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Out-of-sequence emergent thrusting during the Early Tertiary, within the Sevier hinterland, Montana recess, southcentral Idaho

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Out-of-sequence emergent thrusting during the Early Tertiary, within the Sevier hinterland, Montana recess, southcentral Idaho

by

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Table of Contents

List of Tables

List of Figures

Abstract

The Smiley Creek conglomerate (senso Volkmann 1972), a synorogenic deposit within southcentral Idaho, preserves a record of out-of-sequence thrusting in the hinterland of the Sevier orogenic belt during the Early Tertiary. The structural and sedimentological evidence indicates that the Smiley Creek conglomerates were initially shed from the emergent Glide Mountain thrust, and then later deposited by more hinterland structures of the Wildhorse thrust system. A paleomagnetically derived depositional age for the Smiley Creek conglomerate, between 63-61 Ma, indicates continued compression along the Glide Mountain thrust and the Wildhorse thrust system within the hinterland of the Montana recess at a time when compression within the adjacent Helena and Wyoming salients was confined to the most foreland structures. Compression within the foreland of the Montana recess ceased during the Late Cretaceous when the Tendoy thrust buttressed against the uplifted Blacktail-Snowcrest arch, inhibiting further eastward progression and resulting in westward propagating out-of-sequence thrusting. Movement along the Glide Mountain thrust, and subsequent folding of the Wildhorse thrust system was the result of the out-of-sequence thrusting shedding the synorogenic deposit into wedge-top basins. The Smiley Creek conglomerate represents the youngest known synorogenic hinterland wedge-top conglomerate, deposited during the Sevier orogeny within the hinterland of the Sevier orogenic belt, southcentral Idaho.

Introduction

Reconstructing the kinematic and depositional history of a fold and thrust belt is often difficult, especially within the hinterland where intense deformation conceals pertinent timing evidence. Most studies therefore focus on foreland basins where emergent structures and growth strata preserved within synorogenic deposits provide a record of deposition and deformation within the evolving fold-and-thrust belt (e.g. Riba 1976, Suppe et al. 1992). Such is true for the Sevier orogenic belt in Idaho, Wyoming, and Montana, where multiple compressional and extensional deformation events, beginning in the Devonian and continuing through the present, have developed, deformed and destroyed, evidence that records the region's geologic evolution. In the foreland of this region ample timing evidence, preserved within synorogenic deposits shed from east-vergent thrust sheets, constrains the sequence of deformation and deposition along the most eastern Sevier structures. The timing of deformation and deposition within the hinterland of this region is less well known since, synorogenic deposits are typically not preserved, and timing evidence is frequently based on less precise tools. However, in the hinterland of the Montana recess in southcentral Idaho, the Smiley Creek conglomerate (senso Volkmann 1972, Paull et al. 1974), is preserved within a series of isolated exposures just east of the Pioneer core complex. The deposit provides the opportunity to ask certain questions such as: What are the structures controlling the formation of the basin and the deposition of the conglomerate? What is the lithologic nature of the deposit? What type of depositional and deformational environment would be representative of such a deposit? What is the age of the deposit? Finally, how does the age and nature of the Smiley Creek conglomerate relate to the timing of deformation within the adjacent hinterlands of the Helena and Wyoming salients?

Geological Setting

Regional deformation within the Northern Rocky Mountains was complex throughout its geologic history, as witnessed by multiple deformation and deposition events, overlapping both spatially and temporally, observable within the rock record of the Sevier fold-and-thrust belt of Idaho, Wyoming and Montana (e.g. Burchfiel et al. 1992) (Figure 1). Beginning with the Antler orogeny during the Late Devonian, a sequence of major compressional deformation events affected the western North American Cordillera (e.g. Burchfiel et al. 1992, Poole et al. 1992). Clastic debris shed from eroding Antler highlands accumulated in thick sequences during the early Mississippian through latest Paleozoic in the adjacent flexurally subsiding Antler foreland basin (Poole et al. 1992). An increase in volcanic activity occurred during the middle to late Mesozoic as evidenced by the emplacement of plutons in much of western and northern Idaho (Cowan and Bruhn 1992). Cooling ages in the suture zones of the Seven Devils arc terrane, northwest Idaho, yield ages of 82 Ma (Lund and Snee 1988). Likewise, in the Albion Mountains, just south of the Snake River Plain within southcentral Idaho, cooling ages range from 80 Ma to 67 Ma (Armstrong 1975). Prior to and coeval with this magmatic activity, Sevier compressional

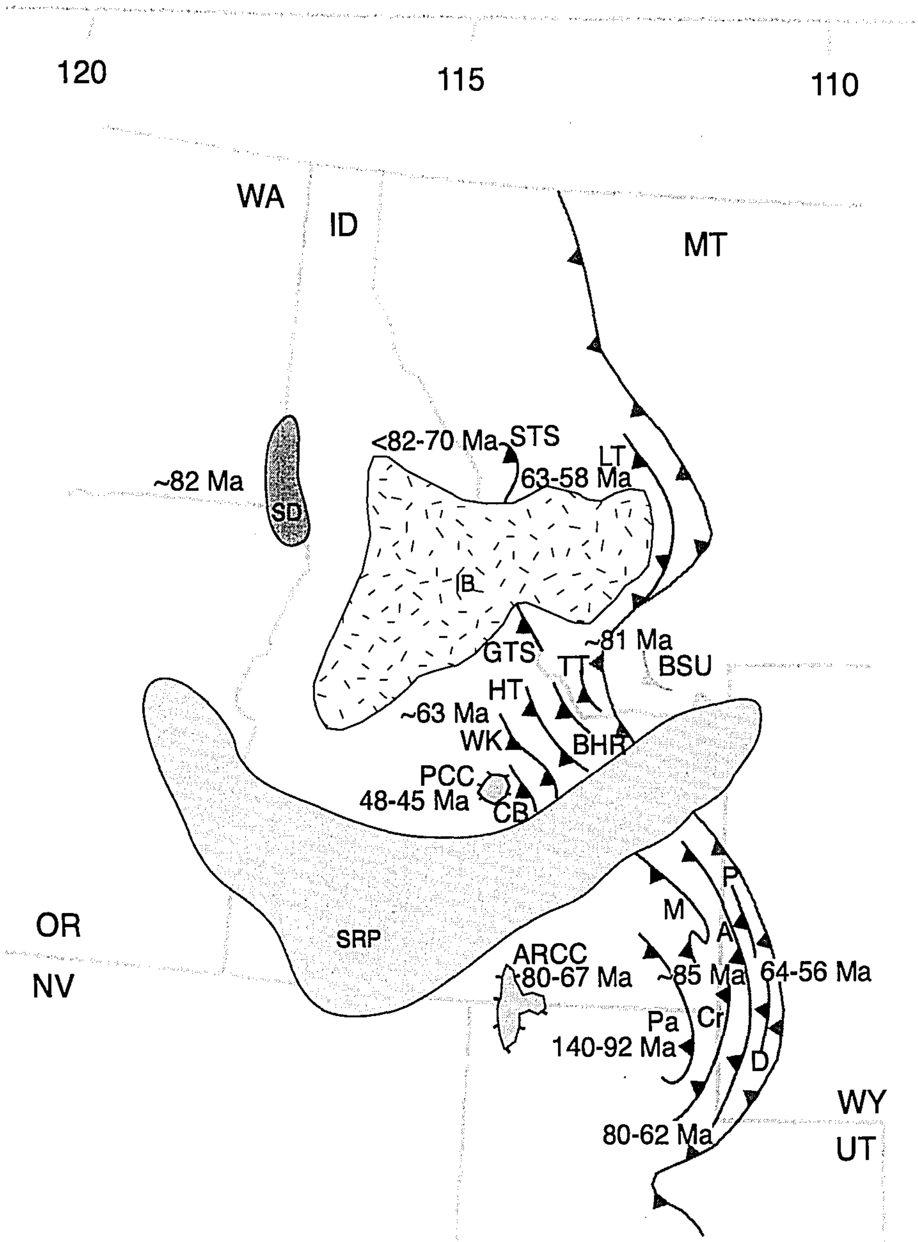


Figure 1. Timing and extent of deformation within the Sevier fold-and-thrust belt, Idaho. (SD=Seven Devils Terrane, IB=Idaho Batholith, SRP=Snake River Plain, PCC=Pioneer Core Complex, ARCC=Albian Range Core Complex, STS=Sapphire thrust system, LT=Lombard thrust, GTS=Grasshopper thrust system, TT=Tendoy thrust, BHR=Beaverhead Range, HT=Hailey thrust, WK=White Knob thrust, CB=Copper Basin block, P=Prospect thrust, D=Darby thrust, A=Absorka thrust, Cr=Crawford thrust, M=Meade thrust, Pa=Paris thrust, BSU=Blacktail-Snowcrest uplift

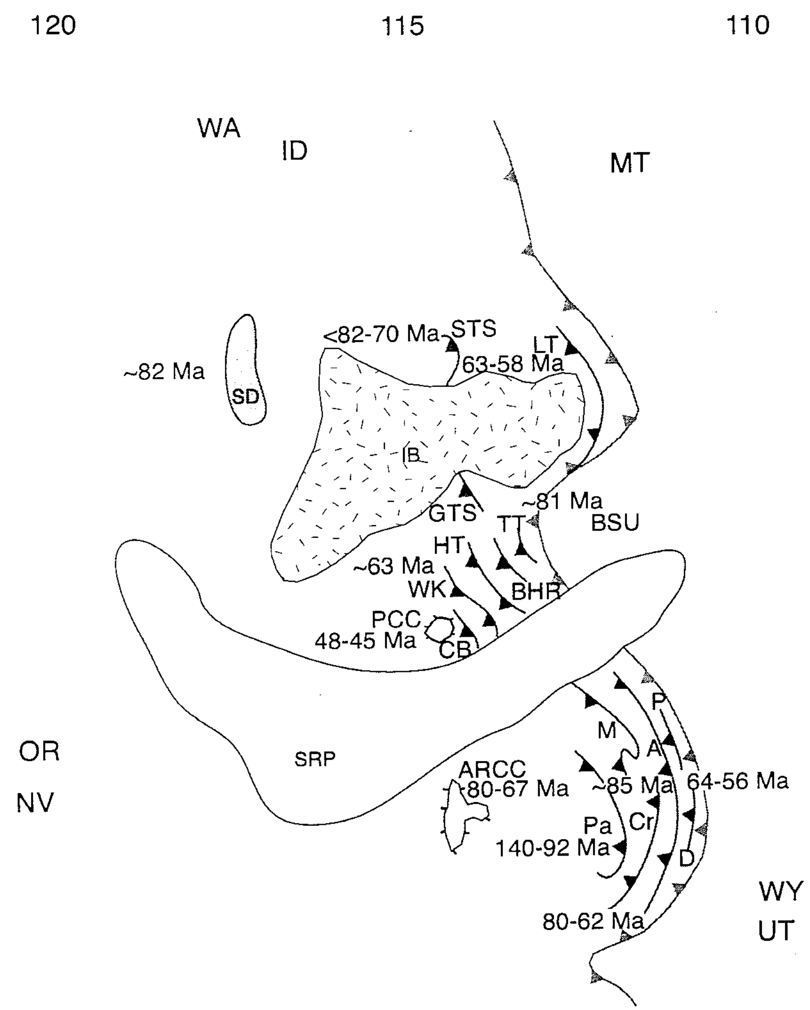


Figure 1. Timing and extent of deformation within the Sevier fold-and-thrust belt, Idaho. (SD=Seven Devils Terrane, IB=Idaho Batholith, SRP=Snake River Plain, PCC=Pioneer Core Complex, ARCC=Albian Range Core Complex, STS=Sapphire thrust system, LT=Lombard thrust, GTS=Grasshopper thrust system, TT=Tendoy thrust, BHR=Beaverhead Range, HT=Hailey thrust, WK=White Knob thrust, CB=Copper Basin block, P=Prospect thrust, D=Darby thrust, A=Absorka thrust, Cr=Crawford thrust, M=Meade thrust, Pa=Paris thrust, BSU=Blacktail-Snowcrest uplift

deformation, which initiated during the Early Cretaceous within the orogenic hinterlands of Idaho, Wyoming, and Montana along the Pioneer, Paris, and Sapphire thrusts respectively, began a sequence of eastward propagating thrust sheets (e.g. Wiltschko and Dorr 1983, Miller et al. 1992, Schmitt et al. 1995). Thrusting within the Helena and Wyoming salients continued an eastward progression until the Late Paleocene to Early Eocene (e.g. Wiltschko and Dorr 1983, Harlan et al. 1988), while eastward thrusting within the Montana recess ceased during the Late Cretaceous (~81 Ma) (e.g. Nichols et al 1985) when the easternmost Tendoy thrust buttressed against the uplifted Blacktail-Snowcrest arch inhibiting further eastward progression. As the Sevier compressional belt continued to propagate to the east, thrust sheets within the Montana recess that could no longer move that direction, began thrusting out-of-sequence to the west (e.g. Miller et al. 1992, Schmitt et al.1995). A major shift in the tectonics from dominantly compressional to dominantly extensional tectonics occurred during the early Cenozoic throughout the North American Cordillera (e.g. Burchfiel et al. 1992). This change in tectonic behavior is often referred to as the "Eocene Tectonic Transition" (e.g. Parrish et al. 1990) and reflects the onset of Basin and Range type extension within the region. In Idaho change from Sevier compression to Basin and Range type extension occurred during the middle to late Eocene as witnessed by the development of the Trans-Challis Fault System (46-52 Ma) (e.g. Bennett 1986), and the widespread emplacement of Challis volcanics (40-55 Ma)(e.g. Moye et al. 1988).

The relative timing of Sevier compression within the Helena (e.g. Harlan et al. 1988) and Wyoming (e.g. Wiltschko and Dorr 1983) salients, as well as the foreland thrusts within the Montana recess (e.g. Schmitt et al. 1995) are relatively well known as a result of preserved fossil assemblages in thrust derived synorogenic deposits (e.g. Nichols et al. 1985) and sedimentologic evidence from thrusting relationships (e.g. Skipp and Hait 1977). However, the timing and sequence of deformation along structures and the ages their associated synorogenic deposits within the hinterland of the Montana Recess are less well known.

