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COMINCO AMERICAN WELL: IMPLICATIONS FOR THE RECONSTRUCTION OF THE SEVIER OROGEN AND BASIN AND RANGE EXTENSION IN WEST-CENTRAL UTAH

MARK H. ANDERS*,†, NICHOLAS CHRISTIE-BLICK*,
and ALBERTO MALINVERNO**

ABSTRACT. **Re-evaluation of acoustic, gamma ray and dip meter logs from the Cominco American Federal No. 2 well in the Sevier Desert basin of west-central Utah sheds new light on the interpretation of Neoproterozoic and Cambrian stratigraphy and Mesozoic structure in a region that has been influential in the development of ideas about crustal shortening and extension. The most prominent of several major thrust faults (the Canyon Range and Pavant thrusts) have been interpreted by DeCelles and Coogan (2006) [Regional structure and kinematic history of the Sevier fold-and-thrust belt, central Utah: Geological Society of America Bulletin, v. 118, n. 7-8, p. 841-864, http://dx.doi.org/10.1130/B25759.1] as having been cut and in part re-activated between late Oligocene and Holocene time by as much as 47 km of displacement on the gently west-dipping Sevier Desert detachment. This interpretation, which is based upon a combination of outcrop, seismic reflection and well data, depends critically on the Canyon Range thrust intersecting the Cominco well at a depth of 2,551 to 2,557 m (8,370-8,389 ft.), and terminating downwards against a re-activated Pavant thrust.**

Our work suggests that the fault at 2,551 m (8,370 ft.) is a strand of the Pavant thrust, and that the Canyon Range thrust cuts the well at a depth of 1,222 m (4,010 ft.). This alternative interpretation depends in turn on identification of the section between the two faults as terminal Neoproterozoic to middle Cambrian Prospect Mountain Quartzite through Chisholm Formation rather than Neoproterozoic "Pocatello Formation," "Blackrock Canyon Limestone" and lower Caddy Canyon Quartzite. To support this interpretation we present evidence for stratigraphic repetition and for deformation at the 1,222 m (4,010 ft.) level. Use of the lithostratigraphic terms "Pocatello" and "Blackrock Canyon" in west-central Utah is shown to be inappropriate, and among the reasons that the critical interval in the Cominco well has been misinterpreted by some authors. If the Canyon Range and Pavant thrusts are both found in the Cominco well, as we suggest, then they cannot be used as a piercing point for the estimation of displacement on the Sevier Desert detachment or as justification for the existence of the detachment. Published estimates of extension across the Sevier Desert basin therefore need to be reduced, potentially to as little as ~10 km.

Key words: Sevier Desert basin, Sevier orogenic belt, Neoproterozoic stratigraphy

INTRODUCTION

West-central Utah has garnered considerable attention over the past three to four decades for insights that have been obtained about mechanisms of shortening and extension in the continental crust (figs. 1 and 2; Armstrong, 1968, 1972; McDonald, 1976; Allmendinger and others, 1983; Smith and Bruhn, 1984; Von Tish and others, 1985; Villien and Kligfield, 1986; Levy and Christie-Blick, 1989; Planke and Smith, 1991; Allmendinger, 1992; Royse, 1993; Anders and Christie-Blick, 1994; DeCelles and others, 1995; Coogan and DeCelles, 1996; Lawton and others, 1997; Mitra and Sussman, 1997; Anders and others, 2001; Niemi and others, 2004; Wills and others, 2005; DeCelles and Coogan, 2006; Christie-Blick and others, 2007, 2009). The chal-

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* Department of Earth and Environmental Sciences and Lamont-Doherty Earth Observatory of Columbia University, Palisades, New York, 10964-8000, USA
** Lamont-Doherty Earth Observatory of Columbia University, Palisades, New York, 10964-8000, USA
† Corresponding author: manders@ldeo.columbia.edu

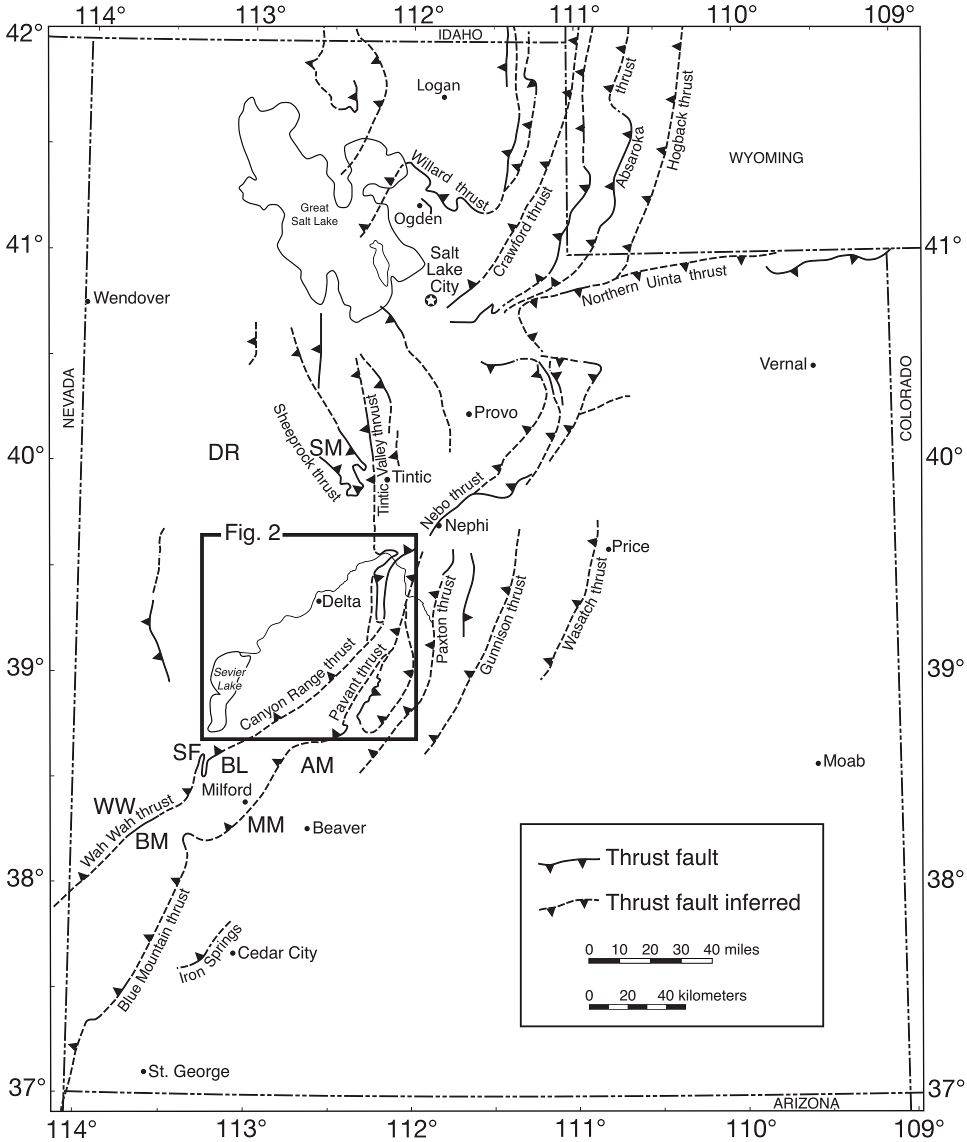


Fig. 1. Major thrust faults in Utah, with an interpretation of regional connections where buried (modified from Willis, 1999; Kwon and Mitra, 2006). Box shows location of figure 2. Abbreviations for ranges: AM, Antelope Mountain; BL, Beaver Lake Mountains; BM, Blue Mountains; DR, Dugway Range; MM, Mineral Mountains; SF, San Francisco Mountains; SM, Sheeprock Mountains; WW, Wah Wah Mountains.

lenge in this work is that the perceived Mesozoic to early Cenozoic structure of the Sevier orogen influences the reconstruction of late Cenozoic Basin and Range extension, and perceptions with respect to extensional structure influence the palinspastic interpretation of the Sevier orogen. A key feature in all recent reconstructions is referred to as the Sevier Desert detachment (fig. 3), an inferred low-angle normal fault that dips westward at 11°, and in different publications is thought to have accommo-

