Paleomagnetism and Magnetic Fabrics of the Glen Mountains Layered Complex, Wichita Mountains, Oklahoma

Matt Hamilton[1], and R. Douglas Elmore[2]*

[1] University of Tulsa, Department of Geosciences. [2] University of Oklahoma, School of Geosciences

*Contact email: *Matt-Hamilton@utulsa.edu*

Introduction

The Southern Oklahoma Aulacogen (SOA) is an inverted early Paleozoic structure, juxtaposing Cambrian igneous rocks against a thick sequence of sediments (Shatski, 1946). It was considered to have formed from the failed arm of a Cambrian rift system by Hoffman et al. (1974), or alternatively interpreted as a "leaky" transform zone from the rifted margin of Laurentia (Thomas, 1991, 2014). It has been pointed out that these models are not necessarily exclusive (e.g., Hanson et al., 2013), and the aulacogen term is retained here for convenience.

During the early Cambrian, a large volume of igneous rock was emplaced into the rift zone (Ham et al., 1964; Gilbert, 1983). The vast majority are either mafic or felsic, though a small amount of intermediate rock has been reported. The total volume of igneous material is estimated to equal or exceed 250,000 km^3, with mafic rocks accounting for about 80% of that (Hanson et al., 2013). After magmatic activity ceased, the area subsided and was progressively buried from the Upper Cambrian through most of the Paleozoic until it was uplifted during the late Pennsylvanian (Ham et al., 1964).

Igneous activity in the SOA is generally considered to have begun with the emplacement of the Glen Mountains Layered Complex (GMLC), a body of layered, anhydrous mafic rocks consisting mostly of anorthosite with lesser amounts of troctolite and gabbro. The GMLC was then cross-cut by the Roosevelt Gabbros and the felsic rocks of the SOA (Gilbert, 1982; Fig. 1)The GMLC makes up the majority of the mafic exposures in the SOA (total area of ~150 km^2). Geophysical data and drilling penetrations indicate a much larger extent in the subsurface and a likely thickness of several kilometers (Ham et al., 1964; Powell, 1986). The GMLC has four major exposures in the Wichita Mountains area. The eastern exposures have very limited accessibility. The present study therefore sampled areas of the western and largest exposure area (Fig. 1).

