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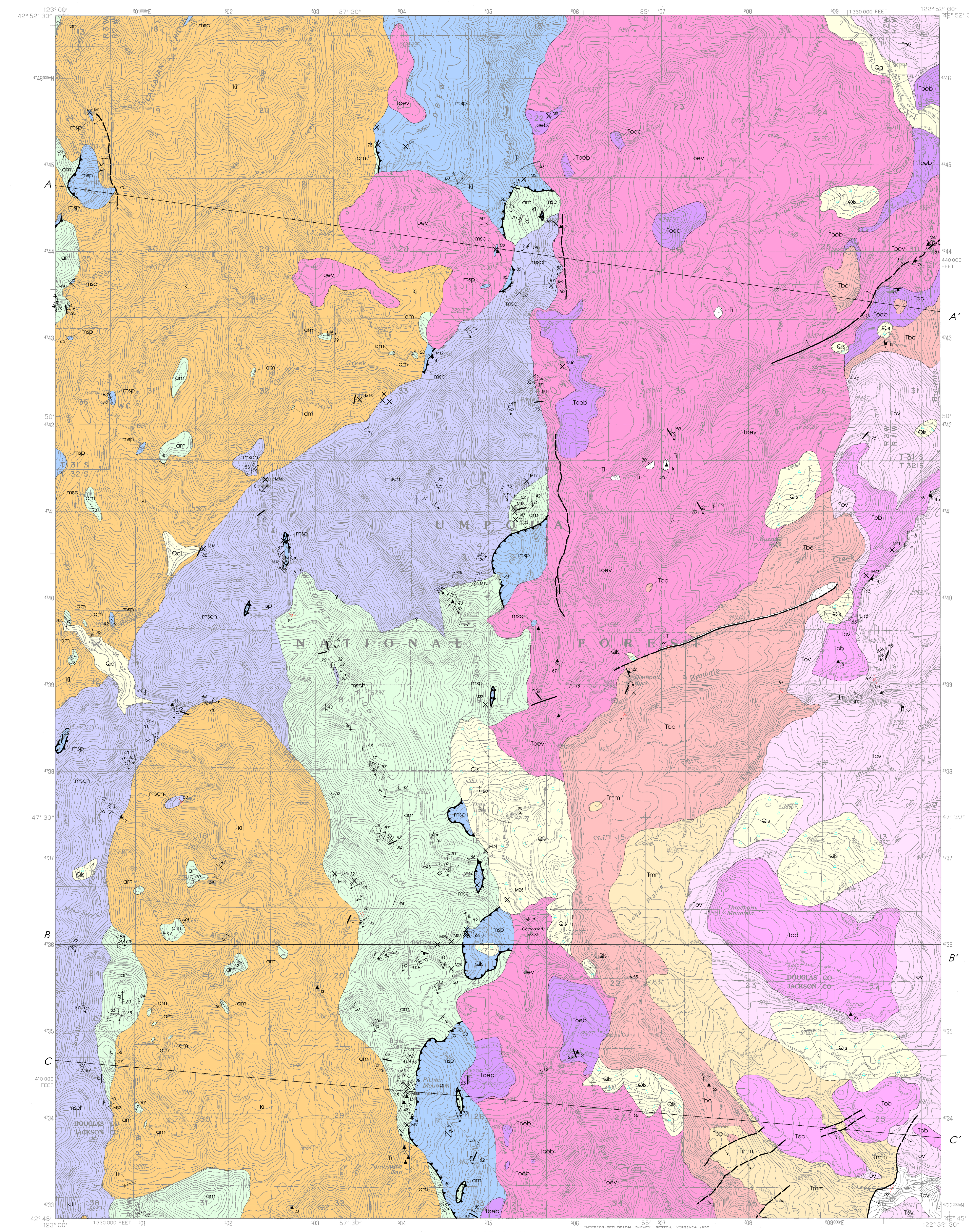
Geologic Map of the Richter Mountain Quadrangle, Douglas and Jackson Counties, Oregon

2001

GMS-103

Geologic Map of the Richter Mountain Quadrangle, Douglas and Jackson Counites, Oregon

By Robert B. Murray



CONTROL BY . . . . USGS, NOS/NOAA
COMPILED FROM AERIAL PHOTOGRAPHS TAKEN . . . . . . 1980 AND 1983
FIELD CHECKED . . . . . . 1984 MAP EDITED 1989
PROJECTION . . . . . . LAMBERT CONFORMAL CONIC
GRID: 1000-METER UNIVERSAL TRANSVERSE MERCATOR . . . . . . ZONE 10
10,000-FOOT STATE GRID TICKS . . . . . . OREGON, SOUTH ZONE
UTM GRID DECLINATION . . . . . . 0°03′ EAST
1989 MAGNETIC NORTH DECLINATION . . . . . . 18° EAST
VERTICAL DATUM . . . . . . NATIONAL GEODETIC VERTICAL DATUM OF 1929
HORIZONTAL DATUM . . . . . . 1927 NORTH AMERICAN DATUM
To place on the predicted North American Datum of 1983, move the projection lines as shown by dashed corner ticks (21 meters north and 95 meters east)
There may be private inholdings within the boundaries of any Federal and State Reservations shown on this map
No distinction made between houses, barns, and other buildings

NORTH

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET

To convert feet to meters multiply by .3048
To convert meters to feet multiply by 3.2808

QUADRANGLE LOCATION

1	2	3
4		5
6	7	8

1 Milo
2 Tiller
3 Pickette Butte
4 Cedar Springs Mountain
5 Ragsdale Butte
6 Skeleton Mountain
7 Cleveland Ridge
8 Trail

ADJOINING 7.5′ QUADRANGLE NAMES

EXPLANATION OF MAP UNITS

(See accompanying text for complete description of geologic units)

Quaternary Deposits

- Qal — Alluvium (Holocene and Pleistocene)
- Qls — Landslide deposits (Holocene and Pleistocene)

Angular Unconformity

Tertiary (Paleogene) Sedimentary and Volcanic Rock

- Tov — Volcanic and volcanogenic rocks (upper and lower Oligocene)
- Tob — Basalt and basaltic andesite flows (upper and lower Oligocene)
- Tmm — Tuff of Mosser Mountain of Hladky (1992) (lower Oligocene)
- Tbc — Tuff of Bond Creek of Smith and others (1982) (lower Oligocene)
- Toev — Volcanic and volcanogenic rocks (lower Oligocene to upper Eocene)
- Toeb — Basalt, basaltic andesite, and andesite flows (lower Oligocene to upper Eocene)

Angular Unconformity

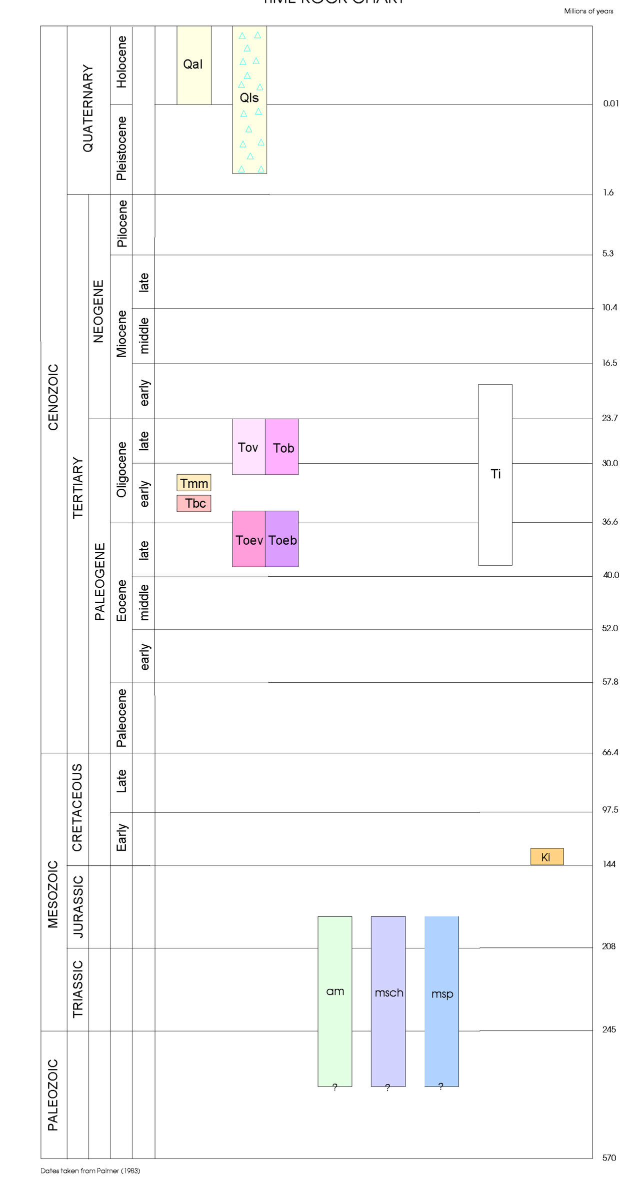
Jurassic or Older Metamorphic Rocks

- am — Amphibolite (Jurassic or older)
- msch — Quartz-mica phylite and schist (Jurassic or older)
- msp — Metaserpentinite (Jurassic or older)

Intrusive Rocks

- Ti — Dikes and small intrusive bodies (Miocene and Eocene)
- Ki — Silicic intrusive rocks (Cretaceous and Jurassic)

TIME ROCK CHART



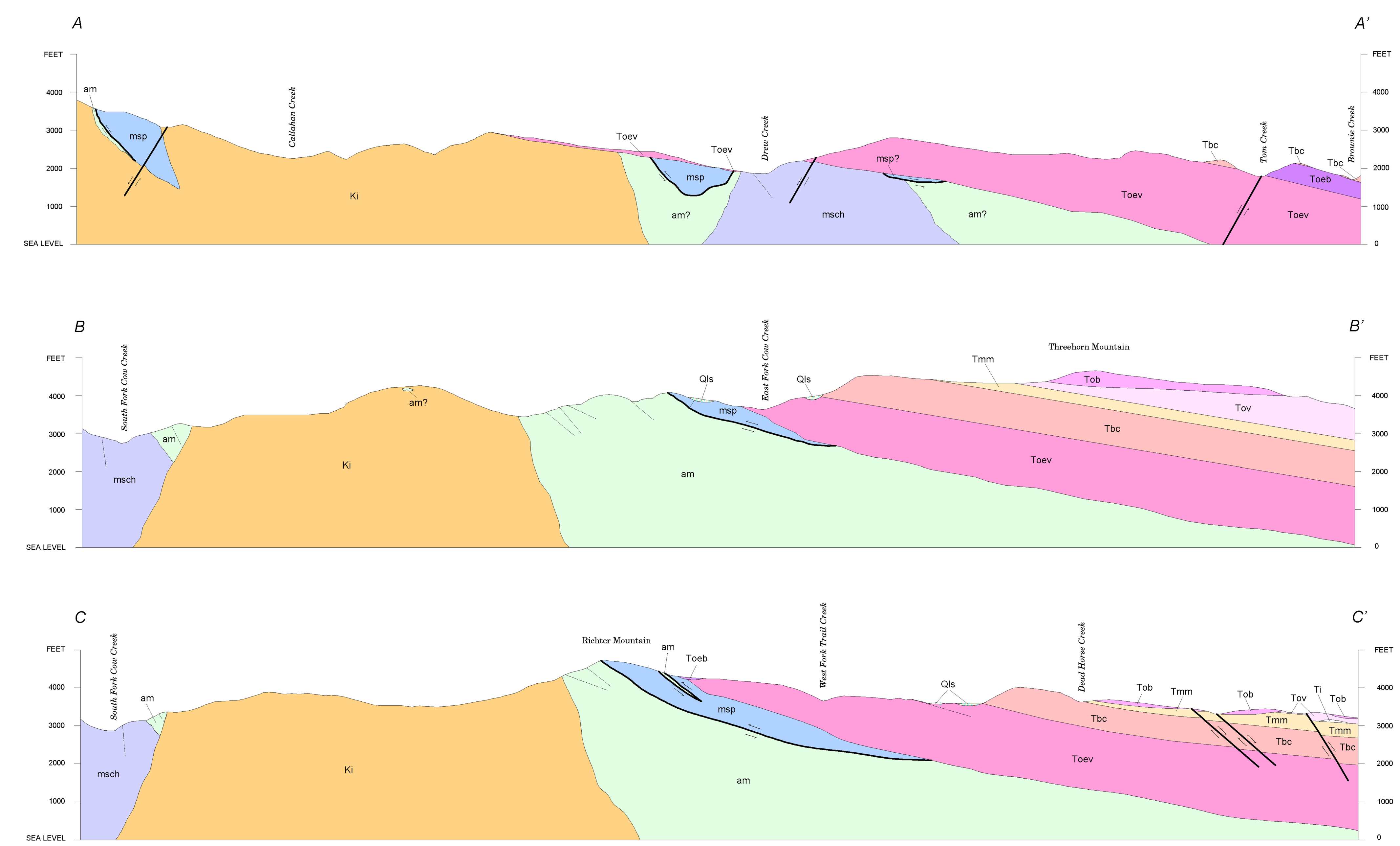
Dates taken from Palmer (1983)

