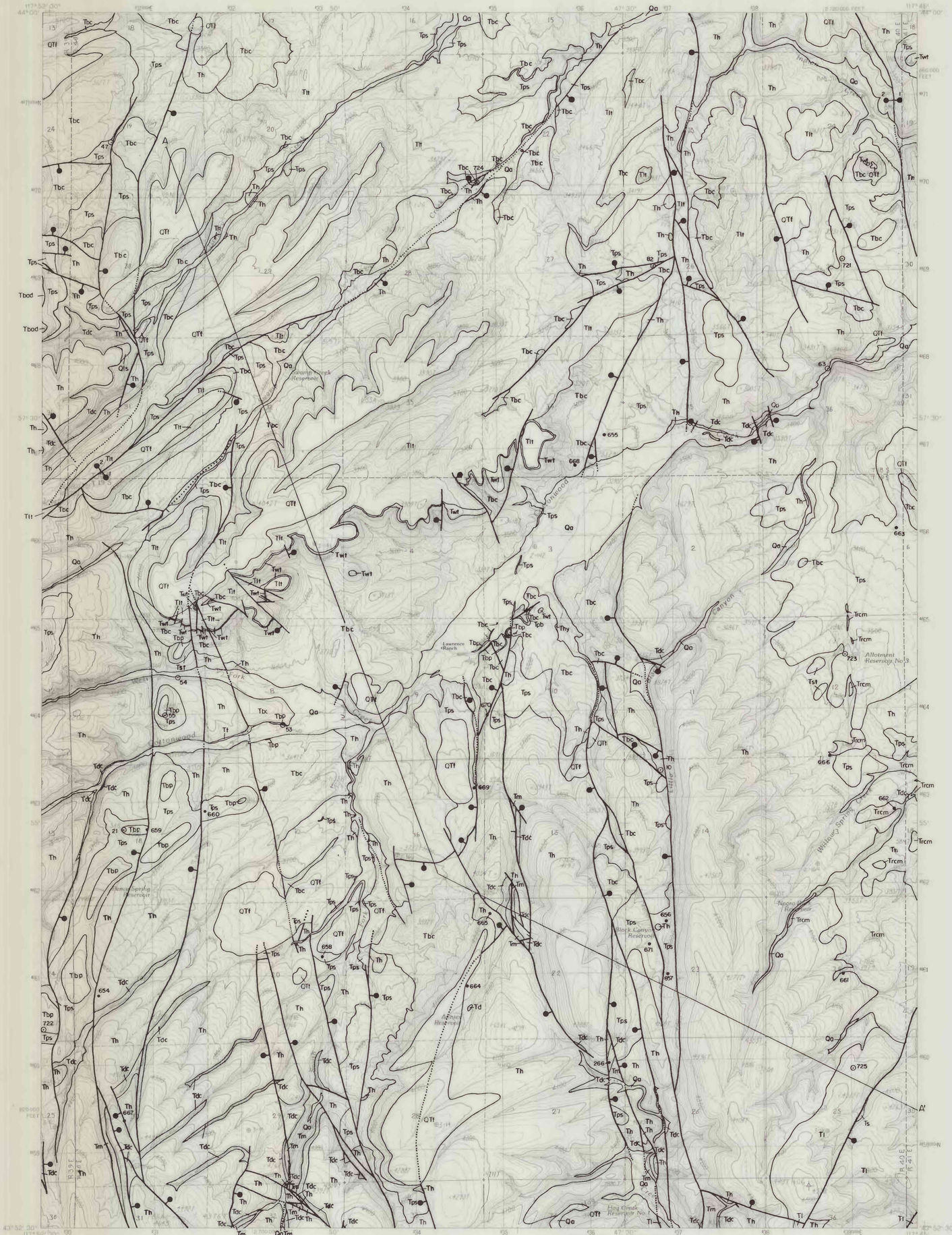
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

