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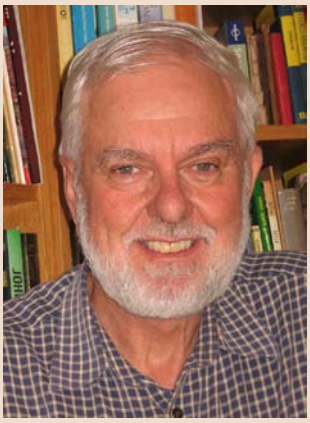
The level of knowledge about exploration geophysical methods in Australia prior to the Imperial Geophysical Experimental Survey (IGES), 1928–30. Part 1



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Introduction

Thyer (1963) begins his 33-page review of geophysical exploration in Australia with the words: "The application of geophysical methods to the search for mineral deposits in Australia *began during 1929 and 1930 with the Imperial Geophysical Experimental Survey [IGES]* …"[1]. Thyer then focuses on the history of geophysical exploration in Australia from 1930, with one exception, as described later in this article.

Rayner (2007) similarly begins his excellent article on the practical reality of the IGES, with the words: "*The Imperial Geophysical Experimental Survey (IGES) of 1929 to 1931 arguably marks the beginning of exploration geophysics in Australia*"[2].

There can be no doubt that the IGES was important in the history of exploration geophysics in Australia; however, there were isolated geophysical surveys in Australia before the IGES. They were single method surveys conducted by observers who may have only known about the method deployed. Some examples follow, but Thyer (*op cit*) and Rayner (*op cit*) were referring to the beginning of systematic exploration geophysics, especially where more than one method is available, and it would seem that essentially they were correct. Certainly, the content of the IGES report (Broughton Edge and Laby, 1931) showed that remarkable advances were made with most methods in the few years of the IGES. The reasons why such concerted activity in Australia came later than in North America, Scandinavia and South Africa will discussed in Part 2 of this article.

Day (1966–1967) in his comprehensive history of geophysics in Australia, states that: "*the application of geophysical methods to prospecting* (as distinct from purely scientific observations)…in this country appears to have commenced shortly after 1910". Here he gives as his references Thyer (1963) and Booth (1938). Day alludes to Australian patents taken out in 1913 by the Electrical Prospecting Company of Sweden (ABEM) and the Schlumberger Company (of France), both involving electrical methods. These patents served to restrict the application of the methods then known, Part 2 of this article discusses how these companies were accused of keeping their knowledge confidential.

Surveys conducted before the IGES

Day (1966–1967) refers to (single-purpose) magnetic surveys conducted by G. F. Dodwell in various places in South Australia from 1915. Some of these surveys noted, incidentally, the association of anomalies with mineralisation. Day (*op cit*) also refers to resistivity depth soundings by Gish and Rooney at Watheroo Observatory WA from 1923 (Gish, 1923; Gish and Rooney, 1925; Rooney and Gish, 1927) and an electrical survey at Broken Hill in 1927 by the South Victoria Prospecting Company[3].

Thyer (1979), who also refers to the Gish and Rooney, the South Victorian Prospecting Company and Dodwell surveys, believed Dodwell's survey in 1915 in the Musgrave Ranges of SA "was perhaps the first recorded use of applied geophysics in Australia", although it was only incidental to a regional geomagnetic survey.

Certainly the first survey of the IGES, an equipotential survey at Anembo, NSW with a known geology and a truly applied purpose, may have a better claim on being the first exploration geophysics carried out in Australia (see Broughton Edge and Laby, 1931, p. 74–5). However, since Broughton Edge and Laby, strangely, do not give any dates for when surveys of IGES were conducted, this claim cannot be substantiated[4].

In regard to the pre IGES surveys Thyer (1979) further suggests that "It seems likely that it was these early successes that stimulated the interest of Australian mining engineers and geologists". Figure 1 shows 'Bob' Thyer giving his 1979 address; Georoots – early geophysical prospecting in Australia to the first ASEG conference in Adelaide.

The pre IGES surveys involved only electrical and magnetic methods. No gravity or seismic surveys were conducted in

[1]Robert F. Thyer was a field assistant in the IGES, then became Chief Geophysicist of the Bureau of Mineral Resources in 1952. He retired as Chief Director (Operations) of the BMR in 1973.

[2]These two references refer to the period of the IGES as 1929–1930 or 1931. However, the official report on the survey, (Broughton Edge and Laby, 1931) "includes a full account of the activities and findings of the Survey, from the date of its inception in London in February 1928, until its close in February 1930. It was the production of the report on the survey that occupied 1931.

[3]Oliver H. Gish and W. J. Rooney, from the Department of Terrestrial Magnetism (DTM) of the Carnegie Institute of Washington (CIW), were primarily conducting global geophysics.

[4]It is intriguing that when describing actual surveys nowhere in Broughton Edge and Laby (1931) are dates indicated. This would appear to be intentional for some reason.

