STRUCTURAL GEOLOGY AND TECTONICS OF NEWLIN CREEK-LOCKE RIDGE, WET MOUNTAINS COLORADO: IMPLICATIONS FOR PROTEROZOIC TECTONICS IN CENTRAL COLORADO

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INTRODUCTION

A fundamental problem in the Precambrian history of central Colorado is recognizing if an observed structure formed during Paleoproterozoic tectonism or during Mesoproterozoic rejuvenation (Karlstrom, 1999). This study has focused on this question through a detailed structural study of the Locke Park-Newlin Creek-Coal Creek region of the Central Wet Mountains (Figure 1). This region provides important new insights into this problem since there is a distinct deformation gradient present within the field area associated with the emplacement of the 1.44 Ga Oak Creek pluton in the northeastern part of the field area. Fabrics associated with the Oak Creek pluton overprint fabrics in strongly deformed gneisses which we interpret to have formed during the Paleoproterozic.

This study builds on the results of Siddoway et al. (2000) who presented a regional synthesis of the Precambrian geology of the Wet Mountains based on detailed mapping projects undertaken during the 1998 Keck Project focused on the Wet Mountains. Siddoway et al. (2000) identified the Newlin Creek shear zone, a northeast dipping contractile shear zone developed within gneiss and migmatite. Our results differ from those presented by Siddoway et al. (2000) because of the recognition of strain gradients associated with the Oak Creek pluton which was not examined by Siddoway et al. (2000). Our results are described below.

Methods

The study area was mapped at a scale of 1:10,000. Precise locations were made using a Garmin hand held GPS receiver. Data was plotted in the field and then compiled into a map of the study area (Figure 1). Strain was quantified using the Rf/ϕ method and the Fry analysis method (Ramsey and Hubber, 1983).

Thirty six thin sections were analyzed in this study. Kinematics were determined by looking for asymmetric structures in planes parallel to the lineation and perpendicular to foliation. Kinematic indicators were also looked for in other planes, but in only one case were any observed.

LITHOLOGIES

A granular orthogneiss which weathers to a pale orange or tan color dominates much of the field area. This rock contains K-feldspar, plagioclase, quartz, biotite and opaque phases. In many cases the biotite is altered to chlorite. Accessory phases include zircon, titanite and apatite. In general the contacts between the orothogneiss and biotite and amphibolite gneisses are concordant, although a few discordant contacts were observed proving an intrusive origin for the orthogneiss. This rock is interpreted to be a strongly deformed Paleoproterozic granitoid, which we refer to as the Newlin Creek orthogneiss.

Supracrustal rocks in the field area include biotite gneiss, amphibolite gneiss, grey weathering quartzofeldspathic gneiss and calc-