In the hinterland of the Sevier orogenic belt at the latitude of the Montana Recess, north of the Snake River Plain, conglomerate deposits, informally named the Smiley Creek conglomerate (Volkmann 1972) are preserved within isolated outcrops located just east of the Pioneer core complex within the Pioneer and White Knob Mountains. One of the thickest exposures of the Smiley Creek conglomerate is within the White Knob Mountains, located just south of the confluence of the Wildhorse Creek and the East Fork of the Big Lost River. Here the Smiley Creek conglomerate lies unconformably on Paleozoic strata of the Devonian Jefferson Formation and the Mississippian Copper Basin Formation of the Glide Mountain thrust sheet (e.g. Ross 1962, Paull et al. 1972, Nilsen 1977, Dover 1983). These Paleozoic units represent the progression in deposition from an outer carbonate platform to the shallow marine Antler foreland basin (e.g. Link et al. 1988). The Mississippian flysch deposits were deformed during Sevier compression and eroded prior to deposition of the conglomerate (e.g. Volkmann

1972) as evidenced by an angular unconformity that separates the tightly folded and cleaved flysch from the overlying Smiley Creek conglomerates. Locally, unconformably overlying the Smiley Creek conglomerate, is a sequence of intermediate to mafic porphyritic units, rhyolitic breccias, intermediate lahars, ignimbrites, and volcanic sedimentary deposits of the Middle Eocene Challis Volcanic Group (e.g. Fisher et al. 1987). These volcanics, which cover ~25,000 km^2 of central Idaho (e.g. Moye et al. 1988), yield regional ages between 40 and 51 Ma (e.g. Link et al. 1988, Moye et al. 1988, Janecke and Snee 1993).

The Smiley Creek conglomerate exposures within the White Knob Mountains of southcentral Idaho, provide an opportunity to examine the role of the underlying Wildhorse thrust system during the deposition of the conglomerates. The Wildhorse thrust system (WTS), is an imbricate fan that carries the Mississippian Copper Basin Formation over lower to middle Paleozoic and Precambrian rocks (e.g. Dover 1981) (Figure 2). The Paleozoic and older rocks are exposed within the Pioneer, Wildhorse, and Dry Canyon windows (e.g. Dover 1981). Specifically, the Dry Canyon window (DCW) displays map patterns characteristic of a structurally controlled eye lid window (Gilluly 1961), one that is controlled by the folding of the underlying imbricate fan (e.g. Dover 1983). Fault branch lines of the WTS, distributed around the DCW, suggest that the WTS is a folded imbricate fan and that the DCW was created and exposed as a result of that folding and subsequent erosion. Dover (1981) estimates that the WTS has experienced some 10's of kilometers of eastward translation and thus it would restore to a position atop the Pioneer Core complex (PCC). This is interpreted

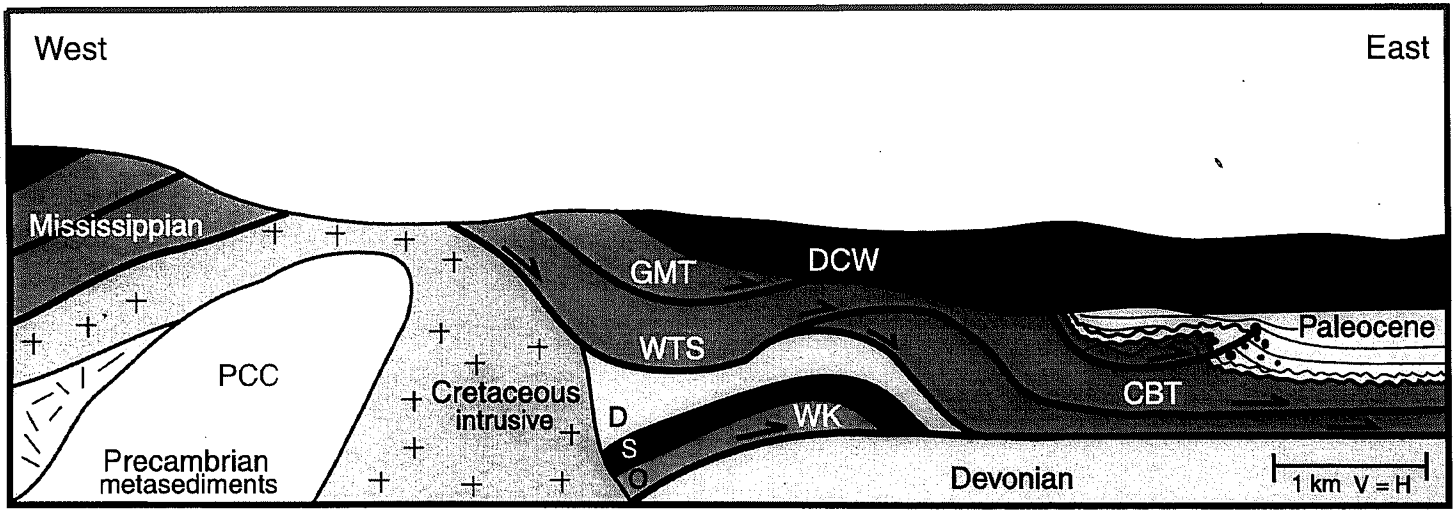


Figure 2. Regional cross-section illustrating the transportation of the Mississippian Copper Basin Formation along the Copper Basin (CBT) and Glide Mountain thrusts (GMT), imbricates of the Wildhorse thrust system (WTS). Folding of the WTS by out-of-sequence thrusting along the White Knob thrust (WK) produced a structural culmination and subsequent erosion revealed the Dry Canyon Window (DCW).

based on the presence of exposed WTS fault branch lines on either side of the PCC (e.g. Dover 1983).

The exact tectonic nature within the Sevier hinterland that resulted in the deposition of the Smiley Creek conglomerate within the wedge-top basin is not well understood. It can be inferred from the presence of the overlying Challis volcanics that the onset of Basin and Range extension and the emplacement of the volcanics aided in the preservation of the deposit. Both compressional and extensional mechanisms, can create structural relief and depositional basins (e.g. Davis et al. 1983, Kulik and Schmidt 1988, Mitra and Sussman 1997). In regions, such as the Sevier hinterland where both mechanisms occurred, the tectonic connection between the structural basin and the accumulating deposit needs to be established. Whether the conglomerate was deposited as a result of erosion off the hanging wall into a thrust bounded basin as Anastasio and Schmitt (1998) assert, or as a result of Eocene extension within the Sevier hinterland, as suggested by Link et al. (1988), the exposure of the Smiley Creek conglomerate in the White Knob Mountains preserves structural evidence to reconstruct the deformational tectonics within the Montana recess during the time of deposition.

The age of the Smiley Creek conglomerate is also not precisely confined, and debate exists as to whether deposition occurred pre-, syn-, or post-Sevier orogenesis. Volkmann (1972) classified the Smiley Creek conglomerate as Late Cretaceous (?) to Paleocene based on his observations of the deposit post-dating the folding of the underlying Paleozoic sequences and pre-dating the postorogenic high angle faulting and deposition of the Eocene Challis volcanics. Pollen analysis by H.A. Leffingwell (e.g. Volkmann 1972) of a shale sample within the Smiley Creek conglomerate yielded no diagnostic age forms, but the presence of angiosperms indicates a post-Albian (97 Ma) age. Dover (1983) interpreted sub-volcanic landslide deposits containing large Ordovician quartzite clasts as evidence that lower plate rocks were being exhumed and the conglomerate was being deposited prior to emplacement of the Challis volcanics during the Early Eocene. O'Neill and Pavlis (1988), based on their findings of cobbles derived from metasedimentary sequences within the conglomerate, concur with Dover's findings that part of the Pioneer core complex was already exposed at high structural elevations relative to the surrounding cover rocks prior to the deposition of the volcanics, and they suggest a Middle Eocene age for the conglomerate. Burton and Blakley (1988) maintain that the Smiley Creek conglomerate is of Eocene age based on late Eocene to early Oligocene palynomorphs assemblages found within the deposit. Burton and Blakley (1988) assert that the Smiley Creek conglomerate represents a conformable transition between pre-Challis alluvial, fluvial, and lacustrine environments that received volcanic debris from nearby Challis eruption centers.

The age of the Smiley Creek conglomerate exposed within the White Knob Mountains has been constrained by a pilot study, which determined a steep paleomagnetic pole position for the site consistent with expected pole positions of North America during the Late Cretaceous or Early Tertiary (e.g. Lastowka et al 1998). Confined normal and reversed polarities were isolated within the preliminary magnetostratigraphic section and indicate that the section must be younger than 83 Ma, the end of the long Cretaceous normal period (e.g. Anastasio and Schmitt 1998). The upper age of the conglomerate is further constrained by $^{40}Ar/^{39}Ar$ dating of whole rock and biotite separates from both intrusive and extrusive rocks of the overlying Challis Volcanics (e.g. Lastowka et al. 1998) (Figure 3). The pilot study analyzed seven samples from representative rocks of the adjacent suite of Challis volcanic lithologies (Figure 4). Four of the samples, representing ages from the Castle Rock porphry, the Challis ignimbrite, the Challis quartz diorite porphry, and undifferentiated Challis volcanics, were step heated, three biotite separates and one whole rock, and the remaining samples, consisting of lithologies from the Castle Rock porphry and the undifferentiated Challis volcanics, underwent total fusion. Flat age spectrum from the step heated biotite separates infer a rapid cooling history yielding an average cooling age of 48.9±0.21 Ma (Figure 3 b,c,d). The step heated basalt whole rock displayed a complex age spectrum indicative of the polymineralic nature of the sample (Figure 3a). The cooling age for the step heated whole rock sample is 48.55±.17 Ma, similar to the observed step heated biotite separate cooling ages. The remaining total fusion samples yielded an average cooling age 49±.94 Ma. It is important to note that the total fusion samples, the step heated biotite separates, and the step heated whole rocks samples consistently exhibited similar cooling ages for Challis volcanics, and yield an average age of cooling of (48.91±.54 Ma) (e.g. Lastowka et al. 1998).

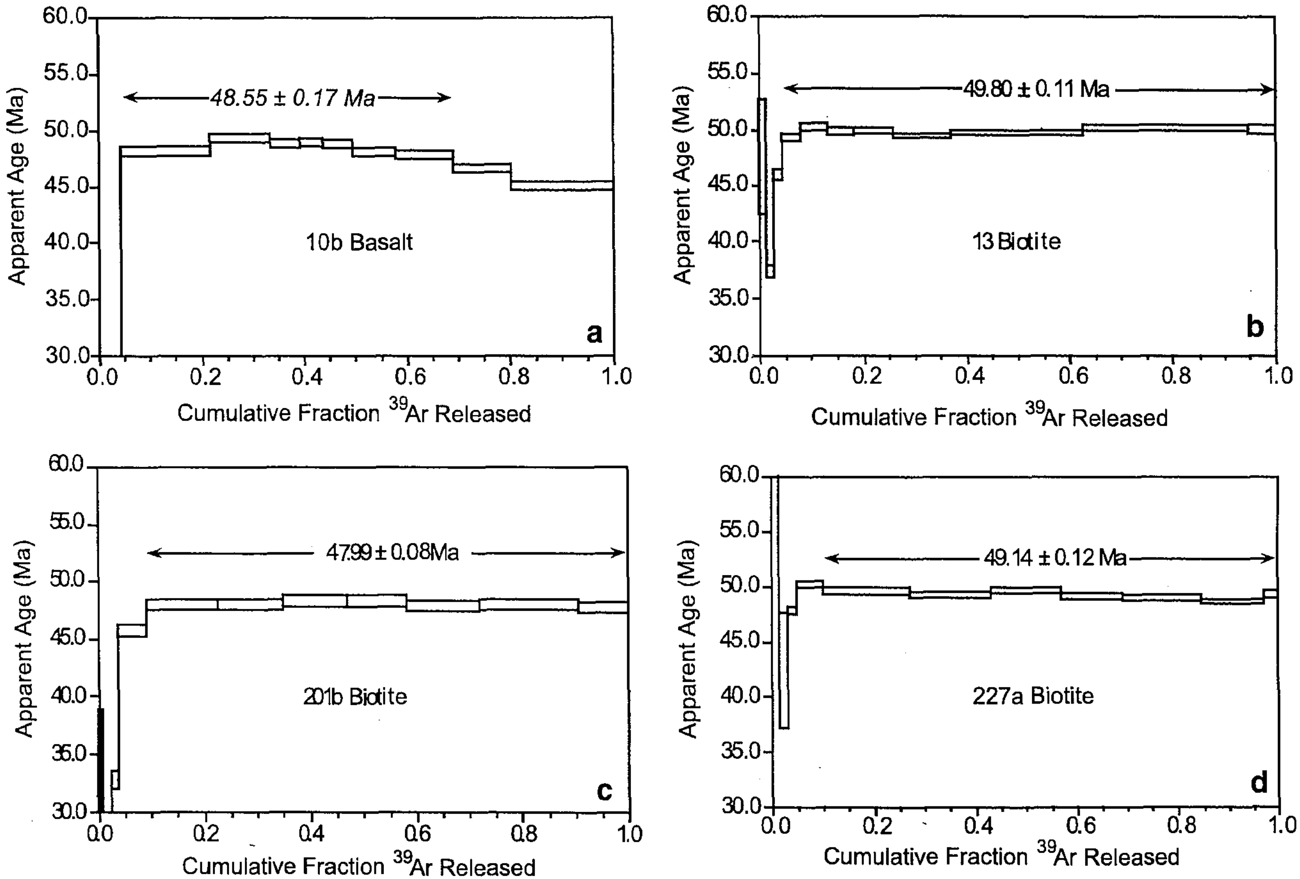


Figure 3. 40Ar/39Ar age spectrum plots of (a) whole rock, and (b,c,d) biotite separates from various lithologies within the Challis Volcanic Group, White Knob Mountains (e.g. Lastowka et al. 1998)

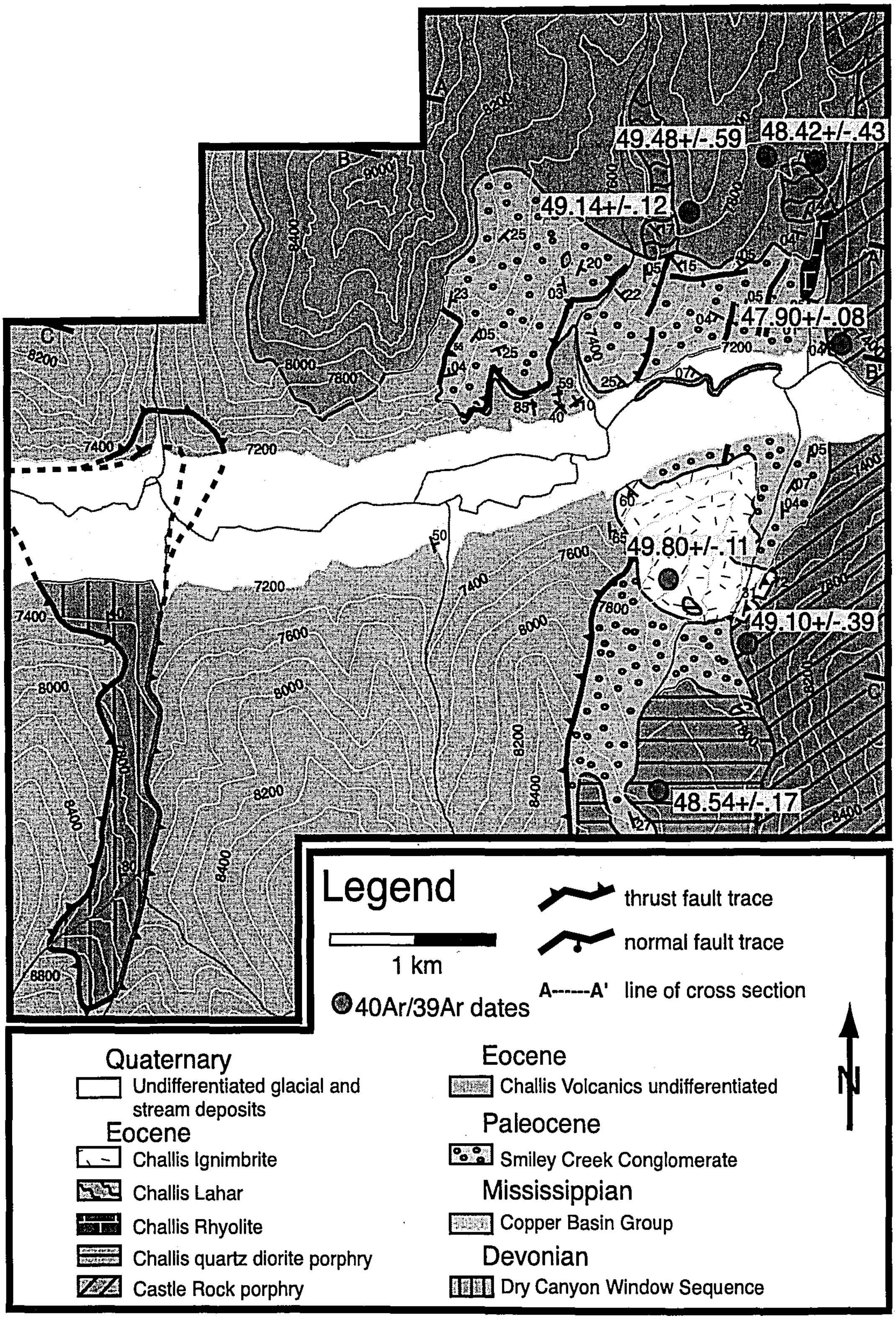


Figure 4. 40Ar/39Ar ages and sampling locations of the Challis Volcanic Group within the study area (e.g. Lastowka et al. 1998).

