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Prof. Ing. Shah Wali Faryad, CSc., v.r.
Chair of the Board
Department of Student Affairs
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Dear Thesis Review Panel,

It has been my pleasure to review Mr. Mgr. Tomek PhD thesis titled "Magnetic Fabric, Magma Flow and Tectonic Deformation in Volcano–Plutonic Systems. In general, the manuscript reads very well, the various chapters are complementary to the goals of understanding magma emplacement at various structural levels, and this thesis will make a valuable contribution to understanding these processes. I fully support allowing Mr. Tomek to defend his PhD thesis and hope to see that he is awarded a well-deserved PhD degree from Charles University in Prague.

Mr. Tomek PhD thesis investigated the dynamics of emplacement and tectonic history of five field areas in a continental magmatic arc and back arc setting that provided various structural windows into the volcano–plutonic complexes. These include, from top to bottom, (1) andesitic lava domes and (2) sub-volcanic magma chambers (<3 km deep) of the Miocene Štiavnica volcano–plutonic complex, Western Carpathians (Slovakia), (3) Shellenbarger pluton (<3 km depth) within the mid-Cretaceous Minarets caldera, Sierra Nevada batholith in California (USA), and ~7–10 km deep granitoids of (4) Lower-Cretaceous Wallowa batholith, Blue Mountains province in Oregon (USA) and (5) Late Devonian Staré Sedlo complex, central Bohemian Massif (Czech Republic). The methods involved extensive field mapping, structural data, analysis of igneous textures, and anisotropy of magnetic susceptibility (AMS) and characterization of magnetic mineralogy using thermomagnetic measurements and optical and back scattered diffraction microscopy. In addition, the third chapter contains U–Th–Pb radiometric dating obtained by laser ablation–inductively coupled plasma–mass spectrometry.

Below I have specific comments to each of the five chapters. At times, my comments are minor, yet for some I express concerns in an attempt to improve the overall quality of the manuscripts.

I hope you find my review useful.

Sincerely

MIKE

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Chapter 1 Growth of intra-caldera lava domes controlled by various modes of caldera collapse, the Štiavnica volcano–plutonic complex, Western Carpathians

Summary
The Štiavnica volcano–plutonic complex is an erosional relic of a ca. 50 km in diameter Miocene caldera-stratovolcano in the Western Carpathians. The complex exposes a vertical section from the volcano basement through subvolcanic intrusions and ring-fault to volcanic edifice, comprising mostly andesitic lava flows and domes. This paper examines internal structure, magnetic fabric derived from the anisotropy of magnetic susceptibility (AMS), and emplacement dynamics of three intra-caldera andesite domes (referred to as Domes 1–3 here) located near the ring-fault. In the conclusions, they argue that all of the domes formed during collapse of the Štiavnica caldera and the various mechanisms of their growth reflect different stages of the caldera evolution from piston (Dome 2), trap-door (Dome 1), and piecemeal (Dome 3) collapse mechanisms.

Comments
Emplacement: The conclusions based on the AMS fabric data are supported by the field observations. The emplacement models proposed are supported by the data. In Figure 9, the inferred traces of the flow fabric are reasonable for Domes 1 and 2. For Dome 3, however, the fabric patterns are difficult to interpret. The model proposed for dome 3 is a reasonable interpretation of the data.

Magnetic Mineralogy: The authors argue that the large magnetic grains seen in the electron backscatter images provide evidence that the magnetic domain state is characterized by multidomain (MD) grains. They further argue that MD grains carry the AMS fabric. I do not agree with this conclusion. In the electron backscatter images numerous very tiny oxide grains are observed which could very well be single domain grains. The presence of SD grains often leads to inverse magnetic fabrics and is a serious concern in AMS studies. I would have liked to have seen additional detailed rock magnetic experiments to fully characterize the magnetic mineralogy (e.g., hysteresis loops, Lowrie-Fuller test, IRM acquisition curves).

Conclusions: I find the emplacement models for the three domes a very eloquent interpretation of the data.

Chapter 2 Magma flow paths and strain patterns in magma chambers growing by floor subsidence: a model based on magnetic fabric study of shallow-level plutons in the Štiavnica volcano–plutonic complex, Western Carpathians

Summary
This paper reports an example of contrasting emplacement mechanisms of two high-level, nearly co-genetic diorite and granodiorite plutons of the Miocene Štiavnica volcano–plutonic complex, Western Carpathians. The paper concentrates on a detailed quantification of fabric parameters and orientation as derived from the anisotropy of magnetic susceptibility (AMS). The AMS data indicate contrasting fabrics in both plutons interpreted as resulting from different emplacement processes. Furthermore, the granodiorite pluton reveals a complicated fabric pattern compatible with a piecemeal subsidence of the pluton floor. Based on this specific case example, the authors develop a general model for intrusive fabric development and strain patterns in shallow-level bell-jar plutons for different modes of floor subsidence.