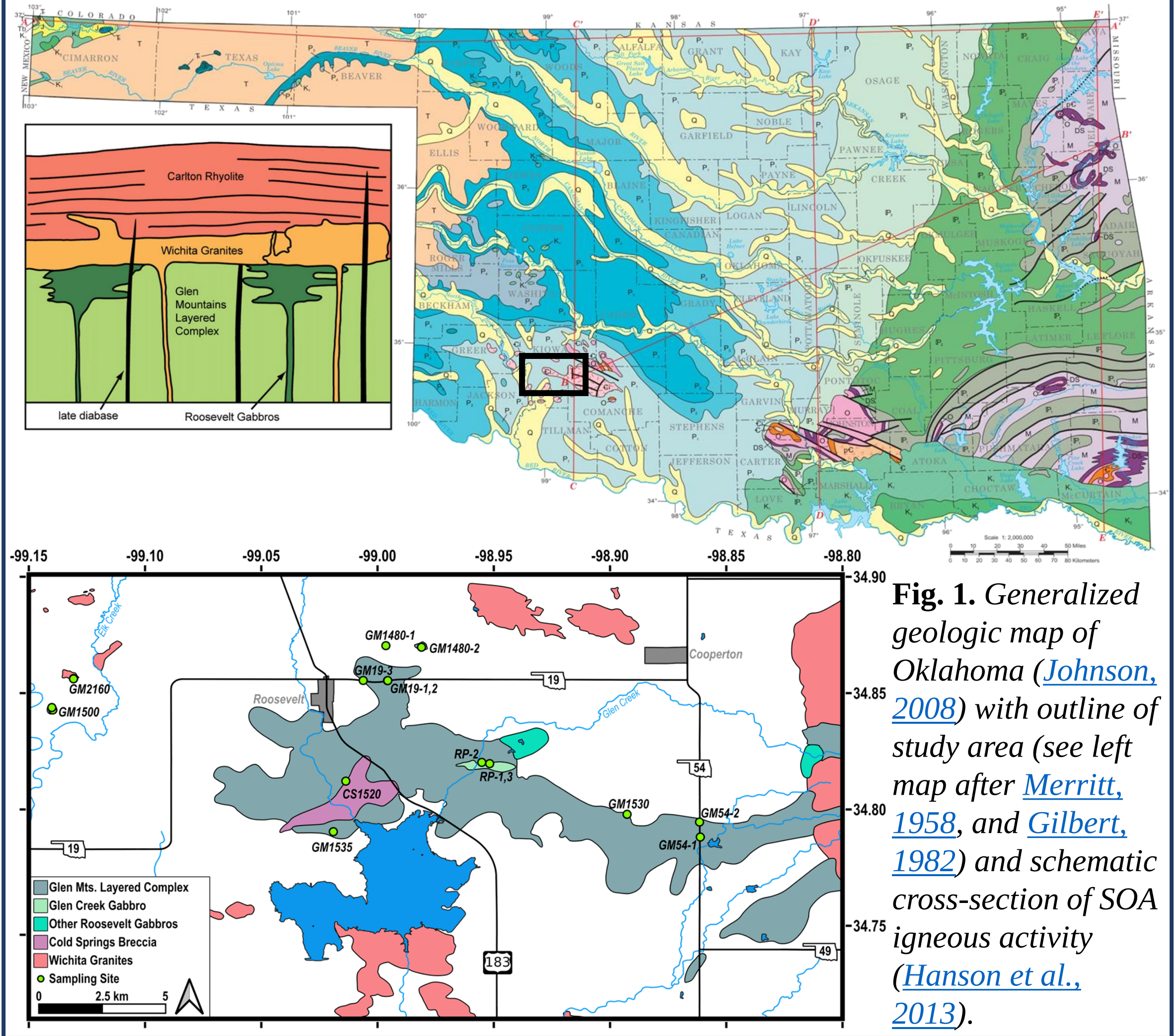

Fig. 1. *Generalized geologic map of Oklahoma (Johnson, 2008) with outline of study area (see left map after Merritt, 1958, and Gilbert, 1982) and schematic cross-section of SOA igneous activity (Hanson et al., 2013).*

Objectives

This study had two main objectives:

1) Investigate Cambrian paleogeography using paleomagnetism.
2) Evaluate emplacement characteristics and post-emplacement structural tilting in the GMLC and associated rocks using magnetic anisotropy.

Remagnetized Roosevelt Gabbros

Two sites were sampled in the Glen Creek Gabbro at Reid's Pit (Powell & Gilbert, 1982), and a site was sampled in amphibole-bearing gabbro along Highway 19 that was described by Powell et al. (1980) as an unnamed dike of Roosevelt Gabbro.

One site from the Glen Creek Gabbro was completely overprinted by a lightning strike and did not yield a recoverable magnetization; the other site (RP-3) contained a southeasterly and shallow down magnetization that was mostly unblocked between 200 and 500°C (Fig. 2). The Roosevelt Gabbro dike along Highway 19 had very noisy magnetic decay, but most samples contained an identifiable southeasterly and shallow up magnetic component that unblocked between 400 and 560°C. The calculated virtual geomagnetic poles (VGPs) are consistent with the late Pennsylvanian to early Permian section of the North American apparent polar wander path (APWP) of Torsvik et al. (2012) (Fig. 2). Similar results have been found in granites and rhyolites of the area, though these gabbros do not exhibit evidence of low-temperature alteration as seen in the silicic rocks. The cause of remagnetization is currently unclear.