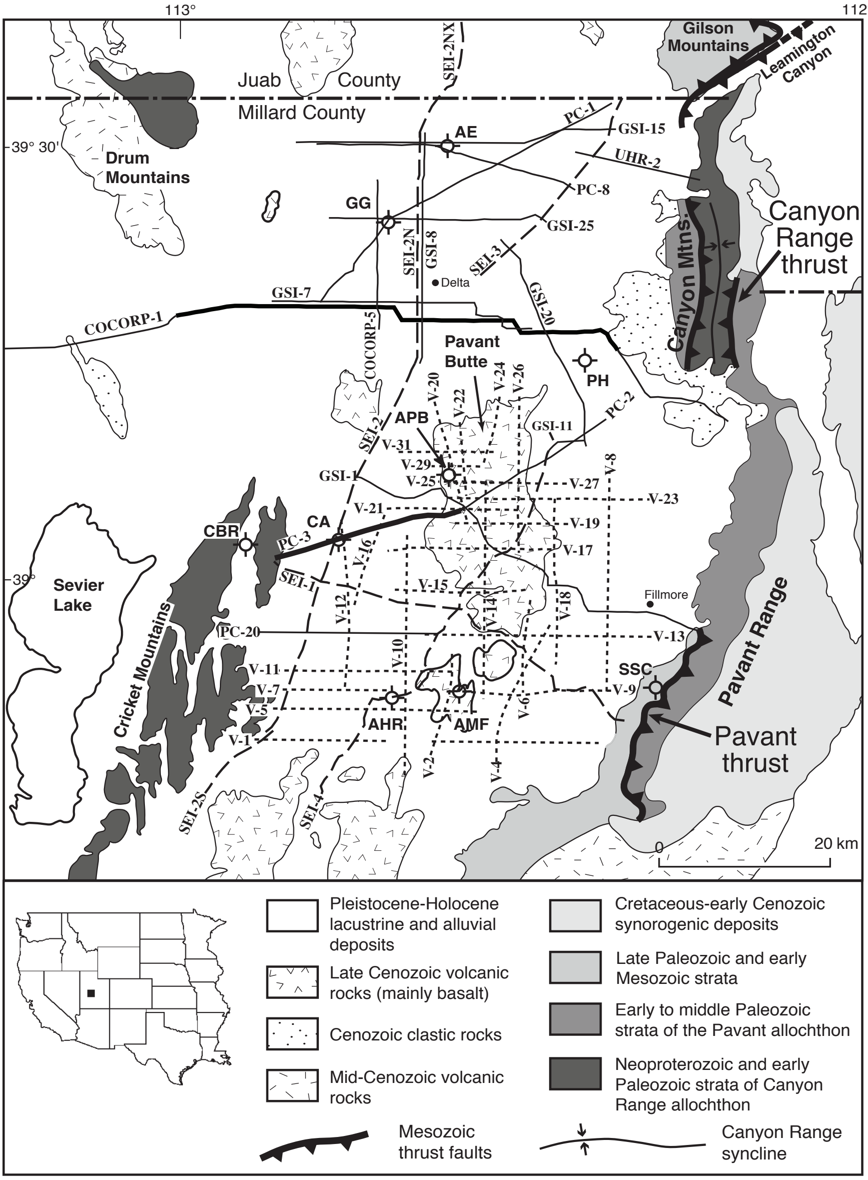


Fig. 2. Generalized map of the Sevier Desert basin of west-central Utah, showing locations of wells and seismic reflection profiles (modified from Wills and others, 2005; Kwon and Mitra, 2006; Christie-Blick and others, 2009; see fig. 1 for location). Wells: AE, Argonaut Energy Federal; AHR, ARCO Hole-in-Rock; AMF, ARCO Meadow Federal; APB, ARCO Pavant Butte; CA, Cominco American Federal (the focus of this paper); CBR, Chevron Black Rock; GG, Gulf Gronning; PH, Placid Henley; SSC, Shell Sunset Canyon. Solid, dashed, and dotted lines with alphanumeric designations correspond with different seismic datasets. Bold lines correspond with segments of Consortium for Continental Reflection Profiling (COCORP) Utah Line 1 (fig. 3), and line PC-3 (fig. 5). Inset map shows location relative to states in the western U.S.

dated 47 km of slip since the mid-Miocene (DeCelles and Coogan, 2006), 39 km (Coogan and DeCelles, 1996), 28 km to 38 km (Von Tish and others, 1985), ~6 km (Planke and Smith, 1991), or no slip (Hintze and Davis, 2003; Wills and others, 2005).

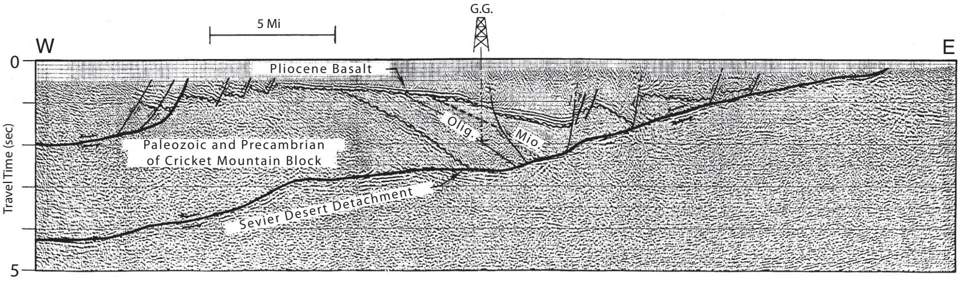


Fig. 3. Seismic reflection profile COCORP Utah Line 1 oriented west to east across the Sevier Desert basin, with interpretation from Von Tish and others (1985). See figure 2 for location. The eastward-dipping panel labeled Olig. (Oligocene) by Von Tish and others (1985) is reinterpreted as Paleozoic and Neoproterozoic (Canyon Range allochthon), based on a velocity (3.2 km s^{-1}) for the basin fill at the Gulf Gronning well (G.G.) that is higher than originally assumed (Anders and others, 1995; Wills and others, 2005). The antiformal structure labeled "Paleozoic and Precambrian of Cricket Mountain Block" is a northern continuation of a comparable feature in line PC-3 (fig. 5).

The most recent displacement on the detachment was arguably no more than 8 kyr ago (Oviatt, 1989; Niemi and others, 2004). The Mesozoic faults that have proven critical to most of these interpretations of extension are the Canyon Range and Pavant thrusts (Allmendinger and others, 1983; Von Tish and others, 1985; Villien and Kligfield, 1986; Mitra and Sussman, 1997; Hintze and Davis, 2003; Wills and others, 2005; DeCelles and Coogan, 2006), structures that have been correlated across the Sevier Desert basin from their outcrop in the Canyon Mountains and Pavant Range to the subsurface of the Cricket Mountains block some 50 km to the west (fig. 2). A single industry well more than any other controls the subsurface interpretation, by virtue of a location close to several key seismic profiles, and the intersection in this well of more than 3,265 m (10,713 ft.) of Neoproterozoic and lower Paleozoic sedimentary rocks (Hintze and Davis, 2003, p. 268; Wills and others, 2005; DeCelles and Coogan, 2006; Christie-Blick and Anders, 2007; Coogan and DeCelles, 2007). The purpose of this paper is to reassess the geology of that well (the Cominco American Federal No. 2 well, or Cominco well for short), and to consider implications for palinspastic reconstruction. We quote well depths and thicknesses using SI units, with English units in parentheses. Data are presented this way because they were originally specified in feet (fig. 4).

MESOZOIC TO EARLY CENOZOIC STRUCTURE OF WEST-CENTRAL UTAH

Mesozoic to early Cenozoic crustal shortening in west-central Utah was accommodated by several major thrust faults, of which the Canyon Range and Pavant thrusts are the most significant in terms of displacement and areal extent (Villien and Kligfield, 1986; Allmendinger, 1992; DeCelles and others, 1995; Hintze and Davis, 2003; DeCelles and Coogan, 2006). The Canyon Range thrust, where best exposed in the Canyon Mountains (fig. 2), places Neoproterozoic predominantly clastic sedimentary rocks over lower Paleozoic mostly carbonate rocks (Christiansen, 1952; Higgins, 1982; Sprinkel and Baer, 1982; Millard, 1983; Holladay, 1984; Hintze, 1991a, 1991b; Lawton and others, 1997; Hintze and Davis, 2002a, 2003). The upper plate of the thrust is folded into a mountain-scale anticline-syncline pair, with only the eastern limb of the anticline preserved in outcrop along the western side of the range (DeCelles and others, 1995; Mitra and Sussman, 1997; Hintze and Davis, 2003; DeCelles and Coogan, 2006). Movement on the Pavant thrust beneath the Canyon Range thrust is inferred to have led to progressive tightening of the syncline while at the same time emplacing

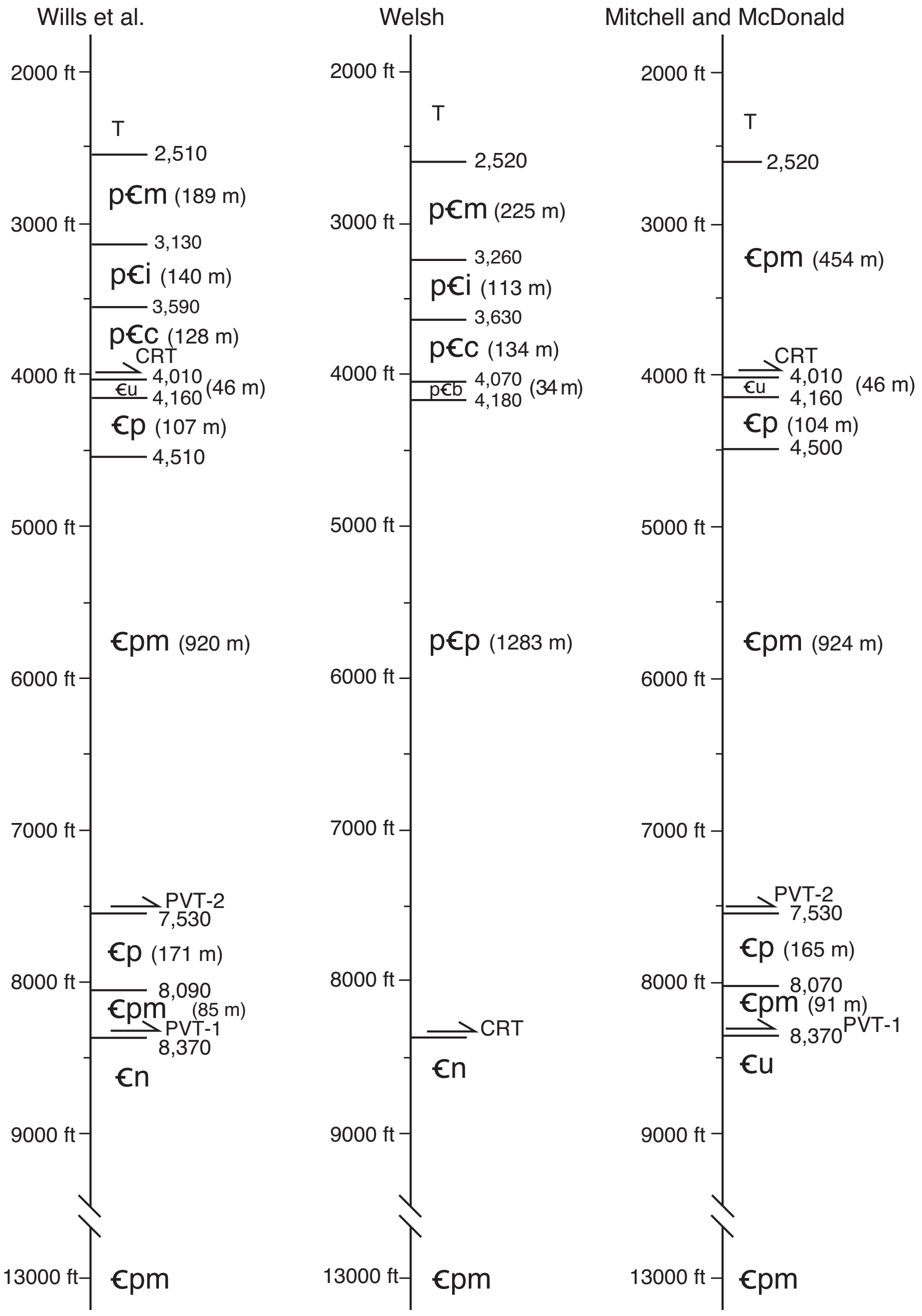


Fig. 4. Interpretations of the stratigraphy encountered in the Cominco American Federal No. 2 well (CA in fig. 2), from Wills and others (2005), Welsh (as reported in Hintze and Davis, 2003, p. 268) and Mitchell and McDonald (1987). Abbreviations: T, Tertiary; pꞒm, Mutual Formation; pꞒi, Inkom Formation; pꞒc, Caddy Canyon Quartzite; Ꞓp, Pioche Formation; Ꞓpm, Prospect Mountain Quartzite; Ꞓn, Notch Peak Formation; Ꞓu, undifferentiated Cambrian. The "Blackrock Canyon Limestone" (pꞒb) and "Pocatello Formation" (pꞒp) of west-central Utah are regarded in this paper as stratigraphically equivalent to Caddy Canyon Quartzite. All measurements in feet except those in brackets are in meters.

both sheets atop the upper Cretaceous-Paleocene synorogenic Canyon Range Conglomerate (DeCelles and others, 1995; Mitra and Sussman, 1997; DeCelles and Coogan, 2006).

