From Paper to Pixels: Preserving the Earth's Magnetic History

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The earth’s magnetic field is a powerful source of information about our planet’s structure and evolution, as well as tool for practical endeavours such as navigation and studying space weather. Our project, in collaboration with Ingenium, aims to digitize and analyze historical magnetograms dating back to 1858. These records, preserved at the Natural Resources Canada Geomagnetic Laboratory, provide invaluable insights into the Earth’s magnetic field variations and space weather over a long period of time. By leveraging advanced algorithms and crowdsourced data correction, we are creating a comprehensive digital archive that will enhance our understanding of geomagnetic phenomena and their impact on modern technology.

Magnetograms, dating back to the late 19th to early 20th centuries before the advent of digital recording, are graphical representations of the Earth's magnetic field variations, recorded and preserved by exposing special light-sensitive photo paper to the small movements of magnetic needles. These historical records are invaluable for studying geomagnetic storms, space weather, and the evolution of the Earth’s magnetic field over time. Magnetograms typically measure three components of the Earth's magnetic field: magnetic declination, magnetic inclination, and the horizontal component. These records capture daily measurements and preserve them on photographic paper. The continuous day-to-day recording of these components over 150 years, starting with the photo paper records and continuing into the digital age, provides a rich dataset that remains partly untapped. The significance of these magnetograms extends beyond their historical value, as they offer insights into the dynamics of the Earth's magnetosphere and its interaction with solar activity. Analyzing these records help us better understand long-term changes in the geomagnetic field and contribute to models predicting space weather, implications for satellite operations, communication systems, and even power grids.

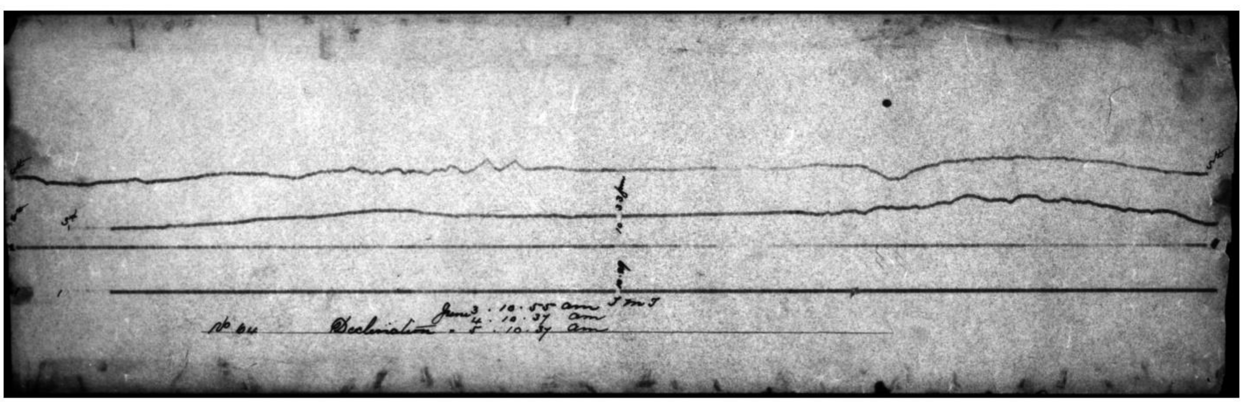

Figure 1: Toronto, 1876 Declination Magnetogram. The top two irregular curves are the daily magnetic field strength readings, while the bottom two straight lines are the baseline and timing records for the days.

A typical magnetogram includes data for two days (represented by the top two lines), a baseline for each day's recording (the two straight lines), and additional hand-written remarks that provide context for the recorded data. These remarks might include information about the type of magnetogram and other pertinent details, assisting researchers and analysts in interpreting the data. Given the vast number of magnetograms—approximately 32,000 photos—an efficient method for analyzing them is essential. A long-running research project, started at Queen’s University and continuing at Trent University, has developed algorithms for processing these images by converting them into matrices of 1s and 0s, representing white and black pixels. This algorithm automatically identifies and traces the top lines of data in most images by detecting peaks in the matrix representations where columns of white pixels appear, indicating the presence of a line.

Challenges arise in the digitization process when there is significant magnetic activity, causing the readings to cross each other and resulting in complex, tangled lines. In these instances, the algorithm can struggle to accurately trace the lines. To address this, we have developed an interactive web application that allows public volunteers to contribute to the project by manually drawing pilot lines over these problematic magnetograms, effectively "fixing" them for the algorithm by giving a reference that allows the trace routine to follow the criss-crossing magnetic field measurements correctly.

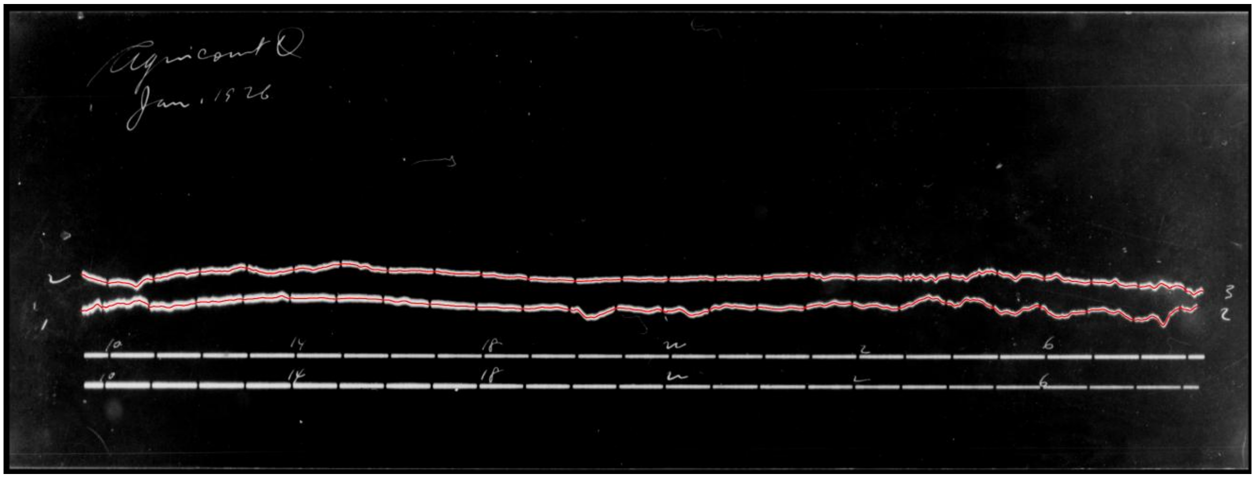

Figure 2: Traced Magnetogram Agincourt, 1926 Declination, with fit data line in red traced overtop. Again, the top two lines are daily records, while the bottom two lines are the baseline and timing references. Note the more apparent visibility of the timing ticks as the regular breaks in the lines – this was the mechanism used to track the hour in the original analog recordings.

Our interactive app serves as a platform for crowdsourced data correction. Volunteers can examine magnetograms, draw correction lines where needed, and submit their fixes. This collaborative effort not only enhances the accuracy of our data but also engages the community in meaningful scientific research. Once a trace is "fixed," users can vote on its accuracy, with the results stored in a reference database, creating a system where the quality of corrections is continually evaluated and improved. Over time, this process helps filter out the accurately fixed traces from consideration, allowing volunteers to focus more on the unfixable or harder-to-fix traces.

References

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