Figure 1. *'Bob' Thyer delivering his address, Georoots – early geophysical prospecting in Australia to the first ASEG conference in Adelaide, August 1979.*

Australia before their use in the IGES other than one by Elbof at Roma in late 1928 (Thyer, 1979, p. 239).

Day (1966–1967) states that "*Systematic geophysical surveying for metalliferous deposits* appears to have commenced about 1925 or 1926", without giving any direct evidence for this assertion. He then refers to the report by E. C. Andrews (1928), Government Geologist of New South Wales, which was reviewed in detail by Henderson (2013). This report was recommending the institution of geophysical facilities by the NSW Geological Survey and will be discussed further in Part 2 of this article, particularly in relation to the methods it described.

Day also claims a paper by H. W. Gepp and others (Gepp et al., 1927) advocating the use of geophysics in Australia, together with the report by Andrews (1928), started the processes that led to the formation of the IGES[5].

Petroleum exploration in Australia commenced later than mineral exploration, and Thyer (1979) claims the "first geophysical prospecting for oil was a gravity survey conducted by IGES in the Lakes Entrance region". However, once again, as dates of IGES surveys are not given this cannot be verified and especially because Thyer (1963) suggested that another survey could be the first. This other survey was a petroleum survey at Roma in Queensland by the German Company, Elbof, involving seismic, gravity and magnetics. Thyer (1979) claims that this survey "commenced late in 1928". Which was first? More on that later.

Sources available before IGES

In the following section, various sources are used to examine what general knowledge existed in Australia before the IGES about various geophysical methods.

The sources, all of which are documents describing geophysical methods and presented and/or published and available in Australia before 1929, are listed in chronological order:

[1] Andrews, March 1925.*
[2] *Western Argus* newspaper, December 1925.
[3] Krahmann, 1926. *(Andrews' copy dated '1928')
[4] Elbof, 1927. *(Andrews' copy, not dated)
[5] Sub-Committee (for Geophysical Surveying) of the Committee of Civil Research, November 1927. *(Andrews' initials on cover)
[6] Gepp et al., June 1927.
[7] Mason, December 1927 *(Andrews' copy dated 21 05 28)
[8] Barton, February 1928 *(Andrews' copy dated 21 05 28)
[9] Andrews, 1928.*
*Denotes copies that were held originally by E C Andrews and are now held by the author[6].

Copies of seven of the nine sources listed were in the possession of E C Andrews, but it is not known if any copies were available elsewhere, except possibly the article written by Krahmann (1926). In this regard it is apparent that Gepp et al. (1927) copied material on magnetics from Krahmann (1926). Gepp et al. (*op cit*) may have used Andrews' copy of Krahmann, or may have had access to another copy.

Also, as Krahmann gave a lecture in Adelaide in October 1927 (see pop out box "Krahmann in Australia"), possibly on the contents of his book, his knowledge was made publicly available just a few months before the IGES.

Andrews' copies of Mason (1927) and Barton (1928) were dated on the cover, presumably by Andrews, as "21/5/28", that is, after his return from North America on 3 March 1928. As a consequence they may not have been seen by anyone else in Australia before the start of the IGES[7].

In addition, as we will see below, some of the sources refer to the Yearbooks of the Geological Survey of Sweden as sources of geophysical information. It is quite possible that these Yearbooks were available in geology libraries in Australia before the IGES.

[5]The story of the formation of the IGES via the Empire Marketing Board and its committees is well described by the Sub-Committee (for Geophysical Surveying) of the Committee of Civil Research (1927), Day (1966–1967, p. 49), Thyer (1979, p. 245), and Butcher (1984) and will not be dealt with any further here.

[6]See Henderson (2013) for more explanation of the author's retrieval of documents once belonging to E C Andrews.

[7]Andrews' return from North America was reported in the *Sydney Morning Herald* of 5 March, 1928 together with some detail on the outcomes of his visit including a description of the geophysical methods he encountered there. See http://nla.gov.au/nla.news-article16446971.

Descriptions of individual sources

In the following descriptions of the individual sources, the theoretical basis for the methods (the measurement of physical property differences, etc.) usually referred to by each is assumed, and also descriptions and operations of instruments have not been included as they are, in any case, now mostly obsolete. The particular methods in these sources are discussed by individual method in Part 2 of this article.

Source [1]: **Andrews, 1925.**

The earliest source of general information on exploration geophysics available in Australia that the author is aware of is a carbon copy of a three-page typed document that was retrieved from the property of E C Andrews, the Government Geologist of the NSW Dept of Mines. It is titled Electrical Prospecting, signed "E. C. Andrews", and dated "5/3/25". The document gives some indication of what Andrews knew in 1925 about the electrical method and its use by others in "the Northern Hemisphere". The document begins, "The literature of prospecting for ore bodies by electrical methods is becoming quite voluminous, dating from 1907 onwards".

