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Edgar H Booth: was he the first Australian exploration seismologist?

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The first exploration seismic survey planned by an Australian commenced in 1929, when E H Booth agreed to act as a consultant to the Imperial Geophysical Experimental Survey (IGES), and to establish its seismic section (Broughton Edge and Laby, 1931)[1].

In this paper, I expand on Booth's previously un-acknowledged geophysical interests and activities, and propose that, as a result, he was the first Australian exploration seismologist.

Existing published information on E H Booth (1893–1963)

The earliest published information on the life of Edgar Harold Booth that I have found is a standard, short, much abbreviated entry in *Who's who in Australia, 1950* (Alexander, 1950). Booth was born in Sydney, and studied engineering from 1911–13 at the University of Sydney, where he was awarded a BSc in 1914, and a DSc in 1935. He died at his home in Sydney. More information is provided in various biographies.

There are at least four biographies of Booth, however, all too little emphasis is given in them to his exploits in geophysics, which were considerable for the time. For example, the entry in the *Australian Dictionary of Biography (ADB)* for Booth (Mitchell, 1993), although over 650 words in total, has only 18 words on his involvement in exploration geophysics and then only refers to his association with the IGES. Mitchell states, "His major research on geophysical exploration stemmed from his association with the [IGES] in 1929–31". This statement does not recognise Booth's development of seismographs before the IGES, which was the reason he was asked to join the IGES. Nor does the statement recognise his involvement in geophysics outside of research, such as his practical field surveys, about which more follows.

The other three biographies, in reference to geophysics, state only that Booth was a "consultant physicist, [IGES] (1928–30)", except that *Physics in Australia to 1945* (Home, 1995) does add his several geophysical publications, which will be discussed below.

The entry on Booth in the *Australian Dictionary of Biography* (*op cit*), is by far the most comprehensive of the four available, and summarises his life as a "soldier, university lecturer and administrator", with no inclusion of 'research physicist', let alone 'geophysicist'.

Mitchell's description of Booth as a 'soldier' relates to his service in the Australian Imperial Force (of WW1) from June 1916, including action in France and Belgium for which he was awarded the Military Cross[2]. His activities during the war will be dealt with in the section on 'Booth and Pollock'.

The description of Booth as a 'university lecturer' relates to him being firstly, Assistant Lecturer and Demonstrator in physics at the University of Sydney in 1915 and, after his war service, a permanent Senior Lecturer until 1937. Booth was known for his imaginative and effective teaching, the production of two classic textbooks, and numerous other articles on physics subjects (see Home, 1995).

The description 'administrator' no doubt acknowledges, in part, Booth's position as President of the Science Teachers Association of New South Wales (1928–32). Such administrative experience may have been the reason Booth was chosen, in 1938, to be the inaugural Warden of the newly established New England University College (NEUC) at Armidale, a position he held until 1945[3].

The Encyclopedia of Australian Science (McCarthy, 1993) entry for Booth lists, for published resources, the above ADB reference, an obituary of Booth in the *Australian Journal of Science* (Somerville, 1964), and his item in '*Physics in Australia to 1945*' (Home, 1995). Another biography in *Trove*, National Library of Australia (Trove, 2009) repeats the same details.

Physics in Australia to 1945 (Home, 1995) lists 23 publications by Booth (only three with co-authors). Included in this list are nine papers in the *Journal and Proceedings of the Royal Society of NSW* in the period from 1922 to 1938, the last being his Presidential Address to the Society. Six of these papers deal with geophysical topics including the detection of vibrations by microphones, surface waves, regional magnetic surveys, and observations on magnetic diurnal variations. Thus, one quarter of his publications are very much on geophysical subjects.

Ever Reaping Something New, a history of the science faculty of the University of Sydney to 1985, has the following summary of Booth's research activities (Branagan and Holland, 1985, p. 95), "Booth's work displayed versatility with practical flair…. he investigated atmospheric dust and ionization, and followed it

[1]The first seismic refraction survey carried out in Australia was only one year earlier in Roma, Queensland, by the German survey company, Elbof (Thyer, 1979).

[2]Booth, like others at the time, continued to use his military rank of 'Major Booth' after the war and, according to Mitchell (1993), "much of his subsequent career had a military flavour".

