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On the connections between hysteresis loops, Sir Alfred Ewing and pigs drawn whilst blindfolded

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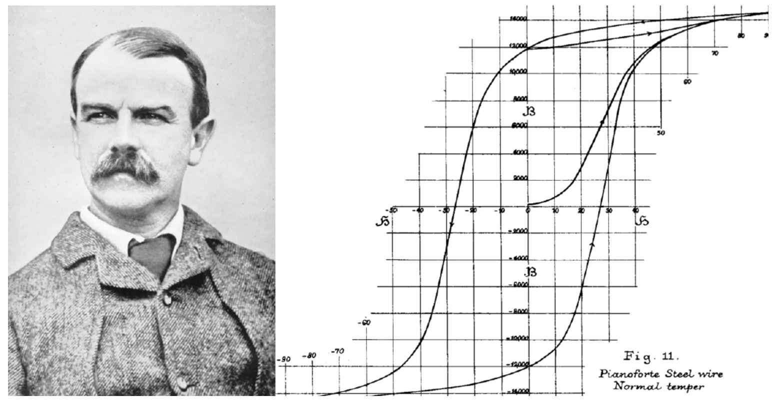
IRM

One of the rites of passage for visiting fellows to the Institute for Rock Magnetism is to draw a pig while blindfolded (or at least with their eyes shut) during our Friday social hour. As Mike Jackson has explained to many a visitor over the years, this IRM tradition was instituted following on the practice of Sir (James) Alfred Ewing who, while entertaining them in his home, invited guests to make such a sketch. It was while researching Ewing for a Spring 2001 IRM quarterly profile that Mike came upon a treasure trove of these "drawn whilst blindfold" sketches in the biography "The Man of Room 40: The Life of Sir Alfred Ewing." These sketches were not made by children visiting the Ewing household. Rather, in the book there are sketches by some of the most accomplished scientists and leaders of the early 20th century including Arthur Eddington, Alexander Graham Bell and Winston Churchill to name but a few. All in all, hundreds of pigs were sketched in Alfred Ewing's 'Pig Book.'

The continuing of Ewing's tradition here at the IRM pays homage to the scientist who first measured hysteresis loops. The reader is encouraged to seek out one of Ewing's early papers (say his 1885 paper Experimental Researches in Magnetism) to see the scores of beautifully documented hysteresis loops resulting from his experiments. He conducted these experiments along with four of his Japanese students while he was on the faculty at the University of Tokyo. One of these loops is reproduced here from an experiment conducted on piano wire (Pianoforte Steel). The observant rock magnetist will note that, in addition to including the major loop, this experiment also included the ZFORC wherein the sample was brought to saturation, brought to zero field and then measured as the field increased back up to saturation (in other words a first-order reversal curve in which the turning point is zero; Yu and Tauxe, 2005). While it wasn't until 2003 that Karl Fabian proposed the rock magnetic parameter of transient energy dissipation (also referred to as transient hysteresis; TH) that can be derived from this portion of the experiment, it is fascinating that data from which such a parameter could be determined dates back to the very first loops.

Not only was Ewing the first to thoroughly document



Left: Photograph of Sir Alfred Ewing taken in 1884 during a holiday in Wales soon after his return from his appointment at the University of Tokyo. Right: Hysteresis loop (note the ZFORC) on piano wire from Ewing's 1885 paper "Experimental Researches in Magnetism."

the phenomena of hysteresis, he also gave it its name. The word hysteresis was proposed by Ewing in 1882 and is derived from the ancient greek word for "to lag behind." Interestingly, Sir William Thomson (more well known by the title Lord Kelvin), who communicated the work to the Royal Society of London, seems not to have been a fan of the word as he added a note to the manuscript that the phenomena be referred to as "effects of retentiveness" rather than hysteresis---going so far as to make sure the manuscript did not include hysteresis in the title and was instead entitled "On Effects of Retentiveness in the Magnetisation of Iron and Steel." However, Ewing was undeterred and continued to use the term throughout his papers and books. It is very much this work that led to Ewing being elected a Fellow of the Royal Society at the age of thirty-two.