MAP SYMBOLS

- Contact -- Approximately located
- Fault -- Dashed where inferred: ball and bar on downthrown block
- Thrust fault -- Approximately located; sawteeth on upper (tectonically higher) plate
- Minor fault (not traced) -- Showing strike and dip
- Minor fault (not traced) -- Vertical or nearly vertical dip
- Inclined joint -- Showing strike and dip
- Minor inclined vein -- Showing strike and dip
- Inclined bedding -- Showing strike and dip
- Inclined cleavage -- Showing strike and dip
- Vertical or near-vertical cleavage -- Showing strike
- Inclined foliation (other than cleavage) -- Showing strike and dip; includes igneous foliation in plutonic rokcs and eutaxitic foliation in welded tuff
- Direction of downslope movement of landslide
- Fold axial plane of outcrop scale fold sets -- Showing strike and dip
- Lineation -- Showing type, bearing, and plunge; types: C = crenulation lineation, Fa = fault slickenside, F = fold axis, M = mineral lineation, carbonized wood labeled as such may be used in combination with other symbols
- Dike -- Showing unit label, direction, and dip
- Rock sample location with map number -- See Tables 1 and 2 in accompanying text
- Mining tunnel or adit, with map number -- See Table 3 in accompanying text
- Mining trench, with map number -- See Table 3 in accompanying text
- Mining pit or prospect, with map number -- See Table 3 in accompanying text

GEOLOGIC CROSS SECTIONS

Dashed lines within units indicate measured foliation or bedding
Thickness of Tertiary volcanic flows and landslide deposits exaggerated



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Field work conducted in 1991-93

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Department of Geology and Mineral Industries
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Geological Map Series

GMS–103

Geologic Map of the Richter Mountain Quadrangle, Douglas and Jackson Counties, Oregon

by

by Robert B. Murray and M. Allan Kays
University of Oregon

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INTRODUCTION

The Richter Mountain quadrangle (Figure 1) covers an area of diverse geology, including pre-Tertiary rocks of the northernmost Klamath Mountains and Tertiary rocks of the Cascade Range. The contact between the two geologic provinces bisects the quadrangle north to south.

Pre-Tertiary metamorphic rocks, which crop out in the west half of the quadrangle, include mafic intrusive and volcanic rocks and organic-rich sedimentary rocks that are tectonically interlayered with serpentinized ultramafic rocks. Metamorphic grade ranges from amphibolite facies at the south edge of the quadrangle, near Richter Mountain, to epidote amphibolite facies in the central part of the quadrangle. Retrograde greenschist facies minerals overprint the rocks in the northern part of the quadrangle. Metamorphic fabrics are well developed, and in amphibolite-facies mica schist near the head of the South Fork Cow Creek is found evidence of two prograde events. Metamorphic isograds and fabrics crosscut all lithologic boundaries and are correlative with textures found in amphibolite and schist throughout the northeast Klamath Mountains.

The metamorphic rocks are intruded by the 141-Ma White Rock pluton, which crops out in two separate bodies divided by a septum of metamorphic rocks along the South Fork Cow Creek. The pluton consists of biotite trondhjemite and hornblende±biotite tonalite, with minor quartz diorite. Dikes spatially associated with the pluton include garnet-muscovite-biotite-bearing late-stage granodiorite, granite, and alkali-feldspar granite.

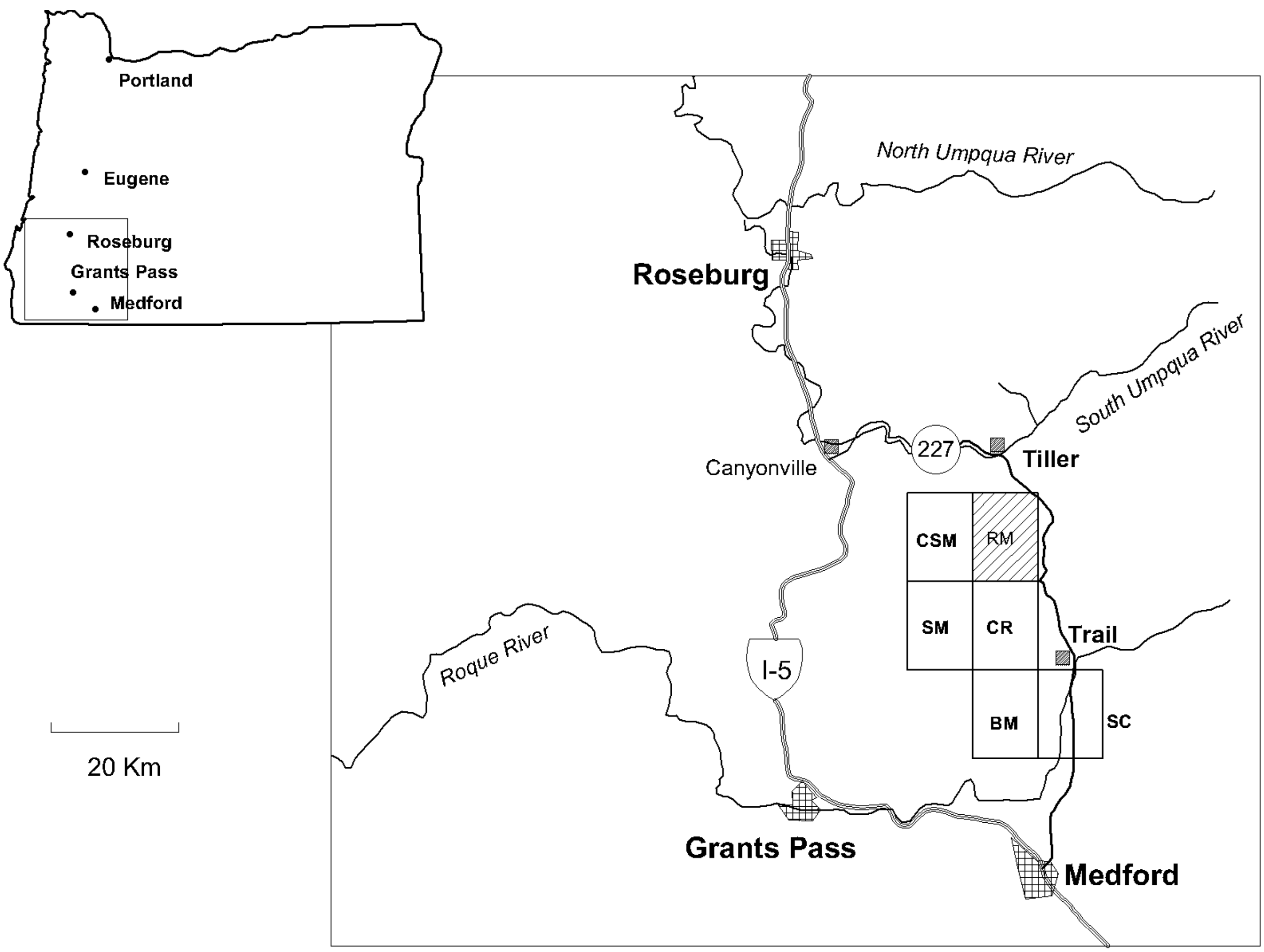

Figure 1. Location map, showing Richter Mountain quadrangle (shaded) and nearby quadrangles mentioned in the text: CSM=Cedar Springs Mountain; SM=Skeleton Mountain; CR=Cleveland Ridge; BM=Boswell Mountain; SC=Shady Cove.

Tertiary volcaniclastic and volcanic rocks crop out across the east half of the quadrangle and as outliers over the pre-Tertiary rocks in the northern part of the quadrangle. The volcaniclastic and volcanic rocks are predominantly tuffaceous sedimentary rocks but include interbedded silicic tuff, mafic to intermediate flows, and minor mafic intrusions. The 34.9-Ma tuff of Bond Creek crops out prominently in the central and eastern parts of the quadrangle. The distinctive rhyolitic biotite-plagioclase-quartz-phyric welded tuff is a marker bed throughout much of the southern Western Cascades (Sherrod and Smith, 1989). In the south half of the quadrangle, the tuff of Mosser Mountain, a plagioclase-phyric dacitic welded tuff, overlies the tuff of Bond Creek.

Metalliferous mineralization is hosted by rocks of both geologic provinces. Thirteen prospects, including massive sulfide, epithermal mercury, and chromite, are listed in the *Mineral Information Layer for Oregon by County* (MILOC) database (Gray, 1991), and numerous altered zones, prospect pits, trenches, and tunnels are scattered across the quadrangle. The Banfield, Rowley, Red Cloud, and Mammoth Lode prospects have had significant development, but only the Banfield (Cu, Zn, and Ag) and Red Cloud (Hg) have recorded production. Small-scale placer mining for gold has taken place along Beaver Creek in the west-central part of the quadrangle. Rock aggregate, used primarily for road building, has been quarried from mafic volcanic rocks and serpentinite in numerous localities within the quadrangle. The tuff of Bond Creek is used locally as a minor source of road aggregate and flagstone.

Nearly 95 percent of the quadrangle is within the Umpqua National Forest. The quadrangle is drained primarily by Cow Creek, Callahan Creek, and tributaries of Elk Creek, which flow into the South Umpqua River. West Fork Trail Creek and Dead Horse Creek, small streams that flow south to the Rogue River, drain the southeast corner of the quadrangle.

EXPLANATION OF MAP UNITS

Rock names follow usage of Streckeisen (1976), Schmid (1981), and LeBas and others (1986). Mineralogic descriptions are based on petrographic analysis; mineral percentages are from point counts on ignimbrites and granitic rocks and are visually estimated for other rocks. Mineral chemistry was determined petrographically for volcanic rocks and by microprobe for metamorphic and granitic rocks. Epoch designations are based on Palmer (1983).

Quaternary Deposits

Qal **Alluvium (Holocene)**—Gravel, sand, and silt deposited along modern stream channels

Qls **Landslide deposits (Holocene and Pleistocene)**—Fragments of bedrock mixed with gravel, sand, silt, and clay and displaced downslope by gravity sliding. Especially common where volcaniclastic rocks (units Tov and Toev) have become oversteepend where they underlie lava flows or welded tuffs. The large landslide covering 196 hectares (485 acres) in the central part of the quadrangle near Drew Lake contains numerous blocks of the tuff of Bond Creek tens of meters across; orientation of some blocks shown by foliation symbol in this deposit. Only large deposits are shown, with indication of the direction of their movement

Angular unconformity

Tertiary (Paleogene) Sedimentary and Volcanic Rocks

Tov **Volcanic and volcanogenic rocks (upper and lower Oligocene)**—Tuffaceous sedimentary rocks, with minor tuff, mafic to intermediate lava flows, and paleosols not mapped separately. Tuffaceous sedimentary rocks are predominantly tan and brown conglomerate, locally altered to olive or celadon-green, with minor interbedded sandstone and siltstone. Conglomerate, interpreted to have debris-flow (lahar) origin, contains poorly sorted, subrounded to angular clasts in a matrix of altered fine-grained material that was probably originally ash. Clasts are slightly to moderately porphyritic mafic volcanic rocks and pumice, typically less than 5 cm, but as large as 2 m at the base of some beds. Conglomerate with large clasts is commonly clast supported; rare outcrops show weak imbrication. Some depositional units grade upward to sandstone or siltstone. Plagioclase, clinopyroxene, and rare quartz crystals are always present in the matrix but generally total less than 1–2 percent of the rock. Areas underlain by conglomerate are typically steep, commonly poorly vegetated, and prone to landsliding. Pyroclastic interbeds within the tuffaceous sedimentary rocks are typically lapilli tuff less than a few meters thick. Top of the unit is not exposed within the Richter Mountain quadrangle, but estimated thickness ranges from 1.8 to 4.5 km regionally (Peck and others, 1964). Correlative with the Little Butte Volcanic Series as mapped by Peck and others (1964) north of the quadrangle. May be equivalent to rocks mapped as Roxy Formation east of Medford (Wells, 1956). Age based on stratigraphic evidence; unit overlies 34.9-Ma tuff of Bond Creek, is stratigraphically equivalent(?) with 29.4-Ma mafic flow northeast of quadrangle, and underlies 21.4-Ma mafic flow east of the quadrangle (Fiebelkorn and others, 1983, their Jackson County map numbers 5 and 7)

