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Beverley F. Ronalds

The Beginnings of Continuous Scientific Recording using Photography: Sir Francis Ronalds' Contribution

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Thomas Malone, Photograph of Francis Ronalds, c.1850. © Royal Society.

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Introduction

The application of photography to scientific investigation was achieved very early in the history of the medium. It is 170 years since the first successful 'movie camera', complete with a sophisticated optical system, was built to register the continual variations of meteorological and geomagnetic parameters over time.

The inventor was Sir Francis Ronalds FRS (1788-1873). When Ronalds (fig. 1) is remembered today it is generally for his electric telegraph, which he had developed thirty years earlier and for which he was knighted 25 years subsequent to the creation of his camera. He also has nearly two hundred other scientific achievements to his name.[1]

Figure 1
Thomas Malone,
Photograph of Francis Ronalds, c.1850.
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Ronalds documented his initial ideas for photo-recording in 1840-1,[2] almost immediately after Henry Fox Talbot introduced his photographic process. The next year, the British Association for the Advancement of Science (now called the British Science Association) commenced operations at the Kew Observatory near London.[3] Ronalds became Director of the observatory soon afterwards and by April 1844 was able to begin detailed experimentation with photography. The goal was to develop self-registering instruments to ease the load on observers and already he had a vision of producing "graphic reports of our Kew Observations."[4] His first cameras were built a year later.

The Cameras

Ronalds' initial machine, made in April 1845,[5] was configured to capture the observations of his atmospheric electricity apparatus and in August that year he demonstrated the recording of atmospheric pressure and temperature.[6] By March 1846, he had extended his approach to geomagnetism.[7]

The heart of the machine was a horizontal camera box holding achromatic lenses (which were generally provided by Andrew Ross) and a simple mechanical aperture diaphragm to regulate the light.[8] The light source was daylight, where possible, and an oil lamp at night. The instrument signalling the phenomenon of interest was also placed inside the camera. A slowly moving photosensitive surface driven by clockwork through a

1. Beverley F. Ronalds, *Sir Francis Ronalds: Father of the Electric Telegraph*, Imperial College Press 2016.
2. Francis Ronalds, Journal of Meteorological Observations at Kew Observatory, 1845-6, National Meteorological Archive.
3. Robert Scott, 'The History of the Kew Observatory', in: *Proc. Roy. Soc. Lond.*, vol. 39, 1885, 37-86.
4. Letter, Francis Ronalds (London) to George Airy, 29 April 1844, RGO 6/701, by permission of Science and Technology Facilities Council and Syndics of Cambridge Univ. Library.
5. Letter, Francis Ronalds (Padua) to Sanuel Carter, 21 February 1860, UCL Library Services, Special Collections, GB 0103 MS ADD 206.
6. Francis Ronalds, Memorial on Self-registering Instruments, draft, 30 September 1848, IET 1.9.1.
7. Letter copy, Francis Ronalds to Edward Sabine, 24 March 1846, IET 1.4.17b.
8. Francis Ronalds, 'On Photographic Self-registering Meteorological and Magnetic Instruments', in: *Phil. Trans. R. Soc. Lond.*, vol. 137 Part I, 1847, 111-117.

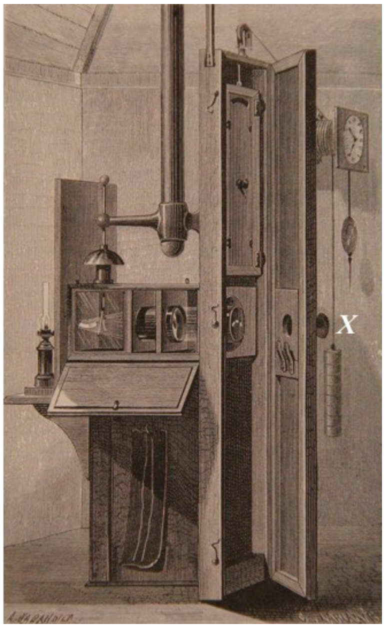

Figure 2
The photo-electrograph – Ronalds' first photo-recording machine at Kew observatory.
From: Gaston Tissandier, *La Photographie,* Paris 1873, 273, fig. 56.
At the centre is the horizontal camera box 7.5 cm square and 40 cm long, while the photosensitive surface travels inside the vertical case. The microscope *X* allows the image to be viewed.