OPEN-FILE REPORT 98-493
Pamphlet accompanies map



Base from U.S. Geological Survey, 1990

Lambert conformal conic projection. 1927 North American datum
10,000-foot grid based on Oregon coordinate system, south zone
1000-meter Universal Transverse Mercator grid ticks, zone 11

SCALE 1:24 000

KILOMETERS 0 1 2
METERS 1000 0 1000 2000
MILES 0 1
FEET 1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10 000

CONTOUR INTERVAL 20 FEET

OREGON
QUADRANGLE LOCATION

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1999

Geology mapped in 1990

Manuscript approved for publication on September 9, 1998

CORRELATION OF MAP UNITS

Qa	Quaternary	QUATERNARY
Qls		
QTf	Quaternary and (or) Pliocene and (or) late Miocene	
Twt	middle to late Miocene	
Tbc		
Tlt		
Tbp		
Thy		
Tbad	middle Miocene	TERTIARY
Tps		
Tl		
Ts		
Th		
Tdc		
Trcm		
Tm	early to middle Miocene	

DESCRIPTION OF MAP UNITS

Qa **Alluvium (Quaternary)**—Sand and gravel, most extensive along Cottonwood Creek, its west and south forks, and Swamp Creek. Locally includes slope wash and talus. Unit is at least 6 m thick in the larger drainages

Qls **Landslide deposits (Quaternary)**—Debris that slid from Hunter Creek Basalt see below) and partly covers Dinner Creek Welded Tuff (map unit Tdc; see below) in NW1/4 sec. 31, T. 18 S., R. 40 W.

QTf **Alluvial fan deposits (late Miocene and (or) Pliocene and (or) Quaternary)**—Deposits of angular cobble and boulder gravel that retain alluvial fan morphology. Clasts include Hunter Creek Basalt (map unit Th; see below) and porphyritic basalt (probably from map unit Tbp, see below) as much as 1 m across, Dinner Creek Welded Tuff (see below) as much as 2 m across, and smaller clasts of laminated welded tuff, rhyolite similar to rhyolites of the Westfall Butte Volcanics (Evans and Binger, 1997), and black obsidian (maximum diameter 15 cm) in a matrix of brown sand, silt, and clay. As much as 100 m thick

Twt **Welded tuff (middle or late Miocene)**—White to light-gray, strongly welded ash-flow tuff that contains minor conspicuous black glass shards. Weathers into slabs as much as 3 m across, but generally no more than 30 cm in diameter. Most of rock consists of clear glass shards. Contains 2 percent anhedral phenocrysts of fractured and embayed potassium feldspar and quartz as much as 1 mm long. Secondary hematite is disseminated in the rock. Unit is 3 to 12 m thick. May have erupted from the Westfall Butte volcanic center to the west. Major- and minor-element analyses of a sample of the welded tuff are in tables 2 and 3 (sample 721)

Tbc **Bully Creek Formation (middle to late Miocene)**—Formation named by Kittleman and others (1965). Mostly white to light-gray, locally gray and pale-brown siltstone, tuffaceous siltstone, sandstone, tuff and lapilli tuff and subaqueous ash-flow tuff. In places, formation contains beds of pebbly sandstone, conglomerate, and turbidite as much as 3 m thick. Weathers to white to light gray silty regolith. Poorly to moderately lithified. Well-lithified beds are welded tuff, in part phonolitic, and sandstone cemented by brown hematite or silica. Beds are 1 to 60 cm thick; sandstone beds are locally crossbedded. The conglomerate is poorly bedded or massive. Clasts are angular to subangular and comprise as much as 30 percent of the rock in a light-gray sandy matrix. Clasts include laminated rhyolite similar to rhyolite of the Westfall Butte Volcanics (Evans and Binger, 1997), white and gray felsic material, obsidian, pumice fragments (in part rounded), basalt resembling Hunter Creek Basalt (map unit Th; see below), scoria, and welded tuff resembling Dinner Creek Welded Tuff (map unit Tdc; see below). The largest clast found in the conglomerate is an isolated 1-m-long slab of dark brown hematite-cemented sandstone. Lapilli tuff contains as much as 35 percent lapilli (maximum diameter 15 cm) of white to gray pumice. Tuff contains diatom frustules indicating deposition in a lacustrine environment. Local small-amplitude folding of bedding in tuff and lapilli tuff was probably syndepositional. A subaqueous ash-flow tuff is about 3 m thick and contains angular fragments of thin-bedded tuffaceous siltstone at its base that were likely ripped up from subjacent lacustrine beds. This basal breccia grades up to white to light gray tuff, which is conformably overlain by thin bedded tuffaceous siltstone. This ash-flow tuff could be a marker bed, as similar rocks are found elsewhere in the Bully Creek (Brooks and O'Brien, 1992a; Evans and Keith, 1996; Evans, unpub. mapping, 1994, Swede Flat 7.5' quadrangle). Maximum thickness of the formation is 180 m in the central part of the quadrangle, as suggested on the cross-section. Age is middle to late Miocene regionally; in the quadrangle, the formation is probably middle Miocene, as suggested by stratigraphic relations with middle Miocene units Twt and Tbp (see text)

Tlt **Lapilli tuff (middle Miocene)**—Light-brown, generally poorly indurated lapilli tuff. Weathers to light-brown powdery soil. Contains angular to subrounded lapilli as large as 15 cm of obsidian, white glassy welded tuff similar to welded tuff of the Westfall Butte Volcanics (Evans and Binger, 1997), very fine grained rhyolite, granophyre, rhyolite porphyry, rhyolite (flow?) breccia, perlite, and minor basalt in a matrix of brown chalcedony and clear glass that contains less than 1 percent phenocrysts of plagioclase, quartz, pyroxene, and magnetite. The tuff appears to be unsorted and may be an ash-flow deposit. Maximum thickness of the unit is about 100 m. Similar to unit Tbs of Brooks and O'Brien (1992a)

Tbp **Basalt porphyry sill (middle Miocene)**—Black to gray vesicular, glomeroporphyritic, diktytaxitic basalt that contains as much as 20 percent vesicles, some of which are filled with amygdules of yellow-brown chalcedony. Basalt contains as much as 35 percent phenocrysts mostly of plagioclase as much as 3 mm long, some of which are in clumps as much as 3 cm across. Clinopyroxene is ophitic and forms oikocrysts as much as 3 mm across; in places, the clinopyroxene is nearly opaque in thin section owing to disseminated opaque magnetite and hematite. The groundmass consists of dark brown to opaque glass containing disseminated opaque minerals. Some of the plagioclase is embayed by the glass. Modal composition is: plagioclase 60 percent; clinopyroxene 30 to 40 percent; and glass, including disseminated opaque minerals, as much as 20 percent. Chemical composition is high-alumina basalt (tables 1 and 2, samples 722, 21, 53, and 55). Xenoliths of diatomite are present locally. A 1.5- to 2.5-m-thick dike that originated from the sill intrudes the overlying Bully Creek Formation (unit Tbc, see below) in SW1/4 sec. 3, T. 19 S., R. 40 E. Sill is 6 m thick

Thy **Hyaloclastite (middle Miocene)**—Massive and bedded deposits of mixed white silt and angular clasts of black glass in N1/2 sec. 10, T. 19 S., R. 50 E. Unit interpreted as partly reworked ejecta of a phreatomagmatic eruption of sill-forming basalt (map unit Tbp) into wet sediments of the Bully Creek Formation (map unit Tbc; see below). Unit is at least 3 m thick

Tbad **Basaltic andesite, andesite, and dacite flows (middle Miocene)**—Eastern-most outcrops of dark-gray to black, fine-grained basaltic andesite, andesite, and dacite flows that are widespread in the northern part of the Westfall Butte quadrangle and comprise one member of the Westfall Butte Volcanics (see Evans and Binger, 1997, for detailed description of unit). Outcrops in the Little Black Canyon quadrangle are along the western margin in E1/2 sec 25, T. 18 S., R. 39 E. The flows overlie the pyroclastic and sedimentary rocks unit (map unit Tps; see below), but their stratigraphic relation to the Bully Creek Formation (map unit Tbc) is not known