Comments
Overall, this manuscript presents a good discussion of using AMS fabric data as a complementary tool for evaluating magma emplacement in shallow level plutons. In general, the text of the manuscript reads fairly well in most places and to a lesser extent the data support the author's conclusions. I have several comments/concerns regarding the origin of the AMS fabrics, minor clarification to figures, and suggestions for enhancing grammar throughout the manuscript. These suggestions are provided in the hopes that they will improve the overall quality of the manuscript and clarify a several points throughout the text.

Major Concerns: Although at this stage with the manuscript published, my following criticism cannot be resolved. I nonetheless provide it in the hopes that it is clear to the PhD student author that sample density is one of the keys to a large scale AMS study of shallow level intrusions. A major criticism of this manuscript is the extremely limited number of sampling sites established in the two plutons; 9 sites in the diorite and 16 sites in the granodiorite. The 9 sites in the diorite are spread across an area of ~ 1 km^2 and the 16 sites in the granodiorite cover an area of about 2 km^2. I understand that the availability of outcrop seriously controls the sampling density; however, it seems that the authors are basing their fundamental hypothesis on a very limited data set. I would feel more comfortable if the authors provided a more detailed description of the sampling challenges for these plutons. If they sampled every available outcrop in the region, then I understand the limited number of sites established in the plutons. Otherwise, I feel the conclusions drawn in this paper are premature based on the small data set. I want to emphasize, that I do not doubt the emplacement models that they develop for the variously shaped intrusions; I am concerned only with the small data set presented in this paper.

Magnetic Mineralogy: In terms of the magnetic mineralogy from the two plutons, the authors provide Curie point estimates and low temperature susceptibility data. The Curie points occur at 580°C for both intrusions evidenced by an abrupt drop in susceptibility following a rapid increase in susceptibility defining a Hopkinson peak. The authors conclude that the magnetic mineralogy, and hence the AMS, is controlled by a ferromagnetic phase of restricted composition (i.e., magnetite). I do not doubt the author's interpretation that the dominant magnetic phase is a titanomagnetite phase. My concern is the magnetic grain size. Are the magnetite grains single domain or multidomain? The resulting AMS fabrics will be very different if the magnetic grain size is SD versus MD. If the magnetite grains are SD, then the AMS fabric will be an inverse magnetic fabric, where the maximum low-field magnetic susceptibility is normal to the long axis of the SD grain [Rochette et al., 1992; Potter and Stephenson, 1988]. My question: What is the magnetic grain size?

Chapter 3 Volcano–tectonic interactions, crustal strain, and plate kinematics during Late Cretaceous shutdown of the Sierra Nevada magmatic arc, California

Summary

The mid-Cretaceous Minarets caldera is a volcano–plutonic complex in the central Sierra Nevada batholith, California. This system reveals the complex interactions among continental margin arc volcanism, tectonic deformation of the magma–host rock system, and changes in plate motions during subduction of oceanic lithosphere. They conclude that their structural and anisotropy of magnetic susceptibility (AMS) data indicate that the Shellenbarger pluton was overprinted by ~NNE–SSW horizontal shortening and subvertical stretching during both late stages of magma crystallization and postmagmatic alteration from hydrothermal fluid flow focused to the pluton center.

Comments

Instrumentation: It is not clear why the authors are operating the MFK1-A at 450 A/m. Typically the instrument is set at 200 A/m. I would have liked to see an explanation; I have a guess as to why the field was set this high, but I prefer that it comes from the authors.

Magnetic Mineralogy: Given the high degree of variability of the rocks types, why only four "representative" samples were ran for thermomagnetic characterization? Curie point estimates are automated and thus very easy to run.

Discussion: page 79: I question whether any primary magmatic fabrics remain in these rocks. The authors go on to argue that the plagioclase laths define a magmatic fabric that has been enhanced by the shape or distribution anisotropy fabric of magnetite single grains and aggregates. I would argue that as the crystal mush cooled the regional stress field realigned any primary magmatic layering to reflect the regional stress field; thus transposing the primary magmatic layering. The secondary magnetite associated with the hydrothermal fluids then used the silicate framework to grow (mimic fabric) to enhance the magnetic susceptibility. If this is what the authors are arguing for, then it was not very clear; at least to me.