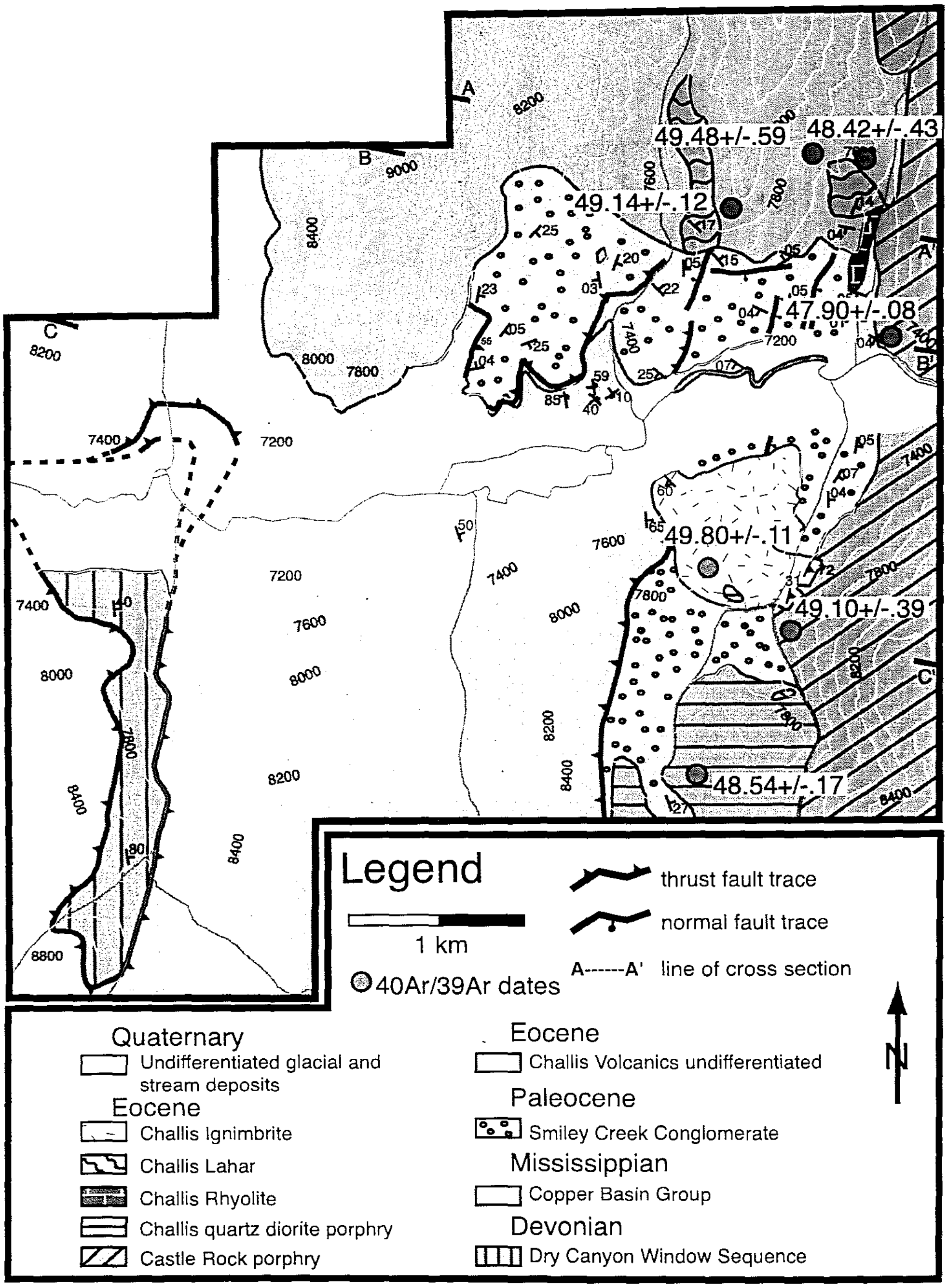


Figure 4. 40Ar/39Ar ages and sampling locations of the Challis Volcanic Group within the study area (e.g. Lastowka et al. 1998).

Field Methods and Results

Geologic mapping at a scale of 1:12,000 was completed in order to outline syndepositional basin geometries and characterize basin bounding faults and fault-related-folds within the Smiley Creek conglomerates exposed in the White Knob Mountains, just east of the Pioneer core complex (Figure 5). The oldest rocks found within the map area are located southwest of the conglomerate exposures within a strongly folded, steeply dipping thrust, part of the Wildhorse thrust system, which exposes lower thrust sheets containing Devonian massive limestone rocks of the Jefferson Formation (e.g. Skipp and Sandberg 1975, Dover 1981). Extensive deposits of Mississippian clastic rocks of the Copper Basin Formation (e.g. Paull et al. 1972, Paull and Gruber 1977, Nilsen 1977), Glide Mountain thrust sheet (e.g. Dover 1981, 1983), are found to the north- and southwest of the Smiley Creek conglomerates. These Antler derived, shallow marine to partly terrigeneous, clastic units consist of tightly folded, thinly bedded, dark gray argillites (e.g. Paull et al. 1972, Dover 1981) unconformably overlain by light colored, cobble to boulder conglomerates containing argillite, chert, and quartzite clasts. These light colored conglomerates are separated from the lower deformed flysch deposits by an angular unconformity, representative of an earlier erosion surface. Parallel beds within the light colored conglomerate are slightly tilted to the northwest between 25°-30°.

Unconformably overlying the dipping, light colored conglomerate deposits is a sequence of coarse, red conglomerates informally referred to as the Smiley

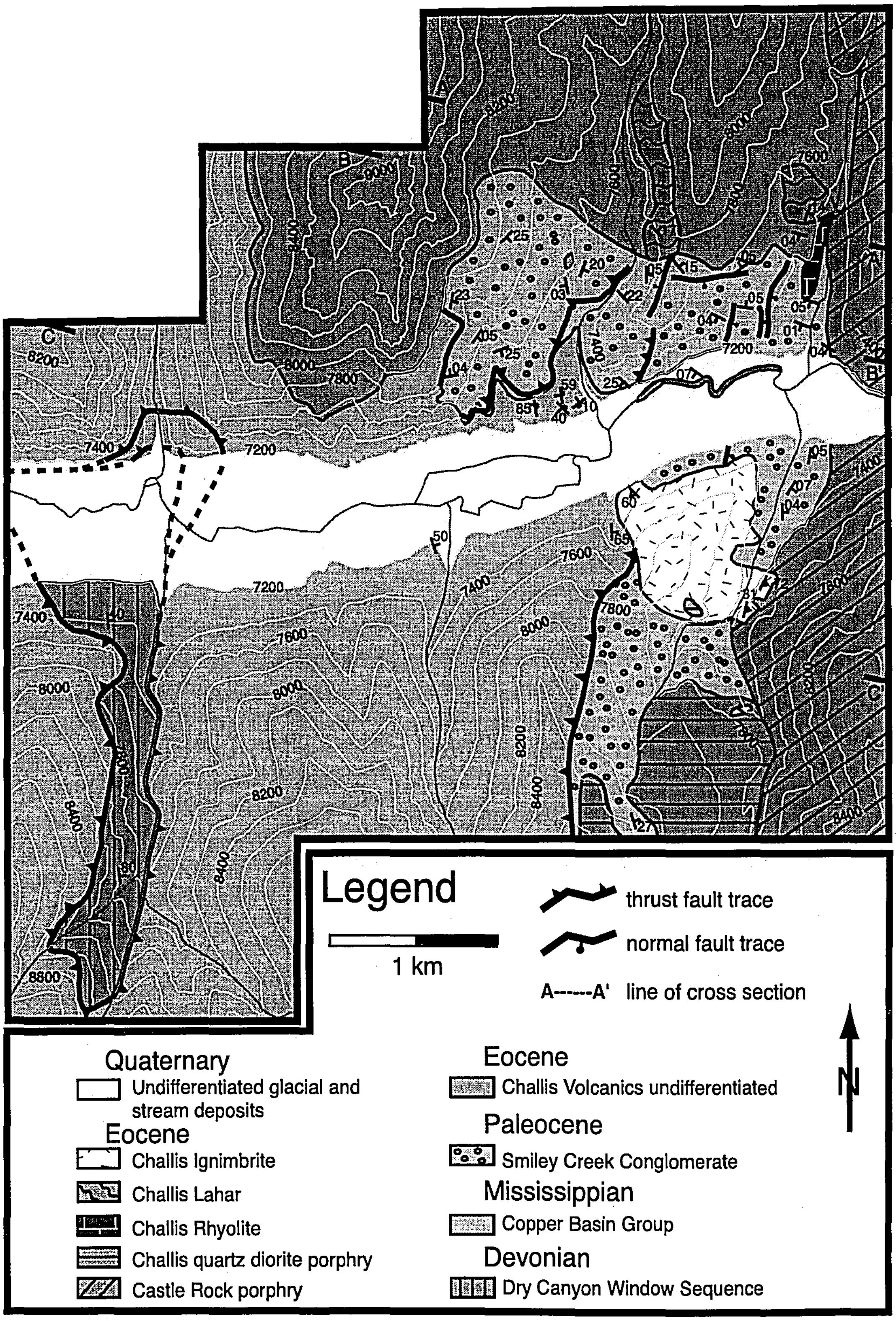


Figure 5. Geologic and structural map of the Smiley Creek conglomerate study area, White Knob Mountains, central Idaho.

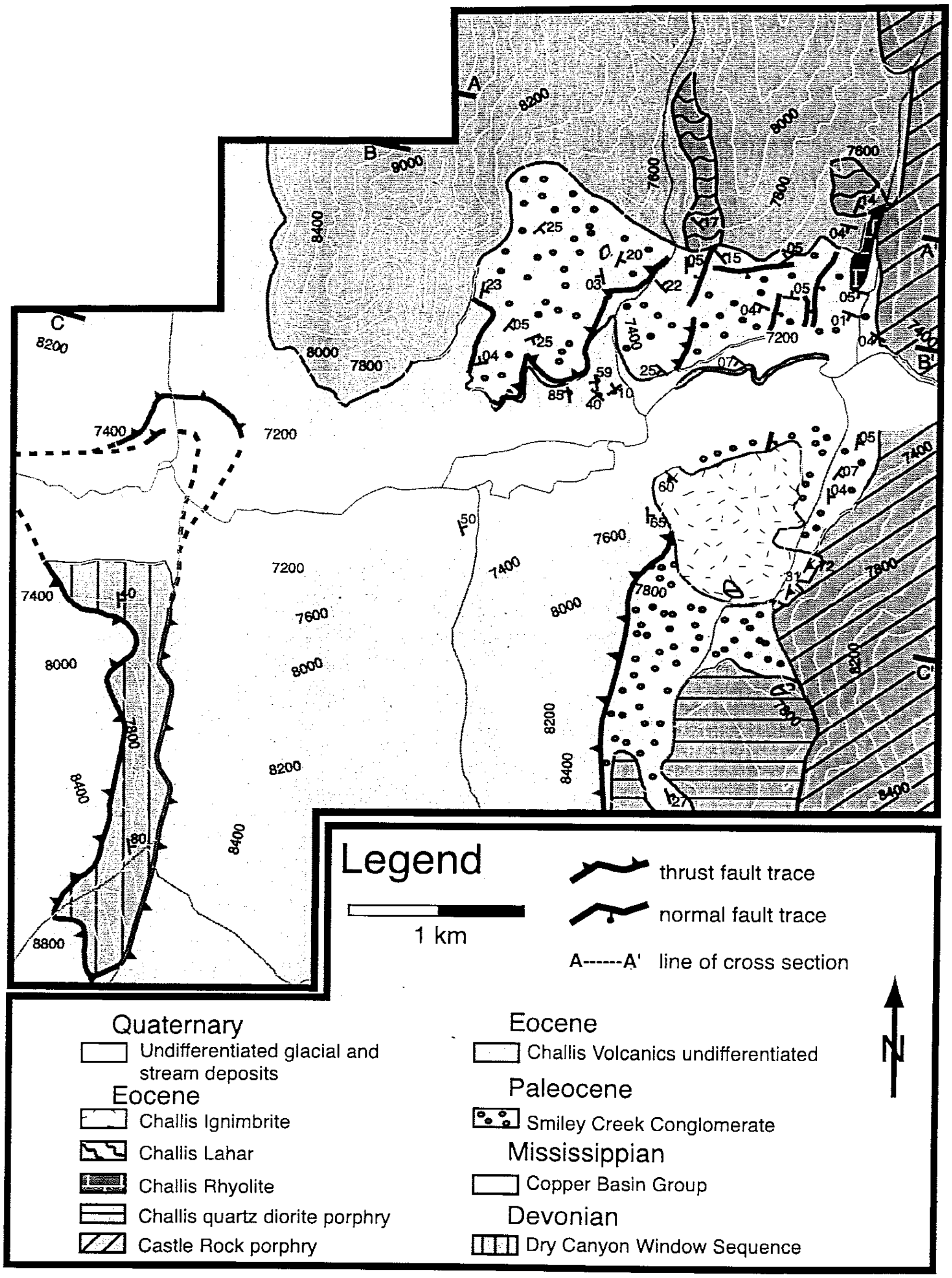


Figure 5. Geologic and structural map of the Smiley Creek conglomerate study area, White Knob Mountains, central Idaho.

