of the International Seismological Association for the year 1904 (Rosenthal, 1907). During the following years, Siegmund Szirtes could publish phase readings from internationally distributed seismic stations in catalogues and bulletins for the years 1905 – 1908 (Szirtes, 1909a + b, 1910a + b, 1912a + b, 1913a + b). Macroseismic observations were collected and published in bulletin form by Gerland’s Ph.D. student Adolf Christensen, Robert Lais (1886 – 1945; see Zilch, 1947), Emilio Oddone (1861 – 1940), Emil Rudolph, Erwin Scheu (1886 – 19??), August Sieberg, and Gerland’s Ph.D. student Georg Ziemendorff (Rudolph, 1905; Oddone, 1907;

Christensen & Ziemendorff, 1909; Scheu, 1911; Scheu & Lais, 1912; Sieberg, 1917); for further details on the contents of these old bulletins see Chapter 88 by Schweitzer & Lee. The production of these bulletins stopped due to World War I and the dissolution of the International Seismological Association.

August Sieberg (1875 – 1945, Krumbach, 1949; **Figure 15**), compiled not only macroseismic data but he also developed and published during his years in Strasbourg his modification of the macroseismic intensity scale of Forel and Giuseppe Mercalli (1850 – 1914; e.g. Kertz, 2002). He followed Adolfo Cancani's (1856 – 1904) suggestion (Cancani, 1903) and defined for the first time a 12-grade macroseismic intensity scale (Sieberg, 1912). This scale was generally in use in Europe until the 1990s. With his tectonic, geological, geographical, historical, and technical studies about earthquakes, their causes, and their effects, he dominated this field of seismology for the next decades (e.g. Sieberg, 1930, 1932). Sieberg was also known for his talent as painter. His publications and especially his textbooks contain numerous sketches and paintings from his hand for illustration and documentation purposes (e.g. Sieberg, 1904, 1908, 1923, 1927, 1930, 1932; **Figure 20**). From 1913 until the end of World War I, Beno Gutenberg (1889 – 1960; **Figure 27**) was another employee of the Central Bureau. After being wounded by a grenade, Gutenberg commuted during the war between his work in Strasbourg and the fronts in the west and the east, where he was specialist for meteorological problems (weather and wind forecast, using sound to locate cannons). In Strasbourg, he mostly worked on regional travel-time curves, microseisms, and the character of seismic phases, he supported Hecker in publishing the famous German edition of Galitzin's 'Vorlesungen über Seismometrie' (lessons on seismometry) (Galitzin, 1914; see also Schmidt, 1979), and he analyzed the records of the seismic station in Strasbourg.

It should also be mentioned that during this first period of ISA, records of the first international seismic station, installed on Iceland in the name of ISA, were routinely analyzed in Strasbourg. A second international seismic station was installed by the ISA in Ksara (Lebanon). In addition, Georg (Georges) Rempp (1882 – 1937) from Strasbourg built the first seismic station on Spitsbergen in the Svalbard Archipelago in Longyear-City (today Longyearbyen), at that time an American settlement for coal mining (Rempp, 1914a). Later, Georg Rempp and Carl Mainka analyzed the seismograms from this station in detail in Strasbourg (Rempp, 1914b; Mainka, 1914). At least six larger regional events ($\Delta = 180 - 300$ km) were observed between October 1911 and May 1912, which first demonstrated the relatively high seismicity in this region. The largest of these events was also observed at stations in Central Europe and Russia.

In 1913, Argentina became the 23rd member of ISA, and following the yearly reports of Hecker, published in 'Gerlands Beiträge zur Geophysik', there appeared to be a normal, routine development of the ISA, its Central Bureau, and a fruitful international cooperation in seismology. Nevertheless, the political and social "earthquake" in Europe due to World War I changed everything.

As far as it is visible in the yearly reports, the Central Bureau tried to keep running its business as usual during the whole war. Due to the changes in the political landscape in Europe after World War I, Strasbourg again became part of France and the responsibility for the Central Bureau of the ISA became part of the postwar problems between France and Germany. The German employees of the institute in Strasbourg had to leave the institute on December 23, 1918, and were transported out of France on January 6, 1919, without any possibility of carrying their belongings with them (Hecker, 1924; Sapper, 1940). The Central Bureau and the 'Hauptstation für Erdbebenforschung', most of the instruments, the scientific material and the libraries of both institutes and their employees became inaccessible for German seismology. Unfortunately, many things were also lost for the whole seismological community. So, German seismology after World War I was without its most important research institute besides Göttingen. It would take about five years before Germany could found a central institute for seismology again: in 1923, Hecker became the director of the

‘Reichsanstalt für Erdbebenforschung’ in Jena (Hecker, 1924; Sieberg, 1939; Krumbach, 1950; Güth et al., 1974; Germann, 1981; Cremer, 2001).

As mentioned before, the first time period, for which the convention about the International Seismological Association was signed, ended during World War I. After the war, it became clear that the international scientific cooperation had to be reorganized. The International Research Council founded the International Union for Geodesy and Geophysics (IUGG) in 1919 and seismology was to be a section of this Union. In April 1922, the Third General Assembly and the 5th Conference of the Permanent Commission of the ISA had a meeting in Brussels and the old International Seismological Association dissolved itself on April 24, 1922. One month later, at the first General Assembly of the IUGG in Rome, the new Seismology Section of the IUGG was established. This time, German seismologists could not participate or become members of this Section. The reason for this was that directly after World War I, relations between the German scientists and the International Research Council were deeply disturbed, especially because of the very emotional resolution of the ‘Inter-Allied Conference on International Scientific Organisations’, published just before the end of World War I (Nature, 1918).

Without the possibility of participating in international seismological conferences, the German seismologists needed a forum for discussion. Emil Wiechert invited German seismologists to a special meeting in September 1922 at the yearly conference of the ‘Deutsche Naturforscher und Ärzte’ (German natural scientists and physicians) in Leipzig, and Hecker proposed at this meeting the foundation of the ‘Deutsche Seismologische Gesellschaft’ (Wiener & Bauschinger, 1923). The 24 seismologists present spontaneously followed the idea and founded this society, which became the nucleus of the ‘Deutsche Geophysikalische Gesellschaft’ founded two years later on the second meeting of the ‘Deutsche Seismologische Gesellschaft’ in Innsbruck, Austria (Defant, 1924). At the end of the 1920s, the common scientific interests between single seismologists became more important than ‘old political’ problems, and after solving financial problems with paying the yearly fees to the IUGG, Germany became an official member of the IUGG in 1937 (Kohlschütter, 1937).

7 Emil Wiechert and the First Institute of Geophysics (1898)

Emil Wiechert (1861 – 1928, see e.g. Angenheister, 1928; Gutenberg, 1928; Gerecke, 1962; Schröder, 1982; Kertz, 2002; Ritter & Schweitzer and Hennings & Ritter both in Chapter 79.24 Part C on Handbook CD #2; **Figure 16**) was born in Tilsit (today Sovjetsk) in Ostpreussen (today Region of Kaliningrad, Russia) and was educated in Königsberg (Kaliningrad). At the University in Königsberg, he studied physics and mathematics, completed his Ph.D. in 1889, and became the title professor of physics in 1896. In the same year, he proposed that X-rays are electromagnetic waves with exceedingly small wavelengths. In 1896/1897, he was one of the first to discover that cathode rays are particle streams and he correctly measured the ratio between the mass and the charge of these particles, which we call electrons today. However, he had not done the final step and explained the low mass of these particles with respect to a hydrogen atom with the existence of a new elementary particle, the ‘electron’. Wiechert is still identified with the Liénard-Wiechert potential (1900).

In Königsberg Wiechert also became interested in the constitution of the Earth and during his last year in Königsberg, he published for the first time his idea of an iron core inside the Earth (Wiechert, 1896, 1897a + b; Brush, 1980, 1982). In 1897, he followed Woldemar Voigt (1850 – 1919), whom he knew from Königsberg, to the University of Göttingen and became ‘Assistent’ at the astronomical institute, under which the departments for geomagnetism, geodesy, and theoretical astronomy were united. Some months after his arrival in Göttingen the head of the institute, Professor Ernst Schering (1833 – 1897), died and the university took the chance for a general reorganization. One result of this reorganization was that Wiechert was nominated as ‘Professor für Geophysik’ (Professor of Geophysics) in 1898. Geophysics

was at the end of the 19th century a very young science (Kertz, 1979). After Maurycy Pius Rudzki (1862 – 1916) had been installed in 1895 as ‘Professor für mathematische Geophysik und Meteorologie’ at the Jagiellonian University of Kraków, Poland (see Helbig & Szaraniec, 1999; Chapter 79.43 Part I, 7.1 on Handbook CD # 2 by Maj), Wiechert’s nomination was worldwide the second time that ‘geophysics’ was used to name a professorship. Wiechert became responsible for the geomagnetic observatory, which had a long tradition in Göttingen back to the days of Carl Friedrich Gauß (1777 – 1855, e.g. Bühler, 1981, 1986; Kertz, 2002) and Wilhelm Eduard Weber (1804 – 1891; Kertz, 2002). In his work, Wiechert was not focused only on geomagnetism, and in the same year (1898), he achieved a renaming of the observatory as ‘Institut für Geophysik’ (Institute of Geophysics). This institute (**Figure 17**) was now, as defined in its name, not only responsible for geomagnetic observations, but also for all kinds of physics related to the Earth. As far as I know, it was worldwide the first time that the phrase ‘geophysics’ was used in the name of an institute.

One part of the work at the newly founded institute was seismology, and of course, Wiechert knew about the most recent developments in seismology. In 1898/1899, Wiechert had already begun to install the first horizontal pendulums in Göttingen, and for the first time in seismology, he invented and tested the advantages of an air-damped mechanical seismometer (Wiechert, 1899, 1906; Berlage, 1930). After a visit in Italy, where he got new ideas on how to construct a seismometer, he built his first famous astatic pendulum in 1900 (Wiechert, 1903a + b, 1904, 1906; Dewey & Byerly, 1969). In 1903, he published his important monograph about the theoretical basics of a mechanical seismometer (Wiechert, 1903a). During the next years, Wiechert improved his horizontal pendulums, he constructed instruments with different masses, and in 1904/1905, he built his first astatic vertical pendulum (Wiechert, 1906). This type of seismograph, the astatic pendulum, would be installed all over the world and became a standard instrument until World War II. Following a listing of seismological stations in the world and their instrumentation by Berlage (1930), about 100 “Wiechert’s” were installed worldwide.

The astatic pendulums in Göttingen were placed in the ‘Erdbebenhaus’ (earthquake house), specially built in 1902 in the garden of the new institute’s building, which is located on the Hainberg above the roofs of Göttingen and the instruments are still in operation (Wiechert 1906; Duda et al. 1990; see also Schreiber, 2000; Ritter, 2002). Wiechert’s inscription (**Figure 18**) above the door to the seismometer building is

‘Ferne Kunde bringt Dir der schwankende Fels – Deute die Zeichen!’

(The trembling rock bears tidings from afar – Read the signs!),

a motto which described the program during these years for all seismological research in Göttingen.

8 Early Seismological Research in Germany

8.1 Early Work About the Character of Motion of Earthquake Waves

After the first observations of earthquakes with horizontal pendulums, it became an open question whether the observed movements were due to the tilt of the Earth’s surface or due to horizontal movement, a question that was in principle not possible to answer with horizontal pendulums alone. To explain the observed amplitudes, Schmidt showed with theoretical calculations that horizontal movements are much more likely than tilt (Schmidt, 1898). In the same year, Wilhelm Schlüter (1875 – 1902, see Wiechert, 1903c, **Figure 19**), the first student of Wiechert in Göttingen, started to build his so-called klinograph, an instrument which could only sense rotational acceleration round a horizontal axes but not horizontal movements or static tilt. He compared the records of this instrument with the records of a horizontal pendulum installed in parallel, and he could show that earthquake waves do not produce any measurable rotational acceleration, which should be seen in the case that the observed

movements of the horizontal pendulum are caused by tilt waves (Schlüter, 1901, 1903a). Schlüter rebuilt his klinograph as a vertical instrument and constructed the first long-period vertical motion seismometer (Schlüter, 1903b, Dewey & Byerly, 1969). Then, comparing the signals on the vertical records with the ones on the horizontal records, Schlüter (1903b) became the first to measure incidence angles of seismic rays at a seismic station. He found systematic changes for these angles with respect to the distance to the event, which confirmed Schmidt's theory about the curvature of seismic rays, and Schlüter contributed with his data to the further developments in the ray theory for seismic waves (see the following section). This promising young scientist died of diabetes at the age of only 26 years, before most of his results were published.

The next step in analyzing the motion of earthquake waves was done in the Ph.D. thesis of Hugo Arnold. He, also student of Wiechert in Göttingen, was the first in Germany who digitized P-phase onsets of a 'Wiechert seismometer'. Then, he removed the instrument response by integration and calculated the ground displacement (Arnold, 1909). He described in all details his problems of integrating an analog registration and discussed the results of the Russian seismologist B. J. Pomeranzeff in St. Petersburg, who had made such calculations for data from a 'Bosch-Omori seismometer' (Pomeranzeff, 1904).

8.2 Seismic Phases

Rebeur-Paschwitz tried to identify the different seismic phases in his seismograms and he found the difference between body waves and surface waves (Rebeur-Paschwitz, 1895a + b). With the improving recording capabilities of seismographs during the 1890s, it became clear that a typical seismogram contains three different parts: the so called first and second precursors (body waves) and the main waves (surface waves). The identification of the first precursors with compressional waves, which should also theoretically be the fastest, was easy; the association of the second precursors with the expected shear waves was made by Oldham, who analyzed records of the great Assam event of 1897. The next important step was the observation that body waves can be reflected and converted (Wiechert, 1907; Zoeppritz, 1907). This dramatically changed the interpretation of the observed seismograms by reducing the number of unexplainable onsets. The Institute of Geophysics in Göttingen started with the routine analysis of seismograms in 1903, and its station bulletin was published in weekly and yearly reports. In 1903/1904, Georg von dem Borne (1867 – 1918, see Poggendorff, 1926), the analyst of the seismograms, developed together with Wiechert the Latin based nomenclature still in use today to describe seismic onsets:

P	undae primae	first waves (first precursors), compressional waves
S	undae secundae	second waves (second precursors), shear waves
L	undae longae	long waves (main shock), surface waves
i	impetus	onset, impulsive beginning
e	emersio	emergent, slow increase of amplitudes

This naming system for seismic phases was then systematically extended by combining the characters P and S for converted phases like PS or SP (e.g. Geiger, 1909) or by doubling the characters for reflected phases like SS and PP (e.g. Geiger & Gutenberg, 1912a + b). Later (see e.g. Angenheister, 1921), the surface waves were subdivided into LR (for Rayleigh waves) and LQ (for Querwellen, i.e. transverse waves = Love waves). An illustration of the ideas about the Earth's interior and the ray paths of seismic waves as understood at the beginning of the 20th century can be found in **Figure 20**.

8.3 Wave Propagation Studies

The famous series ‘Ueber Erdbebenwellen’ (About Earthquake Waves) by Wiechert and his students and colleagues started with a review paper by Wiechert about the theory of elastic waves, ray tracing, and in addition, several results of his own research (Wiechert, 1907). The identification of surface reflections was mentioned before; another important point was the discussion about the change of the amplitudes and the incidence angle of seismic waves at the Earth’s surface due to the complex interference of direct, reflected and converted waves. In this paper, Wiechert stated for the first time that for investigations of the polarization of seismic waves, this effect has to be taken in account. He also calculated theoretical travel-time curves for different kinds of first and second order discontinuities.

Zoeppritz applied Wiechert’s theory and derived the full set of reflection and refraction coefficients for the amplitude of a plane wave approaching a first order discontinuity (Zoeppritz, 1919) independently from Knott (1899). It seems that the work of the British seismologist Cargill Gilston Knott (1856 – 1922; Kertz, 2002) was not known in Germany until the middle or late 1920s and in today’s literature, the equations to calculate reflection and transmission coefficients can still be found as ‘Zoeppritz equations’. Karl Zoeppritz (1881 – 1908, see Wiechert, 1912; Kertz, 2002; Ritter & Schweitzer in Chapter 79.24 Part C on Handbook CD #2; **Figure 21**) studied geology, and after his Ph.D. in Freiburg im Breisgau he came to Wiechert in Göttingen and became his ‘Assistent’ in the summer of 1906. During the winter of 1907/1908, he contracted a serious infection and died at the age of 26 on July 20, 1908. Most of his scientific work during these two years was revised by Wiechert, Geiger, and Gutenberg and published after his death. The last of these papers, in which he derived the reflection and transmission coefficients, was printed after World War I in 1919. However, his colleagues knew his results beforehand, and they used his formulas to develop a method for employing amplitude ratios between direct P phases and surface reflections (PP) to derive travel-time curves and Earth models (e.g. Zoeppritz † & Geiger, 1909; Zoeppritz † et al., 1912).

These travel-time curves were in use for the production of the Bulletins of the British Association for the Advancement of Science, Seismology Committee (1913 – 1917), which were published by Herbert Hall Turner (1861 – 1930) as a continuation of Milne’s Shide Circulars. At the reorganizing conference of the ISA during the IUGG meeting in Rome (1922), Turner became President of the ISA and, following the suggestion of Professor Giovanni Agamennone (1858 – 1949) from Rome, the British Association was asked to change its bulletin to The International Seismological Summary (ISS). The first ISS locations and phase identifications were also based on the travel-time tables derived in Göttingen before the First World War. During the 1920s, Turner gradually expanded these tables for newly discovered phases and better phase observations, often suggested and derived by Gutenberg. After Turner’s death J. S. Hughes took over the ISS and changed in 1934 to the Jeffreys-Bullen tables, which were used starting with the bulletin issue of 1930 (for the history of the ISS see Chapter 4 by Adams).

8.4 From Travel-Time Curves to Velocity Models

In 1888, August Schmidt, Stuttgart, had published a paper in which he showed for the first time that seismic waves follow not straight but curved lines, if the seismic velocity is increasing with depth. The observed velocities at the Earth’s surface are not identical with the velocities with which the seismic waves propagate in the Earth, and if the hypocenter is deep, the travel-time curves observed must have a turning point. Sieberg tried to introduce the phrase ‘Schmidt’s law’ for these results in the literature but failed (Sieberg, 1904, 1923).

The ideas of Schmidt were further theoretically developed by Maurycy Pius Rudzki (1862 – 1916, see Helbig & Szaraniec, 1999; Chapter 79.43 Part I, 7.1 on Handbook CD # 2 by Maj) from Kraków in Poland (Rudzki, 1898a + b) and Hans Benndorf (1870 – 1953; Kertz, 2002) from Graz in Austria. Benndorf solved the problem of calculating the ray path and the

travel time of a seismic wave (Benndorf, 1905, 1906). He used Schlüter's incidence-angle observations (i.e. in essence ray parameters) as input data to prove what was later called 'Benndorf's law'. This equation gives the relation between the sine of the incidence angle of a seismic wave reaching the Earth's surface, the wave velocity at the Earth's surface, and the ray parameter, i.e. the derivative of the travel-time curve with respect to the epicentral distance. So, Benndorf solved the forward problem, i.e. the ray tracing, but not the inversion from observed travel-time data to a model of the seismic velocities inside the Earth. It was the young mathematician Gustav Herglotz (1881 – 1953; Kertz, 2002; **Figure 22**), who came from the University in Graz to the University in Göttingen, who solved the problem. In 1907, he showed Wiechert that Benndorf's equation for calculating travel times and ray paths of seismic waves in the Earth can be transformed and inverted in the same way as the known integral equation of Niels Henrik Abel (1802 – 1829) (Abel, 1826; Herglotz, 1907; Byerly, 1963). Some years later, the British mathematician Harry Bateman (1882 – 1946), also working during part of this time in Göttingen, published the same results (Bateman, 1910a + b). During the following years, Bateman's paper was often cited and used in the English-speaking world (e.g. Knott, 1919). However, it was Wiechert together with his 'Assistant' Ludwig Geiger who simplified the solution of Herglotz, converted it to a practical form, applied the inversion for the first time to observed travel-time data from different authors, and discussed the various results (Wiechert & Geiger, 1910). Today this method is known as the 'Herglotz-Wiechert Inversion' or the 'Wiechert-Herglotz Inversion'.

