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Paleomagnetic and AMS results from two layered mafic laccoliths, north-central Montana, USA

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Magnetic properties of plutons can yield important information about magmatic processes and emplacement dynamics. The Shonkin Sag (SS) and Square Butte (SB) laccoliths, part of the Cenozoic Montana alkaline province in north-central Montana, are little eroded shallow level, mafic layered intrusions representing different stages in the formation and growth of laccoliths. Both bodies exhibit thin, finer grained shonkonitic sills that emanate subhorizontally for 100s of meters into the Upper Cretaceous Eagle Sandstone. The circular-shaped, SS laccolith is about 7 km2 in areal extent, and reaches a maximum thickness of 70 m. In contrast, the SB laccolith is over 480 m thick and is the largest of the many laccoliths in the province. Both intrusions are strongly differentiated into a lower shonkonite overlain by syenite. The main shonkonitic part of the SB laccolith exhibits a uniform remanence direction comparable to the time averaged expected early Eocene field direction (e.g., D = 344°, I = 68°, a95= 2.1°, N = 35 samples distributed over 8 sites). In contrast, the lower shonkonitic part of the SS exhibits a remanence direction that differs significantly from the expected field direction (e.g., D = 300°, I = 70°, a95= 10°, N = 22 sites). Interestingly, the upper highly differentiated syenite yields a ChRM that differs from the main shonkonite, suggesting that cooling overall, was sufficiently protracted to allow the recording of some paleo-secular variation. Cooling age data are currently being obtained from these rocks to evaluate this. Anisotropy of magnetic susceptibility (AMS) as well as anhysteretic remanent magnetization (AARM) data are being obtained from 69 sites sampled throughout the SS and 51 sites sampled along the northern and southeastern parts of the SB. The main body of the SS reveals dominantly subhorizontal and prolate AMS fabrics that vary strongly and abruptly in orientation. Notably, some sites separated by

less than 50 m and at similar locations vertically within the main body of the laccolith reveal significantly different Kmax directions. A vertical transect through the southeastern portion of the SB laccolith reveals dominantly subhorizontal and triaxial AMS fabrics with Kmax orientations varying in all directions. Toward the interior of this large laccolith, the shonkonite exhibits a strong magmatic fabric defined by isolated, subhorizontal syenitic blebs trapped in shonkonite. AMS results from this part of the laccolith show a strong oblate fabric, with a vertical Kmin orientation. Our field observations and analytical results suggest early laccolith development via rapid pulses of low volume magma input during lateral sill growth. Continued growth during laccolith development involved higher volume magma input, and rapid vertical thickening allowing for gravity-controlled differentiation.