Creek conglomerate (Volkmann 1972). The unconformable surface between the stratigraphically lower light colored conglomerates and the Smiley Creek conglomerate is not consistent in orientation or character, and is observed as an erosional surface in portions of the contact exposed to the north, and as a fault surface at all other locations, suggesting variances in structural relief along the Mississippian erosional surface. Slip direction indicators on the exposed contact fault surfaces indicate multiple senses of slip in different directions.

The Smiley Creek conglomerate is unconformably overlain by intermediate to mafic porphyritic units, rhyolitic breccias, intermediate lahars, ignimbrites, and volcanic sedimentary deposits of the Middle Eocene Challis Volcanic Group (e.g. Fisher et al. 1987). The Challis volcanics also unconformably overlie the highly folded and cleaved Mississippian rocks west of the exposed conglomerates.

The Smiley Creek conglomerate is cut by contractional as well as extensional structures. A prominent west dipping fault scarp, from here on referred to as the Glide Mountain thrust, is present on the north side of the river. Numerous, ~1-3 m diameter, reworked conglomerate boulders are found proximal to the fault scarp on the forelimb of the Glide Mountain thrust. These boulders fine away from the fault scarp to the east (~100 m), and end abruptly up section within the deposit. Onlapping bedding geometries within the conglomerate against the fault scarp on the back limb of the fold display bedding dips that shallow up section and away from the scarp. Bedding of conglomerates located directly above the fault tip, dip at relatively low angles on either side of the structure, but become horizontal within a few meters above the tip. Bedding thicknesses on the back limb of the Glide Mountain thrust also decrease upsection.

High-angle extensional structures are also observed within the Smiley Creek conglomerate. Mesoscopic extensional faults within the conglomerate are generally steeply east-dipping, with the largest of these structures offsetting beds by only a few meters (<10). However, most of the extensional structures within the conglomerate are not of that scale (< 5 m). The extensional faults that cut though the deposit do not offset the overlying Challis volcanics. An east-west striking neotectonic fault scarp, found on the north side of the mapping area shows a south-side down behavior as displayed by a ~1m ground surface offset, indicating active present day extension within the study area.

A composite cross-section spanning three along strike transects illustrates structural and large-scale depositional geometries related to the Glide Mountain thrust (Figure 6). The composite cross section delineates the observable onlapping bedding geometries on the back limb of the Glide Mountain thrust, as well as the distribution of the recycled conglomerate boulders proximal to the fault scarp on the forelimb of the fold. The cross section also indicates the connection between the Glide Mountain thrust and the Wildhorse thrust system.

Sedimentologic Methods and Results

In order to describe the character of the Smiley Creek conglomerate and the inherent nature of the depositional history, general lithofacies descriptions

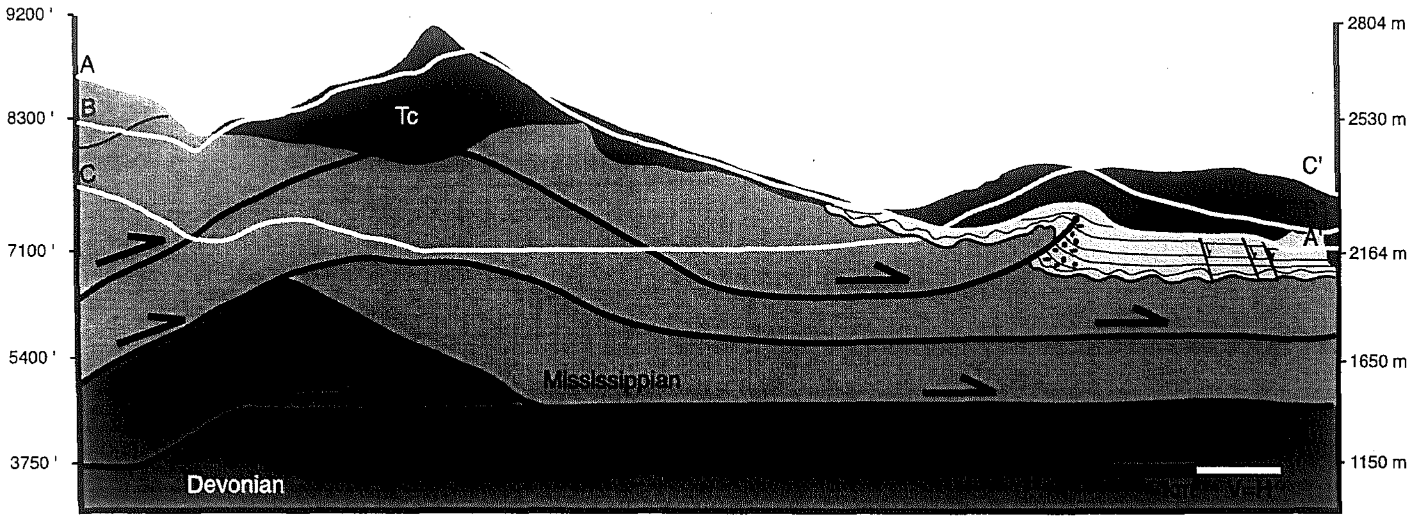


Figure 6. Cross-sections spanning three along strike transects (A-A', B-B', C-C') through the study area. Sections illustrate geologic and structural map patterns within the map area. White lines delineate present day erosion surface.

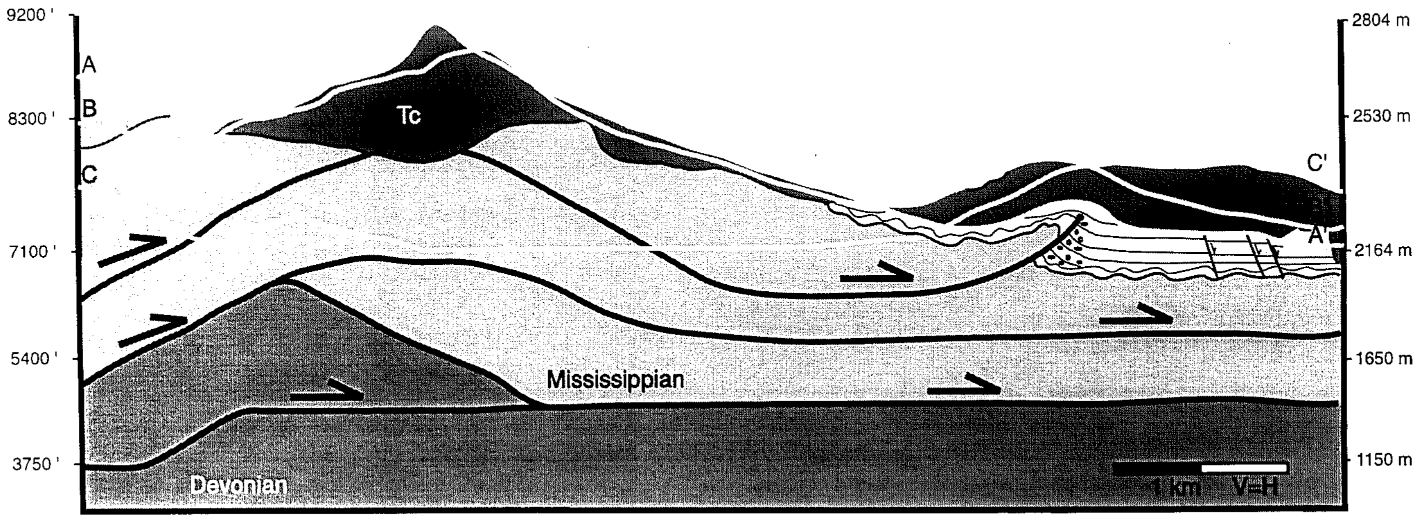


Figure 6. Cross-sections spanning three along strike transects (A-A', B-B', C-C') through the study area. Sections illustrate geologic and structural map patterns within the map area. White lines delineate present day erosion surface.

correlated within vertical measured stratigraphic sections were measured and described. Four correlated stratigraphic sections, spanning the complete vertical thickness of the conglomerate exposures, were measured along the forelimb of the fold (sections A, B, and C) and on the back limb of the fold (section D) (Figure 7b). A composite stratigraphic section, comprised of the three forelimb sections, was created for ease of analysis (Figure 7a).

The composite forelimb section extends from conglomerate exposures along stream banks of the Big Lost River, upsection to the contact of the basal Challis volcanics, a total of 183 m. The back limb stratigraphic section extends from the bank exposures along the creek just east of the Glide Mountain thrust, up section eastward to the top of the adjacent conglomerate ridge, extending 59 m. Lithofacies characterizations were made throughout the sections, paying particular attention to the presence of fine grained beds and changes in conglomerate facies appearance.

Sedimentological characterizations of the Smiley Creek conglomerate reveal four distinct conglomerate facies packages. The first package, labeled 'a' (Figure 8) is found at lower stratigraphic levels on the back limb of the Glide Mountain thrust, and is located unconformably above the folded Mississippian units. This package is characterized by a light colored, disorganized, moderately sorted, matrix supported, pebble to cobble conglomerates containing argillite, chert, and quartzite clasts. Clasts within unit 'a' are generally sub-rounded to sub-angular in shape. The matrix is composed mainly of sand sized argillite, chert, and quartzite clasts. The thickness of this unit is quite variable given by

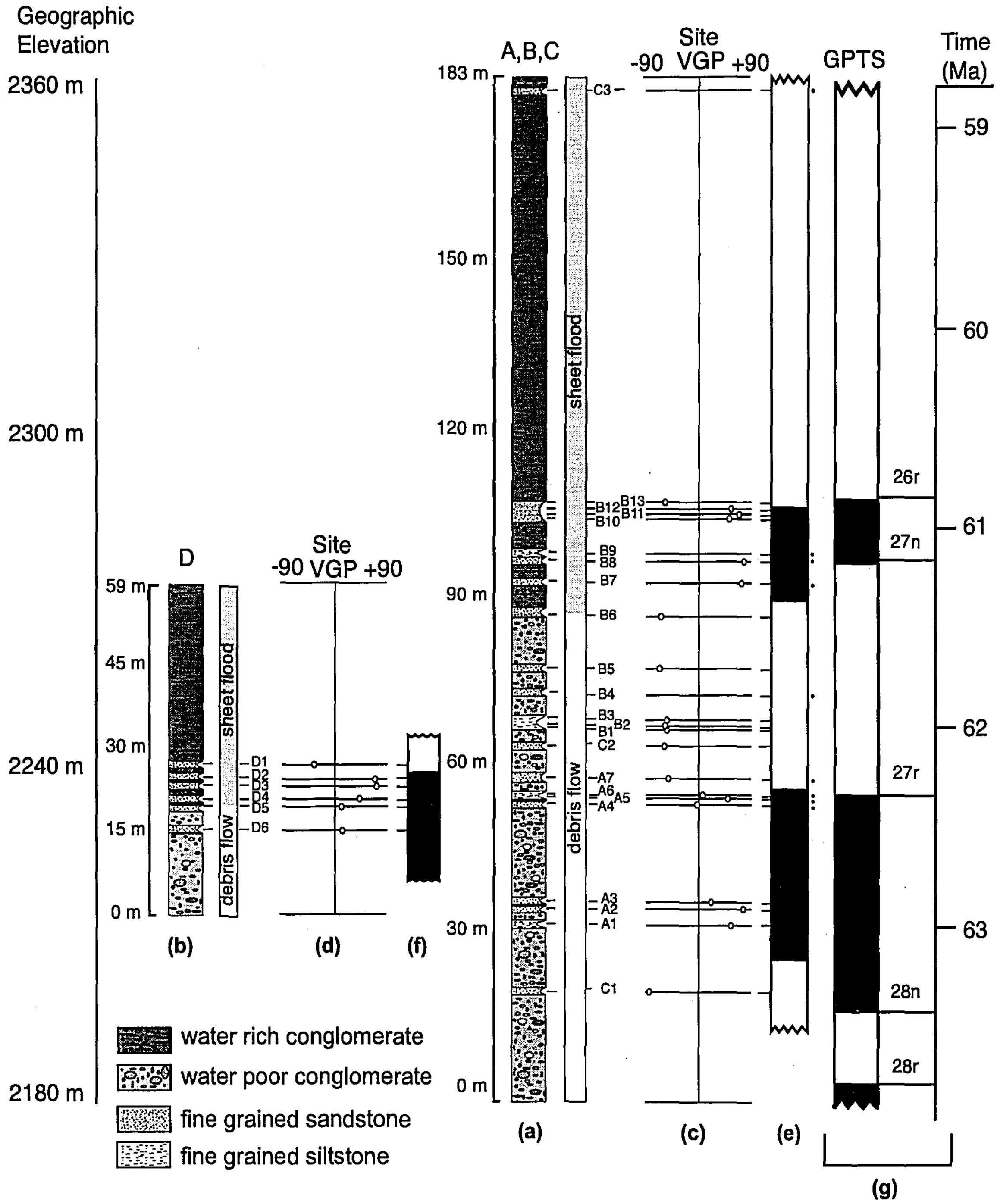
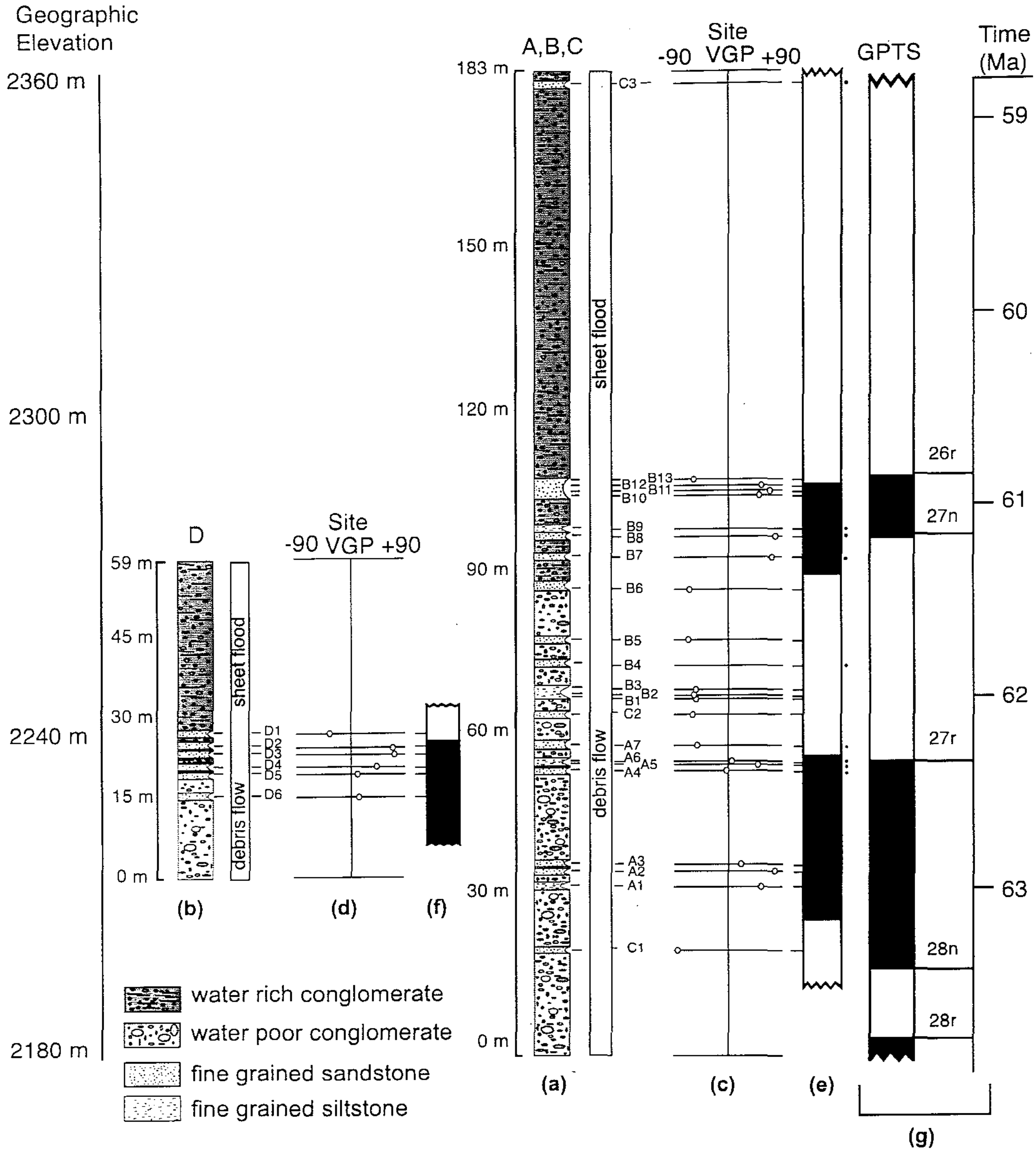