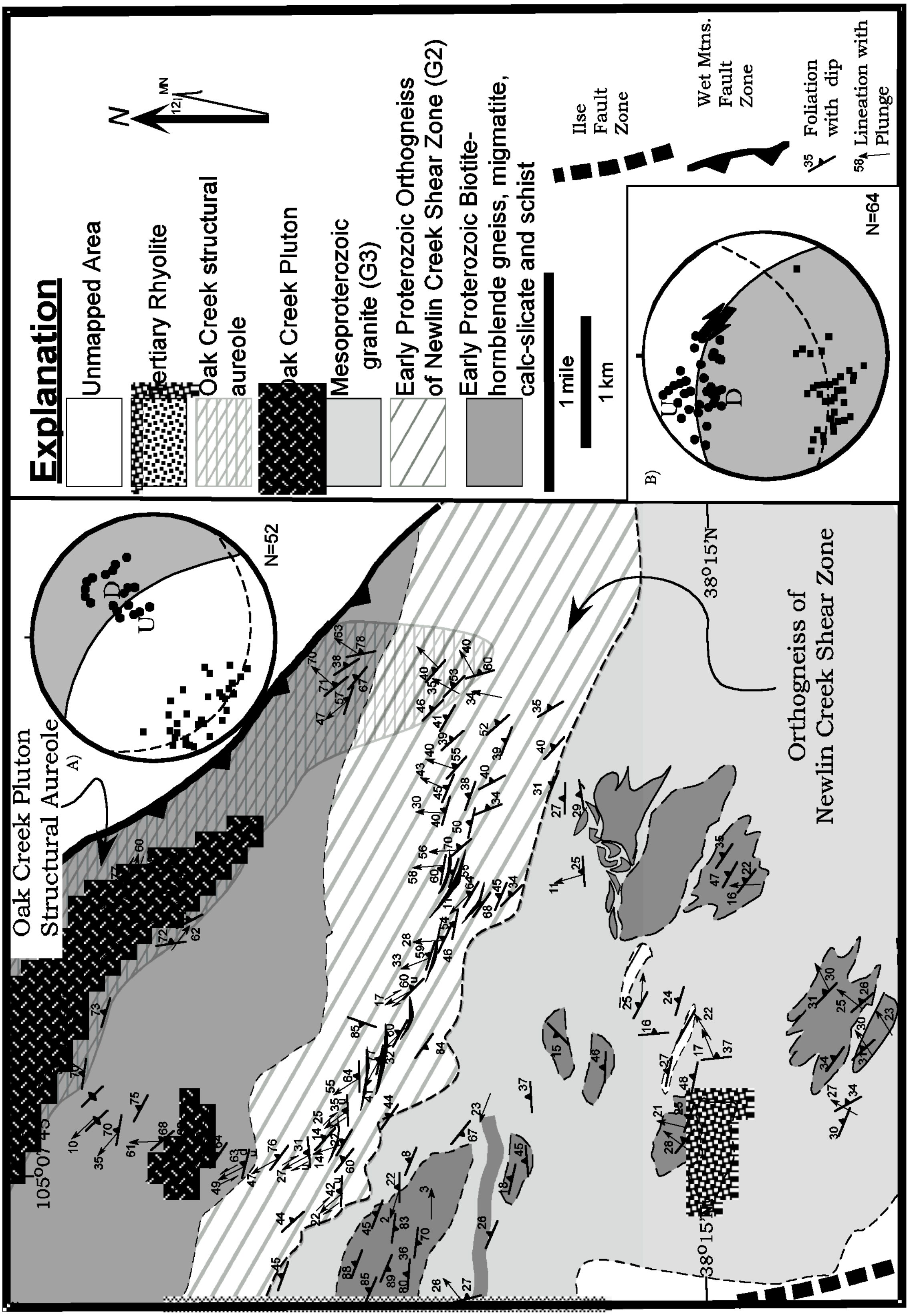

Figure 1. Geological Map of the study area. Region to the south of the Newlin Creek orthogneiss modified from Siddoway et al. (2000). A) Equal area lower hemisphere projection of structural data from the Oak Creek aureole. B) Structural data from Newlin Creek Shear zone. Black squares poles to foliation, black circles mineral lineations in both.

silicate. The biotite gneiss commonly contains the assemblage biotite + K-feldspar + plagioclase + quartz +/- sillimanite +/- garnet. The association of garnet and sillimanite was not observed. Amphibolite gneiss contains hornblende + plagioclase + biotite + opaques +/- orthopyroxene +/- clinopyroxene. The heavily altered texture of the pyroxenes makesit unclear if they are phenocrysts preserved from the igneous protolith or if they are metamorphic in origin. Calc-silicates contain diverse mineral assemblages. A common assemblage is grossular + calcite + K-feldspar + clinopyroxene + orthopyroxene + tremolite + foresterite +/- quartz. Calcite and tremolite are the most common phases in all of the calc-silicates. Quartzofeldspathic gneiss contains assemblages quite similar to the biotite gneiss except that modally K-feldspar and plagioclase are the dominant phases, and biotite is present in lesser amounts. Outcrop scale fold interference patterns demonstrate that all of the supracrustal rocks have been folded at least twice.

The association of sillimanite and K-feldspar in migmatite coupled with the mineral assemblages in the calc-silicates suggests

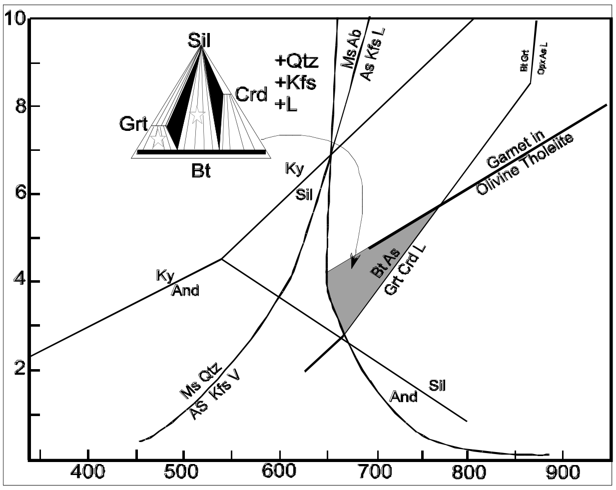

Figure 2. Pressure-Temperature diagram after Spear et al., 1999. Garnet in line is from Ringwood 1972, and marks the appearance of garnet in a mafic granulite with a composition of Olivine Tholeiite. Gray region is favored P-T estimate.

temperatures were above 650 º C and possibly as high as 750 º C. The absence of garnet in the amphibolite gneiss suggests pressures did not exceed 6 kbar (Figure 2).

The Oak Creek pluton is a K-feldspar megacyrstic porphyritic monzogranite to quartz monzonite (Cullers et al., 1993). In all outcrops observed in this study the Oak Creek pluton is foliated with the foliation locally becoming gneissic. The pluton's fabric is concordant with that of the country rocks and contains concordant screens of migmatitic country rock. In the study area the overall geometry of the Oak Creek pluton is of a moderate to steeply northeast dipping sill.