Tob **Basalt and basaltic andesite (upper and lower Oligocene)**—Dark-gray to black, red- to brown-weathering, variably porphyritic lava flows. Zoned plagioclase laths up to 3 mm are ubiquitous, commonly forming glomerocrysts with clinopyroxene. Subhedral clinopyroxene up to 2 mm, olivine (typically altered to iddingsite), and magnetite are also common phenocrysts. Groundmass is typically plagioclase ($An_{60–70}$), clinopyroxene, and magnetite with brown glass or very fine-grained alteration products in an intergranular-intersertal texture. Accessory minerals include apatite and rare quartz. Two chemical analyses are hypersthene normative. Combined thickness of two flows at Threehorn Mountain is more than 90 m (295 ft) thick (cross section B–B′); a flow that crops out in Brownie Creek is more than 120 m (395 ft) thick

Tmm **Tuff of Mosser Mountain of Hladky (1992) (lower Oligocene)**—Tan to orange, locally altered to celadon-green, plagioclase-pyroxene±quartz-bearing dacitic welded ash-flow tuff. Rests directly upon the tuff of Bond Creek within the Richter Mountain quadrangle, but the two tuffs are separated by a cobble lag in the adjacent Cleveland Ridge quadrangle (Wiley, 1993). Rounded, subhedral plagioclase laths up to 2 mm are andesine or labradorite ($An_{45–55}$); have oscillatory zoning, typically with numerous, very fine scale reversals; commonly occur in glomerocrysts; and form 20–40 percent of the rock. Opaque minerals form about 1 percent of the rock. Clinopyroxene occurs as an accessory. Quartz crystals exist only in trace amounts. Brown calcareous material fills cavities left by the weathering of pyroxene(?). Lithic fragments, including a variety of mafic rocks, compose from 3 percent to nearly 16 percent of the tuff; pumice less than 4 percent. Groundmass is completely recrystallized to an equigranular mix of quartz, K-feldspar, and rare spherulites. Distinguished from the tuff of Bond Creek in the field by its orange tint in outcrop, abundance of subhedral plagioclase phenocrysts, only trace amounts of quartz, and lack of biotite. Maximum thickness within the Richter Mountain quadrangle is about 85 m (280 ft) at the south edge of the quadrangle; pinches out northwest of Threehorn Mountain near center of quadrangle

Tbc **Tuff of Bond Creek of Smith and others (1982) (lower Oligocene)**—Tan to pink, welded, biotite-plagioclase-quartz bearing, rhyolitic ash-flow tuff. Weathers to rusty brown; vapor-phase recrystallization of pumice fragments and along fractures is white. Flattened pumice fragments impart eutaxitic texture and parting. Crystals of quartz, plagioclase, and biotite compose 23–30 percent of the rock; pumice up to about 13 percent; lithic fragments are sparse, except near the base of the unit, and include a variety of volcanic rocks. Quartz crystals are rounded bipyramids and fragments up to 3 mm. (Crystals weathering out of the tuff are the source of "diamonds" in Diamond Creek.) Strongly pleochroic brown biotite occurs as euhedral plates up to 2 mm. Plagioclase is oligoclase ($An_{20–27}$) and occurs as rounded laths up to 4 mm that have oscillatory zoning with numerous reversals. Oxidation of the abundant groundmass magnetite produces the pink color seen in outcrops. Trace amounts of zircon occur in some samples. Despite its fresh appearance in outcrop the tuff is nearly completely devitrified. Pumice clasts have axiolitic textures, and the groundmass is mixed silica and K-feldspar with granular and spherulitic textures. Relict shards are visible in some samples.

Southeast of Drew Lake, float from the base of the unit indicates a zone of dense welding. Crystals and lithic fragments are abundant, and the rock is a crystal tuff. The groundmass is very fine grained and gray in hand sample; in thin section, relict shards are visible despite complete recrystallization to a spherulitic texture. Pumice is sparse, and the rocks lack the prominent eutaxitic texture and parting that characterizes the tuff higher in the section. Biotite-bearing, granular, non-indurated deposits exposed in roadcuts nearby (UTM 4735730N 506150E) may be the product of a Plinian airfall eruption preceding the eruption of the ignimbrite. In this vicinity, where a complete section is apparently preserved, thickness of the unit is approximately 120 m (395 ft). At the south edge of the quadrangle the unit is approximately 160 m (525 ft) thick. It is a cliff-forming unit, often forming pinnacles at fracture intersections, Diamond Rock being the most striking example. Oversteepened outcrops are commonly sources of landslides. On the eastern dip slope of the unit, a thin soil has developed that turns into sticky clay in wet weather. Potassium-argon age of 34.9±1 Ma from biotite (Smith and others, 1980; Fiebelkorn and others, 1983). Unit marks the base of the Little Butte Volcanic Series of Peck and others (1964). Whole-rock chemical analysis contains approximately 74.6 percent SiO_2 (map no. 22, Table 1)

Toev **Volcanic and volcanogenic rocks (lower Oligocene to upper Eocene)**—Similar to unit Tov but includes silicic volcanic clasts (for example, map no. 7, Table 1) and rare metamorphic clasts locally near the base of the Tertiary section. Clasts are typically less than 5 cm but may be as large as 1 m at the base of some depositional units. Carbonized or silicified wood is abundant locally. Rare pyroclastic interbeds are less than a few meters thick, are quite weathered, and distinguished from the tuffaceous sedimentary rocks by their lack of mafic volcanic clasts. A 2-m-thick flow or sill sampled for chemical analysis (map no. 9, Tables 1 and 2) plots in the mugearite field of a total alkali-silica classification diagram (Le Bas and others, 1986). However, a three-weight-percent loss on ignition for the sample indicates that some caution is required interpreting the analysis. Typically hydrothermally altered near its base where it lies unconformably on pre-Tertiary metamorphic rocks. Thickness of unit varies considerably; may be as thick as 610 m (2,000 ft) at north edge of the quadrangle, 466 m (1,463 ft) thick at south edge of the quadrangle, and less than 185 m (607 ft) near Drew Lake, near the center of the quadrangle. Stratigraphically equivalent with tuffaceous rocks, conglomerate, and volcanic flows north of the quadrangle mapped as Colestin Formation by Peck and others (1964). Age based on stratigraphic evidence and regional correlations. Fossil flora in the Colestin Formation is upper Eocene (Peck and others, 1964); whole-rock K-Ar age of 36.9±0.8 Ma from basaltic dike inferred to be equivalent to unit in Boswell Mountain quadrangle (Wiley and Hladky, 1991); unit underlies 35-Ma tuff of Bond Creek. May be older to the south where section is thicker and contact with underlying Payne Cliffs is exposed (Tom Wiley, written communication, 1997)

Toeb **Basalt, basaltic andesite, and andesite (lower Oligocene to upper Eocene)**—Black to dark-gray, red- to brown-weathering, aphyric to moderately porphyritic lava flows. Locally amygdaloidal with chalcedony, calcite, and zeolite infillings. Aphyric flows commonly have a platy fracture. Porphyritic flows typically have plagioclase laths up to 1.5 mm (rarely up to 3 mm) with oscillatory zoning (cores An_{74-78}), commonly forming glomerocrysts up to 4 mm with clinopyroxene±olivine. Subhedral clinopyroxene up to 2 mm is common, whereas olivine up to 3 mm and orthopyroxene up to 1.5 mm are less common. Groundmass consists of plagioclase (An_{65-67}), clinopyroxene, magnetite, and rare olivine crystals with brown glass in an intergranular-intersertal texture. Outcrop patterns suggest that many lavas were intracanyon flows; mafic rocks exposed in the canyons of Deadhorse Creek and Tom Creek are 85 m (280 ft) and 135 m (443 ft) thick, respectively

Angular unconformity

Jurassic or Older Metamorphic Rocks

am **Amphibolite (Jurassic or older)**—Predominantly gray-green epidote-plagioclase-hornblende gneiss and schist, grading to blue-black amphibolite facies hornblende-plagioclase-bearing rocks near Richter Mountain in south-central part of quadrangle. Also includes pyroxene±garnet±calcite-bearing rocks spatially associated with the White Rock pluton, chlorite-rich zones spatially associated with volcanogenic massive sulfide deposits, small tectonic blocks of metaserpentinite, and blackwall assemblages of chlorite and actinolite at the contact between serpentinite and amphibolite. A marble interbed with epidote, pyroxene, and euhedral garnet porphyroblasts crops out in Drew Creek just south of the contact with metaserpentinite (unit msp) near the north edge of the quadrangle (UTM 4744460N 505330E). Some small roof pendants over the White Rock pluton are indicated only by a cleavage symbol on map.

In amphibolite-facies schist, a centimeter-scale spaced cleavage is defined by aligned hornblende; hornblende prisms and stretched plagioclase define a mineral lineation in many outcrops. Gneissic banding is defined by alternating hornblende-rich and plagioclase-rich layers. Igneous textures, including chilled dike margins and diabasic and gabbroic textures, are preserved locally. Amphibole (magnesio-hornblende; nomenclature after Leake, 1978) and plagioclase (An_{30-59}) form majority of the rock; epidote is a trace to minor constituent.

In epidote-amphibolite-facies rocks, the amphiboles are predominantly magnesio-hornblende but include tschermakitic and ferro-tschermakitic hornblende; rare samples have actinolite cores. Plagioclase ranges from An_2 to An_{58} and shows no evidence of a peristerite gap. Epidote, quartz, and biotite gradually increase northward from Richter Mountain, despite relatively constant chemical composition of the rocks (Murray, 1994). Schist with abundant chlorite and biotite locally shows a crenulation lineation, and gneissic banding is defined by alternating amphibole-rich and epidote-rich layers.

Isotopic dating of metamorphic hornblende in correlative amphibolite includes an age of 150±11 Ma (K-Ar) for a gabbroic amphibolite at Red Mountain, immediately west of the quadrangle (Kays and others, 1977), and approximately 145 Ma ($^{40}Ar/^{39}Ar$) from amphibolite in the adjacent Cleveland Ridge and Skeleton Mountain quadrangles (Donato 1991a,b); minimum protolith age is 160±1 Ma, on the basis of intrusive relations with the Wimer pluton (Donato, 1991b; Doug Yule, preliminary data, written communication, 1997). Amphibolite, mica schist, and serpentinite within the quadrangle are correlated with rocks of the May Creek terrane, the northernmost terrane of the Western Triassic and Paleozoic belt (TrPz) (Irwin 1989; see also discussion in "Geologic History" section below); oldest rocks of the TrPz are of late Paleozoic age (Irwin, 1989). Contact with the structurally underlying quartz-mica schist is gradational and probably repeated by one or more low-angle faults

msch **Quartz-mica phyllite and schist (Jurassic or older)**—Dark-gray to black graphitic phyllite and quartz-biotite schist with abundant white quartz segregations. Has undergone multiple deformations, and a well-developed crenulation lineation and refolded fold axes are typical. Garnet, staurolite, mica, and chlorite porphyroblasts are common; may contain sillimanite in amphibolite-facies schist near the head of South Fork Cow Creek at south edge of quadrangle and in roof pendants above the White Rock pluton. Staurolite is absent, and garnet is partially to completely replaced by a very fine grained retrograde assemblage in northern part of the quadrangle. Amphibole-bearing interbeds and smaller tectonic blocks of ultramafic rock not mapped separately. Age equivalent to amphibolite (unit am) based on gradational nature of contact between units

msp **Metaserpentinite (Jurassic or older)**—Green to bluish-black, red-weathering, highly serpentinized ultramafic rock. Commonly talc+chlorite+antigorite, but locally includes chrysotile veinlets and lizardite replacing relict olivine, orthopyroxene, and clinopyroxene. Rarely foliated with a weakly developed, anastomosing, spaced cleavage defined by talc and stretched spinel-group minerals. Protolith age unknown, but serpentinized and tectonically mixed with amphibolite prior to metamorphism approximately 145 Ma (Donato, 1991a,b). Size of some smaller bodies may be exaggerated on map