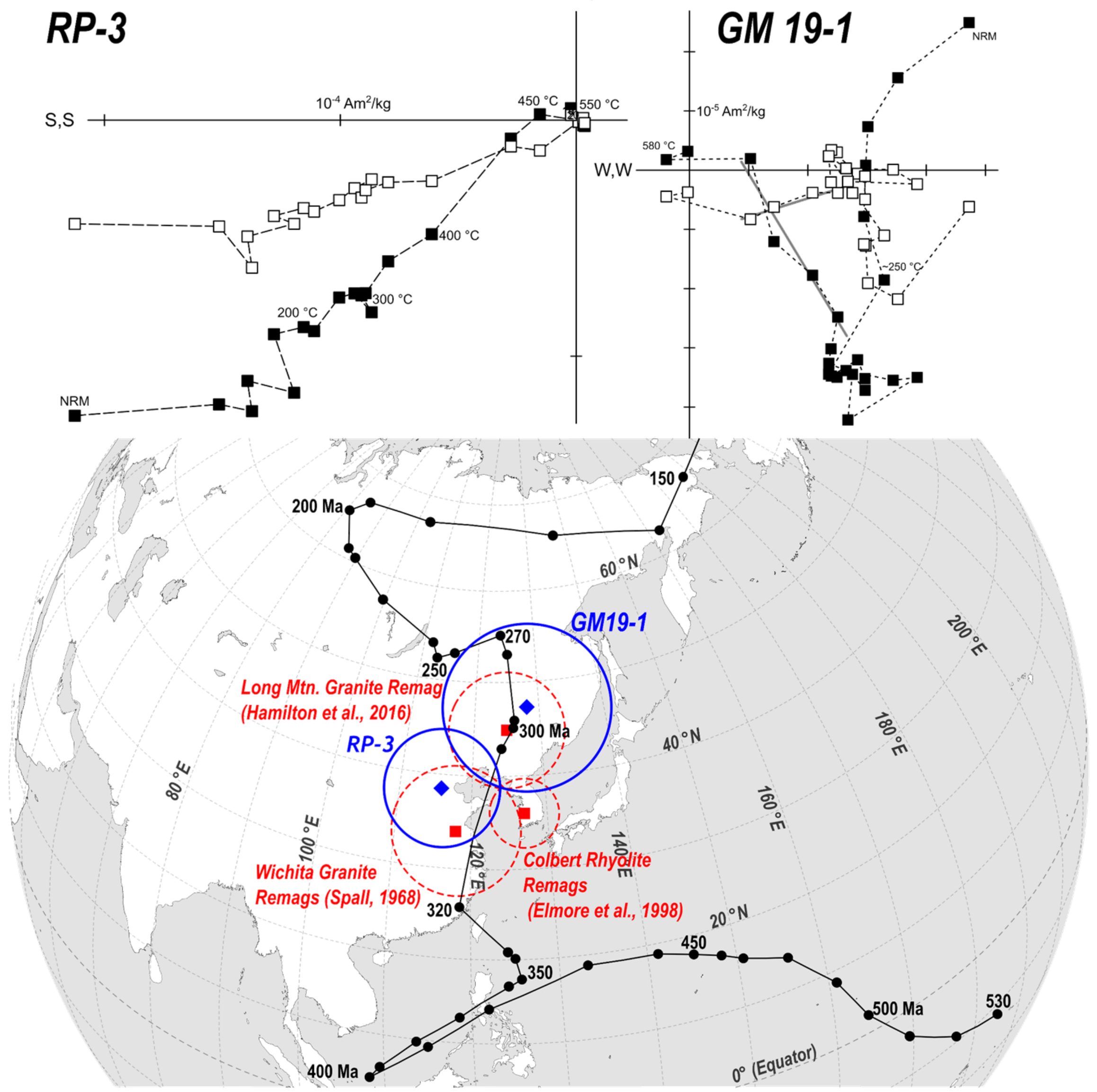

Fig. 2. *Paleomagnetic results from Roosevelt Gabbro sites. (Top) Orthogonal projection plots (Zijderveld, 1962) of magnetic decay in Glen Creek Gabbro and unnamed Roosevelt Gabbro dike. (Bottom) Comparison of calculated VGPs to the North American APWP (Torsvik et al., 2012). The gabbros plot along the late Paleozoic section of the path, as do other recognized remagnetizations in the SOA.*