Figure 3
Francis Ronalds, *Electrogram Negative*, 9 December 1845. Cambridge University Library RGO 6/701 298.
The thicker outer curves *a* and *b* on either side of the thin centreline show the divergence of the straws in the electrograph and therefore the changing electric intensity in the air.
A third thinner curve c to the left of the centreline indicates the electricity to be positive. Ronalds settled on a size of 33 cm × 9 cm for his photographic traces.

long case recorded the minute by minute variation of the instrument over a twelve or twenty-four hour period. One of the features Ronalds introduced was a microscope (labelled *X* in figure 2) for viewing the image to ensure that it was correctly positioned and focussed. He found it sufficiently useful to explain and illustrate to photographer John Egerton, who 'most gladly' adopted it.[9] This functionality of seeing the image itself rather than the object to be photographed has of course only become the norm in the digital age.

The first machine, the so-called electrograph, was described and illustrated in Gaston Tissandier's *La Photographie* (1873).[10] A long vertical conductor extending through the roof of the observatory collected the electricity from the air, from where it flowed to two straws of an electrometer that then diverged through repulsion. Only the tips of the straws were visible through the arced slit in the diaphragm and the photograph thus depicted a pair of curved lines with their separation varying according to the changing intensity of the electricity. A third indicator was also incorporated to show whether the charge was positive or negative. A trace created by the camera in late 1845 survives, which Ronalds had posted to the Astronomer Royal (fig. 3). The electrometer lines on the negative have the whiteness of the photographic paper as they did not receive any light while the darkest bands occur when the sun was shining most brightly.[11]
With the thermograph and barograph, the photo was an undulating light and dark band with the boundary between them being the changing height of the mercury (fig. 4).[12] Perturbations in the geomagnetic field were recorded using a magnet suspended on a long silk thread (fig. 5).

Kew was established primarily as an experimental facility for developing new instruments and processes, rather than to conduct regular observations.[13] Ronalds thus created his prototype cameras simply to demonstrate the feasibility of photo-recording in an observatory setting. The success of the original instruments meant that he was soon requested to supervise the manufacture and installation of machines for routine use in other observatories; these included Toronto,[14] Madrid,[15] Oxford[16] and probably Paris.[17] He also provided ongoing advice to their observatory Directors on photographic method.

Renowned astronomer, chemist and photographer Sir John Herschel followed Ronalds' progress with interest and was instrumental in arranging a £250 award to him in 1849 from the British Prime Minister Lord Russell.[18] It was a reflection not only of the quality of the cameras but also

9. Letter copy, Francis Ronalds (Kew) to John Egerton, 7 April 1846, IET 1.4.17b and Letter, John Egerton (London) to Francis Ronalds, 7 April 1846, IET 1.3.106.
10. Gaston Tissandier, *La Photographie*, Paris 1873.
11. Francis Ronalds, 'On the Meteorological Observations at Kew, with an Account of the Photographic Self-registering Apparatus', in: *Report of the British Association for 1846*, 1847, 10-11; reprinted in: *Athenæum*, 1846, 1000-1001; reprinted as: 'Self-registering Meteorological Apparatus at Kew', *Year-Book of Facts in Science and Art*, 1847, 125-127; reprinted in: *The Decorator's Assistant*, I, 1847, 55-56.
12. Francis Ronalds, 'Report concerning the Observatory of the British Association at Kew, 1850-1', in: *Report of the British Association for 1851*, 1852, 335-370.
13. 'Report of the Proceedings of the Council in 1849-50', *Report of the British Association for 1850*, 1851, xvi-xxi.
14. Francis Ronalds, 'Report concerning the Observatory of the British Association at Kew, 1848-49', in: *Report of the British Association for 1849*, 1850, 80-87 and 'Report concerning the Observatory of the British Association at Kew, 1849-50', in: *Report of the British Association for 1850*, 1851, 176-186.
15. Correspondence &c on Mr F. Ronalds's Atmospherico-Electrical Apparatus, and on Magnetic Instruments at the Madrid Observatory, 1851-5, IET 1.9.1.