Intrusive Rocks

Ti **Dikes and small intrusive bodies (Miocene to Eocene)**—Light-gray to black basalt and basaltic andesite. Mafic dikes and sills are moderately abundant in the east half of the quadrangle; only large or laterally persistent bodies are shown on map. Basaltic andesite that crops out in a northeast-striking dike north of Brownie Creek, and in a northeast-trending series of plugs near the head of Tom Creek, consists of plagioclase, pyroxene, and magnetite, all seriate with grain size up to 0.5 mm. Plagioclase occurs as randomly oriented, stubby grains or in bundles of complexly intergrown, elongate prisms. Pyroxene grains are anhedral or subhedral with plagioclase inclusions. Magnetite is anhedral to subhedral, commonly skeletal, with plagioclase and pyroxene inclusions; abundance is close to 5 percent, making the rock highly magnetic. The groundmass consists of green and brown fibrous alteration minerals, granular epidote, apatite needles, interstitial K-feldspar and rare quartz. Narrow basaltic dikes intruding the White Rock pluton near the south edge of the quadrangle have modal olivine coexisting with quartz and plagioclase xenocrysts and granitic xenoliths. Subhedral olivine crystals, up to 1.5 mm across, are mostly altered to iddingsite. Clinopyroxene is a rare phenocryst up to 1.5 mm but commonly rims granitic xenoliths. Groundmass consists of plagioclase (An_{73-83}), clinopyroxene, and abundant, very fine grained magnetite in variably altered brown glass. One analysis contains approximately 52 percent SiO_2 (map no. 5, Table 1)

Ki **Silicic intrusive rocks (Cretaceous)**—Medium- to coarse-grained, seriate, hornblende±biotite tonalite, biotite trondhjemite, and minor quartz diorite of the White Rock pluton and minor granodiorite, true granite, and alkali-feldspar granite of related dikes and sills. Outcrops are typically massive, crumbly, and crosscut by numerous fractures and thin leucocratic veinlets. Foliation is rare, observed primarily in dikes, near large xenoliths and roof pendants, and locally near the contact with the country rock; near Tombstone Gap, rare biotite-rich schlieren have a weak internal foliation that dissipates into unfoliated trondhjemite. Transitions between tonalite and trondhjemite are gradational. Tonalite tends to be relatively amphibole rich immediately adjacent to the country rock. Dikes and sills commonly are texturally and compositionally zoned, with aplitic margins surrounding pegmatitic cores. Contact between country rock and pluton is discordant and brecciated. Granodiorite, true granite, and alkali-feldspar granite occur in late-stage dikes that crosscut the upper level of the peripheral body near Tombstone Gap and intrude amphibolite surrounding the pluton; none were observed within the main body where it crops out in the quadrangle.

Primary minerals in the tonalite and trondhjemite include plagioclase and quartz with variable amounts of hornblende and biotite. In tonalite, the color index averages 15. Plagioclase occurs as anhedral and subhedral grains with well-developed albite, albite-pericline, and albite-carlsbad twin combinations. Oscillatory normal zoning outlines euhedral cores but is crosscut by patchy albitization along cracks. Core compositions of plagioclase in a trondhjemite dike range from An_{33} to An_{19}; rim compositions range from An_{14} to An_{6}. Large grains have small euhedral to subhedral amphibole and plagioclase inclusions and locally have overgrown interstitial quartz and biotite along their rims. Plagioclase in contact with K-feldspar has myrmekitic texture.

Quartz is anhedral and commonly smaller than plagioclase in a given sample. It typically occurs in polycrystalline aggregates and fills interstices between larger plagioclase and amphibole. Potassium feldspar is rare except in dikes and sills, where it commonly coexists with muscovite, biotite, and garnet; near Tombstone Gap it also occurs in biotite-rich granodiorite and true granite dikes. It is a late-forming mineral that grew interstitially with quartz and mica, poikilitically enclosing them in some samples; it has tartan twinning indicative of microcline and is microperthitic.

Amphibole was an early crystallizing phase in tonalite and is commonly included within larger plagioclase grains; in rocks with modal K-feldspar it occurs only as inclusions within plagioclase. Typically it formed as twinned, euhedral or raggedly subhedral grains up to 4 mm in longest dimension. Pleochroism is α = amber, β = green, γ = blue-green, but rare zoned grains have green-brown pleochroic cores and blue-green pleochroic rims. Unzoned amphibole from a tonalite sample analyzed with the microprobe has a composition straddling the tschermakitic hornblende and tschermakite dividing lines (nomenclature after Leake, 1978). Some grains have inclusions of plagioclase, opaques, and apatite. Rare skeletal grains are present in mafic enclaves that may be partially digested amphibolite xenoliths.

Biotite occurs as anhedral to subhedral plates typically up to 1 mm across, but locally up to 4 mm. Rare plates as large as 10 mm have been observed in samples collected south of the Richter Mountain quadrangle. Pleochroism is amber to red-brown or pale to dark-olive green. Biotite crystallized with quartz and small grains of plagioclase between larger plagioclase grains. In rocks that also contain amphibole, the two minerals are commonly intergrown, with grain boundaries exhibiting both sharp equilibrium textures and ragged and resorbed replacement textures, indicating replacement of amphibole by biotite. In some trondhjemite dikes, coarse biotite plates are arranged concentrically in round clusters up to 2 cm in diameter or in angular or amoeboid clots 5–10 cm across. Clots compose up to 40 percent of otherwise leucocratic dikes and are commonly connected with thin veinlets of biotite, as if being stretched apart.

Accessory minerals include apatite, titanite, rare zircon, and allanite. Apatite is a common accessory in the tonalite and quartz diorite but quite rare in the trondhjemite and K-feldspar-bearing rocks. Titanite is less common than apatite, but like apatite is more common in tonalite. Opaque minerals include magnetite, ilmenite, and pyrite. Pyrite is most abundant in a sample from a melanocratic tonalite dike intruding graphitic mica schist in Cow Creek canyon just west of contact with the eastern peripheral body (map no. 12, Table 1). Very fine grained, pale-blue needles observed in some samples may be tourmaline. Some dikes contain muscovite and garnet. In pegmatitic true-granite dikes, muscovite grew in sheaves up to 1 cm that radiate out from and appear to have seeded on a mineralogic band that is also rich in garnet.

Deuteric alteration is ubiquitous, with plagioclase replaced by sericite and/or muscovite, epidote, and albite; biotite by epidote, chlorite, and muscovite; and hornblende by biotite, epidote, and chlorite. In many samples the deuteric minerals are well developed and compose a relatively large percentage of the rock. Isotopic ages for the pluton include a cooling age of 141±4.2 Ma (K-Ar) from biotite in trondhjemite collected at the south end of the pluton (Fiebelkorn and others, 1983); a U-Pb age of approximately 135 Ma from zircon also collected at the south end of the pluton (Doug Yule, preliminary data, written communication, 1995), and a cooling age of 130-Ma (K-Ar) for hornblende from amphibolite in contact with the north end of the pluton (Kays and others, 1977)

GEOLOGIC HISTORY

In the Richter Mountain quadrangle, a north-south-trending boundary separates volcanic rocks of the Western Cascades geologic subprovince on the east from metamorphic and plutonic rocks of the northernmost Klamath Mountains province on the west. Near the boundary, outliers of Western Cascade rocks overlie rocks of the Klamath Mountains.

The Klamath Mountains province is an amalgamation of numerous thrust-fault-bounded terranes, progressively accreted to the western margin of North America through plate-tectonic processes (Irwin, 1989, 1994) (Figure 2). Common assemblages include ultramafic and mafic ophiolitic rocks formed at mid-ocean or back-arc spreading centers, island-arc volcanic rocks formed on the landward side of the convergent plate boundary, and sediments deposited upon the oceanic basement and later accreted with it to the overriding continent. The terranes form a sequence of east-dipping, concentric arcs centered around a core of early Paleozoic rocks that crop out in northern California. From the central core westward, terranes are both structurally deeper and progressively younger. Only the westernmost, younger terranes extend north into Oregon.

The Klamath Mountains province also includes abundant intrusive rocks. Pre-amalgamation plutons are cogenetic with the volcanic-arc terranes they intrude; post-amalgamation plutons are probably related to the subduction processes that drove accretion (Irwin, 1989).

Tectonic processes related to subduction and accretion at the convergent plate margin produced numerous regional metamorphic events within the Klamath Mountains (Coleman and others, 1988). Metamorphism of the Paleozoic rocks in the core of the province occurred in the Middle Devonian; metamorphism in the western terranes began in the Middle Jurassic and continued into the Early Cretaceous (Coleman and others, 1988; Harper and others, 1994). Uplift and exposure of the province began in the Early Cretaceous (Harper and others, 1994) and continued into the Tertiary (Coleman and others, 1988).

In the Richter Mountain quadrangle, rocks of the Klamath Mountains include serpentinized ultramafic rocks, amphibolite, and metasedimentary rocks—all of which are part of the May Creek terrane (Donato, 1991b, 1992; Kays, 1992). Granitic rocks, primarily tonalite and trondhjemite of the White Rock pluton, intrude the metamorphic rocks. Although metamorphism, deformation, and intrusion of the White Rock pluton have obscured original relationships, several lines of evidence suggest that the metamorphic rocks were formed together as part of an ophiolite complex and overlying sediment at an oceanic spreading center.

Relict igneous textures in the amphibolite near Richter Mountain indicate that it formed as sheeted dikes and small intrusions common in the middle to upper level of ophiolite complexes. Rare-earth and trace element signatures of the amphibolite are transitional between mid-ocean ridge and island-arc basalts, typical of back-arc basins (Donato, 1991a,b, 1992; Murray, 1994). Lacking are pillow structures commonly found near the top of an ophiolite, but limited geochemical evidence suggests that epidote amphibolite schist and gneiss that crop out in the central part of the quadrangle are genetically related to the sheeted dikes and small plutonic bodies and may be the deformed remnants of the missing pillow basalt (Murray, 1994). Graphitic quartz-mica schist that crops out in the Cow Creek and Drew Creek drainages is interpreted as metamorphosed sediment originally deposited upon the ophiolite sequence. The protolith age of the ophiolitic rocks is unknown, but it must be Jurassic or older, based on the metamorphic age of the amphibolite as discussed below.

Deformation and metamorphism of the ophiolitic rocks probably began shortly after their formation. Faulting associated with active spreading in the back-arc basin would have juxtaposed mafic and ultramafic rocks and allowed deep circulation of seawater and consequent sea-floor metamorphism (Saleeby, 1984; Karson and others, 1987). Although the sea-floor metamorphism has been largely overprinted by later dynamothermal metamorphic events, the presence of chlorite-actinolite blackwall assemblages, rather than rodingites, along contacts between ultramafic rock and adjacent country rock indicates that serpentinization must have preceded their juxtaposition (Rice, 1983).

Eventually, the back-arc basin began to close, and normal faulting characteristic of a spreading center was replaced by thrust faulting, shearing, and consequent prograde metamorphism associated with the collapse of the basin. There is evidence that the metamorphic rocks in the Richter Mountain quadrangle underwent two distinct dynamothermal events. In mafic rocks, mineral banding that developed in an early event (S_1) is folded to form isoclinal, intrafolial, "fish-hook" folds that are transposed by a second foliation (S_2). In mica schist that crops out near the head of South Fork Cow Creek, S_1 is enclosed in an early generation of staurolite porphyroblasts (M_1), which are in turn enclosed by S_2. The inclusion trails within the staurolite are truncated at the porphyroblast rim and are typically at a high angle to S_2, which bends around and thus must postdate the M_1 porphyroblasts. Growth of a second generation of porphyroblasts (M_2) late in, or following, the development of S_2 is indicated by the presence of zoned garnet porphyroblasts and staurolite porphyroblasts with inclusion trails that are parallel with S_2.

Over the course of a lengthy deformation, ophiolitic rocks and their sedimentary cover, initially juxtaposed at the spreading center, were further disrupted to produce the block-on-block melange and inverted stratigraphy observed today. Bedding, intrusive contacts, early fault contacts, and the S_1 foliation were rotated so that all early surfaces are parallel with the S_2 metamorphic foliation. Except in the nose of small isoclinal folds in S_1, the two foliations are indistinguishable in outcrop, and they form the dominant structural feature in the quadrangle today. While several thrust faults are inferred where metaserpentinite bodies structurally overlie metasediments or amphibolite within the quadrangle, numerous others may have gone unrecognized because of the parallelism of all other features; regionally, intraterrane thrust faults are common (Donato, 1990, 1991b; Smith and others, 1982).