8.5 Estimating the Source Parameter of an Earthquake

At the beginning, earthquakes were only locatable with macroseismic observations. The different seismic phases, their travel times, and their ray paths through the Earth were unknown. Different methods by different authors were developed to locate earthquakes for which only instrumental observations were available. In Göttingen two remarkable methods were developed, which still are in use.

August Abt (1867 – 1951, see Asbeck, 1951), a high school teacher, borrowed a small horizontal pendulum from Wiechert, which had been used in Göttingen before Wiechert built the astatic pendulums, and installed this seismometer with a photographic registration tool in the basement of his high school building (Oberrealschule, Humboldtschule) in Essen/Ruhr. Abt wrote a Ph.D. thesis about his experiment under the supervision of Wiechert (Abt, 1907). In this thesis, he compared the records of his instrument with the records of the stations in Göttingen and in Uppsala (Sweden) for the period between November 1904 and November 1905. In Uppsala, Filip Åkerblom (1869 – 1942) was responsible for the Wiechert pendulum installed with support of the Institute of Geophysics in Göttingen and Åkerblom had spent some time in Göttingen to learn about seismology and to analyze the seismic records (Åkerblom, 1906a + b, Schröder, 1988).

In addition to his comparative work, Abt collected the reported onset times for specific events from other stations in Europe. Then, by using a least-squares algorithm and under the plane-wave assumption, he calculated the horizontal apparent velocities and the azimuth of approach for the different phases. With his measured velocities he confirmed Benndorf's results (Benndorf, 1906) and the apparent velocities calculated from Wiechert's and Zoeppritz's travel-time tables (Wiechert, 1907; Zoeppritz, 1907). As far as I know, Abt's work is the first description of measuring azimuth and ray parameter of a seismic wave by using a network of seismic stations: the concept of a seismic array.

Another important step forward in locating seismic events was the work of Ludwig Geiger (1882 – 1966, see Anonymous, 1966; Ritter & Schweitzer, 2002, Chapter 79.24 Part C on Handbook CD #2; **Figure 23**). Geiger was the son of a pharmacist in Basel, Switzerland, and studied physics in Basel, Berlin, Heidelberg, and finally in Göttingen, where he finished with a Ph.D. thesis about observations of the Zeeman-effect for sodium in 1906 at Institute for Mathematical Physics with Woldemar Voigt. Then he became interested in seismology, and

in April 1907, he started as ‘Assistent’ of Wiechert at the Institute of Geophysics. Geiger worked together with Wiechert and Zoeppritsch, and later with Gutenberg, on travel-time curves, the velocity structure of the Earth, and the location of earthquakes. Although he was seven years older than Gutenberg they not only worked together, but during their common time in Göttingen they also had private contact. According to his son Urs Peter Geiger, the usual question was, if they met for a drink, would it be a big or a little celebration; by the time it finished, it was often a big one.

In 1913, Geiger received the ‘Observator’ position at the ‘Samoa-Observatorium’ (Samoa-Observatory) near Apia on Upolu, an island in the Samoan Archipelago. This Samoa-Observatory (Angenheister, 1974; **Figure 25**) was founded and managed by the ‘Göttinger Gesellschaft der Wissenschaften’, the scientific academy of University Göttingen. During the entire period between 1904 and 1921, scientists from the Institute of Geophysics worked at this place as ‘Observator’s and/or Directors. They substantially contributed to the seismological database in Göttingen with their local and regional observations of large south-pacific earthquakes, especially of the Tonga-Fiji region. In addition to Geiger and among others, Franz Linke (1878 – 1944, Mügge & Möller, 1944; **Figure 24**), Gustav Heinrich Angenheister (1878 – 1945, Förtsch, 1950; Ritter et al. in Chapter 79.24 Part C on Handbook CD #2; **Figure 26**), and Kurt Wegener (1878 – 1964, the brother of Alfred Wegener; Kertz, 2002) worked in Samoa as seismologists.

In July 1914, Gustav Heinrich Angenheister arrived in Samoa as planned exchange for Ludwig Geiger. There both were surprised by the beginning of World War I and became prisoners of war after the allies with a ship coming from New Zealand occupied the archipelago. Geiger had gone to Samoa without a Swiss passport, but he convinced the occupation authorities that he needed to contact a Swiss Consul. In March 1915, Geiger left Samoa on a New Zealand naval ship, and was carried to Vancouver, Canada, the nearest Swiss Consulate. He convinced the Consul about his Swiss nationality and returned to Europe. There, the French authorities arrested him, because they believed that he was a German spy. He was transported to the Swiss border, was again arrested by the Swiss, and he came before a Swiss military tribunal because he had not followed the calling up for the Swiss mobilization at the beginning of World War I. Finally, Geiger managed all these problems, but he lost as a foreigner the possibility to work as a seismologist in post-war Germany. Because he also could not find an equivalent position in Switzerland after the war, Ludwig Geiger joined his brother’s pharmaceuticals factory and he became a successful manager of an international company.

In 1910 and in parallel with his inversion work with Wiechert, Geiger developed the basic formulas for locating earthquakes by using the absolute travel times of seismic phases and known travel-time curves; at that time, he used only the first P onsets (Geiger, 1910). He developed a linearized equation system for finding the final epicenter by starting from a first solution and minimizing the residuals by a least-squares fit. With his inversion algorithm, he also calculated error ellipses and demonstrated his method with an example. His inversion, extended by the inversion for the source depth and the possibility to improve the solution by several iterations, is still the most frequently applied algorithm for determining an earthquake location today.

8.6 Gutenberg and the Earth’s Core

As mentioned before, Emil Wiechert had been interested in the problem of the Earth’s core since the beginning of his geophysical career and he had proposed the existence of an iron core (Wiechert, 1896, 1897a + b; Brush, 1980, 1982). However, the seismological proof was not yet given. Seismologists were trying to improve the travel-time curves, and most teleseismic observations ended somewhere at a distance between 100° and 120°. Just before Wiechert published the first ‘Über Erdbebenwellen’ paper (Wiechert, 1907), the British geologist and seismologist Richard Dixon Oldham (1858 – 1936, e.g. Kertz, 2002) published

a paper in which he claimed to have observed and modeled the Earth's core by delayed P phase observations (Oldham, 1906). Oldham himself was not very convinced by his P observations because of their scatter. More important for his argument was the delay of S phase observations at distances beyond 120° . As Wiechert pointed out in his 1907 paper, Oldham's delayed S-phase observations are mostly SS phases, i.e. the reflections of S phases at the Earth's surface. This argument was later accepted and published by Oldham himself (Oldham, 1919). However, one can conclude that Oldham discovered and published about the shadow effect of the Earth's core for the first time, but misinterpreted seismic phases and failed to model the core depth and the seismic velocities outside and inside the core.

In Göttingen, the seismologists worked hard to derive a reliable travel-time curve for distances up to 100° , and collected observations of earthquakes from longer distances. As mentioned before, the Samoa-Observatory was at the right place for this. With local and regional observations from Samoa and other stations in south Asia, the seismologists in Göttingen were able to locate large events in the southern Pacific area with a precision good enough to extend the observed travel-time curves derived from observations in Göttingen. In his paper of 1907, Wiechert mentioned that P phases from events in the Samoa region were delayed in Göttingen. This was similar to the observations of Oldham published one year earlier (Oldham, 1906). However, Wiechert did not invert these data into a model.

In 1911/1912, the situation was different. The data density was much higher, especially the Samoa data (Wegener, 1912), a method used to extend and confirm observed travel-time curves by interpreting observed amplitude ratios (P/PP) was developed (Zoeppritz \dagger et al., 1912), and finally, the Herglotz-Wiechert inversion was ready to use.

In 1911, Beno Gutenberg (1889 – 1960, see e.g. Byerly, 1953; Jeffreys, 1960; Richter, 1962; Knopoff, 1998, 1999; Schweitzer, 1989; Kertz, 2002; for his bibliography see Chapter 79.24 Part D on Handbook CD #2 by Schweitzer; **Figure 27**) finished his Ph.D. about microseism observations and the possible sources of microseisms in Göttingen (Gutenberg, 1911). He was born in 1889 in Darmstadt and came to Wiechert to study geophysics in 1908. After his Ph.D., he continued to work in Göttingen until October 1912. Then he served one year in the army, and from October 1913 he was employed at the Central Bureau of the International Association for Seismology (ISA) in Strasbourg. Due to World War I, he also lost his job in Strasbourg in 1918 and became unemployed as a seismologist. Gutenberg moved back to Darmstadt and started to work in the small soap factory of his father. But his scientific interests were undimmed and in 1922, he took the opportunity to cooperate with the Institute of Meteorology and Geophysics at the nearby University of Frankfurt am Main, where Franz Linke was the Professor of Geophysics and Meteorology. For the next eight years, he managed the soap factory, especially after the death of his father in 1927. During the evenings, he worked on geophysics, wrote numerous papers about seismology, meteorology, geodynamics, and the structure of the Earth. In addition, he wrote three monographs and published and contributed extensively to two famous textbooks on geophysics (Gutenberg, 1926-1929; Gutenberg, 1929-1932). Gutenberg became an extraordinary Professor of Geophysics at the University of Frankfurt and was responsible for the analysis of the seismograms from the geophysical and meteorological station, the 'Taunus-Observatorium' (Taunus Observatory) (**Figure 28**). However, he failed to get a permanent position at a German university. Therefore he accepted in 1930 the chair for geophysics at the California Institute of Technology in Pasadena, California (see e.g. Goodstein, 1984; Goodstein & Roberts, 1988). During the following years, Beno Gutenberg established the Seismological Laboratory (of which he later became director) in Pasadena as one of the world's leading seismological institutes.

After Gutenberg finished his Ph.D., the problem of the Earth's core was awaiting him. He put all of the evidence together and wrote his most important paper about the velocity structure of the Earth's interior (Gutenberg, 1913, 1914). Gutenberg was now able to explain the time delay of the observations beyond about 105° with a reasonable model. He estimated the radius of Earth's core as 3480 km, a value with less than one percent difference from

modern estimates. He calculated the negative P-velocity jump at the core-mantle boundary from the mantle to the core in the right order, and his velocity model for the lowermost mantle already showed a decreased velocity gradient above the core; Keith Edward Bullen (1906 – 1976; Hales, 1979) would later call this region D'' (Bullen, 1950). Gutenberg correctly associated the first S observations beyond 80° with a phase converted from S to P to S on its way through mantle, core and mantle again (SKS), and he associated and identified the phase PKS. Finally, he calculated a set of theoretical travel-time curves for many phases not observed at that time, such as the reflections from the core PcP and ScS (**Figure 29**). The biggest mistake he made in this paper was related to the S velocities in the core. He had no observations of S phases passing the core and used a ratio of 1.8 between P and S velocities to calculate theoretical S velocities. Later, Gutenberg tried to find corresponding S-phase observations but failed (e.g. Gutenberg, 1923a). It was the British geophysicist Harold Jeffreys (1891 – 1989; Crampin, 1989; Kertz, 2002), who proved that the core must be liquid, and that therefore no S phase can pass it (Jeffreys, 1926). However, both Gutenberg and Jeffreys overlooked the existence of an inner core, which was discovered by the Danish seismologist Inge Lehmann (1888 – 1993; Emmerich & Schweitzer, 1988; Bolt, 1997; Kertz, 2002) in 1936 (Lehmann, 1936, 1987).

8.7 Surface Waves

As mentioned before, surface waves were addressed in the early years of instrumental seismology as the main phase. Due to the instrumentation at the end of the 19th century, surface waves dominated all seismograms and were therefore investigated; Rebeur-Paschwitz calculated velocities for the first teleseismically observed waves (Rebeur-Paschwitz, 1889, 1895a). However, a detailed investigation of surface waves required better instrumentation, which was e.g. developed in Göttingen. Consequently, the next acknowledgeable result about surface wave interpretation was made in Göttingen: In 1905, Gustav Heinrich Angenheister (1878 – 1945, Förtsch, 1950; Ritter et al. in Chapter 79.24 Part C on Handbook CD #2; **Figure 26**) came from the University in Heidelberg, where he finished his studies with a Ph.D. in experimental physics, to Göttingen as Wiechert's 'Assistent'. He started the investigation of surface waves and compared the amplitudes of waves, which traveled along the minor and major paths along the great circle through source and receiver. For one event (Calabria, Italy, on September 8, 1905), Angenheister could combine three ray-path observations: Samoa – Göttingen, and Calabria – Göttingen observed on the minor and major arcs. All these wave paths approximately follow the same great-circle path.

For surface waves with periods around 20 seconds, Angenheister determined the amplitude decay with respect to the different path lengths and he was therefore the first who measured the attenuation of a seismic wave (Angenheister, 1906a + b). In his studies, he found a mean value for the amplitude decay rate of about 0.0031 / km, which corresponds to a quality factor Q of about 300. During the next years, Angenheister worked at the Samoa-Observatory as 'Observator' (1907 – 1909, 1911 – 1912) and later as its 'Direktor' (1914 – 1921). During his time in the Samoan Archipelago, he collected more surface wave observations. After World War I, New Zealand became responsible for the Samoan Archipelago and Angenheister handed the observatory over to the authorities of New Zealand (Angenheister, 1974). He came back to Göttingen and published a paper, in which he demonstrated the differences in the seismic velocities between continental and oceanic wave paths for surface waves, which were mainly sensitive to the elastic constants in the Earth's crust (Angenheister, 1921). In addition, he also got different attenuation values: the mean amplitude decay rate for continental wave paths was about three to four times smaller than for waves with oceanic wave paths. After Wiechert's death in 1928, Angenheister became his successor and was the second professor of geophysics in Göttingen until he died in 1945 shortly after World War II.

In parallel, Ernst Tams (1882 – 1963, see Hiller, 1964; **Figure 30**) also worked on surface waves. Tams was born in Hamburg and got his first education in geophysics in Göttingen at Wiechert's institute. Then he moved to Strasbourg and became Gerland's last student and

‘Assistent’. In 1908, he moved back to Hamburg, became head of the earthquake station, and later professor at the new University of Hamburg. In 1921, Tams published his surface wave velocity observations for different wave paths, and obtained the same result as Angenheister: the surface waves are faster for oceanic paths than for continental ones (Tams, 1921). Tams connected his results with the ideas of Alfred Lothar Wegener (1880 – 1930, e.g. Benndorf, 1931; Kertz, 1980, 1999, 2002; **Figure 31**), who had proposed two different types of crust, the oceanic (Sima) and the continental (Sial), to explain his ‘Theorie der Kontinentalverschiebung’ (Theory of Continental Drift). Wegener used the results of Tams and Angenheister as confirmation of his ideas (Wegener, 1922). This was the first relation between seismology and what we call plate tectonics today. Decades later, seismology and the concept of plate tectonics are used both to investigate and explain the dynamics of our planet.

In the 1920s, Gutenberg also became more interested in surface waves. He confirmed the results of Tams and Angenheister with more and better data, he calculated the first dispersion curves for surface waves, and proposed a method for inverting dispersion curves of surface waves into depth distributions of seismic velocities (Gutenberg, 1923b, 1924b, 1925b, 1926a). With these results, Gutenberg was convinced of the principal differences between stable continents and the deep-sea oceanic crust. Influenced by Wegener, he started the development his own theory of continental drift (‘Fließtheorie’), and became a supporter of large horizontal movements of the continents throughout his career (see e.g. Gutenberg, 1927b + c, and also 1960, and Marvin, 1973). During these years Gutenberg also began his work on seismological evidence for a weaker zone in the upper-most mantle (asthenosphere). He observed a reduction in P-wave amplitudes for regional P phases, which had their turning point in the Earth’s mantle deeper than 60 km. He could explain this phenomenon with constant and/or slightly reduced seismic velocities below the Earth’s crust down to the depth of about 80 km (Gutenberg, 1926b).

A systematic investigation of dispersion curves of surface waves from 37 earthquakes observed at the stations in Göttingen (25), Samoa (6), and Zi-Ka-Wei (Shanghai) (6) was made by Walter Rohrbach, one of Angenheister’s students in Göttingen (Rohrbach, 1932).

On the theoretical side, Karl Uller (1872 – 1959), professor of theoretical physics in Gießen and known as a resolute opponent of the theory of relativity and of quantum physics (Richter, 1980), developed over many years and in numerous publications his unified wave theory. In this theory, Uller simultaneously derived the formulas for Rayleigh and Love waves (Uller, 1918), but also many theoretically proposed wave types, which were never observed. However, Uller contributed to the ideas of the generation of surface waves by reflection and refraction of body waves (Uller, 1914, 1928a), to the induction of surface-wave like motions at an internal boundary (leakage), and to the creation of guided waves (Uller, 1928b). In addition, his wave theory had some influence during the time between the two World Wars. For example, Gutenberg cited and used Uller’s derivations of the propagation of elastic waves in his textbooks quite often (Gutenberg, 1926-1929, 1929-1932).

8.8 The Investigation of the Uppermost Kilometers of the Earth’s Crust with Artificial Sources

The systematic investigation of non-seismic sources for ground movements recorded with seismographs was from the beginning one of the tasks in the working program in Göttingen (Gutenberg, 1911). For instance, it was discovered that some microseismic noise was generated by the gas-driven machines of the Göttingen power station at about 2.5 km distance. Ludger Mintrop systematically investigated this effect. Ludger Mintrop (1880 – 1956; e.g. Schleusener, 1956; Schulze, 1974; Kertz, 1991, 2002; **Figure 32**) learned farming on his father’s farm in Werden (today part of Essen, Ruhr-District). However, farming had no future in the fast developing industrial Ruhr-District and he went to the Realgymnasium (Helmholtzschule) in Essen. After practical work in the coalmines, he started in 1902 studying at the Königlich-Preußische Bergakademie (mining college) in Berlin and became a

state-certified ‘Markscheider’ (German title for land surveyors in mining). In the course of his work in Aachen as Markscheider and teacher, Mintrop was exposed to seismology, since he was responsible for the Aachen earthquake station. In 1907, he took the chance and moved to Göttingen to study geophysics at Wiechert’s institute. With his mining background, he was mostly interested in surface structures and measurement of elastic waves caused by industry and mining induced events. Parallel to his studies in Göttingen, in 1908 he became a teacher at the mining school in Bochum (Mintrop, 1912b; Rüter, 1997), a neighbor city of Essen, where he installed a seismic station (Mintrop, 1909, 1912a). Under the supervision of Wiechert in Göttingen, Mintrop started with experiments to investigate seismic-wave propagation in the uppermost layers with artificial sources. He used small explosions or large falling masses to generate elastic waves. These waves were recorded either at the regular seismic station of the institute or with specially built, portable seismographs. His 4000-kg steel ball, which could fall 14 m from a specially constructed rack, is famous. Both the steel ball and the rack can be visited in the garden of the institute in Göttingen (**Figure 33**). He wrote his Ph.D. thesis about his investigations of the microseisms caused by the aforementioned power plant (Mintrop, 1911) and reported about his experiments with artificial sources and about his portable instruments (Mintrop, 1910, 1912b). In 1912, Mintrop mentioned the reflection of seismic waves, generated by artificial sources, from layers in the uppermost crust (Mintrop, 1912b). Georg von dem Borne (Borne, 1908) had already proposed a systematic use of such data for the investigation of the uppermost layers, but it was Mintrop who made the first practical implementations. During World War I, he acquired more experience with mobile instruments by locating cannons by their seismic signals. As practical as he was, he also saw some financial profit in his constructions and patented his mobile seismographs (for details see Mintrop, 1930, 1953).

Ludger Mintrop’s most important contribution to seismology was made in summer 1919, when he discovered that the usually curved travel-time graph ends in a linear graph. His explanation was, under the assumption that the lower layer of a first order discontinuity has a higher seismic velocity than the upper layer, that after hitting the discontinuity a seismic wave travels with the velocity of the lower layer along this discontinuity. The seismic headwave was discovered and with this discovery, refraction seismology was born. In applied seismics the headwave is sometimes called the Mintrop-wave in honor of its discoverer. Again, Mintrop tried to patent his method and reported about the new possibilities (Mintrop, 1920, 1930). In 1920, he measured refracted and reflected waves at several places in Germany and founded the first commercial seismic company in Germany on April 4, 1921: the ‘SEISMOS GmbH’ (see also Cremer, 1999, 2001). During the following years, the SEISMOS was one of the world’s leading prospecting companies with internationally operating measuring groups. Although the success of Mintrop’s method was obvious, his colleagues were skeptical about his explanation, which was unclear because of his pending patent. However, he apparently convinced Wiechert, who promoted in his last years the usage of quarry blasts to investigate the crust.