It was quite prescient of Ewing to have formulated the definition of hysteresis in the broadest possible sense. He defined it thusly: "When there are two qualities, M and N, such that cyclic variations of N cause cyclic variations of M, then if the changes of M lag behind those of N, we may say that there is Hysteresis in the relation of M to N." In the time since, this phenomenon that was first articulated with respect to the magnetization of materials has been widely adopted as a term in physics, economics, climate science, ecology, physiology, as well as other fields.

Following his five year appointment in Japan, Ewing held professorships at University College Dundee and the University of Cambridge. He was at Cambridge when he

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Visiting Fellows' Reports

Geomagnetic assisted chronologies in the Antarctic Peninsula Region

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The Larsen Ice Shelf System Antarctica (LARISSA) project is a collaborative program whose goal is to investigate the modern geology, glaciology, oceanography, and biology of the Larsen-B Ice Shelf system and the Antarctic Peninsula Ice cap, and apply the modern system relationships to the interpretation of paleorecords (sediment cores and ice cores) of ice shelf behavior and stability (Domack et al., 2012). Our first field season in January-February 2010 included two major work areas on the western Antarctic Peninsula, Barilari Bay and Hugo Island Trough (Fig. 1a), on the inner and middle (respectively) continental shelf of the western Antarctic Peninsula. The sediment sequences recovered from these sites record the retreat of the Antarctic Peninsula Ice Cap following the Last Glacial Maximum (LGM), incursions of circumpolar deepwater onto the continental shelf, and the history of small ice shelves that occupied bays and fjords during the Holocene. One of the main challenges in processing these (and all) Antarctic paleorecords is the construction of a reliable age model.

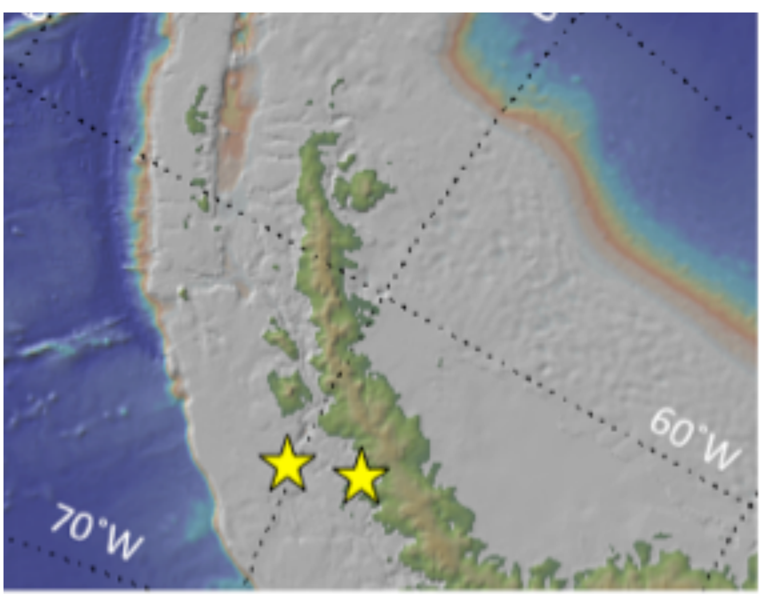

Figure 1. Antarctic Peninsula seafloor bathymetry and locations (stars) of Hugo Island Trough and Barilari Bay, a middle shelf trough and inner shelf bay, respectively (map constructed with GeoMapApp)

