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What do fault patterns reveal about the latest phase of extension within the Northern Snake Range metamorphic core complex, Nevada, USA?

Zeshan Ismat [a,*], Paul Riley [b], Jory Lerback [c]

[a] Department of Earth and Environmental Science, Franklin and Marshall College, Lancaster, PA 17603, USA
[b] Exxon-Mobil, Houston, USA
[c] Earth Water Global, Washington D.C., USA

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ABSTRACT

The Northern Snake Range is a classic example of a metamorphic core complex, Basin-and-Range province, United States. It is composed of a plastically deformed footwall and a brittlely deformed hanging wall, separated by the Northern Snake Range low-angle detachment (NSRD). Brittle deformation, however, is not confined to the hanging wall.

This paper focuses on exposures in Cove Canyon, located on the SE flank of the Northern Snake Range, where penetrative, homogeneous faults are well exposed throughout the hanging wall, footwall and NSRD, and overprint early plastic deformation. These late-stage fault sets assisted Eocene-Miocene extension. Detailed analysis of the faults reveals the following: (1) The shortening direction defined by faults is similar to the shortening direction defined by the stretching lineation in the footwall mylonites, indicating that the extensional kinematic history remained unchanged as the rocks were uplifted into the elastico-frictional regime. (2) After ~17 Ma, extension may have continued entirely within elastic-frictional regime via cataclastic flow. (3) This latest deformation phase may have been accommodated by a single, continuous event. (3) Faults within NSRD boudins indicate that deformation within the detachment zone was non-coaxial during the latest phase of extension.

1. Introduction

The Northern Snake Range, east-central Nevada, is one of the most intensely studied metamorphic core complexes in the Basin-and-Range province (Fig. 1) (e.g. Coney, 1980; Davis, 1980; Coney and Harms, 1984; Lister and Davis, 1989; Burchfiel et al., 1992). The Northern Snake Range core complex is bound by the Northern Snake Range detachment (NSRD) – a domiform detachment fault with an underlying thick (up to 100 m), gently dipping (sub-horizontal in places), mylonitized shear zone (Miller et al., 1983, 1987; Gaudemer and Tapponnier, 1987; Lee, 1995; Miller and Gans, 1999). The NSRD is a classic detachment in that it is characterized by high shear strain and a sharp metamorphic gradient (e.g. Cooper et al., 2010; Gébelin et al., 2011, 2015). It separates the 'brittle' deformed hanging wall, i.e. *upper plate*, from the mylonitized footwall, i.e. *lower plate*, or *metamorphic core* (Gans and Miller, 1983; Bartley and Wernicke, 1984). Brittle deformation, such as faults, however, is not confined to the hanging wall. Fault sets extend throughout the entire Northern Snake Range and overprint the plastic deformation in the NSRD shear zone and footwall (Miller et al., 1983; Gans and Miller, 1983; Miller and Gans, 1999). These penetrative fault sets suggest that the NSRD and footwall were progressively uplifted from the quasi-plastic regime into the elastico-frictional regime during deformation.

A complex history of initial shortening followed by discontinuous extension has shaped the Northern Snake Range (Miller et al., 1983, 1999; Gébelin et al., 2015). Detailed analyses of the extension history, via thermochronology and field relationships of sedimentary strata, suggests that motion across the NSRD was episodic and discontinuous (Lee and Sutter, 1991; Lee, 1995; Miller and Gans, 1999). In addition, the amount of shear that took place across the NSRD increases and changes from shear dominated by coaxial strain to non-coaxial strain in the direction of transport (Gaudemer and Tapponnier, 1987; Lee et al., 1987; Lee, 1995; Miller and Gans,

* Corresponding author.
E-mail address: zeshan.ismat@fandm.edu (Z. Ismat).