After a request by Prof. Wilhelm Meinardus (1867 – 1952), professor for geography at the university in Göttingen, Wiechert’s student Hans Mothes started with seismic measurements on the Hintereisferner, a glacier in the Ötztal Alps (Förtsch & Soffel, 1998). Mothes was the first to measure the seismic velocities of ice in a glacier and to determine the thickness of a glacier with seismic methods (Mothes, 1926, 1927). Similar studies on other alpine glaciers were made in preparation for the 1930 Greenland expedition of Alfred Wegener. During this expedition Bernhard Brockamp (1902 – 1968) measured for the first time the thickness of the inland ice of Greenland (Brockamp, 1935). In Germany, many refraction and reflection studies followed during the next years and successively the principal structure of the crust was deciphered.

I will not end this description of the roots of modern seismology without mentioning a paper of the Austrian-German mathematician Johann Radon (1887 – 1956). Johann Radon, born in Tetschen, Bohemia (today Czech Republic), spent his career as a professor of mathematics at different universities in Germany and Austria. In 1917, he published his

famous paper about an integral transformation today called the ‘Radon transformation’ (Radon, 1917). As far as I know, he never had any relation to geophysics, but in this paper, Radon described the fundamental principles of modern tomography, which have enabled seismologists during the last two decades to investigate the 3D structure of the Earth.

9 Resume

As a personal resume of the work on the history of seismology in Germany, I have to say that I learned a lot about seismology and the persons who contributed to establish seismology as a science. However, I was also surprised by how strongly the beginning of modern seismology was influenced by cultural and political factors: The death of several young and talented scientists due to illnesses curable today (Rebeur-Paschwitz, Schlüter, and Zoeppritz) and due to an accident (Ehlert) were huge losses. The result of the catastrophe of World War I was a dramatic change in the political landscape of Europe. For many years, the German seismology was handicapped due to the lost of working and research possibilities for scientists in Strasbourg (e.g. Gutenberg, Hecker, and Sieberg). Some of the seismologists only survived by totally changing their field of interest (Geiger) or by relegating their scientific interests to a private evening and weekend activity while running another business (Gutenberg).

10 Acknowledgments

The work on this paper would not have been finished without the support of Rainer Kind, Horst Neunhöfer, Joachim Ritter, Rolf Schick, Götz Schneider, Liane Tröger, and Walter Zürn. I thank Urs Peter Geiger, who informed me about the eventful vita of his father; Arthur Gutenberg, a friend at long standing who has assisted me in my research about his father; Peggy Hellwig, who helped to find a more poetic translation of Wiechert’s motto on seismology, and Sebastian Zoeppritz, who sent me a copy of a picture from his great-uncle, which he could find in his archive of the Zoeppritz family. I especially thank Rainer Kind and Joachim Ritter for their help in locating, finding, and copying many historic papers, and some of the biographical information. Peter Malischewsky helped me to understand the early ideas about surface waves, for which I thank him. I also thank Robin Adams, Hans Berckhemer, Karl Fuchs, Ben Howell, Gerhard Müller, and Erhard Wielandt for reviewing the manuscript and for their corrections and comments. Lyla Taylor corrected the language of the manuscript, thank you Lyla. This is NORSAR contribution 682.

11 References

To support the reader in searching the cited literature, I tried to decode all initials in names of the authors and the abbreviations of the names of journals and periodicals. The titles of the contributions always follow the original writing as published. For some papers, I had only reprints available, which may have a different page numbering than the versions published in the journals.

- Abe, Katsuyuki (1994). Instrumental magnitudes of historical earthquakes, 1892 to 1898. *Bulletin Seismological Society America* **84**, 415-425.
- Abel, Niels Henrik (1826). Auflösung einer mechanischen Aufgabe. *Journal für reine und angewandte Mathematik (Crelles Journal)* **1**, Heft 2.
- Abt, August (1907). Vergleichung seismischer Registrierungen von Göttingen und Essen (Ruhr). Inaugural-Dissertation (Ph.D. thesis), Philosophische Fakultät, Georg-August-Universität zu Göttingen, Göttingen 1907, 26 pp. + curriculum vitae.
- Åkerblom, Filip (1906a). Vergleichung der Diagramme aus Upsala und Göttingen, deren Wellen die Erde umkreist haben. *Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse*, 121-123.
- Åkerblom, Filip (1906b). Seismische Registrierungen in Upsala Oktober 1904 – Mai 1905. *Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse*, 125-140.
- Angenheister, Gustav G. (1964). Georg Cornelius Karl Gerland. In: *Neue deutsche Biographie*. Edited by Historische Kommission bei der bayerischen Akademie der Wissenschaften **4**, Berlin, 305.
- Angenheister, Gustav G. (1974). Geschichte des Samoa-Observatoriums von 1902 bis 1921. In: Birett et al. (1974), 43-66.
- Angenheister, Gustav Heinrich (1906a). Bestimmung der Fortpflanzungsgeschwindigkeit und Absorption von Erdbebenwellen, die durch den Gegenpunkt des Herdes gegangen sind. *Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse*, 110-120.
- Angenheister, Gustav Heinrich (1906b) Seismische Registrierungen in Göttingen im Jahre 1905. *Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse*, 357-416. This paper is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Angenheister, Gustav Heinrich (1921). Beobachtungen an pazifischen Beben. *Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse*, 113-146.
- Angenheister, Gustav Heinrich (1928). Emil Wiechert †. *Zeitschrift für Geophysik* **4**, 113-117.
- Anonymous (1944). Prof. Dr. Carl Mainka †. *Beiträge zur angewandten Geophysik* **11**, 1-2.
- Anonymous (1966). Two obituary notices of Ludwig Geiger: R. S. in *National-Zeitung Basel* **552**, 28. 11. 1966 and G. A. W. in *Basler Nachrichten* **506**, 29. 11. 1966.
- Arnold, Hugo (1909). Die Erdbewegung während des ersten Vorläufers eines Erdbebens. Inaugural-Dissertation (Ph.D. thesis), Philosophische Fakultät, Georg-August-Universität zu Göttingen, 48 pp. + curriculum vitae, also in: *Beiträge zur Geophysik* **10**, 269-317.
- Asbeck (1951). Nachruf Professor Dr. August Abt †. In: *Schulzeitung für die Schüler, Lehrer, Eltern, Ehemalige und Freunde der Humboldt-Schule zu Essen, Jahrgang* **15**, Heft 1, Herbst 1951.
- Bartels, Julius, editor (1948a). *Naturforschung und Medizin in Deutschland 1939 – 1946*, für Deutschland bestimmte Ausgabe der FIAT Review of German Science
Band 17, Geophysik Teil 1, Dieterich'sche Verlagsbuchhandlung Wiesbaden 1948, 237 pp.
Band 18, Geophysik Teil 2, Dieterich'sche Verlagsbuchhandlung Wiesbaden 1948, 321 pp.
- Bartels, Julius, editor (1948b). *FIAT Review of German Science 1939 – 1946, Geophysics*, published by Office of Military Government for Germany, Field Information Agencies Technical, British, French, U.S.,
Part 1, Dieterich'sche Verlagsbuchhandlung Wiesbaden 1948, 237 pp.
Part 2, Dieterich'sche Verlagsbuchhandlung Wiesbaden 1948, 321 pp.
- Bateman, Harry (1910a). Die Lösung der Integralgleichung, welche die Fortpflanzungsgeschwindigkeit einer Erdbebenwelle im Innern der Erde mit den Zeiten verbindet, die die Störung gebraucht, um zu verschiedenen Stationen auf der Erdoberfläche zu gelangen. (The solution of the integral equation which connects the velocity of propagation of an earthquake wave in the interior of the earth with the times, which the disturbance takes to travel to different stations on the earth's surface.) *Physikalische Zeitschrift* **11**, 96-99.

- Bateman, Harry (1910b). The solution of the integral equation connecting the velocity of propagation of an earthquake-wave in the interior of the earth with the times which the disturbance takes to travel to the different stations on the earth's surface. The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science, **Series 6, 19**, 576-587.
- Belar, A. (1903). Prof. G. Gerland. Die Erdbebenwarte **2**, 179-182.
- Benndorf, Hans (1905). Über die Art der Fortpflanzung der Erdbebenwellen im Erdinneren. 1. Mitteilung. Sitzungsberichte der Kaiserlichen Akademie in Wien. Mathematisch-Naturwissenschaftliche Klasse **114**, Mitteilungen der Erdbebenkommission, **Neue Folge 29**, 1-42.
- Benndorf, Hans (1906). Über die Art der Fortpflanzung der Erdbebenwellen im Erdinneren. 2. Mitteilung. Sitzungsberichte der Kaiserlichen Akademie in Wien. Mathematisch-Naturwissenschaftliche Klasse **115**, Mitteilungen der Erdbebenkommission, **Neue Folge 31**, 1-24.
- Benndorf, Hans (1931). Alfred Wegener. Gerlands Beiträge zur Geophysik **31**, 337-377.
- Berlage, Hendrik Petrus jun. (1930). Seismometer. In: Gutenberg (1929 – 1932), 299-526.
- Birett, Herbert (1974). Quellen zur Geschichte der Geophysik. In: Birett et al. (1974), 267-274.
- Birett, Herbert, Klaus Helbig, Walter Kertz & Ulrich Schmucker, editors (1974). Zur Geschichte der Geophysik. Festschrift zur 50jährigen Wiederkehr der Gründung der Deutschen Geophysikalischen Gesellschaft. Springer Verlag, Berlin Heidelberg New York, XV + 288 pp.
- Bolt, B. (1997). Inge Lehmann. Biographical Memoirs of Fellows of the Royal Society **43**, 285-301.
- Borne, Georg von dem (1904). Seismische Registrierungen in Göttingen, Juli bis Dezember 1903. Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse, 440-464. This paper is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Borne, Georg von dem (1908). Die physikalischen Grundlagen der tektonischen Theorien. Beiträge zur Geophysik **9**, 378-403.
- Börngen, Michael, Joachim Homilius & Franz Jacobs (1997). Die Deutsche Geophysikalische Gesellschaft, 1922 – 1997. In: Neunhöfer et al. (1997), 7-26.
- Brockamp, Bernhard (1935). Die Mächtigkeit des grönländischen Inlandeises. Zeitschrift für Gletscherkunde, für Eiszeitforschung und Geschichte des Klimas **23**, 277-285.
- Brush, Stephen G. (1980). Discovery of the Earth's core. American Journal of Physics **48**, 705-724.
- Brush, Stephen G. (1982). Chemical history of the Earth's core. EOS, Transactions American Geophysical Union **63**, 1185-1186 + 1189.
- Brush, Stephen G. & Helmut Erich Landsberg (1985). The history of geophysics and meteorology – an annotated bibliography. Garland Publishing New York and London.
- Bühler, Walter K. (1981). Gauss. A biographical study. Springer, Berlin, Heidelberg, New York 1981. Edition in German: Gauss. Eine biographische Studie. Springer, Berlin, Heidelberg, New York 1986, viii + 191 pp.
- Bullen, Keith Edward (1950). An earth model based on a compressibility-pressure hypothesis. Monthly Notices Royal Astronomical Society, Geophysical Supplements **6**, 50-59.
- Byerly, Perry (1953). Fifteenth award of the William Bowie Medal, Citation. Transactions American Geophysical Union **34**, 353-354.
- Byerly, Perry (1956). Subcontinental structure in the light of seismological evidence. Advances in Geophysics **3**, 105-152.
- Byerly, Perry (1963). The Earth's mantle in the early days (presidential address). Union Géodésique et Géophysique Internationale, Comptes Rendus **14**, Réunion à Berkeley. Août 1963, 32-42.
- Cancani, Adolfo (1904). Sur l'emploi d'une double échelle sismique des intensités, empirique et absolue. In: Rudolf (1904), Annexe A 10, 281-283.
- Cara, Michel (1990). The development of instrumental seismology at Strasbourg and in France. In: Ferrari (1990), 183-192.
- Cara, Michel, Daniel Rouland, E. Peterschmitt, & L. Trotignon (1987). Historical instruments and seismograms in Strasbourg. Gerlands Beiträge zur Geophysik **96**, 374-384.
- Cederberg, Arno Rafael & Peeter Tarvel eds. (1926 – 1929). Eesti biograafiline leksikon. K. – Ü. Loodus, Tartus 1926 – 1929, 18 + 643 pp.
- Christensen, Adolf & Georg Ziemendorff (1909). Les tremblements de terre ressentis pendant l'année 1905. Publications du Bureau Central de l'Association Internationale de Sismologie, Série B, Catalogues, Strasbourg, 543 pp. This book is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Crampin, S. (1989). Memorial Sir Harold Jeffreys, F.R.S. 1891 – 1989. Geophysics: The Leading Edge of Exploration **8**, 90-91.
- Cremer, Marielle (1999). Seismik zu Beginn des 20. Jahrhunderts – Internationalität und Disziplinbildung. Dissertation (Ph.D. thesis) Fachbereich Mathematik, Universität Hamburg, Hamburg 1999, 328 pp.

- Cremer, Marielle (2001). Seismik zu Beginn des 20. Jahrhunderts: Internationalität und Disziplinbildung. Berliner Beiträge zur Geschichte der Naturwissenschaften und der Technik **28**, ERS-Verl. Berlin 2001, 333 pp.
- Dahlen, Francis Anthony & Jeroen Tromp (1998). Theoretical seismology. Princeton University Press, XIV + 1025 pp.
- Davison, Charles (1895). Dr. E. von Rebeur-Paschwitz. Nature **52**, 599-600. This obituary is reproduced in the computer-readable file of Chapter 79.24 Part C on the attached Handbook CD #2.
- Davison, Charles (1924). Obituary. Prof. Fusakichi Omori. Nature **113**, 133.
- Davison, Charles (1927). The founders of seismology. Cambridge University Press. Reprint: Arno Press New York 1978.
- Defant, Albert (1924). Geophysik. Verhandlungen der Gesellschaft deutscher Naturforscher und Ärzte, 88. Versammlung zu Innsbruck vom 21. – 27. September 1924, 40-41.
- Dewey, James & Perry Byerly (1969). The early history of seismometry (to 1900). Bulletin Seismological Society America **59**, 183-227.
- Duda, Seweryn J., Kailash N. Khattri, George Purcaru & Rolf Schick (1990). Wiechert-Seismograms of the Göttingen Observatory – microfilming and reinterpretation. Gerlands Beiträge zur Geophysik **99**, 313-336.
- Ehlert, Reinhold (1898a). Horizontalbeobachtungen im Meridian zu Strassburg i. E. Von April bis Winter 1895. Beiträge zur Geophysik **3**, 131-215
- Ehlert, Reinhold (1898b). Zusammenstellung, Erläuterung und kritische Beurtheilung der wichtigsten Seismometer mit besonderer Berücksichtigung ihrer praktischen Verwendbarkeit. Beiträge zur Geophysik **3**, 350-475. This paper is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Elstner, Claus (1981). Beiträge von Erdzeitenuntersuchungen zu Vorstellungen über die Struktur des Erdkörpers. Akademie der Wissenschaften der DDR, Forschungsbereich Geo- und Kosmoswissenschaften, Veröffentlichungen des Zentralinstitutes für Physik der Erde **64**, 25-31.
- Emmerich, Helga & Johannes Schweitzer (1988). Inge Lehmann – die Entdeckerin des inneren Erdkerns. Deutsche Geophysikalische Gesellschaft e.V., Mitteilungen **2/1988**, 5-6.
- Eschenhagen, Max (1895). Nekrolog Dr. E. v. Rebeur-Paschwitz. Astronomische Nachrichten **136**, Nr. **3507**, 19-20.
- Ferrari, Graziano, ed. (1990). Gli strumenti sismici storici Italia e contesto europeo – historical seismic instruments Italy and the European framework. Istituto Nazionale di Geofisica, Bologna, 198 pp.
- Ferrari, Graziano, ed. (1992). Two hundred years of seismic instruments in Italy 1731-1940. Istituto Nazionale di Geofisica, Bologna, 156 pp.
- Förtsch, Otto (1950). Gustav Heinrich Angenheister †. Gerlands Beiträge zur Geophysik **61**, 291-295.
- Förtsch, Otto & Heinrich Soffel (1998). Die wissenschaftlichen Arbeiten am Geophysikalischen Institut der Universität Göttingen unter Professor Gustav Heinrich Angenheister von 1928 bis 1945. Deutsche Geophysikalische Gesellschaft e.V., Mitteilungen **3/1998**, 8-18.
- Galitzin (also Golicyn), Prince Boris Borisovič (1914). Vorlesungen über Seismometrie, deutsche Bearbeitung unter Mitwirkung von Clara Reinfeldt, herausgegeben von Oskar Hecker. Verlag Teubner, Berlin 1914, VIII + 538 pp. This classic textbook on seismology is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Geiger, Ludwig (1909). Seismische Registrierungen in Göttingen im Jahre 1907 mit einem Vorwort über die Bearbeitung der Erdbebendiagramme. Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse, 107-151. This paper is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Geiger, Ludwig (1910). Herdbestimmung bei Erdbeben aus den Ankunftszeiten. Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse, 331-349.
translated into English by F. W. L. Peebles & Anthony H. Corey, S.J.:
Geiger, Ludwig (1912). Probability method for the determination of earthquake epicenters from the arrival time only. Bulletin St. Louis University **8**, 60-71.
- Geiger, Ludwig & Beno Gutenberg (1911). Konstitution des Erdinnern, erschlossen aus dem Bodenverrückungsverhältnis der einmal reflektierten zu den direkten Longitudinalwellen. Physikalische Zeitschrift **12**, 814-818.
- Geiger, Ludwig & Beno Gutenberg (1912a). Konstitution des Erdinnern, erschlossen aus der Intensität longitudinaler und transversaler Erdbebenwellen, und einige Beobachtungen an den Vorläufer. Physikalische Zeitschrift **13**, 115-118.