The sedimentary records recovered from Barilari Bay and Hugo Island Trough contain diatomaceous muds. Both sites preserve biogenic calcite (mainly calcareous foraminifers) and display magnetic susceptibility values that are higher than most diatomaceous cores from western AP fjords and bays (Brachfeld 2006). This combination is exciting and unique for the Antarctic margin, where diatomaceous muds are typically weakly magnetic and for which biogenic calcite is rarely preserved. A combination of u-channels and 2-cm cubes was used to sample the cores in order to construct paleosecular variation and relative paleointensity records. Some intervals could not be sampled with u-channels due to the presence of large dropstones or disturbance induced by prior sampling. U-channel measurements were made on the IRM's 2G LongCore cryogenic magnetometer with in-line AF demagnetization unit. The natural remanent magnetization (NRM) was stepwise demagnetized in 5-mT increments, followed the acquisition and AF demagnetization of ARM.

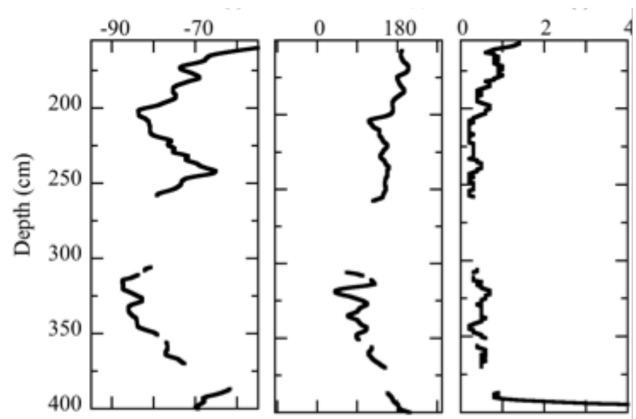

Figure 2. Hugo Island Trough inclination, declination, and maximum angular deviation (MAD) values calculated from principal component analysis (PCA) of the 20-50 mT alternating field demagnetization levels. Data gaps represent dropstone intervals or core disturbance, some of which can be filled using cube samples.

The sediments possess a strong, stable NRM with an easily isolated characteristic component and MAD values < 2˚. The present-day inclination at the study area is -57˚ and the geocentric axial dipole field value for the site latitude is -77˚. Down-core inclination values are largely within this range, with one extended period of steeper inclinations between 300-350 cm. Radiocarbon dating of calcareous foraminifers is currently in progress. Preliminary correlation of the magnetic susceptibility profiles of the Hugo Island Trough and Barilari Bay records with those of nearshore sites such as the Palmer Deep (Domack et al., 2001) suggests these records extend 12,000 years and ~ 7000 years, respectively, and have the potential to increase our knowledge of Holocene geomagnetic field behavior at high southern latitudes.

As always, many thanks to the entire IRM community for their help and their hospitality during my visit.

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Rapid Response:

Chelyabinsk event and magnetic characterization of Chelyabinsk meteorite

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Introduction: As for many Russian scientists, my life and research projects suddenly changed on February 15, 2013 when the small asteroid (later recovered in the form of Chelyabinsk meteorite fragments) exploded in a spectacular fireball in the atmosphere above the Chelyabinsk region (Russia). The Vernadsky Institute of Geochemistry and Analytical Chemistry of the Russian Academy of Sciences (GEOKHI) is the Russian organization officially in charge of the national collection of extraterrestrial materials and was responsible for collection, characterization, and storage of Chelyabink meteorite fragments as well declaration of this new Russian meteorite to the Meteoritical Society (USA).

A scientific expedition, organized by GEOKHI and headed by Dr. D.D. Badjukov, resulted in a collection of >450 meteorite fragments with total mass ~3.5 kg.

The Chelyabinsk meteorite was classified as an LL5 ordinary chondrite (LL for «low iron-low metal»; petrological type 5 refers to thermal metamorphism of ~ 650-700°C), shock stage S4 (moderately shocked up to 30-35 GPa), and weathering W0 (as it is a fall not a find, there are no traces of terrestrial weathering). The majority (2/3) of stones are composed of a light lithology with a typical chondritic texture (Fig. 1a). A significant portion (1/3) of the stones consist of dark fine-grained impact melt (Fig. 1b). There are black-colored thin shock veins in both light and dark lithologies, which were most likely formed as a result of shock metamorphism on the parent body whereas the dark phase (shock melt) was formed as a result of a secondary shock event.

