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Anisotropy of Magnetic Susceptibility and Petrologic data bearing on Exhumation of Precambrian Gneiss in Gallinas Canyon

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Models for exhumation of deep to mid crustal rocks rely heavily on documentation of rocks structures (e.g. stretching lineations and foliations) which may not be visibly obvious in the field. In an attempt to better document exhumation features of the Paleo Proterozoic gneiss, within the northeastern Sangre de Cristo Mountains, Gallinas Canyon, NM, anisotropy of magnetic susceptibility (AMS) analysis was conducted on amphibolite-facies gneisses and migmatites. The AMS technique can detect anisotropies of less than 1% and allows for the evaluation of non-visible petrofabrics within the rocks. Oriented AMS samples, typically eight to twelve samples per site, were collected from twelve sites distributed throughout the canyon with an addition twenty-eight sites planed to be collected during the fall 2007 and spring 2008. All samples were analyzed on an AGICO static KLY-4S Magnetic Susceptibility/Anisotropy System at the University of New Mexico Rock Magnetism Laboratory in order to characterize the magnetic fabric and phases within the rock. Preliminary rock magnetic data indicate that the dominate magnetic phase in most specimens analyzed is a ferri/ferromagnetic (magnetite, maghemite) as demonstrated by an average bulk susceptibility of 8.5x10−3 SI. Further rock magnetic experiments are being conducted to identify other magnetic phases. The AMS fabric data are consistent with the macroscopic structural data, which was only visible at approximately half of the sites visited. In general, this combined structural data reveal a gentle to moderate northeast-dipping foliation and a moderate plunging southwest trending lineation (average of 53º toward 230º). We propose that our petrofabric and rock magnetic data may reflect oblique convergence of this region during exhumation from mid crustal depths. Our study shows that AMS petrofabric analysis is a simple yet powerful tool for obtaining high quality orientation data from higher-grade, deeply exhumed rocks where visible rock structures may be tenuous.

PRELIMINARY AMS DATA BEARING ON THE DEFORMATIONAL HISTORY OF THE PROTEROZOIC BASEMENT IN THE LAS VEGAS AREA, SOUTHERN SANGRE DE CRISTO MOUNTAINS, NEW MEXICO

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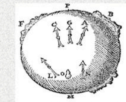
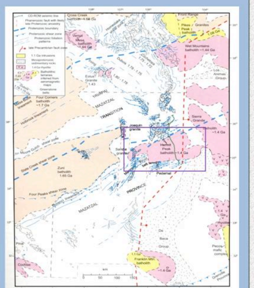


from Gilbert (1600) De Magnete

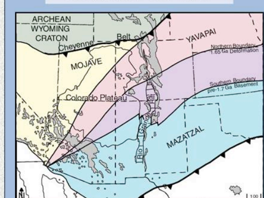
ABSTRACT

Models for the deformational history of deep- to middle-crustal rocks rely heavily on the documentation and interpretation of rock structures which are not always detectable in the field. Anisotropy of magnetic susceptibility (AMS) analysis allows for the evaluation of non-visible petrofabrics as it can detect structural anisotropies of less than 1% in rock samples. We conducted anisotropy of magnetic susceptibility (AMS) analysis on Proterozoic basement rocks west of Las Vegas, NM, in an attempt to better document and interpret deformation features. We studied medium-grade gneisses outcropping along County Road 65 in the Gallinas Canyon, which dissects a portion of the Hermit's Peak batholithic complex. Rock types include quartzofeldspathic gneisses, biotite schists, and laminated amphibolites. The gneisses show intense penetrative deformation defined by a strong steeply dipping northeast trending axial planar foliation. Minor macroscopic linear structures, including isoclinal fold hinges and prismatic mineral alignments, plunge moderately to the southwest. Oriented AMS samples, typically eight to twelve samples per site, were collected from twelve sites distributed throughout the canyon. All samples were analyzed on an AGICO static KLY-4S Magnetic Susceptibility/Anisotropy System at the University of New Mexico Rock Magnetism Laboratory in order to characterize the magnetic mineralogy and magnetic fabric of the rocks. Preliminary rock magnetic data indicate that the dominant magnetic phase in most specimens is a ferri/ferromagnetic oxide (magnetite, maghemite) as demonstrated by an average bulk susceptibility of 8.5x10−3 SI. Additional rock magnetic experiments are being conducted to identify other magnetic phases. The AMS fabric data are consistent with the macroscopic structural features, particularly the lineations, which were visible at only a fraction of the study sites. We propose that our petrofabric and rock magnetic data reflect the dominance of northwest-southeast contractional deformation and southwest-northeast extension in the assembly history of the continental lithosphere during the Proterozoic. Our study shows that AMS petrofabric analysis is a simple yet powerful tool for obtaining high quality orientation data from crystalline rocks for which visible rock structures may be lacking or tenuous.



An interpretive tectonic map of basement rocks in the New Mexico region showing foliation trajectories. The Hermit's Peak batholith is outlined in the center of the map. Figure taken from Karlstrom et al., 2004.