Figure 7. Magnetostratigraphic sections of conglomerates located on the forelimb (A,B,C) and the back limb (D) of the Cave fault. (a) Combined stratigraphic section of the three forelimb sections. (b) Stratigraphic section of the back limb section. (c) Site VGP paleolatitudes for the forelimb sections. (d) Site VGP paleolatitudes for the backlimb section. (e) Observed polarity section for the forelimb sections. (f) Observed polarity section for the back limb section. (g) Global Polarity Time Scale of Cande and Kent (1995).



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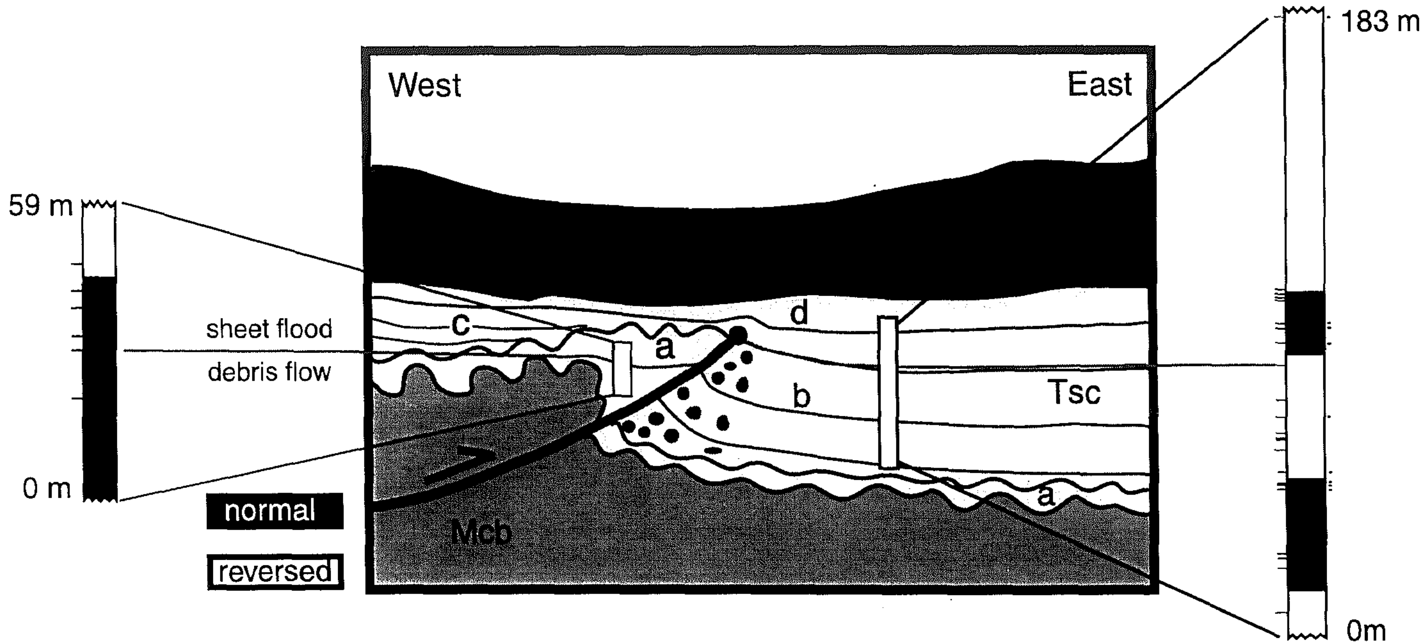


Figure 8. Cross-section and associated magnetic sections through the Smiley Creek conglomerate deposits located proximal to the Glide Mountain thrust. Differentiated conglomerate packages are labeled 'a', 'b', 'c', and 'd'. Recycled conglomerate boulders are located proximal to the fault scarp on the forelimb of the fold.

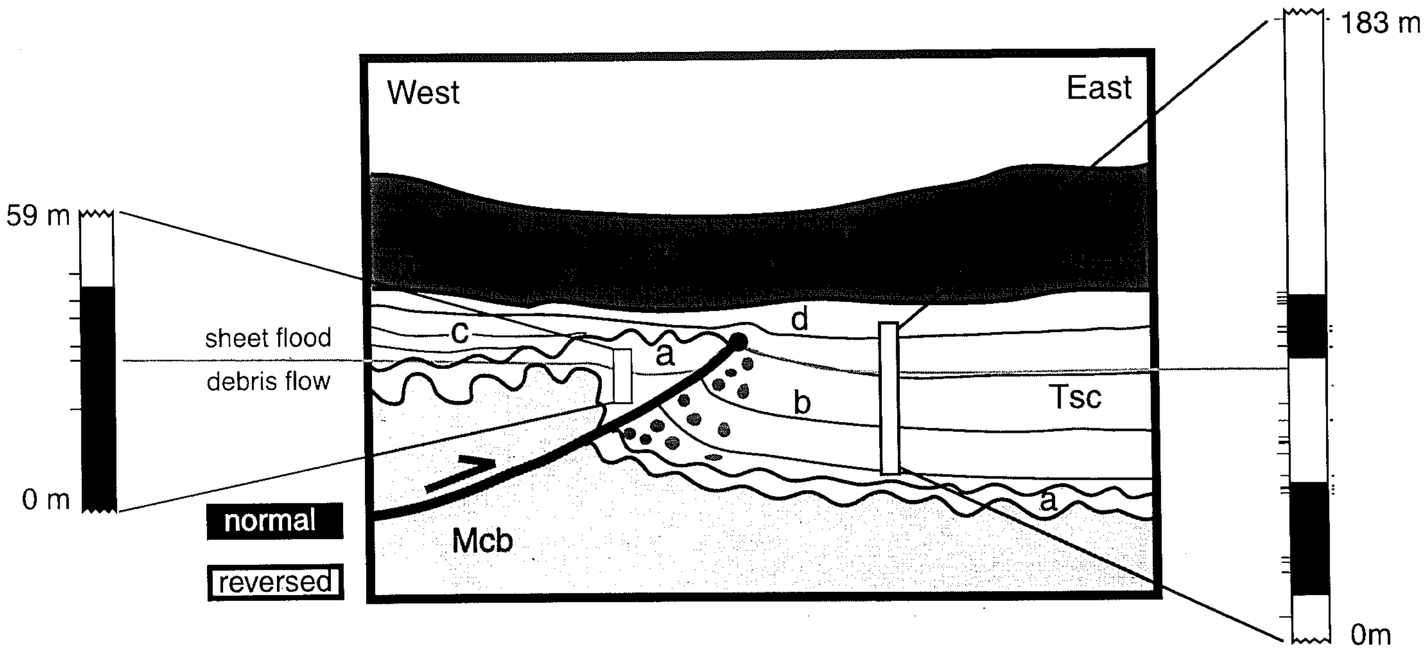


Figure 8. Cross-section and associated magnetic sections through the Smiley Creek conglomerate deposits located proximal to the Glide Mountain thrust. Differentiated conglomerate packages are labeled 'a', 'b', 'c', and 'd'. Recycled conglomerate boulders are located proximal to the fault scarp on the forelimb of the fold.

the undulating nature of the angular unconformity separating the light colored conglomerates from the underlying folded Mississippian lithologies.

The second conglomerate package labeled 'b' (Figure 8) is located on the forelimb of the Glide Mountain thrust and represents the stratigraphically lowest exposed conglomerates on this portion of the fold. This package is characterized by a disorganized, poorly sorted, matrix supported, pebble to boulder, argillite-chert-quartzite conglomerate. Clasts within unit 'a' are generally sub-angular to sub-rounded in shape. The matrix is composed mainly of sand to gravel size clasts of argillite, chert, and quartzite. Neither the matrix nor the clasts yield any sense of imbrication. Lenses of fine grained siltstone and sandstone are scattered throughout the package. The detrital lenses range in thickness from 1 to 10's cm, and vary in width from 10's cm to 10's m. These fine grained units are often recessive from the more massive conglomerate beds. Several paleosols are also scattered throughout this unit, they are generally scarce, yet evenly spaced and comprise less than 1 m of the entire 183 m section. The paleosols are up to 10's cm in height and are often found in channel-like depressions that are not laterally continuous. These 'fossil soils' (e.g. Kraus 1999) have a general mottled, light gray to tan character, and contain reduced root traces. The conglomerates of unit 'b' located on the forelimb of the Glide Mountain thrust contain numerous, ~1-3 m, recycled conglomerate boulders, as mentioned above. These light-colored, recycled conglomerate boulders contain clasts and matrix composed of pebble to cobble sized clasts of argillite, chert, and quartzite. Very crude horizontal stratification is observed within the conglomerates of unit 'b'. This package of conglomerate extends laterally from the Glide Mountain thrust to the east, until an abrupt contact with the adjacent Challis volcanics. Unit 'b' varies in thickness along the exposure; thicker proximal to the scarp and thinner towards the east, averaging 90 m.

The third conglomerate package labeled 'c' is located on the back limb of the fold directly above the dipping beds of the light colored conglomerates of unit 'a' (Figure 8). The conglomerates of this package are disorganized, poorly sorted, matrix supported, pebble to boulder, argillite-chert-quartzite conglomerates, that unlike unit 'b', lack the large (~1-3 m) recycled conglomerate boulders. The clasts within this unit are again, sub-angular to sub-rounded. The matrix supporting unit 'c' is composed of sand to gravel size, argillite, chert, and quartzite clasts. Again, neither the matrix nor the conglomerates of unit 'c' display any sense of imbrication. Thin lenses of recessed, fine grained sandstone and siltstone beds are similarly scattered throughout conglomerate package 'c', as they are in unit 'b'. Conglomerates of package 'c' are 19 m thick and extend laterally along the stream cut valley exposed on the back limb of the fold.

The fourth conglomerate package, labeled 'd' (Figure 8), conformably overlies the stratigraphically lower conglomerates of units 'b' and 'c', as well as buries the tip of the emergent Glide Mountain thrust. Unit 'd' is a moderately sorted, clast supported, pebble to cobble argillite-chert-quartzite conglomerate that extends from the hinterland to the foreland along the emergent fold. Clasts within this unit are sub-angular to sub-rounded and display no sense of imbrication direction. This unit does contain sand to gravel size argillite, chert and quartzite matrix clasts, but is dominantly clast-supported. Beds within this upper conglomerate deposit are less massive than those of the lower coarser conglomerates and display more pronounced horizontal stratification. This conglomerate package has a relatively uniform thickness on the forelimb of the fold (96 m), and is somewhat thinner on the back limb of the fold (40 m). Unit 'd' does not crop out at the same elevation on both limbs of the fold, and is located ~30 m lower on the back limb than on the forelimb. The thin sandstone and siltstone layers, observed in conglomerate packages 'b' and 'c', are more abundant in unit 'd', and are generally thicker (10's cm). An unambiguous paleocurrent direction within the conglomerate packages was not detected due to a lack of consistent imbrication within both the clasts and the matrix.

Paleomagnetic Methods and Results

In order to constrain the age of the deposit, and therefore constrain the age of local Sevier hinterland deformation, the magnetostratigraphy of the Smiley Creek conglomerate was measured. Oriented core samples, 25 mm in diameter, were collected from strata on both limbs of the Glide Mountain thrust with the use of a Pomeroy gasoline-powered, diamond coring drill (Figure 8). Given the coarseness of the deposit, all fine grained siltstone and sandstone beds within the measured section were selected for paleomagnetic sampling. Seventy-eight oriented core samples were collected at 26 horizons (~3-4 samples/horizon), within the measured sections (Table 1).