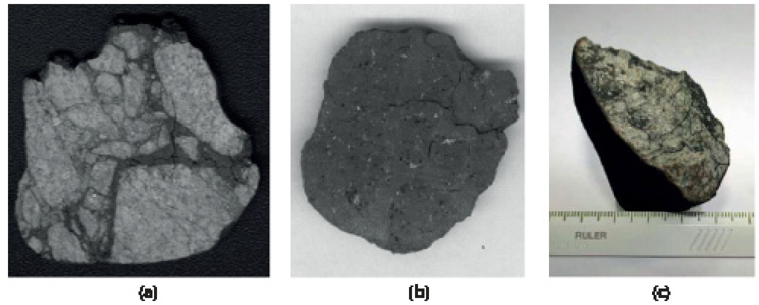

Figure 1. Chelyabinsk meteorite. (a) Light phase; (b) dark phase; (c) typical fragment with fusion crust.

Results: During my IRM visit I carried out a full magnetic characterization of both the light and dark lithologies of the Chelyabinsk meteorite. Previous scans of magnetic susceptibility of >100 Chelyabinsk specimens from Moscow collection (with m> 3g, the criterion for the fusion crust to be neglected with confidence, see Rochette et al., 2003) showed that log(χ) of the shock melt is slightly higher than log(χ) for the light phase (log(χ) (in 10^{-9} m^3/kg): 4.65±0.09 (38 specimens) for the dark phase against 4.54±0.10 (66 specimens) for the light phase) indicating that shock melt is richer in metal. On the basis of magnetic susceptibility, both light and dark lithologies fit well with typical LL5 data (Rochette et al., 2003), being slightly richer in metal than an average LL5.

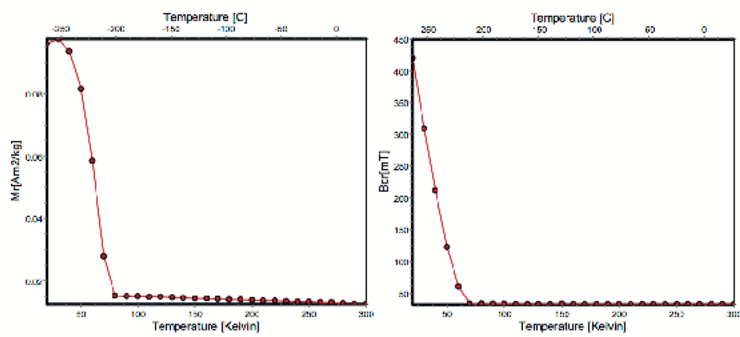

Figure 2. Saturation remanence and remanent coercivity versus temperature for a sample of light lithology (measured using cold VSM)

Magnetic remanence of the Chelyabinsk meteorite at room temperature is dominated by nickel iron: kamacite (bcc) and taenite (fcc). No tetrataenite was found (as indicated by low Bc and Bcr values: typical room temperature Bc< 1 mT, Bcr ~15-20 mT against e.g., Bcr=120-160 mT for previously investigated L4 ordinary chondrite Saratov, where magnetic remanence was dominated by tetrataenite, see Bezaeva et al., 2010). Magnetic properties of Chelyabinsk at low temperatures (see Fig. 2) are clearly dominated by chromite ($FeCr_2O_4$), which undergoes a ferrimagnetic-to-paramagnetic transition at ~75K (Gattacceca et al., 2011).

