Appendix A – Data and Methods Supplement

DATABASE

Potential field data are from the United States Geological Survey (USGS) U.S. Gravity Database (http://gis.uta.edu/subpages/GMData.html?option=com_content&view=article&id=197%3Agdrp-home&catid=51%3Amain-site&Itemid=59) and the North American Magnetic Map (https://mrdata.usgs.gov/magnetic/). The aeromagnetic survey flight line spacing is ~1.5 km and the land gravity station spacing is ~5 km. Based on the density of sample measurements, the total magnetic intensity data are gridded to a 1.0 km cell size, and the Bouguer land and shipborne gravity data are gridded to 2 km cell size. The magnetic data are not reduced to the magnetic pole.

ROCK PROPERTIES

Rock properties, including magnetic susceptibilities, measured in centimeter gram seconds (cgs), and densities, measured in grams per cubic centimeter, are derived from laboratory measurement of rock samples from the southeastern U.S., or determined using seismic compressional-wave velocities from regional seismic surveys and Nafe-Drake equations that relate p-wave velocity to density (Ludwig et al., 1970). Because all rock properties are calibrated to samples from the region, susceptibility and density values are valid inputs to forward models. The magnetic susceptibility of diabase/gabbro is one
exception in that magnetic susceptibility measurements have not been made from
samples in the southeastern U.S., despite the fact that the rock type has been encountered
in the subsurface in Georgia (Chowns and Williams, 1983). The susceptibility value used
in the forward model is derived from samples taken from the Newark-Gettysburg Triassic
basin of Pennsylvania. This susceptibility value is valid in the context of the southeastern
U.S. because the Newark-Gettysburg and South Georgia rift basins both belong to a
genetically related system of rift basins that preserve Triassic strata and Upper Triassic-
Lower Jurassic CAMP magmatism in the form of diabase sills and basalt flows (Sumner,
1977). In south Georgia, diabase from four wells located within 50 km of the model
profile intrude Newark series strata and are dated from 182± to 209±14 Ma, which is
within the range of dates reported for diabase in the Newark-Gettysburg basin (Chowns
and Williams, 1983). A table of magnetic susceptibilities and densities used in potential
field forward modelling appears below.

**FILTERING**

Filtering of the total magnetic intensity data was performed in the frequency-wave
number domain after Fourier transformation. Highpass filtering was implemented using a
second-degree Butterworth residual filter in Geosoft Oasis Montaj to isolate wavelengths
less than 50 km. The cell size of the resulting grid was maintained at 1 km.

**FORWARD MODELING**

Simultaneous forward modeling of gravity and magnetic data was performed using an
interactive, iterative technique within Geosoft GM-SYS software, which incorporates the
methodology of Talwani et al. (1959) and Talwani and Heirtzler (1964) for computing
the gravitational and magnetic response from a specified horizontal prism with a simple
cross-sectional polygon geometry (in the plane of the model profile) and assigned density
and magnetic susceptibility. Because of the elliptical shape of the magnetic source (i.e.
the Tifton anomaly, Fig. 1), a 2.5D forward model algorithm was used to calculate the
resulting gravitational and magnetic fields. The 2.5D method allows the user to place
finite limits on the horizontal prisms that would normally extend to infinity in 2D models.
Polygon geometries, including the base of coastal plain sediments, base of Triassic basin
fill, and depth to Moho, were constrained by three boreholes to basement, the Seisdata-8
seismic reflection data, and the preliminary SUGAR velocity model. The geometry of
these boundaries are important because they represent the strongest density contrasts
along the model profile. With these geometries set, the polygons were assigned
representative density and magnetic susceptibility values (see discussion above). Then
polygon geometry, as well as assigned density and magnetic susceptibility values, for the
intrusion that is the source of the BMA were varied to produce a consistent model
solution, for which calculated anomaly best fit the observed anomaly.

REMANENT vs. INDUCED MAGNETIZATION

No remanent magnetization was assumed for the source body in the onshore profile (Fig.
3). As Holbrook et al. (1994) noted, given the uncertainties in the age and duration of
rifting and direction of the paleofield, estimates of the direction of remanent
magnetization are difficult and involve assumptions for which there is little direct
evidence. There are few direct measurements of remanent magnetization of CAMP age
mafic rocks. Phillips (1983) reported paleomagnetic investigations on CAMP age basalt
samples recovered from three USGS deep test holes at Clubhouse Crossroads near
Charleston, S. C., where 23 flows were identified. Six of the flows had negative magnetic
inclinations, which were interpreted as reversed polarity; one test hole contained a
definite sequence of five reversed-polarity intervals separated by four normal polarity
intervals. The frequent polarity reversals during the Jurassic complicate any assumption
of one remanent magnetization direction. Holbrook et al. (1994) modeled the offshore
BMA signature assuming an induced anomaly from highly magnetized transitional crust
with magnetic susceptibilities from 0.026 to 0.035 cgs. Austin et al. (1990) modeled the
BMA source as a strong, remanently magnetized mafic body (0.045 to 0.067 cgs),
assuming an Early Jurassic paleofield: declination = -2.2°, inclination = 46.0°. Davis, et
al., (2018) investigated emplacement rates for packages of basalt flows (seaward dipping
seismic reflectors or SDRs) that form part of the source of the ECMA, offshore North
Carolina. Using the measurements of Philips (1983), they found that the combination of
varying-polarity basalt layers causes the remanent anomalies of the layers to cancel out,
significantly limiting the amplitude that the integrated magnetic anomaly can produce.
Therefore, at reasonable rates of continental extension (< 20 mm yr-1) and magnetic
chron duration (0.5 Ma), modeling results preclude the development of large, exclusively
positive, high amplitude magnetic anomalies from remanent magnetization. Instead,
Davis, et al. (2018) conclude that the ECMA is best explained as an induced magnetic
anomaly from SDRs with a magnetic susceptibility of 0.05 cgs. Both induced and
remanent solutions can produce the BMA offshore, and both models require a highly
magnetized mafic source. Given the similarities in the expected magnetic anomalies
produced and the uncertainties regarding the polarity of remanent magnetization, we have
assumed induced magnetization for our onshore source (Fig. 3).