Peak metamorphic conditions reached during the two early prograde events may be estimated from mineral assemblages in the amphibolite, mica schist, and serpentinite. Taken together, the transition from amphibolite facies to epidote amphibolite facies in mafic rocks just north of Richter Mountain, the lack of prograde olivine in serpentinite, and the occurrence of sillimanite as the first aluminosilicate in the mica schist, indicate temperatures of approximately 550°C and pressures of 3.5 kbar or greater (Murray, 1994). Somewhat lower temperatures are indicated for the early event by the occurrence of manganese-rich cores in zoned garnet porphyroblasts and rare actinolite cores in hornblende. Results of garnet-biotite geothermometry calculated from rim compositions and numerous authors' corrections are generally consistent with temperature estimates based on the coexisting mineral assemblages (Murray, 1994).

Intrusion of the White Rock pluton near the beginning of the Cretaceous constrains the timing of the S_2 deformation event in the Richter Mountain quadrangle. The pluton has weakly developed mineral deformation textures, but dikes and sills related to the pluton crosscut or intrude the S_2 foliation, and a narrow thermal aureole locally overprints the foliation in the surrounding metamorphic rocks. This indicates that deformation was waning by the time of the intrusion.

The isotopic age and crosscutting relationships of the pluton are consistent with evidence cited by Harper and others (1994) for a period of active Nevadan deformation in the northern Klamath Mountains that lasted from ~156 to 150 Ma, followed by waning deformation until about 130 Ma. In addition, metamorphic mineral ages from May Creek amphibolite and coincidence of the S_2 foliation with the northeast-trending foliation developed throughout the northern Klamath Mountains (Donato, 1991b; Harper and others, 1994; Kays, 1995) indicate that the S_2–M_2 event in the Richter Mountain quadrangle correlates with Nevadan deformation, associated with the eastward underthrusting of the Josephine ophiolite and other Western Jurassic belt rocks (Harper and others, 1994).

The age of the S_1–M_1 deformation and metamorphism is not as well constrained as the S_2 deformation, but crosscutting relationships with isotopically dated intrusives do shed some light. The 160±5-Ma Wimer pluton (U-Pb, zircon; preliminary data, Doug Yule, written communication, 1997) crosscuts a shear zone at the contact between amphibolite and schist of the May Creek terrane south of the quadrangle (Donato, 1991b, 1992); also, an unnamed hornblende diorite body (154-Ma igneous age; U-Pb, zircon; Donato, 1992)

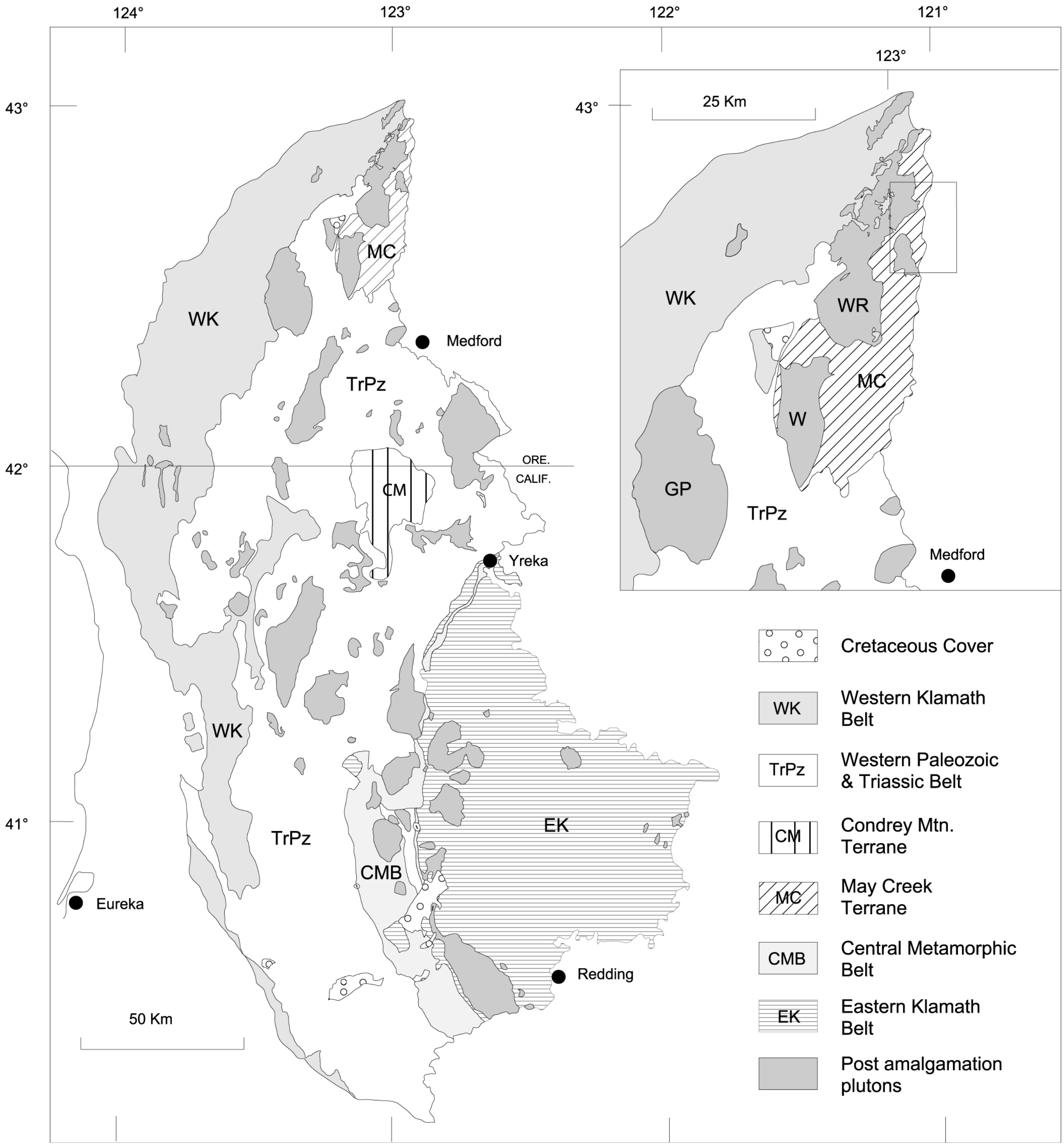

Figure 2. Simplified geologic map of the Klamath Mountains province (modified from Irwin, 1989, 1994). For simplicity, terranes and subterranes are grouped into the four lithotectonic belts originally described by Irwin (1960, 1966). Exceptions are the May Creek terrane, at the north end of the western Triassic and Paleozoic belt, which includes the west half of the Richter Mountain quadrangle; and the Condrey Mountain terrane, in northern California, which may be part of the Western Klamath belt exposed in a window through the TrPz. The inset shows details of the north end of the province—the Richter Mountain quadrangle is outlined, and large plutons are labeled: GP=Grants Pass pluton; W=Wimer pluton; WR=White Rock pluton.

intrudes, contact-metamorphoses, and engulfs amphibolite schist xenoliths. These relationships suggest that early deformation and metamorphism took place prior to the onset of Nevadan deformation. It is possible that the S_1–M_1 event correlates with the initial closure of the back-arc basin and the amalgamation of Western Paleozoic and Triassic belt terranes in northern California about 165–169 Ma (Coleman and others, 1988; Wright and Fahan, 1988).

Following the intrusion of the White Rock pluton, the S_2 foliation and other parallel surfaces were folded again. S_2 cleavage is folded into tight centimeter-scale folds (F_3), but development of an S_3 cleavage is rare and is observed only locally in the mica schist. Because F_3 fold axes are generally parallel with M_2 mineral lineations, and because the style of the F_3 folding is consistent with deformation in the Western Klamath terrane during late-stage Nevadan deformation (Harper and others, 1994), it is probable that the F_3 folding in the Richter Mountain quadrangle took place in the waning stages of Nevadan deformation. If so, it provides additional evidence that the early deformation (F_1–S_1) observed in rocks of the May Creek terrane within the Richter Mountain quadrangle took place prior to the Nevadan deformation.

A period of retrograde metamorphism (M_3) followed the Nevadan deformation event. Garnet porphyroblasts in the north half of the quadrangle are partially to completely replaced by a fine-grained retrograde assemblage, and M_3 epidote and chlorite porphyroblasts that enclose the S_2 fabric show no evidence of deformation. Amphibole-plagioclase geothermometry (method of Holland and Blundy, 1994) calculated from rim compositions in a mafic sample collected from the north-central part of the quadrangle gives a temperature of approximately 432°C (Murray, unpublished data, 1994). It is unclear whether M_3 correlates with heating by the pluton or with a later heating event that took place in the northern Klamath Mountains about 112 Ma (Harper and others, 1994).

Post-Nevadan deformation includes meter-scale open folding (F_4) and kilometer-scale doming. F_4 fold axes trend north-south or northwest-southeast and plunge gently in either direction. The F_4 folds fold all early structures in the metamorphic rocks, but their age must predate the late Eocene, as they are not observed in the overlying Tertiary volcanic rocks.

Metamorphic foliations mapped by Wiley (1993) in the northwest corner of the Cleveland Ridge quadrangle, south of the Richter Mountain quadrangle, define an antiform with a north-south axis that plunges southward. Outcrop patterns and metamorphic foliations in the Richter Mountain quadrangle indicate that the antiform continues north as well.

In the central part of the Richter Mountain quadrangle, the east limb of the antiform is defined by consistently east-dipping foliations in the metamorphic rocks. Mica schist exposed in the core of the antiform is overlain structurally by amphibolite, which is overlain, in turn, by mixed amphibolite and serpentinite.

Although the west limb of the antiform has been mostly obliterated by intrusion of the White Rock pluton, the outcrop pattern of roof pendants and of rocks that crop out immediately west of the Richter Mountain quadrangle mirrors that of the east limb: amphibolite flanks the schist, and serpentinite crops out further from the axis of the antiform. In addition, although structural measurements taken from roof pendants are similar to measurements taken throughout the quadrangle, a relatively higher percentage of west-dipping foliations is within the roof pendants. Regionally, a progressive increase in west-dipping foliations westward across the Richter Mountain and adjacent Cedar Springs Mountain quadrangles can be observed (Kays, 1995). In the northern part of the quadrangle, the antiform plunges to the north-northeast. In outcroppings along Drew Creek, the mica schist grades northward into amphibolite, which in turn is structurally overlain by serpentinite.

Formation of the antiform apparently postdates formation of the F_4 folds, which do not affect the overlying Tertiary rocks. Also, the lack of a retrograde greenschist facies metamorphism in amphibolite near Richter Mountain indicates that it was buried deeply enough during the post-Nevadan M_3 retrograde event to have preserved its prograde mineralogy, thus constraining the age of the doming as younger than the retrograde event. Apparently, most of the uplift of the pre-Tertiary rocks occurred prior to the onset of Western Cascade volcanism, because they buttress the volcanic rocks to the east. However, easterly dips of up to 17° in the Tertiary rocks as well as a series of northeast-striking normal faults that cut the tuff of Bond Creek in the southeastern part of the quadrangle indicate that uplift continued into at least the early Oligocene.

Deposition of the volcanic rocks that now cover the east half of the Richter Mountain quadrangle began in the late Eocene. Tuffaceous sedimentary rocks and volcanic flows (unit Toev) that underlie the ~35-Ma tuff of Bond Creek (unit Tbc) are as thick as 610 m (2,000 ft) in the northern part of the quadrangle, which indicates that substantial volcanic activity took place prior to the eruption of the ignimbrite. To the south, in the Cleveland Ridge and Boswell Mountain quadrangles, lowermost Western Cascade rocks overlie the upper(?) Eocene Payne Cliffs Formation (Wiley and Hladky, 1991; Wiley, 1993). A diorite dike dated 36.9±0.8 Ma (whole-rock K-Ar, Wiley and Hladky, 1991) intrudes the Payne Cliffs Formation in the northwest part of the Boswell Mountain quadrangle, approximately 16 km (10 mi) south of the Richter Mountain quadrangle. The dike is inferred to be related to basalt flows within the volcanic and volcanogenic rocks (unit Toev) on the basis of chemical and petrographic similarities (Wiley and Hladky, 1991). Because the Payne Cliffs Formation does not crop out in the Richter Mountain quadrangle and the thickness of volcanic rocks underlying the tuff of Bond Creek diminishes to the north, it is possible that the oldest volcanic rocks exposed within the Richter Mountain quadrangle are somewhat younger than those exposed to the south (Tom Wiley, written communication, 1997).