Investigations of the Chelyabinsk event and Chelyabinsk meteorites are of great interest at the moment and an acquisition of new data and new information takes place daily. Reconstruction of the orbit of the Chelyabinsk meteoroid (published one week after the Chelyabinsk event!) by Zuluaga & Ferrin (2013) allowed classification of the meteoroid among the near Earth asteroid families; presumably its parent body belonged to the Apollo asteroids. The Chelyabinsk meteorite was the subject of a big press-conference in Moscow with all main Russian TV channels on March 14, 2013 and a joint research seminar at Sternberg Astronomical Institute (M.V. Lomonosov Moscow State University, Moscow) as well as a NY Times article from March 25, 2013 (by H. Fountain). It is likely that a special session of Chelyabinsk meteorite will be organized at the 76th Annual Meeting of the Meteoritical Society (July 29 – August 2, 2013, Edmonton, Canada).

We are looking forward to receiving new information on the Chelyabinsk event & meteorite as a result of joint international scientific efforts and collaborations. Many thanks to IRM to having made the magnetic characterization of Chelyabinsk meteorite possible that fast!

Acknowledgements: I am grateful to Dario Bilardello (IRM), Peter Solheid (IRM) and Mike Jackson (IRM) for their help & assistance with experiments. I would like to thank Joshua Feinberg (IRM), Bruce Moskowitz (IRM), Subir Banerjee (IRM), Pierre Rochette (CEREGE/Aix-Marseille University, France), Mikhail A. Nazarov (GEOKHI RAS, Russia) and Dmitri D. Badjukov (GEOKHI RAS, Russia) for helpful discussions.

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The next Visiting Fellowship application deadline is April 30, 2013.

Current Articles

A list of current research articles dealing with various topics in the physics and chemistry of magnetism is a regular feature of the IRM Quarterly. Articles published in familiar geology and geophysics journals are included; special emphasis is given to current articles from physics, chemistry, and materials-science journals. Most are taken from INSPEC (© Institution of Electrical Engineers), Geophysical Abstracts in Press (© American Geophysical Union), and The Earth and Planetary Express (© Elsevier Science Publishers, B.V.), after which they are subjected to Procrustean culling for this newsletter. An extensive reference list of articles (primarily about rock magnetism, the physics and chemistry of magnetism, and some paleomagnetism) is continually updated at the IRM. This list, with more than 10,000 references, is available free of charge. Your contributions both to the list and to the Current Articles section of the IRM Quarterly are always welcome.

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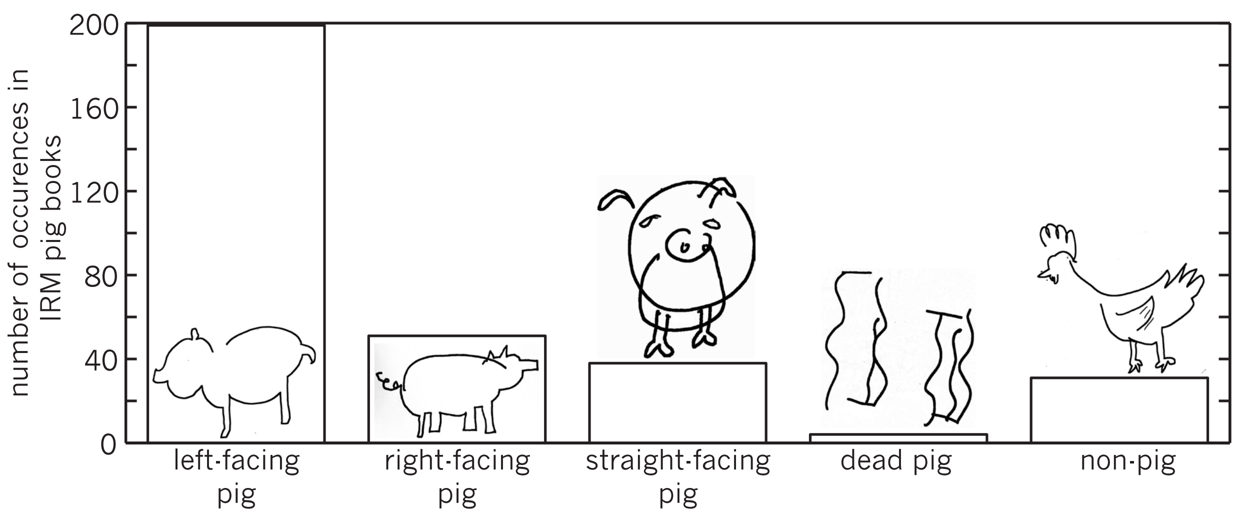
Sir Alfred Ewing and Pigs (continued from pg. 1)