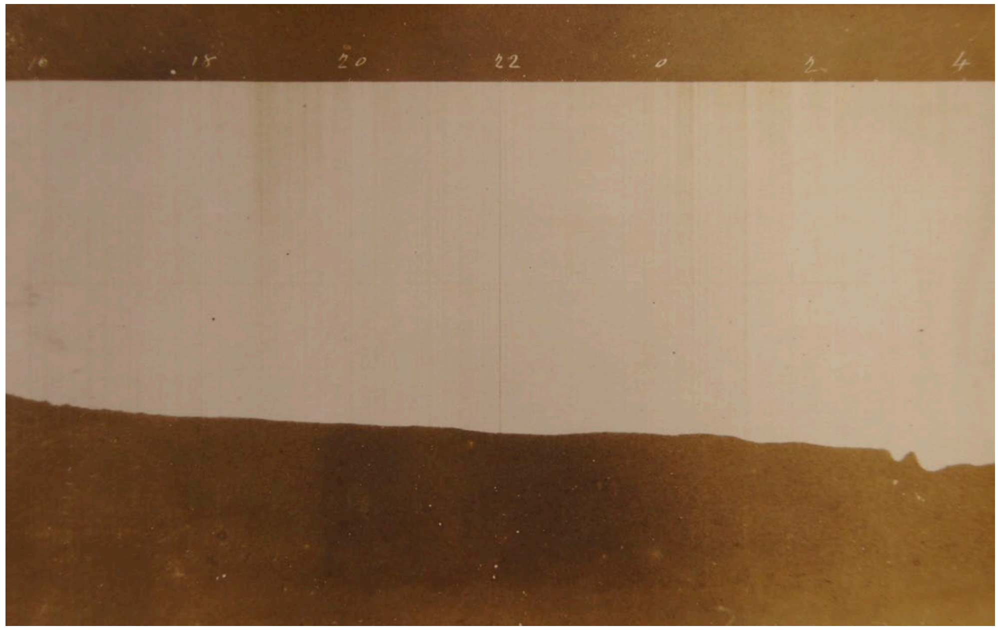

Figure 4
William Crookes and Manuel Johnson, *Thermogram*, print from waxed-paper negative, 28 April 1855. IET 1.9.1.
A 13-hour section is depicted, showing the changing height of the mercury in Ronalds' thermograph at the Radcliffe Observatory in Oxford.

their importance for observational science. He also received encouragement from Sir David Brewster and Robert Hunt, two early authors on photography.[19]

Photographic Processes

Ronalds' application called for unusual requirements in photography and he put as much effort into materials and processing as into his cameras. He also interacted with many of the pioneers of photography in England in attempting to perfect his techniques. The various people mentioned in this paper – unlike Ronalds himself – are introduced in texts like John Hannavy's *Encyclopedia of Nineteenth-Century Photography* (2008).[20]

