New airborne magnetic data evaluate SWEAT reconstruction

C. A. Finn[1] and S. Pisarevsky[2]

[1]U.S. Geological Survey, Denver Federal Center, Denver, CO 80225, USA (cfinn@usgs.gov)
[2]School of GeoSciences, The University of Edinburgh, Grant Institute, The King's Buildings, West Mains Road, EDINBURGH EH9 3JW, U.K.

Summary Airborne magnetic data provide a means for guiding reconstructions of Precambrian continents, in particular the hotly debated western continuations of Laurentia, in that the magnetic data tie existing isolated interpretations of geologic units through continuous data coverage, provide plate scale views of geology and tectonics and extend interpretations of units buried beneath cover. The aim of this paper is to demonstrate the approach of using reconstructed magnetic data to evaluate the SWEAT plate reconstruction. The first step is to identify key piercing points in the SWEAT plate reconstruction model, determine the sources of magnetic anomalies associated with those piercing points and then match anomalies across continental boundaries.

Citation: Finn, C. A. and S. Pisarevesky (2007), New airborne magnetic data evaluate SWEAT reconstruction**,** in Antarctica: A Keystone in a Changing World – Online Proceedings of the 10th ISAES X, edited by A.K. Cooper and C.R. Raymond et al., USGS Open-File Report 2007-1047, Extended Abstract 170, 4 p.

Introduction

Airborne magnetic data provide a means for guiding reconstructions of Precambrian continents, in particular the hotly debated western continuations of Laurentia, in that the magnetic data tie existing isolated interpretations of geologic units through continuous data coverage, provide plate scale views of geology and tectonics and extend interpretations of units buried beneath cover. Recent release of digital continental-scale aeromagnetic compilations [*ADMAP group*, 2001; *Milligan and Tarlowski*, 1999; *Ministry of Geology of the U.S.S.R.*, 1974; *NAMAG*, 2002] as well as new aeromagnetic data from Antarctica [*Anderson et al.*, 2006; *Studinger et al.*, 2004; *Studinger et al.*, 2006] that provide a glimpse of the sub-ice Precambrian geology in critical areas for reconstructions allow us to use them for plate-tectonic scale reconstructions. Attempts have been made on a local scale to use the continuity of aeromagnetic anomalies as a means to link Precambrian continents [*Bird and Roest*, 1998; *Sears and Price*, 2003] but these efforts were hampered by the lack of digital data. Reconstruction of parts of Gondwana with aeromagnetic and satellite magnetic data have been more successful [*Finn et al.*, 2006; *Reeves*, 1998]. In this paper we combine magnetic data, plate reconstructions and regional geologic mapping to help constrain the SWEAT reconstruction of Rodinia. "Piercing points" have been used to match Precambrian cratonic blocks and orogenic belts thought to be pieces of the same ancient continent. These piercing points include coeval and genetically similar Archean to Mesoproterozoic rocks [*Dalziel*, 1991; *Moores*, 1991], Neoproterozoic rifted margins [*Blewett et al.*, 1998; *Ross and Villeneuve*, 2003], apparent similarities in supracrustal successions [*Hanson et al.*, 1998], and detrital zircons and suggested source areas [*Goodge et al.*, 2004] (Fig. 1).

The aim of this paper is to demonstrate the approach of using reconstructed magnetic data to evaluate the SWEAT plate reconstruction. The first step is to identify key piercing points in the SWEAT plate reconstruction model, determine the sources of magnetic anomalies associated with those piercing points and then match anomalies across continental boundaries.

