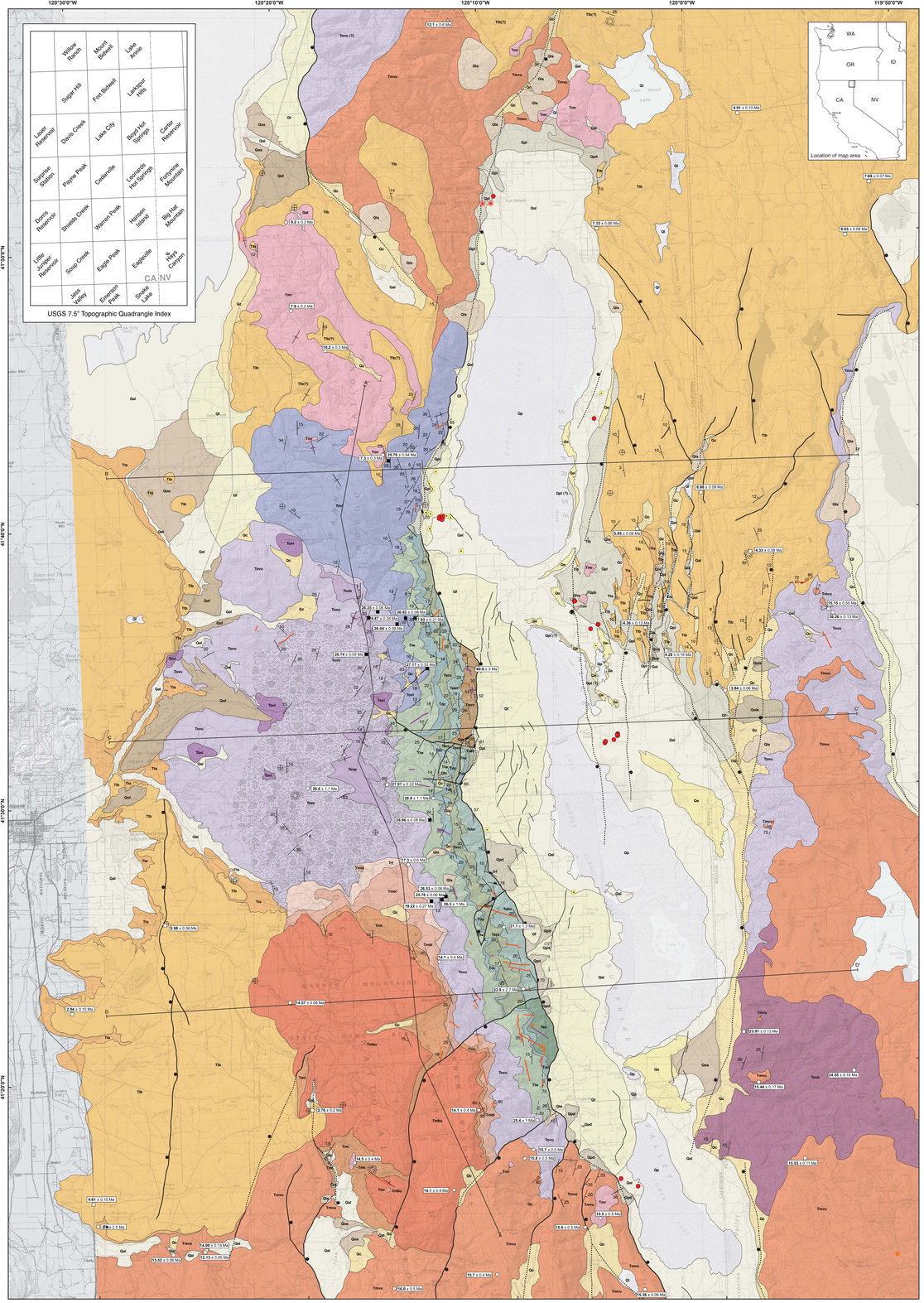

Holocene sediments

- Qal Alluvium
- Qf Fan deposits
- Qc Colluvium
- Qe Eolian deposits (sand dunes)
- Qhs Hot spring deposits
- Ql/Qp Lake and playa deposits
- Qls Landslides