Magnetic Mineralogy

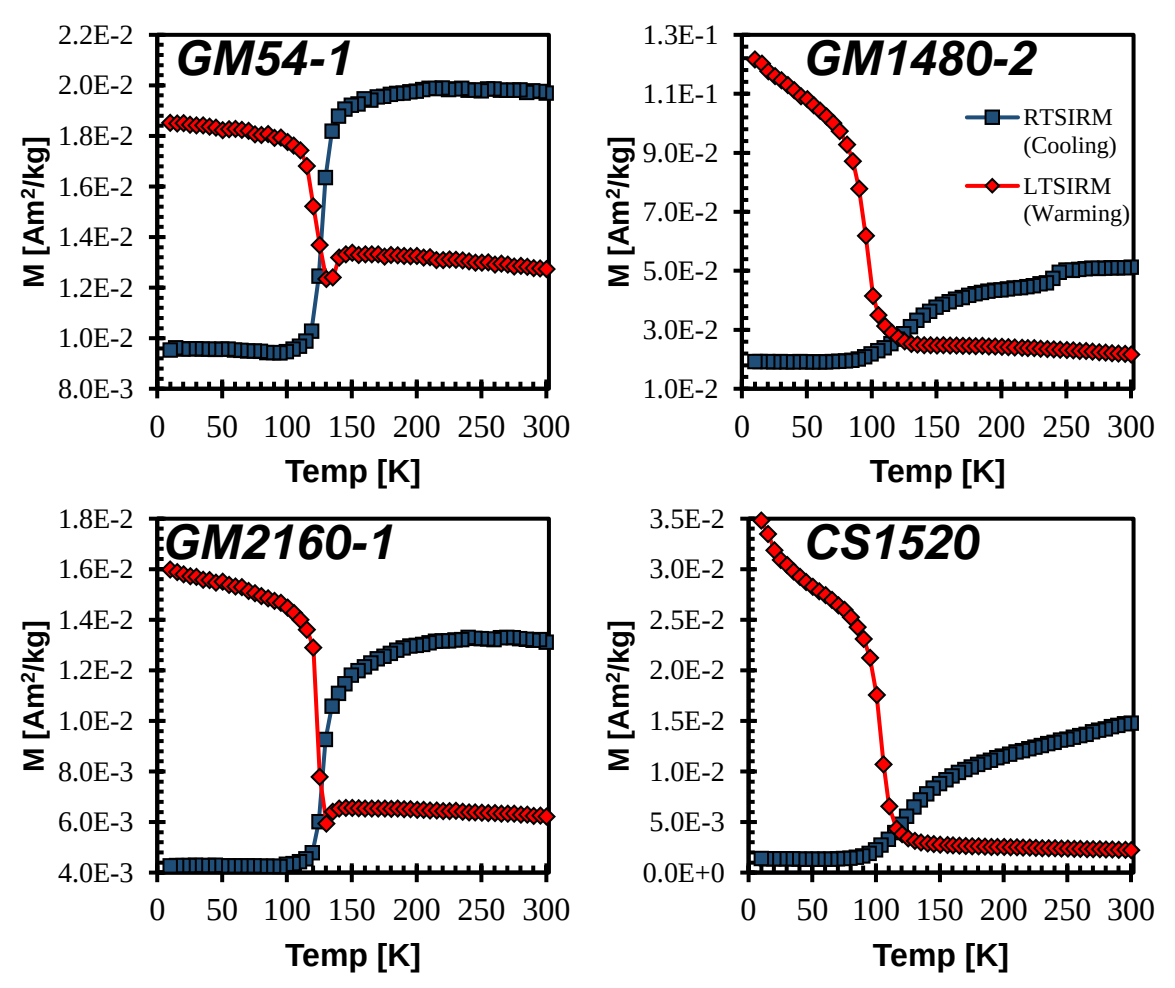

Fig. 3. *Rock magnetic remanence sweeps – cooling of room-temperature saturation magnetization, and warming of low-temperature saturation. LT-SIRM sequences show sharp transitions at the characteristic isotropic point of magnetite. Most also show slight curvature during cooling of room-temperature saturation, indicating partial oxidation (Özdemir & Dunlop, 2010). A small Morin transition indicating hematite is also seen near 250 K in GM1480-2.*

Paleomagnetism (GMLC)

Samples from the Glen Mountains Layered Complex yielded a variety of remanent magnetic directions. Most sites yielded mean directions that were either northeasterly and shallowly up or southwesterly and shallow down (e.g., the GM54 sites in Fig. 4). These components often did not fully unblock until 580°C or even slightly higher. A few sites (e.g., GM19-2) yielded multiple components, with one unblocking at lower temperatures and the other persisting at temperatures well above 500°C.