SWEAT magnetic reconstruction

Unlike reconstructions of Gondwana, where the shapes of its various pieces are reasonably well-determined based on palaeomagnetic, palaeontological, geological, and geochronological data [*McElhinny et al.*, 2003], the composition and shapes of the pieces of Rodinia are far less-constrained [*Pisarevsky et al.*, 2003]. Western Laurentia is thought to be rifted away from its ancient continuation during the breakup of Rodinia roughly between 750 and 550 Ma (e.g., *Pisarevsky et al.*, 2003 and references therein). If so, the piercing points and their magnetic signatures must be preserved on the both sides of the suggested conjugate margin. Unfortunately, all the passive continental margins developed since Neoproterozoic eventually became active margins and consequently significant juvenile highly magnetic material has been produced during subsequent accretional and/or collisional events, masking the signal of the older rocks. Despite the short duration of Rodinia (1100-750 Ma), many of the piercing points used in the reconstructions are Archean-Mesoproterozoic in age. Our approach is to compare the magnetic signatures of relatively undeformed portions of the Antarctic and Laurentian cratons. The eastern boundary of relatively undeformed East Antarctic craton is defined by airborne and satellite magnetic and seismic tomography data (Fig. 1) [*Finn et al.*, 2006] In order to examine the SWEAT pinning points (Fig. 1) in the Antarctic magnetic data, the completely overprinted Neoproterozoic rifted margin sources consisting of magnetic quiet zones over rift sedimentary rocks and high amplitude positive anomalies over Paleozoic-Cenozoic igneous rocks [*Finn et al.*, 2006] are ignored and only anomalies inboard of the Neoproterozoic lows are compared to Laurentia (Fig. 2). For Laurentia, the Neoproterozoic boundary has been defined by isotopic, gravity and magnetotelluric data [*Grauch et al.*, 2003; *Kistler*, 1983; *Tosdal et al.*, 2000; *Wooden et al.*, 1998]. We do not attempt to match up the shapes of the continental fragments.