Table 1. Paleomagnetic Sample ChRM Directions in Geographic Coordinates

Sample*	Declination	Inclination	Strike+	Dip+	Class
A1.1	82.3	-76.8	45	7	III
A1.2	9	65.4	45	7	
A1.3	58.6	77.7	45	7	
A2.1	1.7	36.4	45	7	I
A2.2	349.9	60.4	45	7	
A2.3	14.5	49.1	45	7	
A2.4	12.3	60.5	45	7	
A3.1	279.4	-5.5	68	5	III
A3.2	326.4	-21.4	68	5	
A3.3	327.8	-16.4	68	5	
A4.1	285.5	47.5	62	5	III
A4.4	245.3	-41.4	62	5	
A5.1	253.9	40.5	62	5	III
A5.3	36.3	-26.6	62	5	
A6.1	237.2	-37.4	62	5	III
A6.2	265.7	38.8	62	5	
A6.3	12.1	-21.7	62	5	
A7.1	38.1	63.4	110	1	II
A7.2	197.3	-34.8	110	1	
A7.3	311.6	-68.6	110	1	
B1.1	207.6	-56.8	330	3	I
B1.2	217.2	-50.2	330	3	
B1.3	201.1	-63.8	330	3	
B1.4	218.6	-53.8	330	3	
B2.1	197.1	-55.9	330	3	I
B2.2	198	-58.4	330	3	
B2.3	212	-67.2	330	3	
B3.1	167.4	-69	78	4	I
B3.2	194.8	-26.6	78	4	
B3.3	194	-57.9	78	4	
B3.4	217.9	-62	78	4	
B5.1	212.7	-50.7	98	4	I
B5.2	241	-65.4	98	4	
B5.3	170.6	-71.7	98	4	

Table 1. (continued)

Sample*	Declination	Inclination	Strike	Dip	Class
B6.1	183.5	-63	98	4	II
B6.2	178.9	-40.6	98	4	
B6.3	199.5	-77.3	98	4	
B6.4	290.8	-38.8	98	4	
B7.1	18.7	54.6	98	4	I
B7.2	23	58.7	98	4	
B8.2	17.3	54.4	97	4	I
B8.3	3.4	59.5	97	4	
B8.4	20.1	60.3	97	4	
B10.1	172.6	45.6	93	2	II
B10.2	14.1	57.2	93	2	
B10.3	8.2	47.2	93	2	
B10.4	172.1	-43.4	93	2	
B10.5	346.9	59.4	93	2	
B11.1	21.2	61.4	93	2	I
B11.2	47.1	54.7	93	2	
B11.3	5.5	53.4	93	2	
B11.4	14.4	69.2	93	2	
B11.5	30.1	26.8	93	2	
B12.1	5.2	56.3	93	2	I
B12.2	352.1	38.6	93	2	
B12.3	218	-52.7	93	2	
B13.1	194.7	-62.5	93	2	I
B13.2	202.2	-74.6	93	2	
B13.3	13	56.6	93	2	
C1.1	176.1	-62.7	90	3	I
C1.2	194	-60.1	90	3	
C2.1	182.3	-58.7	90	3	I
C2.2	187.7	-61.7	90	3	
D1.1	145.3	-59.3	329	9	I
D1.3	139	-36.5	329	9	
D1.4	56.2	69	329	9	
D2.2	29.7	42.4	317	22	I
D2.3	346.1	47.5	317	22	
D3.1	339.7	51	317	22	II
D3.3	47.7	24	317	22	
D3.4	339.7	56.5	317	22	

Table 1. (continued)

Sample*	Declination	Inclination	Strike	Dip	Class
D4.1	8.3	35.1	325	18	III
D4.3	38.6	-24.9	325	18	
D5.1	192.1	23.1	325	18	III
D5.2	0.1	64.6	325	18	
D5.4	247.1	61.9	325	18	
D6.1	263.9	50.3	325	18	III
D6.2	283.5	-0.4	325	18	

*First two alpha-numerics correspond to the site
+Strike and Dip were measured using right hand rule

Oriented cores were prepared for analysis by cutting them to a uniform length of 25 mm. First, a detailed pilot study was conducted in which 28 oriented cores were thermally demagnetized in a Schonstedt TSD-1 thermal demagnetizer and their remanence measured on a two-axis CTF superconducting magnetometer. The pilot study consisted of samples from representative rock types throughout the four measured sections. This initial demagnetization was carried out in 100°C temperature steps to 400°C, 50°C temperature steps between 400°C and 600°C, 10°C temperature steps between 600°C and 650°C, and 5°C temperature steps from 650°C to 695°C. The pilot study revealed that the majority of the samples lost magnetic intensity above 550°C. The remaining samples were subsequently thermally demagnetized in 100°C temperature steps to 500°C, and then 20°C steps to 580°C. The natural remanent magnetism (NRM) intensities were relatively weak, generally between 1.5 – 0.91 mA/m in all sampled horizons. NRM directions varied markedly between north and down and south and up. The results from each sample were plotted on orthogonal vector end-point diagrams (Zijderveld 1967) and principle component analysis (Kirschvink 1980) was used to isolate the characteristic remanent magnetization (ChRM) for each sample. One component of magnetization with a relatively constant direction was isolated in most samples following progressive stepwise thermal demagnetization. Typical results of thermal demagnetization are illustrated by orthogonal vector endpoint diagrams

(Figures 9 a-d). The ChRM was isolated between 600°C and 665°C. Hematite is probably the magnetic mineral in these rocks, based on their brick red color and unblocking temperatures between 600°C-665°C (Figure 9).

Sample characteristic directions were averaged by Fisher (1953) statistics to obtain the site mean direction for each stratigraphic sampling location. Data coherence was quantified at each site using Fisher's (1953) precision parameter, κ. The precision parameter is a measure of the concentration of the vector distribution about the true mean direction (Butler 1992). Sites were classified as 'class I' for $\kappa \geq 10$, 'class II' for $\kappa < 10$ but with an unambiguously normal or reversed polarity mean direction, and 'class III' when $\kappa < 10$ and the polarity determination was ambiguous. Site classification reveals 14 class I sites (54%), 4 class II sites (15%), and 8 class III sites (31%).

No fossils are available to constrain the deposit's age. The only age constraint for the deposit is the time interval between 49 Ma, the age of the overlying basal Challis volcanics (e.g. Lastowka et al. 1998) and 83 Ma, the end of the long Cretaceous normal period (Harland et al. 1990). In order to verify the age constraints determined by the pilot study, the formation mean direction for the Smiley Creek conglomerate at the study site was calculated. All class I site magnetic field directions were averaged using Fisher (1953) statistics, and a formation mean direction was determined. The calculation yields a formation mean direction of D=13.4°, I=58.4° (α_{95} = 5.9°, N = 14, κ = 49.9). This formation

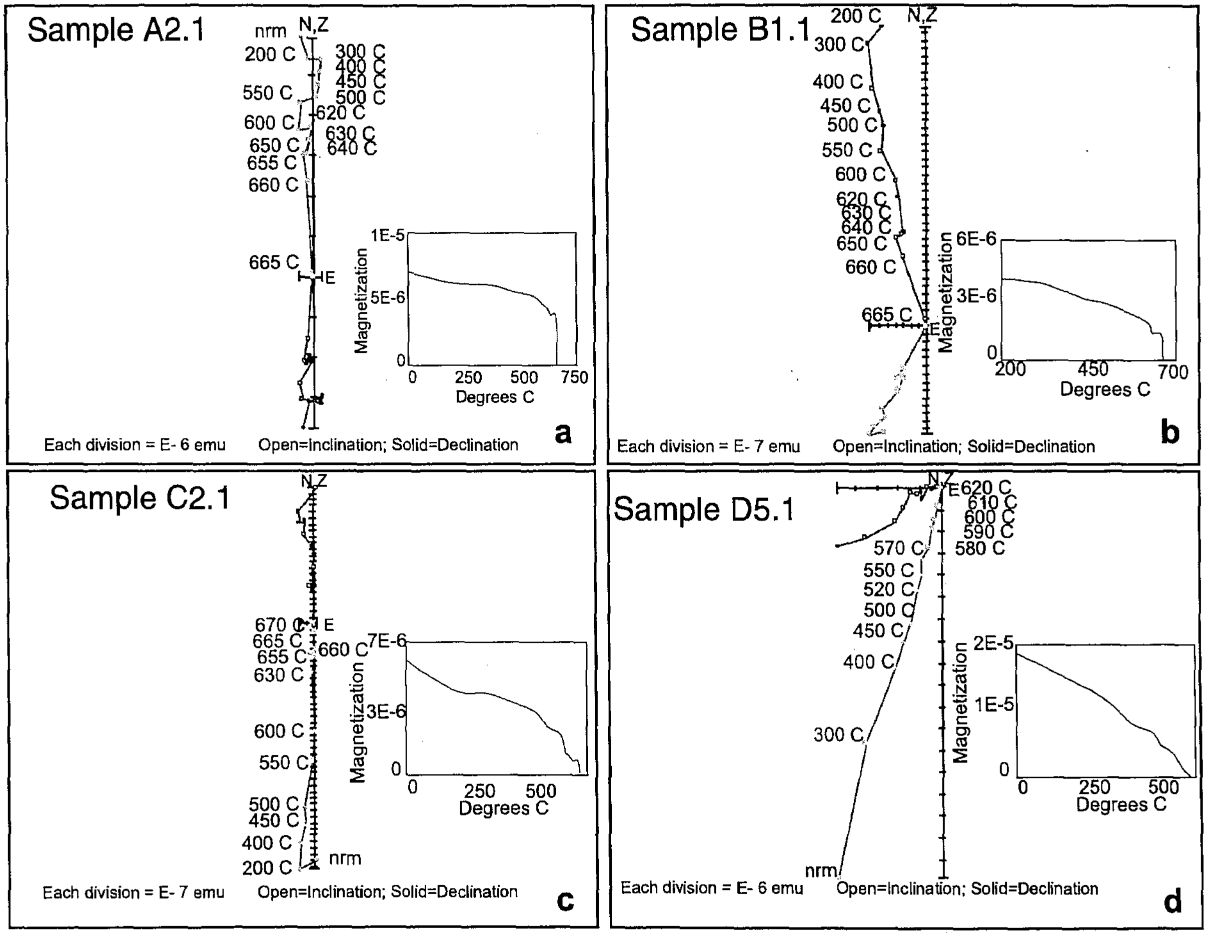


Figure 9. Typical orthogonal vector endpoint diagrams for samples within the four measured sections illustrating the change in magnetic declination and inclination during progessive thermal demagnetization. Inset boxes indicate the decrease in magnetization intensity through the heating steps.

mean direction was compared to expected field directions for the study area during the Late Cretaceous through the mid-Eocene. The expected directions were calculated from their respective North American paleopoles (Diehl et al. 1983, Dickinson and Butler 1998). The mean directions and associated 95% confidence limits for both observed and expected positions were plotted on an equal-area projection (Figure 10). The observed formation mean does not coincide with the magnetic field directions determined from the Late Cretaceous, Paleocene, or Eocene North American paleopoles. The formation mean direction is distinguishable at the 5% significance level from the Late Cretaceous, Paleocene, and Eocene expected directions, since the α_{95} 95% confidence ellipses do not overlap (Butler 1992). However, the expected Late Cretaceous and Early Tertiary directions are not distinguishable from one another at the 5% given that their respective mean directions fall within the α_{95} 95% confidence ellipses for each direction (Butler 1992) (Figure 10).

Demarest's (1983) statistical analysis was used to calculate the amount of vertical axis rotation and flattening that is required to align the Smiley Creek conglomerate formation mean direction with the expected directions for the Late Cretaceous and Early Tertiary North American paleopoles. Comparing the Smiley Creek conglomerate formation mean direction of D= 13.39° (± 5.94°), I= 58.4° (± 4.2°), to the Late Cretaceous direction in geographic coordinates indicates a 22.49° (± 7.04°) clockwise rotation and a 8.6° (± 4.17°) inclination

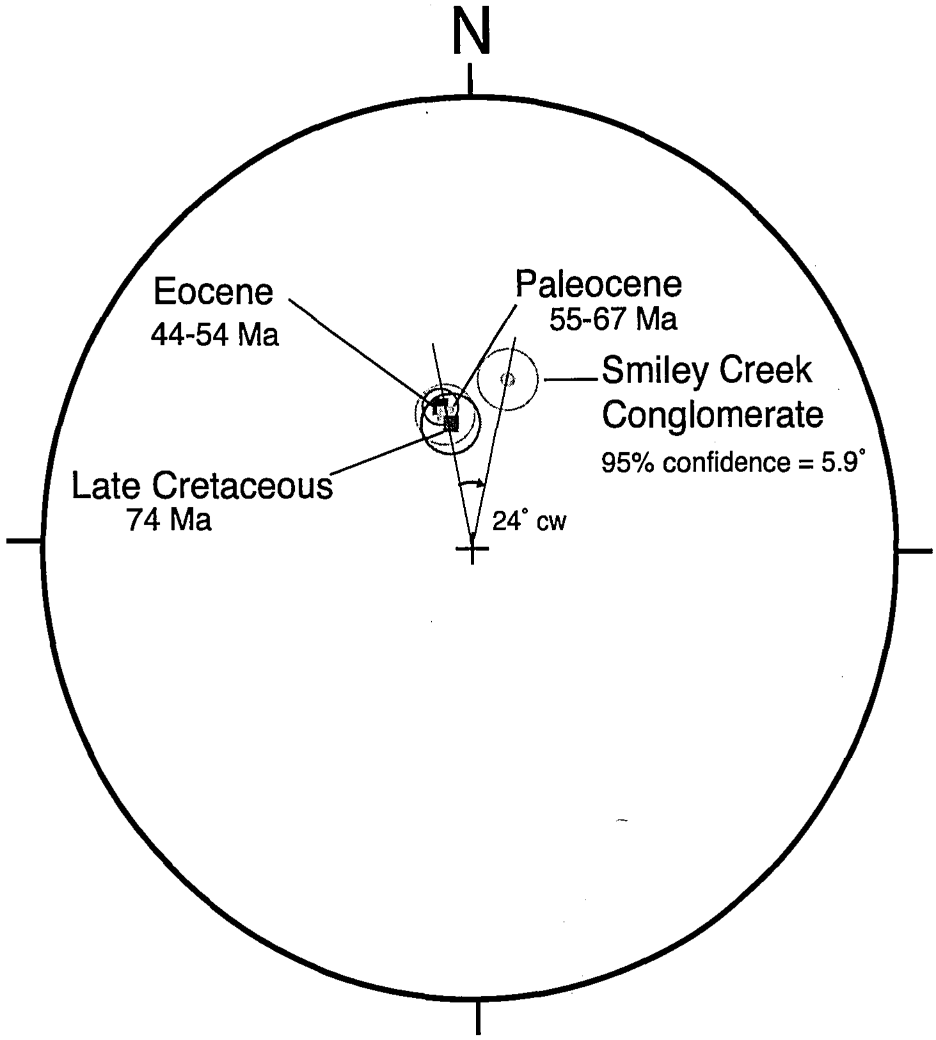
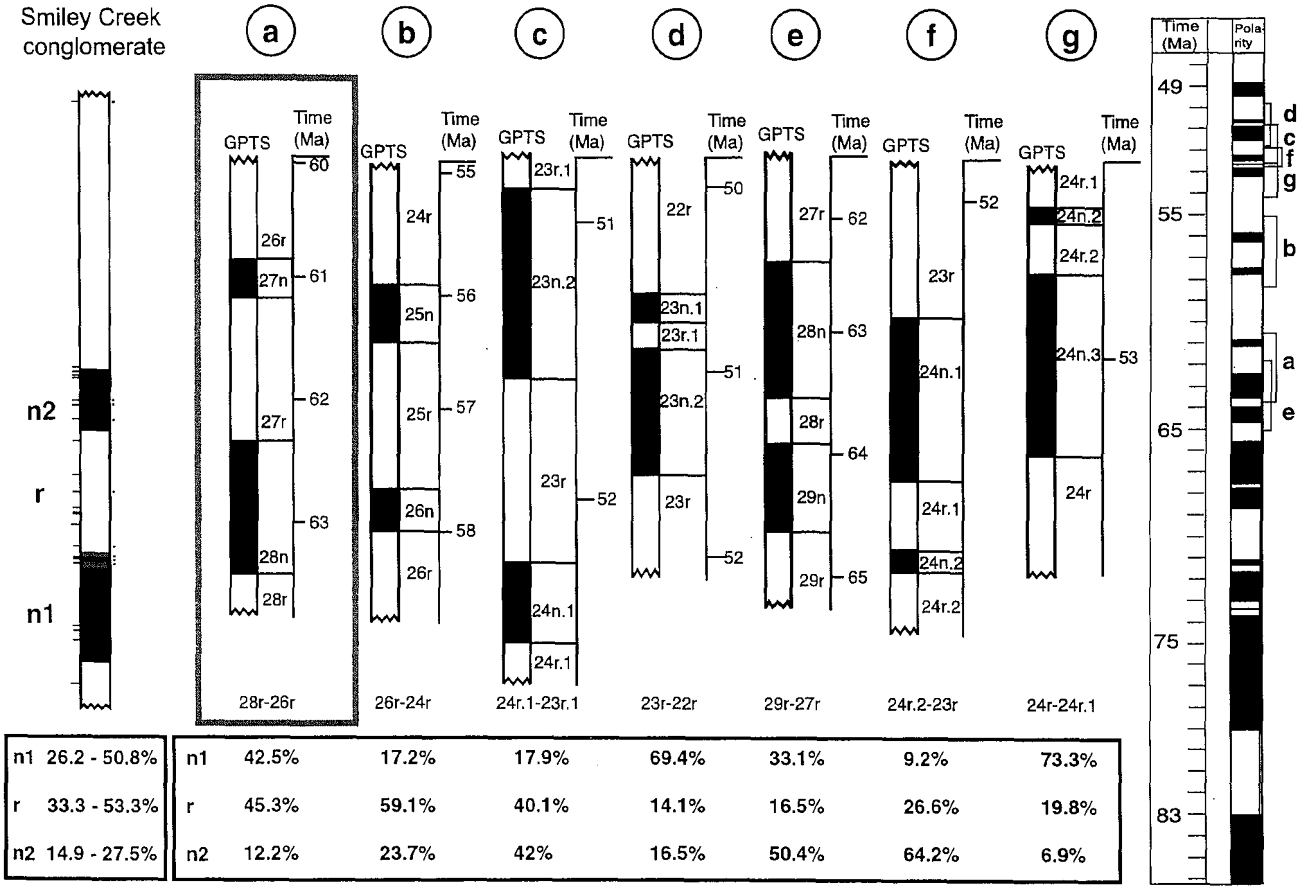