It is not clear why the year 1907 was chosen for the start of the literature survey. However, Thyer (1979) noted that in 1907 "the primitive electrical method…achieved some success at Kongsberg, Norway". In the report from the *Western Argus* newspaper, to be discussed in detail below, 1907 was also the year when; "The 'electromagnetic methods' (*sic*) for prospecting were first adopted" (*Western Argus*, 1925).

Andrews then lists: "Prof. C. Schlumberger, Chief Inspector of Mines for France; Mr. G. Bergstrom, Geological Survey, Sweden; H. Lundberg, H. Nathorst, and S. F. Kelly, U. S. A." as "prominent in this connection" (that is, electrical methods).

Also, Andrews states, "Especially significant are the prospecting results obtained by the Geological Survey of Sweden during the period 1913 to 1924…". Andrews then describes the 'electrical method' as he knows it, which was the 'equipotential method'. This, I believe is **the first description of the equipotential method in documentation in Australia.** Figure 2 is a simple illustration of the principle of use the equipotential method to detect anomalously conductive bodies. This method is described in more detail in 'The Electrical Method' in Part 2 of this article.

The author is not aware of this document of Andrews ever entering the public domain.

Source [2]: ***Western Argus*, 1925**.

On 22 December 1925, the *Western Argus* newspaper from Kalgoorlie, WA contained an article titled: Electric Prospecting – Methods in Use. It acknowledged that the source was a paper by Hans Lundberg, read before the American Institute of Mining and Metallurgical Engineers (AIME)[8].

The article describes "two principal [electrical] groups, potential and electromagnetic". As we shall see later, the 'electromagnetic' method referred to here has a grounded source and thus not full

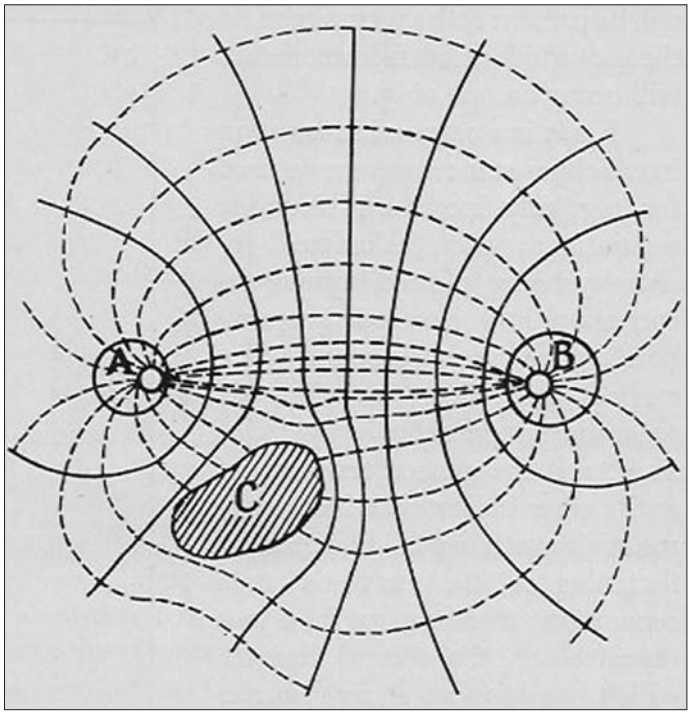

Figure 2. *An illustration of the principle of the equipotential method showing the distortion of the field by a conductive body, C (from Broughton Edge and Laby, 1931, Fig. 6).*

EM. The 'potential' method is "tracing equipotential curves" and the "electromagnetic methods are of more recent origin". "The main development [of the latter] occurred in 1921 [by] Karl Sundberg…" (that of using a non-contact receiver). Note that the first group, the equipotential method, was described by Andrews for the first time in 1925 and here, the author believes that, **for the first time in Australia, the 'electromagnetic method' (such as it was then known to be) is described**. Details of these methods are outlined individually in Part 2, in the 'Electrical Method'.

Source [3]: **Krahmann, 1926**.

This source is a 43-page soft cover book describing all the known geophysical methods in 1926, including radioactivity and "geo-thermic" with 36 figures, including some of equipment and some of operators in the field. Details of these methods will be discussed in Part 2 of this article. See Figure 3 for the Table of Contents ("Index")[9].

Krahmann's term "Electromagnetic" refers to a grounded source and inductive receiver similar to the Sundberg method referred to in the *Western Argus*, 1925. The Preface to Krahmann (1926) advises that this book is an "elaboration" of two lectures given in September 1925 to engineers in Linz, Austria and Bucharest, Romania. He gave a similar lecture in Adelaide in October 1927 (see pop-out box on Krahmann in Australia).