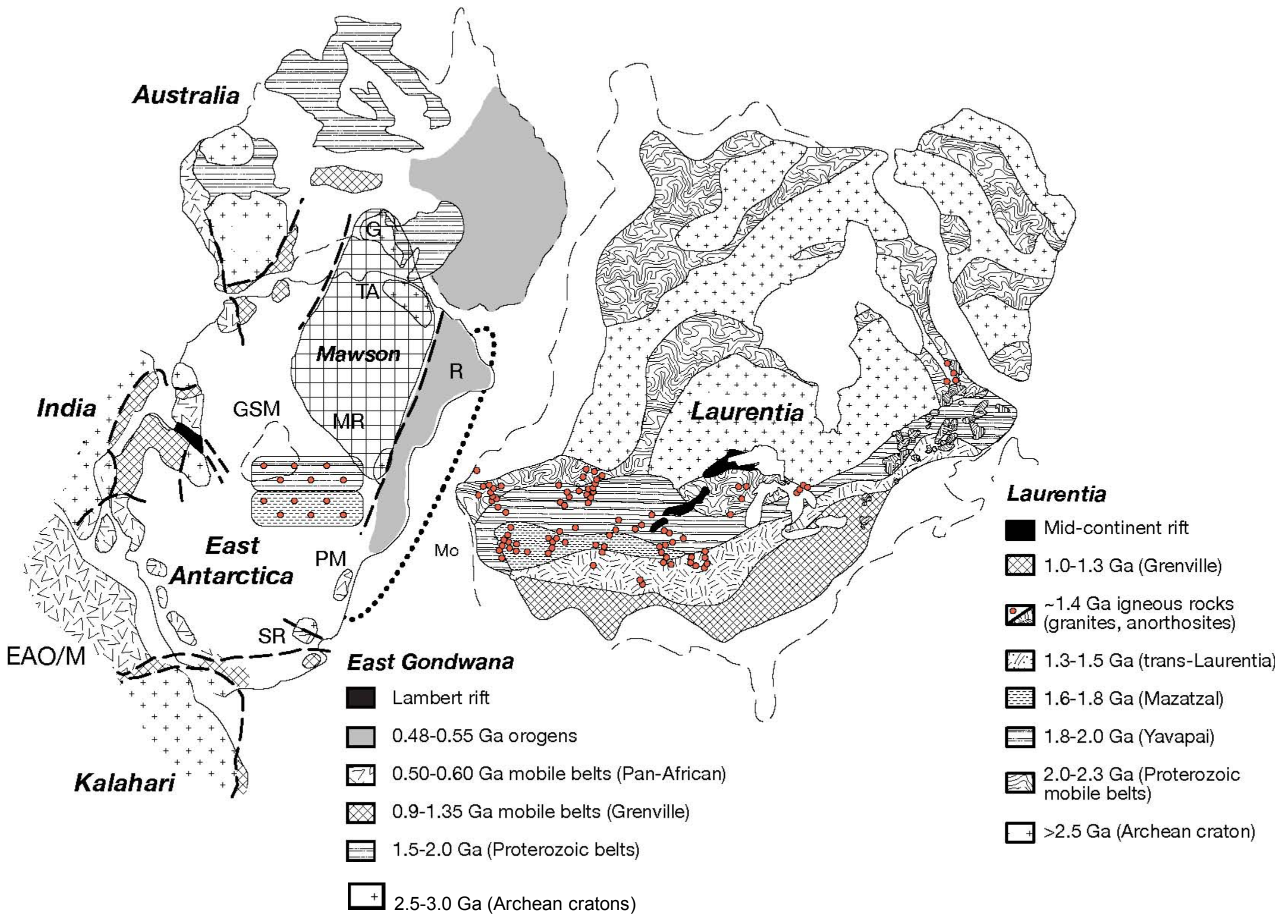

Figure 1. Paleogeographic reconstruction of central Rodinia [from *Goodge et al.,* 2004), emphasizing postulated fit of East Antarctica-Australia and western Laurentia prior to rift separation, based on geologic, age and isotopic correlation. Sedimentary provenance connection between Pandurra Formation (Pa) and Prichard Formation (Pr), indicated by light blue symbols. G = Gawler Province; GSM = Gamburtsev Subglacial Mountains; Mo = Mojave Province; MR = Miller Range; PM = Pensacola Mountains; R = Ross Orogen; SR = Shackleton Range; TA = Terre Adélie.

Aeromagnetic coverage of East Antarctica's proposed Laurentian border consists mainly of isolated profiles and transects with widely-spaced flight lines crossing the polar plateau (Fig. 2). In contrast, the flight line spacing of magnetic surveys over Laurentia is covered by magnetic surveys with line spacing varying from 100 m to 6000 m [*NAMAG*, 2002]. We rotated airborne magnetic data from Antarctica and Laurentia (Fig. 1) into their relative SWEAT positions [*Dalziel*, 1991; *Reeves and de Wit*, 2000]. As the methods used to compile the aeromagnetic data vary, quantitative comparison of maps is not always possible. We compare varying attributes of the magnetic data where possible--anomaly sign and amplitude, wavelengths, and trend. The original Antarctic magnetic data is compared to low-pass filtered magnetic data from Laurentia. The low-pass filtering of the magnetic data over Laurentia reduced the signal related to Cenozoic volcanic rocks that obscure the Precambrian basement, although it is still visible as subtle "bumps" in the Mojave province (Fig. 2) [*Finn and Sims*, 2005].

The main provinces in Laurentia, the Paleoproterozoic Yavapai and Archean Mojave, that have been linked to Antarctica are characterized by magnetic quiet zones reflecting their magnetite-poor character [*Finn and Sims*, 2005]. In contrast, high-amplitude (>400 nT at ~4000 m below the surface) positive anomalies oriented north northwest (in rotated coordinates) characterize the East Antarctic craton in the northern part of the study area (AEROTAM and Miller Range transects, Fig. 2). Sources of magnetic anomalies related to undeformed East Antarctic craton are completely unknown due to lack of exposure, but their complete difference with those found in Laurentia suggest no correlation between the proposed piercing points.

The part of the South Pole transect that is not related to known Phanerozoic rocks is dominated by a 60-km-wide, ~60 nT linear NE-trending (in rotated coordinates) magnetic low flanked on its East Antarctic side by positive 20 and 50 nT highs, and occasional circular shaped anomalies of more than 100 nT and 10–30 km diameter [*Studinger et al.*, 2006]. The magnetic low is flanked by a positive linear anomaly, between 30 and 60 km wide, with amplitudes greater than 150 nT. The minimum depths to these sources are ~ 2500-3500 m. This magnetic signature does not look like the Miller Range or AEROTAM datasets (Fig. 2). The corresponding province in Laurentia is the ~1.4 Ga A-type Granite-rhyolite province (Fig. 1) whose magnetic anomalies from shallow sources and those buried ~5 km deep generally exceed 300 nT [*Finn and Sims*, 2005]. No regional high-amplitude positive magnetic anomalies are observed in Antarctica in this region.