It has been suggested that the Canyon Range thrust is part of the same thrust system as the Frisco thrust of the San Francisco Mountains (SF in fig. 1) along the southwestern margin of the Sevier Desert and the Wah Wah thrust of the Wah Wah Mountains (WW in fig. 1) still further to the southwest (Misch, 1960; Miller, 1966; Armstrong, 1968; Levy and Christie-Blick, 1989; Willis, 1999; Friedrich and Bartley, 2003; Hintze and Davis, 2003). Willis (1999) and Hintze and Davis (2003) have suggested that this system also includes the Antelope Mountain thrust in the northern Mineral Mountains (MM in fig. 1; Liese, ms, 1957; Coleman and others, 1997) and the Sheeprock and Pole Canyon thrusts of the Sheeprock Mountains (SM in fig. 1) at the northern edge of the Sevier Desert (Cohenour, 1959; Christie-Blick, 1983; Morris, 1983; Levy and Christie-Blick, 1989; Mukul and Mitra, 1998) and/or the Tintic Valley thrust (Kwon and Mitra, 2006). According to Friedrich and Bartley (2003, p. 1487), the backward-breaking sequence of duplex thrust development below the Wah Wah thrust differs from the overall forward-breaking character of thrust imbrications beneath the Canyon Range thrust in the Canyon Mountains. These authors nonetheless regard the faults as "broadly correlative." Each of the regionally correlated thrust faults occupies a comparable position within the Sevier orogen, and juxtaposes similar-aged Neoproterozoic to lower Paleozoic strata with comparable stratigraphic separation. Displacement along the Canyon Range thrust is inferred by DeCelles and Coogan (2006) to have been as great as 117 km on the basis of a regional cross-section integrating outcrop, well and seismic reflection data.

The Pavant thrust crops out in the Pavant Range, directly south of the Canyon Mountains, and at a deeper structural level within the orogen (fig. 2; Maxey, 1946; Hickcox, ms, 1971; Burchfiel and Hickcox, 1972; Royse, 1993; Hintze and Davis, 2003). Lower Cambrian rocks constituting the lower plate of the Canyon Range thrust are juxtaposed by the Pavant thrust above Mesozoic strata. It has been suggested that the Pavant thrust is part of the same thrust system that includes the Blue Mountain thrust of the Blue Mountains southeast of the Wah Wah Mountains (BM and WW in fig. 1; Morris, 1983; Willis, 1999; Hintze and Davis, 2003). Walker and Bartley (1990) proposed that the Beaver Lake Mountains thrust of the Beaver Lake Mountains (BL in fig. 1), located to the south of the Cricket Mountains, is also part of the Pavant thrust system. Welsh (1972) and Morris (1983), in contrast, regarded the Beaver Lake Mountains thrust as a continuation of the Frisco-Canyon Range thrust system. Overall displacement along the Pavant thrust is estimated by DeCelles and Coogan (2006) as ~42 km, much of it associated with the development of duplex structures beneath the west side of the Canyon Mountains (DeCelles and others, 1995; Mitra and Sussman, 1997).

While differences of opinion about the regional correlation of thrust faults cannot be entirely resolved, and the character of any large fault undoubtedly varies in three dimensions as displacement is partitioned across multiple strands and splays, we expect both the Canyon Range thrust and Pavant thrust to project beneath the Cricket Mountains block on the west side of the Sevier Desert (fig. 2: Allmendinger and others, 1983; Von Tish and others, 1985; Wills and others, 2005; DeCelles and Coogan, 2006). The issue to be re-examined here with available subsurface data, and particularly with reference to the Cominco well, is how those faults relate to each other at depth and to the interpreted Sevier Desert detachment.

LATE CENOZOIC EXTENSION ACROSS THE SEVIER DESERT BASIN

The interpretation of large-scale late Cenozoic extension across the Sevier Desert basin is supported by two main lines of reasoning (see McDonald, 1976; Allmendinger and others, 1983; Von Tish and others, 1985; Mitchell and McDonald, 1987; Allmendinger, 1992; DeCelles and others, 1995; DeCelles and Coogan, 2006; Christie-Blick and others, 2009). The first relates to high-angle faults that have been imaged in seismic profiles and that appear to sole into a laterally continuous set of gently west-dipping reflections (fig. 3). In the northern part of the Sevier Desert basin, the latter project to depth beneath the Cricket Mountains block. Given that at least some of the high-angle faults offset lake sediments as young as 8 ka (Oviatt, 1989; Black and others, 2003), it follows that the reflections against which those faults terminate must correspond with an active or recently active low-angle normal fault: the Sevier Desert detachment (McDonald, 1976; Allmendinger and others, 1983; Von Tish and others, 1985; Mitchell and McDonald, 1987; Planke and Smith, 1991). A second, somewhat more tentative line of reasoning is that in order to reconstruct a plausible late Mesozoic critical taper across the Sevier orogen at the latitude of the Sevier Desert, large-scale displacement on the inferred detachment must be restored (DeCelles and others, 1995; DeCelles and Coogan, 2006). A possible difficulty with this argument is that other solutions involving high-angle normal faulting and erosion can be imagined (Wills and others, 2005; Christie-Blick and others, 2007). The argument also requires assumptions about the placement at depth of the lowest thrust fault. The interpretation of the Sevier Desert detachment ultimately depends upon the correlation of seismically imaged structural features in the Cricket Mountains block, above the inferred detachment, with the thrust faults and folds exposed today beneath the detachment in the Canyon Mountains and the Pavant Range.

In an attempt to estimate the magnitude of extension across the Sevier Desert basin, Von Tish and others (1985) interpreted a particular set of east-dipping reflections beneath the western part of the basin as Oligocene lake deposits ("Olig." in the COCORP Utah Line 1; fig. 3). They assumed for this purpose that Oligocene sedimentary rocks encountered at the bottom of the Gulf Gronning well (GG in fig. 2) project onto the seismic profile at the depth of the dipping reflections. Restoring the Oligocene deposits to horizontal results in 28 km to 38 km of extension. The principal difficulty with this reconstruction is that Von Tish and others (1985) assumed an unrealistically low velocity of 2,438 m s^{-1} (8,000 ft. s^{-1}) for the conversion of depth to two way time at the Gulf Gronning well. When a more plausible average value of 3.2 km s^{-1} is used, based on *in situ* measurements in the Sevier Desert basin for Miocene and older rocks (68% of the stratigraphy at Gulf Gronning), the Oligocene section in the well projects above the stratigraphic level of the dipping reflections (Anders and others, 1998; Wills and others, 2005; Christie-Blick and others, 2007).

Working independently, but at about the same time, Planke and Smith (1991) came up with a substantially lower "horizontal extension" estimate of ~6 km. They assumed that the cross-sectional area of the basin fill, as imaged in seismic reflection data, is equivalent to the maximum depth of the detachment multiplied by the horizontal component of displacement. Given that the hanging-wall cutoff for the base of the Tertiary appears to have been displaced 27 to 33 km from its footwall counterpart in three different profiles (fig. 13 of Planke and Smith, 1991), this is equivalent to an updip slip rate for the detachment that is 4 to 5 times the slip rate at depth. The unstated assumption that leads to this strange conclusion is that displacement along the detachment involved no overall change in elevation: the volume now occupied by Cenozoic sedimentary rocks is exactly equivalent to the volume of crustal rocks moved out of the way. Were Planke and Smith (1991) to have interpreted their data in a manner comparable to that of Von Tish and others (1985), their estimate for the magnitude of extension would have been indistinguishable.

In the most recent assessment of extension across the Sevier Desert, DeCelles and others (1995), Coogan and DeCelles (1996), Mitra and Sussman (1997), and DeCelles and Coogan (2006) interpreted a set of antiformal seismic reflections (Cricket Mountains block in fig. 3) to include the Canyon Range thrust terminating downwards against reflections associated with the Sevier Desert detachment. They assumed that the Pavant thrust provided a pre-existing weakness on which extensional backsliding subsequently took place. According to this view, the folded Canyon Range thrust in the subsurface is a counterpart of the incomplete anticline-syncline pair exposed in the Canyon Mountains. Restoration of the two features provides the basis for the estimation of 47 km of slip along the detachment. The hypothesized offset depends critically on the interpretation of stratigraphy and fault location in the Cominco well (DeCelles and Coogan, 2006; Christie-Blick and Anders, 2007; Coogan and DeCelles, 2007).

REGIONAL STRATIGRAPHY

The regional Neoproterozoic and Paleozoic stratigraphy of west-central Utah has been established through many decades of geological mapping, stratigraphic paleontology and sedimentological studies (see for example, Christiansen, 1952; Crittenden and others, 1971, 1983; Lemmon and Morris, 1979, 1984; Hintze, 1981a, 1981b, 1981c, 1984, 1991a, 1991b; Christie-Blick, 1982, 1997; Higgins, 1982; Abbott and others, 1983; Millard, 1983; Hintze and others, 1984; Holladay, 1984; Christie-Blick and Levy, 1989; Levy and Christie-Blick, 1991; Link and others, 1993; Levy and others, 1994; Hintze and Davis, 2002a, 2002b, 2002c, 2003; Hintze and others, 2003; Hintze and Kowallis, 2009; Link and Christie-Blick, 2011). The Paleozoic part of the succession, which consists predominantly of marine carbonate rocks and interstratified siltstones is best studied and most finely divided on the basis of fossils and well developed sedimentary cyclicity, particularly in the middle to upper Cambrian. (See Hintze and Davis, 2003, p. 48-65 for a summary of stratigraphic units in the Canyon Range thrust plate.) The Neoproterozoic to lower Cambrian portion of the succession consists predominantly of non-marine to marine quartzite and siltstone overlying glacial-marine diamictite and associated mostly clastic sedimentary rocks. These older rocks are less widely exposed and, above the level of the glacial deposits, less varied in lithology (Christie-Blick, 1982, 1997; Christie-Blick and Levy, 1989; Levy and Christie-Blick, 1991; Link and Christie-Blick, 2011). The Neoproterozoic rocks are also mostly unfossiliferous, with the exception locally of acritarchs (Knoll and others, 1981; Dehler and others, 2007; Link and Christie-Blick, 2011) and stromatolites (see for example, Millard, 1983), and subject to lateral changes in facies, so that only coarse subdivision is possible at a regional scale. Trace fossils make an appearance in the lower Cambrian, in the transition from the Prospect Mountain Quartzite through siltstone and sandstone of the Pioche Formation (and lateral equivalents) to interstratified carbonate and mostly fine-grained terrigenous rocks (Hintze and Davis, 2003).