- Geiger, Ludwig & Beno Gutenberg (1912b). Ueber Erdbebenwellen. VI. Konstitution des Erdinnern, erschlossen aus der Intensität longitudinaler und transversaler Erdbebenwellen, und einige Beobachtungen an den Vorläufern. Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen. Mathematisch-physikalische Klasse, 623-675.
- Gerecke, Friedrich (1962). Zum Gedenken. In: Zum Gedenken Emil Wiecherts anlässlich der 100. Wiederkehr seines Geburtstages. Deutsche Akademie der Wissenschaften zu Berlin. Veröffentlichungen des Institutes für Bodendynamik und Erdbebenforschung in Jena **72**, Akademie-Verlag Berlin 1962, 5-14.
- Gerland, Georg (1895). Dr. E. v. Rebeur-Paschwitz †. Petermanns Mitteilungen aus Justus Perthes' Geographischer Anstalt **41**, 260-261.
- Gerland, Georg (1896). Ernst Ludwig August v. Rebeur-Paschwitz. Leopoldina **22**, 14-17.
- Gerland, Georg (1898). Ernst Ludwig August v. Rebeur-Paschwitz. Beiträge zur Geophysik **3**, 16-18.
- Gerland, Georg (1899a). Dr. Reinhold Ehlert, †. Petermanns Mitteilungen aus Justus Perthes' Geographischer Anstalt **45**, 21-22.
- Gerland, Georg (1899b). Dr. Reinhold Ehlert. Beiträge zur Geophysik **4**, 105-107.
- Gerland, Georg (1900). Die Kaiserl. Hauptstation für Erdbebenforschung in Strassburg und die moderne Seismologie. Beiträge zur Geophysik **4**, 427-472.
- Gerland, Georg (1903a). Erster Jahresbericht des Direktors der Kaiserlichen Hauptstation für Erdbebenforschung bis zum Abschluss des Rechnungsjahres 1900. Beiträge zur Geophysik **5**, I-XVI.
- Gerland, Georg (1903b). Jahresbericht des Direktors der Kaiserlichen Centralstation für Erdbebenforschung von April 1901 bis April 1902. Beiträge zur Geophysik **5**, XVII-XXIV.
- Gerland, Georg (1905a). Gründung, Organisation und Aufgaben der internationalen seismologischen Assoziation. Beiträge zur Geophysik **7**, 469-479.
- Gerland, Georg (1905b). Jahresbericht des Direktors der Kaiserlichen Hauptstation für Erdbebenforschung für das Rechnungsjahr 1904. Beiträge zur Geophysik **5**, 493-522.
- Germann, Dietrich (1981). Die seismische Station an der Universität Jena und die Neugründung einer deutschen Zentralstation für Erdbebenforschung 1923. Akademie der Wissenschaften der DDR, Forschungsbereich Geo- und Kosmoswissenschaften, Veröffentlichungen des Zentralinstitutes für Physik der Erde **64**, 32-38.
- Goodstein, Judith R. (1984). Waves in the earth: Seismology comes to Southern California. Historical Studies Physical Sciences **14**, 201-230, reprinted in: Arbeitskreis Geschichte der Geophysik in der Deutschen Geophysikalischen Gesellschaft, Mitteilungen **8**, Heft 1/1989, 1-40.
- Goodstein, Judith R. & P. Roberts (1988). Filming seismograms and related materials at the California Institute of Technology. In: Lee et al. (1988), 380-389.
- Gutenberg, Beno (1911). Die seismische Bodenunruhe. Inaugural-Dissertation (Ph.D. thesis), Philosophische Fakultät, Georg-August-Universität zu Göttingen, Göttingen 1911, 40 pp. + curriculum vitae, also in: Gerlands Beiträge zur Geophysik **11**, 314-353.
- Gutenberg, Beno (1913). Über die Konstitution des Erdinnern, erschlossen aus Erdbebenbeobachtungen. Physikalische Zeitschrift **14**, 1217-1218.
- Gutenberg, Beno (1914). Ueber Erdbebenwellen. VII A. Beobachtungen an Registrierungen von Fernbeben in Göttingen und Folgerungen über die Konstitution des Erdkörpers. Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen. Mathematisch-physikalische Klasse, 125-177.
- Gutenberg, Beno (1923a). Über den Erdkern in 2900 km Tiefe und die an ihm stattfindenden Reflexionen und Brechungen von Erdbebenwellen. Zeitschrift für angewandte Geophysik **1**, 105-115.
- Gutenberg, Beno (1923b). Absorption und Fortpflanzungsgeschwindigkeit von seismischen Oberflächenwellen. Physikalische Zeitschrift **24**, 458-459.
- Gutenberg, Beno (1924a). Die seismische Bodenunruhe. Verlag Bornträger, Berlin 1924, X + 69 pp.
- Gutenberg, Beno (1924b). Dispersion und Extinktion von seismischen Oberflächenwellen und der Aufbau der obersten Erdschichten. Physikalische Zeitschrift **25**, 377-381, 1924
- Gutenberg, Beno (1925a). Der Aufbau der Erde. Verlag Bornträger, Berlin 1925, VIII + 168 pp. Edition in Russian: Stroenie zemli. Perevod s nemeckogo i s dopolenijami A. N. Zilbermana. Redakcija M. I. Polikarpova. Oformlenie O. N. Persijaninovej. Korrektura E. V. Smirnovoj. Vypuskajuščaja T. S. Malyševa. Ob'edinennoe Naučno-Tekhnicheskoe Izdatel'stvo, Moskva 1934, ONTI – 1935, 169 pp.
- Gutenberg, Beno (1925b). Bearbeitung von Aufzeichnungen einiger Weltbeben. Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft **40**, 57-88.

- Gutenberg, Beno (1926a). Über Gruppengeschwindigkeit bei Erdbebenwellen. *Physikalische Zeitschrift* **27**, 111-114.
- Gutenberg, Beno (1926b). Untersuchungen zur Frage bis zu welcher Tiefe die Erde kristallin ist. *Zeitschrift für Geophysik* **2**, 24-29.
- Gutenberg, Beno editor & author (1926 – 1929). *Lehrbuch der Geophysik*. Verlag Bornträger, Berlin 1926-1929, VI + 1017 pp.
Edition in Russian: *Učebnik geofisiki. Perevod nemeckogo M. I. Polikarpova* (1936?).
- Gutenberg, Beno (1927a). *Grundlagen der Erdbebenkunde*. Verlag Bornträger, Berlin 1927, 189 pp.
Edition in Russian: *Osnovy sejsmologii. Perevod s nemeckogo pod redakciej i s dopolenijami G. A. Gamburceva. Glav. redakciej obščetehničeskich. literatury i nomografii*, Moskva i Leningrad 1935, 149 pp.
- Gutenberg, Beno (1927b). Die Veränderung der Erdkruste durch Fließbewegungen der Kontinentalscholle. *Gerlands Beiträge zur Geophysik* **16**, 239-247.
- Gutenberg, Beno (1927c). Die Veränderung der Erdkruste durch Fließbewegungen II. *Gerlands Beiträge zur Geophysik* **18**, 281-291.
- Gutenberg, Beno (1928). Geh. Reg.-Rat Prof. Dr. E. Wiechert †. *Meteorologische Zeitschrift* **45**, Kleine Mitteilungen, 183-185. This obituary is reproduced in the computer-readable file of Chapter 79.24 Part C on the attached Handbook CD #2.
- Gutenberg, Beno, editor & author (1929 – 1932). *Handbuch der Geophysik. Band 4: Erdbeben*. Verlag Bornträger, Berlin 1929-1932, XII + 1202 pp.
- Gutenberg, Beno, editor & author (1951). *Internal constitution of the Earth*. 2nd Edition, Dover Publications, New York 1951, 439 pp.
- Gutenberg, Beno (1953). Fifteenth award of the William Bowie Medal, Response and Acceptance. *Transactions American Geophysical Union* **34**, 354-355.
- Gutenberg, Beno (1960). Polar wandering, displacements of continents, and subcrustal currents. In: *Festschrift zum 70. Geburtstag von Ernst Kraus. Abhandlungen der deutschen Akademie der Wissenschaften Berlin 1960, Klasse III*, 306-310.
- Güth, Dorothea, Dietrich Germann & Johannes Stelzner (1974). *Zur Geschichte der Forschungseinrichtungen für Seismologie in Jena von 1899 – 1969*. Akademie der Wissenschaften der DDR, Forschungsbereich Kosmische Physik, Zentralinstitut für Physik der Erde, Potsdam 1974, 26 pp.
- Hales, Anthony L. (1979). Keith Edward Bullen (1906 – 1976). *Records of the Australian Academy of Science* **4**, no. 2, Canberra, 1979.
- Hardtwig, Erwin (1962). *Theorien zur mikroseismischen Bodenunruhe*. Geophysikalische Monographien **2**. Akademischer Verlag Geest & Portig, Leipzig 1962, XIV + 302 pp.
- Hecker, Oskar (1924). Zur Gründung der Reichsanstalt für Erdbebenforschung in Jena. *Veröffentlichungen der Reichsanstalt für Erdbebenforschung* **3**, 3-9.
- Herbert-Gustar, A. Leslie & Patrick A. Nott (1980). "John Milne: father of modern seismology". Paul Norbury Publications, Tenderden, Kent, xvi + 199 pp.
- Helbig, Klaus & Edward Szaraniec (1999). Frühe Untersuchungen über seismische Anisotropie. *Deutsche Geophysikalische Gesellschaft e.V., Mitteilungen* **4/1999**, 16-21.
- Herglotz, Gustav (1907). Über das Benndorfsche Problem der Fortpflanzungsgeschwindigkeit der Erdbebenwellen. *Physikalische Zeitschrift* **8**, 145-147.
- Hiller, Wilhelm (1953). 30 Jahre Deutsche Geophysikalische Gesellschaft, 1922 – 1952. *Zeitschrift für Geophysik Sonderband* (**19**), V-VIII.
- Hiller, Wilhelm (1964). In Memoriam Ernst Tams. *Zeitschrift für Geophysik* **30**, 49-50.
- Hurtig, Eckart (1981). Ernst August v. Rebeur-Paschwitz und seine Bedeutung für die Entwicklung der Seismologie. *Akademie der Wissenschaften der DDR, Forschungsbereich Geo- und Kosmoswissenschaften, Veröffentlichungen des Zentralinstitutes für Physik der Erde* **64**, 54-59.
- Hurtig, Eckart & Georg Kowalle (1988). Analysis of historical seismograms from the Potsdam station (GDR) in the period 1902 – 1910. In: Lee et al. (1988), 51-56.
- Jeffreys, Harold (1926). The rigidity of the Earth's central core. *Monthly Notices Royal Astronomical Society, Geophysical Supplements* **1**, 371-383.
- Jeffreys, Harold (1960). Beno Gutenberg. *Quarterly Journal Royal Astronomical Society* **1**, 239-242.
- Kertz, Walter (1979). *Die Entwicklung der Geophysik zur eigenständigen Wissenschaft*. Gauss-Gesellschaft e.V. Göttingen, *Mitteilungen* **16**, 41-54.
- Kertz, Walter (1980). Alfred Wegener – Reformator der Geowissenschaften. *Physikalische Blätter* **36**, 347-353. This paper is reproduced in the computer-readable file of Chapter 79.24 Part C on the attached Handbook CD #2.
- Kertz, Walter (1991). Ludger Mintrop, der die angewandte Geophysik zum Erfolg brachte. *Deutsche Geophysikalische Gesellschaft e.V., Mitteilungen* **3/1991**, 2-16.

- Kertz, Walter (1999). *Geschichte der Geophysik*. Edited by Ruth Kertz & Karl-Heinz Glaßmeier. Georg Olms Verlag, Hildesheim 1999, 376 pp.
- Kertz, Walter (2002). *Biographisches Lexikon zur Geschichte der Geophysik*. Edited by Karl-Heinz Glaßmeier & Ruth Kertz. Braunschweigische Wissenschaftliche Gesellschaft, Braunschweig 2002, 384 pp.
- Knopoff, Leon (1998). Beno Gutenberg 1889 – 1960. *Biographical Memoirs* **76**, National Academy of Sciences. National Academy Press, Washington D.C. 1998, 35 pp.
- Knopoff, Leon (1999). Beno Gutenberg – June 4, 1889 – January 25, 1960. *Deutsche Geophysikalische Gesellschaft e.V., Mitteilungen* **4/1999**, 2-15.
- Knott, Cargill Gilston (1889). The earthquake of Tokio, April 18, 1889. *Nature* **41**, 32.
- Knott, Cargill Gilston (1899). Reflexion and refraction of elastic waves, with seismological applications. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science, Series 5*, **48**, 64-97 + 567-569.
- Knott, Cargill Gilston (1919). The propagation of earthquake waves through the earth and connected problems. *Royal Society Edinburgh, Proceedings* **39**, 157-208.
- Koenig, Manfred (1974). Die Deutsche Geophysikalische Gesellschaft, 1922 – 1974. In: Birett et al. (1974), 3-13.
- Kohlschütter, Ernst (1937). Beitritt Deutschlands zur IGGV. *Zeitschrift für Geophysik* **13**, 202-204.
- Kövesligethy, Radó von (1914). John Milne. *Mitteilungen des Zentralbureaus der Internationalen Seismologischen Assoziation Nr. 3/1914*, 67-70. Published as supplement to Gerlands Beiträge zur Geophysik **13**.
- Kozák, Jan (2001). 100-year anniversary of the first international seismological conference. *Studia geoph. et geod.* **45**, 200-209.
- Kozák, Jan & Axel Plešinger (2003). Beginnings of regular seismic service and research in the Austro-Hungarian Monarchy: Part I. *Studia geoph. et geod.* **47**, 99-119.
- Krumbach, Gerhard (1949). August Sieberg zum Gedächtnis. In: *Seismische Arbeiten 1947/48*, Deutsche Akademie der Wissenschaften zu Berlin, Veröffentlichungen des Zentralinstitutes für Erdbebenforschung in Jena **51**, 6-9.
- Krumbach, Gerhard editor (1950). 50-Jahr-Feier des Zentralinstitutes für Erdbebenforschung, 25. – 29. Juli 1949. Deutsche Akademie der Wissenschaften zu Berlin, Veröffentlichungen des Zentralinstitutes für Erdbebenforschung in Jena **53**, 50 pp.
- Lais, Robert (1913). *Catalogue général des tremblements de terre, ressentis par l'homme et registres par des instruments pendant l'année 1907*. Publications du Bureau Central de l'Association Internationale de Sismologie, Série B, Catalogues, Strasbourg. This book is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Lee, Willie H. K., Herbert Meyers & Kunikiko Shimazaki (eds.). *Historical seismograms and earthquakes of the world*. Academic Press, San Diego 1988, XIV + 513 pp. This out-of-print book is reproduced as computer-readable file on the attached Handbook CD #1 (under the directory of \17Lee).
- Lehmann, Inge (1936). P'. Publications du Bureau Central Séismologique International, Série A, Travaux Scientifiques **14**, 87-115.
- Lehmann, Inge (1987). Seismology in the days of old. EOS, Transactions American Geophysical Union **68**, 33 + 34-35.
- Macelwane S. J., James B. (1951). Evidence on the interior of the earth derived from seismic sources. In: Gutenberg (1951), 227-304.
- Mack, Karl (1927). Geschichte der Hohenheimer Erdbebenwarte von ihren Anfängen bis zum Jahr 1925. *Württembergische Jahrbücher für Statistik und Landeskunde* 1925/26, 87-98.
- Mainka, Carl (1914). Ergebnisse der Erdbebenstation Adventbay auf Spitsbergen in der Zeit vom 27. Oktober 1911 bis 18. Juni 1912. *Gerlands Beiträge zur Geophysik* **13**, Kleine Mitteilungen, 103-113.
- Marvin, Ursula B. (1973). *Continental drift: the evolution of a concept*. Smithsonian Institution Press Washington, 239 pp.
- McCooley, Christopher (1995). John Milne: the first modern seismologist. *Silver Kris*, August 1995, 62-64.
- Meinhold, Rudolf (1981). Von den Anfängen der angewandten Seismik in Deutschland. Akademie der Wissenschaften der DDR, Forschungsbereich Geo- und Kosmoswissenschaften, Veröffentlichungen des Zentralinstitutes für Physik der Erde **64**, 117-129.
- Meisser, Otto (1947). G. Angenheister. *Geofisica Pura e Applicata* **10**, 201-202.
- Meyer, Joachim (1974). Künstliche Bodenerschütterungen mit der Mintrop-Kugel. In: Birett et al. (1974), 67-73.

- Milne (1895). Suggestion for a systematic observation in the northern hemisphere of earth waves and vibrations travelling great distances. Tokyo 31. January 1895.
- Milne, John & Georg H. Darwin (1904). Memorandum on the formation of an International Association for Seismology. In: Rudolf (1904), Annexe A 6, 263-265.
- Mintrop, Ludger (1909). Die Erdbebenwarte der Westfälischen Berggewerkschaftskasse zu Bochum. Glückauf **45**, 357-366 + 393-403.
- Mintrop, Ludger (1910). Über künstliche Erdbeben. Verhandlungen des Internationalen Kongresses für Bergbau und Hüttenwesen, angewandte Mechanik und praktische Geologie. Selbstverlag des Arbeitsausschusses des Kongresses. Düsseldorf 1910, 98-112.
- Mintrop, Ludger (1911). Über die Ausbreitung der von den Massendrücken einer Großgasmaschine erzeugten Bodenschwingungen. Inaugural-Dissertation (Ph.D. thesis), Philosophische Fakultät, Georg-August-Universität zu Göttingen, Verlag W. Girardet Essen, 33 pp.
- Mintrop, Ludger (1912a). Die Erdbebenwarte der Westfälischen Berggewerkschaftskasse in Bochum. Gerlands Beiträge zur Geophysik **11**, Kleine Mitteilungen, 95-102.
- Mintrop, Ludger (1912b). Über seismographische Aufzeichnungen von Bodenerschütterungen durch Verkehrseinrichtungen, Maschinen, Sprengungen und dergleichen künstliche Erdbeben. Verhandlungen der Gesellschaft deutscher Naturforscher und Ärzte, 84. Versammlung zu Münster in Westfalen vom 15. – 21. September 1912, 2. Teil, I. Hälfte, 201-204.
- Mintrop, Ludger (1920). Ermittlung des Aufbaus von Gebirgsschichten aus seismischen Beobachtungen. Zeitschrift der Deutschen Geologischen Gesellschaft **72**, 369-370.
- Mintrop, Ludger (1930). Zur Geschichte des seismischen Verfahrens zur Erforschung von Gebirgsschichten und nutzbaren Lagerstätten. Mitteilungen der Seismos-Gesellschaft **2**, Seismos G.m.b.H, Hannover 1930, 114 pp.
Edition in English: On the history of the seismic method for the investigation of underground formations and mineral deposits. Publications of the Seismos Company **2**, Seismos G.M.B.H., Hannover 1930, 128 pp.
- Mintrop, Ludger (1953). Die Entwicklung der Sprengseismik. Zeitschrift für Geophysik, Sonderband (**19**), 101-122.
- Mothes, Hans (1926). Dickenmessung von Gletschereis mit seismischen Methoden. Geologische Rundschau **27**, 397-400.
- Mothes, Hans (1927). Seismische Dickenmessungen von Gletschereis. Zeitschrift für Geophysik **3**, 121-134.
- Mügge, Ratje & Fritz Möller (1944). Nachruf auf Franz Linke. Meteorologische Zeitschrift **61**, 253-257.
- Nature, editorial office (1889). Notes, According to the Japanese Weekly Mail, an earthquake... Nature **40**, 162-163; see the reproduction in **Appendix 1**.
- Nature, editorial office (1918). Inter-allied conference on international scientific organisations. Nature **102**, 133.
- Neunhöfer, Horst (1985). Primär- und Sekundäreffekte bei der Ausbreitung seismischer Oberflächenwellen und ihre geophysikalische Ursachen. Akademie der Wissenschaften der DDR, Forschungsbereich Geo- und Kosmoswissenschaften, Veröffentlichungen des Zentralinstitutes für Physik der Erde **85**, Potsdam 1985, 111 pp.
- Neunhöfer, Horst, Michael Börngen, Andreas Junge & Johannes Schweitzer, editors (1997). Zur Geschichte der Geophysik in Deutschland – Jubiläumsschrift zur 75jährigen Wiederkehr der Gründung der Deutschen Geophysikalischen Gesellschaft, Hamburg 1997, 235 pp.
- Oddone, Emilio (1907). Les tremblements de terre ressentis pendant l'année 1904. Publications du Bureau Central de l'Association Internationale de Sismologie, Série B, Catalogues, Strasbourg, 12 + 361 pp. This book is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Oldham, Richard Dixon (1906). The constitution of the interior of the Earth, as revealed by earthquakes. Quarterly Journal of the Geological Society of London **62**, 456-473.
- Oldham, Richard Dixon (1919). The interior of the Earth. Geological Magazine **56** (**New series, Decade 6, Volume 6**), 18-27.
- J. C. Poggendorffs biographisch-literarisches Handwörterbuch für Mathematik, Astronomie, Physik, Chemie und verwandte Wissenschaftsgebiete **5**, 1904 bis 1922. Verlag Chemie, Leipzig/Berlin 1926, 1320.
- Pomeranzeff, B. J. (1904). Comtes rendus des séances de la Commission sismique permanente. Tome I., Livraison I, 1904.
- Radon, Johann (1917). Über die Bestimmung von Funktionen durch ihre Integralwerte längs gewisser Mannigfaltigkeiten. Berichte über die Verhandlungen der königlich sächsischen Gesellschaft der Wissenschaften zu Leipzig **39**, 262-277.