The lack of similarities of magnetic signatures between Antarctica and Laurentia indicate that the piercing points used in the SWEAT reconstruction are not valid. However, geochemical and geochronological data suggest a link between a granite boulder found in the Miller Range and the granite-rhyolite province [*Goodge et al.*, this issue]. This would suggest that the magnetic highs observed over the AEROTAM and Miller Range transects may relate to the highs associated with the ~1.4 Ga Laurentian Granite rhyolite province. If the AEROTAM and Miller Range magnetic highs relate to the same rocks, and are linked to the granite rhyolite province, the SWEAT fit would be moved north by at least 1000 km (Fig. 2). Modeling of the magnetic data from Antarctica and Laurentia will help confirm whether the sources of the magnetic anomalies are similar. Evaluation of the new reconstruction will require examination of the aeromagnetic fit between Mojavia and the Mawson block as well as anomalies associated with Proterozoic rocks in northern Laurentia with the Gawler craton (Fig. 1).

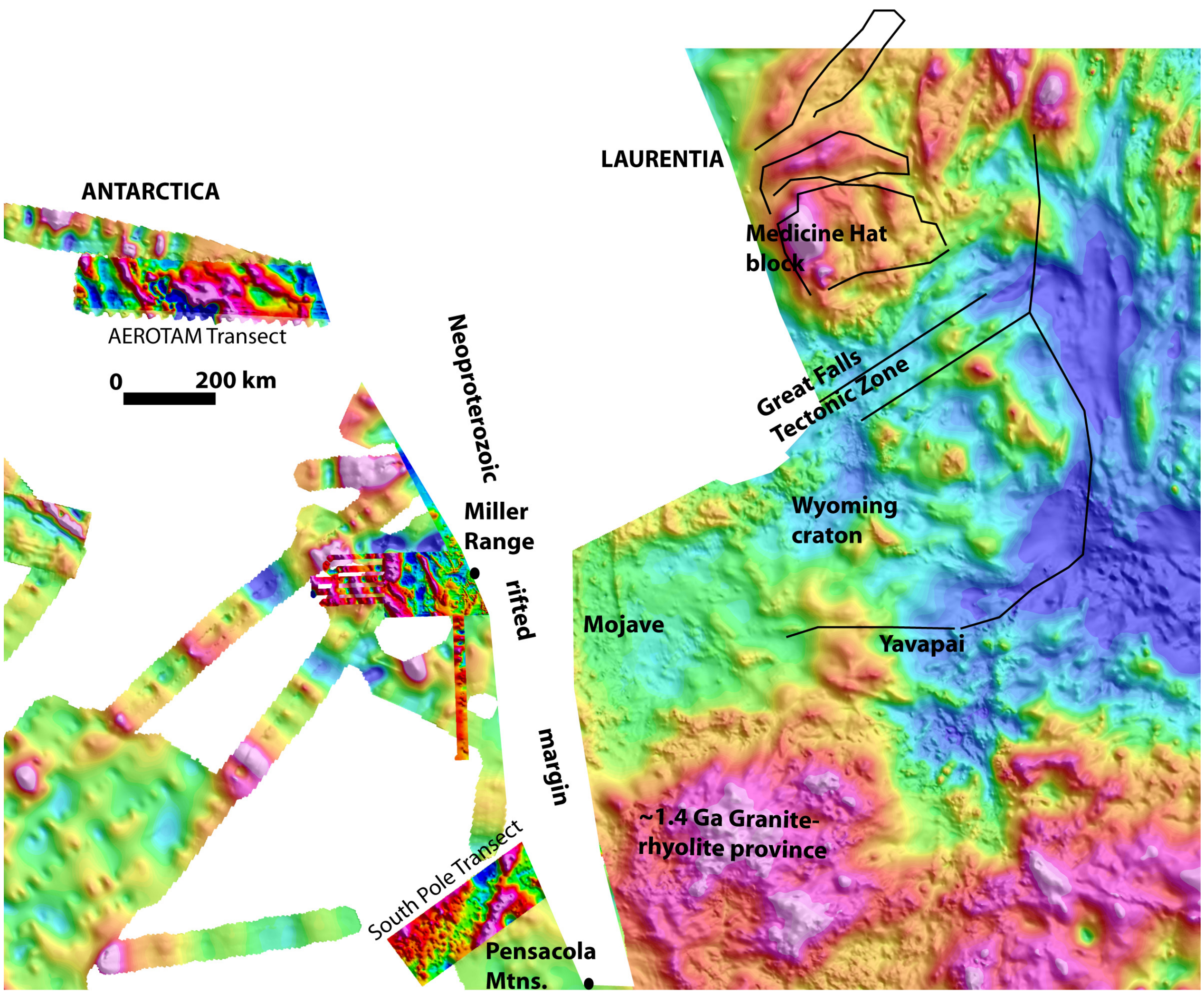

Figure 2. Color shaded-relief image of a merged compilation of aeromagnetic data from Antarctica rotated in the SWEAT configuration (Moores, 1991; Dalziel, 1991) so that it aligns with magnetic data from SW Laurentia filtered to enhance Precambrian basement. Thick black lines delineate Precambrian province boundaries [*Karlstrom et al.*, 2001].

Acknowledgements. We thank Eric Anderson, Ron Sweeney and anonymous reviewers for helpful reviews and John Goodge for providing Figure 1. This work was funded by National Science Foundation Grant OPP-0232042 and U.S. Geological Survey.

References

ADMAP group (2001), ADMAP: Magnetic Anomaly Map of the Antarctic, in British Antarctic Survey Miscellanous Series, Sheet no. 10, scale 1:10,000,000, www.geology.ohiostate.edu/geophys/, edited by P. Morris and R. von Frese.