Pleistocene sediments

- Qoa Older alluvium
- Qof Older fan deposits
- Qols Older landslide deposits
- Qpb Pleistocene beach gravels of Lake Surprise
- Qpd Pleistocene deltas of Lake Surprise
- Qpl Pleistocene lake sediments of Lake Surprise

Late Miocene-Pliocene volcanic rocks

- Tlb Low-K olivine tholeiitic basalts
- Tls Tuffs and tuffaceous sediments
- Tmr Mid-Late Miocene rhyolites

Mid-Miocene volcanic rocks

- Tmbu Basalt and andesite flows, upper
- Tmt Tuff and reworked tuff
- Tmb Basalt and andesite flows, lower
- Tmvu Mid-Miocene volcanic rocks, undifferentiated

Early Miocene volcanic rocks

- Trt Rhyolitic and andesitic ash flow tuffs

Oligocene volcanic rocks

- Tovb Bald Mountain basalt
- Tovp Payne Peak andesite
- Tovh Hays Volcano
- Tovc Cedar Pass volcanic complex
- Tovi Intrusive rocks of Cedar Pass complex
- Tovu Oligocene volcanic rocks, undifferentiated
- Tovl Lake City basalts

Oligocene sedimentary rocks

- Tlw Lost Woods Formation
- Tdc Deep Creek Formation
- Tscc Steamboat Formation, Cougar Cliffs member
- Tsbn Steamboat Formation, Badger's Nose member
- Tsu Oligocene sedimentary rocks, undifferentiated

Eocene rocks

- Tmrv McCulley Ranch Formation

- 15 Strike and dip of bedding
- 70 Strike and dip of fault plane
- 80 Strike and dip of dike
- Vertical bedding
- Horizontal bedding
- Volcanic vent
- Drill hole
- Hot springs
- Contact
- Normal fault, ball on downthrown block
- Normal fault, concealed, ball on downthrown block
- Quaternary fault scarp
- Maximum lake level, Pleistocene Lake Surprise (Zimbelman et al., 2008)
- 14.1 ± 0.4 Ma Geochronological age, symbol indicates source:
  - Colgan et al., in prep
  - Carmichael et al., 2006
  - Duffield and McKee, 1986
  - Keats, 1985
  - Axelrod, 1966
  - Geochemistry sample location
- Basaltic dike
- Andesitic dike
- A A' Cross-section lines

Includes mapping from the South Warner Wilderness done by Duffield et al, 1976, compiled from the original field sheets of Wendell Duffield, and modified by checking with orthophotoquads, geochronology, and additional field mapping. Quaternary faults scarps are from Hedel, 1984; and Bryant, 1990. Locations of geothermal drill holes were compiled from drilling records. See Appendix A for complete unit descriptions, geochronology, and geochemical data.

north

0 2 4 6 8 10 kilometers

Scale 1:100,000

Unit descriptions

Qal **Quaternary alluvium** *(Holocene)* Unconsolidated sedimentary deposits associated with modern fluvial systems.

Qf **Quaternary fan deposits** *(Holocene)* Unconsolidated coarse gravel deposits in alluvial fans.

Qc **Quaternary colluvium** *(Holocene)* Unconsolidated soil and sediments deposited at the base of slopes by sheet-wash.

Qe **Quaternary eolian deposits** *(Holocene)* Eolian sand dunes, mostly stabilized as indicated by vegetation growth.

Qhs **Quaternary hot spring deposits** *(Holocene)* Siliceous and calcareous sinter, where sufficiently abundant to be mapped separately.

Ql/Qp **Quaternary lakes and playa lake deposits** *(Holocene)* Perennial lakes (Ql) and evaporite and clay deposits in ephemeral lakes.

Qls **Quaternary landslides and slumps** *(Holocene)* Undifferentiated landslides, including debris flows and slump blocks.

Qoa **Quaternary alluvium - older** *(Pleistocene?)* Older fluvial deposits, possibly Pleistocene, currently being dissected by modern streams.

Qof **Quaternary fan deposits - older** *(Pleistocene?)* Older fan deposits, possibly Pleistocene, currently being dissected by modern streams.

Qols **Quaternary landslides - older** *(Pleistocene?)* Stratigraphically and geomorphically older landslides and debris flows, possibly Pleistocene.

Qpb **Quaternary beach deposits** *(Pleistocene)* Beach berm deposits from Pleistocene Lake Surprise, mostly fine gravel. Silicified near Leonards Hot Springs.

