PROCESSING ARTIFACTS IN THE GRAVITY AND MAGNETIC DATA OF

THE WABEHUCA (Wadena, Becker, Hubbard, Cass Counties) STUDY AREA: SOME CAVEATS

Val W. Chandler

Minnesota Geological Survey

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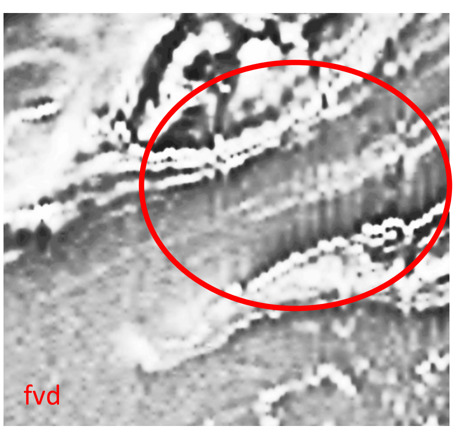
Introduction

Precambrian bedrock in the Wadena, Becker, Hubbard, and Cass (WaBeHuCa) County Geologic Atlas study area are almost completely covered by thick Quaternary glacial sediments. In the absence of deep drill holes, geophysics provides the only means of investigating geology, both at the bedrock surface and deeper. Included in this package are the results of inverse modeling (geophysics_data_point_models) assuming planar (Euler) or pipe-like (Keating) sources, as well as the results of forward modeling, assuming two-dimensional (strike-infinite) sources (grav_mag_model_sections). These models are valuable for visualizing geologic cross-sections to depths of several kilometers however; geologic mapping of the bedrock surface has relied mostly on map-images of processed gravity and magnetic data (regional_gravity_mag_maps).

As useful as these map-images have been, however, one should always be mindful of various artifacts that are present in the data, and the remainder of this document will describe the most serious of these. Artifacts can arise in a variety of ways, including errors in flight path recovery and leveling of the aeromagnetic data, imperfections in sampling and gridding of aeromagnetic and gravity data, the effect of side-lobes in derivative-enhanced aeromagnetic and gravity data, and distortions from filtering extremely strong, spike-like peaks in the magnetic anomaly data.

Aeromagnetic Artifacts Associated with Errors in Flight Line Recovery and Leveling

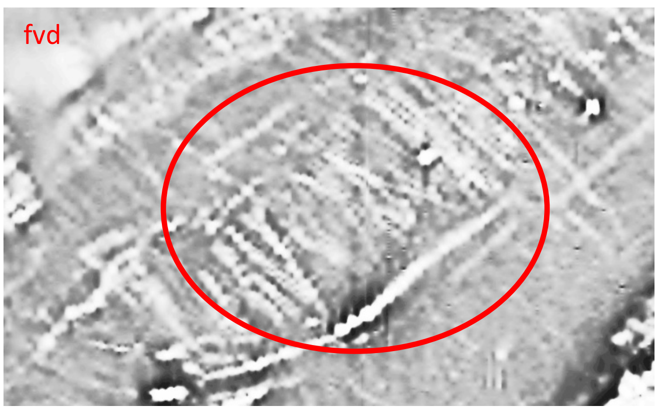
During the original survey program and the subsequent upgrade (Chandler, 2007), every effort was made to minimize errors associated with flight path recovery and leveling, but a few problem areas persist. One such problem area is Mille Lacs Lake, part of which underlies the southeastern corner of the study area. Acquisition in this area predated the Global Positioning System, and flight path recovery was by dead-reckoning between photo-picked locations at opposite shores of the lake, which were typically over 25 km apart. The only option at the time was to eliminate those flight-line segments that caused the worst artifacts and accept the remainder as-is. The resulting errors in flight path recovery and leveling are manifested by north-south striping, which can be observed in the vicinity of UTM (448000, 5128400; Nad83, Z15N), both in the first vertical derivative (WaBeHuCa_mag10_micro_fill_rtp_fvd_v2) and second vertical derivative



(WaBeHuCa_mag10_micro_fill_rtp_svd_v2) maps. Similar north-south stripping in the derivative data occurs intermittently over other parts of the study area, most commonly in the vicinity of strong magnetic highs; these artifacts are most likely related to minor locational or tie-leveling errors in high gradient areas.