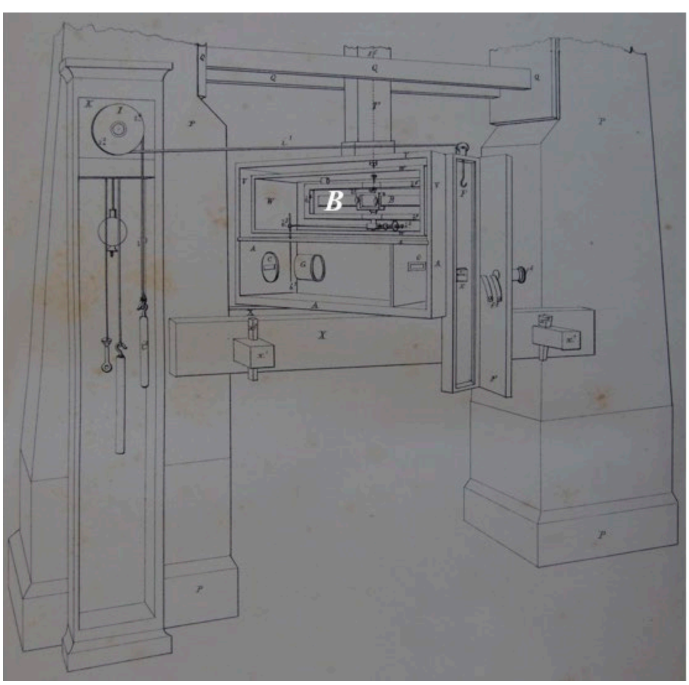

Figure 5
Ronalds' initial magnetograph, 1846, from: Francis Ronalds, 'On Photographic Self-registering Meteorological and Magnetic Instruments', in: *Phil. Trans. R. Soc. Lond.*, vol. 137 Part I, 1847, 115.
The 61 cm long magnet *B* is suspended horizontally on a 2.7 m long silk skein. Its lateral rotations under changing geomagnetic forces are translated for registration into motion of a vertical index in the camera box below. The instrument is framed into sturdy stone pillars to prevent any movement that could contaminate the delicate magnet oscillations. The core of the machine is held at the Science Museum.

Firstly, Ronalds needed very high chemical sensitivity to enable relatively rapid movements of the instruments to be captured in the photograph. The traces also had to be as sharp and delicate as possible, with high contrast, for the curves to be later quantified with precision. Photographic paper therefore needed to be fine and suitably finished to avoid fuzziness. Another challenge with paper was shrinkage and distortion caused by wetting and drying during the chemical processing, which could alter the scale of the image in some ill-defined way.

Furthermore, the workflow needed to be practical for an observatory conducting continuous daily photographic registration – the processing could not be too complex, time-consuming or expensive. As Ronalds explained in 1846:

I hope to be able to reduce the Knack-ery of the paper process to a simple, certain, & easy machine-ical operation.[21]

Materials were required to be prepared in advance without deterioration and the workflow had to be tolerant to delays at any point in the procedure caused by other priorities in the

16. *Astronomical and Meteorological Observations made at the Radcliffe Observatory*, 1854.
17. Francis Ronalds, *Descriptions de quelques Instruments Météorologiques et Magnétiques*, 1855, 68pp.
18. Letter, John Herschel (Collingwood) to Francis Ronalds, 13 May 1849, IET 1.9.1.
19. David Brewster, 'Photography', in: *North British Review*, vol. 7, 1847, 465-504 and Robert Hunt (ed.), *Hunt's Hand-book to the Official Catalogues of the Great Exhibition*, 1851.
20. John Hannavy (ed.), *Encyclopedia of Nineteenth-Century Photography*, Routledge 2008.
21. Letter, Francis Ronalds (Chiswick) to George Airy, 16 October 1846, RGO 6/42.

observatory. The images themselves needed to be able to be copied readily for distribution and to retain their features over time as part of an ongoing record. Finally, consumables and operator time could not be too costly as multiple daily photographs were required in a working observatory. Ronalds was pushing photographic suppliers to the limit. A note survives from this time in the Ronalds Archive at the Institution of Engineering and Technology (IET):

> *Mr Talbot thinks that the conditions are not compatible[?] with economy. There would be no objection to give double the market price if it answered all the conditions required. He has the subject under his own consideration.*[22]

With photography at this time still being very new, Ronalds built flexibility into his machines and they could deploy either Talbot's or Louis Daguerre's media. He chose the Calotype initially and received assistance from several of Talbot's associates, including Henry Collen and later Nicolaas Henneman and Thomas Malone. It was actually Collen who published the first paper on Ronalds' cameras, in the 1846 *Philosophical Magazine.*[23] Ronalds was annoyed by this and recorded that "Collen claims a share in my inventions unjustly."[24] It was his view that Collen had helped only with the processing.[25]

The relationship with Malone over the period 1847-9 was more rewarding personally and Ronalds was generous in his acknowledgement of Malone's extended efforts to produce materials and techniques tailored to his machines.[26] Malone advised Ronalds in 1847 of an early breakthrough:

> *This power of keeping the latent impression is valuable as it can be brought out at leisure... Mr Talbot is in Town but fears he will not have time to go to Kew.*[27]

The next year, Malone recorded that results were mixed:

> *I am just now very nervous about our new paper. We have received a few sheets unsized, I have not yet been successful in sizing them myself... It is very tough & I think very close in texture... As soon as possible I will try it for your use – Failure is impossible – nevertheless we may have some trouble to get it right.*[28]

After eighteen months they were still at work, with Malone advising Talbot:

> *Mr Ronalds of Kew has been with me in the evening experimenting for his registration plan.*[29]

Samples of several of the photographic papers Ronalds trialled are retained in the Ronalds Archive, including from the Chafford Mill run by the Turner family, Whatman's paper, as well as Talbot's.[30]