Qpd **Quaternary delta deposits** *(Pleistocene)* Gilbert-type fan delta deposits from Pleistocene Lake Surprise. Remnants of deltas on the floor of Surprise Valley are flat-topped with steep foreset beds of coarse gravel and horizontal topsets.

Qpl **Quaternary pluvial lake deposits** *(Pleistocene)* Lake sediments deposited in Pleistocene Lake Surprise. Primarily fine-grained sediments, often tuffaceous, but also includes minor gravels and waterlain tuffs.

Tlb **Tertiary low-K, olivine tholeiitic basalts** *(late Miocene-Pliocene)* Low-potassium, high-alumina olivine tholeiites, generally holocrystalline and diktytaxitic, with a very restricted range of compositions and ranging in age from ~3-8 Ma. Includes the Vya Group, Devil's Garden, and Alturas Plateau basalts of Carmichael et al. (2006). Individual flows are 1-10 m thick and interbedded with Tls, though occasionally multiple flows pond to 25-30 m.

Tls **Tertiary tuffs and tuffaceous sediments** *(late Miocene-Pliocene)* Generally silicic volcaniclastic sediments consisting of conglomerate, sandstone, and siltstone interbedded with rhyolite ash and silicic ash-flow tuff up to 100 m thick. North of Leonards Hot Springs, Tls consists of graded 10-30 cm thick beds of pebble conglomerate (most basalt pebbles) interlayered with coarse-grained, 2-3 cm thick sandstone beds of similar composition. In places, the conglomerate and sandstone interfinger with ash-rich, greenish gray siltstone and rhyolite tuff and ash-flow tuff. The siltstone is poorly bedded, normally graded and includes reworked tuff and lithic fragments. Rhyolite tuff beds are unwelded and contain abundant glass shards, lapilli, and phenocrysts of plagioclase and quartz. The entire sequence is interbedded with Tlb throughout the map area; on the west side of the Warner Range, it may include the Alturas Tuff of Carmichael et al (2006) and Collins (1999).

Tmr **Tertiary rhyolite flows and domes** *(mid-late Miocene)* Rhyolite domes and flows, often including obsidian carapaces, that range in age from 7-15 Ma. Rhyolites are generally light gray and phenocryst-poor. In the northern portion of the Warner Range, these directly overlie the 27 Ma Lake City basalts (Tovl).

Tmbu **Tertiary basalt and andesite flows** *(Mid-Miocene)* A stack of ~100 basaltic to andesitic lava flows that reaches 1000 m thick. Individual flows are 2–5 m thick, occasionally up to 20 m, with scoriaceous tops and massive interiors. The interiors of some units exhibit coarse, gabbro-like textures in hand specimen and thin section, suggesting that they are sills. Flows often have prominent columnar jointing, but are locally glassy and flow-banded. Phenocrysts are variably abundant and include plagioclase, pyroxene, and olivine. Duffield and McKee (1986) divided these flows into two units ("Tvm" and "Tvb") separated by a layer of tuff, but they are indistinguishable in outcrop and have a small age range from 14-16 Ma, so here they are considered upper (Tmbu) and lower (Tmbl) divisions of one unit.

Tmbl

Tmt **Tertiary tuff and tuffaceous sediments** *(Mid-Miocene)* Graded, cross-bedded coarse sandstones 90-200 m thick, with abundant plagioclase crystal fragments and dark lava chips, and massive, inversely graded deposits of angular mafic lava blocks in a sandy matrix. Below the summit of Warren Peak, this unit includes a layer of tuff with a fine-grained gray ashy matrix supporting a mixture of <1 cm white pumice lapilli and angular black fragments of what appears to be glassy lava. Mapped as Tvt by Duffield and Weldin (1976).

Tmvu **Tertiary volcanic rocks, undivided** *(mid-late Miocene)* Undifferentiated Miocene volcanic rocks, primarily mid-Miocene, and including Tmr, Tmt, Tmbu, and Tmbl.