- Rebeur-Paschwitz, Ernst von (1883). Über die Bewegung der Kometen im widerstrebenden Mittel mit besonderer Berücksichtigung der sonnennahen Kometen. Phil. Dissertation, Berlin 1883, 47 pp.
- Rebeur-Paschwitz, Ernst von (1889). The earthquake of Tokio, April 18, 1889. *Nature* **40**, 294-295; see the reproduction in **Appendix 1**.
- Rebeur-Paschwitz, Ernst von (1892). Das Horizontalpendel und seine Anwendung zur Beobachtung der absoluten und relativen Richtungs-Änderungen der Lothlinie. *Nova Acta der Ksl. Leop.-Carol. Deutschen Akademie der Naturforscher* **Band LX**, Nr. 1, Halle 1892, 216 pp.
- Rebeur-Paschwitz, Ernst von (1893a). Ueber die Möglichkeit, die Existenz von Mondgliedern in der scheinbaren täglichen Oscillation der Lothlinie nachzuweisen. *Astronomische Nachrichten* **133**, Nr. **3169**, 1-24.
- Rebeur-Paschwitz, Ernst von (1893b). Ueber eine muthmaassliche Fernwirkung des Japanischen Erdbebens von Kumamoto, 1889 Juli 28. *Astronomische Nachrichten* **133**, Nr. **3174**, 98-100.
- Rebeur-Paschwitz, Ernst von (1893c). On the observation of earthquake waves at great distances from the origin, with special relation to the great earthquake of Kumamoto, July 28th, 1889. *Seismological Journal of Japan* **2**, 111-114.
- Rebeur-Paschwitz, Ernst von (1894a). Description of an apparatus for recording by photography the motions of horizontal pendulums. *Seismological Journal of Japan* **3**, 35-54.
- Rebeur-Paschwitz, Ernst von (1894b). On a remarkable earthquake disturbance observed at Strassburg, Nicolaiew, and Birmingham. *Nature* **51**, 208-211.
- Rebeur-Paschwitz, Ernst von (1895a). Horizontalpendel-Beobachtungen auf der Kaiserlichen Universitäts-Sternwarte zu Strassburg 1892 – 1894. *Beiträge zur Geophysik* **2**, 211-536.
- Rebeur-Paschwitz, Ernst von (1895b). Vorschläge zur Errichtung eines internationalen Systems von Erdbeben-Stationen. *Beiträge zur Geophysik* **2**, 773-782.
- Rempp, Georg (1914a). Aufstellung und Betrieb eines Seismographen auf der Deutschen geophysikalischen Station Adventbay (Spitsbergen) 1911/12. *Gerlands Beiträge zur Geophysik* **13**, Kleine Mitteilungen, 91-99.
- Rempp, Georg (1914b). Die mikroseismische Unruhe nach den Registrierungen der Deutschen geophysikalischen Station Adventbay (Spitsbergen) 1911/12. *Gerlands Beiträge zur Geophysik* **13**, Kleine Mitteilungen, 100-102.
- Richter, Charles Francis (1962). Memorial to Beno Gutenberg (1889 – 1960). *Proceedings Volume Geological Society America, Annual Report for 1960*, 92-104.
- Richter, Steffen (1980). Die »Deutsche Physik«. In: Herbert Mertens & Steffen Richter (editors). *Naturwissenschaft, Technik und NS-Ideologie*. Suhrkamp Verlag, Frankfurt 1980, 116-141.
- Ritter, Joachim R. R. (2002). On the recording characteristics of the original Wiechert seismographs at Göttingen (Germany). *Journal of Seismology* **6**, 477-486.
- Ritter, Joachim R. R. & Johannes Schweitzer (2002). Ludwig Carl Geiger – (Geo)Physiker in Göttingen und auf Samoa. *Deutsche Geophysikalische Gesellschaft e.V., Mitteilungen* **2/2002**, 20-29.
- Rohrbach, Walter (1932). Seismische Untersuchungen des Geophysikalischen Institutes in Göttingen. IV. Über die Dispersion seismischer Oberflächenwellen. *Zeitschrift für Geophysik* **8**, 113-129.
- Rosenthal, Elmar (1907). Katalog der im Jahre 1904 registrierten seismischen Störungen. *Publications du Bureau Central de l'Association Internationale de Sismologie, Série B, Catalogues*. Veröffentlichungen des Zentralbureaus der Internationalen Seismologischen Assoziation. Serie B, Kataloge. Strassburg 1907, 12 + 145 pp. This book is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Rothé, Jean-Pierre (1981). Fifty years of history of the International Association of Seismology (1901 – 1951). *Bulletin Seismological Society America* **71**, 905-923.
- Rudolph, Emil (1902). Verhandlungen der vom 11. bis 13. April 1901 zu Strassburg abgehaltenen ersten internationalen seismologischen Konferenz, redigiert vom Sekretär der Konferenz Prof. Dr. E. Rudolph. *Comptes-rendus des séances de la première conférence sismologique internationale réunie à Strasbourg du 11 au 13 avril 1901, rédigés par le Secrétaire de la Conférence Prof. Dr. E. Rudolph*, Beiträge zur Geophysik, Ergänzungsband I, Verlag Wilhelm Engelmann Leipzig 1902, 439 pp.
- Rudolph, Emil (1903a). Die Fernbeben des Jahres 1897. *Beiträge zur Geophysik* **5**, 1-93. This paper is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Rudolph, Emil (1903b). Seismometrische Beobachtungen. *Beiträge zur Geophysik* **5**, 94-169. This paper is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Rudolph, Emil (1904). Verhandlungen der vom 24. – 28. Juli 1903 zu Strassburg abgehaltenen zweiten internationalen seismologischen Konferenz, redigiert vom Sekretär der Konferenz Prof. Dr. Emil

- Rudolph. Comptes-rendus des séances de la deuxième conférence sismologique internationale réunie à Strasbourg du 24 au 28 juillet 1903, rédigés par le Secrétaire de la Conférence Prof. Dr. Emil Rudolph, Beiträge zur Geophysik, Ergänzungsband II, Verlag Wilhelm Engelmann Leipzig 1904, 362 pp.
- Rudolph, Emil, (1905). Katalog der im Jahre 1903 bekannt gewordenen Erdbeben. Beiträge zur Geophysik, Ergänzungsband III, Verlag Wilhelm Engelmann Leipzig 1905, XVII + 674 pp.
- Rudzki, Maurycy Pius (1898a). Ueber die scheinbare Geschwindigkeit der Verbreitung der Erdbeben. I. Studie aus der Theorie der Erdbeben. Beiträge zur Geophysik **3**, 495-518.
- Rudzki, Maurycy Pius (1898b). Von der Gestalt elastischer Wellen in Gesteinen. II. Studie aus der Theorie der Erdbeben. Beiträge zur Geophysik **3**, 519-540.
- Rüter, Horst (1997). Die Geschichte der Geophysik in Bochum. In: Neunhöfer et al. (1997), 98-101.
- Sapper Karl (1915). Emil Rudolph †. Gerlands Beiträge zur Geophysik **14**, without page numbers. This obituary is reproduced in the computer-readable file of Chapter 79.24 Part C on the attached Handbook CD #2.
- Sapper, Karl (1940). Georg Gerland (1833 – 1919) / Professor der Geographie. In: Lebensbilder aus Hessen und Waldeck **2**, 150-162.
- Scheu, Erwin (1911a). Catalogue général des tremblements de terre, ressentis par l'homme et registres par des instruments pendant l'année 1906. Publications du Bureau Central de l'Association Internationale de Sismologie, Série B, Catalogues, Strasbourg. This book is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Scheu, Erwin (1911b). Catalogue régional des tremblements de terre ressentis pendant l'année 1906. Publications du Bureau Central de l'Association Internationale de Sismologie, Série B, Catalogues, Strasbourg, 112 pp. This book is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Scheu, Erwin (1917). Catalogue régional des tremblements de terre ressentis pendant l'année 1908. Publications du Bureau Central de l'Association Internationale de Sismologie, Série B, Catalogues, Strasbourg, 194 pp. This book is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Scheu, Erwin & Robert Lais (1912). Catalogue régional des tremblements de terre ressentis pendant l'année 1907. Publications du Bureau Central de l'Association Internationale de Sismologie, Série B, Catalogues, Strasbourg, 123 pp. This book is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Schick, Rolf & Erhard Wielandt (1994). Zur Geschichte der instrumentellen Erdbebenbeobachtung und Erdbebenforschung in Württemberg und Hohenzollern. Jahreshefte der Gesellschaft für Naturkunde in Württemberg **149**, 75-98.
- Schleusener, Alfred (1956). In Memoriam Prof. Dr. Dr. h. c. Ludger Mintrop. Zeitschrift für Geophysik **22**, 58-64. This obituary is reproduced in the computer-readable file of Chapter 79.24 Part C on the attached Handbook CD #2.
- Schlüter, Wilhelm (1901). Schwingungsart und Weg der Erdbebenwellen. I. Teil: Neigungen. Inaugural-Dissertation (Ph.D. thesis), Philosophische Fakultät, Georg-August-Universität zu Göttingen, Göttingen 1901, 60 pp. + curriculum vitae.
- Schlüter, Wilhelm (1903a). Schwingungsart und Weg der Erdbebenwellen I. Teil. Beiträge zur Geophysik **5**, 314-359.
- Schlüter, Wilhelm (1903b). Schwingungsart und Weg der Erdbebenwellen II. Teil. Beiträge zur Geophysik **5**, 401-466.
- Schmidt, August (1888). Wellenbewegung und Erdbeben. Ein Beitrag zur Dynamik der Erdbeben. Jahreshefte des Vereins für vaterländische Naturkunde in Württemberg **44**, 248-270.
- Schmidt, August (1898). Die Aberration der Lothlinie, Beiträge zur Geophysik **3**, 1-16.
- Schmidt, August (1900). Das Trifilargravimeter. Beiträge zur Geophysik **4**, 109-115.
- Schmidt, Peter (1979). Boris Borisovich Golitsin (1862 – 1916). Schriftenreihe für geologische Wissenschaften **14**, 91-104.
- Schreiber, Hermann (2000). Historische Gegenstände und Instrumente im Institut für Geophysik der Universität Göttingen. Akademie der Wissenschaften zu Göttingen, Kommission für historische Apparate (Herausgeber), 48 pp.
- Schröder, Wilfried (1982). Emil Wiechert und seine Bedeutung für die Entwicklung der Geophysik zur exakten Wissenschaft. Archive of History of Exact Sciences **27**, 369-389.
- Schröder, Wilfried (1988). Uppsala und Göttingen: Streiflichter zum Beginn der internationalen seismologischen Kooperation. Gerlands Beiträge zur Geophysik **97**, 450-459.
- Schulze, Gustav-Adolf (1974). Anfänge der Krustenseismik. In: Birett et al. (1974), 89-98.
- Schweitzer, Johannes (1989). Beno Gutenberg (1889 – 1960). Deutsche Geophysikalische Gesellschaft e.V., Mitteilungen **3/1989**, 7-10.

- Sieberg, August (1904). Handbuch der Erdbebenkunde. Vieweg Verlag, Braunschweig 1904, XVII + 360 pp.
- Sieberg, August (1908). Der Erdball seine Entwicklung und seine Kräfte. Verlag J. F. Schreiber, Eßlingen 1908, XVII + 394 pp.
- Sieberg, August (1912). Über die makroseismische Bestimmung der Erdbebenstärke. Gerlands Beiträge zur Geophysik **11**, Kleine Mitteilungen, 227-239.
- Sieberg, August (1917). Catalogue général des tremblements 1908. Publications du Bureau Central de l'Association Internationale de Sismologie, Série B, Catalogues, Strasbourg. This book is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Sieberg, August (1923). Geologische, physikalische und angewandte Erdbebenkunde. Mit Beiträgen von Beno Gutenberg. Verlag Gustav Fischer, Jena 1923, IV + 572 pp.
- Sieberg, August (1927). Geologische Einführung in die Geophysik. Verlag Gustav Fischer, Jena 1927, X + 374 pp.
- Sieberg, August (1930). Die Erdbeben. In: Gutenberg (1929 – 1932), 529-686.
- Sieberg, August (1932). Erdbebengeographie. In: Gutenberg (1929 – 1932), 688-1005.
- Sieberg, August (1939). Der Anteil Deutschlands und der Reichsanstalt für Erdbebenforschung an der Entwicklung der Erdbebenkunde. Festrede zum 40-jährigen Bestehen der Reichsanstalt für Erdbebenforschung am 22. Juli 1939. (Printed talk)
- Siebert, Manfred (1997). Geschichte des Instituts für Geophysik in Göttingen. In: Neunhöfer et al. (1997), 107-114.
- Stoneley, Robert (1967). History of modern seismology. In: International dictionary of geophysics, edited by Stanley Keith Runcorn et al., Pergamon Press Oxford, Oxford 1967, 724-729.
- Szirtes, Siegmund (1909a). Katalog der im Jahre 1905 registrierten seismischen Störungen I. Teil. Publications du Bureau Central de l'Association Internationale de Sismologie, Série B, Catalogues. Veröffentlichungen des Zentralbureaus der Internationalen Seismologischen Assoziation. Serie B, Kataloge. Strassburg 1909, 4 + 193 pp. This book is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Szirtes, Siegmund (1909b). Katalog der im Jahre 1905 registrierten seismischen Störungen II. Teil. Publications du Bureau Central de l'Association Internationale de Sismologie, Série B, Catalogues. Veröffentlichungen des Zentralbureaus der Internationalen Seismologischen Assoziation. Serie B, Kataloge. Strassburg 1909, 7 + 68 pp. This book is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Szirtes, Siegmund (1910a). Katalog der im Jahre 1906 registrierten seismischen Störungen, I. Teil, Die schwächeren und weniger ausgeprägten Störungen (III B). Publications du Bureau Central de l'Association Internationale de Sismologie, Série B, Catalogues. Veröffentlichungen des Zentralbureaus der Internationalen Seismologischen Assoziation. Serie B, Kataloge. Strassburg 1910, 4 + 110 pp. This book is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Szirtes, Siegmund (1910b). Katalog der im Jahre 1906 registrierten seismischen Störungen, II. Teil, Die grossen und gut ausgeprägten Störungen (III B). Publications du Bureau Central de l'Association Internationale de Sismologie, Série B, Catalogues. Veröffentlichungen des Zentralbureaus der Internationalen Seismologischen Assoziation. Serie B, Kataloge. Strassburg 1910, 8 + 86 pp. This book is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Szirtes, Siegmund (1912a). Katalog der im Jahre 1907 registrierten seismischen Störungen. Publications du Bureau Central de l'Association Internationale de Sismologie, Série B, Catalogues. Veröffentlichungen des Zentralbureaus der Internationalen Seismologischen Assoziation. Serie B, Kataloge. Strassburg 1912, 10 + 120 pp. This book is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Szirtes, Siegmund (1912b). Registrierungen der besser ausgeprägten seismischen Störungen des Jahres 1907, Ergänzung zum seismischen Katalog. Publications du Bureau Central de l'Association Internationale de Sismologie, Série B, Catalogues. Veröffentlichungen des Zentralbureaus der Internationalen Seismologischen Assoziation. Serie B, Kataloge. Strassburg 1912, 5 + 111 pp. This book is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Szirtes, Siegmund (1913a). Katalog der im Jahre 1908 registrierten seismischen Störungen. Publications du Bureau Central de l'Association Internationale de Sismologie, Série B, Catalogues. Veröffentlichungen des Zentralbureaus der Internationalen Seismologischen Assoziation. Serie B, Kataloge. Strassburg 1913, 8 + 133 pp. This book is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).

- Szirtes, Siegmund (1913b). Registrierungen der besser ausgeprägten seismischen Störungen des Jahres 1908, Ergänzung zum seismischen Katalog. Publications du Bureau Central de l'Association Internationale de Sismologie, Série B, Catalogues. Veröffentlichungen des Zentralbureaus der Internationalen Seismologischen Assoziation. Serie B, Kataloge. Strassburg 1913. This book is reproduced as computer-readable file on the attached Handbook CD #3 (under the directory of \88Schweitzer).
- Tams, Ernst (1921). Über die Fortpflanzungsgeschwindigkeit der seismischen Oberflächenwellen längs kontinentaler und ozeanischer Wege. Centralblatt für Mineralogie, Geologie und Paläontologie 1921, 44-52 + 75-83.
- Tams, Ernst (1950). Materialien zur Geschichte der deutschen Erdbebenforschung bis zur Wende des 19. zum 20. Jahrhundert. II. Die geschichtliche Entwicklung der Mikroseismik in Deutschland und den angrenzenden deutschen Sprachgebieten. III. Die Begründung eines systematischen Erdbebendienstes. Deutsche Akademie der Wissenschaften zu Berlin, Mitteilungen des Deutschen Erdbebendienstes, **Sonderheft 2**, Akademie-Verlag, Berlin 1950, 169 pp.
- Tams, Ernst (1952). Materialien zur Geschichte der deutschen Erdbebenforschung bis zur Wende des 19. zum 20. Jahrhundert. Neues Jahrbuch für Geologie und Paläontologie, **Abhandlungen 95**, 99-292.
- Teupser, Christian (1981). Seismologische Forschungen in Jena seit 1923. Akademie der Wissenschaften der DDR, Forschungsbereich Geo- und Kosmoswissenschaften, Veröffentlichungen des Zentralinstitutes für Physik der Erde **64**, 190-197.
- Uller, Karl (1914). Zurückwerfung und Brechung elastischer Wellen. Verhandlungen der Deutschen Physikalischen Gesellschaft **16**, 835-849.
- Uller, Karl (1918). Elastische Oberflächenplanwellen. Annalen der Physik (**IV**) **56**, 464-469.
- Uller, Karl (1928a). Wellen-Induktion. Gerlands Beiträge zur Geophysik **19**, 134-146.
- Uller, Karl (1928b). Die geführten elastischen Zweimittel-Planwellen in ruhenden, festen, isotropen und schwerelosen Mitteln. Gerlands Beiträge zur Geophysik **20**, 410-423.
- Wegener, Alfred (1922). Die Entstehung der Kontinente. Dritte gänzlich umgearbeitete Auflage. Verlag Vieweg, Braunschweig 1922, VIII + 144 pp.
- Wegener, Kurt (1912). Die seismischen Registrierungen am Samoa-Observatorium der Kgl. Gesellschaft der Wissenschaften zu Göttingen in den Jahren 1909 und 1910. Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse, 267-384.
- Wiechert, Emil (1896). Über die Beschaffenheit des Erdinnern. Sitzungsberichte der Physikalisch-ökonomischen Gesellschaft zu Königsberg in Preußen **37**, 4-5.
- Wiechert, Emil (1897a). Über die Massenverteilung im Innern der Erde. Verhandlungen der Gesellschaft deutscher Naturforscher und Ärzte, 68. Versammlung zu Frankfurt am Main 21. – 26. September 1896, 2. Teil, I. Hälfte, 42-43.
- Wiechert, Emil (1897b). Ueber die Massenverteilung im Innern der Erde. Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse, 221-243.
- Wiechert, Emil (1899). Seismometrische Beobachtungen im Göttinger Geophysikalischen Institut. Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse, 195-208.
- Wiechert, Emil (1903a). Theorie der automatischen Seismographen. Abhandlungen der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-Physikalische Klasse, **Neue Folge 2, Nr. 1**, 128 pp.
- Wiechert, Emil (1903b). Ein astatisches Pendel hoher Empfindlichkeit zur mechanischen Registrierung von Erdbeben. Physikalische Zeitschrift **4**, 821-829.
- Wiechert, Emil (1903c). Dr. Wilhelm Schlüter. Beiträge zur Geophysik **5**, 701-703.
- Wiechert, Emil (1904). Ein astatisches Pendel hoher Empfindlichkeit zur mechanischen Registrierung von Erdbeben. Beiträge zur Geophysik **6**, 435-450.
- Wiechert, Emil (1906). Das Institut für Geophysik der Universität Göttingen. In: Festschrift 1906, Die Physikalischen Institute der Universität Göttingen. Verlag Teubner Leipzig 1906, 119-188.
- Wiechert, Emil (1907). Über Erdbebenwellen. Theoretisches über die Ausbreitung der Erdbebenwellen. Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse, 413-529.
- Wiechert, Emil (1908). Die Erdbebenforschung, ihre Hilfsmittel und ihre Resultate für die Geophysik. In: Verhandlungen der Gesellschaft deutscher Naturforscher und Ärzte, 79. Versammlung zu Dresden 15. – 21. September 1907, 1. Teil, 212-232.
- Wiechert, Emil (1912). Vorwort zu (preface to) Zoeppritz † et al. (1912), 121-123.