Aeromagnetic and Gravity Artifacts Associated with Gridding Unevenly Distributed Data

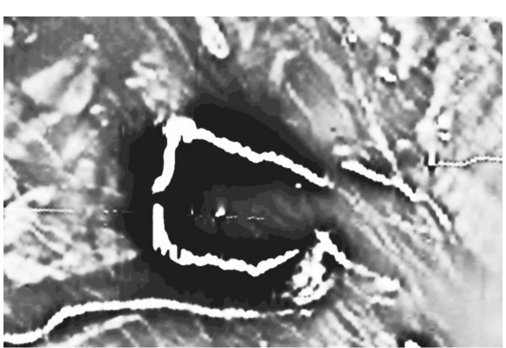
Some artifacts are caused by problems that are associated with evenly spaced gridding of data points that are actually unevenly distributed. Many parts of the state were surveyed using aeromagnetic flight lines that were flown at a height of 150 meters above ground and spaced approximately 400 meters apart. Along-line sampling is adequate at 46-75 meters, but the relatively wider line spacing of 400 meters between lines equates to a line-spacing/height ratio of 2.67, which is high relative to recommended ratios of 2 to 1 for reliable contour and derivative maps, respectively (Reid, 1980). One manifestation of this sampling problem is that minimum curvature gridding of narrow, linear magnetic anomalies, such as those caused by diabase dikes, tend to form bead-like highs at flight-line crossings. These can become quite pronounced in derivative-enhanced data. In the case of dike swarms, where sub-clusters of tightly-spaced dikes occur, the beads tend to align, collectively creating a subtle array of tightly spaced linear trends perpendicular to the dike trend. One such area is in the vicinity of UTM



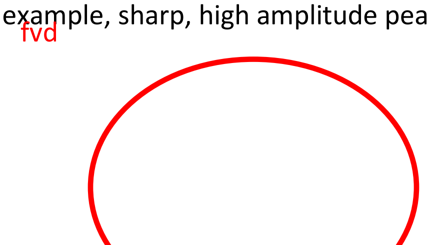
(370500, 5141200; Nad83, Z15N), where both the first vertical derivative (WaBeHuCa_mag10_micro_fill_rtp_fvd_v2) and second vertical derivative (WaBeHuCa_mag10_micro_fill_rtp_svd_v2) maps show a subtle northeast-striking cross-chatter within a small cluster of northwest-striking dikes. Similar cross-chatter effects occur elsewhere in the study area, most commonly within clusters of tightly spaced linear anomalies. While some actual sources may locally exist along these cross-dike trends, most of this tightly spaced cross-chatter is interpreted to be sampling and gridding artifacts.

Some sampling-related problems also exist with the gravity data. Ground-based stations have been acquired at one-mile intervals along drivable roads and trails, but many large coverage gaps persist over large lakes and swamps. Gridding in these large coverage gaps are likely to produce artifacts, especially with derivative-enhanced data. One such gap corresponds to Mille Lacs Lake in the southeastern part of the study area. When using gravity map-images for geologic mapping, the original distribution of stations should always be considered.

Filter Instabilities: Side-Lobes and Other Effects

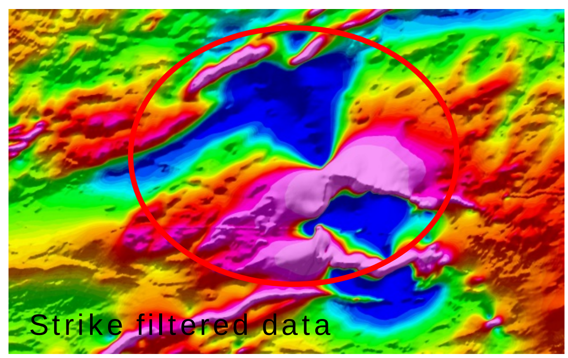


Derivative filters are somewhat oscillatory by nature, and among the more common artifacts are side-lobes. For example, sharp, high amplitude peaks in the derivative-



enhanced aeromagnetic data are commonly associated with pronounced lows that closely wrap around the derivative peaks. Examples of bright highs accompanied by dark rims occur abundantly in both the first vertical derivative (WaBeHuCa_mag10_micro_fill_rtp_svd_v2) and second vertical derivative (WaBeHuCa_mag10_micro_fill_rtp_svd_v2) maps. These wrapping lows are most likely side-lobe effects, and do not necessarily indicate low or reverse magnetism in the wall rock. Similarly, prominent belts of strongly positive anomalies in the second vertical derivative of the gravity data are commonly flanked by pronounced lows. This anomaly configuration is particularly evident in the west-central and northwestern parts of the second vertical derivative (WaBeHuCa_grav_2014_all_svdu2_mil_v2). The prominent highs observed here most likely reflect high-density metavolcanic rocks, but the significance of the flanking lows is somewhat more problematic. In some situations such lows could actually reflect low-density rocks, but in others they could reflect, at least in part, a side-lobe effects associated with axial highs. Quandaries of this sort demonstrate the pitfalls of assigning relative rock property values on the basis of derivative data only.