was appointed to the post of Director of Naval Education. The powers that be had come to the realization that a naval officer could not simply be a seaman, but must be "a man of science as well." This connection to the Navy led to Ewing's subsequent work during the First World War as the leader of the British cryptoanalysis effort in a section referred to through the war effort as "Room 40." This effort was greatly aided by a German naval codebook recovered by the crew of two Russian vessels who just a few weeks into the war destroyed a German ship in the Gulf of Finland. Under Ewing's leadership, "Room 40" is credited with playing an important role in multiple naval engagements through their decryptions. Ewing's next appointment was at Edinburgh where he returned for an appointment as Vice-chancellor. He had done his graduate work there as a student of Fleeming Jenkin, who had recommended him for the appointment in Tokyo where his research on magnetism took off.

It was during this time back in Edinburgh that the pig sketches were made in the 'Pig Book' at the Ewing residence. Ewing's house at 16 Moray Place in central Edinburgh is only two kilometers away from the Arthur's Seat hill comprised of Carboniferous volcanics. Alfred Ewing would have known that the magnetite in those basalts would yield beautiful hysteresis loops. Perhaps he was even aware that, contrary to his assertion in *Magnetic Induction in Iron and Other Metals* that magnetite "is the only substance that shares with iron, nickel and cobalt the distinction of being strongly magnetizable," hysteresis loops were being developed from natural crystals of hematite in the lab of T. Townsend Smith at the University of Kansas (Smith, 1920). We know that in addition to the prodigious tasks of administration that he took on at the University of Edinburgh, Ewing still thought about things magnetic and although he described himself in 1930 as "a hopelessly old-fashioned magnetician" when opening the discussion on magnetism of the Physical Society, he continued to argue strongly for the study of ferromagnetism so that the then poorly understood phenomena could eventually be understood.

So why did this distinguished scientist have his distinguished guests do these undistinguished sketches in his home? The practice of drawing a pig while blindfolded originated as a drawing-room game in 19th century England. It was popularized by The Strand Magazine, a monthly serial in which the Sherlock Holmes short stories were first published, and which in 1899 published a



Orientation data for the 323 "pigs drawn whilst blindfolded" sketches in the IRM pig books. The tendency for left-facing pigs was noted in the 1899 article in The Strand Magazine and is pronounced in the compiled data for IRM pigs as well. Kris Asp and Becky Strauss compiled the database of pig sketches utilized for generating this figure.

collection of blindfolded pig drawings by "leading representatives of science, art, literature and society." In the early 20th century, the craze was spreading through North America and one could choose from a number of guest books that were printed with the sole purpose of providing a medium in which blindfolded guests would draw pigs. An advertisement in a 1906 Publisher's weekly for a pig book by the Saalfield Publishing Company of Akron, Ohio proclaims that: "The Pig Book is the novelty of the year and Pig Parties are everywhere. There is no fun equal to that of watching each blindfolded guest draw a pig in the Pig Book."