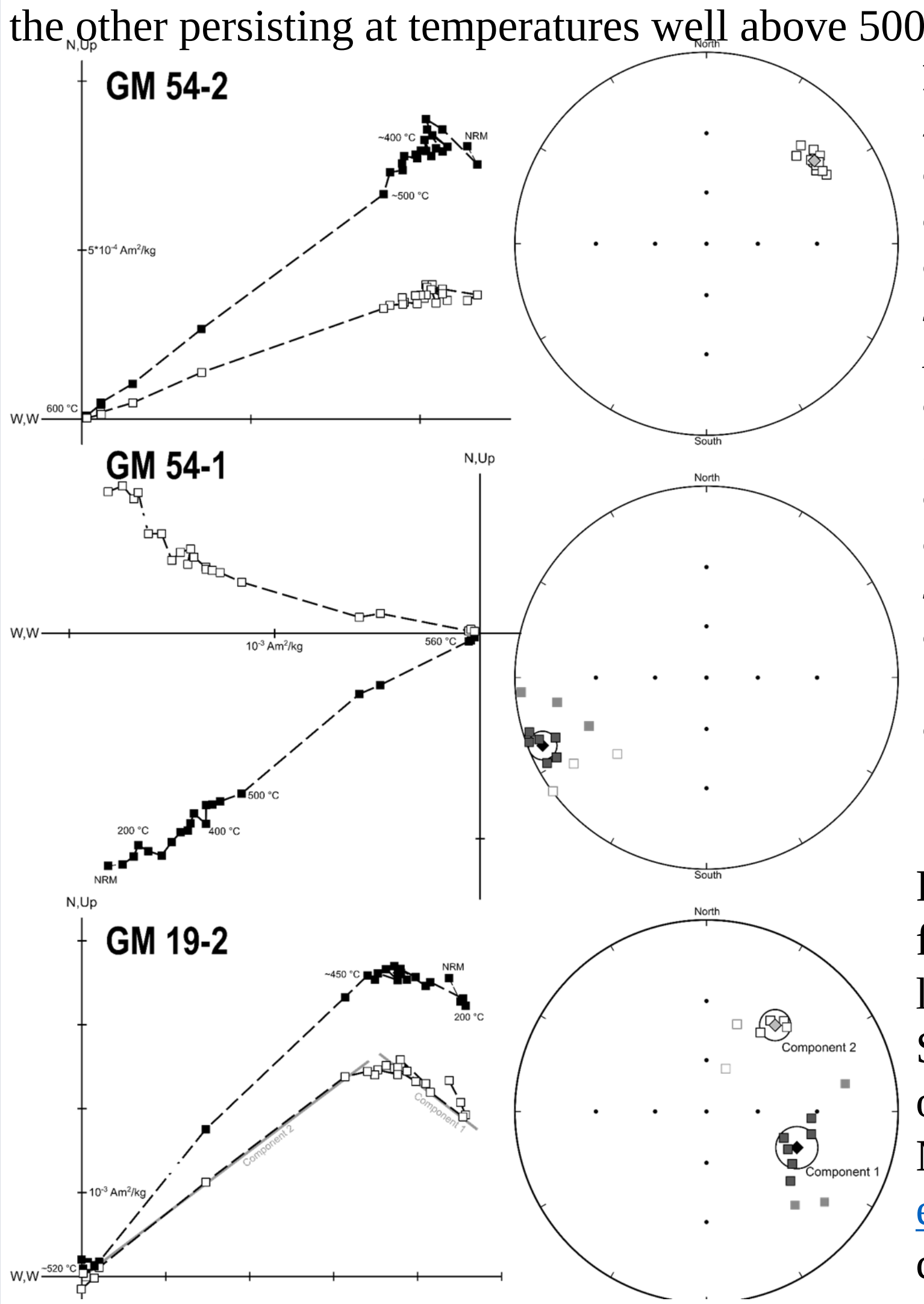

Fig. 4. *Representative Zijderveld decay plots (left) and corresponding equal area plots (right) of picked components from selected sites in the Glen Mountains Layered Complex. Samples depicted in gray rather than black were considered erroneous and not used for calculation of final site statistics. Note minimal decay before 500°C in GM54 sites and multiple components in GM19-2.*

Paleomagnetic results from the GMLC show a large amount of scatter. Several sites cluster near or southeast of the 530 Ma pole of McCausland et al. (2007) and are considered to be valid. The mean pole direction from these sites is essentially identical to that of Roggenthen et al. (1981) (Fig. 5). Other sites are more problematic. Components from GM1500 (two sites on an isolated anorthosite hill west of the main GMLC) show curvature and deviate from the path, likely due to late Paleozoic partial overprints. Others deviate strongly but without evidence of overprint and may represent Cambrian geomagnetic instability. These also resemble previous results from the Wichita granites and rhyolites.