Terminal Neoproterozoic Lithostratigraphy Clarified

As first recognized by Crittenden and others (1971) at a regional scale from southeastern Idaho to southern Utah, post-glacial Neoproterozoic strata are divisible into four gross lithic units (with local variants, which we mostly ignore here for the sake of brevity): 1) up to several hundred meters of gray to olive drab siltstone and minor quartzite mapped as the upper member of the Pocatello Formation in Idaho and the Kelley Canyon Formation in northern and west-central Utah; 2) as much as 1,000 m or more of vitreous white to tan cross-stratified quartzite with minor olive drab siltstone and carbonate rocks (Caddy Canyon Quartzite); 3) a distinctive interval of olive drab to grayish red or liver-colored siltstone and thin sandstone, a few tens of meters to more than 250 m thick (Inkom Formation); and 4) up to several hundred meters of grayish red quartzite and pebbly quartzite that is abundantly cross-stratified and generally less well sorted and more feldspathic than the Caddy Canyon Quartzite (Mutual Formation). The Mutual Formation is overlain by 800 m to more than 2,000 m of white to gray cross-stratified quartzite and pebbly quartzite that is referred to in western Utah and above the Canyon Range thrust as Prospect Mountain Quartzite, and in more eastern (structurally lower) thrust sheets as Tintic Quartzite. (The distinction between the latter is made conventionally on the basis of the early Cambrian versus middle Cambrian age of overlying siltstones.) The term "Pocatello Formation" was reserved for sections in Idaho that include a thick succession of diamictite (Scout Mountain Member) and mostly extrusive metavolcanic rocks (Bannock Volcanic Member). In Utah, a plethora of local formational names is used for correlative glacial and volcanic rocks owing to marked lateral variations in lithology and stratigraphy (Crittenden and others, 1983; Link and Christie-Blick, 2011). The transition from the Pocatello Formation to the Caddy Canyon Quartzite is also marked near Pocatello, Idaho by several tens of meters of locally oolitic limestone, quartzite and argillite (Blackrock Canyon Limestone; Crittenden and others, 1971; Smith and others, 1994) and by several hundred meters of distinctive, thinly bedded sandstone and siltstone with abundant syn-depositional dikelets (Papoose Creek Formation). Comparable carbonate rocks, sandstones and siltstones are present only locally in Utah, and not necessarily at the same stratigraphic level (Christie-Blick and Levy, 1989).

Neoproterozoic strata of the Canyon Mountains include 50 to 200 m of sandy and locally oolitic, pelletal, intraclastic and stromatolitic limestone that Crittenden and others (1971) took to represent "a distal tongue of the Blackrock Canyon Limestone." Several hundred meters of quartzite and siltstone beneath those beds and immediately above the Canyon Range thrust was interpreted as occupying "the stratigraphic position of the upper member of the Pocatello Formation in Idaho." Strata above the carbonates were assigned tentatively to the Caddy Canyon Quartzite and the Inkom and Mutual formations. Given that glacial deposits are not exposed in the Canyon Mountains, Crittenden and others (1971) appear to have been influenced in their thinking by the character of the carbonate, by the thickness of the exposed interval beneath the Mutual Formation and by correlation with what they took to be a generally siltier sub-Mutual section in the Sheeprock Mountains on the northern edge of the Sevier Desert (SM in fig. 1) where thick glacial deposits are preserved (Cohenour, 1959). Subsequent mapping in the Sheeprock Mountains demonstrated that Cohenour had misinterpreted the structure and in places confused Caddy Canyon and Mutual quartzites (Christie-Blick, 1982, 1983). Indeed, instead of passing laterally into siltstone in the manner in which Crittenden and others (1971) envisaged (their fig. 7), the Caddy Canyon Quartzite of the Sheeprock Mountains is at least 2,000 m thick (Christie-Blick, 1982, 1997). In the same range, however, the remapped Caddy Canyon Quartzite does pass locally into interstratified sandstone and siltstone, and in one section it includes a layer of stromatolitic limestone.

The simplest interpretation of these observations is that the entire predominantly quartzitic sub-Inkom succession in the Canyon Mountains is equivalent to the Caddy Canyon Quartzite (Christie-Blick, 1982; Levy and Christie-Blick, 1991). There is no basis for referring any of the Canyon Mountains stratigraphy to the Pocatello Formation or Blackrock Canyon Limestone. First, the lateral equivalent of the upper member of the Pocatello Formation is both thick in the Sheeprock Mountains (<600 m) and composed predominantly of siltstone, not quartzite. Second, given a stratigraphic context more similar to that of northern Utah than southeastern Idaho, it makes more sense to refer the post-glacial siltstone to the Kelley Canyon Formation.

Similar considerations apply to several other ranges to the west and south of the Sevier Desert, where rocks composed predominantly of quartzite and siltstone are preserved beneath strata correlated with confidence with the Inkom and Mutual formations: the Drum Mountains (fig. 2), and the Dugway Range, San Francisco Mountains, Beaver Lake Mountains and Wah Wah Range (DR, SF, BL and WW in fig. 1;

Staatz and Carr, 1964; Woodward, 1968, 1972; Lemmon and Morris, 1979, 1984; Christie-Blick, 1982; Abbott and others, 1983; Christie-Blick and Levy, 1989; Levy and Christie-Blick, 1991; Hintze and others, 1984; Levy and others, 1994; Hintze and Davis, 2002b, 2002c, 2003; Friedrich and Bartley, 2003). In each case, the preserved section does not extend downward to the glacial interval or to thick siltstone comparable to the Kelley Canyon Formation of the Sheeprock Mountains. Rocks mapped as Blackrock Canyon Limestone in the northern San Francisco Mountains (Lemmon and Morris, 1984) and southern Wah Wah Range (Abbott and others, 1983) consist mainly of non-carbonate deposits with interbeds of limestone, dolomite and marble. The distinctive lithology and structures of the Papoose Creek Formation are not represented, in spite of the use of this lithostratigraphic term by Abbott and others (1983) for 200 m of sandstone and quartzite in the Wah Wah Range. Six hundred meters of quartzite and minor argillite mapped as Pocatello Formation in the same range bears no resemblance to the upper member of the Pocatello Formation in the vicinity of Pocatello, Idaho.

Given that these stratigraphic issues were largely resolved more than twenty years ago (Blick, ms, 1979; Christie-Blick, 1982), persistent misuse of the term “Pocatello Formation” in the Sevier Desert literature is puzzling. Responsibility appears to rest primarily with the authors of three Brigham Young University Masters theses completed in the early 1980s on the geology of the Canyon Mountains (Higgins, 1982; Millard, 1983; Holladay, 1984). Subsequent workers, who focused largely on structural geological issues, accepted the Canyon Mountains designations without concern for the regional stratigraphy (for example, DeCelles and others, 1995; Lawton and others, 1997; Mitra and Sussman, 1997; Hintze and Davis, 2003; DeCelles and Coogan, 2006; Coogan and DeCelles, 2007; compare Wills and Anders, 1999; Wills and others, 2005). However, Hintze and Kowallis (2009, p. 211) reverted to placing the names of sub-Inkom units in the Wah Wah Range and San Francisco–Beaver Lake Mountains in quotation marks to express uncertainty in the correlation.

Neoproterozoic strata that consist predominantly of quartzite and underlie siltstones of the Inkom Formation are referred here, in their entirety, to the Caddy Canyon Quartzite. More relevant than terminology to the interpretation of the Cominco well is the observation that south and west of the Sheeprock Mountains, the Caddy Canyon Quartzite passes laterally into a more heterolithic succession of quartzite, sandstone and siltstone, with minor carbonate. Although stratigraphic details vary from one range to another, this part of the Neoproterozoic succession is in most places finer grained overall than the Prospect Mountain Quartzite, with which it might be confused in the Cominco well.

STRATIGRAPHIC AND STRUCTURAL INTERPRETATION OF THE COMINCO AMERICAN FEDERAL NO. 2 WELL

The Cominco American Federal No. 2 well was drilled in 1980 to a total depth (TD) of 4,021 m (13,193 ft.). It is generally agreed that much of the stratigraphy encountered in the well is of Neoproterozoic to Paleozoic age (fig. 4). However, interpretations differ with respect to stratigraphic details and the placement of major thrust faults, and hence the structural interpretation of a key seismic reflection profile (PC-3; figs. 2 and 5) that connects the well to the pre-Tertiary geology of the Sevier Desert basin. Profile PC-3 was originally published by McDonald (1976) and Mitchell and McDonald (1987), and subsequently reproduced and reinterpreted by Wills and others (2005, their fig. 11) and, in a reprocessed version, by Coogan and DeCelles (2007, their fig.1).