It seems that Sir Alfred Ewing agreed that there was no fun equal to these shenanigans and one hopes that his guests did too. The Strand Magazine described those whose blindfolded pig drawings appeared in their compilation as having "world-wide renown [that] is only equalled by their ready kindness and courtesy in ministering to the pleasure and benefit of those around them, and their exceeding indulgence in yielding to an audacious request." Here at the IRM, rock magnetists of world-wide renown have also shown such kindness and courtesy while yielding to this audacious request. As can be seen in the collection compiled from the pig book archive, the results compare quite favorably to those drawn by leading intellectuals from a century ago. We can take heart to know that this tradition of absurdity at the IRM was one carried out by the father of hysteresis---a phenomena that is leveraged every day here at the IRM to advance rock magnetic research (including that of the Chelyabinsk meteorite whose time from fall to being measured on an IRM vibrating sample magnetometer might have just set a speed record---see Natalia Bazaeva's piece in this issue).

The section of Ewing's biography associated with the publication of drawings from Ewing's pig book ends with this thought: "One is thus fortunate in being able to prove to succeeding generations that, in the twentieth century, there were some among the intellectualists who, though no longer children, were able to return for a moment to that blissful state from which the wise take care never to depart." Now thanks to the Pig Books at the IRM, we know that rock magnetists the world over are also able, in the twenty-first century, to enter this same state.

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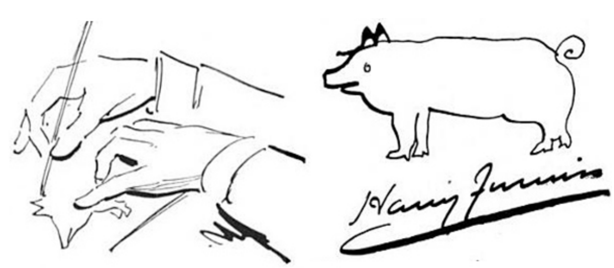
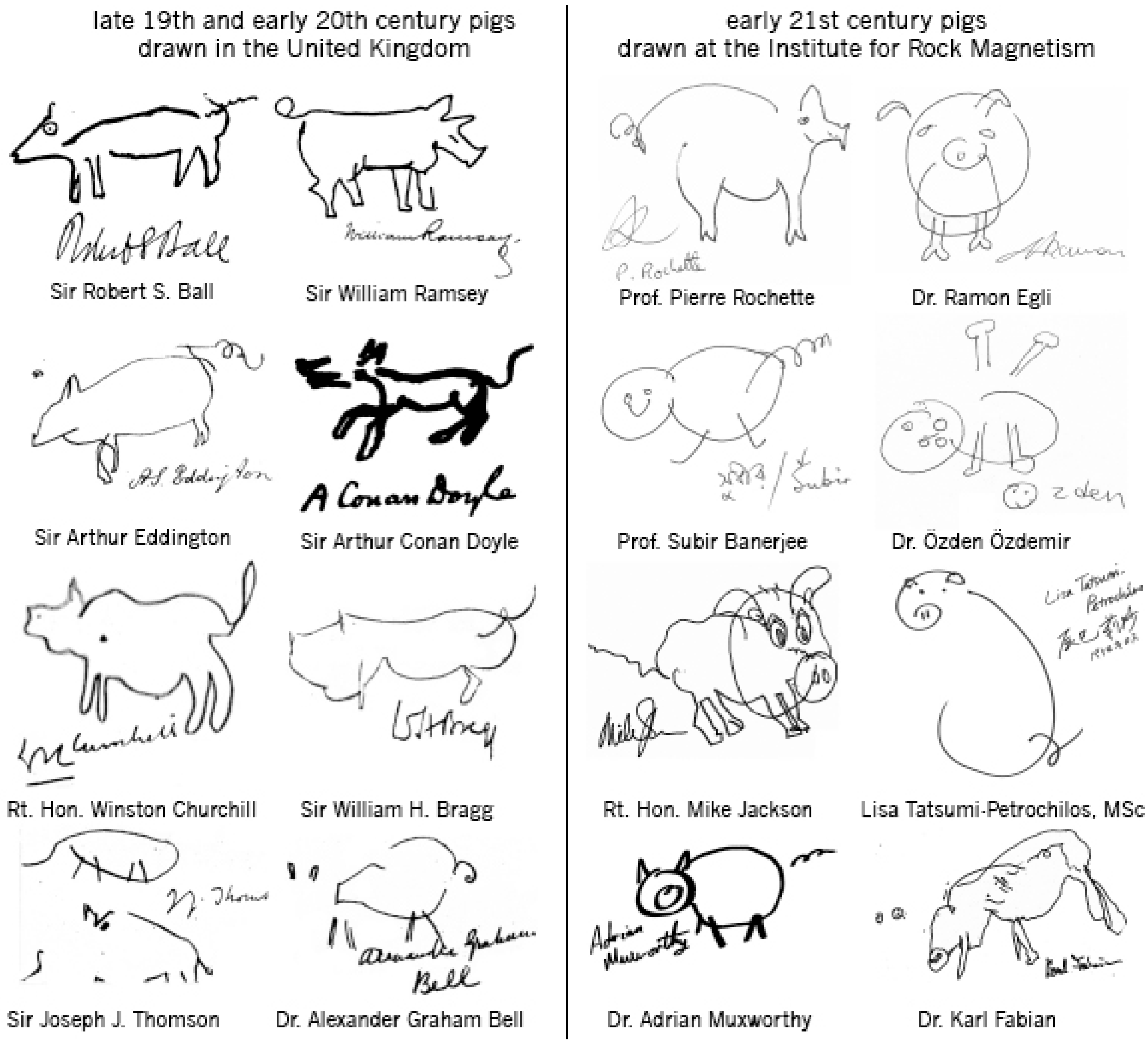
Tips for success with blindfolded pig sketches