Domal Shape: Although not a big criticism, I do not see evidence based on map pattern or in the field photos to argue for a "domal" shape to the pluton; I see a sill-like geometry.

Page 83, Closing Statements: The authors state "The presence of overprinting foliations in shallow (<2 km emplacement depth) subvolcanic intrusions (e.g., Shellenbarger granite) suggests that the crystallizing plutons behaved as rheologically weak inclusions in the stiff brittle crust where the contractional component of transpression was partitioned into active magma regions, recorded by magmatic and magnetic fabrics, and the wrench component was partitioned into shear zones or brittle faults. This inference challenges the common view that minor high-level intrusions (dikes, necks, small subvolcanic plutons) typically preserve only magma flow related fabrics as they solidify too fast to record the slow regional tectonic deformation. We thus conclude that fabrics in shallow-level intrusions may capture instantaneous tectonic strain in the upper crust as do large deeper granitoid plutons." This is a very big leap! The argument that dikes, necks, and small subvolcanic plutons may record regional strain is highly speculative. I would qualify this argument in that only under a very special set of conditions would this occur in shallow level intrusion, such a region of high differential stress.

Chapter 4 Simultaneous batholith emplacement, terrane/continent collision, and oroclinal bending in the Blue Mountains Province, North American Cordillera

Summary

This paper discusses mechanisms, kinematics, and timing of initiation of the tectonic curvature observed in the Blue Mountains Province in northeastern Oregon. Magmatic fabric patterns and anisotropy of magnetic susceptibility (AMS) in the Wallowa batholith record three phases of progressive deformation of the host Wallowa terrane during Early Cretaceous, 1) Oblique ~NE–SW shortening, 2) pure shear-dominated ~NNE–SSW shortening, and 3) around 126 Ma the northern portion of the superterrane became ʿlocked'leading to reorientation of the principal shortening direction to ~NNW–SSE while its still deformable southern portion rotated clockwise about a vertical axis.

Comments

General: I am concerned with the limited number of AMS sites established in each of the plutons (7 sites in the Pole Ridge pluton, 15 sites in the Hurricane Divide pluton, 2 sites in the Saw Tooth stock, and 18 sites in the Craig Mountain pluton). Sample density is critical in AMS studies.

Magnetic Mineralogy: Given the high degree of variability of the rocks types, why were only six "representative" samples ran for Curie point estimates; these are automated and thus very easy to run.

AMS interpretation: The authors interpret the AMS data to reflect post-emplacement increments of regional tectonic strain. This interpretation is valid.

I have no other concerns related to this manuscript.

Chapter 5 Granitic magma emplacement and deformation during early-orogenic syn-convergent transtension: The Staré Sedlo complex, Bohemian Massif

Summary
The Late Devonian Staré Sedlo complex, Bohemian Massif was emplaced as a subhorizontal sheeted sill pluton into a transtensional zone. The transtensional setting is documented by strong constrictional fabric with variably developed subhorizontal magmatic to solid-state foliations suggesting vertical shortening. The authors argue that the magma/host rock system in transtension must have evolved from initial crack tip propagation and vertical expansion due to new magma additions through conduit flow to ductile thinning after the magma input had ceased. The sill emplacement and their subsequent deformation are then interpreted as recording early-orogenic syn-convergent sinistral transtension along the rear side of an upper-crustal wedge, which was extruded both upward and laterally in response to subduction and continental underthrusting.

Comments
General: Of the five manuscripts in the thesis, this manuscript is in need of numerous grammatical corrections. The content is solid and I enjoyed the paper.

Magnetic Mineralogy: Why were only five “representative” samples ran for Curie point estimates; these are automated and thus very easy to run.

AMS: I am concerned with the limited number of AMS sites established in the pluton (13 sites); sample density is critical in AMS studies. A significant amount of assumptions are being put forth with very little data to support the conclusions. For this study, I would have liked to see different structural levels sampled within the pluton. For example, vertical transects up canyon walls. If this was not possible and every available outcrop was sampled then I understand. Exposure is always a limiting factor. However, this should be discussed in the narrative of the manuscript.

Conclusions: Although I am skeptical of the results as the data are sparse, based on the AMS fabrics presented the data support the authors conclusions.