Tps **Pyroclastic and sedimentary rocks (middle Miocene)**—Mostly light- to dark-gray, blue-gray to blue-black, light- to dark-brown, greenish- and yellowish-brown and locally black and lavender tuff, palagonitic tuff, welded tuff, lapilli tuff, and tuff breccia. The unit also contains subordinate siltstone, lithic sandstone, conglomerate, and arkose, some of which contains muscovite. The pyroclastic beds contain light-brown, brown, red, and red-brown fragments of welded vitric tuff, some of which contains disseminated minute grains of magnetite. Lapilli comprise as much as 60 percent of some beds, and consist of fine grained basalt and basaltic scoria, rhyolite that contains disseminated microcrystalline opaque minerals and (or) spherulites, rhyolite porphyry, devitrified welded tuff, obsidian, and light- to dark-brown pumice. Some welded tuff fragments resemble Dinner Creek Welded Tuff (map unit Tdc; see below); blocks of Dinner Creek as much as 2.5 m across are found in tuff breccia. A 3-m-thick bed of lavender welded tuff breccia in SW1/4 sec.19, T. 18 S., R. 40 E. contains as much as 10 percent angular blocks of gray pumice as much as 1 m across, light-gray rhyolite as much as 1.5 m across and smaller fragments less than 20 cm across of fine grained basalt, possibly the Hunter Creek Basalt (map unit Th; see below). In places, fine-grained basalt fragments as large as 60 cm across comprise most of the lapilli and blocks in lapilli tuff and tuff breccia. Phenocrysts as long as 0.5 mm comprise 1 to 15 percent of pyroclastic rocks and consist of generally anhedral plagioclase, potassium feldspar, quartz, pyroxene, and magnetite. Siltstone is thin bedded (1 to 4 cm). Sandstone and conglomerate are thin to thick bedded (1 to 30 cm), and contain as much as 25 percent angular to subrounded clasts, some in the conglomerate reaching boulder size (maximum 50 cm in diameter). A 2-m-thick sill or dike of very vesicular (40 percent) basaltic andesite (tables 2 and 3, sample 47) intrudes the clastic rocks in SW1/4 sec.19, T. 18 S., R. 40 E. Maximum thickness of the unit in the quadrangle is about 105 m (see cross-section). Basal beds of the unit as much as 4 m thick interfinger with upper flows of the Hunter Creek Basalt (map unit Th; see below) in the overflow channel of Allotment 3 Reservoir, NE1/4 sec. 12, T. 19 S., R. 40 E., and near the SE corner of sec. 21, T. 18 S. R. 40 E., constraining the age of the unit to the middle Miocene age of the Hunter Creek Basalt. The unit is partly correlative with unit Tst in the adjacent Westfall Butte 7.5' quadrangle (Evans and Binger, 1997) to the west and unit Tvt of Brooks and O'Brien (1992a) in the Westfall quadrangle to the east

Tl **Littlefield Rhyolite (middle Miocene)**—Formation named by Kittleman and others (1965). Exposed in southeast corner of the quadrangle where it overlies Hunter Creek Basalt (Th) and the rhyolite of Cottonwood Mountain (map unit Trcm; see below). The Littlefield Rhyolite is lithologically indistinguishable from the rhyolite of Cottonwood Mountain (map unit Trcm; see below) in the field so that, where the Hunter Creek Basalt is not present, separation of the two rhyolite units is difficult. In places, tuffaceous sediments (map unit Ts; see below) are used to separate the rhyolite units. Littlefield Rhyolite is as much as 150 m thick in the southeast corner of the quadrangle, close to its thickness (134 m) in the adjacent South Mountain quadrangle (Evans, 1990b) to the south. Detailed descriptions of the unit are given elsewhere (Evans, 1990a,b). Major- and minor-element analyses of a sample are shown in tables 2 and 3 (sample 725). Age is based on stratigraphic position between middle Miocene units and radiometric ages of Lees ($^{40}Ar/^{39}Ar$ method, 1994)