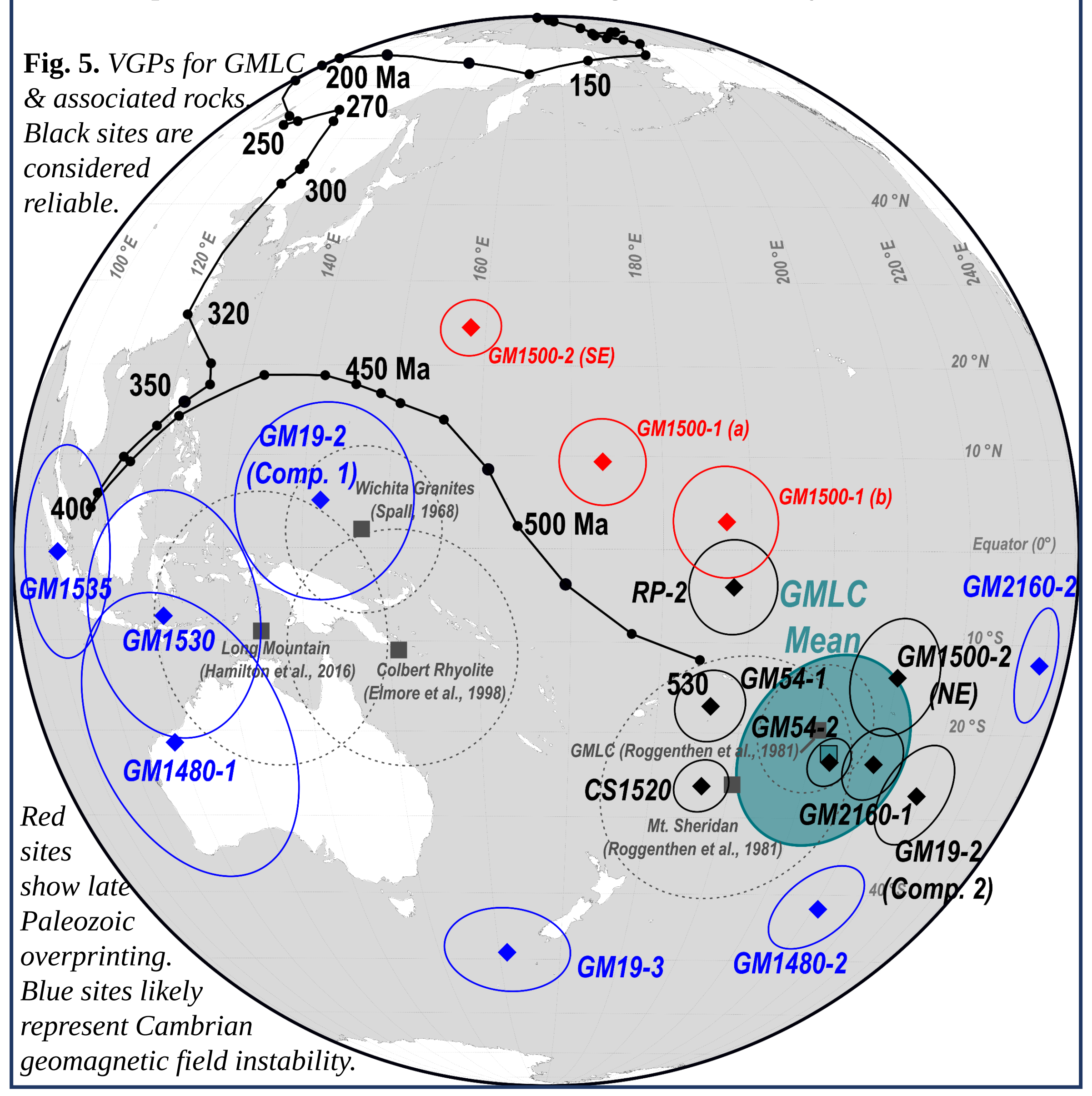

Fig. 5. *VGPs for GMLC & associated rocks. Black sites are considered reliable.*

Red sites show late Paleozoic overprinting. Blue sites likely represent Cambrian geomagnetic field instability.

Magnetic Anisotropy & Tilting

Anisotropy of magnetic susceptibility (AMS) has often been used in investigation of layered mafic intrusions, in which there is typically a well-developed magnetic foliation which mimics mappable layering (e.g., Ferré et al., 2009).

Here, we apply AMS to investigate the GMLC, as layering is often interpreted at larger scales but absent or cryptic in many outcrops. The GMLC is often inferred to be tilted, with most authors suggesting dips of 10 to 20° to the northeast (e.g., Powell et al., 1980; Gilbert, 1982). AMS foliations would likewise be expected to show such dip. They do not (Fig. 6). Instead, sites with strong foliations show a variety of dip directions, but confidence intervals are near zero. AMS shows no evidence for a consistent tilt in the GMLC.