REGIONAL SETTING



Precambrian provinces in southwestern Laurentia including the Mojave province (1.8-1.7 Ga arcs built on older crust), the Yavapai province (1.80-1.70 Ga dominantly juvenile arc crust), and Mazatzal province (1.7-1.60 Ga dominantly juvenile crust. Figure taken from M. Williams (www.geo.umass.edu/structure/rockies/index.html).

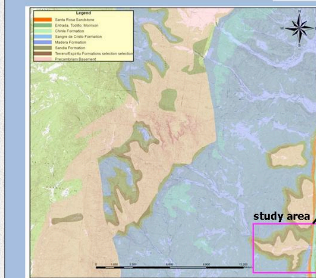
Proterozoic rocks of New Mexico and adjacent states range in age from 1.80-1.0 billion years (Ga). These rocks record several mountain building events, including a 1.80-1.65 Ga episode of assembly of continental lithosphere – the Yavapai orogeny; a separate 1.67-1.65 Ga period of terrane accretion – the Mazatzal orogeny; and a younger 1.45-1.35 Ga episode of pervasive within-plate magmatism. This project will study the Hermit's Peak batholith, a Proterozoic plutonic-metamorphic complex that occurs in the southern Sangre de Cristo Mountains northwest of Las Vegas, New Mexico. To date, no detailed petrologic work has been conducted to resolve the magmatic, metamorphic, and deformational events that produced the Hermit's Peak batholith. This work represents the initial results of a detailed anisotropy of magnetic susceptibility study of Hermit's Peak batholith gneisses aimed at characterizing the structural elements of the rocks and refining the deformation events that affected this portion of the Proterozoic crust.

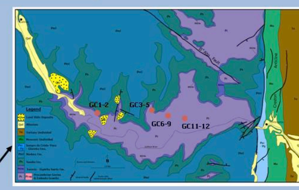
RESEARCH QUESTIONS

- *What is the range of igneous and meta-igneous rock compositions in the Hermit's Peak batholith?*
- *How do the rock compositions compare to modern lava eruptions in known tectonic settings?*
- *When did the rocks deform and what type of conditions were they subjected to?*
- *How does the construction of the Hermit's Peak batholith compare to other southwest Proterozoic metamorphic-plutonic assemblages?*

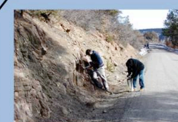
Hermit's Peak, a famous landmark of the southern Sangre de Cristo Mountains. The altitude of the highest peak is about 2,125 meters. This view looks to the northwest from Mineral Hill, south of Gallinas Creek. Most of the peak is granite, amphibolite, and quartzofeldspathic gneiss of Late Proterozoic age. The mountain is capped by a veneer of west-dipping Mississippian and Lower Pennsylvanian sedimentary rocks (Baltz, 1972).

Sampling Location





Geologic map of the Gallinas Canyon area, San Miguel County, New Mexico from Baltz (1972) and Baltz and Myers (1999). The Precambrian comprises massive and nonfoliated granite and granite pegmatite (Pcep) and undifferentiated metamorphic rocks (Pc) including quartzofeldspathic gneiss, amphibolitic gneiss, and biotite schist.



AMS Sampling Sites: Eight to fourteen independent samples were drilled over an area of about 25 m². Preliminary results represent data from eleven sites collected from four areas within the lower canyon area. In total, 180 AMS specimens were analyzed.

AMS Technique and Theory

Anisotropy of Magnetic Susceptibility (K)

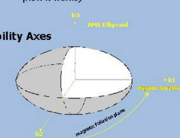
(how it works)

Principal Susceptibility Axes

Maximum (K_1)

Intermediate (K_2)

Minimum (K_3)



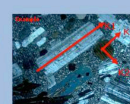
K = the dimensionless proportionality constant between the applied magnetic field (H) to the induced magnetization (M)

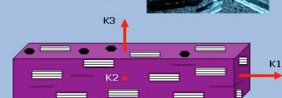
$$M_{1,2,3} = (K_{1,2,3})H$$

AMS "Mimics" Silicate Fabric

K1, magnetic lineation (flow, transport direction)

K1-K2, foliation plane (flattening plane)





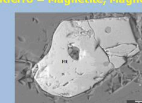
Source of AMS - Magnetic Mineralogy

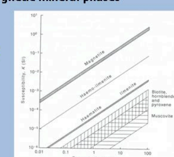
The total susceptibility = sum of the diamagnetic + paramagnetic + anti-ferromagnetic + ferromagnetic mineral phases

Kdia =Quartz, feldspars

Kpara = Iron bearing silicates

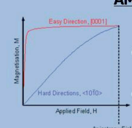
Kferro = Magnetite, Maghemite

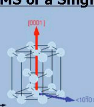


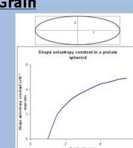


The susceptibility magnitude of the Gallanis Canyon gneiss indicates that a ferromagnetic phase (likely magnetite) carries the AMS in these rocks. The dominantly prolate-shape of the susceptibility ellipsoids suggests that a mineral phase with a strong shape-anisotropy controls the AMS fabrics.