In Chapter One (Krahmann, 1926) on methods in general, Krahmann attributes the "rapid and already quite successful development" of geophysics to "revolutionary technical

[8]Lundberg, a mining engineer and geologist, was with the Swedish American Prospecting Corporation based in New York at the time. No reference is given but it is possible it was Lundberg and Nathorst (1922), a Yearbook of the Swedish Geological Survey.

[9]E C Andrews' copy of Krahmann, 1926, has the stamp of "K. Burggraf"(*sic*), the representative of Elbof Geophysical Co. Ltd. in Australia, on the cover. Also, there is "E. C. Andrews" and "1928", presumably, in Andrews' handwriting. Figure 1 in Henderson (2013) shows this front cover.

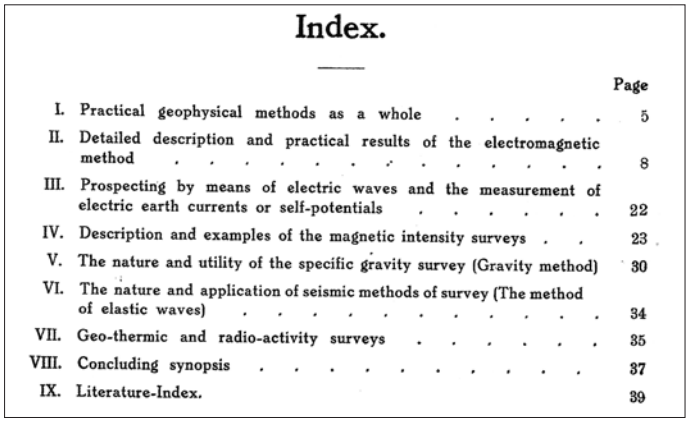

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Figure 3. *List of contents of Krahmann (1926). Note Chapter VII, rare topics at this time.*

advances", the depletion of raw materials and the general economic situation during and after WWI necessitating "cheaper and more comprehensive methods of investigation than drilling".

The references are extensive, mostly dated to the late 1890s to early 1920s, and categorised as to the type of method. One of the earliest reference is an 1833 work on the self-potential method by "Mr Fox". Thyer (1979) says, "Fox, as early as 1832 published his researches with the self potential method in the proceedings of the Royal Society". Figure 4 is a simple illustration of the principle of the self potential method whereby a natural potential surrounding some oxidised, conductive ore bodies is observed. More will be written about this method in Part 2 of this article.

Krahmann in Australia (and South Africa, briefly)

Dr Rudolph Krahmann was an engineer from Berlin. Newspaper reports put him in two states of Australia in 1927 and 1928. On 20 October 1927, as reported in the *Adelaide News* in a 103 word item, "Dr. R. Krahmann, of Berlin" gave a "lecture" at the University of Adelaide, "delivered in English and illustrated with many lantern slides". He is described in the item as "the leader of a party of highly trained investigators who have been invited to visit New Zealand and Australia to undertake researches by geophysical methods".

The newspaper then lists the methods "now in vogue" as the same as in Krahmann's book, (1926) including "geo-thomic" (sic).

The *Brisbane Courier*, on 11 April 1928, reported that "Dr. Krahmann, who represents a German company [Elbof]… *returned* yesterday to Roma to make a secondary preliminary survey of that oil field". Thyer (1979) states "Elbof succeeded in arranging a contract at Roma and work commenced in late 1928….". "Elbof used gravity (torsion balances), seismic (Schweydar seismograph), magnetic and its own magneto-inductive methods". Also in the *Brisbane Courier* item, "A director of one of the oil companies operating in the Roma area declared yesterday that he had been convinced *'against his will'* that geophysical prospecting had become an exact science".

Thyer (1979) also claims that Krahmann "commented favourably on the decision to form the IGES but said that he had found within Australia a tendency to regard *geophysics as a doubtful science"*.

de Beer (2011) informs us that Krahmann emigrated to South Africa in 1930 and became so famous there for his discoveries (using an Askania magnetometer) that the highest award now given by the South Africa Geophysical Association (SAGA) is the Krahmann Memorial Award.

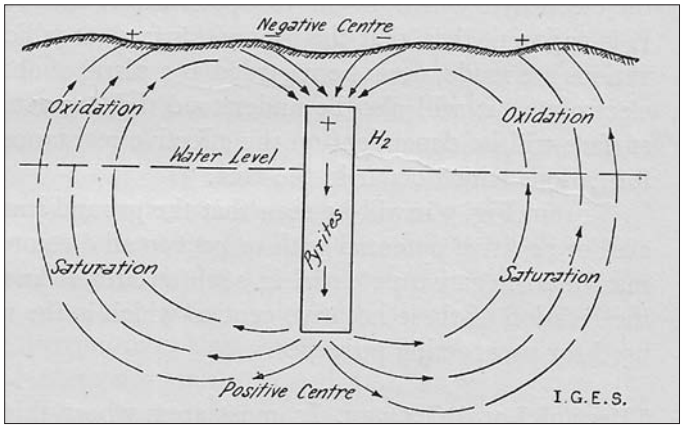


Figure 4. *A schematic of the principle of the self potential method (from Broughton Edge and Laby, 1931, Fig. 1).*

Source [4]: **Elbof, 1927**.