[3]Booth is said to have run the College in somewhat of a military fashion, consistent, perhaps, with his continued preference for being referred to as 'Major Booth'. In 1954 the NEUC became the University of New England.

closely with seismic surveys with his newly developed hot-wire microphone as a detector of small vibrations" (see more on this in the section on 'Booth's research into the seismic method' below). "Principles of magnetic surveying for geological interpretation applied to a survey of the 'Gib' (Mount Gibraltar) at Bowral completed the geophysical side of his work" (this work will be examined further in the section on 'Booth as a field geophysicist' below).

Booth and Pollock

As we know from Broughton Edge and Laby (1931, p. 3), when organizing the IGES it was realized that there were "neither experienced operators nor the necessary equipment" even to test seismic methods. However, the Australian Branch of the Institute of Physics "drew attention to the fact that, following on their war [WW1] experiences of seismic methods, the late Professor J A Pollock FRS and Major (sic) E H Booth, [both] of Sydney University, had for some years been carrying out experiments by an electrical recording system which is very similar to that now being employed in geophysical investigations", and thus recommended that seismic methods be included in the IGES[4].

Branagan and Holland, (*op cit*), in regard to Pollock's war experience, add, "In November 1915 it was decided by the Federal Defence Department to form a Military Mining Corps… under the command of Edgeworth David." As part of this Corps, "Pollock devised a geo-telephone for underground listening…" (p. 91). Also, "At the time of his death [22 May 1922], Pollock was engaged in acoustical work related to the transmission of earth waves, based on his experience in France [during WW1]" (p. 92). Booth (1926*b*) acknowledged that Prof Pollock had encouraged him to continue on this work after his death.

Booth's research into the seismic method

Since existing biographies on Booth make no reference to his seismic research, information about this work has been compiled from his own geophysical publications and from references to his work in the Report of the IGES (Broughton Edge and Laby, 1931). Details of some of Booth's seismic experiments before the IGES are given in two papers in the *Journal and Proceedings of the Royal Society of NSW* (Booth, 1926*a*, 1926*b*).

In this first specifically geophysical paper in the Journal (Booth, 1926*a*), Booth described in 13 pages, with graphs, the various microphones used in WW1 to detect artificial earth disturbances. These included the French "Télégéphone" and other microphones, or "seismomicrophones". He showed laboratory results from examining the various types of detectors and, in particular, their sensitivities. He concluded that the 'Télégéphone" was the most satisfactory.

In the very next paper in the Journal (Booth, 1926*b*), he reported on detecting and examining "minute earth vibrations of microseismic nature by means of microphones". This is preceded by a theoretical examination of wave types, including Rayleigh waves.

The next insight into Booth's research, and in particular its use in the IGES, is given in Broughton Edge and Laby (1931), in the section on the Seismic Method written by Booth and R L Aston (of whom, more will follow). In this section they describe the electromagnetic seismometer used by the IGES, and also the hot-wire seismometer patented by "Major Edgar Booth" and first used in the IGES[5].

The electromagnetic seismometer was built at the University of Sydney to a standard principle whereby "the relative motion of inertia mass and framework is translated into relative motion of a coil of wire and a magnetic field". The resulting current produced in the electromagnet from cutting the field is proportional to the relative velocity of the frame, which may be due to seismic ground motion. This principle of operation is the same as still used today in seismic geophones (more typically now with a suspended magnet in an EM coil). Figure 1 illustrates a cut-away section of the seismometer showing its construction including the electromagnet and the coil.

"The hot-wire seismometer first makes use of hydraulic magnification, the inertia mass and frame being arranged as piston and cylinder respectively. Their relative motion forces air through a small orifice containing a grid of fine platinum wire … kept at a dull red heat by an electric current". The air flowing past the wire cools it and hence its resistance (constantly measured by a galvanometer) reduces in proportion to the velocity of the air and so too, the velocity of the ground movement[6]. Figure 2 shows the components of this seismometer, both in section and plan view. According to the way it is mounted it can detect not only the vertical component, but also the horizontal component if mounted vertically, and parts of both components if the mount is inclined to the vertical.