The tuff of Mosser Mountain (unit Tmm) directly overlies the tuff of Bond Creek in the south half of the Richter Mountain quadrangle. Some time elapsed between the deposition of the two ignimbrites, however, because cobble lag deposits separate the two tuffs farther south (Wiley, 1993). Overlying the tuff of Mosser Mountain is another thick sequence of interbedded volcaniclastic rocks and flows (units Tov and Tob). Combined thickness of the sequence is about 280 m east of Threehorn Mountain (cross section B-B')—which is a small fraction of the estimated 1.8 to 4.5 km thickness regionally (Peck and others, 1964). A mafic flow to the east, stratigraphically above any strata within the Richter Mountain quadrangle, has been dated about 21.4 Ma (Fiebelkorn and others, 1983).

The age of Tertiary intrusive rocks (unit Ti) that intrude the tuff of Bond Creek and underlying volcanic and volcanogenic rocks is unknown but must be less than about 35 Ma. A gabbro sill that crops out within 1 km (0.6 mi) of the southern edge of the quadrangle has a K-Ar whole-rock minimum age of 21.9±0.3 Ma (Wiley, 1993).

Tertiary-age deformation includes continuing uplift of pre-Tertiary basement rocks, as discussed above, and high-angle faulting. Two sets of normal faults are evident within the quadrangle. North-south striking faults are found locally along the contact between the pre-Tertiary rocks and Tertiary volcanic rocks. Although the contact is clearly depositional, alteration and topographic features provide evidence for later faulting. Fifarek (1981) cites geophysical evidence for an apparent normal offset of at least 120 m (400 ft) along the fault mapped east of the Rowley Mine. The fault mapped near the contact in the north-central part of the quadrangle is inferred from the alignment of saddles and low knobs and interpreted to be a high-angle fault with a down-to-the-west normal offset. Rare north-south-striking faults that cut only pre-Tertiary rocks are inferred to be of Tertiary age.

Faults striking northeast-southwest crop out along Tom Creek, north of Diamond Rock, and near the south edge of the quadrangle. The northeast-southwest structural grain is also present in the alignment of dikes and streams draining the eastern half of the quadrangle. The northeast-southwest-trending contact between the White Rock pluton and metamorphic country rocks is intrusive wherever it has been observed within the quadrangle—which probably reflects intrusion of the pluton into the preexisting fabric developed throughout the northern Klamath Mountains during Nevadan deformation.

GROUNDWATER RESOURCES

The Richter Mountain quadrangle is underlain by bedrock that yields small quantities of water to wells, typically enough only for domestic use. Pre-Tertiary metamorphic and plutonic rocks that crop out in the west half of the quadrangle are characterized by low porosity and permeability, and groundwater flow is primarily a function of fracture density in these rocks. Volcanic rocks that crop out in the east half of the quadrangle have variable porosity and permeability. Tuffaceous sedimentary rocks and ash-flow tuff typically have low fracture density and matrices of weathered ash, which inhibits groundwater flow. However, the high fracture density and auto-brecciated and scoriaceous zones of some volcanic flows provide pathways for groundwater; these zones commonly are marked by springs following periods of precipitation or melting snow. Unconsolidated deposits are restricted to modern stream channels. They do not constitute sizeable aquifers but may provide the primary source of water to people living along Elk and Cow Creeks (Doug Woodcock, Oregon Water Resources Department, written communication, 1996).

MINERAL RESOURCES

Numerous mineral prospects are scattered across the Richter Mountain quadrangle. Volcanogenic massive-sulfide, chromite, and asbestos deposits occur within pre-Tertiary metamorphic rocks, and epithermal mercury deposits occur within both Tertiary volcanic rocks of the Western Cascades and pre-Tertiary rocks immediately adjacent to the contact between the two geomorphic provinces. Several prospects have seen limited development; however, at the time of this study most excavations were overgrown, and exposure was generally limited to shallow test pits, caved portals, or dumps. An exception to the poor exposure is found at the Mammoth Lode, where an extent of approximately 70 m (230 ft) of underground workings is open. Details of individual prospects are found in the literature (Shenon, 1933; Wells and Waters, 1934; DOGAMI, 1940, 1943; Lowell, 1942; Ramp, 1961, 1972; Brooks, 1963; Fifarek, 1981, 1992) and are updated and summarized by Murray (1994).

PRECIOUS METALS

Although mesothermal gold deposits are the most common lode-gold deposit type and have been significant producers within the Klamath Mountains province, no deposits of this type have been discovered within the Richter Mountain quadrangle. The only reported precious metal production from within the quadrangle consists of 19 oz of silver recovered from 52 tons of copper ore shipped from the Banfield Mine in 1928 (Shenon, 1933). Assays of that shipment indicated a gold content of 0.01 oz/ton, which was too low for the smelter to pay on (credit the mine for recovered gold) at that time (Diamond-A-Corporation, unpublished reports). Gold has been described as present at the Rowley and Mammoth Lode massive sulfide deposits, but we find no recorded production (DOGAMI, 1943; Gray, 1991).

The only other gold prospects listed in the MILOC database for the Richter Mountain quadrangle are the Red Hill and Evans Group prospects, which may be two names for the same prospect (Murray, 1994). Mineralization exposed in a small pit at the head of a tributary to Beaver Creek (UTM 4740400N 502640E) is an iron-oxide-stained silica boxwork hosted by a serpentinite lens within interlayered amphibole schist and quartz-mica schist—all metamorphosed at epidote amphibolite facies. The serpentinite is locally altered to a talc-rich assemblage that overprints relict metasomatic blackwall assemblages, which indicates that mineralization postdates metamorphism. Pyrite is disseminated in the adjacent schist and the less altered serpentinite. It is reported that some gold may be panned from gossanlike pockets in the talc-rich zone, but channel samples indicate low gold content (Ramp 1972). A series of talc+pyrite altered serpentinite pods extends north from the pit, along Wildcat Ridge, for about 250 m. Several of these pods have been explored with prospect pits—apparently without encouraging results, as they are now completely overgrown.

Similar alteration zones are located in serpentinite exposed along a zone that extends to the northeast from Neuman Gap for more than 4 km (2.5 mi; map nos. M8 and M12; Table 3). The serpentinite crops out as small tectonic blocks in mica schist or within windows through overlying Tertiary rocks. Alteration along this trend is not restricted to serpentinite host rocks, however. Tonalite of the White Rock pluton (map no. M13; Table 3) and tuffaceous sedimentary rocks within a Tertiary outlier (map no. M7; Table 3) are also altered.

The origin of the alteration zones is unclear. Their occurrence along a persistent northeast-trending linear and the alteration of different host rocks along the trend suggest that the alteration is related to a structural feature. On the other hand, the close spatial association with the overlying Tertiary volcanic rocks suggests that the alteration may be related to Tertiary hydrothermal circulation similar to that seen along the contact between Tertiary and pre-Tertiary rocks to the east (see the following section on mercury deposits). Table 2 shows geochemical analyses of samples (map nos. 1 and 4) from two altered zones at the northeast end of the trend (map nos. M8 and M12) along with analyses of altered rocks collected along the Tertiary-pre-Tertiary contact near the center of the quadrangle (map nos. 2 and 8).

Placer claims located along Beaver Creek have no record of production. Despite considerable initial development, early work apparently ceased after less than an acre was mined (Ramp, 1972). As of 1992, mining efforts are restricted to feeding gravel to a suction dredge wash plant. Because the placer claims should have derived some of their gold from the Red Hill and Evans Group prospects, lack of significant production from the placer claims suggests that the lode prospects were not strongly mineralized, at least at or somewhat above the present level of erosion.

BASE METALS

Numerous volcanogenic massive sulfide deposits are located within pre-Tertiary amphibolite along a trend that extends from an unnamed prospect (map no. M5; Table 3) north of the Banfield mine, south to the Wet Brush prospect, located 4 km (2.5 mi) south of the quadrangle boundary. Two of the deposits, the Banfield and Rowley, have undergone considerable exploration and development. Production from the Banfield mine includes 10,059 lbs Cu and 19 oz Ag shipped in 1928, and an additional 400 lbs Cu and some Ag shipped in 1956 (Ramp, 1972).

Most of the massive sulfide prospects are within metamorphosed volcaniclastic rocks near a gradational contact with organic-rich metasedimentary rocks. Fifarek (1992) classified the Rowley and Banfield deposits as Besshi type—deposits characterized by copper- and zinc-rich massive sulfide ore within metamorphosed flysch sediments and mafic volcanic rocks. The Mammoth Lode prospect and a gossan at Richter Mountain, however, differ from the other prospects in the district in that they are hosted by what has been interpreted as a sheeted-dike complex (Donato, 1991a,b, 1992; Murray, 1994). Serpentinite spatially associated with the deposits was juxtaposed either shortly after formation of the massive sulfides in the spreading center environment or during Nevadan deformation.

The sulfide deposits and their host rocks were metamorphosed to amphibolite or epidote amphibolite facies. At the Rowley prospect, the massive sulfide is within quartz+chlorite±muscovite or quartz+albite+chlorite schist (Fifarek, 1981). To the north, at the Banfield mine, the schist grades into a banded quartz-chlorite iron formation, which includes concentrations of magnetite±sulfide (Fifarek, 1981). At the Mammoth Lode, where rocks underwent amphibolite-facies metamorphism, the ore is within sericite+quartz+chlorite schist. Ore horizons are concordant with lithologic layering and metamorphic foliation, and the small-scale structures and interlayering of ultramafic, mafic, and sedimentary protoliths suggest that considerable shearing took place, which has contributed to the disruption of the ore body at the Banfield Mine and may be responsible for the apparent overturning of the section at the Rowley prospect (Fifarek, 1981, 1992).

The massive sulfide bodies at the Banfield, Rowley, and Mammoth Lode prospects are copper and zinc rich, with only traces of lead and precious metals (Lowell, 1942; DOGAMI, 1943; Fifarek, 1981; Gray, 1991). Cinnabar mineralization at the Banfield is related to a Tertiary mineralization event (Diamond-A-Corporation, unpublished reports, 1966, 1980; Fifarek, 1981). Grades of up to several percent copper for the Banfield and Rowley prospects quoted by Ramp (1972) are restricted to small pods of massive ore, and average grades are much lower (Diamond-A-Corporation, unpublished reports, 1980; Fifarek, 1981). The same restricted extent is probably true of early reported grades averaging 4.5 percent Cu at the Mammoth Lode (DOGAMI, 1943). The numerous gossans located during this study were examined only in reconnaissance but appear to have a low overall sulfide content, primarily as pyrite, with little or no base metal sulfides.

In addition to the massive sulfide mineralization, anomalous values of copper and zinc were found in an andesite flow overlying amphibolite at the south edge of the quadrangle (sample from within the Cleveland Ridge quadrangle, UTM 4732830N 505140E; Wiley, 1993).

MERCURY

The MILOC database (Gray, 1991) lists eight mercury prospects within the Richter Mountain quadrangle, and Brooks (1963) adds the Mammoth Lode Mine to the list of mercury occurrences. Only the Red Cloud Mine has seen production, with six flasks of mercury recorded and probably 63 produced (Brooks, 1963).

Although all but one of these prospects is hosted by pre-Tertiary rocks of the Klamath Mountains province, they are considered to be part of the belt of mercury deposits that runs the length of the Western Cascades subprovince in Oregon. In the Richter Mountain quadrangle most are near the contact between the two provinces, and at the Banfield mine alteration related to the mercury mineralization crosscuts nearby Tertiary rocks. The depositional contact between the two provinces is marked by carbonate and clay alteration nearly everywhere within the quadrangle, often to the extent that the original rock textures are completely destroyed. Locally, the alteration textures resemble autobrecciation that occurred along the base of volcanic flows emplaced over lahars or epiclastic deposits higher in the Tertiary section, and they are interpreted to result from similar processes that took place at the base of the Tertiary volcanic section.

Longer lived hydrothermal circulation through permeable zones along the contact could also have been driven by geothermal gradients within the Tertiary volcanic pile. However, mercury mineralization appears to be restricted to areas where the depositional contact has been modified by later faulting. Detailed mapping by Fifarek (1981) in the Banfield-Rowley area indicates that cinnabar and related Tertiary alteration is localized by faulting that crosscuts the local metamorphic fabric. At the Red Cloud Mine, mineralization is also localized along a well-sheared fault zone that crosscuts the metamorphic foliation (Brooks, 1963).

