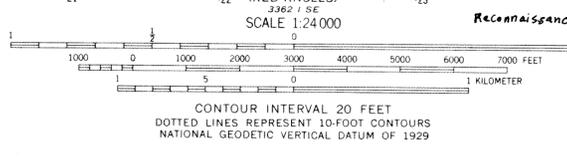
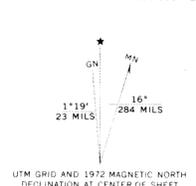


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1000-meter Universal Transverse Mercator grid ticks,
zone 12, shown in blue. 1927 North American datum



Reconnaissance geologic mapping by Lehi F. Hintze 1988-89
Ar/Ar dates received in 2002

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INTERIM GEOLOGIC MAP OF THE
LITTLE DRUM PASS QUADRANGLE,
MILLARD COUNTY, UTAH
by Lehi F. Hintze

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INTERIM GEOLOGIC MAP OF THE LITTLE DRUM PASS QUADRANGLE,
MILLARD COUNTY, UTAH

by
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INTRODUCTION

This quadrangle covers most of the Little Drum Mountains, which is a small northwest-trending range in the Basin and Range Province. The Little Drum Mountains are about six miles (10 km) across at their widest and about 20 miles (32 km) long. The southeastern end of the range is about 20 miles (32 km) west of Delta, Utah (figure 1). Excellent bedrock exposures reveal that the range is almost entirely made up of rocks of volcanic origin – lahars, lava flows, ash-flow tuffs, and volcanic conglomerate and sandstone – that are late Eocene (35 to 39 Ma) in age. These volcanic rocks were likely derived from eruptive centers to the north in the adjacent Drum and Keg Mountains. The Little Drum Mountains were later tilted into a west-dipping homocline during Basin and Range faulting.

The range was previously studied by Leedom (1974) and Pierce (1974), and the adjacent Red Knolls, Smelter Knolls West, and Whirlwind Valley NW and SW quadrangles were mapped by Hintze and Oviatt (1992), Hintze and Oviatt (1993), and Hintze (1981), respectively. Ore deposits to the north in the Drum Mountains have been studied by Crittenden and others (1961), Bailey (1974), Lindsey (1982), Nutt and Yambrick (1989), Nutt and others (1991, 1996), Nutt and Thorman (1992), and Shubat and Snee (1992).

The Little Drum Mountains are too low to induce much precipitation, so they have no springs or perennial streams. Nor do they show overt evidence of economic mineralization (ore), and so have been little prospected. But they do preserve a fine record of 4 million years worth of layered volcanic deposits on the south margin of the Drum-Keg Mountain volcanic centers, as documented by new Ar/Ar dates (table 1) obtained by the Utah Geological Survey from various rock units as described below. Chemical analyses of the igneous rocks are reported in table 2 and the rocks are classified using total-alkali-silica (TAS) plots (figure 2) of Le Bas and others (1986). Using the dates (table 1) with the physical stratigraphy in the quadrangle, the stratigraphic relationships between several units in Little Drum Mountains have been revised from those shown in Hintze and Davis (2002a-b). In particular, I now recognize that rocks I mapped as upper “volcanic sequence of Dennison Canyon” (Hintze and Davis, 2002b) unconformably overlie and are younger than the Red Knolls Tuff; these post-Red Knolls rocks are here informally designated as the “volcanic rocks of Horse Canyon.” Hintze and Davis (2002a-b) do show the regional geologic setting of the Little Drum Pass quadrangle.

DESCRIPTION OF GEOLOGIC UNITS

Qaf₁ Post-Bonneville alluvial-fan deposits (Holocene)

These fans consist of poorly sorted, coarse- to fine-grained alluvium of ephemeral washes in channels and alluvium, sheetwash, and flows in fans on piedmont slopes. These deposits obscure, and the washes cut the Bonneville shoreline of latest Pleistocene Lake Bonneville. The distal parts of these fans are composed of silt and sand reworked from lacustrine deposits of Lake

Bonneville. Gravel in these deposits (pebble, cobble, and boulder) increases upslope. Small areas of Qaf₁ are included within areas mapped as Qla if they cannot be shown at a scale of 1:24,000. The thickness of these fans is generally less than 10 feet (3 m).

Qaf₂ Pre-Bonneville alluvial-fan deposits (late and middle Pleistocene)

These fans are composed mostly of poorly sorted, coarse-grained debris, and form dissected (inactive) remnants that overlie Tertiary volcanic rocks above the Bonneville shoreline of latest Pleistocene Lake Bonneville. The Bonneville shoreline is locally cut into these fans (note on plate 1), and these fans are therefore pre-latest Pleistocene in age. In some dry washes on the Whirlwind Valley side of the Little Drum Mountains, stage III pedogenic carbonate is present a few feet below the surface of these fans. The work of Machette (1985) on pedogenic carbonate to the south near Beaver, Utah, implies these fans are as old as middle Pleistocene. The pre-Bonneville alluvial-fan deposits thicken valleyward to several hundred feet. A possible pediment surface under Qaf₂ is reflected in low-relief outcrops of Drum Mountains Rhyodacite (Tdr) in the northeast and northwest parts of the quadrangle. The rhyodacite typically has high-relief exposures. Similar low-relief is apparent on units Th₂ and Trk on the west margin of the Little Drum Mountains.

Qla Lacustrine and/or alluvial gravel (Holocene and Pleistocene)

Thin lacustrine gravel deposits overlie pre-Lake Bonneville alluvial fans on the piedmont of the Little Drum Mountains. Deposits mapped as Qla are below the Bonneville shoreline and are pre-Lake Bonneville alluvial-fan deposits mantled by a thin cover of lacustrine gravel. This

unit has been mapped where it is difficult to map fan and lacustrine deposits separately. This lacustrine gravel was reworked from the coarse-grained fans by waves and currents during the transgressive phases of Lake Bonneville. The gravel is moderately well rounded and sorted, and locally contains gastropods; it generally varies from pebbly sand and silt to sandy pebble gravel. In some areas the lacustrine-gravel component of Q1a is so thin it cannot be easily distinguished from the pre-Bonneville alluvial-fan gravel on which it lies. But Lake Bonneville shorelines, which are visible on aerial photographs, are “etched” across the pre-Bonneville alluvial fans, indicating that waves in Lake Bonneville modified the alluvial-fan surfaces, and that post-Bonneville fluvial activity has been negligible in these areas. This unit is less than 10 feet (3 m) thick.