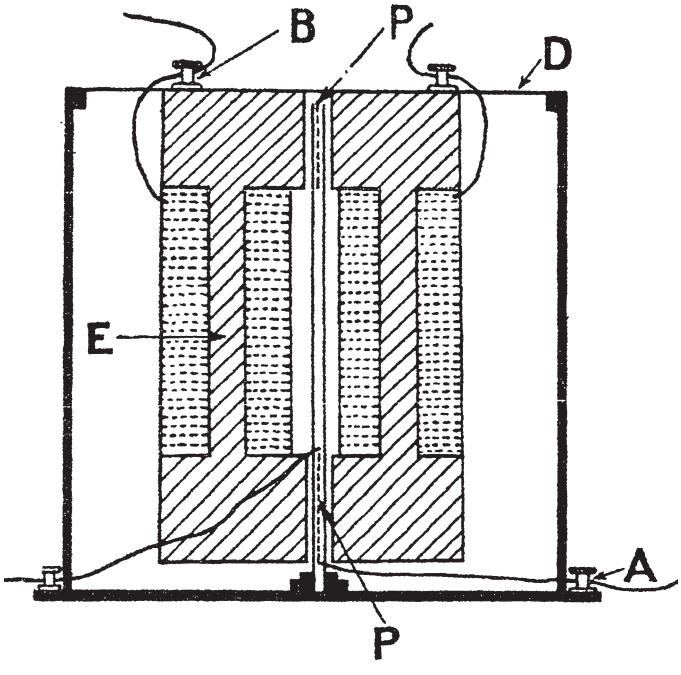

Figure 1. *The electromagnetic seismometer made at the University of Sydney, where E is the electromagnet suspended from the diaphragm, D and P is a thin flat coil passing between the poles of the electromagnet. B is the excitation circuit to E and A is connected to the recorder (from Broughton Edge and Laby, 1931, fig. 259).*

[4]Pollock was a co-inventor, with R Threlfall, of the first gravity meter built in the world, as recalled in Henderson (2015).

[5]That is, Australian Commonwealth Provisional Patent, No. 23,284, by Major Edgar Booth.

[6]How was this principle ever devised? Remarkably, it actually worked! See Figure 3.

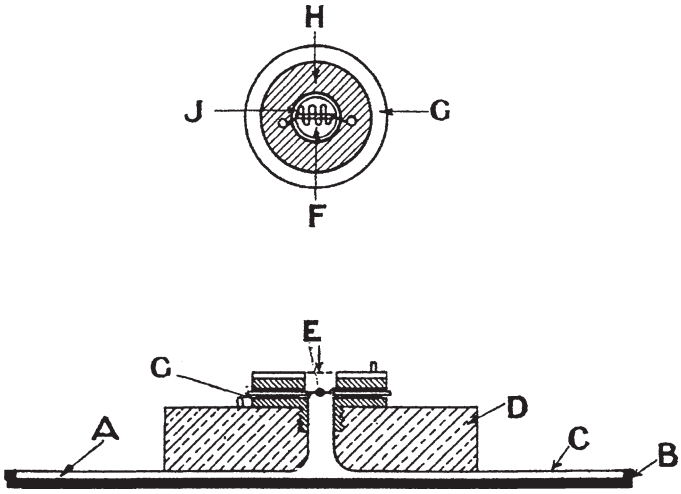

Figure 2. *The essentials of the construction of the hot-wire seismometer are illustrated first in section, where D is the inertia mass, G is a mica disc and then in plan, where F is the hot-wire microphone, J is a fine platinum wire on a porcelain rod (from Broughton Edge and Laby, 1931, fig. 260).*

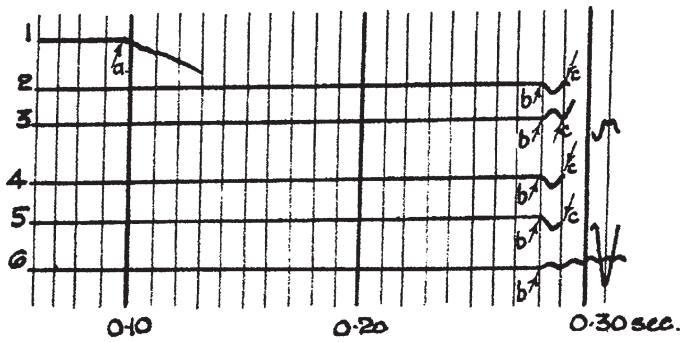

Figure 3. *A typical example of a seismic record from a hot-wire seismograph showing on trace 1 the shot firing time designated by 'a' and the first arrival is indicated by 'b' on each of the other traces (from Broughton Edge and Laby, 1931, fig. 261 (ii)).*

A typical example of a hot-wire seismograph recording as used in the IGES is shown in Figure 3. This must, therefore, be one of the first seismic refraction records produced by Australians.