- Wiechert, Emil & Ludwig Geiger (1910). Bestimmung des Weges der Erdbebenwellen im Erdinnern. *Physikalische Zeitschrift* **11**, 294-311.
- Wielandt, Erhard & Rolf Schick (1997). Hundert Jahre Erdbebenforschung in Stuttgart. In: Neunhöfer et al. (1997), 134-140.
- Wiener, Otto & Julius Bauschinger (1923). Geophysik. Verhandlungen der Gesellschaft deutscher Naturforscher und Ärzte, 87. Versammlung zu Leipzig vom 17. – 24. September 1922, 351.
- Zilch, A., Robert Lais †. *Archiv für Molluskenkunde* **76**, 75-77.
- Zoeppritz, Karl (1907). Über Erdbebenwellen. II. Laufzeitkurven. *Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse*, 529-549.
- Zoeppritz, Karl (†) (1919). Erdbebenwellen VII. VIIb. Über Reflexion und Durchgang seismischer Wellen durch Unstetigkeitsflächen. *Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse*, 66-84.
- Zoeppritz, Karl † & Ludwig Geiger (1909). Über Erdbebenwellen. III. Berechnung von Weg und Geschwindigkeit der Vorläufer. Die Poissonsche Konstante im Erdinnern. *Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse*, 400-428.
- Zoeppritz, Karl †, Ludwig Geiger & Beno Gutenberg (1912). Ueber Erdbebenwellen. V. Konstitution des Erdinnern, erschlossen aus dem Bodenverrückungsverhältnis der einmal reflektierten zu den direkten longitudinalen Erdbebenwellen, und einige andere Beobachtungen über Erdbebenwellen, *Nachrichten von der Königlichen Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-physikalische Klasse*, 121-206.

12 Appendices

Appendix 1. Earthquake on April 17, 1889 in Japan

The Nature note about the Earthquake on April 17, 1889 in Japan (Nature, editorial office, 1889) and the paper of Rebeur-Paschwitz about his observation of this earthquake (Rebeur-Paschwitz, 1889):

ACCORDING to the *Japan Weekly Mail*, an earthquake of a most unusual character was recorded at 2h. 7m. 4ts. p.m., on Thursday, April 18, in the Seismological Observatory of the Imperial University, Tokio. The peculiarity lies, not in its violence, but in the extreme slowness of its oscillations. The beginning of the shock had all the characteristics of the ordinary earthquake, but gradually the motion augmented, until at a certain stage of the shock it reached 17 millimetres, but the ground swayed so gently that the house did not vibrate visibly, nor were the senses alive to it. It took from four to seven seconds to complete one oscillation—a most unusual phenomenon, and one never before noted in the Observatory. The motion was almost entirely confined to the horizontal plane, and mostly south to north, but there were a few vertical motions of equally slow periods. This state of things lasted for 10 minutes 36 seconds. Prof. West, of the Engineering College, observed the water in a small pond to oscillate gently from north to south. At one time the water-level fell about 2 inches on one side of the pond, and exposed the bank, while, a few seconds later, the water immersed it nearly to the same depth, exposing the opposite bank, and this process continued for a quarter of an hour. "Slow oscillations of this nature have been called earth-pulsations, and these usually take place where there is a destructive earthquake or a submarine disturbance going on at a great distance. Earth-pulsations are known to have caused slow oscillations of the water in lakes. From this fact it may not be unreasonable to conjecture that a terrestrial or submarine agitation of unusual

magnitude has taken place somewhere. The authorities of the Science College have sent to the Hydrographical Bureau of the Naval Department, asking for information as to the state of the tide and seas. It may be as well to remark that it is not certain whether the maximum motion of 17 millimetres, as given by the seismograph, is perfectly accurate, as it is very difficult to measure slow oscillation like this with absolute certainty." It is now known as a fact that Vries Island, outside Yokohama Bay, and possibly sixty miles off, was in a state of violent volcanic eruption.

The Earthquake of Tokio, April 18, 1889.

READING the report on this earthquake in NATURE (June 13, p. 162), I was struck by its coincidence in time with a very singular perturbation registered by two delicate horizontal pendulums at the Observatories of Potsdam and Wilhelmshaven. These instruments, which represent, with some modification, Prof. Zollner's horizontal pendulum, were established in March 1889, for studying the slight movements of the ground. The motion of the pendulum, which is left to oscillate freely whenever its equilibrium is disturbed, is registered by the same photographic method as that employed for magnetic observations. The pendulum is in the plane of the meridian, so that any shock, the direction of which is not in this plane, will produce oscillations of the pendulum, diminishing gradually, if it is left undisturbed after the shock. The pillars supporting the instruments are fixed in a depth of 1 metre below the ground of the cellar which was chosen as a suitable place for the erection of the instrument.

During the three months from April to June, the disturbance of April 17, 18h. G.M.T., was the most remarkable which occurred. The following readings of Greenwich mean time, which are best explained by the accompanying figures, are taken from the original photographs; it must, however, be mentioned that the small scale of 11 millimetres per hour does not allow a very accurate determination of time, and that an error of one minute or two is quite probable.

(1) *Potsdam*.—1889, April 17. From 5h. until 17h. 21m., great steadiness of image.

h.	m.	
17	21	First traces of disturbance.
17	39	Beginning of small oscillations.
17	54.3	Motion <i>suddenly</i> increases and reaches its maximum at
18	1	Amplitude of oscillation 154 millimetres. The amplitude then suddenly diminishes.
18	43	} Maxima of oscillation.
18	58	
19	45	
20	0	Perfect steadiness of image.

(2) *Wilhelmshaven*.—Here, also, the image is perfectly steady until 17h. 30m.

h.	m.	
17	30	Beginning of small oscillations.
17	48–17 51	A short interval of perfect steadiness.
17	51	The movement <i>suddenly</i> increased, and as the light is not strong enough to mark the single oscillations, the image disappears until
18	38	when the principal disturbance reaches its end.
18	51	} Maxima of small oscillations.
19	6	
19	22	
20	2	
20	7	Perfect steadiness.

If we compare these dates, it seems most probable that the moment which shows a sudden increase of motion, and is best marked on the curves, may be considered as the beginning of the principal disturbance. We thus have—

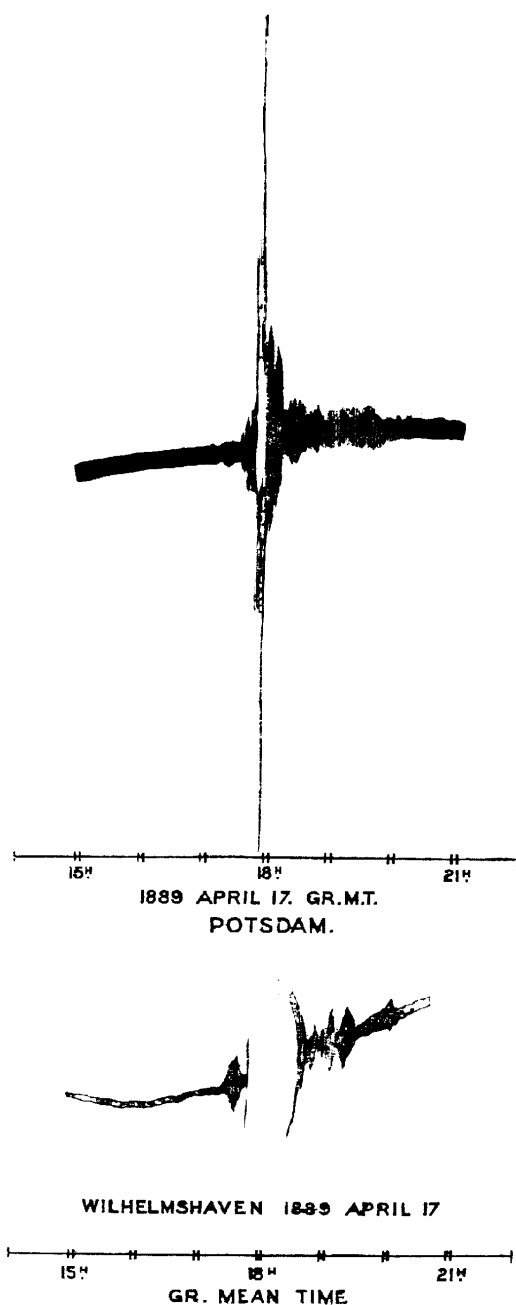
For Potsdam	...	17h. 54.3m.	} Mean, 17h. 52.7m.,
For Wilhelmshaven	...	17h. 51m.	

which, considering the error of the readings, may be taken as one and the same moment.

The beginning of the earthquake of Tokio was observed at 2h. 7.7m. Tokio M.T. The difference of longitude (taken from a map) being 9h. 19.3m. E., we find that the shock occurred at 16h. 48.4m. G.M.T. on April 17, and thus it took 1h. 4.3m. to travel across the body of the earth.

Taking the following longitudes and latitudes—

Tokio	139 50 E.,	35 44 N.
Potsdam	13 4 „	52 24 „
Wilhelmshaven	8 9 „	53 32 „



and neglecting the ellipticity of the earth, we find the following distances:—

Tokio to Potsdam	8221 kilometres.
Tokio to Wilhelmshaven... ..	8307 „

Dividing the mean 8264 by 3858s., we find a velocity of 2142 metres of propagation on the straight line connecting Tokio and a place between Potsdam and Wilhelmshaven, and consequently the shock ought to have been observed at Wilhelmshaven 40s. later than at Potsdam.

The above value of velocity is between the values found by Milne from seismic experiments, viz. 900-1400 metres for different kinds of rock, and by Abbot from the effect of dynamite explosions, viz. 2800 metres. We may therefore safely conclude that the disturbances noticed in Germany were really due to the volcanic action which caused the earthquake of Tokio.

Potsdam, July 5.

E. VON REBEUR-PASCHWITZ.

P. S.—I add a list of the most remarkable disturbances noticed during the course of the observations. Unfortunately, the working of the instrument at Wilhelmshaven was often disturbed by the effects of an excessive dampness in the cellar. The time is G.M.T. as above.

1889, April 5.—A day of great steadiness. A small perturbation begins at 9h. (Potsdam) and 9h. 54m. (Wilhelmshaven). It is divided by a short time of steadiness, 9h. 114m. (Potsdam) and 9h. 168m. (Wilhelmshaven).

April 8.—A fine disturbance begins at 16h. 456m. (Potsdam) and 16h. 474m. (Wilhelmshaven).

April 15.—A day of remarkable unsteadiness; the principal perturbation at both places lasts three hours, and lies between 7h. and 10h. It is impossible to determine a certain phase.

April 25.—A perturbation from 16h. 48m. to 18h. 12m. at Potsdam. No photograph obtained at Wilhelmshaven.

April 28.—An earthquake, consisting of one principal shock, apparently took place at 214h.; the times noted are 21h. 348m. (Potsdam) and 21h. 366m. (Wilhelmshaven).

May 21.—A pretty large disturbance at Potsdam, lasting from 10h. 33m. to 11h. 6m., interrupted by a moment of rest at 10h. 42m. No photograph at Wilhelmshaven.

May 25.—Two very remarkable disturbances at Potsdam—7h. 9m. and 10h. 42m.—each lasting 1h. No photograph at Wilhelmshaven.

May 26.—A disturbance noticed at Potsdam, at 9h. 24m. No photograph at Wilhelmshaven.

May 30.—At Wilhelmshaven, two shocks are noticed—8h. 186m. and 9h. 24m.—which are probably connected with the English earthquake of this day. Perfect steadiness at Potsdam.

May 31.—A disturbance of earthquake-like appearance. Time of beginning, at Potsdam, 8h. 48m.; at Wilhelmshaven, 8h. 444m.; the latter time being rather uncertain, on account of the faintness of the curve.

I hope that one or other of these facts may prove to be of interest to seismologists.

On the Phenomena of the Lightning Discharge, as Illustrated by the Striking of a House in Cossipore, Calcutta.

DURING a heavy thunderstorm which passed over Calcutta about 5.30 p.m. on Saturday, June 8 last, the house of Conductor W. Viney, at Cossipore (a suburb of the city), was struck by lightning, and I have thought that a description of the phenomena connected with it might perhaps be worth placing on record in the columns of NATURE.

I was myself watching the storm from the veranda of my residence about 300 yards distant, and observed that the discharge in question was one of extreme violence. I visited the scene of the accident within a few hours, with Mr. Viney's permission taking the notes from which this account is prepared; and, owing to the exceptional opportunities for observation which obtained in this case, have been able to secure trustworthy statements as to the appearance of the discharge, and further, by inquiry, to satisfy myself upon one or two points which I believe to possess considerable scientific interest.

The house which was struck is large, square, and flat-roofed, and is occupied by three foremen employed in the Government Shell Factory adjacent: it is provided with a lightning-conductor projecting 8 or 9 feet above the roof-level, and situated near to one end of the building, but apparently unconnected with any other portion of the roof. It is possible that a portion of the discharge passed harmlessly away by the conductor, but of this I have no evidence, positive or negative. The lightning entered Mr. Viney's portion of the house by a corrugated iron covered hatchway standing 6 feet high at the corner diagonally opposite

Appendix 2. Invitation to the Second International Conference on Seismology in Strasbourg 1903



II^me Conférence Sismologique Internationale.

Strasbourg (Alsace), 24—28 juillet 1903.

Sous le protectorat
de Son Altesse le Statthalter Impérial d'Alsace-Lorraine,
prince de Hohenlohe-Langenburg.

—♦—

Les préparatifs de la II^me Conférence Sismologique Internationale, qui s'ouvrira à Strasbourg le 24 juillet prochain, étant achevés, nous avons l'honneur de vous donner aujourd'hui les renseignements complémentaires sur l'organisation de la Conférence et sur les fêtes projetées.

I Observations générales.

Toutes les séances se tiendront dans les salles du palais du **Landesausschuss** (Place Impériale), que le bureau du Landesausschuss met à notre disposition pour les travaux de la Conférence. Les séances générales se tiendront dans la grande salle des séances plénières du rez-de-chaussée, les séances des commissions dans les salles du premier étage.

C'est également dans le palais du Landesausschuss (rez-de-chaussée, à gauche) que se trouve le **Bureau de la Conférence**.

Il sera ouvert, dès le 23 juillet, chaque jour de 9 heures du matin à 2 heures de l'après-midi. Jeudi, le 23 juillet, un bureau auxiliaire sera ouvert aux membres de la Conférence au *Casino Civil* (Sturmeckstaden, 1), à partir de 8 heures du soir.

On distribuera au Bureau de la Conférence :

- 1) les cartes de membres;
- 2) les cartes d'accès à la tribune réservée à la presse;
- 3) les cartes d'invitation au dîner offert par le gouvernement d'Alsace-Lorraine;
- 4) les cartes d'invitation pour la réception à l'Hôtel-de-ville;
- 5) les listes d'inscription pour l'excursion du Hoh-Königsbourg.

L'Hôtel des Postes et Télégraphes se trouve à côté du palais du Landesausschuss. On est prié d'adresser tous **les envois postaux**, destinés aux membres de la Conférence, du 23 au 28 juillet à l'adresse suivante :

II^{me} Conférence Sismologique Internationale.

Strassburg i. Elsass.

Landesausschussgebäude.

Une **Salle de correspondance** sera mise à la disposition des membres de la Conférence au rez-de-chaussée du palais du Landesausschuss.

Les communications importantes et les modifications du programme seront notifiées verbalement ou par voie d'affiches.

La participation à la Conférence ainsi qu'aux fêtes et réunions — les soirées du jeudi et du lundi exceptées — sera gratuite pour les membres de la Conférence.

La carte de membre servira de légitimation.

Nous prions *instamment* tous ceux qui ont l'intention de se rendre à notre invitation de bien vouloir **s'annoncer dans le plus bref délai** pour faciliter la tâche de la commission.

Afin que la liste des membres de la Conférence puisse être imprimée et distribuée le plus rapidement possible, les participants sont priés de se rendre au bureau de la Conférence dès leur arrivée à Strasbourg, d'y déposer deux cartes de visite avec indication de leur domicile à Strasbourg, et de faire détacher de la carte de membre le coupon affecté à la liste de présence.

Le **Verkehrsbureau** (Bahnhofplatz, 8) se met gratuitement à la disposition des membres de la Conférence pour tous **les renseignements relatifs aux logements**. On est prié d'y adresser par écrit toutes les demandes à ce sujet.

Les questions relatives à la Conférence même, devront être adressées à M. le professeur Dr. **Rudolph**, Kollegiengebäude der Universität.

II Programme de la Conférence.

Jeudi 23 juillet

8 h. soir : Réunion dans les salles du rez-de-chaussée du Zivilkasino (Sturmeckstaden, 1).

Vendredi 24 juillet

10 h. matin : **Première séance générale.** Ouverture officielle de la Conférence. Discours des autorités et des délégués.

Election du bureau, discussion de l'ordre du jour, désignation des commissions.

Discussion générale du projet de constitution de l'Association internationale, du projet de statuts et de la convention. (Programme I, 1b, 2 et 3.)

midi — 1 h. : Pause.

après-midi : Séance de la commission I pour les questions constitutives.

7¹/₂ h. *soir*: Dîner offert par Son Altesse le prince de Hohenlohe-Langenburg au nom du gouvernement d'Alsace-Lorraine.

(Les membres de la Conférence sont priés de vouloir bien paraître en **habit de cérémonie** à la séance d'ouverture et au dîner offert par le gouvernement.)

Samedi 25 juillet

9 h. — 11 h. *matin*: **Deuxième séance générale.**

Etendue et réglementation des observations de l'Association: Mouvements microsismiques et macrosismiques, pulsations terrestres, variations de niveau, tremblements de terre sous-marins, application pratique des méthodes d'observation sismologique. (Programme II, 1 a—d; 2 a—f.)

11 h. — 1 h.: Séance de la commission II pour les questions scientifiques.

1 h. — 2 h.: Pause.

après-midi: Séance de la commission III pour la réglementation internationale des observations. Suite des délibérations de la commission I.

8 h. *soir*: Réception des membres de la Conférence par le maire et le conseil municipal de la ville de Strasbourg à l'Hôtel de ville (rue Brûlée).

Dimanche 26 juillet

Excursion au Hoh-Kœnigsbourg. Seules les cartes délivrées par le bureau de la Conférence confèrent le droit de participation. Des instructions plus détaillées au sujet de l'excursion seront communiquées ultérieurement.

Lundi 27 juillet

9 h. — 12 h. *matin*: Séance des commissions II et III.

midi — 1 h.: Pause.

1 h.: **Troisième séance générale.** Rapport de la commission I et passage au vote.

7¹/₂ h. *soir*: Dîner dans la grande salle du Baeckehiesel (Allée de la Robertsau), auquel prendront part également les membres de la Société de Géographie. Prix du couvert (sans vin) 4 Marks. Inscriptions au bureau de la Conférence.

9 h. *soir*: Fête champêtre à l'Orangerie, organisée par l'Administration municipale.

Mardi 28 juillet

9 h. *matin*: **Séance de clôture.** Rapports des commissions II et III. Passage au vote.

Le Comité d'Organisation.

13 Figures

Figure 1: Rebeur-Paschwitz's horizontal pendulum, from Rebeur-Paschwitz (1892).

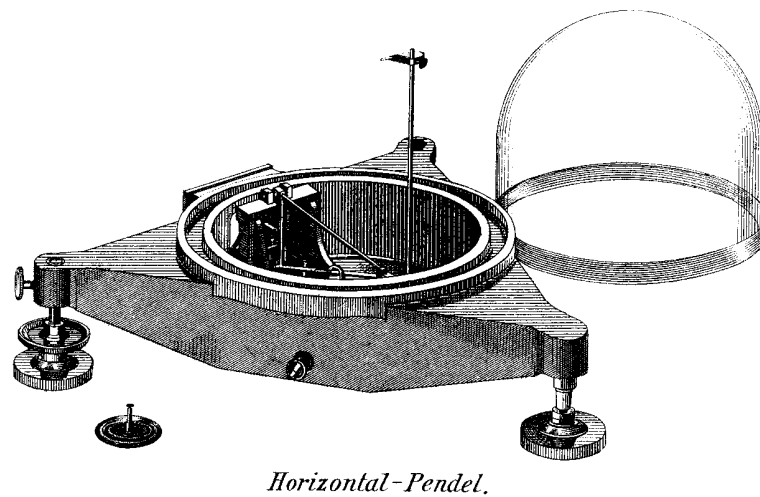


Figure 2: Ernst von Rebeur-Paschwitz (1861 – 1895), courtesy of Universitätsarchiv Tübingen (UAT 209/108, Bl 10).