All workers agree on the presence of a thrust fault at a depth of 2,549 to 2,557 m (8,364-8,389 ft.). Following Mitchell and McDonald (1987), Wills and others (2005) interpreted the contact at 2,551 m (8,370 ft.) as the Pavant thrust (PVT-1 in fig. 4),

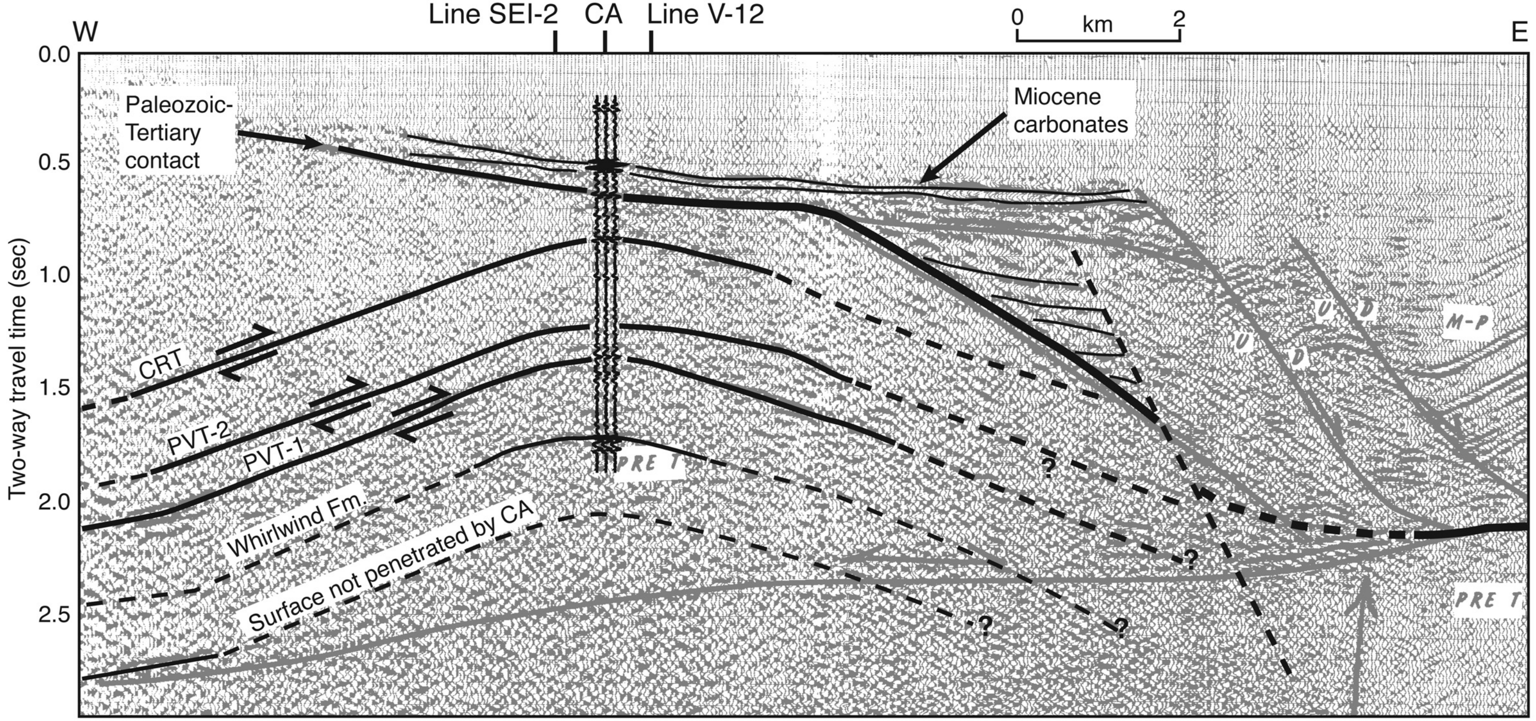


Fig. 5. Western part of connected seismic profiles PC-2 and PC-3 (referred to as PC-3 in this text; modified from McDonald, 1976; see fig. 2 for location). Gray lines represent the interpretation of McDonald; black lines are the interpretation of Wills and others (2005). Line PC-3 crosses the Cominco American Federal No. 2 well (CA). The synthetic seismogram for the Cominco well is discussed in Wills and others (2005).

placing the upper part of the Neoproterozoic–lower Cambrian Prospect Mountain Quartzite atop upper Cambrian to lower Ordovician Notch Peak Formation (the latter based upon a 1980 report of John E. Welsh cited in Hintze and Davis, 2003, p. 268). As reported in Mitchell and McDonald (1987) and Wills and others (2005), a second strand of the same thrust fault was interpreted at a depth of 2,295 m (7,530 ft.) between the Prospect Mountain Quartzite (above) and lower to middle Cambrian Pioche Formation (below; PVT-2 in fig. 4). In his 1980 report, Welsh interpreted a single strand of the fault at 2,549 m (8,364 ft.) between the "Pocatello Formation" (above; Caddy Canyon Quartzite in this paper) and the Notch Peak Formation (below), and took the fault to be the Canyon Range thrust on that basis (CRT in fig. 4). DeCelles and Coogan (2006) and Coogan and DeCelles (2007) adopted the Welsh interpretation, but they placed the fault at a slightly deeper level (2,557 m; 8,389 ft.).

Mitchell and McDonald (1987) and Wills and others (2005) placed the Canyon Range thrust at a depth of 1,222 m (4,010 ft.), 1,335 m (4,379 ft.) shallower than the level picked by Welsh, Coogan and DeCelles. According to Mitchell and McDonald (1987), the higher fault juxtaposes Prospect Mountain Quartzite above undifferentiated Cambrian, Pioche Formation and Prospect Mountain Quartzite. In the interpretation of Wills and others (2005), upper plate rocks are uppermost Caddy Canyon Quartzite (128 m; 420 ft.) overlain by Inkom Formation (140 m; 460 ft.) and lowermost Mutual Formation (189 m; 620 ft.); lower plate rocks consist of undifferentiated Cambrian siltstone and carbonate rocks (46 m; 150 ft.) passing down into Pioche Formation (107 m; 350 ft.) and Prospect Mountain Quartzite (920 m; 3,018 ft.). In the interpretation of J. E. Welsh (cited in Hintze and Davis, 2003, p. 268), the Caddy Canyon Quartzite passes downward with stratigraphic continuity through 34 m (110 ft.) of "Blackrock Canyon Limestone" into 1,283 m (4,210 ft.) of "Pocatello Formation" (also Caddy Canyon Quartzite in this paper).

Given that agreement exists therefore between Mitchell and McDonald (1987) and Wills and others (2005) on the level of the Canyon Range thrust, between Welsh (Hintze and Davis, 2003) and Wills and others (2005) on stratigraphic interpretation above a depth of 1,222 m (4,010 ft.; with a little shading on the depths to formation boundaries), and among all workers on the geology below a depth of 2,549 to 2,557 m (8,364-8,389 ft.), differences of opinion on structural interpretation hinge on the interval from 1,222 to 2,549 m (4,010-8,364 ft.). Here we provide downhole log evidence in support of the lower to middle Cambrian interpretation for the upper part of that interval and for the existence of a marked change in stratal dip at 1,222 m (4,010 ft.) consistent with the presence of a fault.

Stratigraphy Below 2,549 m (8,364 ft.) in the Cominco Well

Each of the interpretations summarized in figure 4 calls for an uninterrupted Cambrian section from the bottom of the Cominco well at a depth of 4,021 m (13,193 ft.) to the faulted top of the Notch Peak Formation at 2,549 to 2,557 m (8,364-8,389 ft.). The section begins at the base with 53 m (173 ft.) of Prospect Mountain Quartzite. These rocks are overlain by 131 m (430 ft.) of phyllitic quartzite assigned to the Pioche Formation, by 27 m (90 ft.) of Howell Limestone, and by 43 m (140 ft.) of phyllitic shale interpreted as Chisholm Formation—the lower part of which is included in the right panels of figures 6 and 7. The Chisholm is overlain in turn by a succession of interstratified limestones and siltstones representing the remainder of the Cambrian section of the Cricket Mountains through the Notch Peak Formation. All thicknesses are from J. E. Welsh (in Hintze and Davis, 2003), with boundaries corresponding with excursions or changes in the character of acoustic and gamma ray logs, and supported by the examination of cuttings (available at the Utah Division of Oil, Gas and Mining). The interpretation of Mitchell and McDonald (1987) is essentially the same, with only

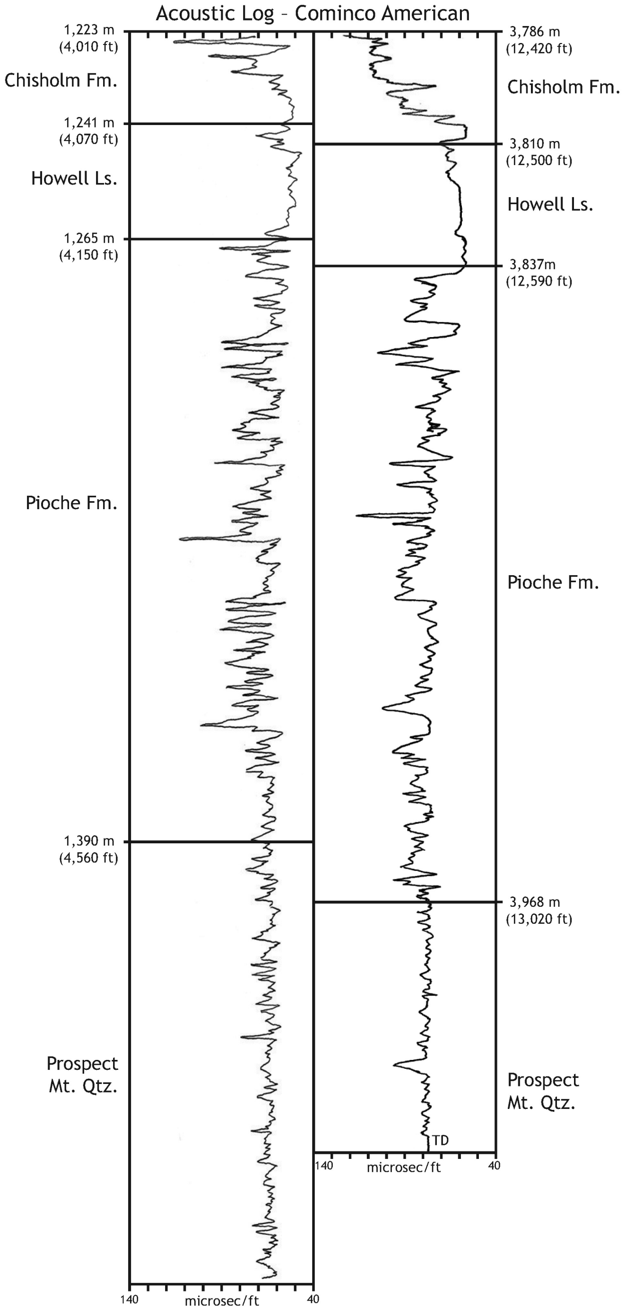


Fig. 6. Sections of the acoustic log data from the Cominco American Federal No. 2 well, hand copied from the original log in order to separate out acoustic data from overlapping data sets. We interpret the left and right panels to represent the same units at different depths in the well (see text for discussion). Depths in the right panel are from John E. Welsh (cited in Hintze and Davis, 2003, p. 268). Depths in the left panel are correlated with Welsh's picks on the basis of these and gamma ray data shown in figure 7. Depths therefore vary slightly from those of Wills and others (2005) shown in figure 4. The data are publicly available from the Utah Division of Oil, Gas and Mining.

