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Forceful emplacement of the Eureka Valley–Joshua Flat–Beer Creek composite pluton into a structural basin in eastern California; internal structure and wall rock deformation

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ABSTRACT

Anisotropy of Magnetic Susceptibility parameters have been analyzed at 311 locations in the Eureka Valley–Joshua Flat–Beer Creek (EJB) pluton of eastern California. The large amount of data has allowed for the AMS parameters to be contoured using techniques that both reveal map-scale trends and emphasize small-scale differences. The contour maps suggest that magnetic susceptibility is dominantly controlled by composition of the magma but may also be affected by emplacement-related strain as the magma chamber inflated and forced the wall rocks outward. Pluton construction involved two major pulses of different composition magmas that were emplaced sequentially but with overlapping periods of crystallization. The magmas initially intruded as sill-like bodies into a structural basin. The magnetic foliation of the pluton cuts across internal magmatic contacts on the map scale and is parallel to local contacts between the pluton and surrounding metasedimentary wall rocks. The magnetic fabric is similar in orientation and symmetry to intense flattening strains recorded in the aureole rocks. The metasedimentary wall rocks have been shortened between 60 and 70% and this strain magnitude is approximately equal on the west, south, and east margins of the pluton. Strain in the wall rocks is dominantly flattening and concentrated into a narrow (1 km wide) inner aureole. Mapping of bedding/cleavage intersection lineations south of the pluton indicates that the magma made room for itself by translating the wall rocks outward and rotating the already inward dipping wall rocks of the structural basin to sub-vertical. Stretching of the inner aureole around an expanding magma chamber was responsible for the intense shortening. Limited data on the Marble Canyon pluton to the south of the EJB pluton indicates a very similar emplacement process.

1. Introduction

Igneous fabrics preserved in plutons have been used as a guide to interpreting magma emplacement processes for many years (Archanjo et al., 1999; Balk, 1937; Bouchez, 1997; Brun and Pons, 1981; Brun et al., 1990; Godin, 1994; Hutton, 1988; Karlstrom et al., 1993; Lagarde et al., 1990; Marre, 1986; Pitcher, 1979; Ramsay, 1989; St Blanquat et al., 2001; Stevenson et al., 2007; Tobisch et al., 1993). However, the magmatic fabric is probably more useful in investigating the later or last stages of magma emplacement because existing fabrics can be modified as more magma enters the chamber, and/or as the magma/mush solidifies. In addition, the orientation of grain-shape foliation and the lineation is a record of the strain in the magma but the amount of translation and the path a grain took to arrive at its present location are not recorded.

An analysis of the wall rocks surrounding plutons can also be incomplete because there are typically very few strain markers. When present these markers can document strain, often concentrating in narrow aureoles, but strain analyses do not yield information on the deformation paths of the wall rocks. The deformation path, which includes the translation and rotation of the wall rocks is only obtained if there is a three-dimensional marker that can be traced out of the deformation zone associated with emplacement of the pluton and back to the region of country rocks not affected by the emplacement. Maps and cross-sections can only provide apparent two-dimensional paths, and may in fact add to the confusion because of their spatial limitations.

Our approach to understanding the emplacement of the Eureka Valley–Joshua Flat–Beer Creek (EJB) composite pluton in eastern California (Figs. 1 & 2) is to combine a detailed petrophysical study of the Anisotropy of Magnetic Susceptibility (AMS) within the pluton with a detailed analysis of the strain and deformation path of the wall rocks. The study of AMS patterns is a commonly employed tool for studying emplacement of plutons (e.g., Archanjo et al., 1999; Birch, 1979; Bouchez, 1997; Ferré et al., 1995; Gleizes et al., 1997; Guillet et al., 1983; Olivier et al., 1997; St Blanquat and Tikoff, 1997). AMS analysis allows for