Figure 3: Recording of the horizontal pendulum in Potsdam with the signals of the first teleseismically observed earthquake of April 17, 1889, from Rebeur-Paschwitz (1889).

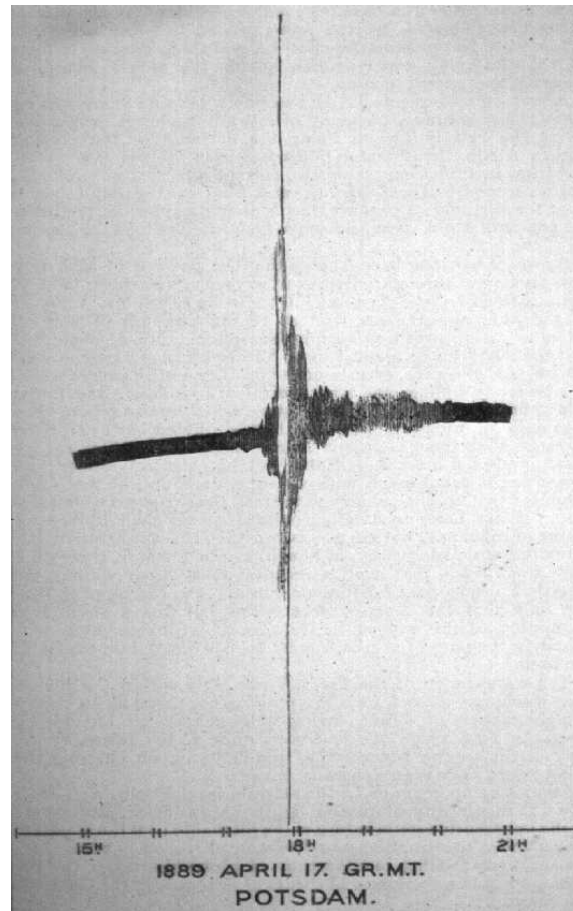


Figure 4: Recording of the horizontal pendulum in Wilhelmshaven with the signals of the first teleseismically observed earthquake of April 17, 1889, from Rebeur-Paschwitz (1889).

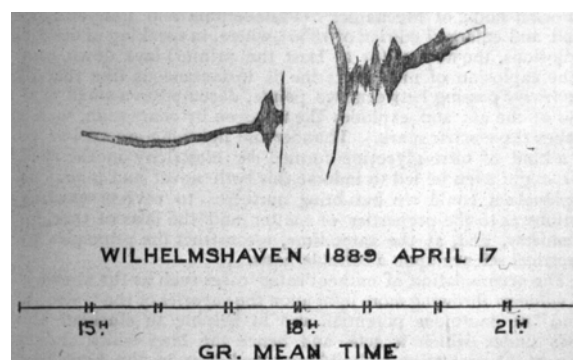


Figure 5: Georg Gerland (1833 – 1919), from *Beiträge zur Geophysik*, Volume 6 (1903).



Figure 7: August Schmidt (1840 – 1929), from Schick & Wielandt (1994).



Figure 6: Reinhold Ehlert (1871 – 1899), courtesy of Universitätsarchiv Tübingen (UAT 209/108, BI 7').



Figure 8: One of the Rebeur-Ehlert horizontal pendulums in Strasbourg (photo by the author). Clearly seen are the masses of the three horizontal pendulums.

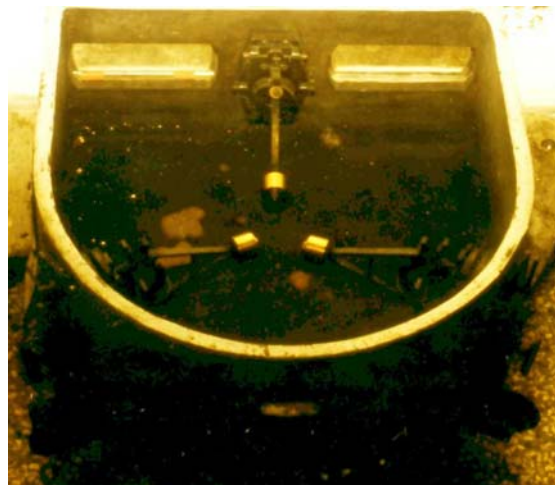


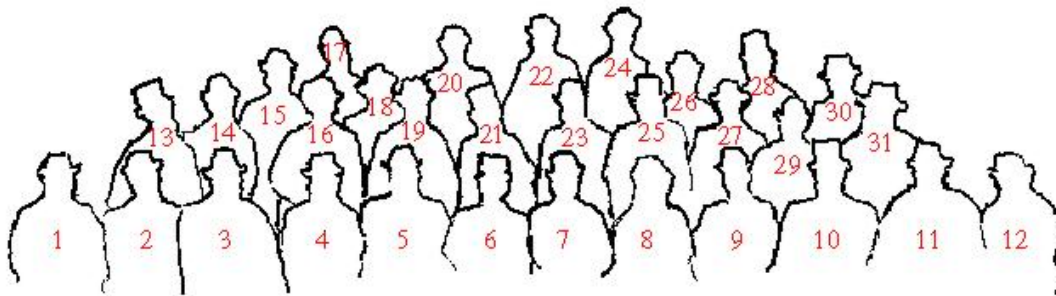
Figure 9: The house built for the seismic station of the ‘Kaiserliche Hauptstation für Erdbebenforschung’ in Strasbourg (photo by the author).



Figure 10: Group photo of Georg Gerland with colleagues and students at the University of Strasbourg about 1895-1898, courtesy of Universitätsarchiv Tübingen (UAT 209/109). On the backside of the picture the people are identified (some names are difficult to read): front row (from left to right): Rubel, Hergesell, Weigand, Gerland, Steuer, and Selcher(?) and back row (again from left to right): Bock, Goetz, Böller, Ehlert, Lengenbeck(?), Sturia(?); the last two persons are unknown.



Figure 11: Group photo of the participants of the First International Conference on Seismology in Strasbourg 1901, courtesy of GeoForschungsZentrum (GFZ) Potsdam. The persons were identified on the original picture. I follow the original German figure caption and added some additional information in parentheses (for numbers see the sketch): 1 Prof. Omori Tokyo, 2 Prof. Wiechert Göttingen, 3 Dr. Schütt Hamburg (Richard Schütt, 1864 – 1943), 4 Prof. Schmidt Stuttgart, 5 Dr. Hecker Potsdam, 6 Prof. Rudolph Strassburg, 7 Prof. Gerland Strassburg, 8 Prof. Weigand Strassburg (Bruno Weigand), 9 Prof. Oddone Pavia, 10 General Pomerantzeff St. Petersburg (H. Pomerantzeff), 11 Staatsrat Lewitzky Jurjew-(Dopart), 12 Prof. Günther München (Siegmond Günther, 1848 – 1923; see Kertz, 2002), 13 Geh.-Rat Wagner Göttingen (Hermann Wagner, 1840 – 1929), 14 Geh.-Rat Helmert Potsdam, 15 Prof. Straubel Jena (Rudolf Constantin Straubel, 1864 – 1943), 16 Assist. Ebell Strassburg ([Carl Wilhelm Ludwig] Martin Ebell, 1871 – 19??), 17 Oberstleutnant Harboe Kopenhagen (Edouard Georg Harboe, 1845 – 1919), 18 Dr. Tetens Strassburg (Otto Peter Harens Tetens, 1865 – 1945), 19 Prof. Láska Lemberg (Václav [also Waclaw] Láska, 1862 – 1943), 20 Prof. Futterer Karlsruhe (Franz Joseph Xaver Futterer, 1866 – 1906), 22 Prof. v. Kövesligethy Budapest, 22 Dr. Polis Aachen (Peter Hermann Johann Polis, 1869 – 1929), 23 Dr. Schafarzik Budapest (Ferencz [also Franz] Xav. Schafarzik, 1854 – 1924), 24 Prof. Leutz Karlsruhe (Heinrich Leutz), 25 Bauinspektor Jähnik Strassburg (A. Jähnik), 26 Prof. Kobold Strassburg (Hermann Kobold, 1858 – 1942), 27 Dir. Wosnessensky Irkutsk (A. W. Wosnessensky, also V. A. Voznesenskij), 28 Geh.-Rat Lewald Berlin (Theodor Lewald, 1860 – 1947), 29 Dr. Ehrismann Strassburg (Henri Ehrismann), 30 Prof. Forel Morges, 31 Prof. Belar Laibach (Albin Belar, 1864 – 1939).



Internationale seismologische Konferenz Strassburg 11.–13. April 1901.

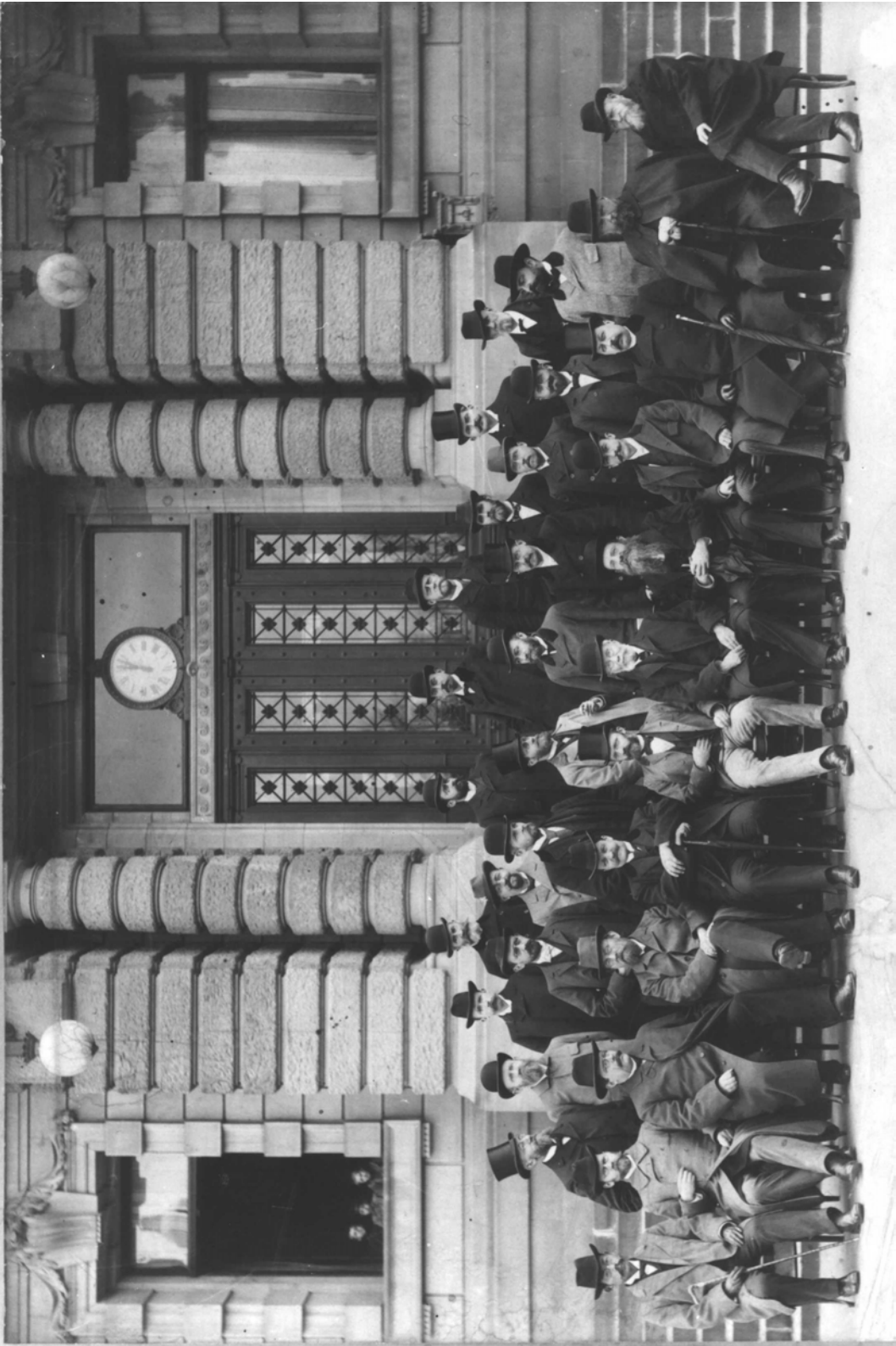


Figure 12: Emil Rudolph (1854 – 1915), from Sapper (1915).

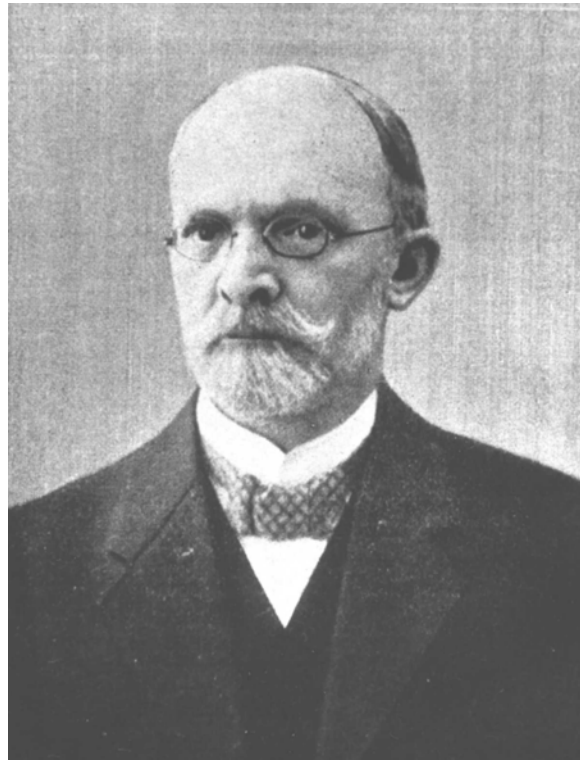


Figure 13: Group photo of the participants of the First General Assembly of the International Seismological Association in The Hague 1907, courtesy of GeoForschungsZentrum (GFZ), Potsdam. The persons were identified on the original picture. I follow the original French figure caption (for numbers see the sketch): 1 Tams, 2 Rudolph, 3 Spas-Watsof, 4 Schütt, 5 Mainka, 6 Prince Galitzin, 7 Mad^{lle} Gerland, 8 Lewitzky, 9 von dem Borne, 10 Michailovitsch, 11 Aguilera, 12 Kaisin, 13 Mad^e Comas Sola, 14 Gerland, 15 Messerschmitt, 16 Wiechert, 17 Stein, 18 Oddone, 19 Zeissig, 20 de Kövesligethy, 21 Mad^e de Azcarate, 22 Lagrange, 23 Schmidt, 24 Palazzo, 25 Hausmann, 26 Darboux, 27 Mad^e de Kövesligethy, 28 Omori, 29 de Azcarate, 30 Klotz, 31 van der Stok, 32 Navarro-Neumann, 33 Mad^e Rudolph, 34 Forel, 35 Nakamura, 36 Mier y Muira, 37 Comas Sola, 38 Mad^e Rosenthal, 39 Cremer, 40 Berloty, 41 van Everdingen, 42 Rosenthal, 43 Mad^{lle} Lewitzky, 44 Agamennone, 45 Rethly, 46 Romeyn, 47 Egenitis, 48 Reid, 49 Bⁿ van Voorst tot Voorst, 50 Lecointe, 51 van Rijckevorsel, 52 Levoir, 53 Hartman, 54 Bigourdan. Schuster, Haid, and Hecker were named as missing on the photograph.

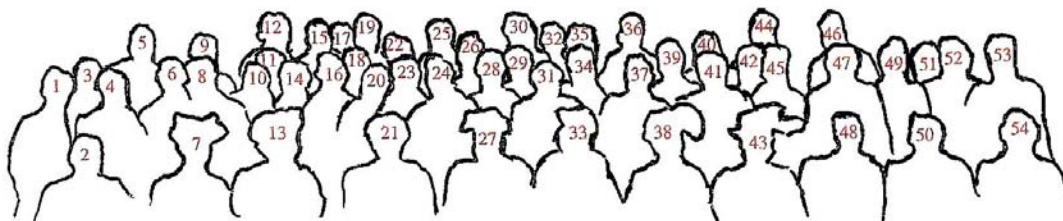




Figure 14: Oskar Hecker (1864 – 1938), from *Zeitschrift für Geophysik*, Volume 10 (1934).



O. Hecker.

Figure 15: August Sieberg (1875 – 1945), from Krumbach (1950).



Figure 16: Emil Wiechert (1861 – 1928), courtesy of Institut für Geophysik, Universität Göttingen.

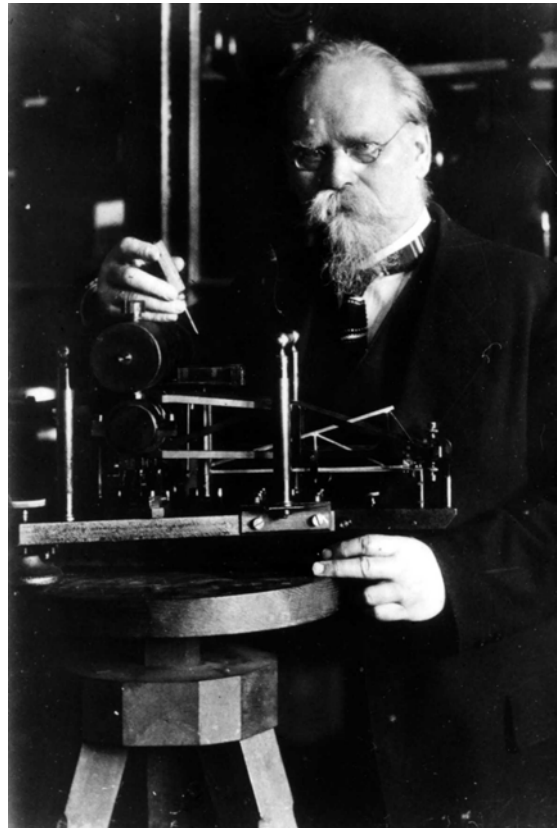


Figure 17: The building of the worldwide first Institute of Geophysics in Göttingen, courtesy of Institut für Geophysik, Universität Göttingen.



Figure 18: Entrance to the ‘Erdbebenhaus’ of the Institute of Geophysics, University Göttingen (photo by the author).



Figure 19: Wilhem Schlüter (1875 – 1902), courtesy of Institut für Geophysik, Universität Göttingen.



Figure 20: Ideas about the structure of the Earth and about the ray path of seismic waves at the beginning of the 20th century (Sieberg, 1908).