22. Note regarding Henry Talbot's views of processing requirements, 19 April 1848, IET 1.3.187.
23. Henry Collen, 'On the Application of the Photographic Camera to Meteorological Registration', in: *Phil. Mag.*, vol. 28 S3, 1846, 73-5.
24. Alfred Frost (ed.),*Catalogue of Books and Papers Relating to Electricity, Magnetism, the Electric Telegraph, &c. including The Ronalds Library, compiled by Sir Francis Ronalds, F.R.S.*, 1880; reprinted: Cambridge University Press 2013.
25. Francis Ronalds, Draft Note for the Athenæum and Literary Gazette, 1846, IET 1.4.6.
26. Francis Ronalds, *Epitome of the Electro-Meteorological and Magnetic Observations, Experiments, &c. made at the Kew Observatory*, 1848, 12pp. and Letter, Thomas Malone (London) to Francis Ronalds, 16 March 1850, IET 1.3.375.
27. Letter, Thomas Malone (London) to Francis Ronalds, 15 October 1847, IET 1.3.178.
28. Letter, Thomas Malone (London) to Francis Ronalds, 26 July 1848, IET 1.3.209.
29. Letter, Thomas Malone to Henry Talbot, 17 February 1849, British Library Add MS 88942/2/80; also Correspondence of William Henry Fox Talbot, <http://foxtalbot.dmu.ac.uk/> (9 July 2015).
30. Unused photographic paper, gelatine sheet tracings and prints, 1848–50, IET 1.7.4.
31. Ronalds 1848 (reference 26).

Despite 'much time and pains',[31] Ronalds' exacting standards could not be reached, so he turned to Daguerre's method in early 1849.[32] He then needed to optimise his workflow anew and, in this period, interactions with practitioners Richard Beard, Antoine Claudet and Thomas Richard Williams are recorded.[33] Daguerreotypes had inherent advantages over paper in their sensitivity to light and image sharpness, and a step-change in precision proved to be possible. Lines on Ronalds' magnetograms were sufficiently sharp to be quantified consistently to an accuracy of 0.05 mm (1/500th of an inch) with the aid of his finely divided measuring board and its magnifying lens.[34] The high precision had the immense value of enabling both severe magnetic storms and typical daily movements of the magnetic needle to be read from a single curve.

Disadvantages of the Daguerreotype included the cost of the silvered plates and the time and labour of processing. The most critical problem Ronalds needed to solve however was a means of copying the impressions and then reusing the plates, for it was too expensive to preserve them. He developed a method of tracing the images using gelatine sheet in 1850; the tracing could then be inked and printed in the manner of a copperplate.[35]

Ronalds chose the Daguerreotype process for an extended formal trial of his instruments funded by the Royal Society and conducted at the Kew Observatory in 1851.[36] Richard Nicklin was employed as his 'photographist'[37] in this period, whom he had met through Beard.

It was around this time that the waxed-paper technique was developed by Gustave le Gray,[38] and it was found to have significant advantageous for the machines. It was first introduced to Ronalds' barograph and thermograph at the Radcliffe Observatory in Oxford in 1854 by (later Sir) William Crookes.[39] Waxed-paper in turn was replaced by gelatinised paper in Ronalds' machines in the 1880s as photography continued to mature.[40]

Take-up of the instruments and their legacy

Ronalds retired from Kew in late 1853 and moved to the Continent. He continued to advise and assist observatories, and worked with instrument-makers such as Ignazio Porro in Paris to make new photo-recording instruments.[41] In the early 1860s, several other manufacturers