Figure 10. Equal-area projection comparison of the Smiley Creek conglomerate formation mean direction and 95% confidence limit, with the expected mean directions and 95% confidence limits for the Late Cretaceous and Early Tertiary North American paleopoles. Arrow indicates the direction of rotation of the observed formation mean direction.

shallowing. The formation mean differs from the Paleocene direction by 24.28° (± 6.86°) of clockwise rotation and 6.6° (± 4.22°) of inclination shallowing. Finally, the Smiley Creek conglomerate formation mean is rotated 24.46° (± 5.68°) clockwise and is 5.4° (± 3.79°) shallower than the expected Eocene direction. All directions indicate a positive 22-24° clockwise rotation and a positive 5-8° flattening in the formation mean direction (Figure 10).

Site mean directions from each stratigraphic level were used to calculate a virtual geomagnetic pole (VGP) paleolatitude (Figure 7 c,d). The VGP latitude for each site was the basis for classifying the sites as either normal or reversed polarity (normal polarity for positive VGP latitudes and reverse polarity for negative VGP latitudes). Within the 183 m sampled section, 5 magnetozones were observed. Both normal and reversed polarity directions were constrained by multiple samples at multiple horizons as revealed by the site VGP latitudes (Figure 7 e,f).

The resulting magnetostratigraphy for the forelimb and back limb stratigraphic columns were correlated to the geomagnetic polarity time scale (GPTS) of Cande and Kent (1995) between 49 Ma–83 Ma (Figure 11). The stratigraphic thickness of the normal and reversed polarity intervals, constrained by the stratigraphic position of the sites, was measured to determine the proportion of each polarity interval relative to the total length of the 183 m section. A minimum and maximum thickness for each interval was calculated



n1	26.2 - 50.8%	n1	42.5%	17.2%	17.9%	69.4%	33.1%	9.2%	73.3%
r	33.3 - 53.3%	r	45.3%	59.1%	40.1%	14.1%	16.5%	26.6%	19.8%
n2	14.9 - 27.5%	n2	12.2%	23.7%	42%	16.5%	50.4%	64.2%	6.9%

Figure 11. Comparison of the relative normal and reversed polarity interval lengths of the Smiley Creek conglomerate section to all possible normal-reversed-normal intervals of the GPTS (Cande and Kent 1995) between 83-49 Ma. The sections are ranked 'a' though 'g', with 'a' yielding the best fit for polarity chrons 28r-26r, indicating an age of deposition for the conglomerate between 63.6 and 60.9 Ma. Only 'a' has interval length ratios of N:R:N ~= 1:1:0.5, similar to that observed for the Smiley Creek section assuming a constant accumulation rate.

based on the stratigraphic separation of the sites bracketing the reversal boundaries, and a range of proportional lengths resulted. The range of relative lengths of normal and reversed polarity intervals within the Smiley Creek conglomerate section, was compared to the relative polarity interval lengths in the GPTS of Cande and Kent (1995) between 83-49 Ma. It was assumed that the accumulation rate remained constant during the deposition of the 183 m section. The Smiley Creek section shows a 1:1:0.5 ratio for the confined normal-reversed-normal interval. The best match was found to be within polarity chrons 28n and 27n, yielding an age for the deposit between 63.6 - 60.9 Ma, within the Early Paleocene (Figure 11a). This age corresponds to an average accumulation rate of ~33 m/my for the Smiley Creek conglomerate.

Discussion

Depositional geometries and magnetostratigraphic data from both limbs of the Glide Mountain thrust allow for reconstruction of the depositional and deformational history of the Smiley Creek conglomerate within the hinterland of the Sevier orogenic belt in the Montana recess of southcentral Idaho. The onlapping relationships of proximal bedding within unit 'c' on the back limb of the fold, and the shallowing of bedding dips upsection on both limbs of the Glide Mountain thrust, are characteristic geometries of stratigraphic sequences that have been deposited during the development of an underlying structure (e.g. Riba 1976, Suppe et al. 1992), such sequences are defined as growth strata (e.g. Suppe et al. 1992) (Figure 8). Syntectonic strata have been used as tools to define the chronology of deformation (e.g. Suppe et al. 1992, Zapata and Allmendinger 1996, Meigs 1997). Meigs (1997) successfully used syntectonic geometrical patterns to describe the kinematic history for the leading edge of the Sierras Marginales thrust sheet in the Spanish Pyrenees. The syntectonic strata within the Pyrenean foreland thrust provided a sequential history of the structure's development, and when correlated with timing constraints provided a temporal evolution for the kinematic history.

In addition to the geometrical patterns preserved within syntectonic strata of the Smiley Creek conglomerate proximal to the fault scarp, the presence and distribution of the large recycled conglomerate boulders on the forelimb of the fold, support the observations made by the strata, and indicate that the Glide Mountain thrust was active during deposition of the Smiley Creek conglomerate (Figure 8). More precisely, the distribution of the boulders, which dissipate along section to the east and end abruptly upsection, suggest that the light colored conglomerates within unit 'a' carried in the hanging wall of the Glide Mountain thrust was their source. The composition and character of the recycled conglomerate boulders proximal to the fault scarp within unit 'b' is similar to the composition and character of the light colored conglomerate deposit located on the back limb of the fold. The uniform dip of the parallel beds within the light colored conglomerates of package 'a' indicates that these conglomerates were deposited prior to the deposition of the overlying conglomerates of package 'c', and prior to movement along the Glide Mountain thrust, and therefore represent pre-growth or more specifically pre-Glide Mountain thrust conglomerates (Figure

12 A). The presence of the recycled conglomerate boulders, located only on the forelimb of the fold, also implies that the Glide Mountain thrust was at one time an emergent structure, thrusting from west to east, and carrying the pre-growth conglomerate unit in its hanging wall while shedding the conglomerate boulders into the foreland basin off the tip of the thrust (Figure 12 B).

The structural development of the Glide Mountain thrust, however, does not summarize the entire depositional history of the deposit. The Glide Mountain thrust is buried by the conglomerates of package 'd', indicating a second source of sediment input from a structure that is carrying the same pre-growth conglomerate unit in its hanging wall. Bedding planes within unit 'd' are relatively horizontal, except for a few beds slightly folded directly above the thrust tip, suggesting that the Glide Mountain thrust continued to be active for a short time, following the initiation of sediment input from a different source (Figure 12 C). Without the presence of a distinct imbrication direction, the source direction of the conglomerates within package 'd' is not precisely constrained, however, the observation that the deposit is thicker to the west and thinner to the east suggests a more hinterward conglomerate source. One possible source for the conglomerates of package 'd' is the Mississippian Copper Basin Formation and the overlying pre-growth conglomerates being transported off the emerging Dry Canyon Window as a result of out-of-sequence thrusting, and folding of the Wildhorse thrust sheet; of which the Glide Mountain thrust is an imbricate (Figure 13). The map patterns of the trailing fault branch lines of the Wildhorse thrust system, distributed about the exposed DCW are characteristic of a folded

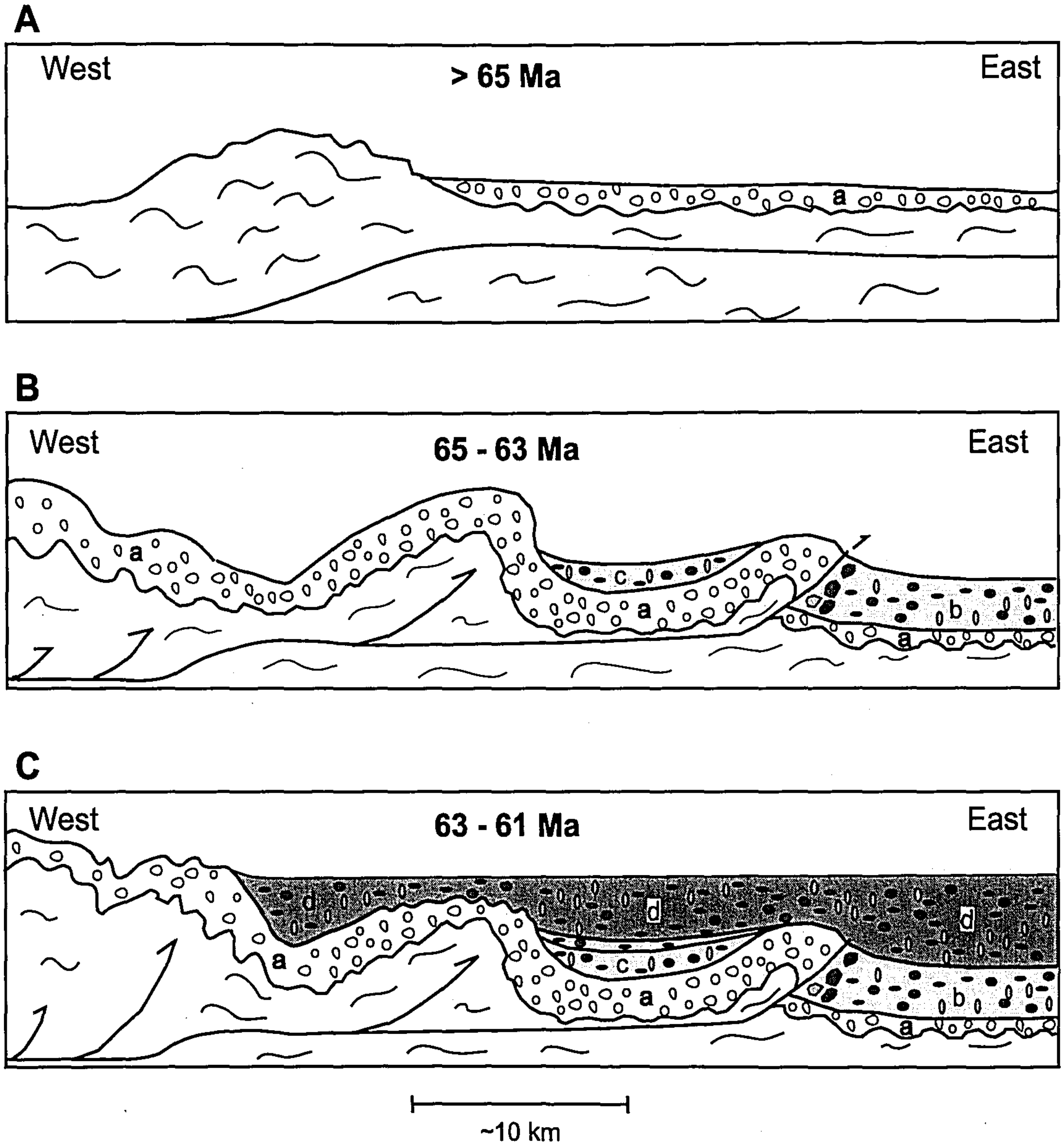


Figure 12. Relative spatial and temporal correlation of the distribution of the Smiley Creek conglomerate packages 'a', 'b', 'c', and 'd', during Sevier compressional deformation. (Schematic reconstruction, not drawn to scale)

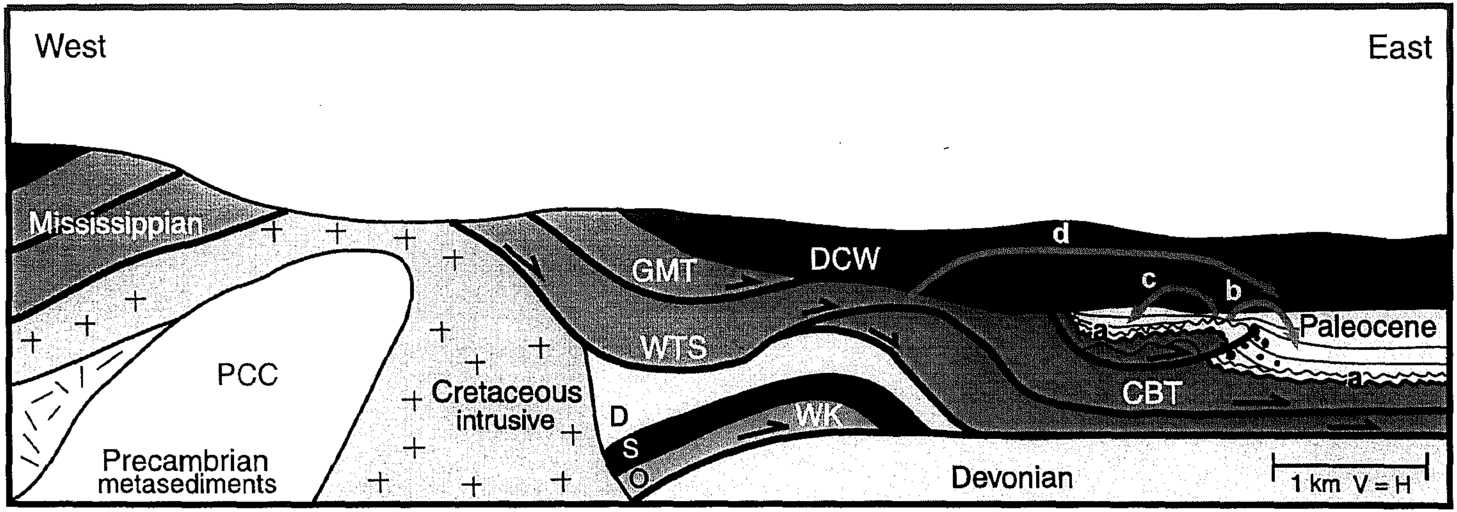


Figure 13. Regional cross-section where arrows illustrate the transportation direction of the conglomerates within packages 'b' and 'c' sourced by the pre-growth conglomerates of package 'a' in the hanging wall of the emergent Glide Mountain thrust. The conglomerates within package 'd', as shown by the arrow, are from more hinterland thrusts of the Wildhorse thrust system (WTS) as rocks above the Dry Canyon Window (DCW) are being eroded after being uplifted as a result of out-of-sequence thrusting along the White Knob thrust(WK).