Q1g Lacustrine gravel (latest Pleistocene)

This beach gravel was deposited on or just below the highest (Bonneville) shoreline of Lake Bonneville about 15,000 years ago. The unit consists of fine- to coarse-grained sand and gravel in small beaches; gravel content is generally 50 to 65 percent and made up of subangular to rounded pebbles and cobbles. Deposit thickness is less than 15 feet (5 m) in the quadrangle. In the Little Drum Pass quadrangle, Currey (1982) placed the Bonneville shoreline at an elevation of 5,179 feet (1,579 m) (beach ridge in SE corner of section 26, T. 16 S., R. 11 W.) and Fitzhugh Davis (written communication, 1992) placed it at 5,177 feet (1,578 m) (small V-bar in SE corner of quadrangle).

Q1l Lagoon fill (latest Pleistocene)

These are light-colored, poorly bedded deposits of silt, sand, and clay that filled small lagoons behind Lake Bonneville shoreline barrier beaches. The fill was mostly deposited about 15,000 years ago, when the beach gravels were deposited. Thickness of the fill is less than 10 feet (3 m).

Qmc Colluvium (Holocene and Pleistocene)

These deposits are unconsolidated angular debris and talus that accumulated at the base of steep slopes. The deposits are up to 30 feet (10 m) thick.

Volcanic rocks of Horse Canyon (new name) (Eocene)

This informal unit is here introduced and named for Horse Canyon in this quadrangle; it contains three informal members (Th₃, Th₂, and Th₁). A new name and unit are needed because I now recognize that the “volcanic sequence of Dennison Canyon,” as used in Hintze and Davis (2002b), both overlies and underlies the Red Knolls Tuff. The volcanic rocks of Horse Canyon are isotopically and stratigraphically younger than the Red Knolls Tuff. Unit 2 (Th₂) unconformably overlies the Red Knolls Tuff. The “volcanic sequence of Dennison Canyon,” as revised here, underlies and is isotopically older than the Red Knolls Tuff.

Leedom (1974) and I differ in the mapped distribution of these volcanic units. Our map differences may reflect the fact that I had color aerial photographs and his were black and white, and also that I am primarily a stratigrapher, while he was searching for volcanic vents in the Little Drum Mountains (Leedom, 1974). He concluded that vents for these units were in the Little Drum Mountains and I came to believe that the source vents lay in the Drum-Keg

Mountains area north of the quadrangle. The relatively low silica content of these latitic rocks (table 2) implies they could have flowed away from vents to the north, rather than accumulating near vents. But, the clastic rocks below the lava flows look similar to near-vent pyroclastic rocks below the rhyolitic Topaz Mountain Rhyolite (Lindsey, 1979, 1982) and rhyolite of Keg Mountain (Shubat and others, 1999). A half-day field examination by Jon K. King failed to resolve the vent locations.

Th₃ Unit 3, lava flow or flows

Leedom (1974) mapped this as part of his unit Tl₃, hornblende pyroxene latite, which he described as follows: “Dark gray to black, glassy, flow-banded, massive, platy-jointed; interbedded with flow breccias, oxidized blocks in pink-red, white, or orange matrix; phenocrysts of 20% plagioclase, 5% hornblende, 4% augite, hypersthene in pilotaxitic to trachytic groundmass [unoriented to subparallel microlites] of plagioclase, alkali feldspar, pyroxenes, oxides.”

Ar/Ar sample #6 from unit 3 (section 3, T.16 S., R.11 W.) yielded the youngest date in the quadrangle, 35.1 ± 2.1 Ma (table 1), and chemically the sample is a latite (table 2, figure 2). The thickness of Th₃ is about 300 to 400 feet (90-120 m) in its north exposure and thins southward to about 250 feet (75 m).

Th₂ Unit 2, lava flow and tuff

Map unit Th₂ includes parts of Leedom’s (1974) units Tl₃ and Tl₂; most of his general description given above for his Tl₃ applies to unit Th₂, although phenocryst percentages vary and hornblende may not be present. I placed the contact between units Th₃ and Th₂ at the base of the cliffs and crags of unit Th₃ that overlie and protect from erosion a less-resistant, tuffaceous upper

part of unit Th₂. The lower part of Th₂ is a lava flow and its flow breccia. The tuffaceous part of unit 2 is locally missing near the north margin of the quadrangle. The map shows that unit Th₂ is typically about 150 feet (45 m) thick, but is thickest, up to 250 feet (75 m) thick, just south of the north edge of the quadrangle. The southward thinning of Th₃ and Th₂ supports a vent area to the north.

Th₁ Unit 1, clastic volcanic rocks

Map unit Th₁ covers nearly the same area as Leedom's (1974) unit Tvb, vitrophyre breccia, which he described as poorly-sorted angular to sub-rounded fragments (lapilli to blocks up to 2 feet [60 cm] across) of black vitrophyre (welded tuff) and lava flows in pink to pink-orange matrix of phenocrysts, and lithic and pumice fragments. The lava-flow clasts are from the underlying unit (conglomerate Td₂).

In Horse Canyon, the lowest exposures of the unit look like a clast-supported volcanic breccia, with the pinkish matrix having the same phenocrysts and groundmass as the pinkish clasts. Higher upsection the unit looks like the conglomerate of Dennison Canyon, with angular to rounded clasts floating in a white to light pink and locally orange matrix. Near the top of unit Th₁ in Horse Canyon, the vitrophyre and lava-flow clasts are more abundant, but still matrix supported, and at the top look like the vitrophyric and devitrified lava at the base of the overlying lava flow (Th₂). Near the top of unit 1 is a zone that is orange-weathering and more resistant to erosion than underlying and overlying unit-1 rocks, possibly due to welding when heated by the overlying lava flow (Th₂).

The pinkish-orange unit 3 shows prominently on color aerial photos, in contrast to the drab greenish-gray tones of most adjacent units. It also is less resistant than adjacent units and

forms slopes, except where the orange, resistant zone has not been eroded away. It is up to about 200 feet (60 m) thick.