The Flat prospect is the only mercury prospect listed in the MILOC database that crops out within Tertiary rocks (map no. M21; Table 3). No evidence for the prospect was located at the listed UTM coordinates, but at the nearby Arsenic Flash prospect (map no. M20; Table 3) epiclastic rocks are altered to celadonite, silicified, and crosscut with numerous quartz veinlets. A calcite-cemented breccia with hematitic alteration within tuffaceous rocks located at the confluence of Tom Creek and Brownie Creek, near the northeast corner of the quadrangle (map no. M4; Table 3) was sampled for geochemical analysis. It contains less than 1 ppb gold and equally scant concentrations of other metals (map no. 3; Table 2).

CHROMITE

The Short claim (map no. M2; Table 3) is the only chromite prospect within the Richter Mountain quadrangle listed in the MILOC database, and it was not found in the course of field work for this study. The UTM coordinates given by Gray (1991) are at the north end of what is now a gravel pit in serpentinite, and the prospect may have been excavated. A prospect pit was located in serpentinite a short distance northwest of the quarry, but no evidence of chromite was observed. Ramp (1961) quotes a report of a small pit about 2 m in diameter and 1 m deep at the prospect, with a few tons of ore produced near the end of World War I and stockpiled on the dump.

ASBESTOS

Small veinlets of chrysotile asbestos are common in serpentinite within the Richter Mountain quadrangle, but they rarely form more than 1–2 percent of the rock. An exception is found within a serpentinite roof pendant over the White Rock pluton along Hatchet Creek in the northwest corner of the quadrangle. That locality contains several veins and veinlets of chrysotile asbestos, the largest of which is approximately 50 cm across. The Green Butte asbestos claims were staked on the large vein and southward over tonalitic bedrock to a second, larger, serpentinite roof pendant, but only the one large chrysotile vein was found in this study.

GEOCHEMISTRY

A total of 23 samples was analyzed to provide geochemical data for the quadrangle. The samples are representative but do not provide a complete cross section of rock types found, especially within the Tertiary section. Samples were analyzed for major and minor oxides and trace elements (Tables 1 and 2). Selected samples of altered rocks were also analyzed for a suite of trace elements.

Samples collected from the White Rock pluton (laboratory numbers RM-) were prepared at the University of Oregon. Sample weights were at least 1.5 kg, except for sample RM-692A (~650 g), collected from a fine-grained tonalite dike. Samples were broken by hammer, then crushed in a half-inch iron jaw crusher. After coarse crushing, each sample was rolled, coned, and quartered several times. The reduced sample was crushed to minus ¼ in. in a stainless-steel mortar and pestle. The sample was once again rolled, coned, and quartered, and pulverized in a shatter box, using tungsten carbide grinding vessel. Except for sample 692A, the first quarter of the reduced sample was pulverized and discarded to precontaminate the shatter box. Sample 692A was too small to discard a portion, so clean silica sand was pulverized prior to processing.

Major oxide and trace-element analyses for the plutonic rock samples were obtained by Calvin Barnes, Texas Tech University, Lubbock, Texas, using induction coupled plasma atomic emission spectrometry (ICP-AES) for all elements except for rubidium, which was analyzed by flame emission spectrometry. Samples were dissolved by a fusion technique similar to that described by Feigenson and Carr (1985). All analyses were corrected for machine drift with the use of in-house standards. Precision was 3 percent or better for the major elements, Rb, Sr, Zr, Y, Ba, and Sc; and 5 percent or better for the other elements.

All other samples (laboratory numbers BBG-) were prepared by the Oregon Department of Geology and Mineral Industries laboratory in Portland, Oregon. The samples were crushed to minus ¼ in. in a Braun chipmunk crusher, then crushed to about minus 10 mesh in a Marcy cone crusher. Both crushers used manganese-steel crushing media. Each crushed sample was split in a Jones-type splitter to obtain a 250-g subsample for trace-element analysis, and a 100-g sample, where required, for whole-rock analysis. The subsamples were milled to about minus 200 mesh, subsamples for trace-element analyses in chrome-steel media and subsamples for whole-rock analyses in corundum media.

Whole-rock analyses were obtained by X-ray fluorescence at X-Ray Assay Laboratories (XRAL) of Don Mills, Ontario, Canada. XRAL used a fused button for its analyses, prepared from 1.3 g of sample roasted at 950°C for one hour, then fused with 5 g of lithium tetraborate and melt-cast into a button. Detection limit for major oxides was 0.01 percent, for minor elements 10 ppm. Loss on ignition (LOI) was determined by roasting.

Trace-element analyses consisted of a 15-element geochemical package, including gold, performed by U.S. Mineral Laboratories (formerly M.B. Associates) of North Highlands, California, who used a proprietary acid dissolution method and organic extraction of a 15-g subsample. All elements except for gold were analyzed by ICP-AES. Gold was determined by graphite furnace atomic absorption spectrometry. Detection limits were 1.0000 ppm for As, Se, and Zn; 0.5000 for Ga, Ge, and Te; 0.2500 for Bi, Pb, and Sb; 0.1000 for Cd, Hg, and Mo; 0.0500 for Cu; 0.0150 for

Ag; and 0.0005 for Au.

A second gold analysis was done by Bondar-Clegg, Ltd., of North Vancouver, British Columbia, Canada. The method employed a fire-assay preconcentration of the gold in a 20-g subsample (gold was collected with added silver), acid dissolution of the resulting bead, and direct current plasma emission spectrometer finish. The detection limit was 1 ppb.

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Table 1. Whole-rock analyses, Richter Mountain

Map number	Laboratory[1] number	Cadastral location[2] ¼	¼	Sec.	T. S.	R. W.	UTM coordinates[3] Northing	Easting	Elevation (ft)	Map lithology
5	BBG-909	NE	NE	3	32	2	4741540N	507050E	2,970	Basaltic andesite
6	BBG-904	SE	SW	4	32	2	4739958N	504590E	3,240	Epidote amphibolite schist
7	BBG-907	SE	SE	4	32	2	4739653N	505582E	3,460	Rhyolite clast
9	BBG-912	NW	SW	10	32	2	4738640N	505812E	3,760	Mugearite
10	BBG-910	NW	NW	12	32	2	4739262N	509040E	3,600	Basaltic andesite
11	BBG-905	NE	SW	7	32	2	4738770N	501349E	2,510	Mica schist
12	RM-692A	SE	NE	13	32	3	4737472N	500763E	2,600	Tonalite dike
13	RM-1546	NE	SW	20	32	2	4735505N	503025E	3,820	Tonalite
14	RM-1542A	SE	NE	29	32	2	4734268N	504053E	4,470	Granitic sill, aplitic margin
14	RM-1542P	SE	NE	29	32	2	4734268N	504053E	4,470	Granitic sill, pegmatitic core
15	BBG-903	SE	NE	29	32	2	4734180N	504026E	4,440	amphibolite
16	BBG-902	SW	NW	28	32	2	4734010N	504116E	4,700	amphibolite
17	RM-1428	NE	SE	29	32	2	4733661N	504030E	4,620	Trondhjemite
18	BBG-901	SE	SE	29	32	2	4733547N	504076E	4,600	Trondhjemite
19	RM-1433	SE	SE	29	32	2	4733491N	504043E	4,560	Trondhjemite
20	RM-1545	NW	NW	32	32	2	4732965N	502735E	3,640	Trondhjemite
21	BBG-908	NW	NW	27	32	2	4734760N	506029E	4,200	Basaltic andesite
22	BBG-906	SW	NW	26	32	2	4734380N	507550E	3,920	Rhyolitic welded tuff
23	BBG-911	NW	SW	24	32	2	4735194N	509186E	4,000	Basaltic andesite

[1] BBG samples processed by DOGAMI, analyzed by X-Ray Assay Laboratories, Don Mills, Ontario, Canada.
RM samples processed by R.B. Murray, analyzed by Calvin Barnes, Texas Tech University, Lubbock, Tex.
[2] Cadastral locations referenced to Willamette Meridian and Base Line.
[3] UTM Zone 10, 1927 North American Datum.

➤quadrangle, Douglas and Jackson Counties, Oregon

Laboratory no.	Unit	Al_2O_3 (%)	SiO_2 (%)	TiO_2 (%)	Fe_2O_3 (%)	MnO (%)	CaO (%)	MgO (%)	K_2O (%)	Na_2O (%)	P_2O_5 (%)	LOI (%)	Total (%)
BBG-909	Ti	15.1	52.1	1.44	10.6	0.17	7.92	3.49	0.93	2.83	0.23	3.5	98.3
BBG-904	am	16.8	50.6	1.35	7.62	0.14	9.33	7.28	0.53	3.81	0.21	2	99.7
BBG-907	Toev	15.6	69.2	0.523	1.47	0.03	3.95	0.39	2.29	3.5	0.13	2	99.1
BBG-912	Toev	19.7	49.5	0.967	8.32	0.14	8.14	3.71	1.04	4.23	0.17	3	98.9
BBG-910	Tob	16.5	54.7	1.55	9.59	0.17	7.19	2.8	1.2	3.17	0.28	1.25	98.4
BBG-905	msch	16	64	0.786	6.2	0.08	2	2.65	2.66	2.12	0.24	2.5	99.2
RM-692A	msch	17.87	58.98	0.55	6.73	0.17	7.21	2.72	0.78	3.71	0.21	1.13	100.1
RM-1546	Ki	18.74	63.63	0.42	3.69	0.08	6.48	1.1	0.35	4.57	0.19	0.69	99.9
RM-1542A	am	14.21	74.9	0.04	0.46	0.11	1.13	0.12	3.19	4.59	0.02	0.39	99.2
RM-1542P	am	13.94	75.75	0.03	0.44	0.14	0.78	0.11	3.42	4.54	0.03	0.36	99.5
BBG-903	am	18.1	53.6	0.609	5.67	0.11	9.01	6.75	0.14	4.78	0.11	0.75	99.6
BBG-902	am	16.7	49.1	0.996	7.89	0.15	11.5	7.77	0.14	2.99	0.11	1.15	98.5
RM-1428	Ki	15.19	71.84	0.18	1.88	0.11	3.03	0.66	1.55	4.28	0.09	0.81	99.6
BBG-901	Ki	16.3	69.9	0.224	1.59	0.09	3.27	0.61	1.47	4.99	0.07	0.75	99.3
RM-1433	Ki	17.02	72	0.05	0.46	0.03	3.2	0.14	1.26	5.25	0.05	0.79	100.2
RM-1545	Ki	16.61	69.94	0.24	2.34	0.05	4.52	0.75	0.83	4.13	0.12	0.61	100.1
BBG-908	Toeb	15	51.8	0.914	8.81	0.18	10.5	6.88	0.48	2.08	0.14	1.95	98.7
BBG-906	Tbc	12.9	74.6	0.184	1.59	0.02	1.01	0.2	3.44	3.31	0.03	1.25	98.5
BBG-911	Tob	19.5	51.5	1.05	8.47	0.15	10.2	4.16	0.72	2.47	0.27	1.2	99.7