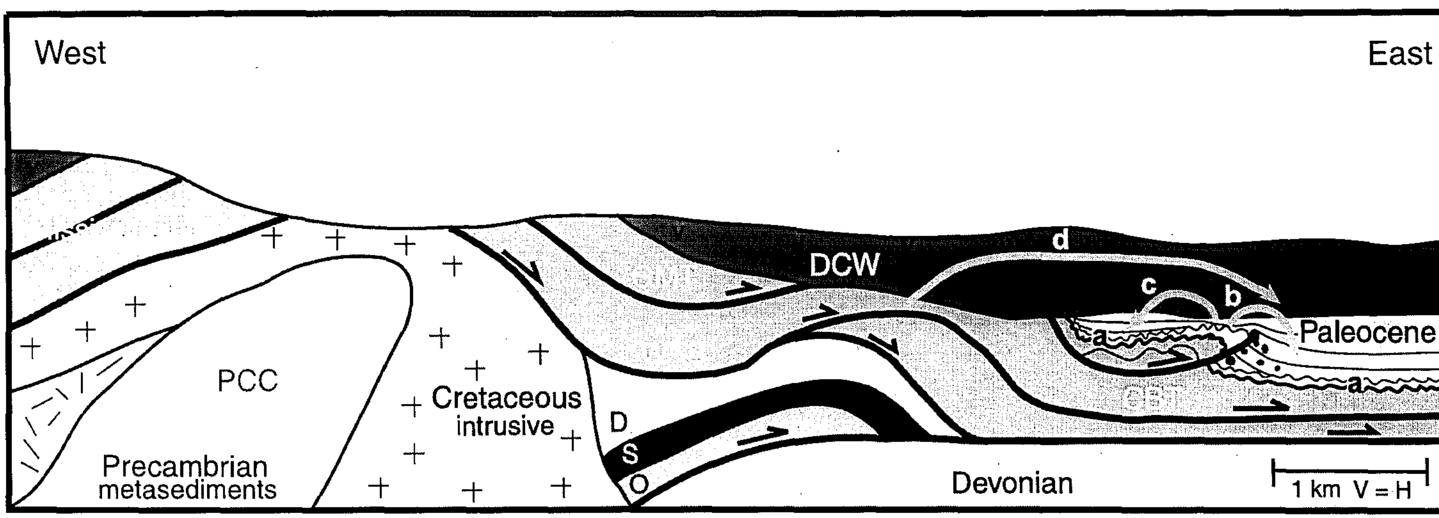


Figure 13. Regional cross-section where arrows illustrate the transportation direction of the conglomerates within packages 'b' and 'c' sourced by the pre-growth conglomerates of package 'a' in the hanging wall of the emergent Glide Mountain thrust. The conglomerates within package 'd', as shown by the arrow, are from more hinterland thrusts of the Wildhorse thrust system (WTS) as rocks above the Dry Canyon Window (DCW) are being eroded after being uplifted as a result of out-of-sequence thrusting along the White Knob thrust(WK).

imbricate fan (Gilluly 1961). Both the map patterns of the decollement and the overlying imbricates, which include the Copper Basin and Glide Mountain thrusts, support the notion that the WTS is a folded imbricate fan, maintaining the belief that out-of-sequence thrusting within lower Paleozoic units and folding of the WTS beginning in the west, created a structural culmination by uplifting the overlying Mississippian Copper Basin Formation. The subsequent erosion of these uplifted Mississippian units, exposing the DCW, provides the sediment source for the conglomerates of package 'd', which initially accumulate on the back limb of the Glide Mountain thrust and eventually bury the thrust and the underlying fan deposits once adequate debris is produced (Figure 12d). As folding along the WTS progresses, slip along the Glide Mountain thrust ended and movement along the emergent structure ceases at some time following the onlapping of the conglomerates of package 'd'.

In addition to the visible bedding geometries within the Smiley Creek conglomerate, an observable change in facies within the 183 m exposure, supports the argument that deformation locally along the Glide Mountain thrust and then distally in the hinterland, was occurring coeval to the deposition of the deposit. A distinct change in the conglomerate facies is discernable on both limbs of the emergent Glide Mountain thrust. The coarse grained poorly sorted, crudely stratified, and unimbricated nature of conglomerates within packages 'b' and 'c', are consistent with water poor (less than 30%), debris flow dominated alluvial fan deposits (Blair and McPherson 1994, Schmitt personal communication 1999). The nature of conglomerate package 'd', which conformably overlies the lower stratigraphic conglomerates of packages 'b' and 'c', is consistent with a sheet flood dominated alluvial fan deposit. Well developed horizontal stratification within the unit is indicative of more water rich sheet flood depositional events (e.g. Blair and McPherson 1994). The facies change within the deposit is speculated to be due to sediment input from a larger drainage basin, as a result from the change in source from the Glide Mountain thrust to structures further in the hinterland uplifting the DCW. The change in the conglomerate facies from the debris flow dominated to sheet flood dominated alluvial fan processes is located ~30 m lower on the back limb of the Glide Mountain thrust (Figure 7a,b). The offset in the facies transition on the limbs of the fold can be attributed to sediment initially accumulating on the back limb of the fold unable to disperse over the structurally elevated Glide Mountain thrust, which acts as a buttress to the debris being shed off the emerging DCW. As deformation in the hinterland progressed, and sediment was readily being shed off the DCW, debris overtopped the Glide Mountain thrust and blanketed the underlying fan deposits and the fault tip (e.g. Horton 1998).

Combining the structural and sedimentological inferences made regarding the processes controlling the deposition of the Smiley Creek conglomerate, the magnetostratigraphic data provide further insight into the timing of deformation and deposition within the basin and further hinterland, and therefore provide insight into the age of the deposit. Given the constraint of the age determined by the pilot study (49-83 Ma), the magnetostratigraphy further constrains the age of the Smiley Creek conglomerate to be between 63.6-60.9 Ma. Although the

Smiley Creek conglomerate formation mean direction is statistically different from the tightly clustered Late Cretaceous and Early Tertiary paleopole directions, the observed vertical axis rotation (~24° clockwise) (Figure 10) is consistent with estimated amounts of vertical axis rotation, from both measured and modeled fault block data collected within southern Idaho north of the Snake River Plain (e.g. Westaway 1989, Janecke et al. 1991). Janecke et al. (1991) modeled vertical axis rotations within Lost River Range, just east of the White Knob Mountains, using the McKenzie and Jackson (1986) block rotation model, and calculated clockwise vertical axis rotations between 15°-30°. The clockwise rotation observed within southern Idaho is a result of the onset of Basin and Range type extension during the Middle to Late Tertiary (e.g. Janecke et al. 1991). The observed 5°-8° mean inclination flattening within the Smiley Creek conglomerate does not have relevance to rotation and can be attributed to post-depositional sediment compaction as opposed to a tectonically caused shallowing. Paleomagnetic studies completed by Tan and Kodama (1999) have successfully shown that paleomagnetic inclination shallowing can result from post-depositional sediment compaction. A recent study by Tan and Kodama (1999) report inclination shallowing within the red beds of the Mauch Chunk Formation on the order that is observed within the Smiley Creek conglomerate. After measurement of anisotropy isothermal remanence (AIR) within the Mauch Chunk Formation, Tan and Kodama (1999) suggest that the inclination shallowing within the red beds is greater than 7°.

The preservation of the syntectonic strata and the observable facies change within the deposit, can be successfully correlated to the measured magnetostratigraphic section determining the relative times of activity for the Glide Mountain thrust, the out-of-sequence thrusting in the hinterland, and the folding of the Wildhorse thrust system (Figure 7). The oldest known age of the Smiley Creek deposit, and the oldest known age for the timing of thrusting along the Glide Mountain thrust, is given by the stratigraphically lowest conglomerates on the forelimb of the fold, and indicates that thrusting was active prior to 64-63.6 Ma. The facies change on the back limb of the Glide Mountain thrust that occurred between 63.6-62.5 Ma, represents the oldest known age for the conglomerates of package 'd', which signifies active out-of-sequence thrusting and folding within the WTS. The age of these conglomerates also indicates that movement along the Glide Mountain thrust continued to be active though this time as the WTS was beginning to be folded and as the conglomerates of package 'd' were accumulating on the back limb of the emerging thrust. The age of the facies change on the forelimb of the deposit, between 62.5-61.3 Ma, signifies the overflow of the more hinterland conglomerates and the last stages of movement along the Glide Mountain thrust.

Given these ages and the known thickness of the deposit, a minimum mean accumulation rate of ~33 m/my for the Smiley Creek conglomerate. This is a minimum rate since secondary processes, such as overland flow, and soil development, can degrade or erode a alluvial fan (e.g. Blair and McPherson 1994). The occurrence of such processes would be represented by lenses of winnowed clasts, paleosols, bioturbated horizons, or diagenetically altered zones (e.g. Blair and McPherson 1994). Both winnowing zones and diagenetically altered paleosols containing plant root remnants, are present within the Smiley Creek conglomerate, providing evidence that some erosional processes have taken place on the face of the fan, and therefore decreasing the original thickness of the deposit and the actual accumulation rate.

The Early Paleocene age determined for the Smiley Creek conglomerate is significant in that this deposit records the youngest Sevier compression within the hinterland of the Idaho, Wyoming and Montana Sevier orogenic belt (e.g. Wiltschko and Dorr 1983, Miller et al. 1992, Schmitt et al. 1995), and is evidence of significant out-of-sequence thrusting within the Montana recess (Figure 1). The Paris thrust in the Wyoming salient (e.g. Wiltschko and Dorr 1983) and the Sapphire and Grasshopper thrust systems within the Helena salient (e.g. Miller et al. 1992, Schmitt et al. 1995), both indicate that compression within the hinterland of the orogenic belt began during the Early to Late Cretaceous and was completed by 70 Ma (e.g. Cowan and Bruhn 1992). Conversely, the foreland Lombard thrust in the Helena salient (e.g. Schmitt et al. 1995) and the Darby and Prospect thrusts in the Wyoming salient (e.g. Wiltschko and Dorr 1983), indicate that thrusting along these foreland most structures began ~64 Ma and was complete by 56 Ma, marking the initiation of the 'Eocene Tectonic Transition' (e.g. Parrish et al. 1990) within the region. The Smiley Creek synorogenic conglomerate preserves the record that Sevier compression along the Glide Mountain thrust and the associated Wildhorse thrust system was active

~63 Ma at a time when hinterland structures of the adjacent Helena and Wyoming salients had ceased motion and compressional deformation was confined to the foreland most structures of those belts. It is likely, given the presence of the pre-growth conglomerates, located unconformably above the deformed Mississippian flysch deposits, that Sevier compression in the hinterland of the Montana recess was occurring at the same time as compression in the hinterland of the Helena and Wyoming salients. The eastward propagation of thrusting, however, within the Montana recess ceased when the foreland most Tendoy thrust buttressed against the uplifted Blacktail-Snowcrest arch ~81 Ma, inhibiting further foreland progression and effectively forcing the hinterland to shorten by out-of-sequence thrusting. There are three possible compressional scenarios deforming the hinterland of the Montana recess during the time of deposition of the Smiley Creek conglomerate that could have potentially aided in the deposition of the deposit. The first scenario, as described by Mitra and Sussman (1997), implies that the Sevier orogenic wedge was subcritical at a time prior to the deposition of the conglomerates and that subsequent internal shortening in an effort to maintain a critical taper necessary for forward propagation, deposited the Smiley Creek conglomerate in a thrust bounded hinterland basin. The second scenario suggests that the collision of the Tendoy thrust with the uplifted Blacktail-Snowcrest arch, a Laramide structure, in the foreland of the Montana recess, resulted in break back thrusting in the hinterland of the Montana recess, subsequently depositing the Smiley Creek conglomerate off the emergent Glide Mountain thrust and more hinterward structures of the

Wildhorse thrust system (e.g. Schmitt et al. 1995). The third scenario implies that vertical kinematic partioning, leading to upper crustal shortening and mid-crustal extension within the Sevier hinterland, resulted in the exhumation of the Pioneer core complex coincident with folding of the WTS and deposition of the Smiley Creek conglomerate (e.g. Hodges and Walker 1992). In each scenario it is inferred that out-of-sequence thrusting along the Wildhorse thrust system, during the Early Paleocene, uplifted and shed pre-growth conglomerates, eastward along the Glide Mountain thrust and more hinterward structures, depositing the recycled synorogenic Smiley Creek conglomerates into structurally controlled wedge-top basins within the Montana recess of southcentral Idaho.

Conclusion

The Smiley Creek synorogenic conglomerate deposit, located in the Sevier hinterland of the Montana recess within south-central Idaho, was shed from the emergent Glide Mountain and Copper Basin thrusts of the Wildhorse thrust system, during the Early Paleocene. The deposit preserves a sedimentary record of the transition in source area from the emergent Glide Mountain thrust to the more hinterward structures of the Wildhorse thrust system, and records the contemporaneous structural deformation in the hinterland of the Montana recess associated with the change in source area. The Smiley Creek conglomerate maintains a record of significant out-of-sequence thrusting along the Wildhorse thrust system within the Idaho-Wyoming-Montana Sevier fold-and-thrust belt during the Late Cretaceous and Early Tertiary. The conglomerate represents the youngest known synorogenic Sevier deposit in the hinterland of the Idaho-Wyoming-Montana orogenic belt.

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