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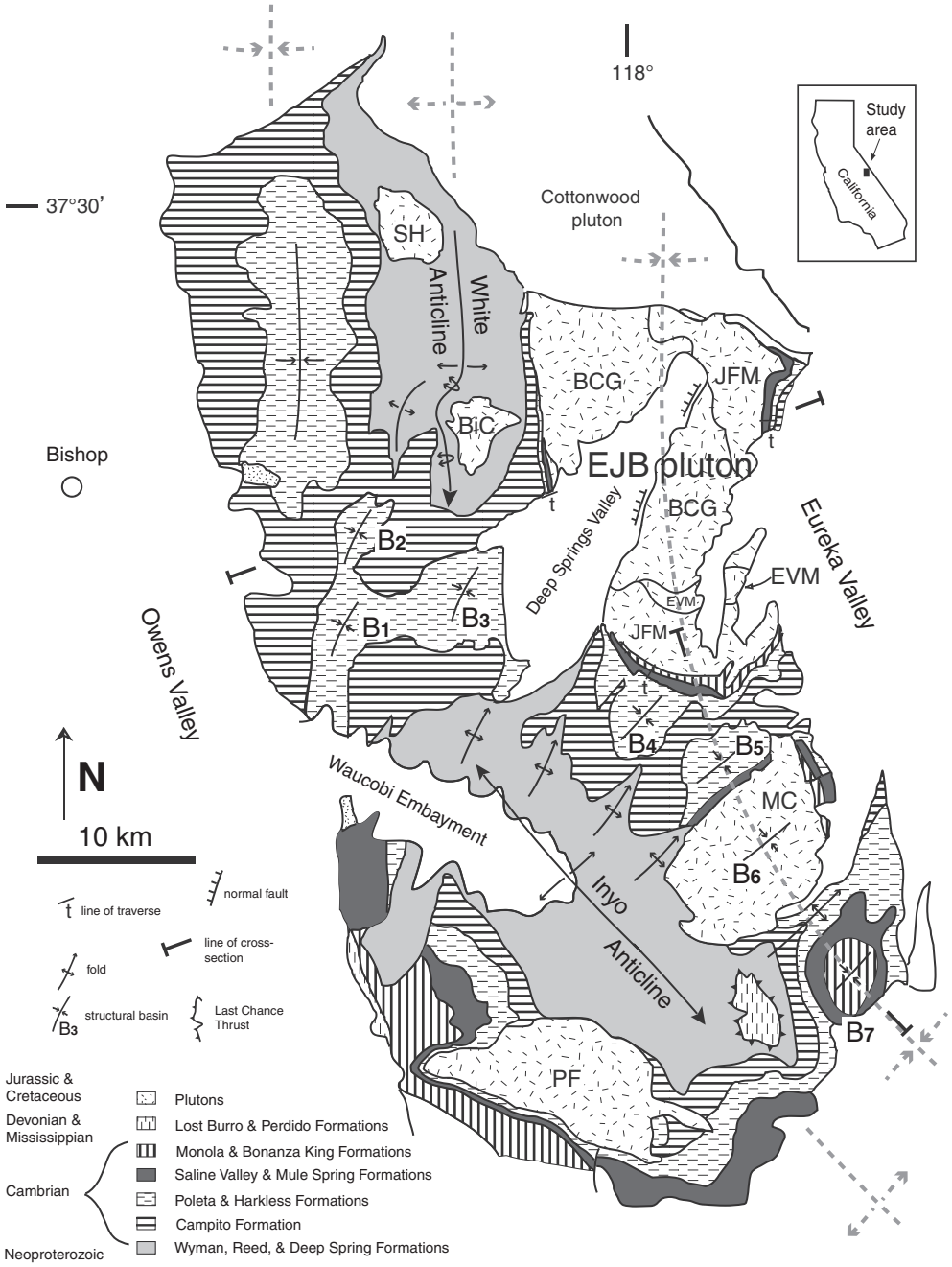

Fig. 1. Generalized geologic map of central White-Inyo range in eastern California. B1 through B7 indicate locations of structural basins resulting from the two periods of folding in the region. Modified after Nelson et al. (1991) and Morgan et al. (1998). BCG, Beer Creek granite; BiC, Birch Creek pluton; EVM, Eureka Valley Monzonite; JFM, Joshua Flat Monzonite, MC, Marble Canyon pluton; PF, Papoose Flat pluton; SH, Sage Hen Flat pluton.

foliation and lineation orientations to be accurately determined at each sampling site, although there is not a simple relationship between anisotropy magnitudes and strain (Archanjo et al., 1995). Our AMS study is unique in that we have a large data set (over 300 locations) that allows for many of the magnetic parameters to be contoured in map view with various geospatial techniques that give varying degrees of importance to pluton-wide trends versus more local trends within the pluton. We conclude that the current orientation of the magnetic fabric developed diachronously over the entire period of construction of the pluton through individual pulses of magma, thereby explaining why observed foliations cross some internal magmatic contacts. We interpret the last stage of foliation development as being related to the flattening of the crystal rich magma or mush against the surrounding sedimentary wall rocks as overall expansion of the pluton occurred during injection of the last pulses of magma. Flattening strains are documented in the aureole rocks surrounding the pluton.

The space required for construction of the EJB pluton can be accounted for by outward and upward translation of the country rocks, although it is assumed that upward translation of the roof rocks also occurred. The associated three-dimensional deformation path of the country rocks was estimated by mapping the cleavage-bedding intersection lineation and modeling the translation and rotation out of the regional, pre-pluton emplacement lineation trend. The pre-pluton emplacement regional structure of sedimentary rocks exposed in the White-Inyo Range is characterized by domes and basins, formed from overprinting tectonic events in the Paleozoic and possibly early