This work is the fourth edition of a company booklet produced by Elbof Geophysical Co. Ltd. (otherwise Piepmeyer & Co. Ltd.) Kassel, Germany. The work is 47 pages long and in six chapters describes all the methods including "geo-thermic" and radioactivity, but excluding seismic. Details of these methods will be discussed in Part 2 of this article. The illustrations and case studies are copious, and there is an extensive bibliography[10].

The Introduction, Chapter I, states that geophysical methods have been added to the "observational methods of the geologist… during the last decade". They are "not to take the place of deep boring or sinking…they are only intended to point to the best localities". And, "Recent progress has so far improved the sensitivity of the instruments that data can now be obtained at considerable depths". A combination of methods is advocated.

The chapter on "Geo-electrical exploration" begins with an extensive list of typical conductivities and an illustration of a laboratory "Sandbox" for testing the conductivities of target rocks. This sandbox is shown in Figure 5. The author has a long interest in the use of physical models and this description of a model is one of the earliest encountered (see also references to models in Mason, 1927, discussed below).

Source [5]: **Sub-Committee (for Geophysical Surveying) of the Committee of Civil Research, 1927.**

The Sub-Committee (for Geophysical Surveying) of the Committee of Civil Research was appointed to provide a report to the Empire Marketing Board (EMB) on geophysical

[10]The copy originally held by E. C. Andrews has written on the cover, in pencil, "From Co. for Scientific and Industrial Research, Melbourne". They were possibly an agent in Australia for Elbof although the 'Manager' of Elbof, as we know from above, is K. Burggraf in Sydney.

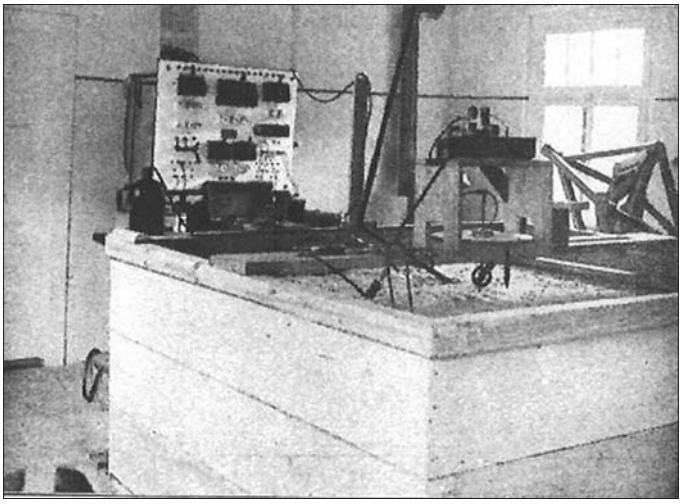
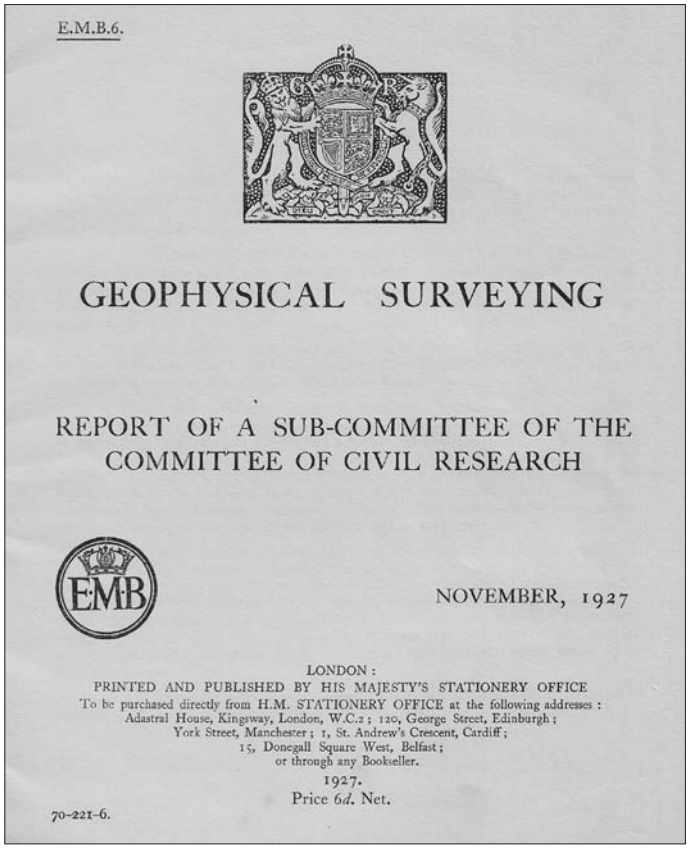


Figure 5. *The experimental sandbox in the Elbof laboratory, a physical modeling facility before 1927 (from Elbof Geophysical Co. Ltd., 1927, p. 7).*

surveying. Their report was published in November 1927 as Publication no. 6 of the EMB, and available at a cost of six pence. The title page is shown in Figure 6. At least one copy existed in Australia and was in the possession of E C Andrews in about 1928.