**EULER DECONVOLUTION INVERSE MODELING**
Inverse modeling of total field magnetic data was performed by 3D located Euler deconvolution. Euler deconvolution estimates the depth and location of a magnetic source by examining the rate of change of the magnetic field as a function of distance (Thompson, 1982; Reid et al., 1990). This technique can be applied to profile or grid data to solve for Euler’s Homogeneity Equation:

\[(x-x_0) \frac{dF}{dx} + (y-y_0) \frac{dF}{dy} + (z-z_0) \frac{dF}{dz} = N (B-F)\]

Where \(x_0, y_0, z_0\) is the source location whose magnetic field is \(F\), measured at point \(x, y, z\). \(B\) is the regional value of the Total Field. \(N\) is the Euler’s structural index (SI), which characterizes the source’s geometry. The SI can be varied from zero to three: 0 (contact of infinite depth), 1 (dike), 2 (pipe), and 3 (sphere). The Euler method also yields estimates of the standard deviation of \(z_0\). This quantity \(\sigma_0\) is treated as an “error bar” on the depth estimate and forms the basis for an algorithm that determines whether or not a depth estimate is to be retained. This feature permits an uncertainty level in the depth estimate to be set such that all solutions falling below that threshold are discarded.

Inverse modeling by 3D located Euler deconvolution involves a reduction to magnetic pole transform, and the calculation of an analytic signal grid. The reduction to magnetic pole transform converts magnetic data recorded in the inclined Earth’s magnetic field to what they would look like at the magnetic pole, where the magnetic field is vertical. The transform locates anomalies above causative bodies, assuming that remanent magnetism is small relative to induced magnetism. The amplitude of the
analytic signal is the square root of the sum of the squares of the derivatives in the x, y, and z directions:

\[ A(x, y) = (dx^2 + dy^2 + dz^2)^{1/2}. \]

The analytic signal is useful in locating magnetic sources, particularly where remanent magnetization or low magnetic latitude complicates interpretation, because the amplitude of the analytic signal of the total magnetic field produces a peak over magnetic contacts regardless of the direction of magnetization (MacLeod, et al., 1993). The peak values from analytic signal grid are used to guide the Euler algorithm in order to reduce the number of Euler solutions and the associated uncertainty (Thompson, 1982). Euler results were obtained using a structural index of two and a depth uncertainty of ten percent.
### Densities Used in Gravity Forward Modelling

<table>
<thead>
<tr>
<th>Unit</th>
<th>Density (g/cm³)</th>
<th>Reference</th>
</tr>
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<tbody>
<tr>
<td>Allochthonous Crust (per-Gondwanan/Gondwanan)</td>
<td>2.75</td>
<td>Holbrook, et al. (1994)</td>
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<td></td>
<td>Cumbest, et al. (1992)</td>
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<td></td>
<td></td>
<td>Luetgert, et al. (1994)</td>
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<tr>
<td>Mafic Intrusions</td>
<td>3.0</td>
<td>Duff, et al. (2017)</td>
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<td>Cumbest, et al. (1992)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Beck (1965)</td>
</tr>
<tr>
<td>Coastal Plain Sediments</td>
<td>2.0</td>
<td>Luetgert, et al. (1994)</td>
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<td></td>
<td></td>
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<tr>
<td>Triassic Sediments</td>
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<td>Basement</td>
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<td></td>
<td>Christensen, et al. (1995)</td>
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<td>Mantle</td>
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### Magnetic Susceptibilities Used in Magnetic Forward Modelling

<table>
<thead>
<tr>
<th>Unit</th>
<th>Susceptibility (cgs)</th>
<th>Reference</th>
</tr>
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<tbody>
<tr>
<td>Allochthonous Crust (per-Gondwanan/Gondwanan)</td>
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<td>Sumner (1977)</td>
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<td>Cumbest, et al. (1992)</td>
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<tr>
<td>Mafic Intrusions</td>
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<td>Sumner (1977)</td>
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<td>Beck (1965)</td>
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<tr>
<td>Coastal Plain Sediments</td>
<td>0</td>
<td>Cumbest, et al. (1992)</td>
</tr>
</tbody>
</table>


Davis, J.K., Bécel, A., and Buck, W.R., 2018, Estimating emplacement rates for seaward-dipping reflectors associated with the U.S. East Coast Magnetic Anomaly:


