INTERIM GEOLOGIC MAP OF THE PINTURA QUADRANGLE, WASHINGTON COUNTY, UTAH

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NOTES ON THE GEOLOGY OF THE PINTURA 7-1/2 MINUTE QUADRANGLE, WASHINGTON COUNTY, SOUTHWESTERN UTAH

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INTRODUCTION

The Pintura quadrangle is located in Washington County, southwestern Utah, about 20 miles (32 km) northeast of St. George and 30 miles (48 km) southwest of Cedar City (figures 1a and 1b). Although no large towns are presently located within the quadrangle, it is bisected by Interstate 15 and has recently begun to be affected by the nearly 200 percent population increase experienced by Washington County between 1980 and 1998 (Utah Governor's Office of Planning and Budget, 2000). The climate in the Pintura quadrangle is arid; mean annual precipitation varies from less than 12 inches (30.5 cm) near Anderson Junction to about 20 inches (51 cm) in the eastern foothills of the Pine Valley Mountains (Cordova, 1978). Several perennial streams flow through the quadrangle, including Ash Creek, Wet Sandy, and Leeds Creek, whose sources are in the eastern Pine Valley Mountains, and LaVerkin Creek, whose source is east of the quadrangle (figure 2a).

This pamphlet describes only selected aspects of the geology of the Pintura quadrangle, including tectonic structures in the context of the regional evolution of southwestern Utah, field relations, ages, and geochemistry of Quaternary basalt (map unit Qbp), and some natural resources. More comprehensive descriptions of the geology of the Pintura quadrangle, and the stratigraphic units exposed therein, can be found in Dobbin (1939), Gregory and Williams (1947), Cook (1957, 1960), Kurie (1966), Rowley and others (1979), Stewart and others (1997), Biek (1997, 1998), Hurlow (1998), and Pearthree and others (1998).

TECTONIC SETTING

The Pintura quadrangle is in the transition zone between the Basin and Range and Colorado Plateau geologic provinces (figure 1b; Best and Hamblin, 1978; Scott and Swadley, 1995; Maldonado and Nealey, 1997). The Basin and Range Province is characterized by superposition of Cenozoic volcanism and normal faulting on Mesozoic contractional structures. The Mesozoic structures are part of the Cordilleran thrust belt, which deformed Paleozoic and Mesozoic carbonate and siliciclastic strata of the Cordilleran miogeocline (Armstrong, 1968; Royse and others, 1975; Allmendinger, 1992; Willis, 1999). The Colorado Plateau is underlain by strata deposited east of the Cordilleran hinge line, and is typically structurally simpler than the Basin and Range Province. The transition zone contains structural and stratigraphic characteristics of both provinces.

Topographic uplift in eastern Nevada and western Utah, driven by thrust faulting and folding in the Cordilleran thrust belt, led to deposition of the fluvial Iron Springs Formation (map unit Kis) in southwestern Utah during Late Cretaceous time (Fillmore, 1991; Goldstrand, 1994). Contractional deformation migrated eastward into southwestern Utah during latest Cretaceous to early Paleocene time, forming: (1) in the Pintura quadrangle, the Pintura and Kanarra anticlines, an intervening syncline (not exposed), and thrust faults that cut the eastern limb of the Kanarra anticline (cross section A-A'; figure 2b; Gregory and Williams, 1947; Cary, 1963; Kurie, 1966); (2) the Virgin anticline southwest of the Pintura quadrangle (figure 1a; Dobbin, 1939); and (3) several thrust faults and folds in the Cedar City area north and northeast of the quadrangle (figure 1a; Threet, 1963; van Kooten, 1988). The late Campanian-early Paleocene Canaan Peak Formation (map unit TKcp) was deposited during the waning stages of contractional deformation, and the Paleocene-Eocene Claron Formation (map units Tcl and Tcu) was deposited after deformation had ceased (Taylor, 1993; Goldstrand, 1994). In the Pintura quadrangle, the Canaan Peak Formation comprises fluvial conglomerate deposited on the hinge zone of the Pintura anticline; this formation was only recently identified in the eastern Pine Valley Mountains (R.E. Anderson *in* Goldstrand, 1992), and is more extensively exposed in south-central Utah (Bowers, 1972; Goldstrand, 1994).

GEOLOGIC EVOLUTION AND STRUCTURES

The north-trending Pintura anticline is best exposed in the north-central part of the Pintura quadrangle, where it plunges north and is cored by the Navajo Sandstone (map unit Jn) at present exposure levels (figure 2b; Carey, 1963). Where the Canaan Peak Formation unconformably overlies the Navajo Sandstone on the hinge zone of the Pintura fold, over 4,000 feet (1,220 m) of stratigraphic section, including all of the Late Cretaceous Iron Springs Formation, were removed by erosion. The Pintura anticline formed between early and late Campanian time (about 84 to 72 Ma), the youngest known age of the Iron Springs Formation and the oldest known age of the Canaan Peak Formation, respectively (Goldstrand, 1992, 1994), but both dates are poorly constrained and are derived from outside the quadrangle. The Paleocene-Eocene Claron Formation was deposited on the inactive, erosionally beveled Pintura fold, as demonstrated in the northern part of the Pintura quadrangle and the adjacent Signal Peak quadrangle where, from east to west, it unconformably overlies the Navajo Sandstone, Canaan Peak Formation, Carmel Formation (map units Jcpr, Jccc, and Jcco), and Iron Springs Formation on the west limb of the anticline.

The Kanarra anticline strikes northeast and is exposed along the Hurricane Cliffs in the east-central part of the Pintura quadrangle, where it folds Permian and Triassic units in present exposures, and continues 30 miles (48 km) north to Cedar City (figures 1a and 2b; Gregory and Williams, 1947;

Threet, 1963; Averitt and Threet, 1973; Kurie, 1966). The east limb of the Kanarra anticline generally dips from 20 to 60 degrees east and is well exposed. The Kanarra anticline's west limb dips up to 70 degrees west, and is discontinuously exposed along the Hurricane Cliffs due to erosion and truncation by the Hurricane fault. Grant and others (1994) depicted the Kanarra anticline as a fault-propagation fold, related to an east-directed thrust fault in the subsurface.

The east limb of the Kanarra anticline is cut by the west-directed Taylor Creek thrust fault that, in the best exposures at the south end of the Hurricane Cliffs, places the Lower Permian Fossil Mountain Member of the Kaibab Formation over the Lower Triassic lower red member of the Moenkopi Formation. In the hanging wall of the Taylor Creek thrust fault in the eastern half of section 13, T. 40 S., R. 13 W., the lower Moenkopi and Kaibab Formations are overturned, and the middle red member of the Moenkopi Formation is tightly folded into a series of northeast-trending anticlines and synclines. Several smaller east- and west-directed thrust faults displace the Virgin Limestone and middle red members of the Moenkopi Formation in the upper plate of the main thrust fault. We interpret this overturning and small-scale folding as the result of deformation in the footwall of an east-directed thrust fault (cross section A-A').

During Oligocene to Quaternary time, volcanism and extensional faulting dominated the tectonic setting of southwestern Utah. Oligocene to early Miocene calc-alkalic ash-flow tuff, breccia, and flows covered most of southwestern Utah; their source areas were primarily the Indian

Peak and Caliente caldera complexes in western Utah and eastern Nevada, though local sources were also active in the Bull Valley Mountains, about 14 miles (23 km) west-northwest of Pintura (figure 1a; Cook, 1960; Mackin, 1960; Rowley and others, 1979; Rowley and others, 1995; McKee and others, 1997).

Monzonite laccoliths of the "iron axis" were emplaced around 21 Ma, including the Pine Valley laccolith (map unit Tip), part of which crops out in the Pintura quadrangle (figure 1a; Cook, 1957, 1960; Blank and others, 1992; McKee and others, 1997; Hacker, 1998). The Pine Valley laccolith chiefly intruded the middle part of the Claron Formation (Cook, 1957, 1960; Hacker, 1998), but it also intruded the lower part of the Iron Springs Formation in the Pintura quadrangle. Volcanic flows formed where the intrusion breached the surface (Cook, 1957; Hacker, 1998); small exposures of these flows are exposed in the northern part of the Pintura quadrangle (map unit Tvp). Intrusion of the Pine Valley laccolith uplifted the land surface, resulting in emplacement of large landslides that moved from the uplifted roof of the intrusion to topographically lower areas (Cook, 1957; Blank and others, 1992; Hacker, 1998). These landslides are represented by megabreccia deposits exposed north and west of the Pine Valley Mountains (Cook, 1957; Blank and others, 1992; Hacker, 1998); such deposits presumably once covered much of the Pintura quadrangle, but have since been removed by erosion or are now covered by younger deposits. However, a small erosional remnant of one of these megabreccia deposits may crop out in the northwestern part of section 2, T. 40 S., R. 13 W. in the Pintura quadrangle, but meager exposures preclude a firm interpretation.

Relatively minor normal faulting and crustal extension accompanied the eruption of Oligocene and Miocene calc-alkaline volcanic rocks in eastern Nevada and western Utah (Best and Christiansen, 1991; Rowley and others, 1995). More significant crustal extension, manifested by steeply dipping normal faults and bimodal basaltic and rhyolitic volcanism, began in southwestern Utah during late Miocene time, after emplacement of the iron axis intrusions (Anderson and Mehnert, 1979). Numerous steeply dipping normal faults cut the hinge zone and west limb of the Pintura anticline in the Pintura quadrangle. These faults moved mainly between about 21 Ma and latest Pleistocene time, because they cut the monzonite of the Pine Valley Mountains but either do not cut Pleistocene-age alluvial fans (map unit Qafo) or displace them significantly less than they do older units. The largest of these faults dips steeply east and is discontinuously exposed along the eastern margin of the Pine Valley Mountains; it juxtaposes a hanging wall composed of the upper part of the Navajo Sandstone and the overlying Canaan Peak and Claron Formations and monzonite of the Pine Valley Mountains, against a footwall composed of the lower part of the Navajo Sandstone, a stratigraphic separation of about 500 feet (152 m).

The Hurricane fault is a late Tertiary-Quaternary age, west-side-down normal fault that strikes north to northeast and can be traced for about 160 miles (250 km) from the Grand Canyon, Arizona, to Cedar City, Utah (figures 1a and 2b; Huntington and Goldthwait, 1904; Dobbin, 1939; Gardner, 1941; Hamblin, 1965; Kurie, 1966; Anderson and Mehnert, 1979; Hamblin and others, 1981; Anderson and Christenson, 1989; Stewart and Taylor, 1996; Pearthree and others, 1998). The

Hurricane fault forms the western boundary of the rugged Hurricane Cliffs, which are an eroded fault-line scarp in its footwall. The Hurricane fault consists of relatively straight, narrow segments separated by relatively sharp bends (Stewart and Taylor, 1996; Stewart and others, 1997; Biek, 1998; Lund and Everitt, 1998; Higgins, in prep.). The straight segments, referred to as geometric segments by Stewart and Taylor (1996) and as sections by Pearthree and others (1998), are delineated based on the geometry of the fault trace, not rupture history. These geometric segments (sections) are about 6 to 25 miles (10-40 km) long and consist of closely spaced, steeply dipping, sub-parallel normal faults. The bends, referred to as geometric segment boundaries by Stewart and Taylor (1996) and section boundaries by Pearthree and others (1998), consist of broad, structurally complex zones of faulting and folding (Stewart and Taylor, 1996; Stewart and others, 1997). The Pintura quadrangle contains the southern part of the Ash Creek geometric segment (section) of the Hurricane fault and part of its southern geometric segment (section) boundary (figure 2b; Stewart and Taylor, 1996; Biek, 1998; Lund and Everitt, 1998; Higgins, in prep.).

Estimates of the timing and amount of displacement on the Hurricane fault vary, although it is generally accepted that stratigraphic separation increases from south to north (Gardner, 1941; Kurie, 1966; Anderson and Mehnert, 1979; Stewart and others, 1997). Most workers think that displacement on the Hurricane fault began no earlier than early Miocene time, and Anderson and Mehnert (1979) suggested that motion did not begin until latest Pliocene or Pleistocene time.

Attempts to estimate tectonic throw on the Hurricane fault are greatly complicated by deformation near the fault trace, and by the fact that the fault cuts and modifies the hinge zone and west limb of the Kanarra anticline (Hamblin, 1965; Kurie, 1966; Anderson and Mehnert, 1979; Anderson and Christenson, 1989). In the Pintura quadrangle, Stewart and Taylor (1996) measured about 1,480 feet (450 m) of stratigraphic separation of geochemically correlated Quaternary basalt exposures in the hanging wall and footwall, as mentioned above. For pre-Tertiary rocks, Stewart and Taylor (1996) estimated about 8,250 feet (2,520 m) of stratigraphic separation and Hurlow (1998) illustrated about 2,800 to 5,000 feet (850-1,524 m) of stratigraphic separation on the southern part of the Ash Creek segment of the Hurricane fault. Reconstruction of the footwall geology of the Hurricane fault above the present land surface on cross section A-A' indicates throw of about 8,000 feet (2,438 m) on the base of the Shinarump Conglomerate Member of the Chinle Formation (unit TRcs), due to the combined effects of displacement on the Hurricane fault, and reverse drag and normal faulting in its hanging wall. This estimate depends strongly on assumptions about the geometry of eroded parts of the Kanarra anticline, the subsurface shape of the Hurricane fault, and the subsurface geometry of the syncline between the Pintura and Kanarra anticlines.

Deformation of the hanging wall of the Hurricane fault in the Pintura quadrangle is extensive. Quaternary basalt adjacent to the fault trace is folded into an open anticline, as demonstrated by map relations, and by paleomagnetic data discussed below (Hamblin, 1965; M. Hozik, Richard Stockton College, *in* Lund and Everitt, 1998). This fold is locally cut by numerous normal faults. Stewart and Taylor (1996) described a small reverse fault and anticline in Quaternary basalt within the segment boundary in the southern part of the Pintura quadrangle. Anderson and Christenson (1989) and Lund and Everitt (1998) documented several east-side-down fault scarps in Quaternary basalt and Pleistocene alluvial fans (map unit Qafo) between the Hurricane fault and the eastern Pine Valley Mountains, and named this region the Ash Creek graben (figure 2b).

Cross section A-A’ illustrates many aspects of the structure of the Pintura quadrangle described above, including the Kanarra and Pintura anticlines and the intervening buried syncline, the Taylor Creek thrust and related faults, and the Hurricane fault and the faulting and reverse drag in its hanging wall. Several features in cross section A-A’ are poorly constrained. The geometry of the Hurricane fault is based on cross sections drawn by Hamblin (1965), and is confirmed in part by a single exposure in the northeastern part of the Pintura quadrangle, and by exposures in the Hurricane quadrangle south of the Pintura quadrangle that indicate that the fault dips 65 to 75 degrees near the surface (Biek, 1998). The geometry of the eastern limb of the Pintura anticline and of the adjacent syncline are also speculative, because no outcrops or subsurface data are available to constrain the location, shape, or magnitude of these structures. All folds in cross section A-A’ were constructed using the kink-band method (Suppe and Medwedeff, 1990), maintaining constant stratal thickness. The structure of Tertiary rocks in the hanging wall of the Hurricane fault is based on downdip projection of the Claron Formation, which dips about 30 degrees east in its easternmost exposures. This approach creates about 2,000 vertical feet of “open space” between the top of the

Claron Formation and the base of Quaternary basalt in the subsurface. This open space is filled chiefly by assuming that Miocene volcanic rocks and monzonite of Pine Valley are present above the Claron Formation. Several water-well logs (table 1 and figure 2a) provide minimum estimates of the subsurface thickness of unconsolidated deposits and Quaternary basalt in the hanging wall of the Hurricane fault.

QUATERNARY BASALT

Quaternary basalt that crops out on both the hanging wall and footwall of the Hurricane fault in southwestern Utah and northwestern Arizona is useful in analyzing the displacement history and style of the Hurricane fault and the geomorphic evolution of the region (Hamblin, 1963, 1965; Anderson and Mehnert, 1979; Hamblin and others, 1981; Anderson and Christenson, 1989; Stewart and Taylor, 1996; Pearthree and others, 1998; Willis and others, 1999). A project combining geochemical, geochronologic, and paleomagnetic investigations of Quaternary basalt adjacent to the Hurricane fault is in progress by workers from the Utah Geological Survey, Arizona Geological Survey, Southern Utah University, and Richard Stockton College (New Jersey). Pearthree and others (1998) presented the preliminary results of this study, which are briefly summarized here.

Geochemical and petrographic studies indicate that all of the basalt in the Pintura quadrangle erupted from a common source, termed the Pintura volcanic field, whose eruptive center is located just west of Interstate 15 in the southern New Harmony quadrangle (figure 1a; Grant, 1995; Lund and Everitt, 1998; S. Hatfield, Southern Utah University, written communication, July 14, 2000). The basalt cooling units in the Pintura volcanic field can be subdivided into three distinct geochemical groups, each of which is distributed throughout the quadrangle and is present on both sides of the Hurricane fault (Lund and Everitt, 1998; S. Hatfield, Southern Utah University, written communication, July 14, 2000).

Basalt cooling units exposed on the hanging wall and footwall of the Hurricane fault in the southern part of the Pintura quadrangle have been geochemically correlated and dated. Stewart and Taylor (1996) and Lund and Everitt (1998; samples BRN and ACS, plate 1) reported nearly identical geochemical results for basalt on either side of the Hurricane fault, demonstrating that these flows were offset about 1,480 feet (450 m) by fault displacement. A sample taken from the uppermost cooling unit on the hanging wall (sample ACG-1, plate 1), yielded an $^{40}Ar/^{39}Ar$ whole-rock age of 810 $\pm$ 10 ka (W. Lund, Utah Geological Survey, written communication, July 14, 2000). Two samples of basalt located north of the Pintura quadrangle, one from the hanging wall and one from the footwall of the Hurricane fault, yielded $^{40}Ar/^{39}Ar$ whole-rock ages of 840 $\pm$ 30 ka and 880 $\pm$ 50 ka, respectively (Lund and Everitt, 1998). These two samples have nearly identical geochemistry and are offset about 1,102 feet (336 m) by the Hurricane fault (Lund and Everitt, 1998).

Paleomagnetic data indicate that basalt in the hanging wall of the Hurricane fault, in sections 14, 23, and 26 of T. 40 S., R. 13 W., has been tilted about 10 to 25 degrees toward the fault (M. Hozik *in* Lund and Everitt, 1998). These results agree with the conclusions of Hamblin (1965) that reverse drag, related to the curvature of the Hurricane fault, is an important aspect of deformation of its hanging wall and complicates estimates of tectonic throw on the fault.

ECONOMIC RESOURCES

Water is perhaps the most important and valuable resource in the Pintura quadrangle, considering the rapid population growth and arid climate of Washington County. Wells and springs in the quadrangle are shown on figure 2a and are listed in tables 1 and 2. Toquerville Springs provides culinary water to several public-supply entities. A well drilled by Washington County Water Conservancy District southwest of Anderson Junction in section 28, T. 40 S., R. 13 W. (well 15, table 1) produces water from the Navajo Sandstone. An aquifer test conducted by the U.S. Geological Survey yielded transmissivity estimates of 18,000 square feet per day (1,672 m^2/day) and 900 square feet per day (84 m^2/day) from two observation wells, each located about 380 feet (116 m) but in different directions from the pumping well (Heilweil and others, 2000). Their results indicate strongly anisotropic hydraulic conductivity in the Navajo Sandstone, resulting from a dense array of joints and faults that cut the unit (Cordova, 1978; Hurlow, 1998; Heilweil and others, 2000). Fractures are abundant in the Navajo Sandstone throughout the Pintura quadrangle, and likely formed during both Cretaceous folding and Tertiary-Quaternary normal faulting.

Several oil-test wells are located in the Pintura quadrangle (figure 2a; table 3); none produced significant shows of oil or natural gas. Numerous gravel pits are located in alluvial fans derived from the Pine Valley Mountains and Hurricane Cliffs. The old town site and several shafts of the Silver Reef mining district are located in the southwest corner of the quadrangle. Biek (1997, 1998) reviewed the geology and history of the Silver Reef mining district and listed additional references.

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DESCRIPTION OF MAP UNITS

QUATERNARY

Alluvial deposits

Qa **Alluvial deposits** - Poorly to well-sorted boulder to pebble gravel, sand, silt, and clay deposited in stream channels and flood plains and on alluvial fans at the mouths of small tributary drainages; mapped where stream and alluvial-fan deposits are too small to differentiate. Up to 15 feet (5 m) thick.

Qal_1 **Stream deposits** - Moderately to well-sorted gravel, sand, silt, and clay; includes channel, flood-plain, local small alluvial-fan and colluvial deposits, and stream-terrace deposits less than 10 feet (<3 m) above modern base level. Up to 25 feet (8 m) thick.

Qat_{2-6} **Stream-terrace deposits** - Moderately to well-sorted alluvial gravel, sand, silt, and clay; forms isolated, level to gently sloping surfaces above modern drainages; subscript denotes relative age and height above modern drainages; level 2 deposits (youngest) are about 10 to 30 feet (3-9 m), level 3 deposits are about 30 to 55 feet (9-17 m), level 4 deposits are about 55 to 95 feet (17-29 m), level 5 deposits are about 95 to 130 feet (29-40 m), and level 6 deposits (oldest) are over 130 feet (40 m) above adjacent streams. These terrace levels are probably not directly correlative across the Hurricane fault zone. Deposited principally in stream-channel and flood-plain environments. Up to 30 feet (9 m) thick.

$Qalo_{1\text{-}3}$ **Older stream deposits** - Moderately to well-sorted alluvial gravel, sand, silt, and clay; chiefly channel deposits; mapped adjacent to a small, unnamed wash in the south-central part of the quadrangle; gradational with deposits of unit Qafo to the north; subscript denotes relative age and height above modern drainages; level 1 (youngest) deposits are about 10 feet (3 m), level 2 deposits are about 20 to 30 feet (6-9 m), and level 3 deposits (oldest) are about 30 to 55 feet (9- m) above adjacent streams. Up to about 20 feet (6 m) thick.

Qago **Older stream gravel** - Well-sorted pebble gravel, exposed as small erosional remnants at about 6,700 feet (2,042 m) elevation in the northwestern part of the quadrangle; clasts are rounded and include quartzite, chert, and monzonite of the Pine Valley Mountains; probably deposited in gravel bars. Up to about 10 feet (3 m) thick.

$Qaf_{1\text{-}2}$ **Alluvial-fan deposits** - Poorly sorted, boulder- to clay-size sediment deposited at the base of the Hurricane Cliffs and locally at the mouths of active drainages; clast composition varies widely and reflects lithologies of local upstream drainage basins; subscript denotes relative age and height above modern drainages; level 1 fan deposits (youngest) form active depositional surfaces, whereas level 2 fan deposits (oldest) are deeply incised and now lie up to 50 feet (15 m) above modern channels. Up to about 150 feet (46 m) thick.

Qafo **Older alluvial-fan deposits** - Poorly sorted, subangular to subrounded boulders, gravel, sand, and silt; most clasts are derived from the monzonite of Pine Valley, some of which are up to 20 feet (6 m) in diameter; other clast types include rounded, iron-stained quartzite pebbles, and clasts from Claron, Iron Springs, Carmel, and Navajo strata. Deposited on broad, gently east- to southeast-sloping surfaces at the base of the Pine Valley Mountains that are deeply incised by modern drainages. Up to about 150 feet (46 m) thick.

Artificial deposits

Qf **Artificial fill** - Engineered fill used to create the roadbed of Interstate 15 and, locally, adjacent frontage road, and a single exposure of general borrow material used to create a level drilling platform; although we mapped only the larger deposits, fill should be anticipated in all built-up areas, many of which are shown on the topographic base map. Up to several tens of feet thick.

Colluvial deposits

Qc, Qco

Colluvial deposits - Poorly to moderately sorted, locally derived, gravel, sand, and soil obscuring bedrock; locally includes talus and alluvial deposits; deposited by slope wash, soil creep, and minor debris flows on moderate slopes; where present below unit Qafo, contains Pine Valley monzonite boulders up to 20 feet (6 m) in diameter; older colluvial deposits (Qco) form deeply incised, largely inactive surfaces; generally less than 10 feet (3 m) thick.

Eolian deposits

Qes **Eolian sand deposits** - Well- to very-well sorted, fine- to medium-grained quartz sand, typically present at the base of steep outcrops or in areas of extensive exposures of Navajo Sandstone, from which they are derived. Generally less than about 15 feet (5 m) thick.

Mass-movement deposits

Qmt, Qmto

Talus deposits - Poorly sorted, angular boulders and lesser fine-grained interstitial sediments; locally derived material deposited principally by rockfall on and at the base of steep slopes; locally includes and is gradational with colluvial deposits; older talus deposits (Qmto) form deeply incised, largely inactive surfaces. These deposits are generally less than about 40 feet (12 m) thick.

Qmsy, Qmso

Landslide deposits - Poorly sorted, clay- to boulder-sized, locally derived material deposited by rotational and translational processes. Younger deposits (Qmsy), including historically active landslides, are characterized by hummocky topography, numerous, subdued internal scarps, and chaotic bedding attitudes. Older deposits (Qmso) are deeply incised by active stream channels and their head scarps and hummocky topography have been extensively modified by erosion. Slip surfaces of both units are principally in the Moenkopi, Chinle, and Iron Springs Formations. Thickness highly variable.

Qmfo **Debris-flow deposits** - Poorly sorted, chaotic mixture of gravel and boulders in clay- to sand-sized matrix; extensively modified by erosion, locally overlain by younger alluvial and eolian deposits, and deeply dissected by modern stream channels; deposits in Dry Sandy wash are up to 50 feet (15 m) thick and are composed entirely of Iron Springs Formation clasts; deposits in Grapevine Wash are about 3-10 feet (1-3 m) thick and are composed entirely of Carmel Formation clasts.

Mixed-environment deposits

Qac **Alluvial and colluvial deposits** - Poorly to moderately sorted, clay- to boulder-size sediments deposited in swales and small drainages; gradational with both alluvial and colluvial deposits. Generally less than about 20 feet (6 m) thick.

Qafc **Alluvial-fan and colluvial deposits** - Poorly to moderately sorted, angular to subrounded clay, silt, sand, pebbles, cobbles; alluvial-fan deposits dominant; locally derived and deposited on slopes below outcrop areas and in swales and small drainages; mapped where deposits are either gradational or interbedded at too fine a scale to map individually. Varies from about 10 to 30 feet (3-10 m) thick.

Qcaf **Colluvial and alluvial-fan deposits** - Poorly to moderately sorted, angular to subrounded clay, silt, sand, pebbles, and cobbles; colluvial deposits dominant; locally derived and deposited on slopes below outcrop areas and in swales and small drainages; mapped where deposits are either gradational or interbedded at too fine a scale to map individually. Varies from about 10 to 30 feet (3-10 m) thick.

Qae, Qaec

Alluvial and eolian deposits - Poorly to moderately sorted gravel, sand, and silt deposited in fans and channels; well-sorted, fine- to medium-grained eolian sand forming dunes; alluvial-fan deposits dominant; mapped where deposits are either gradational or interbedded at too fine a scale to map individually. Qaec has white to pale gray caliche, up to 3 feet (1 m) thick. Varies from about 10 to 30 feet (3-10 m) thick.

Qea **Eolian and alluvial deposits** - Well-sorted, fine- to medium-grained eolian sand forming dunes; poorly to moderately sorted gravel, sand, and silt deposited in fans and channels; eolian deposits dominant; mapped where deposits are either gradational or interbedded at too fine a scale to map individually. Varies from about 10 to 30 feet (3-10 m) thick.

Qeca **Eolian and alluvial deposits with thick carbonate soil on basalt flow** - Thin cover of ancestral Ash Creek gravels on top of Pintura flows, partly concealed by eolian silt and sand; includes well-developed pedogenic carbonate. Generally less than a few feet thick.

Stacked-unit deposits

Qe/Qafo

Eolian sand over older alluvial-fan deposits - Well-sorted eolian sand deposits over older alluvial-fan deposits; mapped where eolian deposits are too thin or too small to show separately.

Qa/Qafo

Alluvium over older alluvial-fan deposits - Moderately to well-sorted stream and alluvial-fan deposits, reworking older alluvial-fan deposits; mapped where younger alluvial channels are too small to show individually.

Basaltic flows

Qbp **Pintura flows** - Medium- to dark-gray basalt with fine- to medium-grained phenocrysts of olivine + plagioclase; groundmass contains microscopic plagioclase + pyroxene + olivine and glassy to microcrystalline material; cooling units typically have highly vesicular tops and brecciated bases; erupted from the Pintura volcanic center, located north of the Pintura quadrangle in sections 24 and 25, T. 39 S., R. 13 W.; yielded $^{40}Ar/^{39}Ar$ whole-rock ages of 840 $\pm$ 30 ka, 880 $\pm$ 50 ka, and 810 $\pm$ 10 ka (Lund and Everitt, 1998; W.R. Lund, written communication, July 14, 2000); individual cooling units are generally 3 to 20 feet (1-6 m) thick; total accumulations up to 1,140 feet (348 m) thick.

unconformity

TERTIARY

Tvp **Pine Valley latite** - Medium to pale gray volcanic breccia composed of angular clasts of latite in highly brecciated, glassy groundmass of same composition; latite clasts contain medium- to coarse-grained phenocrysts of plagioclase, sanidine, and pyroxene. The latite overlies the monzonite of the Pine Valley Mountains in section 35 of T. 39 S., R. 13 W., and overlies an angular unconformity above a possible gravity-slide mass composed of steeply dipping, highly fractured Claron and Leach Canyon Formations and Bauers Tuff Member of Condor Canyon Formation just north of Dry Wash, in the northwest part of section 2 of T. 40 S., R. 13 W. Approximately 100 feet (30 m) thick.

Tip **Monzonite of the Pine Valley Mountains** - Medium-gray, varying to orange-, lavender-, and green-gray, monzonite with medium- to coarse-grained phenocrysts of plagioclase, clinopyroxene, biotite, sanidine, and orthopyroxene; groundmass is composed of fine-grained to microscopic plagioclase and pyroxene crystals and cryptocrystalline material. Forms sills intruding the middle part of Claron Formation or the lower part of Iron Springs Formation. Up to 450 feet (137 m) thick in map area; upper contact is not exposed.

West of the Pintura quadrangle in the Pine Valley Mountains, the monzonite of the Pine Valley Mountains forms a laccolith, up to 3,330-foot-thick (1,000 m), that intruded the Claron Formation (Cook, 1957, 1960; Hacker, 1998). McKee and others (1997) reported a concordant, early Miocene K-Ar age of 20.9 $\pm$ 0.6 Ma on biotite for a sample from the central part of the laccolith, located about 6 miles (9 km) west-northwest of Pintura.

unconformity

Tccb **Bauers Tuff Member of Condor Canyon Formation** - Dense, resistant, reddish-brown to pinkish-red welded ash-flow tuff, with medium- to fine-grained phenocrysts of plagioclase, biotite, and quartz; matrix is microcrystalline to cryptocrystalline, with conspicuous, pale gray fiamme. Just north of Dry Wash, in the northwest part of section 2 of T. 40 S., R. 13 W., the Bauers Tuff Member is possibly part of a large gravity-slide mass that is largely obscured by younger deposits. McKee and others (1997) reported an early Miocene K-Ar age of 22.6 ± 0.6 Ma on biotite from a sample of the Bauers Tuff from the Bull Valley Mountains, about 14 miles (22 km) west of Pintura. About 40 feet (12 m) thick.

Tl **Leach Canyon Formation** - Pale pink to pinkish-gray welded ash-flow tuff with medium- to coarse-grained phenocrysts of plagioclase, quartz, and biotite; matrix composed of microcrystalline to cryptocrystalline material with angular fragments of red, gray, and pale green tuff with fine-grained phenocrysts of plagioclase, quartz, and biotite; vesicles range from roughly spherical to flattened, and are lined with white secondary minerals and surrounded by pale gray to white alteration halos. Just north of Dry Wash, in the northwest part of section 2 of T. 40 S., R. 13 W., the Leach Canyon Formation is part of a possible gravity-slide mass that is largely obscured by younger deposits. Armstrong (1970) reported a K-Ar age of about 24 million years on biotite from a sample of the Leach Canyon Formation. About 100 feet (30 m) thick.

unconformity

Tbh(?) **Brian Head Formation(?)** - Interbedded sandstone, shale, and volcanic tuff; sandstone is medium-gray to greenish-gray, medium- to fine-grained, tuffaceous litharenite to sublitharenite; mudstone and shale are pale olive gray to pale gray to reddish brown, with moderately to poorly defined lamination; tuff is moderately indurated with orange-pink, microcrystalline to cryptocrystalline groundmass and fine- to medium-grained sanidine, plagioclase, quartz, and biotite phenocrysts. About 30 feet (9 m) thick.

A single outcrop of these rocks is present in a stream-cut bank of Dry Wash in section 34, T. 39 S., R. 13 W. These rocks are tentatively correlated with the Brian Head Formation based on their position above the Claron Formation, and on their similarity to exposures in the west-central Red Hills, about 22 miles (35 km) north-northeast of Cedar City, Utah. The rocks in the Red Hills were mapped by Maldonado and Williams (1993a, 1993b) as the informally named "sedimentary and volcanic rocks of Red Hills," and they were incorporated into the Brian Head Formation (revised) by Sable and Maldonado (1995). The Brian Head Formation (revised) is late Eocene to middle Oligocene in age, based on radiometric ages of ash-flow tuffs from the upper part of the formation and overlying units, and on palynological ages from the underlying Claron Formation (Sable and Maldonado, 1997).

Claron Formation

Tcu **Upper member** - White to pale gray, resistant limestone interbedded with pale gray to pinkish-gray, clay-rich mudstone; limestone has moderately well- to poorly defined bedding, and includes unfossiliferous micrite, fine-grained bioclastic calcarenite, and pelletal calcarenite; calcite-filled veins are common. Deposited in fluvial and lacustrine environments (Taylor, 1993). The contact between the lower and upper members is mapped where gray to pinkish-gray mudstone of the upper member overlies bright red-orange mudstone of the lower member. The Claron Formation is late Paleocene to late Eocene(?) or early Oligocene in age, based on paleontological and palynological data (Goldstrand, 1994), but the age of the contact between the upper and lower members is not known. About 520 feet (159 m) thick.

Tcl **Lower member** - Interbedded mudstone, siltstone, sandstone, conglomerate, and limestone; mudstone is orange-red to red-brown and clayey to silty, and contains thin beds of resistant, reddish-brown siltstone; sandstone is tan to brown, medium- to coarse-grained, cross-bedded to structureless litharenite; sandstone grades into, or is locally incised by, limestone-quartzite-chert-clast pebble conglomerate that is clast-supported, very thick bedded, in discrete channels about 3 feet (1 m) or less thick. The lower to middle part of the lower member contains very resistant micrite with sparse shell fragments that is stained orange, pink, tan, lavender, and yellow; bedding is poorly defined and 2 to 5 feet (0.6-1.5 m) thick; contains vugs about 0.5 to 1 inches (1.3-2.5 cm) in diameter, filled with coarse crystalline calcite and surrounded by a yellow alteration halo. The upper part of the lower member contains medium gray, resistant micrite to calcarenite with moderately to well-defined, medium to thin bedding; bivalve shell fragments are common; many layers contain pellets and/or oncolites and calcite-filled veins and vugs. The base of the lower member is late Paleocene in age (Goldstrand, 1994). About 1,090 feet (332 m) thick.

TERTIARY-CRETACEOUS

TKcp **Canaan Peak Formation** - Conglomerate with minor interbedded sandstone and mudstone; conglomerate is reddish brown, contains pebble- to cobble-sized, rounded clasts of quartzite, welded volcanic tuff, chert, and sandstone, is clast-supported, and is typically structureless although faint pebble imbrication is locally present. Clasts include tan, purple, gray, rusty brown, and black, structureless to cross-bedded quartzite; sandstone that is pale gray to tan-gray, fine- to medium-grained, and well-cemented; and welded tuff containing medium- to fine-grained feldspar (altered) and quartz phenocrysts in a gray, pale green, orange-tan, or purple-brown, devitrified groundmass, which Goldstrand (1992) correlated with Jurassic volcanic rocks exposed in southeastern California. The sandstone is reddish-brown, medium- to coarse-grained, structureless to weakly laminated litharenite in 0.5- to 1-foot-thick (0.2-0.3 m) beds. The mudstone is present at the base and near the top of the formation, and is reddish brown and finely laminated.

The Canaan Peak Formation in the Pintura quadrangle is preserved in paleochannels on the Navajo Sandstone (Goldstrand, 1992) along the crest of the Pintura anticline. Palynomorphs collected from the Table Cliff plateau in south-central Utah indicate a late Campanian to early Paleocene age (Goldstrand, 1994). Thickness ranges from 0 to 119 feet (0-36 m).

unconformity

CRETACEOUS

Kis **Iron Springs Formation** - Interbedded mudstone, sandstone, conglomerate, and thin sandy coquina beds, in order of decreasing abundance. The lower ~100 feet (~30 m) of the formation consists of red to gray mudstone with a single, 1- to 30-foot-thick (0.3-10 m) layer of conglomerate and coarse sandstone; the remainder consists of interbedded sandstone and mudstone, with rare beds of conglomerate and sandstone-matrix coquina.

The mudstone ranges from tan, medium gray, greenish gray, to reddish gray, and is weakly laminated to structureless. The sandstone is tan to brown, locally altered to white or reddish brown, fine to coarse grained, and weakly laminated to planar or trough cross-bedded, with highly contorted laminations and small wood fragments; composition ranges from quartz arenite to litharenite (Goldstrand, 1992; Fillmore, 1991). The conglomerate contains rounded to subrounded, moderately to well-sorted pebble- to cobble-size clasts of quartzite, limestone, lithic fragments, and chert, in decreasing order of abundance. The coquina beds are tan to medium brown, 0.5 to 1 foot (0.2-0.3 m) thick, and contain disarticulated, broken bivalve and gastropod shells in a medium-grained sand matrix. Deposited in a sandy braidplain environment (Fillmore, 1991).

The Iron Springs Formation is Cenomanian to Santonian or early Campanian in age (Goldstrand, 1994), and is up to 3,500 feet (1,067 m) thick in the southeastern Pine Valley Mountains (Cook, 1960); the lower 3,200 feet (975 m) is exposed in the northwest part of the Pintura quadrangle. The lower part was mapped as Entrada Sandstone and Dakota

Formation by Cook (1960), but was included in the Iron Springs Formation by Goldstrand (1994).

K unconformity

JURASSIC

Carmel Formation

Jcpr **Paria River Member** - Interbedded, pale to medium-gray, platy weathering, thin- to medium-bedded, silty to clayey micrite to fine-grained calcarenite with sparse bivalve fossils; pale gray to greenish-gray, massive to poorly laminated silty micrite; and pale yellowish-gray, calcareous mudstone. Deposited in a shallow-marine environment (Imlay, 1980). Upper contact is defined by hard, platy, calcareous siltstone overlain by red-brown, weakly consolidated mudstone of the Iron Springs Formation. Varies from about 360 to 680 feet (110-207 m) thick.

Jccc **Crystal Creek Member** - Poorly exposed brown to reddish-brown, locally gypsiferous mudstone; contains sparse bivalve fossils; typically covered by talus of platy, clayey limestone of the Paria River Member. Deposited in coastal sabkha and tidal-flat environments (Imlay, 1980). Upper contact corresponds to the top of red-brown, typically poorly exposed gypsiferous mudstone, which is overlain by hard, platy, calcareous siltstone of the Paria River Member. Varies from about 130 to 190 feet (40-60 m) thick.

Jcco **Co-op Creek Limestone Member** - Interbedded, pale greenish-gray calcareous mudstone to siltstone and clayey micrite; tan, sandy bioclastic limestone to calcareous sandstone containing disarticulated bivalve, mollusk, and oyster shells and, locally, *Pentacrinus* sp. crinoid columnals; siltstone and micrite have moderately to poorly defined bedding and are resistant; mudstone forms slopes and is poorly exposed; tan, sandy bioclastic limestone to calcareous sandstone marks the top of the member. Deposited in a shallow-marine environment (Imlay, 1980). Varies from about 360 to 450 feet (110-137 m) thick.

J-2 unconformity

Jtc **Temple Cap Formation** - Lower part is reddish-brown gypsiferous mudstone interbedded with sandstone and siltstone and local massive gypsum; upper part is pale pinkish-gray, gypsiferous mudstone to siltstone. Deposited in coastal sabkha and tidal-flat environments (Blakey, 1994; Peterson, 1994). Varies from 0 to about 50 feet (0-15 m) thick. Included in upper part of Navajo Sandstone where too thin to show on map.

J-1 unconformity

Jn **Navajo Sandstone** - Pale reddish-orange, reddish-brown, or white, fine- to medium-grained eolian sandstone (quartz arenite); characterized by trough cross-bedding and well-rounded quartz grains that have frosted surfaces due to abrasion. The lower 100 to 150 feet (30-46 m) is composed of interbedded, fine-grained sandstone, siltstone, and shale that vary from internally structureless to moderately laminated, with gently wavy to flaser-like laminae and soft-sediment deformation features including diapiric and load structures; reddish-brown, fissile to massive siltstone and fine-grained sandstone; and 1- to 3-foot-thick (0.3-1 m) beds of eolian sandstone. Sansom (1992) interpreted this part of the Navajo to have been deposited in a sabkha, representing a transition from fluvial deposition of the underlying Kayenta Formation to eolian deposition of the main part of the Navajo Sandstone. Upper contact characterized by orange to pale gray, cross-bedded eolian sandstone overlain by deep reddish-brown, structureless to poorly bedded sandstone and gypsiferous siltstone of the Temple Cap Formation. About 2,300 feet (701 m) thick.

Jk **Kayenta Formation** - Interbedded, reddish-brown to orange-red, thin- to medium-bedded, fine-grained sandstone, siltstone, and mudstone with planar to ripple laminae; a thin, pale gray-weathering dolomite bed is present in the southwest part of the quadrangle. Deposited in distal river, playa, and minor lacustrine environments (Sansom, 1992; Blakey, 1994; Peterson, 1994). Only the upper 455 feet (139 m) is exposed in section 1 of T. 41 S, R. 12 W., in the southwest part of the quadrangle. The Kayenta Formation is 925 feet (282 m) in the adjacent Harrisburg Junction quadrangle (Biek, 1997).

Moenave Formation

Jm Moenave Formation, undivided - shown on cross section only.

Jms **Springdale Sandstone Member** - Medium to very thick-bedded, fine-grained or rarely medium-grained sandstone, with planar and low-angle cross-stratification, and minor, thin, discontinuous lenses of intraformational conglomerate and thin interbeds of moderate-reddish-brown or greenish-gray mudstone and siltstone; contains locally abundant petrified and carbonized fossil plant remains. Forms rounded cliffs and ledges at the northwest end of White Reef and is host to the ore deposits of the Silver Reef mining district. Deposited in braided-stream and minor flood-plain environments (Clemmensen and others, 1989; Blakey, 1994; Peterson, 1994; DeCourten, 1998). The upper contact is conformable and corresponds to the first appearance of thin-bedded, reddish-brown, fine-grained silty sandstone that overlies very thick bedded, rounded-weathering Springdale Sandstone. About 100 feet (31 m) thick.

Jmw **Whitmore Point Member** - Interbedded, pale-reddish-purple, greenish-gray, and blackish-red mudstone and claystone, lesser moderate-reddish-brown very fine- to fine-grained sandstone and siltstone, and uncommon dark-yellowish-orange micaceous siltstone and very fine- to fine-grained, very pale-orange sandstone; weathers to poorly exposed, brightly colored slopes; contains several 3- to 18-inch-thick (8-120 mm), bioturbated, cherty, dolomitic limestone beds with algal structures and fossil fish scales of *Semionotus kanabensis* (Hesse, 1935; Schaeffer and Dunkle, 1950); the dolomitic limestones vary in color from light greenish gray, very light gray and yellowish gray, and weather to mottled colors of pale yellowish orange, white, yellowish gray, and pinkish gray, commonly with green copper-carbonate stains; lower 25 feet (8 m) consists of reddish-brown sandstones similar to those of the Dinosaur Canyon Member. Forms a mostly covered slope at the northeast end of White Reef. The Whitmore Point Member is conformably overlain by the Springdale Sandstone, although local channeling and mudstone rip-up clasts are present at the contact. Deposited in flood-plain and lacustrine environments (Clemmensen and others, 1989; Blakey, 1994; Peterson, 1994; DeCourten, 1998). About 60 feet (18 m) thick.

Jmd **Dinosaur Canyon Member** - Interbedded, generally thin-bedded, moderate-reddish-brown to moderate-reddish-orange, very fine- to fine-grained sandstone, very fine-grained silty sandstone, and lesser siltstone and mudstone with planar, low-angle, and ripple cross-stratification. Forms a slope at the northeast end of White Reef. The contact with the Whitmore Point Member is conformable and gradational and corresponds to the base of a 6- to 18-inch-thick (0.1-0.4 m), light-gray, bioturbated, dolomitic limestone with algal structures and reddish-brown chert blebs. About 25 feet (7.5 m) of brown sandstone typical of the Dinosaur Canyon Member overlies the dolomitic limestone and is included in the

Whitmore Point Member. Deposited in fluvial and flood-plain environments (Clemmensen and others, 1989; Blakey, 1994; Peterson, 1994; DeCourten, 1998). About 200 feet (61 m) thick.

J-0 unconformity

TRIASSIC

Chinle Formation

TRcp **Petrified Forest Member -** Variably colored mudstone, claystone, siltstone, lesser sandstone and pebbly sandstone, and minor chert and nodular limestone; swelling mudstones and claystones are common throughout and although typically poorly exposed, their bright purple, grayish-red, dark reddish-brown, light greenish-gray, brownish-gray, olive-gray, and similar hues locally show through to the surface; bentonitic mudstones weather to a "popcorn" surface and are responsible for numerous building foundation problems in the region; commonly forms slumps, especially along steep hillsides. Only the lower part of member is exposed east of Toquerville, and the upper part at White Reef. The upper contact corresponds to the first appearance of reddish-brown, non-bentonitic siltstone and fine-grained sandstone, below which lies brightly colored swelling mudstones with nodular limestone. Deposited in a variety of fluvial, flood-plain, and lacustrine environments (Stewart and others, 1972; Dubiel, 1994; DeCourten, 1998). About 400 feet (121 m) thick.

TRcs **Shinarump Conglomerate Member** - Laterally and vertically variable sequence of cliff-forming, fine- to very coarse-grained sandstone, pebbly sandstone, and lesser pebbly conglomerate; clasts are subrounded quartz, quartzite, and chert; mostly thick to very thick-bedded with both planar and low-angle cross-stratification, although thin, platy beds with ripple cross-stratification occur locally; predominantly pale- to dark-yellowish orange, but pale-red, grayish-red, very pale-orange, and pale-yellow-brown hues are common; heavily stained by iron-manganese oxides, locally forming "picture stone"; contains poorly preserved petrified wood and plant debris, commonly replaced in part by iron-manganese oxides. Exposed in the southeast corner of the quadrangle east of Toquerville. The upper contact corresponds to the first appearance of varicolored, swelling mudstone. Deposited in braided streams that flowed north and northwest (Stewart and others, 1972; Dubiel, 1994; DeCourten, 1998). About 120 feet (37 m) thick.

TR-3 unconformity

Moenkopi Formation

TRm **Moenkopi Formation, undivided** - West-dipping, fault-bounded blocks of lower, middle, or upper red strata along the Hurricane fault zone.

TRmu **Upper red member** - Interbedded, mostly thin- to medium-bedded, moderate-reddish-orange to moderate-reddish-brown siltstone, mudstone, and very fine- to fine-grained sandstone with planar, low-angle, and ripple cross-stratification; well-preserved ripple marks are common. Forms ledgy slopes and cliffs in fault-bounded block east of Toquerville. The upper, unconformable contact shows minor channeling at the base of the Shinarump Conglomerate. Deposited in a tidal-flat environment (Stewart and others, 1972; Dubiel, 1994). About 200 feet (61 m) thick.

TRms **Shnabkaib Member** - Forms “bacon striped,” ledgy slopes of laminated to thin-bedded, gypsiferous, pale-red to moderate-reddish-brown mudstone and siltstone, resistant, white to greenish-gray gypsum and lesser thin, laminated, light-gray dolomite beds; gypsum is present as laterally continuous, structureless beds, finely laminated, commonly silty or muddy beds, and nodular intervals that range from less than one inch to about 9 feet (0.01 to 3 m) thick; gypsum also present as secondary cavity fillings and cross-cutting veins; weathers to soft, punky, gypsiferous soils. Present in fault-bounded block east of Toquerville. Upper, conformable and gradational contact corresponds to the top of the highest thick gypsum bed. Deposited in a variety of supratidal, intertidal, and subtidal environments on a broad, coastal shelf of very low relief (Lambert, 1984). Probably about 350 feet (107 m) thick.

TRmm **Middle red member** - Interbedded, laminated to thin-bedded, moderate-reddish-brown to moderate-reddish-orange siltstone, mudstone, and very fine-grained sandstone; white to greenish-gray gypsum beds and veins are common, and lower part includes several thick gypsum beds. Forms slopes along the east side of the Hurricane Cliffs. Upper, conformable and gradational contact corresponds to the base of the first thick gypsum bed. Deposited in a tidal-flat environment (Stewart and others, 1972; Dubiel, 1994). Probably about 200 feet (61 m) thick.

TRmv **Virgin Limestone Member** - Very pale-orange to yellowish-gray, finely crystalline limestone and silty limestone, light-gray to light-olive-gray, coarsely crystalline, fossiliferous limestone with locally abundant circular and five-sided crinoid columnals, gastropods, and brachiopods, and siltstone and mudstone; mudstone and siltstone has variable gray, yellowish gray, and grayish purple hues. Forms three limestone ledges separated by poorly exposed mudstone slopes on the east side of the Hurricane Cliffs. Upper, conformable contact corresponds to the top of the uppermost Virgin limestone bed. Deposited in a variety of shallow-marine environments (Dubiel, 1994). About 120 to 270 feet (37-82 m) thick.

TRml **Lower red member** - Interbedded, laminated to thin-bedded, moderate-reddish-brown mudstone and siltstone with local, thin, laminated, light-olive-gray gypsum beds and veinlets. Forms slopes on the east side of the Hurricane Cliffs, and fault blocks east of Toquerville. Upper, unconformable contact corresponds to the base of the first Virgin limestone bed. Deposited in a tidal-flat environment (Stewart and others, 1972; Dubiel, 1994). About 250 to 315 feet (76-96 m) thick.

TRmt **Timpoweap Member** - Lower part consists of light-brown weathering, light-gray, thin- to thick-bedded limestone and cherty limestone; chert occurs as small disseminated blebs, thus giving weathered surfaces a very rough weathering appearance; upper part consists of grayish-orange, thin- to thick-bedded, slightly calcareous, very-fine grained sandstone, siltstone, and mudstone; both parts form low cliffs and ledges and form a gently undulating surface on top of the Permian-Triassic unconformity. Exposed along the east side of the Hurricane Cliffs. Upper contact is conformable and gradational and corresponds to a change from yellowish-brown, fine-grained sandstone, siltstone, and minor limestone below to reddish-brown siltstone and mudstone above. Deposited in a shallow-marine environment (Nielson and Johnson, 1979; Dubiel, 1994). Varies from 50 to 180 feet (15-55 m) thick (Nielson, 1981).

TRmr **Rock Canyon Conglomerate Member** - Consists of two main rock types: a pebble to cobble, clast-supported conglomerate, with rounded chert and minor limestone clasts derived from the Harrisburg Member of Kaibab Formation, which was deposited in paleovalleys and is up to about 96 feet (29 m) thick; and a widepsread but thin angular breccia up to 10 feet (3 m) thick and which probably formed as a regolith deposit on Harrisburg strata (Nielson, 1991). Conformably and gradationally overlain by limestone of the Timpoweap Member.

TR-1 unconformity

PERMIAN

Kaibab Formation

Pkh **Harrisburg Member** - Thin- to thick-bedded limestone and cherty limestone and minor medium- to very thick-bedded, laminated gypsiferous mudstone; forms ledgy slopes that enclose a resistant, cliff- and ledge-forming medial white chert and limestone interval. The medial limestone includes medium-gray cherty limestone breccia and coarsely crystalline limestone; laminated, thin-bedded, brown-weathering, medium-gray, slightly fetid limestone; grayish-orange-pink intraformational limestone conglomerate; grayish-orange-pink to pinkish-gray oncolitic limestone; and fine- to medium-crystalline limestone with abundant light-brown to moderate-reddish-brown weathering, light-gray chert nodules and lenticular beds with sparse silicified fenestrae bryozoans. Typically forms steep slopes on the east side of the Hurricane Cliffs. Unconformably overlain by Rock Canyon Conglomerate river-channel and breccia deposits. Deposited in a complex sequence of shallow-marine and sabkha environments (McKee, 1938; Nielson, 1981, 1986; Sorauf and Billingsley, 1991). Varies from 120 to 180 feet (37-55 m) thick (Nielson, 1981).

Pkf **Fossil Mountain Member** - Lithologically uniform, light-gray, thick- to very thick-bedded, fossiliferous limestone and cherty limestone; "black-banded" due to abundant reddish-brown, brown, and black chert; fossils are whole brachiopods, broken bryozoans, and disarticulated crinoids; ribbon chert and irregular chert nodules locally make up 30 to 40 percent of the rock. Forms prominent cliff at or near the crest of the Hurricane Cliffs. Conformable contact with Harrisburg strata corresponds to a sharp break in slope. Deposited in a shallow-marine environment (McKee, 1938; Nielson, 1981, 1986; Sorauf and Billingsley, 1991. About 240 to 280 feet (73-85 m) thick (Nielson, 1981).

Toroweap Formation

Ptw **Woods Ranch Member** - Laterally variable, interbedded, yellowish-gray to light-gray, laminated to thin-bedded dolomite and similarly bedded black chert, massive gypsum, gypsiferous mudstone, and limestone; contains local intraformational conglomerate and collapse breccia. Forms steep slope just below top of the Hurricane Cliffs. Contact with Fossil Mountain strata corresponds to a sharp break in slope with slope-forming, gypsiferous siltstone and thin limestone beds below and cliff-forming cherty limestone above. Deposited in a complex sequence of shallow-marine and sabkha environments (McKee, 1938; Rawson and Turner-Peterson, 1979; Nielson, 1981, 1986). About 120 to 250 feet (37-76 m) thick (Nielson, 1981).

Ptbs **rady Canyon and Seligman Members, undivided** - The **Brady Canyon Member** is a lithologically uniform, light- to medium-gray, medium- to coarse-grained, thick- to very thick-bedded, fossiliferous limestone and cherty limestone; fossils are broken brachiopods, bryozoans, and crinoids; ribbon chert and irregular chert nodules locally make up 30 to 40 percent of the rock. Forms prominent gray cliff, similar to Fossil Mountain strata, in the upper part of the Hurricane Cliffs. Contact with Woods Ranch strata is unconformable and corresponds to a sharp break in slope, with cliff-forming cherty limestone below and slope-forming, gypsiferous siltstone and thin limestone beds above. Deposited in a shallow-marine environment (McKee, 1938; Rawson and Turner-Peterson, 1979; Nielson, 1981, 1986). About 220 to 255 feet (67-78 m) thick (Nielson, 1981). The **Seligman Member** forms slopes of yellowish-brown to grayish-orange, very thin- to thin-bedded, planar bedded, very fine-to medium grained sandstone and minor siltstone with brown-weathering nodular chert. The contact with the Brady Canyon Member corresponds to a sharp break in slope, with slope-forming, thin-bedded sandstone below and cliff-forming cherty limestone above. Deposited in shallow-marine and beach environments (McKee, 1938; Rawson and Turner-Peterson, 1979; Nielson, 1981, 1986). About 30 feet (9 m) thick.

Queantoweap Sandstone

Pqu **Upper member of Queantoweap Sandstone** - Yellowish-brown to grayish-orange, very thick-bedded, cross-bedded, fine-grained noncalcareous sandstone (quartz arenite). Forms the bulk of the Hurricane Cliffs with a conspicuous stair-step topography. The contact with the Seligman Member corresponds to a subtle break in slope, with ledge- and cliff-forming cross-bedded sandstone below and slope- and ledge-forming, planar-bedded sandstone above. Deposited in shallow-marine, beach, and dune environments (Nielson, 1981). About 1,300 to 1,630 feet (396-497 m) thick.

Pql **Lower member of Queantoweap Sandstone** - Consists of three main parts of approximately equal thickness: (1) Lower part is slope-forming, brown-weathering, brownish-gray, thin- to medium-bedded, very fine-grained sandy dolomite. (2) Middle part is a cavernous and vuggy weathering, very thick-bedded, yellowish-brown calcareous sandstone. These vuggy beds are locally reddish brown, include sedimentary and karst-like breccias, and weather to a prominent ledge. (3) Upper part forms slopes of yellowish-brown, and minor reddish-brown, thin- to medium-bedded, very fine- to fine-grained calcareous sandstone and silty sandstone. The contact with the upper unit of the Queantoweap Sandstone is sharp and corresponds to the first appearance of very thick-bedded, cross-bedded, noncalcareous sandstone. Probably deposited in a shallow-marine environment. About 120 feet (244 m) thick near the south end of the Pintura quadrangle. The thickness to the north is uncertain due to poorly constrained structural complexity along the axis of the Kanarra anticline; outcrop patterns there suggest a thickness of up to 800 feet (244 m).

Pp **Pakoon Formation** - Light- to medium-gray, thin- to very thick-bedded dolomite, dolomitic limestone, and minor limestone, all with local, yellowish-brown weathering, light-gray to white, irregularly shaped chert nodules; includes thin bed of white chert near the top of the formation; sparse macrofossils, including crinoid columnals, in upper beds. Forms ledges in the lower part of the Hurricane Cliffs. Upper contact appears sharp and corresponds to the first appearance of thin-bedded, yellowish-brown-weathering sandy dolomite beds. Deposited in a shallow-marine environment. Only about the upper 250 feet (76 m) exposed.

Pu **Kaibab Formation, Toroweap Formation, and Queantoweap Sandstone, undivided** - Fault-bounded, highly fractured and brecciated blocks of Kaibab, Toroweap, and/or Queantoweap strata along the Hurricane fault zone.

Subsurface Units

PPc Callville Limestone - shown only on cross section.

Mr Redwall Limestone - shown only on cross section.

Du Devonian, undivided - shown only on cross section.

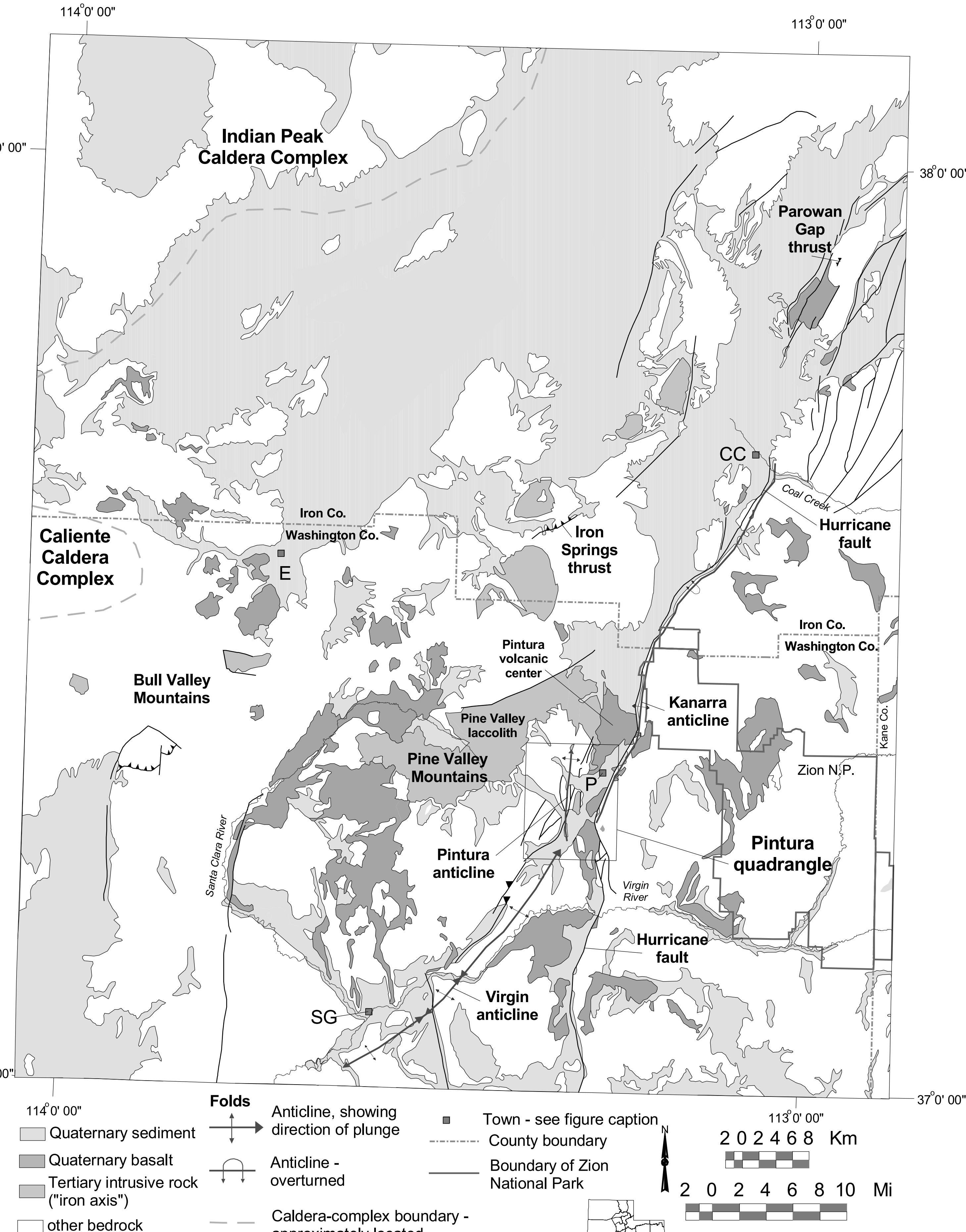


***Figure 1a.** Tectonic setting of Pintura quadrangle in southwestern Utah. Towns: CC = Cedar City; E = Escalante; P = Pintura; and SG = St. George.*

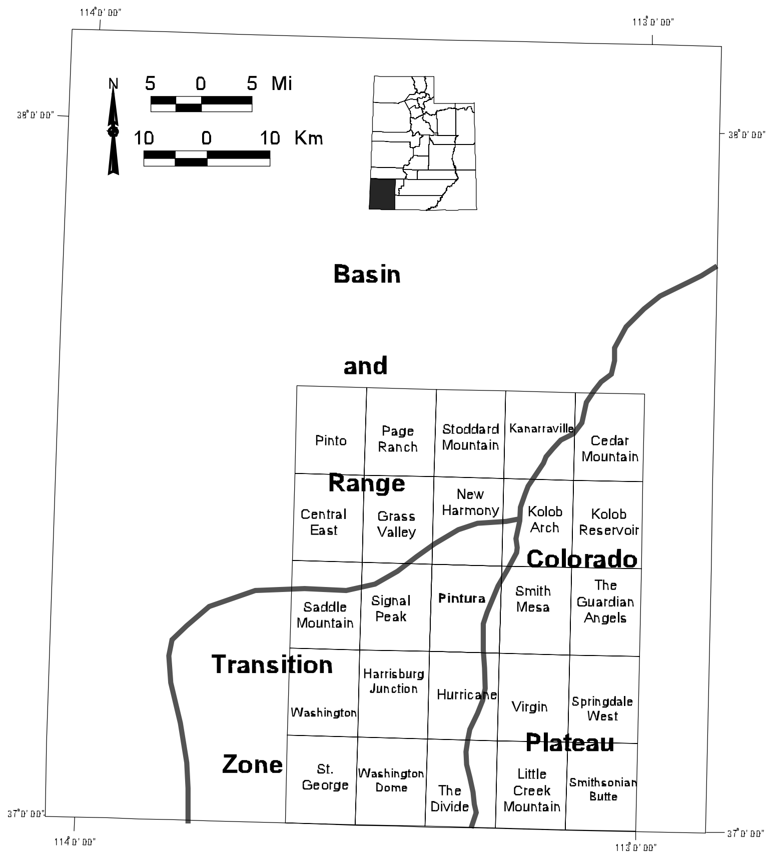


Figure 1b. *Locations of Basin and Range, Colorado Plateau, and transition zone geologic provinces, and of the Pintura and surrounding quadrangles, in southwestern Utah. Geologic province contacts are gradational and approximately located. Geologic maps are available for the Cedar Mountain (Averitt, 1962), Kanarraville (Averitt, 1969), Smithsonian Butte (Moore and Sable, 1994), New Harmony (Grant, 1995), St. George (Higgins and Willis, 1995), Washington (Willis and Higgins, 1995), Harrisburg Junction (Biek, 1997), Hurricane (Biek, 1998), Signal Peak and Signal Mountain (Hacker, 1998), and Washington Dome (Higgins, 1998) quadrangles; and are in preparation for the Kolob Arch, Kolob Reservoir, The Guardian Angels, Springdale West, and The Divide quadrangles (Utah Geological Survey).*

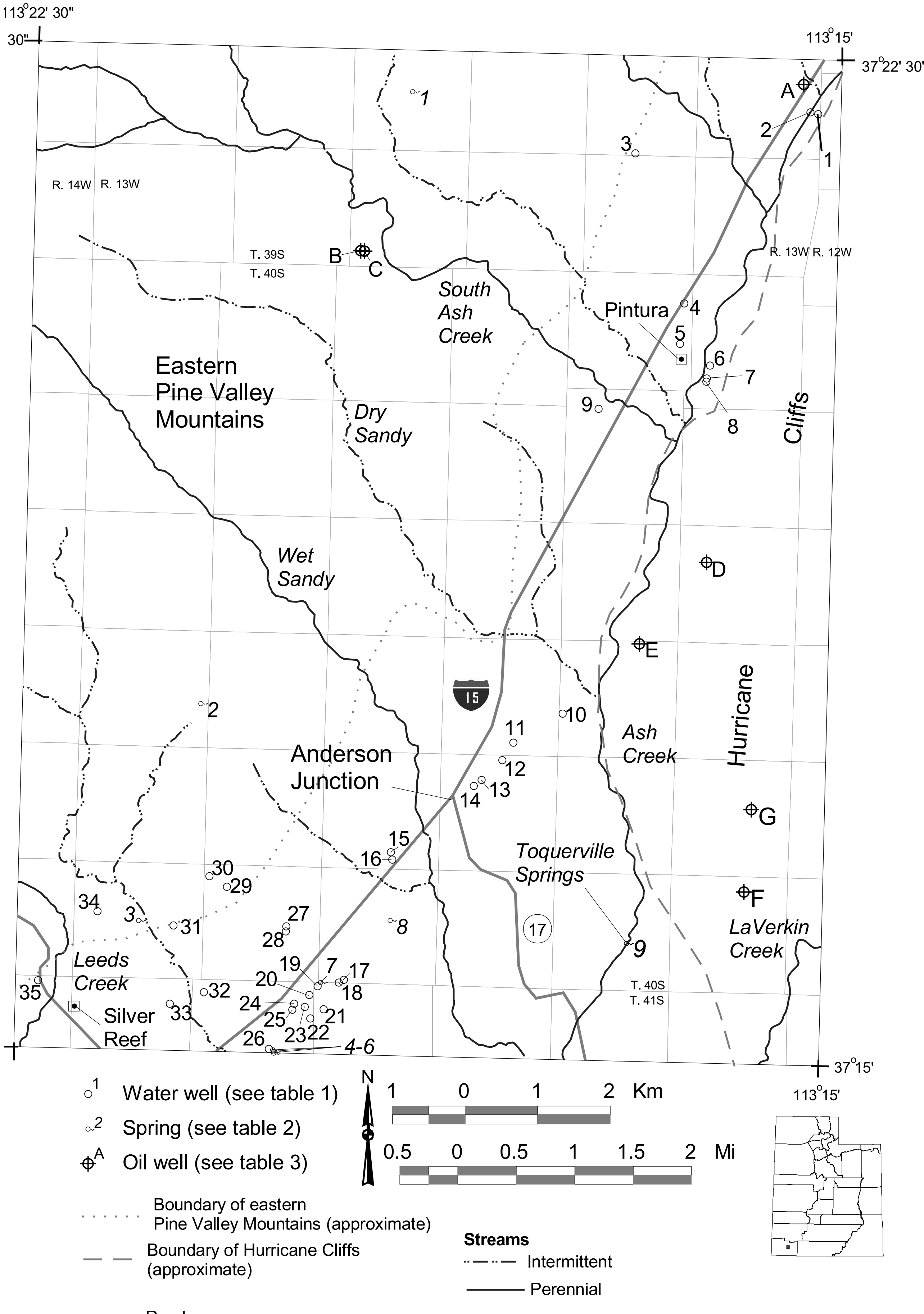
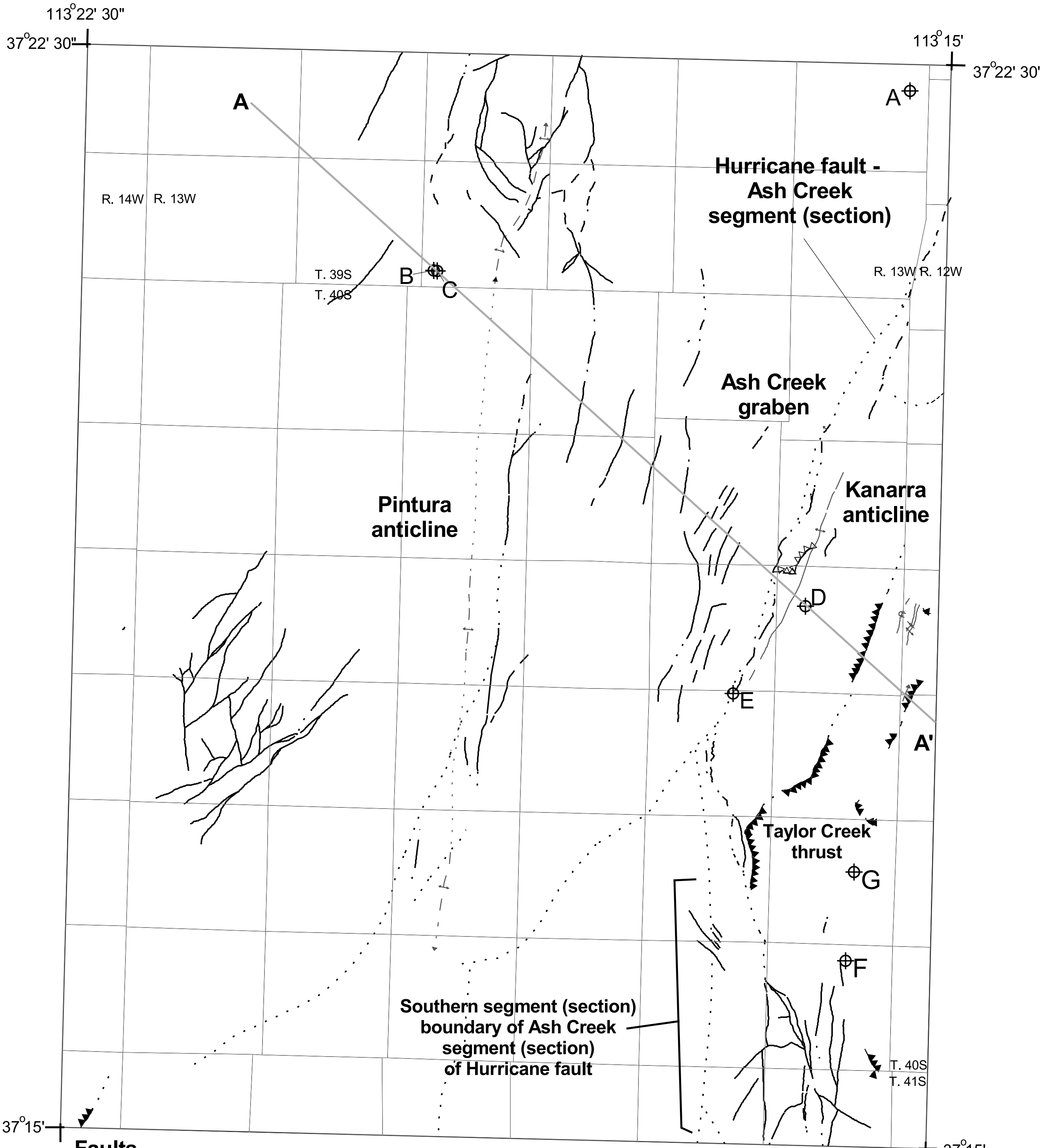


***Figure 2a.** Geographic and hydrologic features of the Pintura quadrangle.*



Faults

Normal (dotted where concealed)

Gently-dipping normal (dotted where concealed)

Thrust (dotted where concealed)

Folds

Anticline (dashed where approximately located, dotted where concealed)

Syncline

Syncline - overturned

Oil well (see table 3)

A A' Cross section

1 0 1 2 Km

0.5 0 0.5 1 1.5 2 Mi

N

Figure 2b. *Tectonic structures of the Pintura quadrangle.*

Table 1. Water wells in the Pintura quadrangle[1].

ID[2]	Point of Diversion[3]	Sec[3]	T[3]		R[3]	
1	S 590 W 129 E4	25	39	S	13	W
2	S 500 W 500 E4	25	39	S	13	W
3	N 130 W 450 S4	26	39	S	13	W
4	S 1290 W 420 NE	2	40	S	13	W
5	S 510 W 550 E4	2	40	S	13	W
6	S 1553 E 800 W4	1	40	S	13	W
7	S 1680 E 836 W4	1	40	S	13	W
8	S 1824 E 800 W4	1	40	S	13	W
9	N 5160 E 1390 SW	11	40	S	13	W
10	N 1948 E 135 SW	23	40	S	13	W
11	N 575 E 620 S4	22	40	S	13	W
12	S 235 E 135 N4	27	40	S	13	W
13	S 1135 W 825 N4	27	40	S	13	W
14	S 138 W 1188 N4	27	40	S	13	W
15	N 795 E 425 S4	28	40	S	13	W
16	N 428 E 540 S4	28	40	S	13	W
17	N 172 E 1137 SW	33	40	S	13	W
18	S 44 E 1151 NW	4	41	S	13	W
19	S 203 E 193 NW	4	41	S	13	W
20	S 605 W 183 NE	5	41	S	13	W
21	S 1180 E 505 NW	4	41	S	13	W
22	S 1650 W 125 NE	5	41	S	13	W
23	S 1131 W 375 N	5	41	S	13	W
24	S 1059 E 1863 N4	5	41	S	13	W
25	S 1345 E 1776 N4	5	41	S	13	W
26	S 3111 E 699 N4	5	41	S	13	W
27	N 2513 W 1444 SE	32	40	S	13	W
28	N 2308 W 1526 SE	32	40	S	13	W
29	S 1000 E 1100 NW	32	40	S	13	W
30	S 541 E 217 NW	32	40	S	13	W
31	S 136 W 1364 E4	31	40	S	13	W
32	S 618 E 486 NW	5	41	S	13	W
33	S 1133 W 1062 NW	5	41	S	13	W
34	N 2958 E 1124 SW	31	40	S	13	W
35	S 132 W 1554 NE	1	41	S	14	W

Notes

1. Data from Utah Division of Water Rights (http://nrwrt1@state.ut.us).
2. Corresponds to number on figure 2a.
3. Location is given in "Point of Diversion" (POD) notation. NW, NE, SW and SE refer to the northwest, northeast, southwest, and southeast section corners, respectively. N4, S4, E4, and W4 = midpoint of northern, southern, eastern, and western section boundary lines, respectively. Sec = Section, T = Township, R = Range.

Example: well 1 is located 590 feet south and 129 feet west of the midpoint of the east boundary line of section 25 in Township 39 South, Range 13 West, relative to the Salt Lake 1855 Base Line and Meridian.

Table 2. *Springs in the Pintura quadrangle[1].*

ID[2]	Name	CFS[3]	Point of Diversion[4]	Sec[4]	T[4]	R[4]
1	Deer Spring	0.013	N 4000 E 2400 SW	28	39S	13W
2	Blue Spring	0.015	N 2000 W 300 SE	19	40S	13W
3	Unnamed Spring	0.018	N 2600 W 2900 SE	31	40S	13W
4	Unnamed Spring	0.089	S 3070 W 1833 NE	5	41S	13W
5	Unnamed Spring	0.089	S 3145 W 1790 NE	5	41S	13W
6	Unnamed Spring	0.089	S 3210 W 1783 NE	5	41S	13W
7	Danish Ranch Domestic Spring/Stream	1.500	S 20 E 340 NW	4	41S	13W
8	Danish Ranch Domestic Spring/Stream	1.500	N 345 W 2120 E4	33	40S	13W
9	Toquerville Springs	1.970	N 2125 E 735 S4	35	40S	13W

Notes

1. Data from Utah Division of Water Rights (http://nrwrt1@state.ut.us).

2. Corresponds to number on figure 2.

3. Water right in cubic feet per second.

4. Location is given in "Point of Diversion" notation. Sec = Section, T = Township, R = Range. Example: spring 1 is located 4,000 feet north and 2,400 feet east of the southwest corner of section 28 in Township 39 South, Range 13 West, relative to the Salt Lake 1855 Base Line and Meridian. N4, S4, E4, and W4 = midpoint of northern, southern, eastern, and western, respectively, section boundary lines.

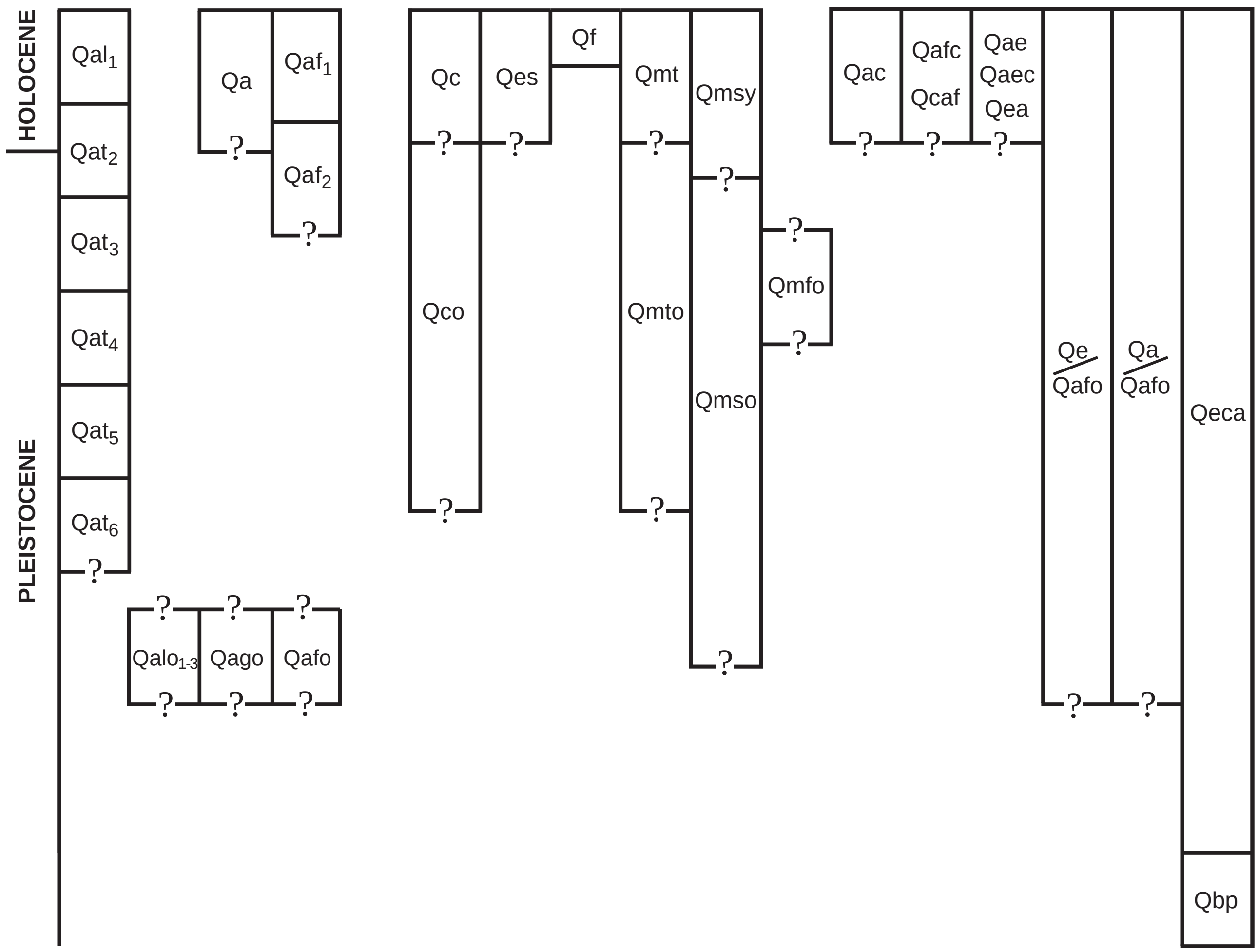
Table 3. Oil-test wells in the Pintura quadrangle[1].

ID[2]	Operator	Well Name	Spot[3]	Sec[3]	T[3]	R[3]	API Number[4]	Year	Elevation (feet)	Depth (feet)	Formation Tops[5]
A	Neptune Explor. Co.	1-25 FEDERAL	2060 FNL 721 FEL	25	39 S	13 W	4305330024	1976	4250	2610	Log not available.
B	Pan American Co.	1 PINTURA UNIT	675 FSL 505 FWL	33	39 S	13 W	4305310879	1962	5272	9501	CHNL 915; SRMP 2635; MNKP 2800; KIBB 4585; QNTP 5390; PKON 6730; CLVL 7470; MSSP 8140; DVNN 8925
C	Sun Oil Co.	1 UNIT	398 FSL 872 FWL	33	39 S	13 W	4305311164	1951	5250	5496	CHNL 905; SRMP 2550; MNKP 2727; KIBB 4998
D	Pease Oil & Gas Co.	1-13 FEDERAL	1625 FNL 1140 FWL	13	40 S	13 W	4305330007	1972	4351	3171	HRSS 1466; DVNN 3995
E	McCulloch Oil Co.	1 GOVT-WOLF	90 FNL 3515 FWL	23	40 S	13 W	4305310704	1964	3799	7315	FULT 375; MSSP 792; DVNN 1742; FULT 3375; TD IN CMBR
F	Titan Oil Co.	36-C1 STATE	660 FNL 1980 FEL	36	40 S	13 W	4305330003	1969	4200	4124	QNTP 1620; PKON 3180; CLVL 3784
G	Buttes Oil & Gas Co.	Pease Federal #1	3050 FSL 1725 FEL	25	40 S	13 W	4305320318	1967	4340	5236	Log not available.