The Sub-Committee was appointed in April 1927, and the report was recommended to the EMB a few months later. The authors of the report consisted of seven distinguished men, many of whom were associated with well-known English institutions,


E.M.B.6.

GEOPHYSICAL SURVEYING

REPORT OF A SUB-COMMITTEE OF THE COMMITTEE OF CIVIL RESEARCH

EMB

NOVEMBER, 1927

LONDON:
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses:
Adastral House, Kingsway, London, W.C.2; 120, George Street, Edinburgh;
York Street, Manchester; 1, St. Andrew's Crescent, Cardiff;
15, Donegall Square West, Belfast;
or through any Bookseller.
1927.
Price 6*d*. Net.
70-221-6.

Figure 6. *The title page of the report on Geophysical Surveying by the Sub-Committee (for Geophysical Surveying) of the Committee of Civil Research (1927).*

together with our own Sir Edgeworth David, Professor Emeritus of Geology, University of Sydney[11].

The Introduction (Section I) of this source lists the terms of reference of the Sub-Committee and the very first of the four was to report on "What recent developments, if any, have been made in the methods employed in geophysical surveying". Section II is entitled "The various methods of geophysical surveying" with sub-headings for "Gravimetric, "Electrical", "Magnetic", "Seismic and Sonic Sounding", and "Thermal" methods. Details of these methods will be discussed in Part 2 of this article. Each sub-section describes what the Sub-Committee believed to be the latest knowledge of the methods at that time at least, it would seem, mainly in Europe. The only examples referred to outside Europe were; the employment of the gravity method (always torsion balance) on salt domes in the Texas Gulf Coast, and the electrical method at the "Britannia Mine in Canada" and another in California. "We did not…make any further enquiry into these applications in Canada and the United States". What a gap they left in their investigations!

The authors claim that with the exception of the magnetic method, which for a long time (indeed from "the middle of the 19th century") was used to map iron ore, particularly in Sweden, "these [other] methods were practically unknown until within the last twenty-five years".

The report then concludes with an interesting insight into the state of knowledge of geophysical methods at least in the British Empire (thereby including Australia and Canada but excluding the USA and the rest of Europe)[12]. "So far as the British Empire is concerned, surprisingly little use has been made of these methods…". Part 2 of this article examines how this "little use" was not true of countries outside the Empire (including USA and Scandinavia). Regarding their value, "… we believe that an extensive trial of the principal methods…would be of great interest and value to the Empire". Hence their promotion of the IGES.

Source [6]: **Gepp et al., 1927**.

In 1927, the *Proceedings of the Australian Institute of Mining and Metallurgy* published a paper titled "Geophysical Prospecting" by H W Gepp, J F Hughes and H S Elford, (Gepp et al., 1927). Butcher (1984) claims it was also "later reprinted by the Aust. Inst. Min. Metall. Eng. in pamphlet form". Also, the *Kalgoorlie Miner* reproduced the paper extensively on 22 June 1927 (Kalgoorlie *Miner*, 1927).

Some background on Herbert Gepp, particularly in relation to his involvement in geophysics matters, is given separately in the pop-out titled "About Gepp".

Little is known about John Frankland Hughes other than he is described as a geophysicist, born in Victoria, who died in 1975. His legacy is his co-authorship of this paper. Harold Stewart Elford (1902-1956) was a chemist by profession and worked, with Gepp in the Australian Development and Migration

[11]As stated above, the story of the formation of the IGES via the Empire Marketing Board is amply told by others.

[12]The British Empire at this time also included South Africa, India and various countries in Africa such as Southern Rhodesia (now Zimbabwe), for a total population of 458 million in 1922. Peter Hartcher (2014) in *The Adolescent Country*, reminds us that "Australia was content to act as a local sub-branch of the British Empire.... until 1940".

About Gepp (in particular, his relationship with geophysical interests)

Herbert William Gepp (1877–1954), also known as "Bert", was Chairman of the Australian Development and Migration Commission from 1926 and very involved in encouraging the formation of the IGES. Thyer (1979) claims Gepp "was largely responsible for establishing the… IGES" and suggests that his representations to the British Empire Marketing Board were "instrumental in Australia being selected as the location for such field tests" (that is, instead of another part of the Empire). Gepp was one of the members of the Australian Geophysical Executive Committee of the IGES (as was E C Andrews). While he showed strong commitment to the promotion of geophysics there is no evidence that he had any formal training in the subject. More on Gepp's continued belief in the value of geophysical prospecting is given in Butcher (1984), pp 33, 34 and 40.