STRUCTURE

Foliations in the study area strike to the northwest with moderate to steep dips towards the northeast (Figure 1). Mineral lineations have moderate, but variable plunges. The trend direction of the mineral lineations appears to be a function of proximity to the Oak Creek pluton. North-northeast trending mineral lineations occur within and adjacent to the Oak Creek pluton, whereas in other parts of the field area mineral lineations plunge to the north-northwest (Figure 1). On this basis we divided the field area into two geometric domains, the 'Oak Creek structural aureole' and the 'Newlin Creek domain' (Figure 1).

The Newlin Creek domain can be divided into high and low strain regions. In the central part of the map area, the Newlin Creek orthogneiss contains strong L-S tectonite fabrics which are locally mylonitic. In several places L>>S attesting to intense stretching during deformation. Fry analysis on gneisses going across strike show the largest strain occurred in the middle of the orthogneiss, with strain decreasing away from the orthogneiss. The intensity of the foliation and lineation as well as the variation in strain intensity suggests that the Newlin Creek orthogneiss forms the core of a major shear zone (Newlin Creek shear zone of Siddoway et al., 2000). Kinematic indicators within the shear zone include asymmetric porphyroclasts, shear bands, and C/S fabrics which consistently indicate top to south reverse sense of motion. The shear zone has a structural thickness of ~2 km.

As the Oak Creek pluton is approached lineations change from being northwest trending to being northeast trending. Within the Oak Creek pluton solid state down dip lineations are present. Kinematic indicators within the Oak Creek pluton demonstrate top down to the northeast normal displacement. Normal sense kinematic indicators are restricted to a relatively narrow region within and adjacent to the Oak Creek pluton (Figure 1).

Differences in orientations and kinematics of shear bands and C/S fabrics from the two domains support this interpretation. Figure 3a shows the average orientation of C and S planes from the Newlin Creek orthogneiss. These planes are shallowly NE-dipping consistent with thrusting within the Newlin Creek shear zone. The transport direction suggested by the geometry of the C/S fabrics is gently north-northwest plunging similar to the orientations of lineations in the Newlin Creek shear zone. In contrast, shear bands within the Oak Creek pluton record a different strain field. The shear bands are steeply dipping and are divided into two sets, a northwest striking sinistral set, and a northeast striking dextral set. The average of the two sets of shear bands is approximately bisected by the average foliation within the Oak Creek Pluton. The orthorhombic symmetry of the shear bands suggests that they accommodated flattening across the margins of the pluton and north-west stretching. Clearly the shear bands in the Oak Creek Pluton record a distinct strain field from the structures found in the Newlin Creek shear zone.

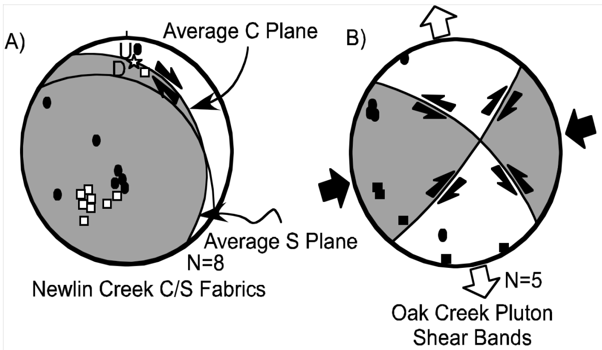

Figure 3. Lower hemisphere equal area projections summarizing the orientations of shear bands and C/S fabrics from the study area. A) Average C (pole = black circle) and S (pole = white square) for Newlin Creek shear zone, star shows inferred movement direction. B) Geometry of conjugate shear bands developed within the Oak Creek Pluton; poles to sinsistral are squares and dextral, circles.

CONCLUSIONS

The structural relationships within the Newlin Creek-Locke Park area have important implications for the tectonic evolution of central Colorado during the Proterozoic. The deformation history of the region began with folding of the host gneiss. The next event was intrusion of the Newlin Creek orthogneiss. The orthogneiss then appears to have localized deformation as attested by high strains occur within it. High temperature deformation fabrics within the orthogneiss suggest that strain may have occurred during or shortly after intrusion.

The timing of these events is not well constrained. The deformation within the Newlin Creek shear zone likely occurred in the Paleoproterozic during Mazatal Orogensis. The structural thickness and intensity of deformation within the shear zone suggest it accommodated significant crustal thickening. The age of the Newlin Creek orthogneiss would provide an upper limit on the age of deformation within the Newlin Creek shear zone.

Reorientation of the lineations from northwest to northeast plunging appears to have occurred as the Oak Creek pluton intruded at 1.44 Ga. Structures within the Oak Creek pluton record a complex strain field involving northeast side down normal motion and flattening across the sill walls. The flattening likely occurred due to inflation of the sill. Thermal softening from the Oak Creek Pluton localized deformation near its margins producing a structural aureole.

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