Booth's involvement in the IGES

The Introduction to the report of the IGES (Broughton Edge and Laby, 1931, p. 4) states, "Major Booth …consented to act as consultant to the Survey in this branch [seismic methods], and on his recommendations the necessary microphones and electromagnetic recording apparatus were obtained". Some of this equipment was from Booth's own designs as described earlier.

Just how much Booth was involved in the field work of the IGES is not clear, as he was not the leader of the field party; although, as we shall see following section 'Booth as a field geophysicist', his activities after the IGES showed he was not averse to field work. The seismic section of the IGES Report (*op cit*, p. (x)) was written jointly by Booth and R L Aston making it one of Booth's 23 publications.

The list of personnel of the IGES (Broughton Edge and Laby, 1931, p. (ix)) has the field leader of the seismic section as the Australian Ronald Leslie Aston, BSc, BE, MSc, who appears to have had no prior experience in seismic methods[7]. This aligns with Booth's statement in his 1938 Presidential Address (Booth, 1938) in regard to the operation of the IGES: "No trained personnel, scientific or otherwise was available in Australia".

Aston was qualified in physics and engineering and, with guidance from Booth, he would have appreciated what was needed to be done in order to conduct a seismic survey. There is no indication of his having conducted any seismic surveys after the IGES or, indeed, engaging in any other geophysical activity.

The seismic method of the type used by the IGES (refraction) was not used by any other Australian crew for at least six years after the IGES. Certainly no surveys of that type were included in Booth's list of surveys, given at the end of his Presidential Address, conducted after the IGES and up until 1937 (Booth, 1938). Whether correct or not, Booth attributes this to seismic being "the most expensive [method] and consequently has regretfully been relegated to the background throughout the financially depressed period [the Depression] elapsing since…". By way of contrast, surveys by other methods, particularly magnetic, which were cheaper, were actively pursued immediately following the IGES[8].

Booth's promotion of geophysical exploration generally.

According to Butcher (1984), "In August 1928, the Australian branch of the Institute of Physics devoted a session to the subject of geophysical prospecting" at which Booth co-authored a paper. "The following year a session was included on 'Seismic Prospecting', at which Booth" was one of the contributors.

On 13 September 1929, Booth gave a "lecture (sic) on Geophysical Prospecting" at the Newcastle School of Arts under the headings of electrical, magnetic, gravity and seismic methods. (*Newcastle Morning Herald and Miners' Advocate*, 1929). "The lecture was illustrated by lantern slides and a short cinematograph film".

Booth's broader knowledge of non-seismic methods may have been gained from publications that were just becoming available, such as those in the possession of E C Andrews of the NSW Department of Mines and described by Henderson (2017).

Booth was President of the Royal Society of New South Wales in 1936-37, and for his Presidential Address chose to speak on the general topic of geophysical prospecting. This address was structured not unlike a series of lectures to students, with each method discussed in a separate section (Booth, 1938)[9]. The theory and instrumentation of all the main methods were outlined in 26 pages, and the surveys conducted since the IGES, in each of the methods (with the exception of the seismic method), were listed in another seven pages.

As Booth said in his introduction to this address, it was customary for the presidential address to be on a subject "with

[7]Aston's biography by Curdie (1993) indicates that for his MSc at Cambridge in 1925 he studied "the effect of boundaries on the deformation of single crystals of aluminium".

[8]These non-seismic surveys conducted after the IGES are detailed in Booth (1938, p. 32–38) and Thyer (1979, p. 247).

[9]This address is also available in book form in the National Library of Australia. https://catalogue.nla.gov.au/Record/2731558

which the retiring President has made himself especially familiar". However, "…my address will be on one not yet covered by a President and one, moreover, of interest and value…to our community". That is, "The subject of geophysical prospecting..."[10].

Booth as a field geophysicist

Three of Booth's papers to the Royal Society of NSW described field surveys, all using the magnetic method. Day (1966) suggests that Booth's forays into the field were "in connection with some purely geological research". However, I believe they were worthy geophysical investigations.

The first paper, which is 14 pages long and was published in 1933 with J M (Jack) Rayner, is titled a "A magnetic survey in the vicinity of a granite bathylith". Its purpose was "to delimit the possible gold-bearing areas" east of Gulgong, NSW (Booth and Rayner, 1933)[11]. It included fold-out plans and magnetometer results plotted as profiles over geological sections. One of the magnetometers used was from the IGES.