Trt **Tertiary rhyolitic tuffs and tuffaceous sediments** *(early middle Miocene)* A poorly exposed unit, up to 250 m thick, consisting of biotite- and sanidine-bearing tuffaceous sandstone and siltstone and densely welded tuffs. The presence of biotite marks them as distinctly different from locally-derived pyroclastic flows. Included in Tvc mapped by Duffield and Weldin (1976), but 17-19 Ma ages suggest a significant hiatus in deposition after the underlying Oligocene layers.

Tovb **Tertiary Bald Mountain basalt** *(Oligocene)* Thin (10-20 m) but continuous basalt flow capping Bald Mountain and dated at 24.47 ± 0.34 Ma (this study).

Tovp **Tertiary Payne Peak andesite** *(Oligocene)* Dark-gray-weathering, phenocryst-poor lava flows with a fine-grained groundmass of plagioclase and pyroxene. Flows cap Payne Peak and surrounding high points.

Tovh **Tertiary Hays Volcano** *(Oligocene)* Volcanic edifice in the Hays Canyon Range composed of basaltic andesite flows, agglutinate lavas, and scoriaceous tuffs. Two dates from flows within the volcanic sequence suggest rapid accumulation of flows: a flow near the more eroded core was dated at 23.91 ± 0.13 Ma, and a flow on the top flank was dated at 24.55 ± 0.16 Ma (Carmichael et al, 2006).

Tovc **Tertiary Cedar Pass volcanic complex** *(Oligocene)* Pyroclastic deposits and lesser lava flows exposed in the vicinity of Cedar Pass, up to 1200 m thick. Mostly massive and unsorted to crudely stratified gravity flows and rock avalanches, though occasionally bedding is well-developed. Lava blocks range in size from a few cm to >2 m, and range in texture from dark, phenocryst-poor lavas to lighter gray-green lavas with abundant phenocrysts of plagioclase and hornblende. In places, porphyritic lava flows with phenocrysts of plagioclase, hornblende, and lesser pyroxene are interbedded with the pyroclastic deposits.

Tovi **Tertiary hypabyssal intrusions** *(Oligocene)* Phenocryst-rich hypabyssal intrusive rocks within the Cedar Pass volcanic complex. Phenocrysts consist almost entirely of hornblende and plagioclase crystals, 2-5 mm in size. Rarely, hornblende crystals reach 2-3 cm.

Tovu **Tertiary undivided volcanic rocks** *(Oligocene)* Consists primarily of several densely welded ash-flow tuffs and less common (mostly andesitic) lava flows of Oligocene age. Includes the "Fortynine Tuff" of Carmichael et al. (2006) and most of Tvc of Duffield and Weldin (1976).

Tovl **Tertiary Lake City basalts** *(Oligocene)* A series of mafic lava flows, tuffs, and tuff breccias that ranges in thickness from a few tens of meters near Cedar Pass to over two kilometers below Buck Mountain. Individual flows are a few meters thick, vesicular with massive interiors, dark when fresh but often reddish-weathering. Flows vary from aphanitic to moderately porphyritic with phenocrysts of plagioclase, olivine, and pyroxene; the olivine is most often altered and the plagioclase is usually partly altered to white mica. Some flows contain abundant (>50%) large (>1cm) plagioclase phenocrysts. Tuffs are poorly exposed, particularly on the east side of the Warner Range, but vent-proximal tuff breccias reach their thickest extent on the west side of the range.

Tlw **Tertiary Lost Woods Formation** *(Oligocene)* Andesitic and basaltic lahars, sedimentary rocks (sandstone, shale and conglomerate) and interbedded flows, 300-1000 m thick. The entire unit is conspicuously red-weathering. Lahars comprise beds ~ 2-3 m thick, with a sandy to pebbly matrix and poorly sorted subangular to angular clasts averaging ~ 10 cm but reaching 40 cm. Andesite and basalt flows are less than 4 m thick and include porphyritic plagioclase basalt and hornblende andesite. Sedimentary successions have conglomerate lenses, sandstones and shales, and contain abundant fossil wood.

Tdc **Tertiary Deep Creek Formation** *(Oligocene)* Poorly-exposed, slope-forming unit consisting mostly of fine-grained tuffs, up to 400 m thick. Includes highly altered and silicified breccia with a green matrix.