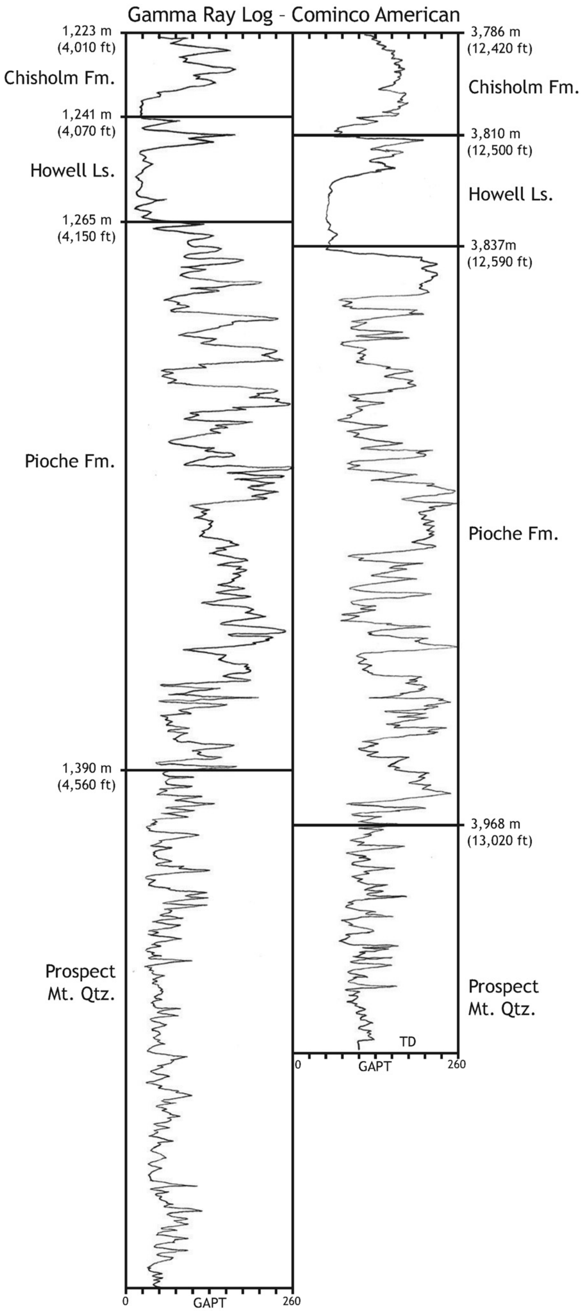


Fig. 7. Sections of the gamma ray log data from the Cominco American Federal No. 2 well, hand copied from the original log in order to separate out gamma ray data from overlapping data sets. We interpret the left and right panels as representing the same units at different depths in the well. See text for discussion and the caption to figure 6.

minor differences of opinion on the placement of lithostratigraphic contacts. Each Cambrian unit in either scheme is thinner than its outcrop equivalent at a higher structural level in the Sevier orogen (Hintze and Davis, 2003; Hintze and Kowallis, 2009).

Repeated Cambrian Stratigraphy in the Cominco Well

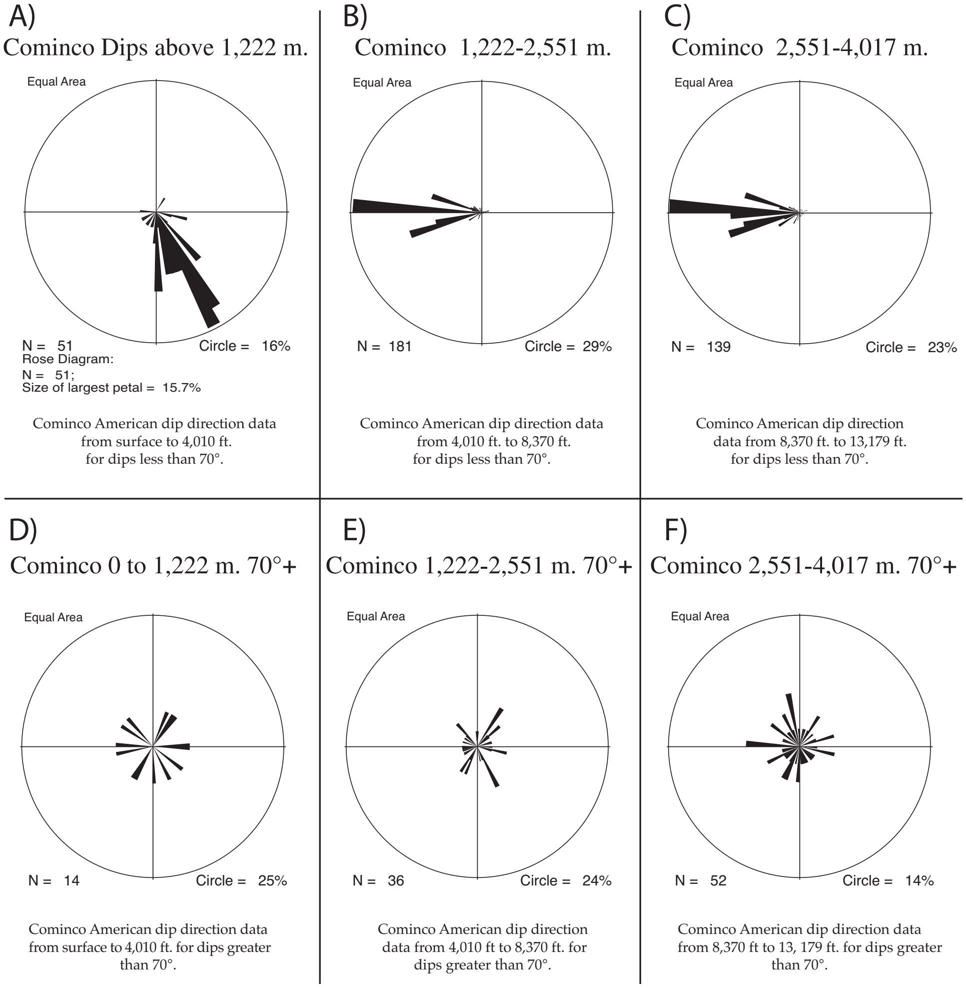
A comparison of acoustic and gamma ray logs for the lower to middle Cambrian rocks at the bottom of the Cominco well with the same logs for the section below 1,222 m (4,010 ft.) suggests that they correspond with the same stratigraphic interval (figs. 6 and 7). The shaly section between a depth of 1,222 m (4,010 ft.) and 1,241 m (4,070 ft.) is Chisholm Formation, not the basal part of the Caddy Canyon Quartzite. The interval from 1,241 m (4,070 ft.) to 1,274 m (4,180 ft.) corresponds with the Howell Limestone and upper part of the Pioche Formation, not with the "Blackrock Canyon Limestone" of J. E. Welsh (in Hintze and Davis, 2003, p. 268). And strata below 1,274 m (4,180 ft.) belong to the remainder of the Pioche Formation and underlying Prospect Mountain Quartzite, not to the "Pocatello Formation" of J. E. Welsh (in Hintze and Davis, 2003; Caddy Canyon Quartzite in this paper). The key to our interpretation of the logs is not merely the character of excursions, particularly at the stratigraphic level of the Howell and Chisholm formations. It is that the 905-m-thick section (2,970 ft.) between depths of 1,390 m (4,560 ft.) and 2,295 m (7,530 ft.) consists primarily of quartzite—a regional-scale characteristic of the Prospect Mountain Quartzite and lateral equivalents, and not of the Caddy Canyon Quartzite (or the misinterpreted "Pocatello Formation") in western and southern Utah.

Planke (ms, 1987, p. 118; AMSTRAT sample log) reported "traces of fossils" in the interval interpreted here as Howell Limestone. We examined several hundred grains from cuttings in thin section, and found no definitive evidence of fossils. However, fossil fragments would have been difficult to identify in the available material. Ooids are abundant, as they are in outcrop at the level of the Howell Limestone in the adjacent Cricket Mountains (Hintze, 1984).

Dip Meter Measurements

The interpretation of thrust faults at depths of 1,222 m (4,010 ft.), 2,295 m (7,530 ft.), and 2,551 m (8,370 ft.) is supported by a compilation of pre-Tertiary dip meter data for the Cominco well (figs. 8, 9 and 10). In Figure 8, dip data are binned into six categories according to whether dips are greater than or less than 70°, and for three stratigraphic intervals: above 1,222 m (4,010 ft.); between 1,222 m and 2,551 m (8,370 ft.); and below 2,551 m. Dips $<70°$ above and below the 1,222 m level have markedly different orientations ($20.8° \pm 12.3°$ with an azimuth of 152° above that depth, and $17.3° \pm 8.3°$ with an azimuth of 270° below it). There is, however, a discrete zone directly above and below the 1,222 m (4,010 ft.) level at which dip orientations become chaotic. The direction of dip is especially variable for 136 m (445 ft.) above the 1,222 m (4,010 ft.) level, and for 180 m (590 ft.) below it, with a thinner interval of 61 m (200 ft.) close to and above the 1,222 m (4,010 ft.) level for which the majority of dips are $>70°$ (fig. 9). We interpret this pattern to be consistent with bedding disruption in a fault damage zone.

A Bengston (1981) plot of dip meter data confirms a marked change in azimuth at a depth of 1,222 m (4,010 ft.) and reveals an increase in the scatter of dip determinations between 2,295 m (7,530 ft.) and 2,551 m (8,370 ft.)—the levels at which Wills and others (2005) and Mitchell and McDonald (1987) located the Canyon Range thrust and two strands of the Pavant thrust, respectively (CRT, PVT-2 and PVT-1 in fig. 10). Above 2,295 m (7,530 ft.) and below 2,551 m (8,370 ft.), dips are mostly $<30°$. The marked change in azimuth at 1,222 m (4,010 ft.) and the general consistency of orientations at greater depths are consistent with the fault-bend folding that is commonly associated with ramp-flat thrust geometry (Boyer and Elliott, 1982). Discordance corresponds with a ramp in one or both plates, and concordance with flats.



Cominco American dip direction data from surface to 4,010 ft. for dips less than 70°.

Cominco American dip direction data from 4,010 ft. to 8,370 ft. for dips less than 70°.

Cominco American dip direction data from 8,370 ft. to 13,179 ft. for dips less than 70°.

Cominco American dip direction data from surface to 4,010 ft. for dips greater than 70°.

Cominco American dip direction data from 4,010 ft to 8,370 ft. for dips greater than 70°.