Trk, Trkv Red Knolls Tuff (Eocene)

This tuff was named by Hintze and Davis (1992) for its occurrence in the nearby Red Knolls quadrangle. It is a light-gray to grayish-orange-pink, crystal-rich, moderately resistant, dacitic, variably welded ash-flow tuff that contains 10 to 30 percent lithic fragments, mostly of volcanic rocks of similar composition. Phenocrysts make up about half of the matrix and are, in decreasing order of abundance: plagioclase, biotite, quartz, hornblende, and a trace of bright-green augite. UGS sample #8 from the Little Drum Pass quadrangle is chemically an andesite (table 2, figure 2). Pierce (1974) and Leedom (1974) incorrectly correlated this tuff with tuff in the Needles Range Formation that is younger.

A new Ar/Ar age, obtained from sample #8 (section 11, T. 16 S., R.11 W.), is 36.48 ± 0.12 Ma (table 1). Because unit Trk includes clasts of Mt. Laird Tuff to the north in the Drum Mountains (Lindsey, 1982), it is listed as younger than the Mt. Laird intrusive dikes (Timl). A black vitrophyre at the base of this tuff is labeled Trkv on the map. The combined thickness of Trk and Trkv is not certain in this quadrangle. The Red Knolls could be about 800 feet (240 m) thick, if the unit dips 10 degrees west; or only 235 feet (72 m) thick, if the unit dips 3 degrees west. The Red Knolls Tuff is only 210 feet (64 m) thick just to the south in the Red Knolls quadrangle type section (Hintze and Davis, 1992). The location of the source of the Red Knolls Tuff, likely a caldera, is not known, but may be in the Drum/Keg Mountains area (Lindsey, 1982, p. 23).

Timl Mt. Laird intrusive dikes (Eocene)

Two dikes in the northwest corner of this quadrangle are likely part of the Mt. Laird Tuff, a regionally extensive unit consisting of ash-flow tuff, tuff breccia, lapilli tuff, flow rocks, and hypabyssal (shallow) intrusive rocks (Lindsay 1979, 1982). Leedom (1974) mapped and described a similar dike to the north in the Lady Laird Peak quadrangle. Utah Geological Survey sample #3 from a dike in the Little Drum Pass quadrangle gave an Ar/Ar age of 37.07 ± 0.28 Ma (table 1), but this dike cuts the Drum Mountains Rhyodacite near where it was dated at 36.68 ± 0.22 Ma (sample #4, table 1 and plate 1). Nutt and others (1996) reported 36.3 ± 0.1 and 36.4 ± 0.1 Ma Ar/Ar ages for Mt. Laird tuff, and several reliable Ar/Ar ages from Mt. Laird intrusives: 36.8 ± 0.1 (oldest) to 36.0 ± 0.1 (youngest) (revised ages are in table 1).

The dikes in this quadrangle are brownish to pinkish gray porphyry with 10% phenocrysts of white feldspar, as much as 0.3 inches (7 mm) long, and lesser mafic (dark) minerals. The biotite phenocrysts are less than 0.04 inches (1 mm) in diameter. Chemically UGS sample #3 is an andesite (table 2, figure 2). The dikes have red borders, likely due to oxidation and heating during intrusion.

Tdr Drum Mountains Rhyodacite (Eocene)

This formation was named by Lindsey (1979), and its type locality was rather broadly identified as being in sections 32, 33, and 34, T.14 S., R. 11 W. of the adjacent Lady Laird Peak quadrangle, some 5 miles (8 km) north of this quadrangle in Juab County. Lindsey (1979, 1982) characterized the rock as including rusty-brown weathering, dark rhyodacite lava flows and flow breccias with phenocrysts of intermediate-composition to calcic plagioclase and pyroxene in an

aphanitic to glassy matrix. According to Lindsey (1979, 1982), the rock is modally a hypersthene andesite, but chemical analyses show the rock to range from rhyodacite to quartz latite. That is, the rock chemistry is more silica rich than the phenocrysts indicate. However, the two samples (UGS #4 and 5) analyzed from the Little Drum Pass quadrangle are chemically andesite (table 2, figure 1). Lindsey (1982) reported a single fission track age of 41.8 ± 2.3 Ma. This age was superseded by Ar/Ar ages reported by Nutt and others (1996) and revised in Table 1: 36.9 ± 0.4 Ma from a sample within the formation, and 37.6 ± 0.2 Ma from a sample at its base.

Additional Ar/Ar ages were obtained in 2002 by the Utah Geological Survey from two samples from this quadrangle: sample #4 gave an age of 36.68 ± 0.22 Ma, and sample #5 gave an age of 36.93 ± 0.22 Ma (table 1). The overlap in age with volcanic sequence of Dennison Canyon (~ 36.7 to 37.5 Ma) and andesitic chemistry suggests these rocks are intercalated, and the andesitic/latitic flows in the Dennison Canyon might be thinner, distal tongues of the multiple lava flows that make up the Drum Mountain Rhyodacite. Unit Tdr is about 1,000 feet (300 m) thick in the Little Drum Pass quadrangle.

Volcanic sequence of Dennison Canyon (Eocene)

This unit was informally named for Dennison Canyon in the Little Drum Pass quadrangle (Hintze and Oviatt, 1993), and, as revised in this paper, still includes all the rocks in and near Dennison Canyon. The revised volcanic sequence of Dennison Canyon includes: a basal tuff (Td₁) and overlying conglomerate, sandstone, and agglomerate (Td₂), with intercalated lava flows (Tdf₂, and Tdf₁), and locally a capping lava flow (Td₃). Leedom (1974) reported a K-Ar age of 38.3 ± 0.4 Ma (corrected), but it is not certain exactly what kind of rock was dated. He described

and mapped it as a hornblende-pyroxene shoshonite lava flow and flow breccia (his unit Ts₂). However, most or all of his flow breccia actually appears to be part of the conglomerate of Dennison Canyon (Td₂). If a lava flow is present, it is much thinner than what he mapped (less than 10 feet [3 m] thick), and is only locally present, intercalated within unit Td₂. Leedom's (1974) age is too old if it is from a lava flow in the Dennison Canyon, but is reasonable if a clast in unit Td₂ was dated.

Td₃ Capping lava flow, unit 3

This unit is reddish-brown, dense, aphanitic lava flow and flow breccia that contain pyroxene and amphibole phenocrysts. It is locally exposed in the quadrangle and caps unit 2 (Td₂). The only contact of Td₃ with younger rocks is a fault contact with the Red Knolls Tuff; however nearby, the Red Knolls Tuff overlies unit Td₂. Pierce (1974) reported that “microscopically it [Td₃] contains about 40% phenocrysts of plagioclase, [and lesser] pyroxene, amphibole and oxides enclosed in a hyalopilitic matrix of gray-brown glass and microlitic plagioclase.” Chemically, the flow is an andesite (UGS #9, table 2, figure 2). The Ar/Ar age for sample #9 (section 14, T. 16 S., R.11 W.) from this unit is 36.66 ± 0.37 Ma (table 1). This is the uppermost lava flow in the volcanic sequence of Dennison Canyon. Td₃ is about 100 feet (30 m) thick.

Td₂ Conglomerate of Dennison Canyon, unit 2

Pierce (1974, p. 122) called this unit his “younger laharic breccia” and described its constituents in some detail, noting that it included boulders as much as 7 feet (2 m) in diameter. I prefer to call it a conglomerate because most of its clasts are rounded to subrounded (as shown in Pierce's 1974, p. 123, figures 3 and 4 photographs). Leedom's (1974) photograph (figure 1, p.

83) shows mixed volcanic and sedimentary rocks, that he described as conglomerate, sandstone, debris flow, and tuff. Pierce (1974), at 0 to 200 feet (0-60 m) thick, underestimated the thickness of unit 2; map calculations indicate unit 2 is about 1,200 feet (360 m) thick.

Andesite(?) lava flows are at three levels in the volcanic sequence of Dennison Canyon and are shown on the geologic map as Tdf₁, Tdf₂ and Td₃. Unit Td₂ was likely deposited over about a million years, as determined by Ar/Ar dating of sample #11 (37.47 Ma) from underlying unit Td₁ and dating of sample #9 (36.66 Ma) from overlying unit Td₃.

Tdf₂ Lava flow 2

Leedom (1974) designated this flow as his Tl₂ (pyroxene latite) and upper Tlbf₂ (pyroxene andesite). He described the pyroxene latite as: “dark-gray to black, glassy, flow-banded; gray to gray-brown, massive, platy-jointed; interbedded with flow breccia, oxidized blocks in pink-red to orange matrix; phenocrysts of 40% plagioclase, 10% augite, hypersthene, in hyalohyaline to pilotaxitic [all glass to microlites with no glass] groundmass of plagioclase, alkali feldspar, glass;” and the pyroxene andesite as “gray to gray-brown, massive, platy-jointed; phenocrysts of 35% plagioclase, 15% augite, hypersthene, in hyalopilitic (glass and microlites) groundmass of plagioclase, pyroxenes, oxides, glass.” Leedom (1974) estimated his Tl₂ unit was as much as 500 feet (150 m) thick. Lava flow 2 (Tdf₂) is about 200 feet (60 m) thick and is interlayered in the upper part of Td₂. The thickness discrepancy may be due to Leedom (1974) including part of the conglomerate of Dennison Canyon in his flow breccia, like for his unit Ts₂.

Tdf₁ Lava flow 1

Leedom (1974) designated this as his lower Tlb₂f (hornblende latite) and described it as follows: “dark gray to gray, massive, jointed; phenocrysts of 15% plagioclase, 20% hornblende,

3% augite, [and] hypersthene in pilotaxitic to trachytic groundmass [unoriented to subparallel microlites] of plagioclase, alkali feldspar, [and] oxides.” Lava flow 1 (Tdf₁) is up to 150 feet (45 m) thick and is interlayered with unit Td₂.

Td₁ Basal tuff of Dennison Canyon, unit 1

This poorly welded, ash-flow tuff is Pierce’s “latite tuff Tt₃.” It forms prominent pink cliffs that extend for more than 5 miles (8 km) along the upper east face of the Little Drum Mountains. The potassium-argon age for this tuff in Hintze and Oviatt (1993) is superceded by the Ar/Ar age of 37.47 ± 0.19 Ma for sample #11 (section 17, T. 16 S., R. 11 W.) (table 1).

Pierce (1974) noted the following composition from thin sections of this tuff: plagioclase, 24%; quartz, 2%; biotite, 5%; amphibole, 2%; pyroxene, 1%; oxides, 1%; lithic fragments, trace; matrix, 65%. Megascopically this tuff has abundant pumice and felsitic lithic fragments. The most common rock fragments are light-gray and of intermediate composition, and contain abundant biotite books up to 0.1 inch (3 mm) in diameter. Biotite is also scattered throughout the matrix of the tuff, and the matrix is white on fresh surfaces. This unit is poorly welded and rather soft. It weathers into honeycomb and small caverns on cliff faces. The tuff attains its maximum thickness of 500 feet (150 m) in section 20 on the west edge of the Smelter Knolls West quadrangle and thins northward to less than 100 feet (30 m). It is at least locally absent in the north part of the Little Drum Pass quadrangle, and unit Td₂ directly overlies the Drum Mountains Rhyodacite (Tdr) and unit 11 of the Little Drum Formation (Tl₁₁). The vent (source) for this tuff is not known.

Little Drum Formation (Eocene)

This formation was formally named and divided into twelve informal members by Hintze and Oviatt (1993) from exposures in the adjacent Smelter Knolls West quadrangle. Only members 12-10 and 8 are exposed in the Little Drum Pass quadrangle. The formation consists of andesitic tuff and volcanic-clast conglomerate that is 1,500 to 2,325 feet (450-708 m) thick in its type section. The formation probably represents deposits from one or more volcanos to the north in the Drum Mountains. Member 2, near the base of the formation has been dated at about 38.5 Ma (UGS #12, table 1).

Tl₁₂ Member 12

Hintze and Oviatt (1993) described this member as: “This thin conglomerate, which separates the prominent ash-flow tuff members Tl₁₁ and Td₁, ranges up to 30 feet (9 m) thick and is composed almost entirely of subrounded cobbles and small boulders of dark-brownish-gray basaltic andesite, many of which are vesicular. This conglomerate is a caprock for a low cuesta at the top of member Tl₁₁. Contact with the underlying member is gradational, with dark igneous cobbles being mixed with reworked tuff in the lower 5 feet (1.5 m) of the conglomerate. Except in this lower tuff-rich zone the conglomerate is unconsolidated and loose where exposed at the surface.” The conglomerate is matrix supported with white tuff.

This unit represents a minor erosional interval between two tuff units, Td₁ (above) and Tl₁₁ (below), whose Ar/Ar ages are 37.47 ± 0.19 Ma and 37.62 ± 0.41 Ma, respectively. On the east-central margin of the Little Drum Pass quadrangle, units Td₁ and Td₂ overlie unit Tl₁₁, and member 12 is not present or not exposed

Tl₁₁ Member 11

Hintze and Oviatt (1993) described this member as: “This partially welded, white, ash-

flow tuff is Pierce's (1974) vitric-lithic tuff Tt₂ which he characterized by the near absence of megascopic phenocrysts and an abundance of white, chalky pumice fragments up to 2 inches (5 cm) long. Pierce gave the modal composition percentages determined from thin sections as follows: plagioclase, 2[%]; quartz, trace; pyroxene, 1[%]; oxides, 1[%]; lithic fragments, 21[%]; [and] matrix, 75[%]. The lithic fragments include pyroxene and hornblende andesite, and more rarely, quartzite pebbles. Chemically the tuff is a rhyolite (UGS #10, table 2, figure 2). Magnetic polarity of this member is normal. The member ranges from 0 to 200 feet (0-60 m) thick, pinching out towards the north." The Ar/Ar age of member 11, as determined from sample #10 (section 29, T.16 S., R.10 W.), is 37.62 ± 0.41 Ma (table 1); this age supercedes the fission-track age reported by Hintze and Oviatt (1993).

Tl₁₀ Member 10

This conglomerate resembles member 8, except that it lacks quartzite cobbles and boulders, being made up almost entirely of reddish-brown-weathering basaltic andesite clasts as much as 3 feet (1 m) in diameter in a poorly cemented sandy grit matrix. Two-thirds of the clasts are vesicular; most are subrounded to subangular, and a few are angular. No bedding or sorting is evident. Member 10 is as much as 220 feet (67 m) thick.

Tl₉ Member 9, not exposed in the Little Drum Pass quadrangle.

Tl₈ Member 8

Hintze and Oviatt (1993) described this member as: "As much as half of the large clasts [that constitute the bulk of this conglomerate] are rounded cobbles and boulders of quartzite; the remainder are subrounded to subangular clasts of volcanic rocks, mostly dark-brownish or greenish-gray andesite. Boulders range up to 3 feet (1 m) across but most are 6 to 8 inches (15-

20 cm). Matrix is mostly comminuted volcanic rock but also includes small, rounded quartzite pebbles. A few of the igneous clasts look like Mt. Laird Tuff, suggesting that this material may have been derived from the Drum Mountains to the north. However, the Mt. Laird Tuff (at 36-37 Ma) is actually isotopically younger than member 11 (~37.5 Ma) (table 1) and member 11 overlies member 8. This conglomerate (member 8) is not consolidated, and no bedding or other means of determining its direction of transport are evident. It is about 250 feet (76 m) thick along the type section traverse.”

Tbp Pyroxene latite of Black Point (Eocene)

This unit was named for Black Point, shown on the Whirlwind NW quadrangle (Hintze, 1981) and the Little Drum Pass quadrangle. This unit is a dark-gray lava flow that contains abundant plagioclase, clinopyroxene, and orthopyroxene phenocrysts in a fine intergranular to intersertal (glass and small crystals) matrix of the same minerals plus Fe-Ti oxides and, for intersertal matrix, glass. Phenocrysts are corroded and have conspicuous glass inclusions. A sample of this unit (UGS #2) is chemically a latite (table 2, figure 2). Sample #2, from the northwest corner of this quadrangle, gave an Ar/Ar groundmass age of 38.80 ± 0.43 Ma (table 1). An earlier sample from the same locality yielded a K-Ar age of 52.2 ± 3.2 Ma, determined on a plagioclase concentrate analyzed by Krueger Enterprises of Cambridge, Massachusetts in December, 1989; this age is anomalous because no other ages this old have been confirmed for volcanic rocks in this part of Utah. This latite appears to be the oldest volcanic rock exposed in the Little Drum Mountains (table 1). But its relationship to the adjacent Drum Mountains Rhyodacite is not clearly exposed. Along its northeast side in the Lady Laird Peak quadrangle, it

is bounded by a lineament that may be a fault or depositional contact with the Drum Mountains Rhyodacite. This lineament is not shown on Hintze and Davis (2002b). The pyroxene latite of Black Point is at least 1,000 feet (300 m) thick and covers about 10 square miles (26 km²) west of the lineament in the Topaz Mountain SW, Whirlwind Valley NW, Lady Laird Peak, and Little Drum Pass quadrangles.

€pc Pierson Cove Formation (Cambrian)

The upper part of the Pierson Cove Formation is exposed in the northeast corner of this quadrangle where it is unconformably overlain by the Drum Mountains Rhyodacite. The Pierson Cove is a dark-gray, medium- to thick-bedded limestone that is about 800 feet (245 m) thick and commonly dolomitized in the Drum Mountains (Dommer, 1980).

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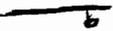
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MAP SYMBOLS

-  contact
-  fault - dashed where approximately located; dotted where concealed; bar and ball on downthrown side where sense of offset known.
-  fault - dashed where approximately located; dotted where concealed; bar and ball on downthrown side where sense of offset known.
-  fault - dashed where approximately located; dotted where concealed; bar and ball on downthrown side where sense of offset known.
-  lineament
- Bonneville-level shoreline -
-  well located
-  approximately located
-  inferred from elevation and scattered lacustrine exposures
-  concealed by younger deposits or eroded away, location based on elevation
-  strike and dip of bedding in sedimentary rock
-  strike and dip of foliation in igneous rock
-  sample location, this report
-  sample location, Leedom (1974)

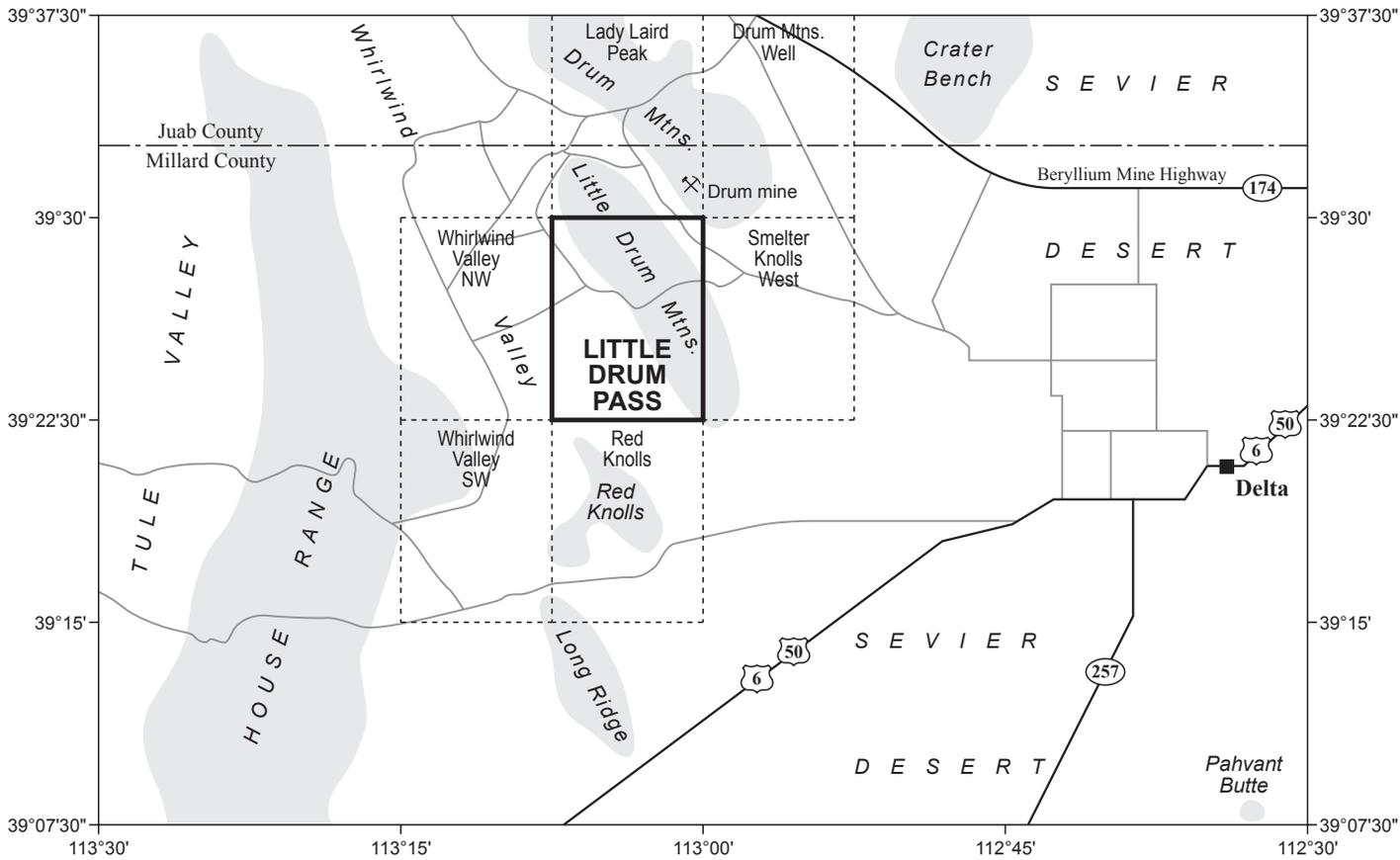


Figure 1. Map showing location of the Little Drum Pass quadrangle and the previously mapped Smelter Knolls West (Hintze and Oviatt, 1993), Red Knolls (Hintze and Davis, 1992), and Whirlwind Valley NW and SW (Hintze, 1981) quadrangles with respect to nearby mountains and valleys. Paved roads are solid lines; selected graded roads are gray lines.

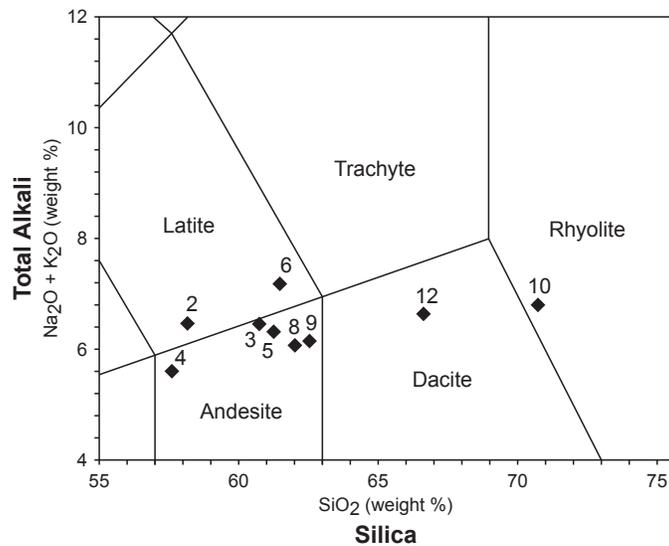
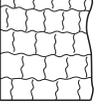
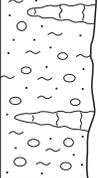
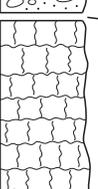


Figure 2. Total alkali and silica plot for UGS samples (rock type fields from Le Bas and others, 1986; plot from Eric Christiansen, Brigham Young University). UGS 11 not plotted because high LOI (loss on ignition) (table 2) indicates alteration.