AMS of a Single Grain

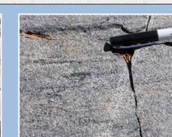




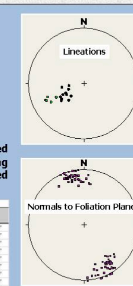


Crystalline Anisotropy
Net alignment of the easy axis of magnetization within the crystal lattice (within a single grain) e.g., hematite

Shape Anisotropy
Alignment of the long axis of the crystals within a rock (multiple grain alignment) e.g., titanomagnetite



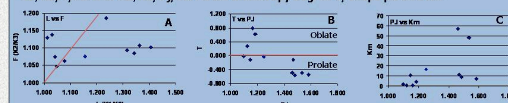
SW-trending moderately plunging lineations defined by aligned prismatic hornblende crystals. Steeply dipping E-NE-trending foliation defined by flattened quartz and feldspar crystals, aligned intergranular biotite, plagioclase laminae, and biotite schistosity.



Anisotropy of Magnetic Susceptibility Data Gallinas Canyon, New Mexico

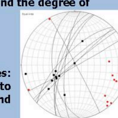
Site	Rock Type	No	N	Km x 10-3 SI	K1	K3	K1-K2 Plane	L	F	P	Pj	T	Sp	WGS 84 Latitude
GC1	Gneiss	12	12	16.7	234/55	110/22	200.0 68.0 W	1.16	1.08	1.25	1.25	-0.03	P	N35, 39.299'
GC2	Gneiss	20	20	1.8	199/41	96/15	186.0 75.0 W	1.05	1.05	1.10	1.10	-0.01	P	N35, 39.419'
GC3	Gneiss	15	15	8.6	236/61	242/2	332.0 88.0 E	1.34	1.09	1.46	1.48	-0.57	P	N35, 39.384'
GC4	Gneiss	18	18	6.9	253/59	105/27	195.0 63.0 W	1.41	1.10	1.55	1.58	-0.56	P	N35, 39.384'
GC5	Gneiss	16	16	48.3	245/54	84/35	174.0 55.0 W	1.36	1.11	1.51	1.53	-0.50	P	N35, 39.329'
GC6	MetaBasalt	11	11	10.4	238/56	331/2	61.0 88.0 S	1.08	1.06	1.14	1.15	-0.11	P	N35, 39.329'
GC7	MetaBasalt	14	14	0.7	354/87	141/3	231.0 87.0 n	1.01	1.13	1.15	1.16	0.80	O	N35, 39.329'
GC8	Gneiss	17	17	10.9	260/7	111/17	201.0 73.0 W	1.24	1.19	1.47	1.47	-0.10	P	N35, 39.329'
GC9	Gneiss	24	24	57.3	236/47	138/9	228.0 81.0 n	1.32	1.09	1.44	1.46	-0.51	P	N35, 39.357'
GC10	Gneiss	17	17	0.6	228/34	136/2	226.0 88.0 n	1.04	1.08	1.12	1.12	0.28	O	N35, 39.357'
GC11	Gneiss	16	16	4.2	18/51	135/20	225.0 70.0 W	1.03	1.14	1.17	1.18	0.62	O	N35, 39.357'

Site, sampling site identifier; No, number of specimens analyzed at each site, N, number of accepted specimens, Km, magnitude of susceptibility (in 10E-3 SI); K1, K3 azimuth and plunge (in degrees) of magnetic lineation and normal to magnetic foliation plane, L, ratio of K1/K2, F, ratio of K2/K3, Pj, corrected anisotropy degree T, shape parameter.

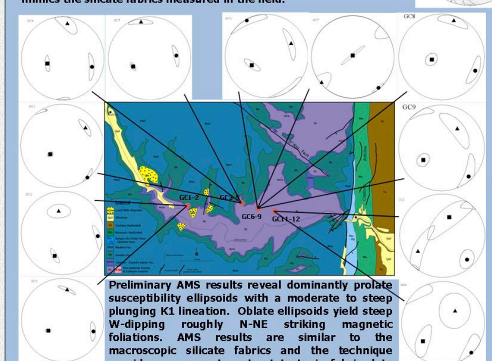


AMS parameters. (A) L versus F plot divides AMS data into prolate, triaxial, and oblate fabrics. Relationship between the (B) shape of the susceptibility ellipsoid, T, and the degree of magnetic anisotropy, Pj, and (C) the bulk susceptibility, Km and Pj.

AMS Results



Lower hemisphere projection of AMS fabric data. Black squares: trend and plunge of K1-Lineations. Red circles: K3-normal to magnetic foliation plane. Magnetic fabric data very similar to and mimics the silicate fabrics measured in the field.



Preliminary AMS results reveal dominantly prolate susceptibility ellipsoids with a moderate to steep plunging K1 lineation. Oblate ellipsoids yield steep W-dipping roughly N-NE striking magnetic foliations. AMS results are similar to the macroscopic silicate fabrics and the technique provides a means to extract tectonic fabric data from rocks that lack visible fabric elements.

Poster #11 presented at the 2008 New Mexico Geological Society Spring Meeting, Socorro, New Mexico.