Ts **Sandstone (middle Miocene)**—Light gray tuff and tuffaceous sandstone as much as 7 m thick in sec. 25, T. 19 S., R. 40 E. Unit is interpreted as a clastic horizon between rhyolite of Cottonwood Mountain and Littlefield Rhyolite. A similar sandstone occurs at Allotment 4 Reservoir about 600 m to the east in the southwest corner of the Westfall quadrangle (Brooks and O'Brien, 1992a, sandstone not mapped)

Th **Hunter Creek Basalt (middle Miocene)**—Formation named by Kittleman and others (1965). Dark-gray to black, very fine grained and glassy, generally aphyric basaltic andesite. Locally very vesicular or scoriaceous in uppermost part of unit. Weathers most commonly to equant angular fragments less than 10 cm across, displays columnar jointing, or forms ledges. At some localities, the formation includes 2-m-thick basal beds of black welded basaltic lapilli tuff that contains minor fragments of fine grained rhyolite and devitrified rhyolitic welded tuff and 2 m of tuffaceous hyaloclastite that contains as much as 75 percent basaltic fragments (maximum diameter 20 cm). Hunter Creek Basalt typically consists of about 5 percent phenocrysts of plagioclase and clinopyroxene as long as 0.5 mm and locally glomeroporphyritic, in a groundmass of plagioclase laths less than 0.3 mm long, interstitial clinopyroxene, and brown to opaque glass. Opacity of the glass in thin sections of some rocks is clearly related to content of minute disseminated opaque mineral grains (magnetite?). Modal composition of the basalt is: plagioclase, 25 to 70 percent: clinopyroxene, as much as 25 percent; and glass, including contained opaque minerals, as much as 50 percent. In places, the unit contains yellow-brown chalcedony amygdules. Major-element composition of samples of this unit is basaltic andesite (tables 1 and 2, samples 723, 724, 10, 54, 63, and 82). The unit appears to be as much as 180 m thick along the ridge east of Little Black Canyon. Age is based on stratigraphic position between middle Miocene units and radiometric ages of Lees ($^{40}Ar/^{39}Ar$ method, 1994)

Tdc **Dinner Creek Welded Tuff (middle Miocene)**—Named by Greene and others (1972); formerly Dinner Creek Welded Ash-Flow Tuff of Kittleman and others (1965). Purple, pink, brown and, locally, white strongly welded rhyolitic ash-flow tuff together with overlying and underlying lithic lapilli tuff members that are usually poorly exposed. The welded member consists largely of partly devitrified glass shards and locally shows axiolitic structure. It contains about 1 percent subhedral phenocrysts, as long as 3 mm, of plagioclase, potassium feldspar (?), and magnetite, and about 2 percent lithic fragments as much as 5 mm long of devitrified welded tuff, fine grained rhyolite that has minute grains of disseminated opaque minerals (magnetite?), and granophyre. In places the welded member is altered to white, green and brown chalcedony and has lithophysae as much as 1 cm across, probably products of vapor phase alteration. In the quadrangle, the unwelded tuff members are as much as 6 m thick, and are absent in places. The whole formation varies from about 18 to 73 m in thickness, thickening to the northwest in the direction of an inferred caldera source north of Westfall Butte (Evans and Binger, 1997). K-Ar dates indicate that the age of the unit is about 15 Ma (Fiebelkorn and others, 1983)