Notes

1. Data from U.S. Bureau of Reclamation.
2. Corresponds to letter on figure 2a.
3. Location is given as distance in feet from section lines. FNL = from north line, FSL = from south line, FEL = from east line, FWL = from west line.
Sec = Section, T = Township, R = Range, relative to 1855 Salt Lake Base Line and Meridian.
4. Petroleum Information (PI) database number.
5. Data from PI database and UGS unpublished records. Formation tops are in feet. CHNL = Chinle Fm., CLVL = Callville Limestone, CMBR = Cambrian, DVNN = Devonian limestone, FULT = fault plane, HRSS = Horeseshoe Mesa Member of Redwall Limestone (Mississippian), KIBB = Kaibab Limestone, MNKP = Moenkopi Fm., MSSP = Mississippian limestone, PKON = Pakoon Fm., QNTP = Queantoweap Sandstone, SRMP = Shinarump Conglomerate Member of Chinle Fm, TD = total depth.

CORRELATION OF QUATERNARY UNITS



TIME STRAT. UNIT		FORMATION		SYMBOL	THICKNESS in feet (m)	LITHOLOGY
Quaternary		Surficial deposits		Q	0-150+ (0-46+)	
Quaternary		Basalt flows		Qbp	0-1,140 (0-348)	
Miocene	Lower	Pine Valley latite		Tvp	~100 (~30)	
Miocene	Lower	Monzonite of the Pine Valley Mountains		Tip	450+ (137+)	K-feldspar megacrysts
Miocene	Lower	Bauers Tuff Member of Condor Canyon Formation		Tccb	~40 (~12)	Combined as unit Tv on cross section A-A’
Miocene	Lower	Leach Canyon Formation		Tl	~100 (~30)	
Oligocene		Brian Head Formation(?)		Tbh?	~30 (~9)	
Eocene		Claron Formation	upper	Tcu	520 (159)	
Eocene		Claron Formation	lower	Tcl	1,090 (332)	
Paleocene		Canaan Peak Formation		TKcp	≤119 (≤36)	
Cretaceous	Upper	Iron Springs Formation		Kis	3,200+ (975+)	soft-sediment deformation
Jurassic	Middle	Carmel Formation	Paria River Member	Jcpr	360-680 (110-207)	
Jurassic	Middle	Carmel Formation	Crystal Creek Member	Jccc	130-190 (40-60)	
Jurassic	Middle	Carmel Formation	Co-op Creek Limestone Member	Jcco	360-450 (110-137)	
Jurassic	Lower	Temple Cap Formation		Jtc	0-50 (0-15)	gypsum

TIME STRAT. UNIT		FORMATION		SYMBOL	THICKNESS in feet (m)	LITHOLOGY
Jurassic	Lower	Navajo Sandstone		Jn	~2,300 (~701)	High-angle cross beds Transition zone
		Kayenta Formation		Jk	455+ (139+)	
		Moenave Formation	Springdale Sandstone Member	Jms	100 (31)	Combined as unit Jm on cross section A-A'
			Whitmore Point Member	Jmw	60 (18)	
			Dinosaur Canyon Member	Jmd	200 (61)	
Triassic	Upper	Chinle Formation	Petrified Forest Member	Ꞧcp	400 (121)	
			Shinarump Conglomerate Member	Ꞧcs	120 (37)	
	Middle	Moenkopi Formation	upper red member	Ꞧmu	200 (61)	
	Lower		Shnabkaib Member	Ꞧms	350 (107)	gypsum
			middle red member	Ꞧmm	200 (61)	
			Virgin Limestone Member	Ꞧmv	120-270 (37-82)	
			lower red member	Ꞧml	250-315 (76-96)	
			Timpoweap Member	Ꞧmt	50-180 (15-55)	
			Rock Canyon Conglomerate Member	Ꞧmr	0-96 (0-29)	
Permian	Lower	Kaibab Formation	Harrisburg Member	Pkh	120-180 (37-55)	gypsum white chert
			Fossil Mountain Member	Pkf	240-280 (73-85)	brachiopods
		Toroweap Formation	Woods Ranch Member	Ptw	120-250 (37-76)	
			Brady Canyon & Seligman Members	Ptbs	250-285 (76-87)	
		Queantoweap Sandstone	upper member	Pqu	1,300-1,630 (396-497)	
			lower member	Pql	120-800 (37-244)	
		Pakoon Formation		Pp	300 (91)	
Pennsylvanian		Callville Limestone		PPc	285 (87)	Shown only on cross section A-A'
Mississippian		Redwall Limestone		Mr	1,220 (372)	
Devonian		Devonian, undivided		Du	570+ (174+)	

Map Symbols

- Contact, dashed where approximately located
- 65 High-angle normal fault, dashed where approximate, dotted where concealed, queried where uncertain; bar and ball on down-thrown side; arrow indicates dip of exposed fault surface
- Low-angle normal fault; open teeth on upper plate
- Thrust fault, dotted where concealed, queried where uncertain; teeth on upper plate
- Axial trace of anticline, showing direction of plunge; dashed where approximate, dotted where concealed
- Axial trace of syncline
- Axial trace of overturned syncline
- 30 Strike and dip of inclined bedding
- 9 Approximate strike and dip of inclined bedding determined from stereoplotter
- Approximate strike and dip direction of inclined bedding
- Strike of vertical bedding
- 52 Strike and dip of overturned bedding
- Pit - sand and gravel
- Quarry - Navajo Sandstone
- Prospect
- Mine shaft
- Spring
- Water well
- Petroleum exploration drill hole - plugged and abandoned
- Sinkhole
- BRN- Sample location and number

Interim Geologic Map of the Pintura Quadrangle, Washington County, Utah

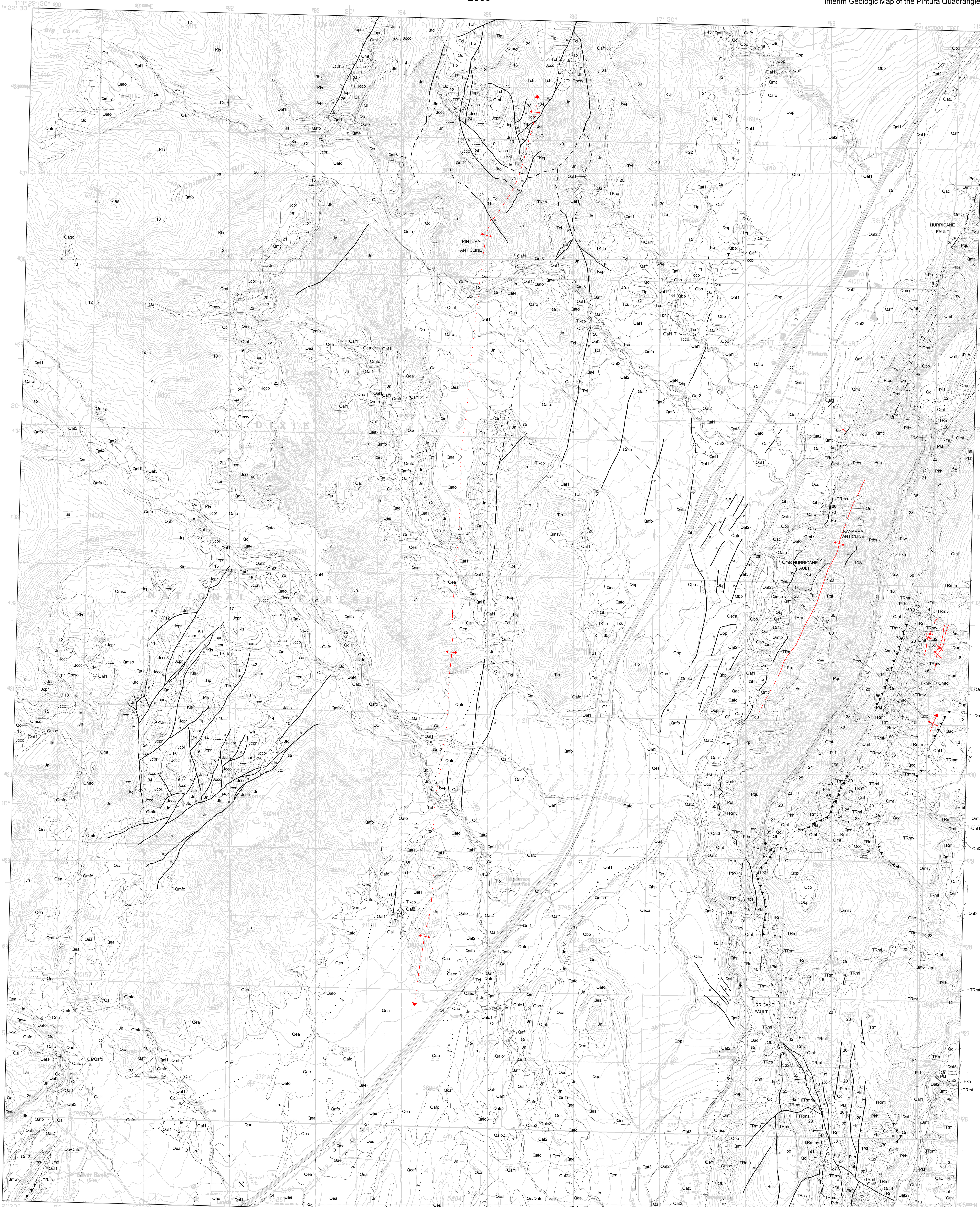
by

Hugh A. Hurlow and Robert F. Biek,
Utah Geological Survey

2000

Utah Geological Survey
a division of
Utah Department of Natural Resources
in cooperation with
U.S. Geological Survey
STATEMAP Agreement No. 99HQAG0138

PLATE 1
Utah Geological Survey Open-File Report 375
Interim Geologic Map of the Pintura Quadrangle



N

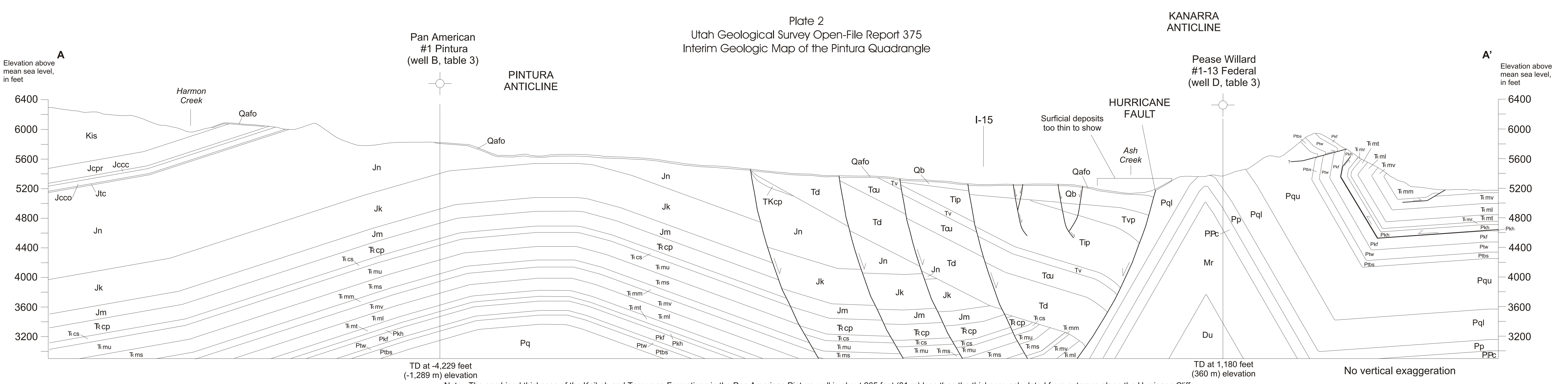
Projection: UTM
Zone: 12
Datum: NAD 27
Spheroid: Clarke 1866

1 0 1 Miles

1 0 1 2 Kilometers

GIS/cartographic preparation by: Kent D. Brown

Plate 2
Utah Geological Survey Open-File Report 375
Interim Geologic Map of the Pintura Quadrangle



Note: The combined thickness of the Kaibab and Toroweap Formations in the Pan American Pintura well is about 265 feet (81 m) less than the thickness calculated from outcrops along the Hurricane Cliffs.