Extremely strong magnetic anomaly peaks can have an adverse effect on other types of filtering, such as strike-sensitive filtering. One example lies near UTM coordinates 317200, 5189300 (Nad83, Z15N) where a fold hinge in an Archean iron-formation is associated with a magnetic high that is over 10,000 nT in amplitude (see map WaBeHuCa_mag10_micro_fill_v2). A strike-reject filter was applied in this area along a 330 degree azimuth to eliminate the interfering effect of northwest-striking dikes, leaving the northeast-striking signature of the Archean rocks (map WaBeHuCa_mag10_micro_fill_rtp_330rj_v2). Although this filtering was useful for mapping the Archean rocks of the area, it produced a peculiar, wedge-shaped, negative anomaly, north of the extreme magnetic high, This anomaly showed little correspondence with the unfiltered total field anomaly data (compare with map WaBeHuCa_mag10_micro_fill_v2), and is consequently rejected as an artifact. Similar cautions would seemingly be appropriate for any strike-filtered data in the vicinity of extreme-amplitude anomalies.



Conclusions

Map-images of gravity and magnetic data are essential to mapping the largely concealed Precambrian bedrock of Minnesota, but the interpreter has to always be vigilant and beware of and separate artifacts from potential anomalies. The artifacts that are mentioned above have only a minor presence in the data, but they can lead to major interpretational errors if the appropriate precautions are ignored. On the other hand, if the cautions are heeded, the interpreter can use processed gravity and magnetic data with a much higher degree of confidence, leading to improved geologic mapping.

References

Chandler, V. W., 2007, Upgrade of Aeromagnetic Databases and Processing Systems at the Minnesota Geological Survey: Minnesota Geological Survey Open File Report OFR 07-06. Retrieved from the University of Minnesota Digital Conservancy, http://hdl.handle.net/11299/199777.

Reid, A. B., 1980, Aeromagnetic survey design: Geophysics, v. 45, p. 973-976.

Appendix A. Explanation of Abbreviations Used in Map-Image File Names

During the gravity and magnetic studies for a given project, a variety of processing options are attempted on each map grid, leading to confusing multitude of files. To help keep track of what operations were done to which files, a short-hand of abbreviations were incorporated into the file names, as explained below.

330rj – Strike-reject filter, direction cosine along an azimuth of 330 degrees, to attenuate the contribution of a northwest-striking dike swarm.

330ps – strike-pass filter, direction cosine along an azimuth of 330 degrees, to emphasize the contribution of a northwest-striking dike swarm.

csr – color shaded relief format, used to distinguish from map-image WaBeHuCa_mag10_micro_fill_rtp_fvd_330rj_v2 , which is presented in gray-scale.

fill – interpolation fill at off-site values which sporadically occurred during compositing of the state-wide grids of aeromagnetic data

fvd – first vertical derivative

grav_2014 – Designates gravity data from the state-wide database as of 2014

mil -- multiplied by one-million,. This was for second vertical derivative gravity data, which were originally output in milliGals/m^2, which resulted in extremely small numbers that could not be properly handled by some of the graphic display options. Multiplying by one-million converts the data into much more manageable units of milliGal/km^2.

Mag10 – Designates gridded aeromagnetic data that were upgraded in 2010 from the state-wide compilation of Chandler (2007). This latest upgrade was primarily focused on improving the merging with Wisconsin and Lake Superior data, and should not have significantly affected the data in this part of Mn.

micro – designates aeromagnetic data that were micro-leveled (see Chandler, 2007)

rtp – reduced to pole (vertical polarization)

svd – second vertical derivative

svdu2 – second vertical derivative of gravity, upward continued 2 km. to mitigate noise

v2 – version 2 of the map-image suite, reflecting an enlargement of the study area. The ordinal study area did not include all of Cass County. Once the Cass CGA was initiated, the study area was expanded to include all of Cass County, and a new suite of map-images was produced.