LITHOLOGIC COLUMN

AGE	FORMATION OR UNIT NAME	SYMBOL	THICKNESS Feet (Meters)	LITHOLOGY	NOTES		
E O C E N E	Volcanic rocks of Horse Canyon	Unit 3	Th ₃	250-400 (75-120)		Lava flow(s) 35.1 ± 2.1 Ma	
		Unit 2	Th ₂	~200 (~60)		Mostly lava flow	
		Unit 1	Th ₁	<200 (<60)		Conglomerate and volcanic breccia	
	Red Knolls Tuff		Trk	est. 235 (72)		36.48 ± 0.12 Ma Trkv-vitrophyre at base	
	Drum Mountains Rhyodacite		Tdr	~1,000 (~300)		Multiple lava flows. 36.68 ± 0.22 and 36.93 ± 0.22 Ma, and intruded by Timl at 37.07 ± 0.28 Ma, and 37.6 ± 0.2 Ma at base. Overlaps ages of Dennison Canyon.	
	Volcanic Sequence of Dennison Canyon	Unit 3	Td ₃	~100 (~30)		36.66 ± 0.37 Ma, lava flow	
		Unit 2, conglomerate	Td ₂	~1,200 (~360)		Td _{f2} lava flow Conglomerate, sandstone, debris flow, and tuff Td _{f1} lava flow	
		Unit 1, basal tuff	Td ₁	100-500 (30-150)		Light pink tuff 37.47 ± 0.19 Ma	
		Little Drum Formation	Member 12	Tl ₁₂	0-30 (0-9)		Conglomerate
			Member 11	Tl ₁₁	0-200 (0-60)		White tuff, 37.62 ± 0.41 Ma
	Member 10		Tl ₁₀	0-220 (0-67)		Andesite clasts	
	Member 9		Tl ₉	0-50 (0-15)*		Not exposed, tuff Quartzite and andesite cobbles and boulders	
Member 8		Tl ₈	250 (75)		Not in contact		
Pyroxene latite of Black Point		Tbp	1,000 (300)*		Lava flow(s) 38.80 ± 0.43 Ma		
C.A.M.	Pierson Cove Formation		Cpc	800 (245)*		Angular unconformity Limestone	

*Total thickness in adjacent quadrangle

All dates Ar/Ar, Table 1

LITTLE DRUM PASS

9-9-03

LITTLE DRUM PASS QUADRANGLE CORRELATION CHART

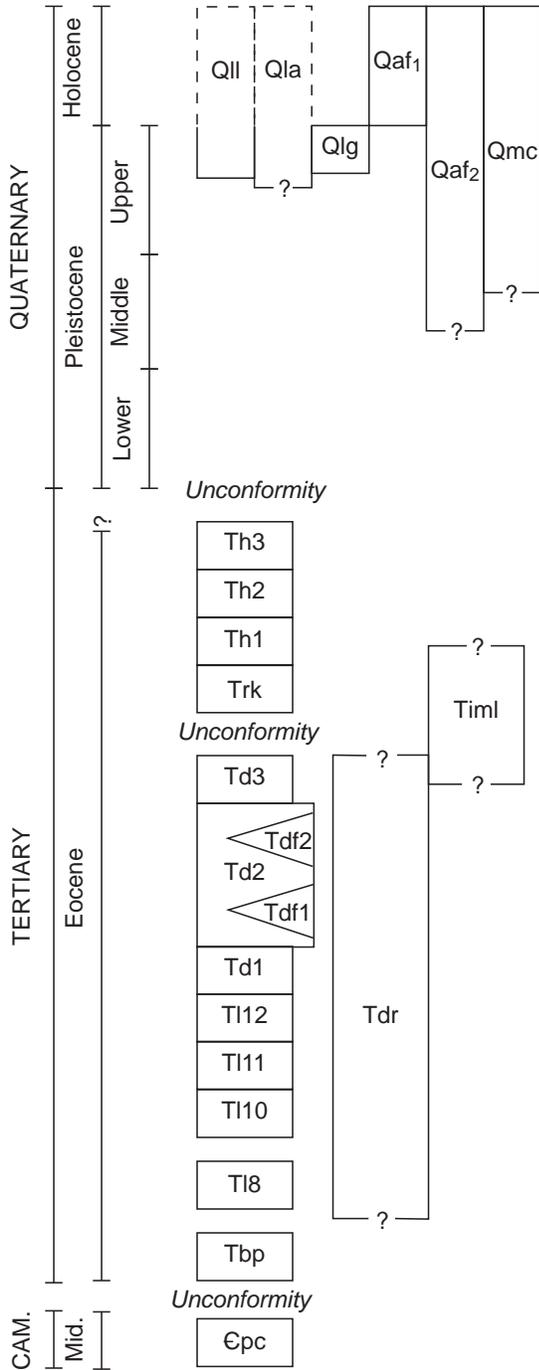


Table 1. Summary of $^{40}\text{Ar}/^{39}\text{Ar}$ ages from Little Drum and Drum Mountains, Juab and Millard Counties, Utah. Listed by stratigraphic position and then date; Drum Mountains Rhyodacite and volcanic sequence of Dennison Canyon are coeval. Ages in Little Drum Mountains from this report (UGS sample number prefix); analyses by New Mexico Geochronology Research Laboratory, Internal report # NMGRL-IR-238; and samples collected by Lehi F. Hintze. Ages in Drum Mountains are from C.J. Nutt and L.W. Snee (U.S. Geological Survey, written communication, October, 2003) (sample numbers marked with *); analyses by L.W. Snee at Argon Laboratory, U.S. Geological Survey, Denver, Colorado.

Sample number	Unit (map symbol)	Mineral	Date and error (Ma)	Notes	Location: Latitude, Longitude (UGS sample locations shown on plate 1)
UGS 6	Latite of Horse Canyon, top unit (Th_3)	hornblende, single crystal	35.1 ± 2.1	Underlying unit (Th_2) overlies Red Knolls Tuff	39° 27' 51" N 113° 04' 16" W
EMD-1-293*	Mt Laird(?) porphyry, core	biotite	$\sim 36.0 \pm 0.1$	Slightly disturbed	39° 33' 16" N 113° 01' 18" W
89DM-458*	Mt. Laird(?) porphyry; altered felsite dike	muscovite	$\sim 36.0 \pm 0.1$	Slightly disturbed	39° 32' 56" N 113° 01' 46" W
UGS 8	Red Knolls Tuff (Trk)	hornblende biotite	36.47 ± 0.81 36.48 ± 0.12	Unit overlies Mt Laird Tuff in Drum Mountains	39° 26' 05" N 113° 03' 43" W
87DM-251a*	Red Knolls Tuff of Hintze and Davis (2002b)	hornblende	36.5 ± 0.3	From mineralogy and lithology, might be Mt Laird Tuff	39° 32' 03" N 113° 00' 08" W
88D178*	Mt Laird Tuff	hornblende biotite	36.3 ± 0.1 36.4 ± 0.1	Type area	39° 34' 34" N 113° 03' 20" W
87DM-215a*	Mt Laird(?) porphyry; dike	hornblende	36.8 ± 0.1	Martha mine area	39° 33' 18" N 113° 02' 14" W
89DM-416*	diorite of Nutt and Yambrick (1989); likely composite stock	hornblende	36.9 ± 0.1	Possible excess Ar; Drum Mts diorite of Hintze and Davis (2002a)	39° 32' 13" N 112° 59' 25" W
HS-86-9*	Mt Laird(?) porphyry; dike	hornblende biotite	37.2 ± 0.2 36.6 ± 0.1	Slight excess Ar from hornblende; Copperhead mine area	39° 33' 35" N 113° 01' 52" W