There are many of us whose efforts to draw pigs whilst blindfolded have not been to the level of excellence that we are accustomed to achieving in other pursuits (such as in the measurement of hysteresis loops). Thankfully, in 1899, Strand Magazine published a letter from a Mr. Harry Furniss that provides clear guidance to achieve optimal results. He wrote: "With pleasure, I inclose my first attempt for you, but it is by no means my best blind pig. I have a trick in drawing with my eyes shut. It is not a difficult one---perhaps you would like to try it. Simply use your left hand as a guide. In drawing a pig with your eyes shut, use the little finger of the left hand to start from, by touch. (keep the left hand on the paper firmly.) Beging with the ears of the pig, then the head, legs, tail---and you can then feel the pen traveling along the back 'till it comes over the little finger again.Then you have the eye a little lower. Don't give this away until you have your piggery full. Wishing you every success.---Believe me, yours sincerely, Harry Furniss." Perhaps these tips will lead you to draw a pig of higher quality on your next IRM visit. If not, you may make Mike happy by drawing the most grotesque pig of all.



Mr. Harry Furniss on "Blindfolded Pigs", 1899, Strand Magazine, Volume 17, page 491.



Selections of pigs drawn whilst blind-folded from the Pig Book of Sir Alfred Ewing (Eddington, Churchill, Bragg, Thomson, Bell), the Strand Magazine (Ball, Ramsey, Doyle) and the IRM Pig Books. The left panel includes drawings by: Sir Robert Ball--Irish astronomer and mathematician who made important early observations and discoveries of nebulae. Sir William Ramsey--Scottish chemist who discovered the noble gases and won the 1904 Nobel Prize in Chemistry for the discovery. Arthur Eddington--British astrophysicist known for his work on the structure and evolution of stars and relativity. Arthur Conan Doyle--Scottish physician and writer, well-known for his stories about Sherlock Holmes. Winston Churchill--British Prime Minister from 1940-1945 and 1951-1955, winner of the Nobel Prize in Literature. William Bragg--British physicist who shared the 1915 Nobel prize with his son Lawrence for their work on x-ray diffraction and crystal structure. J.J. Thomson, British physicist who discovered the electron, invented the mass spectrometer and won the 1906 Nobel Prize in Physics for his work on electrical conductivity of gases. The right panel includes drawings made at the IRM by rock magnetists whose work collectively has been cited 11,835 times.

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