Table 2. Trace-element analyses, Richter Mountain

Map no.	Laboratory[1] no.	Cadastral location[2] ¼	¼	Sec.	T. (S.)	R. (W.)	UTM coordinates[3] Northing	Easting	Elev. (ft)	Lithology	Map unit	Ag	As	Au	Au[4]	Ba
1	BBG-802	NW	SW	27	31	2	4744003N	505099E	2,020	Altered serpentinite	msp	b.d.	11.9	0.001	b.d.	--
2	BBG-805	SW	NE	27	31	2	4744319N	505802E	2,280	Altered breccia	msch	0.086	2.93	0.001	b.d.	--
3	BBG-804	SE	NW	30	31	1	4744079N	510104E	1,600	Altered tuffaceous sediments	Toev	0.031	2.42	0.001	b.d.	--
4	BBG-801	NW	NE	33	31	2	4742793N	504347E	2,280	Altered serpentinite	msch	b.d.	b.d.	b.d.	b.d.	--
5	BBG-909	NE	NE	3	32	2	4741535N	507061E	2,950	Basaltic andesite	Ti	0.074	1.68	b.d.	b.d.	192
6	BBG-904	SE	SW	4	32	2	4739958N	504590E	3,240	Epidote amphibolite schist	am	0.047	b.d.	0.003	4	b.d.
7	BBG-907	SE	SE	4	32	2	4739653N	505582E	3,460	Rhyolite clast	Toev	0.068	1.88	0.001	b.d.	683
8	BBG-803	NW	NW	10	32	2	4739274N	505799E	3,600	Altered tuffaceous sediments	Toev	b.d.	4.33	0.003	2	--
9	BBG-912	NW	SW	10	32	2	4738640N	505812E	3,760	Mugearite	Toev	0.052	b.d.	0.0005	1	324
10	BBG-910	NW	NW	12	32	2	4739262N	509040E	3,600	Basaltic andesite	Tob	0.053	1.56	b.d.	b.d.	276
11	BBG-905	NE	SW	7	32	2	4738770N	501349E	2,510	Mica schist	msch	0.239	b.d.	b.d.	2	1090
12	RM-692A	SE	NE	13	32	3	4737472N	500763E	2,600	Tonalite dike	msch	--	--	--	--	402
13	RM-1546	NE	SW	20	32	2	4735505N	503025E	3,820	Tonalite	Ki	--	--	--	--	147
14	RM-1542A	SE	NE	29	32	2	4734268N	504053E	4,470	Granitic sill, aplitic margin	am	--	--	--	--	1789
14	RM-1542P	SE	NE	29	32	2	4734268N	504053E	4,470	Granitic sill, pegmatitic core	am	--	--	--	--	1139
15	BBG-903	SE	NE	29	32	2	4734180N	504026E	4,440	amphibolite	am	0.018	b.d.	0.002	4	b.d.
16	BBG-902	SW	NW	28	32	2	4734010N	504116E	4,700	amphibolite	am	0.032	b.d.	0.003	3	b.d.
17	RM-1428	NE	SE	29	32	2	4733661N	504030E	4,620	Trondhjemite	Ki	--	--	--	--	593
18	BBG-901	SE	SE	29	32	2	4733547N	504076E	4,600	Trondhjemite	Ki	0.047	b.d.	0.001	4	553
19	RM-1433	SE	SE	29	32	2	4733491N	504043E	4,560	Trondhjemite	Ki	--	--	--	--	508
20	RM-1545	NW	NW	32	32	2	4732965N	502735E	3,640	Trondhjemite	Ki	--	--	--	--	381
21	BBG-908	NW	NW	27	32	2	4734760N	506029E	4,200	Basaltic andesite	Toeb	0.037	2.15	0.001	2	110
22	BBG-906	SW	NW	26	32	2	4734380N	507550E	3,920	Rhyolitic welded tuff	Tbc	0.018	1.13	b.d.	b.d.	930
23	BBG-911	NW	SW	24	32	2	4735194N	509186E	4,000	Basaltic andesite	Tob	0.037	b.d.	0.001	b.d.	116

[1] BBG samples processed by DOGAMI, analyzed by X-Ray Assay Laboratories, Don Mills, Ontario, Canada; or U.S. Mineral Laboratories, Applegate, Calif.
RM samples processed by R.B. Murray, analyzed by Calvin Barnes, Texas Tech University, Lubbock, Tex.

[2] Cadastral locations referenced to Willamette Meridian and Base Line.

[3] UTM Zone 10, 1927 North American Datum.

[4] Second Au analysis by Bondar-Clegg, Ltd., North Vancouver, British Columbia, Canada.

➤quadrangle, Douglas and Jackson Counties, Oregon

Elements (b.d. = below detection limits; -- = no analysis)

Bi	Cd	Cr	Cu	Ga	Hg	Mo	Nb	Ni	Pb	Rb	Sb	Sc	Se	Sr	Te	Tl	V	Y	Zn	Zr
b.d.	b.d.	--	2.42	0.654	1.3	1.29	--	--	0.702	--	b.d.	--	b.d.	--	b.d.	b.d.	--	--	22.4	--
0.539	0.2	--	213	1.46	5.15	1.01	--	--	1.17	--	0.629	--	b.d.	--	b.d.	0.504	--	--	94.5	--
b.d.	0.33	--	15	1.62	0.128	1.4	--	--	3.49	--	0.264	--	b.d.	--	b.d.	b.d.	--	--	128	--
b.d.	b.d.	--	3	b.d.	0.424	1.51	--	--	b.d.	--	b.d.	--	b.d.	--	b.d.	b.d.	--	--	10.7	--
b.d.	b.d.	b.d.	56.7	9.96	b.d.	0.398	b.d.	--	3.1	38	b.d.	--	b.d.	316	b.d.	0.501	--	b.d.	65.1	95
b.d.	b.d.	b.d.	34.7	2.51	b.d.	0.126	b.d.	--	b.d.	12	b.d.	--	b.d.	241	b.d.	b.d.	--	30	20.8	112
b.d.	b.d.	b.d.	15.9	3.04	b.d.	1.93	b.d.	--	2.71	81	b.d.	--	b.d.	261	b.d.	0.721	--	19	23.6	151
b.d.	b.d.	--	30.7	2.39	b.d.	0.779	--	--	3.73	--	0.282	--	b.d.	--	b.d.	b.d.	--	--	112	--
b.d.	b.d.	b.d.	50.4	10.6	b.d.	0.206	b.d.	--	1.75	22	b.d.	--	b.d.	345	b.d.	b.d.	--	11	53.6	37
b.d.	b.d.	b.d.	27.9	6.55	b.d.	0.517	b.d.	--	2.42	27	0.239	--	b.d.	348	b.d.	b.d.	--	40	80.3	111
b.d.	0.176	b.d.	53.2	7.25	b.d.	1.35	24	--	3.36	92	b.d.	--	b.d.	334	b.d.	0.908	--	14	54.1	153
--	--	16	72	--	--	--	3	b.d.	--	16	--	14.6	--	762	--	--	147	16.3	72	66
--	--	19	48	--	--	--	2	b.d.	--	6	--	6.5	--	959	--	--	81	9.4	55	73
--	--	12	3	--	--	--	6	10	--	35	--	2.9	--	176	--	--	4	20.8	15	27
--	--	12	1	--	--	--	9	14	--	47	--	3.7	--	93	--	--	4	27	13	27
b.d.	b.d.	b.d.	1.28	1.4	b.d.	0.212	b.d.	--	0.529	b.d.	b.d.	--	b.d.	254	b.d.	b.d.	--	12	5.96	39
b.d.	b.d.	b.d.	49.3	2.14	b.d.	0.466	b.d.	--	0.321	b.d.	b.d.	--	b.d.	180	b.d.	b.d.	--	22	6.72	62
--	--	13	6	--	--	--	4	19	--	25	--	3.9	--	547	--	--	28	10.3	70	46
b.d.	b.d.	b.d.	7.39	3.58	b.d.	1.25	b.d.	--	1.84	16	b.d.	--	b.d.	826	b.d.	0.484	--	b.d.	50.1	33
--	--	b.d.	8	--	--	--	3	b.d.	--	15	--	1.3	--	682	--	--	9	5.6	10	35
--	--	b.d.	19	--	--	--	1	b.d.	--	14	--	2.8	--	814	--	--	43	4.5	59	60
b.d.	b.d.	b.d.	50	6.29	b.d.	0.374	b.d.	--	1.33	17	b.d.	--	b.d.	362	b.d.	0.543	--	23	32.3	64
b.d.	b.d.	b.d.	2.03	1.87	0.234	1.09	b.d.	--	1.56	101	0.502	--	b.d.	136	b.d.	b.d.	--	13	13.1	98
b.d.	b.d.	b.d.	17.9	8.11	b.d.	0.503	b.d.	--	1.15	17	b.d.	--	b.d.	412	b.d.	b.d.	412	15	30.7	68

Table 3. Mines and prospects, Richter Mountain quadrangle, Douglas and Jackson Counties, Oregon

Map no.	Prospect name	Cadastral location[1] ¼	¼	Sec.	T.(S.)	R.(W.)	UTM coordinates[2] Northing	Easting	Elevation (ft)	Commodity	Map unit	Notes
M1	Green Butte claims	SE	NE	24	31	3	4745587N	500410E	2,840	Asbestos	msp	Chrysotile vein in serpentinite roof pendant
M2	Short claim (Corda Ann)	SW	SE	21	31	2	4745200N	504050E	2,610	Chromite	msp	Not found[3]
M3	Harkins prospect	NW	SE	22	31	2	4745550N	505700E	2,010	Hg	Toeb	Not found[3]
M4	unnamed prospect	SE	NW	30	31	1	4744079N	510104E	1,600	---	Toev	Altered breccia
M5	unnamed prospect	NE	NW	27	31	2	4744822N	505424E	1,955	---	msp	Altered fault
M6	unnamed prospect	SW	NE	27	31	2	4744319N	505802E	2,280	Cu, Hg?	msch	Disseminated sulfides
M7	unnamed prospect	SW	NW	27	31	2	4744317N	504947E	2,100	---	Toev	Trench in altered bedrock
M8	unnamed prospect	NW	SW	27	31	2	4744003N	505099E	2,020	---	msp	Altered bedrock
M9	unnamed prospect	SW	SE	27	31	2	4743593N	505754E	2,060	Cu, Hg?	msch	Altered bedrock
M10	unnamed prospect	SW	NE	34	31	2	4742658N	505842E	2,180	---	Toev	Altered breccia
M11	Banfield mine (South Umpqua mine)	NE	SW	34	31	2	4742342N	505586E	2,210	Cu, Zn, Ag, Hg	msch	Recorded production
M12	unnamed prospect	NW	NE	33	31	2	4742793N	504347E	2,280	---	msch	Altered bedrock
M13	unnamed prospect	NW	SW	33	31	2	4742289N	503519E	2,640	---	Ki, msch	Altered bedrock
M14	Red Hill prospect	NE	NE	6	32	2	4741336N	502484E	2,910	Au	msch	Not found[3]
M15	Diamond Bar placer	NW	SE	6	32	2	4740558N	501720E	2,670	Au	Qal	Placer
M16	Evans Group	NW	SW	5	32	2	4740401N	502648E	3,520	Au	msp	Large excavation and numerous prospect pits
M17	unnamed prospect	NE	NE	4	32	2	4741328N	505466E	2,920	Cu, Zn	msch	Gossan
M18	unnamed prospect	SE	NE	4	32	2	4740984N	505309E	3,350	Cu, Zn	am	Gossan
M19	Rowley mine	SE	SW	4	32	2	4740162N	504867E	3,030	Cu, Zn, Ag, Au	msch	Tunnel
M20	Arsenic Flash prospect	SE	SW	1	32	2	4740249N	509401E	3,300	Hg?	Tob	Altered breccia
M21	Flat claim	NE	SW	1	32	2	4740550N	509650E	3,080	Hg	Tob	Not found[3]
M22	Copper Butte prospect	NW	SE	9	32	2	4738780N	504970E	3,120	Cu, Zn, Ag, Au	am	Not found[3], part of Rowley system?
M23	unnamed prospect	NE	SW	17	32	2	4736835N	503224E	3,760	Cu, Zn	am	Gossan
M24	unnamed prospect	NW	SE	16	32	2	4737079N	504974E	3,790	---	am	Pit in altered bedrock
M25	Nivinson prospect	SE	SW	16	32	2	4736762N	504697E	3,560	Hg	am, msp	Tunnel, pit
M26	Thomason prospect	SW	SE	16	32	2	4736573N	505240E	3,650	Hg	Qls?	Not found[3]
M27	unnamed prospect	NE	NW	21	32	2	4736126N	504739E	4,040	---	msp	Numerous pits in altered bedrock
M28	Red Cloud mine (Mother Lode mine)	SW	NW	21	32	2	4735997N	504415E	3,840	Hg	am	Recorded production
M29	Elkhorn claims (Old Codger)	SE	NW	21	32	2	4735685N	504698E	4,130	Hg	am	Not found[3]
M30	Mammoth Lode	SE	NE	29	32	2	4734268N	504053E	4,470	Cu, Zn, Ag, Au, Hg	am	Massive sulfides exposed in tunnel, pits, and trenching
M31	unnamed prospect	NE	SE	29	32	2	4733921N	504068E	4,700	---	am	Gossan
M32	unnamed prospect	SE	NE	25	32	3	4734135N	500616E	2,950	---	msch	Caved tunnel

1 Cadastral locations referenced to Willamette Meridian and Base Line.

2 UTM Zone 10, 1927 North American Datum.

3 Locations described as “not found” were searched for, but no workings or other evidence is preserved at the UTM coordinates listed in the MILOC database. Information for the prospect is derived from the MILOC database or from the geologic map using the UTM coordinates listed in the database.