Sample no.	Unit (map symbol)	Mineral	Date and error (Ma)	Notes	Location: Latitude, Longitude
UGS 3	Mt Laird intrusive (Timl)	biotite, single crystal	37.07 ± 0.28	Cuts Tdr near UGS 4 sample site	39° 29' 22" N 113° 06' 33" W
UGS 4	Drum Mtns Rhyodacite (Tdr)	hornblende	36.68 ± 0.22		39° 29' 32" N 113° 06' 20" W
88D177*	Drum Mtns Rhyodacite	hornblende	36.9 ± 0.4		39° 34' 32" N 113° 02' 49" W
UGS 5	Drum Mtns Rhyodacite (Tdr)	hornblende	36.93 ± 0.22		39° 27' 42" N 113° 06' 59" W
88D183*	Drum Mtns Rhyodacite, base	hornblende	37.6 ± 0.2	Contact with Tbp nearby; may represent age of part of Tdr that underlies Td ₁	39° 32' 48" N 113° 06' 46" W
UGS 9	Volcanics of Dennison Canyon, top unit (Td ₃)	hornblende	36.66 ± 0.37		39° 25' 08" N 113° 03' 42" W
UGS 11	Volcanics of Dennison Canyon, basal unit (Td ₁)	hornblende biotite	37.05 ± 0.18 37.47 ± 0.19		39° 25' 27" N 113° 00' 18" W
UGS 10	Little Drum Formation, member 11 (Tl ₁₁)	biotite	37.62 ± 0.41		39° 23' 38" N 113° 00' 03" W
UGS 12	Little Drum Formation, member 2 (Tl ₂)	hornblende biotite	38.52 ± 0.60 38.62 ± 0.37	likely not accurate	39° 26' 01" N 112° 58' 38" W
89DM-469*	lithic-rich, muscovite-bearing tuff	muscovite	38.6 ± 0.2	In Drum mine; not seen elsewhere	39° 31' 35" N 113° 00' 31" W
UGS 2	Latite of Black Point (Tbp)	groundmass concentrate	38.80 ± 0.43	Likely not accurate	39° 29' 43" N 113° 07' 28" W

Table 2. Major oxide chemical analyses for samples from the Little Drum Mountains, Millard County, Utah. Listed roughly by age, youngest first; unit Tdr is roughly coeval with units Td3, Tdf2, Tdf1, and Td1. UGS sample locations are given in table 1 and shown on plate 1. L sample number prefixes indicate analyses from Leedom (1974); the locations of these samples are shown on plate 1 and are from Leedom (written communication, 1989). All other analyses were done for this report.

sample no.	map unit	Al ₂ O ₃	BaO	CaO	Cr ₂ O ₃	Fe ₂ O ₃	FeO	K ₂ O	MgO	MnO	Na ₂ O	P ₂ O ₅	SiO ₂	SrO	TiO ₂	LOI	Total
UGS 6	Th3	15.60	0.14	5.41	<0.01	6.17		3.67	1.91	0.12	3.32	0.24	59.81	0.09	0.80	1.91	99.19
L 5-100	Th3	17.24		5.05			4.93	3.52	1.84	0.08	3.02		62.68		0.68	nd	99.14
L 5-101	Th3	17.17		4.23			3.43	3.59	0.87	0.03	3.25		65.93		0.40	nd	98.90
L 5-7	Th1	17.50		4.82			4.51	3.37	1.56	0.13	3.05		61.44		0.50	nd	96.88
UGS 8	Trk	15.78	0.10	4.95	<0.01	6.52		3.07	4.48	0.08	2.82	0.24	60.19	0.07	0.85	2.15	99.18
UGS 3	Tmli	15.11	0.12	5.40	<0.01	7.27		3.48	2.27	0.11	2.78	0.35	58.91	0.11	1.06	2.68	99.65
L 5-52	Tmli	15.23		4.52			5.67	3.76	1.78	0.08	3.13		62.91		0.95	1.51	99.54
UGS 4	Tdr	14.74	0.16	6.96	<0.01	8.35		2.73	3.66	0.12	2.72	0.46	56.07	0.14	1.24	2.19	99.54
UGS 5	Tdr	15.62	0.11	6.82	<0.01	5.26		2.99	2.08	0.11	3.07	0.27	58.82	0.09	0.75	2.71	98.70
L 5-8	Tdr	17.29		6.74		5.20	3.94	2.04	3.59	0.15	3.21		54.54		1.22	nd	97.92
L 5-41	Tdr	16.32		4.88			5.90	3.95	2.91	0.06	3.46		60.48		0.95	nd	98.71
UGS 9	Td3	15.53	0.16	4.96	<0.01	6.27		2.98	2.36	0.10	2.95	0.23	60.32	0.09	0.76	2.04	98.48
L 5-3	Tdf2	18.43		6.16			6.85	2.26	2.69	0.11	3.38		57.08		0.81	nd	97.77
L 5-6	Tdf2	17.35		4.60			4.45	3.43	1.32	0.12	3.11		63.34		0.46	nd	98.18
L 5-2	Tdf1	16.35		5.72			6.29	2.88	2.54	0.12	2.86		59.80		0.08	nd	97.36
UGS 11	Td1	9.37	0.06	24.45	<0.01	3.57		2.03	1.53	0.32	1.37	0.20	37.46	0.04	0.38	18.98	99.76
UGS 10	Tl11	13.09	0.10	2.59	<0.01	2.40		4.14	2.09	0.10	2.08	0.11	64.64	0.05	0.35	8.22	99.57
UGS 12	Tl2	14.41	0.14	4.38	<0.01	3.86		4.10	1.47	0.06	2.17	0.14	62.84	0.14	0.59	4.48	98.78
UGS 2	Tbp	14.77	0.15	6.35	<0.01	7.46		3.45	4.63	0.11	2.91	0.27	57.18	0.08	0.94	1.18	99.48