Trcm **Rhyolite of Cottonwood Mountain (middle Miocene)**—Name suggested by extensive exposures of the rhyolite on Cottonwood Mountain, 23 km northeast of the quadrangle (Evans, unpub. mapping, 1995, Swede Flat 7.5' quadrangle). These rocks were previously named "rhyolite of Bully Creek canyon" by Brooks and O'Brien (1992b) for exposures along Bully Creek, 14 km to the east of the quadrangle. The rhyolite is exposed near the southeast corner of the quadrangle where it underlies Hunter Creek Basalt (map unit Th) and Littlefield Rhyolite (map unit Tl). Unit includes black vitrophyre and dark gray to brown rhyolite. Vitrophyre weathers to subrounded boulders as long as 1 m and contains as much as 10 percent phenocrysts, as long as 3 mm, of glomeroporphyritic plagioclase, magnetite, pyroxene, and potassium feldspar in a groundmass of perlitic glass that contains abundant microlites. Dark-gray and brown rhyolite weathers to slabs as much as 1 m across and 10 cm thick, and contains as much as 10 percent phenocrysts of plagioclase, potassium feldspar, and magnetite as long as 2 mm, in a groundmass of feldspar laths as long as 0.1 mm, light-brown glass that contains spherulites, and abundant, very fine-grained, disseminated hematite. Rhyolite also contains xenoliths of fine-grained dacite (?) 0.2 mm across. Much of the hematite in the rock may be a product of the breakdown of pyroxene. About 60 m of the unit is exposed in the southeastern part of the quadrangle. At least 200 m of the rhyolite is found to the east in the northeastern part of the Little Valley 7.5' quadrangle (Brooks and O'Brien, 1992b) and to the northeast in the Swede Flat 7.5' quadrangle (Evans, unpub. mapping, 1995). Age of the unit is probably middle Miocene, but the exact relation between the rhyolite and the Dinner Creek Welded Tuff (Td) is not known. Age of the unit is based on its stratigraphic position in association with middle Miocene units and a radiometric date of Lees ($^{40}Ar/^{39}Ar$ method, 1994)

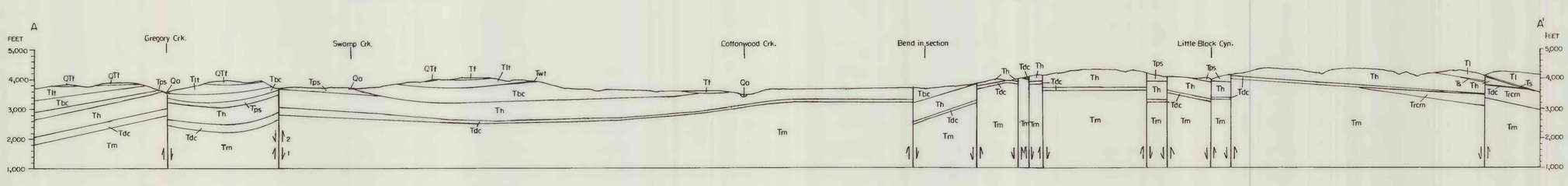
Tm **Basalt of Malheur Gorge (early to middle Miocene)**—Named by Evans (1990a,b; formerly "unnamed igneous complex" of Kittleman and others, 1965). A study by Binger (1997) suggests that the basalt of Malheur Gorge is equivalent stratigraphically, petrographically, chronologically, and geochemically to the Imnaha and Grande Ronde Basalts of the Columbia River Basalt Group. Exposures of the formation in the quadrangle consist of dark gray to black, fine-grained, generally aphyric basalt or basaltic andesite flows typical of the upper part of the formation to the south in the Malheur Gorge area, where 600 m are exposed. More detailed descriptions of the formation are in Evans (1990a,b). Age is based on radiometric ages of Lees ($^{40}Ar/^{39}Ar$ method, 1994)

—— **Contact**

—— **Fault**—Dotted where concealed; bar and ball on down-thrown side. Where direction of movement has changed, oldest movement is labeled "1"

⊙^{10} **Location of unaltered rock sample shown in table 1**

•^{660} **Location of altered rock sample shown in table 4**



GEOLOGIC MAP OF THE LITTLE BLACK CANYON QUADRANGLE, MALHEUR COUNTY, OREGON

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1999

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