Tscc **Tertiary Steamboat Formation - Cougar Cliffs Member** *(Oligocene)* Massive, cliff-forming andesitic lahars and debris flows, 250-350 m thick, with mostly subangular clasts up to 1 m in size. Poorly sorted, and generally matrix supported. Matrix consists mostly of mud, minor ash, and abundant mm-sized hornblende and plagioclase crystals. Clasts are predominantly andesite with purple-grey, aphanitic groundmass, 1-2 mm plagioclase and larger hornblende phenocrysts. The unit forms prominent cliffs south of Simpsons Canyon, but the unit becomes thinner and less resistant to the north. Locally, thinly-bedded conglomerates, sandstones and siltstones are interlayered with the lahars

Tsbn **Tertiary Steamboat Formation - Badger's Nose Member** *(Late Eocene - Oligocene)* Primarily fine-grained volcaniclastic sediments, including a lacustrine shale with abundant leaf fossils of late Eocene-early Oligocene age (Myers, 2006).

Tsu **Tertiary Steamboat Formation - undifferentiated** *(Late Eocene - Oligocene)* Undifferentiated sedimentary unit that includes both members of the Steamboat formation.

Tmrv **Tertiary McCulley Ranch Formation** *(Late Eocene)* Fractured and deeply weathered andesitic debris flows interbedded with andesite flows, minimum thickness of ~650 m. Near the top of the unit, Axelrod (1966) reports a K-Ar age of 40.8 ± 3.0 Ma (corrected) on plagioclase from an andesite flow, suggesting an Eocene age for the entire sequence.

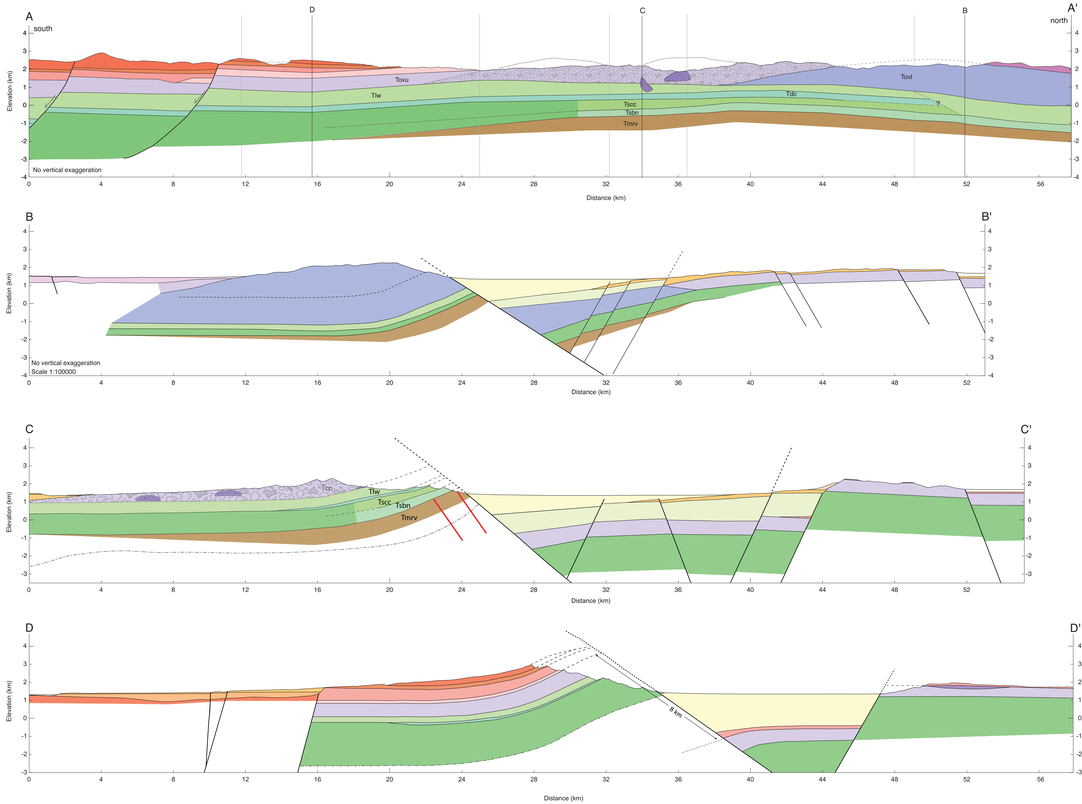

Plate I. Geologic Map of the Warner Range and surrounding region