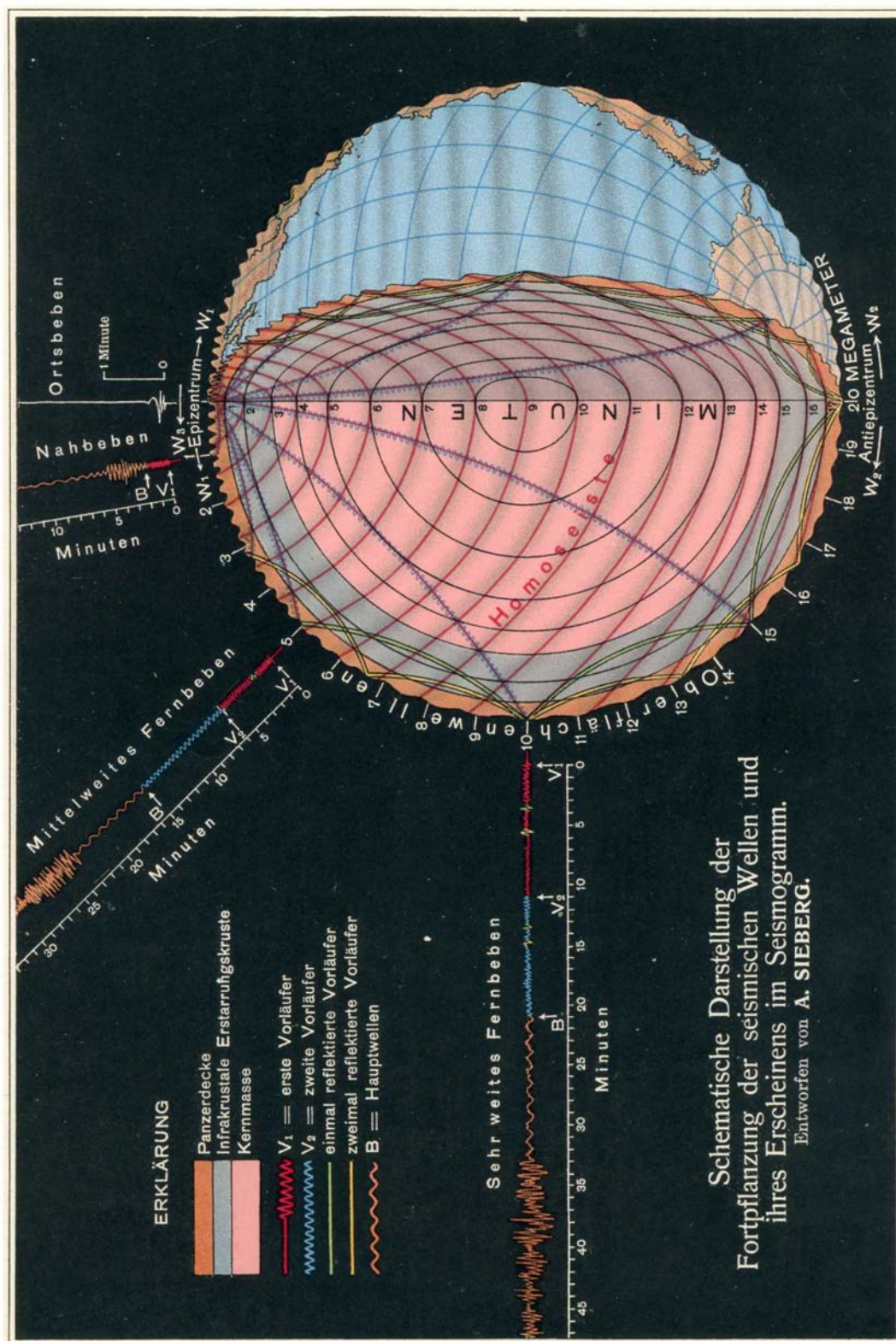


Figure 21: Karl Zieppritz (1881 – 1908), courtesy of his great-nephew Sebastian Zieppritz.



Figure 23: Ludwig Geiger (1882 – 1966), the photo must have been taken in 1932, courtesy of his son Urs Peter Geiger.



Figure 22: Gustav Herglotz (1881 – 1953), courtesy of Akademie der Wissenschaften zu Göttingen.

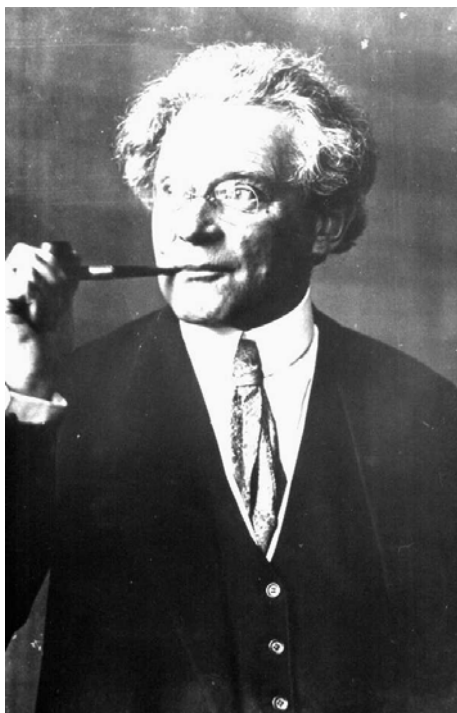


Figure 24: Franz Linke (1878 – 1944), courtesy of Institut für Meteorologie und Geophysik, Universität Frankfurt am Main.



Figure 25: The main building of the Samoa-Observatory founded and managed by the 'Göttinger Gesellschaft der Wissenschaften', the scientific society of Göttingen, courtesy of Institut für Geophysik, Universität Göttingen.



Figure 26: Gustav Heinrich Angenheister (1878 – 1945), courtesy of Institut für Geophysik, Universität Göttingen.

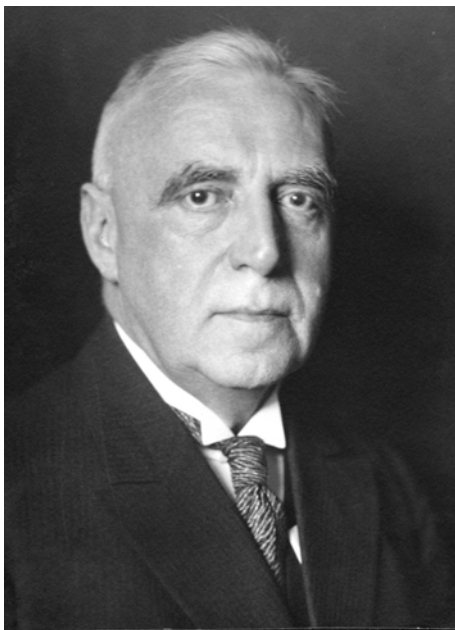


Figure 27: Beno Gutenberg (1889 – 1960), courtesy of his son Arthur W. Gutenberg.



Figure 28: A picture taken in the 1920s of the Taunus-Observatory on top of the Kleine Feldberg, courtesy of Institut für Meteorologie und Geophysik, Universität Frankfurt am Main.

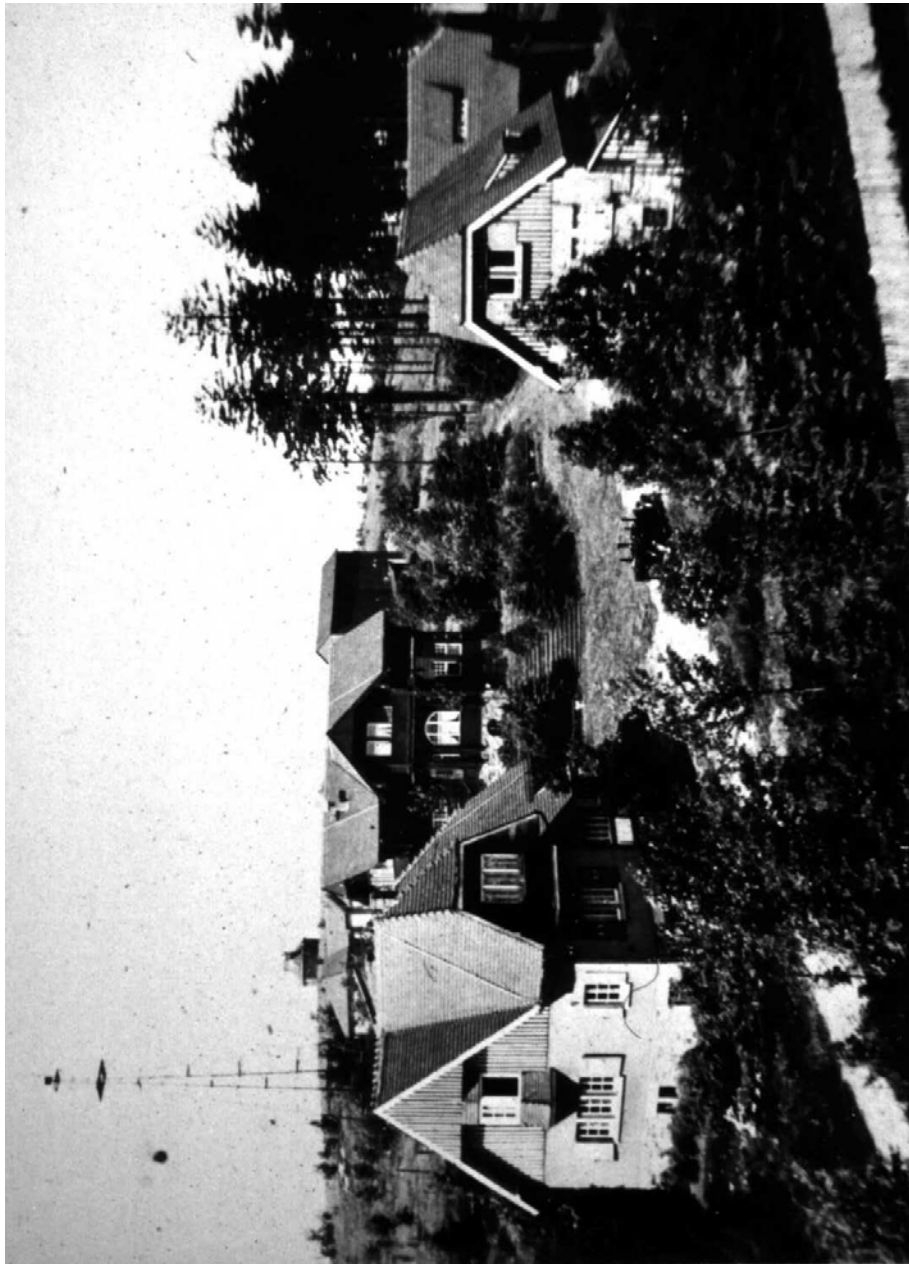


Figure 29: The travel-time chart for teleseismic phases as published by Gutenberg in 1914.

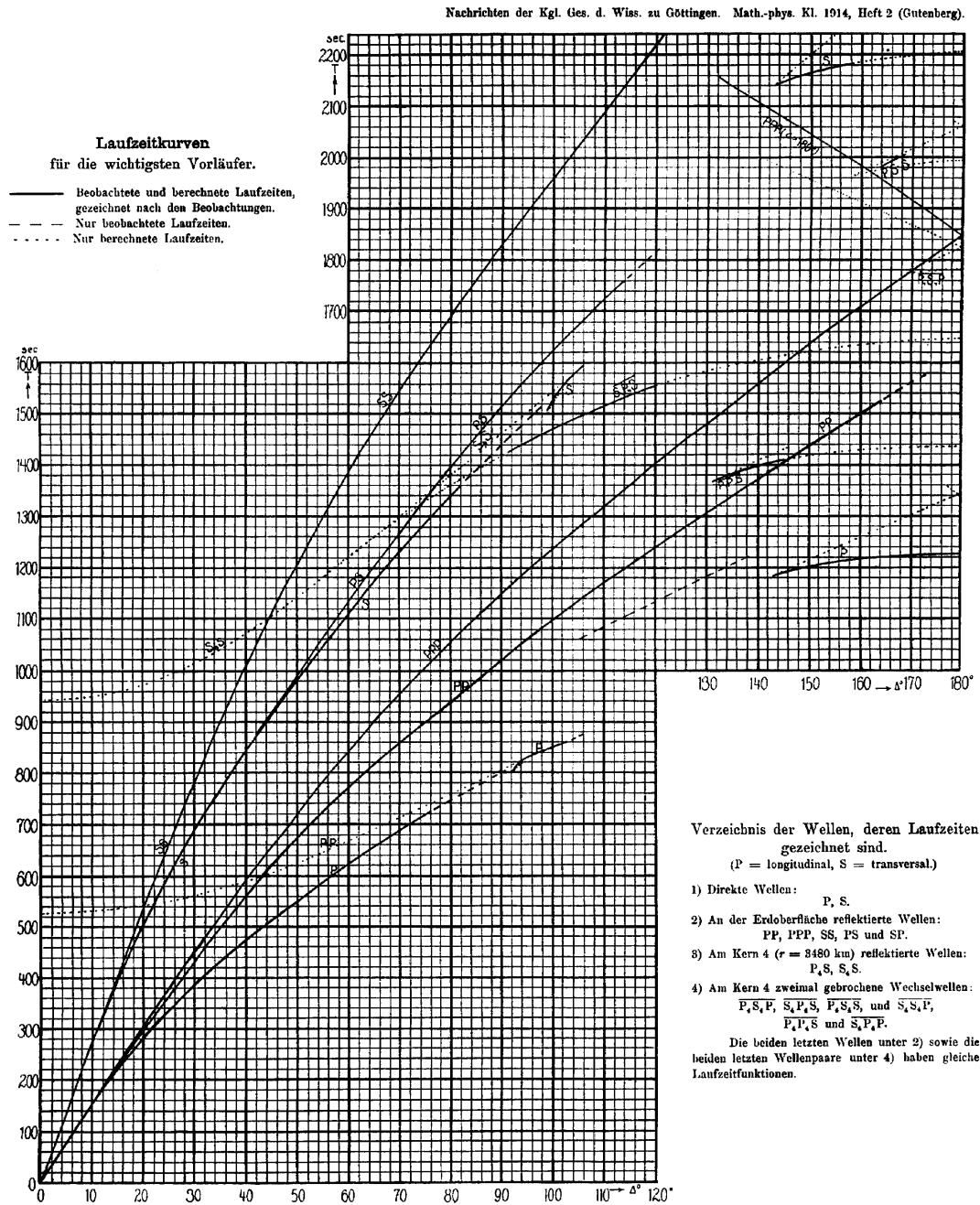


Figure 30: Ernst Tams (1882 – 1963), from Hiller, (1964).

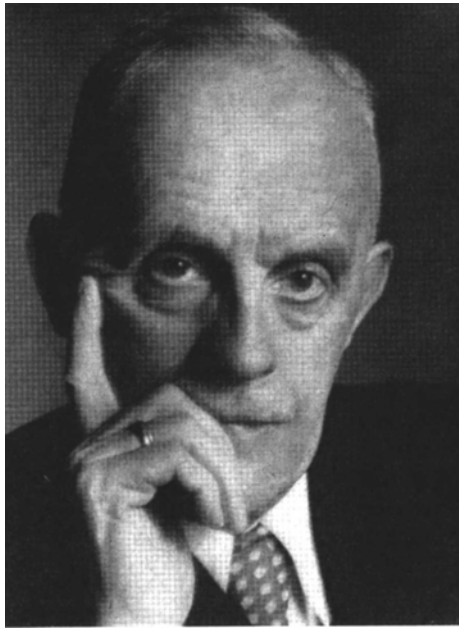


Figure 32: Ludger Mintrop (1880 – 1956), from Schleusener (1956).



L. Mintrop

Figure 31: Alfred Wegener (1880 – 1930), photo by J. Georgi (here from Kertz, 1980).



Figure 33: The ‘Mintrop-Kugel’, a 4000-kg heavy steel ball, used by Ludger Mintrop in 1909 for early experiments with artificial sources in Göttingen (photo by the author).



14 Index

A

Abbadie	5
Abel	16, 23
Abt	16, 23
Agamennone	5, 15, 46
Aguilera	46
Åkerblom	16, 23
Angenheister	12, 14, 17, 19, 20, 23, 52
Arnold	14, 23
Azcarate	46

B

Bateman	16, 23, 24
Bauer	8
Becker	5
Belar	5, 8, 24, 44
Benndorf	15, 16, 20, 24
Berloty	46
Bigourdan	46
Bock	43
Boergen	3, 7
Böller	43
Borne	14, 21, 24, 46
Bosch	6, 14
Brockamp	21, 24
Bullen	15, 19, 24

C

Cancani	5, 11, 24
Chaves	8
Christensen	10, 11, 24
Comas-Sola	46
Copeland	5
Credner	7
Cremer	46
Cruls	7

D

Darboux	46
Darwin, G.	5, 7, 29
Darwin, H.	7
Davison	2, 5, 8, 25

E

Ebell	44
Eginitis	8, 46
Ehlert	2, 6, 22, 25, 42, 43
Ehrismann	44
Eschenhagen	2, 3, 5, 25

Everdingen	46
------------	----

F

Figee	8
Forel	5, 8, 9, 11, 44, 46
Futterer	44

G

Galitzin (Golicyn)	6, 11, 25, 46
Gauß	13
Geiger	14 - 17, 22, 25, 26, 34, 51
Gerland	2, 4 - 10, 19, 26, 42 - 44, 46
Goetz	43
Günther	7, 44
Gutenberg	11, 12, 14, 15, 17 - 20, 22, 25 - 27, 32, 34, 52, 54
Guzzanti	8

H

Haid	46
Harboe	44
Hartman	46
Hausmann,	46
Hecker	10 - 12, 22, 25, 27, 44, 46, 48
Helmert	5, 7, 9, 44
Hepites	8
Hergesell	43
Herglotz	16, 18, 27, 51
Hlasek	8
Hoernes	8
Hogben	8
Hughes	15

J

Jähnik	44
Jeffreys	15, 18, 19, 27

K

Kaisin	46
Kilian	5, 8
Klein	5
Klotz	46
Knott	3, 15, 16, 28
Kobold	44
Kolderup	8
Kortazzi	3, 5, 8
Kövesligethy	4, 9, 28, 44, 46

L

Lagrange	7, 46
----------	-------

Lais	10, 11, 28, 31
Lapparent	8
Láska	8, 44
Lecointe	46
Lehmann	19, 28
Lengenbeck	43
Leutz	44
Levoir	46
Lewald	44
Lewitzky (Levitski)	5, 8, 9, 44, 46
Leyst	8
Liénard	12
Linke	17, 18, 51
Love	14, 20

M

Mack	6, 7, 28
Mainka	6, 11, 28, 46
Mazelle	8
Meinardus	21
Mercalli	11
Messerschmitt	46
Michailovitsch	46
Mier y Muira	46
Milne	3 - 5, 10, 15, 29
Mintrop	20, 21, 29, 55
Mojsisovics	8, 9
Moos	8
Mothes	21, 29
Mušketov	8

N

Nakamura	46
Navarro-Neumann	46
Neumayer	5, 7

O

Oddone	10, 29, 44, 46
Oldham	14, 17, 18, 29
Omori	5, 6, 8, 14, 44, 46

P

Palazzo	8 - 10, 46
Penck	5
Polis	44
Pomeranzeff (Pomerantzeff), B. J.	14, 29
Pomeranzeff (Pomerantzeff), H.	8, 44

R

Radon	21, 22, 29
Rayleigh	4, 14, 20
Rebeur-Paschwitz	2 - 6, 14, 19, 22, 30, 35, 40, 41

Reid	46
Rempp	11, 30
Rethly	46
Reusch	8
Riccò	5, 8
Richthofen	7
Riggenbach-Burckhardt	8
Rijckevorsel	46
Rohrbach	20
Romeyn	46
Rosenthal	10, 30, 46
Rubel	43
Rudolph	9, 10, 30, 31, 44, 46
Rudzki	13, 15, 31

S

Schafarzik	8, 44
Schering	12
Scheu	10, 11, 31
Schlüter	13, 14, 16, 22, 31, 49
Schmidt	6, 7, 13 - 15, 31, 42, 44, 46
Schuster	46
Schütt	7, 44, 46
Selcher	43
Sieberg	9 - 12, 15, 22, 32, 48, 50
Spas-Watsof	46
Stein	46
Sterneck	5, 8
Steuer	43
Stok	8, 46
Straubel	7, 44
Sturia	43
Supan	5, 7
Svedmark	8
Szirtes	10, 32, 33

T

Tacchini	5
Tams	2, 19, 20, 33, 46, 55
Tetens	44
Thoroddsen	7
Turner	15

U

Uller	20, 33
-------	--------

V

Valentiner	7
Vincentini	8
Viniegra	5
Vogel	3
Voigt	12, 16
Voorst tot Voorst	46

W

Wagner	44
Weber	13
Wegener, A.	17, 20, 21, 33, 55
Wegener, K.	17, 18, 33
Weigand	43, 44
Wiechert	6, 12 - 19, 21, 33, 34, 44, 46, 48
Wosnessensky	8
Wosnessensky, Voznesenskij	44

Y

Yamasaki	8
----------	---

Z

Zeissig	46
Ziemendorff	10, 11, 24
Zoeppritz	14 - 18, 22, 34, 51