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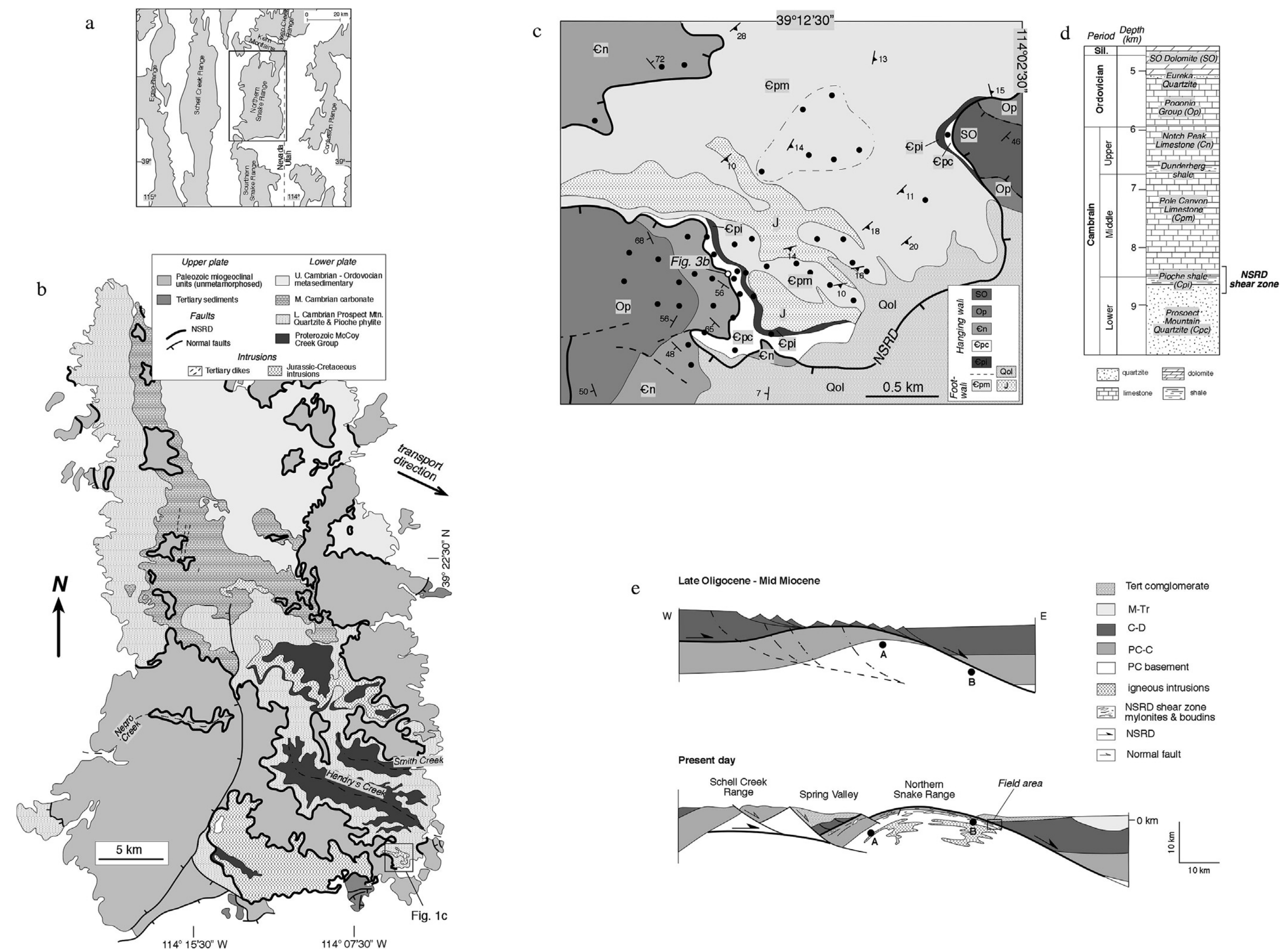

Fig. 1. (a) Simplified geologic map showing the location of the Northern Snake Range (adapted from Miller and Gans, 1999). Boxed area is enlarged in part (b). Black square shows location of Cove Canyon and is enlarged in part (c). (b) Simplified geologic map of the Northern Snake Range (modified from Miller et al., 1999). Boxed area shows location of Cove Canyon, and is enlarged in part (c). (c) Geologic map and (d) stratigraphic column of units exposed in Cove Canyon. (Adapted from Miller and Gans, 1999). Black dots show site locations where detailed field data was collected. The NSRD is shown as a thick black line with tics, drawn on the hanging-wall side. Macroscale normal faults and strike-slip faults are shown as dashed lines. The view exposed at the site labeled with a white dot, across the NSRD, is illustrated in Fig. 3b. Dashed lines encircles 6 sites located within the lower portion of the footwall. (e) Schematic, transport parallel cross-sections showing rolling hinge/isostatic rebound model for the Northern Snake Range that took place during Late-Oligocene to Mid-Miocene (modified from Wernicke, 1992 and Miller et al., 1999).

1999; Gébelin et al., 2011). Recent work has shown that this episodic motion history, and variation in coaxial and non-coaxial deformation across the range, can be explained by a rolling hinge/isostatic rebound model, where the footwall is isostatically uplifted and migrates with the accompanying displacement of the hanging wall (Fig. 1) (Lee, 1995; Axen and Bartley, 1997; Cooper et al., 2010; Gébelin et al., 2015).

In this paper, we examine fault patterns within Cove Canyon, located in the southeastern portion of the Northern Snake Range, where the hanging wall, footwall and NSRD are very well exposed (Fig. 1). In this part of the range, the later stages of extension, based on plastic deformation markers and thermochronology within the footwall, are well documented (Miller et al., 1983, 1999; Lee et al., 1987; Lee, 1995; Gébelin et al., 2015). Here, we ask whether the fault patterns, throughout the hanging wall, footwall and NSRD shear zone, can provide more constraints to the kinematics of the latest phase of Eocene-Miocene extension, which is marked by vertical thinning and horizontal extension (Miller et al., 1983; Lee et al., 1987; Johnston, 2000; Gébelin et al., 2015).

Most of the analysis of the Northern Snake Range, thus far, has been conducted on rocks within the footwall and NSRD shear zone, where deformation took place at higher temperature and pressure conditions than greenschist metamorphic grade (e.g. Miller et al., 1983; Lee et al., 1987; Gaudemer and Tapponnier, 1987; Lee et al., 1987; Lee, 1995). Therefore, some of the older, plastically deformed structures are lost and/or are cryptic due to recrystallization processes. We focus on the brittle structures because they potentially provide a complete history during the later stages of deformation, when the entire range was uplifted into the elastic-frictional regime (Early-Mid Miocene) (Miller et al., 1999; Cooper et al., 2010; Gébelin et al., 2015). In other words, the deformation is not erased by successive generations of faulting.

We extend these fault analyses to asymmetric boudins, which are ubiquitous throughout the NSRD shear zone and well preserved in Cove Canyon. We pay special attention to the boudins because they have been used to address continued debates, such as the degree of coaxial or non-coaxial deformation within the NSRD shear zone (Gaudemer and Tapponnier, 1987; Lee et al., 1987; Davis and Lister, 1989; Gébelin et al., 2015).

To date, brittle deformation analyses within the Northern Snake