Cominco American dip direction data from 8,370 ft to 13, 179 ft. for dips greater than 70°.

Fig. 8. Rose diagrams showing dip direction from the dip log for the Cominco American Federal No. 2 well. Upper panel: Dip directions for dips <70°. Lower panel: Dip directions for dips >70°. Depth ranges: (A) and (D) from the surface to 1,222 m (4,010 ft.); (B) and (E) from 1,222 m to 2,551 m (4,010 ft. to 8,370 ft.); (C) and (F) from 2,551 m to 4,017 m (8,370 ft. to 13, 179 ft.). The data are publicly available from the Utah Division of Oil, Gas and Mining.

Azimuths for features dipping more steeply than 70° are scattered at all structural and stratigraphic levels (lower panel of fig. 8; plus symbols in fig. 10). Such features are thought to represent near-vertical fractures or veins or artifacts of the dip meter data processing, which depends on chosen search angles and correlation intervals (Luthi, 2000). We limit our interpretation of the dip meter data to dips less than 70°—the ones that are most likely to correspond to depositional features.

Canyon Range Thrust at 1,222 m (4,010 ft.)

Consistent with our earlier paper (Wills and others, 2005), the discontinuity recognized at a depth of 1,222 m (4,010 ft.) in the Cominco well on the basis of stratigraphic separation and dip meter evidence is interpreted as the Canyon Range thrust (CRT in figs. 5 and 10). As noted above, the correlation of thrust faults between

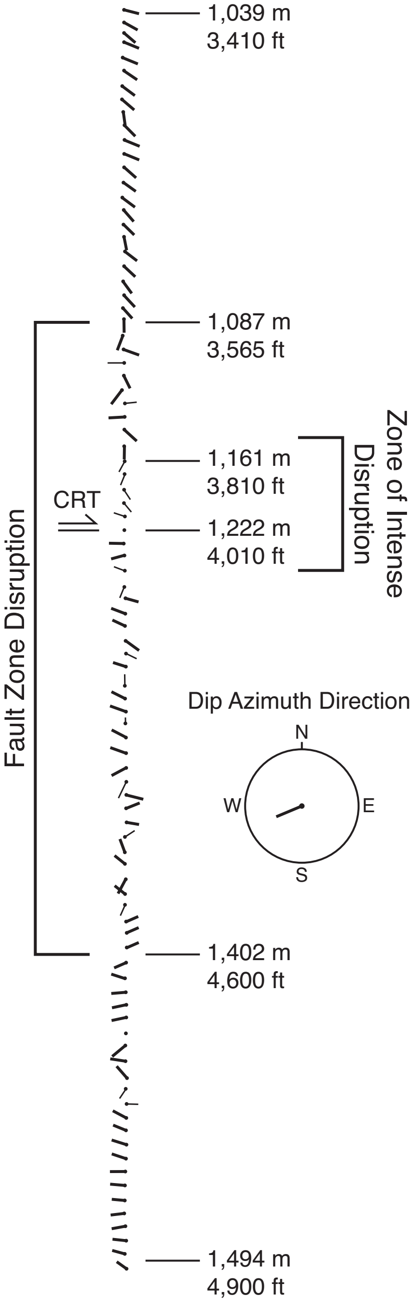


Fig. 9. Dip direction data from the Cominco American Federal No. 2 well, between depths of 1,039 m (3,410 ft.) and 1,494 m (4,900 ft.). Thin lines correspond with dips >70°. CRT represents our inferred depth of the Canyon Range thrust in the well.

isolated exposures or wells is subject to uncertainty as faults propagate through laterally varying stratigraphy, intersect or are otherwise subject to the transfer of slip

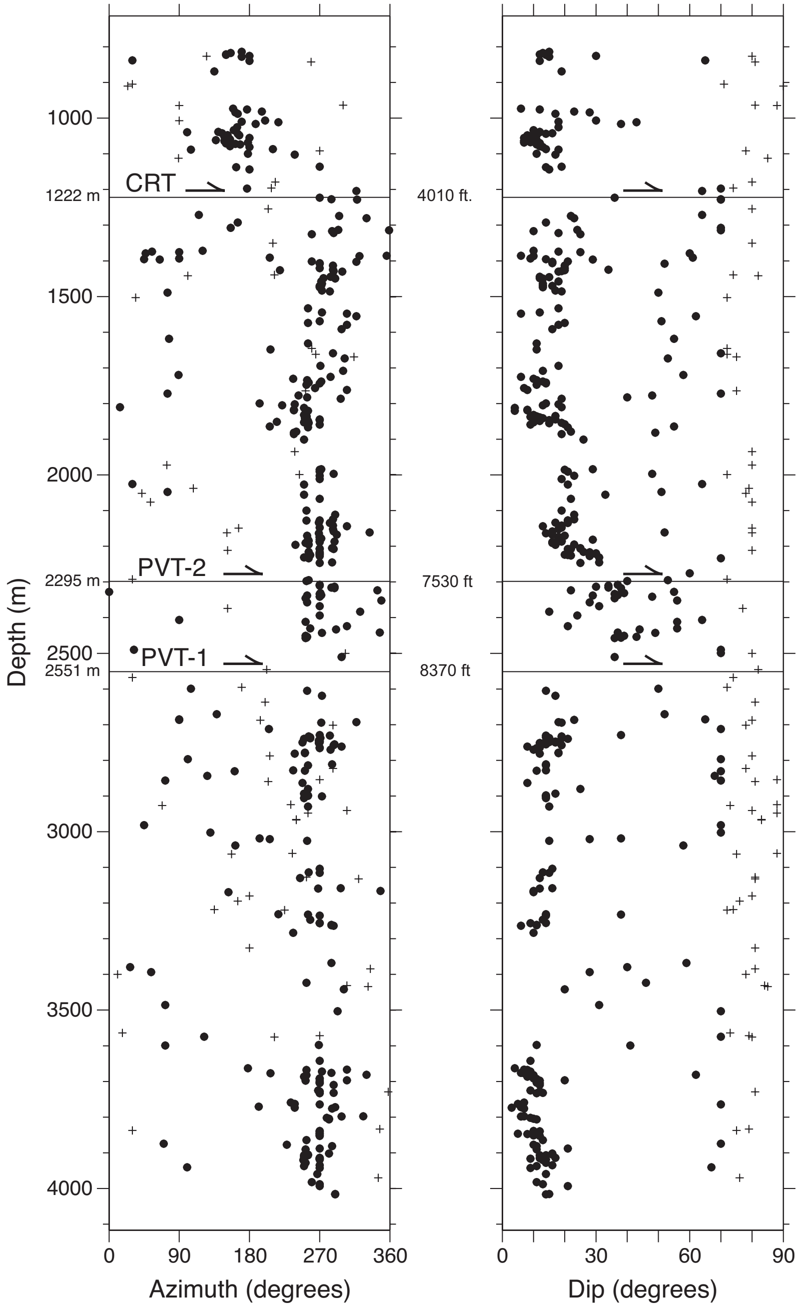


Fig. 10. Dipmeter data from the Cominco American Federal No. 2 well. CRT is the inferred position of the Canyon Range thrust in the well. PVT-1 is the inferred position in the well of the main Pavant thrust splay, and PVT-2 is thought also to be a splay of the Pavant thrust. Small plus symbols correspond with dips >70°.

from one structure to another. More than one fault in a single profile may juxtapose the same stratigraphic units. In the Basin and Range Province, correlation is complicated also by late Cenozoic crustal extension. The Canyon Range thrust and its correlatives are nonetheless distinctive in each transect of the Sevier orogen in emplacing thick Neoproterozoic strata atop rocks of Cambrian to Mississippian age (Christie-Blick, 1983; Morris, 1983; Villien and Kligfield, 1986; Almendinger, 1992; DeCelles and others, 1995; Lawton and others, 1997; Mitra and Sussman, 1997; Friedrich and Bartley, 2003; Hintze and Davis, 2003; DeCelles and Coogan, 2006; Kwon and Mitra, 2006). The most parsimonious interpretation therefore of a fault contact between the Neoproterozoic Caddy Canyon Quartzite and the middle Cambrian Howell Limestone in the Cominco well is that it is the Canyon Range thrust.

Pavant Thrust at 2,551 m (8,370 ft.)

The fault intersected at a depth of 2,551 m (8,370 ft.) is interpreted as a strand of the Pavant thrust on the basis of stratigraphic evidence and its structural position beneath the Canyon Range thrust (PVT-1 in figs. 5 and 10). A second strand of the Pavant thrust (PVT-2) is placed at 2,295 m (7,530 ft.). No significant discordance is observed at either level, consistent with the existence at this location of thrust flats in the footwall and hanging wall of both faults. Stratigraphic arguments point to the existence of an additional strand of the thrust below the well.

The fault at 2,551 m (8,370 ft.) is not the Canyon Range thrust, the interpretation of J. E. Welsh (in Hintze and Davis, 2003), DeCelles and Coogan (2006) and Coogan and DeCelles (2007). First, the hanging-wall rocks are inappropriate (Prospect Mountain Quartzite rather than a deeper level within the Neoproterozoic). One of us (NC-B) corresponded with Welsh when the well was drilled in 1980. Although the Neoproterozoic stratigraphy of west-central Utah had been revised by that time (Blick, ms, 1979), the revision had not yet been published (Christie-Blick, 1982). Welsh's misinterpretation of the Prospect Mountain Quartzite as "Pocatello Formation" should be understood in that context. Second, in the Cominco well the thicknesses of Pioche Formation and Howell Limestone are approximately the same in the disputed section above 2,551 m (125 m, 410 ft.; and 24 m, 80 ft. respectively) as they are below it (131 m, 430 ft.; and 27 m, 90 ft., respectively; figs. 6 and 7; Hintze and Davis, 2003, p. 268). This is consistent with modest displacement along both strands, and not with the presence of a structure interpreted to involve many tens of kilometers of displacement (as much as 117 km according to DeCelles and Coogan, 2006). Third, and perhaps most important, thicknesses of these same units in outcrop in the adjacent Cricket Mountains, in what all workers agree is the upper plate of the Canyon Range thrust, are a factor of two greater (213-244 m, 700-800 ft.; and 91-125 m, 300-410 ft., respectively; Hintze and Kowallis, 2009).