In Gepp's biography, written by B E Kennedy (Kennedy, 1981), Gepp, a mining metallurgist, is reported to have "boundless energy, inventive mind and commitment to industrial growth". He was President of the Australasian Institute of Mining and Metallurgy in 1924, knighted in 1933, and in 1934, became Director of the Aerial Geological and Geophysical Survey of North Australian (AGGSNA), about which much has been written elsewhere. Figure 7 is a photo of Gepp taken at an unknown time.

Figure 7. *Sir Herbert Gepp at an unknown time (from Kennedy, 1981).*

Butcher (1984) suggests "Gepp, largely through his own efforts and determination, worked his way to the pinnacle of Australian society". His annual salary of £5000 was then the highest salary paid to an Australian public servant. Butcher (1984) has more information on Gepp's rise in private industry, at one stage to manager of the newly formed Electrolytic Zinc Co. at the early age of 40.

Commission as Chief Technical Officer.

The paper begins with the object to "bring before Members of the Institute the very important and much discussed question of scientifically prospecting for ores, oil, coal, etc." Its 38 pages cover the methods of "Sound-Vibration, Magnetic, Gravitometric (*sic*) and Electrical", the latter subdivided into "Equipotential, Electro-magnetic, Schlumberger, and General". Details of these methods will be discussed in Part 2 of this article. Section II, titled "General Discussion of Geophysical Prospecting", includes four tables attributed to Heiland (1926) and Sundberg et al. (1925), a bibliography, and four photos of equipment and operators in the field.

Presumably, as none of the three co-authors knew much geophysics, the paper relies heavily (in fact, 90%) on other references from which extensive quotations are reproduced, with very little attributed to the authors themselves. Also, some of the information is not very current or mainstream, as we see in the second part of this article.

Source [7]: **Mason, December 1927.**

This 32-page booklet titled Geophysical Exploration for Ores, is Technical Publication No. 45 of the American Institute of Mining and Metallurgical Engineers (AIME) and was presented to the New York section of AIME in October 1927. The paper has no list of references, although one reference is given as a footnote, and it includes a discussion. A later version published in AIME *Geophysical Prospecting*, 1929 includes an additional written discussion by K. Sundberg, of the Swedish American Prospecting Corporation, Houston, Texas.

The author of the paper, Dr Max Mason, was at the time President of the University of Chicago, Illinois, USA and also Chair of Physical Exploration Corporation of New York[13].

The methods discussed, in order, are: acoustic, gravitational, magnetic, electrical (only self potential), "electromagnetic" (as Schlumberger and Lundberg type equipotential) and 'Inductive' non-contact receiver electromagnetics. Surprisingly, Mason made no mention of the resistivity method as expounded by fellow American, Wenner, in 1915. Interpretation is declared to be the work of the physicist. Many pages discuss the 'philosophy' of interpretation, including the inverse problem and non-uniqueness, at what appears to be at an advanced level. There is a long chapter on "Use of Models", comparing field results to theoretical shapes. In one case, the model is a "sphere of about 3 ft. diameter" but its composition is not disclosed. Then, the results of all methods previously discussed are shown over the same real ore-body (the Falconbridge nickel ore at Sudbury, Ontario, Canada) simplified to a narrow, vertical conductive vein for model comparisons.

Under the heading "Underground Exploration an Attractive Field" it is stated "…we believe underground explorations in producing mines will be an attractive field for future applications…"[14].

Mason's intriguing way of anthropomorphising the geophysical process, such as shouting the question down to the ore-body and listening for an answer, is further described in Henderson (2013).

[13]In the introduction to his paper, Dr Mason explained that as a physicist he was asked by a mining company in 1923, "to review the whole question of the application of physics to ore detection…. This involved a review of the prior work on geophysics…". His paper is a report on these investigations, together with theory and special field tests.

[14]Elbof [4], for electrical methods, at least, also suggests the possibility of "work underground" (see 'Electrical methods' in Part 2 of this article).

Source [8]: **Barton, February 1928.**

This 51-page paper titled "The Eötvös torsion balance method of mapping geologic structure", is a single subject paper and covers most of the subject of theory, measurement and interpretation of results, and includes 20 figures and a half page of references. The author, Donald C Barton, was a consulting geophysicist from Houston, Texas.

The paper was published as Technical Publication No. 50 of the AIME in 1928 and a later version published in AIME *Geophysical Prospecting* in 1929 added 13 pages of discussion, which, in itself, is very informative of the state of knowledge at the time. It included written submissions from E Lancaster-Jones and H Shaw, both from The Science Museum, London, England[15].