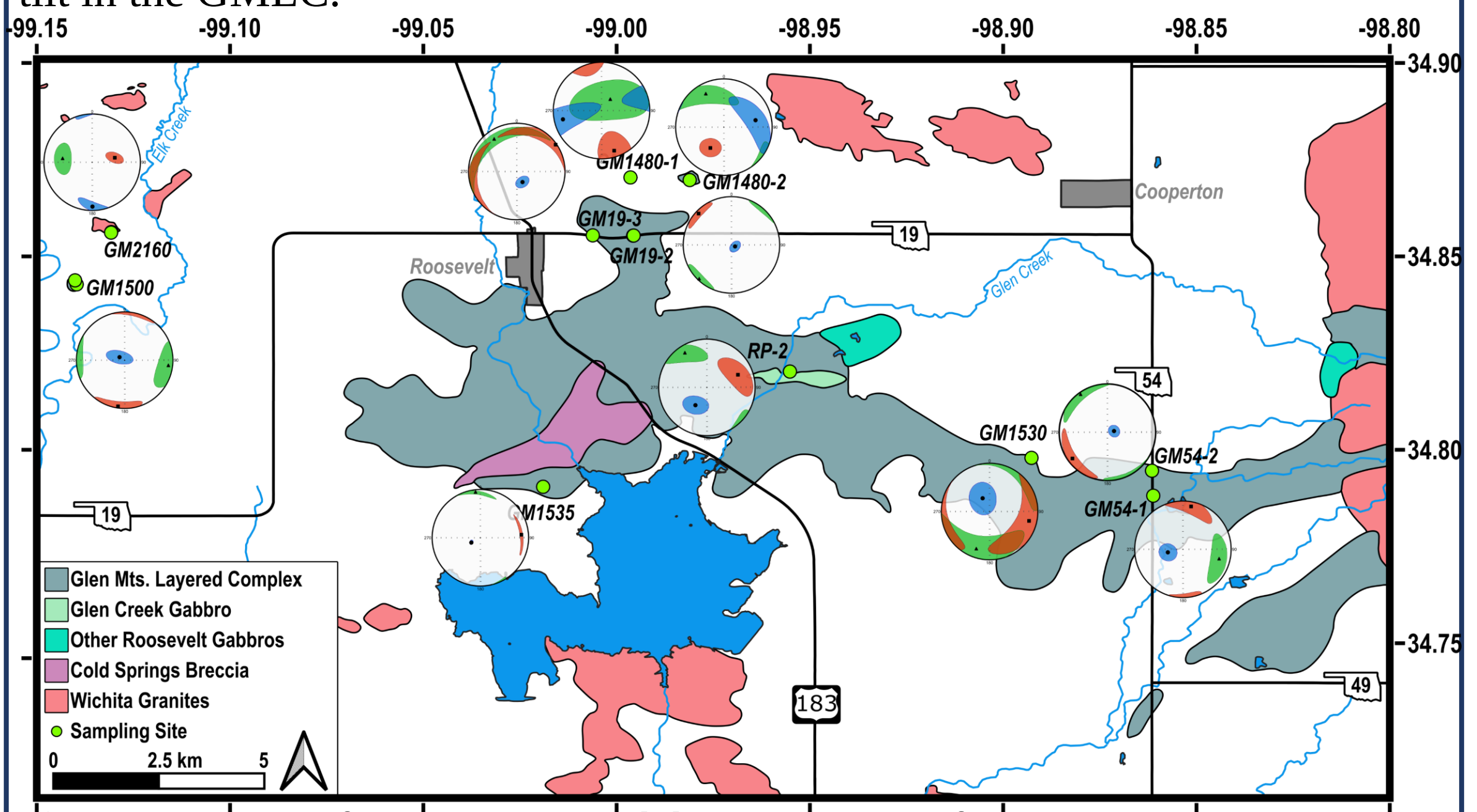

Fig. 6. *Anisotropy of magnetic susceptibility mean tensors for GMLC sites. Orange axis is maximum principal susceptibility (K_1), green is intermediate (K_2), and blue is minimum principal susceptibility (K_3). K_1 and K_2 define the magnetic foliation plane; K_3 is its pole.*

The effect of tilting on the remanent magnetization directions was also evaluated for 4 assumptions of tilting: That there is no tilt, the regional tilt inferred by Cooper (1991), the mean AMS of the GMLC, and site-by-site AMS. In all instances, the GMLC mean pole position hardly varies.