Anderson, E. A., et al. (2006), Aeromagnetic and gravity data over the Central Transantarctic Mountains (CTAM) – distribution of data and maps, U. S. Geological Survey Open-File Report 2006-1255 (http://pubs.usgs.gov/of/2006/1255/).

Bird, R., T, and W. Roest, R (1998), Another look at Rodinia reconstructions; using continental aeromagnetic and gravity data., in The assembly and breakup of Rodinia; proceedings of a workshop, edited by R. Bird, T., pp. 1-5, Geological Society of Australia, Perth.

Blewett, R. S., et al. (1998), U-Pb zircon and Sm-Nd geochronology of the Mesoproterozoic of North Queensland; implications for a Rodinian connection with the Belt Supergroup of North America, Precambrian Research, 89(3-4), 101-127.

Dalziel, I. W. D. (1991), Pacific margins of Laurentia and east Antarctica-Australia as a conjugate rift pair: Evidence and implications for an Eocambrian supercontinent, Geology, 19, 598-601.

Finn, C. A., and P. K. Sims (2005), Signs from the Precambrian, in The Rocky Mountain Region -- An Evolving Lithosphere: Tectonics, Geochemistry, and Geophysics, edited by K. E. K. a. G. R. Keller, pp. 39-54, American Geophysical Union, Washington, DC.

Finn, C. A., et al. (2006), Scouting craton's edge in Paleo-Pacific Gondwana, in Antarctica - Contributions to Global Earth Sciences, edited by D. D. D. Fütterer, G. Kleinschmidt, H. Miller, and F. Tessensohn, pp. 165-174, Alfred Wegener Institute, Potsdam.

Goodge, J. W., et al. (2004), Provenance of Neoproterozoic and lower Paleozoic siliciclastic rocks of the central Ross orogen, Antarctica: Detrital record of rift-, passive-, and active-margin sedimentation, Geological Society of America Bulletin, 116(9/10), 1253–1279 doi: 1210.1130/B25347.25341.