32. Ronalds 1850 (reference 14).
33. Letter, Richard Beard (London) to Francis Ronalds, 25 May 1849, IET 1.3.280 and Kew Observatory Diary, 28 August 1850 – 31 October 1851, National Meteorological Archive.
34. Kew Observatory Diary (reference 33) and John Welsh, 'Report to Francis Ronalds, Esq., on the Performance of his three Magnetographs during the Experimental Trial at the Kew Observatory', in: *Report of the British Association for 1851*, 1852, 328-35.
35. Ronalds 1851 (reference 14).
36. Welsh 1852 (reference 34) and *Athenæum*, 1851, 748.
37. Ronalds 1852 (reference 12).
38. Hannavy 2008 (reference 20).
39. William Crookes, *A Handbook to the Waxed paper Process in Photography*, 1857.
40. George Whipple, 'Photography in Relation to Meteorological Work', in: *Quart. J. R. Meteorological Soc.*, vol. 16, 1890, 141-146.
41. Ignazio Porro, 'Oscillations Diurnes du Pendule', in: *Cosmos Revue Encyclopédique Hebdomadaire*, vol. 8, 1856, 578-579.
42. Gaston Tissandier (ed. John Thomson), 'Photographic Registering Instruments', *A History and Handbook of Photography*, 1876, 268-286, and Isabel Peres, Maria Jardim and Fernanda Costa, 'The Photographic Self-Recording of Natural Phenomena in the Nineteenth Century', in: Antoni Roca-Rosell (ed.) *Circulation of Science and Technology*, Proc. 4th Int. Conf. ESHS, Barcelona, Nov 2010, 2012, 462-476.
43. David Bryden, 'Quality Control in the Making of Scientific Instruments', in: *Bull. Scientific Instrument Soc.*, No. 88, 2006, 48-59.
44. Peres 2012 (reference 42).
45. Bryden 2006 (reference 43).

also made cameras based on Ronalds' designs for the Lisbon,[42] St Petersburg,[43] Coimbra[44] and Stonyhurst[45] Observatories.

The recordings of Ronalds' photo-barograph at Kew began to be used by the Meteorological Department in 1862 to assist in the earliest UK Government weather forecasts.[46] The Department was reshaped into the Meteorological Office in 1867, with Ronalds' cameras justifying its new form – it comprised a network of observing stations around Britain and Ireland, all provided with standardised photo-recording instruments.[47] The network was coordinated from the Kew Observatory. Updated models of Ronalds' barograph and thermograph were installed in these stations[48] and a total of over fifty of the machines were delivered to observatories around the world in the following decades.[49] They were in use well into the twentieth century and at Kew until the Met Office closed its operations there in 1980.[50]

The magnetographs also met with continuing success, with the *Encyclopedia of Geomagnetism and Paleomagnetism* (2007) advising that they "established the standard technique employed for magnetic observatory recording worldwide for more than a century".[51]

Ronalds' camera designs thus played a significant and sustained role in both weather forecasting and in understanding the perennial perturbations in terrestrial magnetism, both of which have considerable associated economic importance and public interest. The machines were also a major reason why Kew survived its early years under the British Association's umbrella and went on to become arguably the world's premier meteorological and geomagnetic observatory. Ronalds' important contributions to observatory science, and to early photography, have now been largely forgotten. Fortunately several of his original cameras and their later improvements are retained at the Science Museum in South Kensington and at the Museum of the History of Science at Oxford and detailed drawings of them also survive.

Beverley F. Ronalds, London, UK and Perth, Australia
Retired professional engineer and academic. Served as Group Executive at CSIRO (Australia's national science laboratory), Woodside Chair of Oil and Gas Engineering at The University of Western Australia, and Lecturer at Imperial College London. Fellow of the Australian Academy of Technological Sciences and Engineering. Currently publishing the monograph *Sir Francis Ronalds*: *Father of the Electric Telegraph* through Imperial College Press.

46. 'Report of the Kew Committee of the British Association for 1861-62', in: *Report of the British Association for 1862*, 1863, xxxii-xxxix.
47. Edward Sabine, 'Note on Meteorological Correspondence', in: *Proc. R. Soc. Lond.*, vol. 15, 1867, 29-38 and 'Anniversary Meeting', *Proc. R. Soc. Lond.* vol. 15, 1867, 268-288.
48. *Report of the Meteorological Committee of the Royal Society 1867*, 1868.
49. Scott 1885 (reference 3) and Bryden 2006 (reference 43).
50. Frederick Scrase, 'Some Reminiscences of Kew Observatory in the Twenties', in: *Met. Mag.* vol. 98, 1969, 180-186 and Kew Observatory Barograms, 1862-1981, National Meteorological Archive Z26.A-Z27.J.
51. David Gubbins, Emilio Herrero-Bervera (ed.), *Encyclopedia of Geomagnetism and Paleomagnetism*, Springer 2007.

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