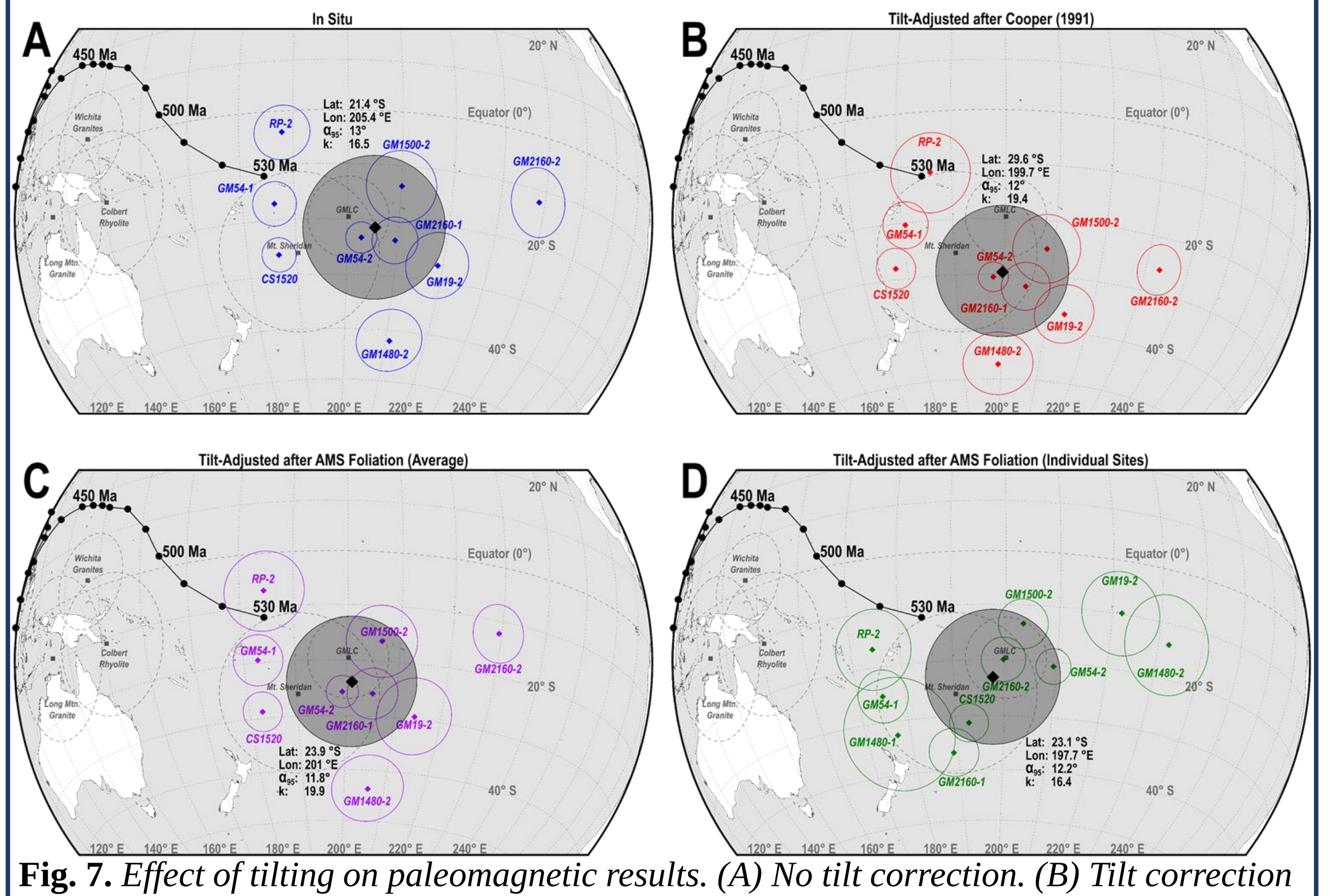

Fig. 7. *Effect of tilting on paleomagnetic results. (A) No tilt correction. (B) Tilt correction based on Cooper (1991) regional mapping. (C) Tilt correction based on mean AMS. (D) Tilt correction based on AMS on a site-by-site basis. Mean pole directions hardly change.*

Acknowledgments

Thanks to Barry Weaver, Will Deaton and Katie Garrett for assistance with field work. Thanks to Charles Gilbert, Jon Price, Shannon Dulin, Ken Kodama and John Tarduno for discussions. Rock magnetic data was collected at the Institute for Rock Magnetism at the University of Minnesota with assistance from Dario Bilardello. This work was supported by a GSA Graduate Student Research Award.