Source [9]: **Andrews, 1928.**

A description of the level of knowledge of the various methods as reported by E. C. Andrews is given in Henderson (2013). Apart from his individual knowledge on the equipotential method as described in Andrews (1925), most of his information is derived from his visit to the USA in 1927, and from Mason (1927) and possibly Barton (1928), copies of whose papers he possessed and are reviewed above. He, like all the sources reviewed, made no mention of the specific activity taking place in South Africa at this time. Nor did he discuss the resistivity method, probably because Mason (1927) did not (see also, Henderson (2013), p. 43, on subject).

Andrews noted patents taken out in Australia for the "Schlumberger Process" in 1913 and 1914 and those of "The Lundberg and Sundberg Process". These patents were also referred to by Day (1966). Andrews is the only source to mention "submarine geological surveying" and recognised the "possibilities of geological surveying by geophysical methods". Andrews was ever the geologist with his constant reference to their indispensability to the interpretation of the geophysical results.

Andrews suggested that the work accomplished at that time in other countries "should be applicable to the case of Australia, although not so marked a degree as in North America**,** which contains a relatively intense concentration of ore deposits, including oil, coal and gas". As if to address this difference, he listed areas that he believed would be applicable to the use of geophysics, namely: "The Greater Roma District", for oil and gas; "the Hunter River Basin", for coal; and the "Broken Hill District", the Greater Cobar District and the "west coast of Tasmania" for metals. The latter area was one included in the IGES, plus another area suggested by Andrews; the Gulgong deep leads, where all four methods of the IGES, including seismic, were employed.

On lack of knowledge before the IGES

An example of how little knowledge there was in Australia before IGES and how little the Sub-Committee (for Geophysical Surveying) of the Committee of Civil Research knew of its state, was in the way that the recommendations of the Sub-Committee with regard to personnel could **not** be met by Australian graduates, with one exception. One recommendation was that "one member of the party should be *a first-class honours graduate in electricity*". Another was that "the party should contain *a first-class honours graduate in physics and mathematics,* who would be responsible to the leader for the gravimetric and magnetic surveys undertaken".

In this regard, Butcher (1984) points out that, at this time, "no physics department in any Australian university provided training or expertise in the area". E H Booth, in his Presidential address to the Royal Society of NSW (Booth, 1938) acknowledged that before the IGES, "no trained personnel, scientific or otherwise, was available in Australia, … no students had yet been trained, although it was known to be absorbing many science graduates of Continental and American universities". Also, we know that lectures on exploration geophysics did not start in Australia until 1950 (Henderson, 2016).

The position of "honours graduate in electricity" was filled by two experienced assistants of Broughton Edge; S H Shaw and J C Ferguson, both science graduates from London, "In order that the electrical investigations might be commenced in Australia with out delay" ('(Broughton Edge and Laby, 1931)', p. 3). Both these men had spent time with Broughton Edge in what was then Rhodesia.

Also, "As regards the physicist to undertake the torsion-balance survey…immediate arrangements should be made…to come to this country for….intensive study of the gravimetric method….in consultation with the Science Museum" (Sub-Committee (for Geophysical Surveying) of the Committee of Civil Research, 1927, p. 17–18). This latter recommendation, at least, acknowledged that the Australian would need training in the UK.

The "physicist" chosen as leader of the Gravimetric section in the IGES was, in fact, the Australian, N B Lewis, BSc, D Phil (Oxon), a graduate of the University of Melbourne. He was however, according to Butcher (1984), at University of Oxford, 1924-26 and the University of Uppsala, Sweden 1926–1927, so was already in Europe to undertake the training in the UK. According to the Introduction to Broughton Edge and Laby (1931), "for some months he had been undergoing his preliminary training in England". Butcher (1984) also claims that Lewis "was in fact a chemical physicist", suggesting that a "physics student in the 'pure' sense" was even less available at this time.

Conclusion to Part 1

Before the IGES, geophysical surveys in Australia numbered possibly only three and were only single method, magnetics or electrical. The gravity and seismic methods, although practiced in other countries, were not applied to metalliferous or petroleum prospects before the IGES. However, at least nine documented sources of geophysical knowledge have been identified by the author as being available before the IGES All but two sources described the gravity method and five described the seismic method.

In Part 2 of this article, which will follow in a subsequent issue of *Preview*, the information in these sources is examined in more detail by method. The reasons why exploration geophysics

[15]Both these men had their own paper in this AIME volume on the gravity method, Shaw's being more general on Gravity Surveying in Great Britain (this relates to information provided by the Sub-Committee (for Geophysical Surveying) of the Committee of Civil Research, November 1927 to follow in Part 2 of this article, 'Gravity Method').

was late in coming to Australia, as compared to other Western countries, are also discussed.

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