We nonetheless agree with Coogan and DeCelles (2007, p. 509) in inferring the presence of a strand Pavant thrust below the bottom of the Cominco well, even if it cannot be resolved in available seismic reflection data (fig. 5). The absence of the stratigraphic contrast that might be expected across a major thrust fault, between rocks above and below the 2,551 m (8,370 ft.) level in the Cominco well, has already been noted. Moreover, unless a deeper strand is present, restoration of the 47 km of displacement on the Sevier Desert detachment envisaged by DeCelles and Coogan (2006) would result in a mismatch between the Cambrian to lowermost Ordovician stratigraphy in the lower part of the Cominco well and coeval rocks in the lower plate of the Pavant thrust in the Pavant Range. The latter rocks are both thinner, and more significantly, of different facies and lithostratigraphy (see Hintze and Davis, 2003). In the Cominco well, the interval from the Pioche Formation to the incomplete Notch Peak Formation is 1,417 m (4,650 ft.) thick. The comparable interval in the Pavant Range, from the Ophir Formation to the Ajax Dolomite is 1,323 m (4,340 ft.) thick. The middle Cambrian interval is appreciably shalier in the Cominco well.

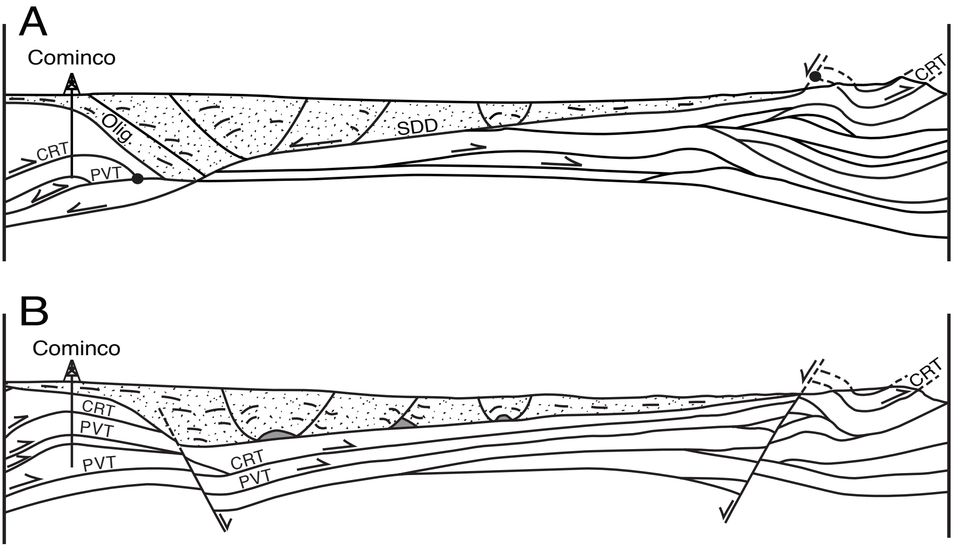


Fig. 11. Contrasting schematic interpretations of the structure beneath the Sevier Desert. A) The model of DeCelles and Coogan (2006), modified from Von Tish and others (1985). Black dots represent piercing points related to the inferred cut-off of the Canyon Range thrust by the Sevier Desert detachment. The volume labeled "Olig." is inferred by Von Tish and others (1985) to represent Oligocene sedimentary rocks tilted by displacement on the detachment. B) A model modified from the work of Hintze and Davis (2003) and Wills and others (2005). Extension is accommodated entirely by high-angle normal faults. The area under the Cominco well represents fault-bend folding associated with a ramp in the Pavant system. The basal décollement of the Pavant thrust was not encountered by the Cominco well. The base of the Cenozoic basin fill (stipple with ticks representing bedding orientation) is a fault in A and an unconformity in B. In both panels, CRT is the Canyon Range thrust, and PVT is the Pavant thrust. The gray scale in B corresponds with thick lacustrine evaporite deposits.

Regional Implications

The significance of the antiformal structure imaged in Line PC-3 (fig. 5) and its down-plunge equivalent in COCORP Line 1 (fig. 3) is that it has long been regarded as the structural counterpart for the missing western limb of the anticline-syncline pair that forms the core of the Canyon Mountains on the east side of the Sevier Desert basin (DeCelles and others, 1995; Coogan and DeCelles, 1996, 2007; Mitra and Sussman, 1997; DeCelles and Coogan, 2006). According to these authors, rocks now found within the Cricket Mountains block on the west side of the Sevier Desert, including an offset Canyon Range thrust, were transported westward along a re-activated Pavant thrust or a new detachment close to that fault (fig. 11A).

This reconstruction is inconsistent with our interpretation of the stratigraphy and structure of the Cominco well, with a comprehensive interpretation of seismic reflection data published by Wills and others (2005), and with the same authors' interpretation of the Chevron Black Rock well 12 km to the west (fig. 2). The Canyon Range thrust parallels or approximately parallels the two upper strands of the Pavant thrust in three dimensions beneath the western side of the southern Sevier Desert basin (line SEI-2 in fig. 2; and fig. 19 of Wills and others, 2005). The Canyon Range thrust is nowhere observed to terminate against a re-activated Pavant thrust in the manner assumed by DeCelles and Coogan (2006). Instead, all of the mapped structures rise southward from the Cominco well and terminate laterally against the unconformity between Paleozoic and Tertiary strata (see seismic profiles in fig. 3 of Planke and Smith, 1991; and fig. 8 of Wills and others, 2005).

Coogan and DeCelles (2007, p. 510) concur with this geometry at and above the level of the Pavant thrust (their Canyon Range thrust) in the southern Sevier Desert basin, but go on to argue that "these observations do not conflict with our cutoff constraints adjacent to and north of the Cominco well." The latter statement is problematic. The fault that aligns approximately with the Sevier Desert detachment on the west side of the Sevier Desert in COCORP Line 1 is a strand of the Pavant thrust (their Canyon Range thrust), based on its upper plate stratigraphy, and as it has been traced in seismic data from the Cominco well (Wills and others, 2005). The continuity of that reflection to depth in the COCORP profile was among key observations for interpreting an extensional detachment. No such reflection exists in the southern part of the basin where mapped strands of the Pavant thrust clearly misalign with any reasonable interpretation of the detachment to the east (Wills and others, 2005). Moreover, if what we regard as the Pavant thrust in the Cominco well is instead the Canyon Range thrust, as Coogan and DeCelles (2007) insist, it cannot terminate against itself in COCORP Line 1.

An alternative interpretation of fault geometry is presented in figure 11B as a hypothesis to be tested. The Pavant thrust is envisaged to have ramped up to the level of the Canyon Range thrust to the west of the Cominco well, folding and locking the latter fault to the west, but permitting continued slip as part of the Pavant system to the east. Lateral propagation of the basal Pavant decollement beneath what is now the Canyon Range resulted in folding and locking of the Canyon Range thrust at that location (Mitra and Sussman, 1997; DeCelles and Coogan, 2006). The main difference between this interpretation and that shown in figure 11A is that both the Canyon Range thrust and the basal decollement of the Pavant thrust system continue beneath the Sevier Desert basin. They are not offset by a detachment fault.

Reconstruction of the Sevier Desert detachment without the constraint provided by thrust correlation reduces the estimate for extension across the basin to ~25 to 39 km, depending on the seismic profile used, the location of the structural pinchout of pre-Tertiary rocks above the detachment, the location of the breakaway, and the assumed direction of extension. In the event that there is no detachment (fig. 11B), based on data summarized in Stein and others (1988), Wills and Anders (1999) and Wills and others (2005) we estimate 10 ± 2 km of extension across the Sevier Desert basin on high-angle normal faults alone.

SUMMARY

Re-examination of acoustic, gamma ray and dip meter logs from the Cominco American Federal No. 2 well on the west side of the Sevier Desert basin reinforces an earlier interpretation of Neoproterozoic to Cambrian stratigraphy, and the placement of thrust faults in that well (Wills and others, 2005). The Canyon Range thrust is inferred to intersect the well at a depth of 1,222 m (4,010 ft.). A lower fault, at 2,551 m (8,370 ft.), is interpreted as a strand of the Pavant thrust, and not the Canyon Range thrust (compare, DeCelles and Coogan, 2006; Coogan and DeCelles, 2007). We agree that a third strand of the Pavant thrust projects below the bottom of the well (4,021 m; 13,193 ft.).

Our interpretation hinges on the correlation of the Chisholm Formation and Howell Limestone between 1,222 m (4,010 ft.) and 1,265 m (4,150 ft.) with the same Cambrian interval lower in the well, and on recognition of the predominantly quartzitic rocks between 1,390 m (4,560 ft.) and 2,295 m (7,530 ft.) as Prospect Mountain Quartzite. The interpretation of the latter as "Pocatello Formation" (Caddy Canyon Quartzite in this paper) is inconsistent with the more varied lithology of the Caddy Canyon Quartzite in west-central and southern Utah. The existence of a continuous stratigraphic section across a depth of 1,222 m (4,010 ft.) in the Cominco well is inconsistent with dip meter evidence for deformation over an interval of more than 300 m (1,000 ft.) encompassing this horizon.

The interpretation of a strand of the Pavant thrust at a depth of 2,551 m (8,370 ft.) is based upon stratigraphic separation (Prospect Mountain Quartzite atop upper Cambrian to lowermost Ordovician Notch Peak Formation), and structural position beneath the Canyon Range thrust. The fault is not the Canyon Range thrust because thicknesses of the lower to middle Cambrian Pioche Formation and Howell Limestone are approximately the same above this level as they are below it, and about half the thickness of the same interval in outcrop in the nearby Cricket Mountains in what all workers agree is the upper plate of the Canyon Range thrust. A comparison of stratigraphy in the lower part of the Cominco well with the lower plate of the Pavant thrust in the Pavant Range and Canyon Mountains to the east is consistent with the presence of one or more additional strands of the Pavant thrust below the well. The antiformal geometry of all thrust faults at the Cominco well is hypothesized to relate to fault-bend folding at a ramp in the Pavant system (fig. 11B).

If our structural interpretation of the Cominco well is correct, the Canyon Range thrust does not terminate against a re-activated Pavant thrust in the manner assumed by DeCelles and Coogan (2006). The inferred geometry is an expectation of a model, not an independent constraint on offset along the Sevier Desert detachment or evidence for the existence of the detachment. Adjustments are needed therefore to the Mesozoic structure in the published regional cross-section on the west side of the Sevier Desert (fig. 3 of DeCelles and Coogan, 2006). The significance of the seismic discontinuity interpreted as the Sevier Desert detachment and the implied magnitude of extension across the Sevier Desert basin await further evaluation through the acquisition of new seismic reflection data and drilling under the auspices of the International Continental Scientific Drilling Project (Christie-Blick and others, 2009).

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