Goodge, J. W., et al. (this issue), Pieces of Laurentia in East Antarctica, in A Keystone in a Changing World – Online Proceedings of the 10th ISAES X, USGS Open-File Report 2007, Extended Abstract edited by A. K. C. a. C. R. R. e. al., U. S. Geological Survey, Reston.

Grauch, V. J. S., et al. (2003), Geophysical and isotopic constraints on crustal structure related to mineral trends in north-central Nevada and implications for tectonic history, Economic Geology and the Bulletin of the Society of Economic Geologists, 98(2), 269-286.

Hanson, R. E., et al. (1998), U-Pb zircon age for the Umkondo Dolerites, eastern Zimbabwe; 1.1 Ga large igneous province in Southern Africa-East Antarctica and possible Rodinia correlations, Geology, 26(12), 1143-1146.

Karlstrom, K. E., et al. (2001), Long-lived (1.8-1.0 Ga) convergent orogen in southern Laurentia, its extensions to Australia and Baltica, and implications for refining Rodinia, Precambrian Research, 111(1-4), 5-30.

Kistler, R. W. (1983), Isotope geochemistry of plutons in the northern Great Basin, Geothermal Resources Council Special Report, 13, 3-8.

McElhinny, M. W., et al. (2003), Paleozoic terranes of eastern Australia and the drift history of Gondwana, Tectonophysics, 362, 41-65.

Milligan, P., and C. Tarlowski (1999), Magnetic Anomaly map of Australia (Third Edition), edited, AGSO, Geoscience Australia, Canberra.

Ministry of Geology of the U.S.S.R. (1974), Aeromagnetic map of the U.S. S. R.

Moores, E. M. (1991), Southwest U.S.-East Antarctic (SWEAT) connection; a hypothesis, Geology, 19(5), 425-428.

NAMAG (2002), Digital data grids for the magnetic anomaly map of North America, U. S. Geological Survey Open-File Report 02-0414, http://pubs.usgs.gov/of/2002/ofr-02-414/.

Pisarevsky, S. A., et al. (2003), Models of Rodinia assembly and fragmentation, Geological Society of London Special Publication, in press.

Reeves, C. V. (1998), Aeromagnetic and gravity features of continental Gondwana and their relation to continental break-up; more pieces, less puzzle, Journal of African Earth Sciences, 27(1A), 153-156.

Reeves, C. V., and M. de Wit (2000), Making ends meet in Gondwana: retracing the transforms of the Indian Ocean and reconnecting continental shear zones, Terra Nova, 12(6), 272-280.

Ross, G. M., and M. Villeneuve (2003), Provenance of the Mesoproterozoic (1.45 Ga) Belt basin (western North America): Another piece in the pre-Rodinia paleogeographic puzzle, Geological Society of America Bulletin, 115(10), 1191-1217.

Sears, J. W., and R. A. Price (2003), Tightening the Siberian connection to western Laurentia, Geological Society of America Bulletin, 115(8), 943-953.

Studinger, M., et al. (2004), Sub-ice geology inland of the Transantarctic Mountains in light of new aerogeophysical data, Earth and Planetary Science Letters, 220(3-4), 391-408.

Studinger, M., et al. (2006), Crustal architecture of the Transantarctic Mountains between the Scott and Reedy Glacier region and South Pole from aerogeophysical data, Earth and Planetary Science Letters, 250(1-2), 182-199 doi:110.1016/j.epsl.2006.1007.1035.

Tosdal, R. M., et al. (2000), Geometry of the Neoproterozoic continental break-up, and implications for location of Nevadan mineral belts, in Geology and Ore Deposits 2000: The Great Basin and beyond, edited by J. K. Cluer, et al., pp. 451-466., Geological Society of Nevada Symposium Proceedings, Reno.

Wooden, J. L., et al. (1998), Pb isotopic mapping of crustal structure in the northern Great Basin and relationships to Au deposit trends, in Contributions to the gold metallogeny of northern Nevada, edited by R. M. Tosdal, pp. 20-34, U.S. Geological Survey Open-File Report.