A second paper, which was 26 pages long and was published in 1935, reports on "a detailed regional magnetic survey" in the Mittagong-Bowral district "primarily to study the nature of the syenite mass" (known as the 'Gib' or Mt Gibraltar) (Booth, 1935). A third paper, which was five pages long and published in 1937, dealt with "some zonal discordances in diurnal magnetic variations" (Booth, 1937). In this study Booth observed the importance of the distance a local magnetometer recording base may be from the survey areas, a matter which is still of concern today.

Booth's promotion of geophysics teaching.

In his Presidential Address (Booth, 1938) Booth indicated, "one year, 1931, a course was conducted at the University of Sydney by myself, for the Extension Board"[12]. Alan Day (1966) adds that Booth gave on this occasion a "series of sixteen lectures, four demonstrations and three field days in geophysical prospecting". In planning the course at this time, Booth may have benefited from the existence of the detailed Report on the IGES (Broughton Edge and Laby, 1931). If so, was this the Report's first use as a textbook? Butcher (1984, p. 39) notes that "despite his [Booth's] claims that this was a successful exercise, it was not repeated". As we shall see below, that was not for want of trying on Booth's part.

In 1937, Booth wrote a proposal to accompany a letter from the Australasian Institute of Mining and Metallurgy (AusIMM) to the Registrar of the University of Melbourne in which he outlined a possible course in geophysics[13]. The proposed course had two schemes, one for a full-time Chair of Geophysics, both pure and applied, and another for a Professor teaching 'geophysical prospecting' for part of his time. The proposal gave estimated costs including the salary of a Professor (1100 pounds), plus the costs of suggested instruments including horizontal and vertical magnetometers, electrical resistivity and EM equipment, all amounting to 675 pounds[14].

I believe that all this demonstrated that Booth had a strong interest in seeing that geophysics was taught at tertiary level in Australia and took steps to achieve it. As he stated in his Presidential Address, delivered in May, 1937 – a few months before his above proposal for teaching, "no students had yet been trained" (Booth, 1938). The Address concluded with a plea for education in geophysics with, "we could train the students here … we have companies who want to employ them". The last sentence of his Address is, "We have no chair of geophysics at any Australian university".

Conclusions

Published biographies of Edgar Allen Booth suggest that he was a physicist that had a small involvement in geophysics, however, in reality, the teaching and practice of geophysics was a big part of his activities. His geophysical work commenced with his observations of the use of microphones to detect artificial ground motion during WW1, and continued with his subsequent investigations into the nature of seismic theory and development of instrument design. This work resulted in him being chosen to establish the seismic method in the IGES, and would not have happened otherwise. His several talks about geophysics, his own field surveys, and his many published papers on geophysical subjects all confirm his strong interest in the subject. An interest that culminated in his choice of exploration geophysics as the topic of his Presidential Address to the Royal Society of NSW. We can also see from this paper, and Booth's involvement with the AusIMM, that he had an interest in establishing geophysics as a subject in universities.

I suggest that Booth could be regarded as a pioneering geophysicist of some note, and certainly the first Australian to understand and organize the practice of the exploration seismology.

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[10]Butcher (1984) claims that this address was "in fact a long complaint about the lack of interest shown in the subject both at the theoretical and applied levels". Whether it was a "complaint", or not, it was, at least, drawing attention to the prevailing situation.

[11]Jack Rayner was, at this time, the sole geophysicist in permanent government service in Australia (with the NSW Dept. of Mines). He was seconded to the IGES and later became author of the Electromagnetic section of the IGES Report (Broughton Edge & Laby, 1931). Subsequently he conducted several surveys for the Department and various companies. (See Thyer, 1979, p. 247).

[12]The University of Sydney Extension Board provided courses to students unable to attend University.

[13]The letter from the AusIMM, dated 20 September 1937, was a result of its Council approving "of the proposal to establish teaching facilities for geophysics at an Australian University. That is, those "which confer degrees in mining". Melbourne had such a department of mining and metallurgy. (pers comm., Lindsay Thomas).

[14]Booth suggested in his proposal that, as AusIMM were primarily interested in the teaching of geophysical prospecting, the scheme for a part-time Professor should be initiated first.

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