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

OPEN FILE REPORT
93-703

123° 07' 30"
42° 07' 30"
123° 00'
42° 07' 30"
42° 00'
123° 07' 30"
42° 00'
123° 00'

Base from U.S. Geological Survey, Carberry Creek, 1983
Lambert conformal conic projection

Geology mapped by M. M. Donato, assisted by S. L. Tomlinson, 1991, and P. Weston, 1992.

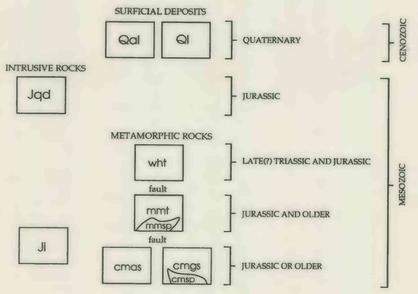
SCALE 1:24 000

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

APPROXIMATE MEAN DECLINATION, 1993

QUADRANGLE LOCATION

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Qal **Alluvium (Quaternary)**-Unconsolidated sand and gravel along rivers and streams

Ql **Landslide deposits (Quaternary)**-Commonly occur in areas underlain by graphite schist of the Condrey Mountain Schist. Many small deposits not shown. Large landslides may actually be composed of coalesced smaller slides

INTRUSIVE ROCKS

Jqd **Quartz diorite (Jurassic)**—Medium- to coarse-grained hornblende-biotite quartz diorite bodies which intrude the western Hayfork and Marble Mountain terranes. Includes the 164-Ma Squaw Mountain pluton, exposed in the northeastern part of the quadrangle and a poorly-exposed quartz diorite body of inferred Jurassic age which intrudes unit mmt south of Applegate Dam

Ji **Deformed intrusive rocks (Jurassic ?)**—Medium- to coarse-grained leucocratic intrusive rocks consisting of plagioclase, K-feldspar, white mica, biotite, and quartz, with accessory garnet and local secondary chlorite. Locally strongly flattened and (or) lineated. Microscopic textures suggest high-temperature (subsolidus) plastic deformation

METAMORPHIC ROCKS

wht **Western Hayfork terrane (Middle Jurassic)**—Protolith predominantly greenish-gray volcanogenic sandstone and interbedded grayish-brown argillite and rare conglomerate. Some units exhibit graded beds and partial Bouma sequences, suggesting deposition by turbidity currents. Sandstone is well-sorted, fine- to coarse-grained, and is composed dominantly of plagioclase, clinopyroxene, brown to greenish-brown hornblende, and variable amounts of mafic to intermediate volcanic and volcaniclastic lithic fragments. Plagioclase and clinopyroxene are the dominant phenocrysts in volcanic lithic fragments, but hornblende is also present. Unit is regionally metamorphosed to greenschist facies except adjacent to the Squaw Mountain pluton, where rocks approach hornblende-hornfels facies. A typical metamorphic mineral assemblage is: chlorite-actinolite-albite-epidote/clinozoisite-sphene. Primary igneous amphibole and clinopyroxene are commonly partially or completely replaced by actinolite, but are preserved locally. Weak flattening foliation and cleavage are locally developed but the unit is mostly undeformed. Rocks in this quadrangle have previously been considered part of the Applegate Group, believed to be Late(?) Triassic and Jurassic by Wardlaw and Jones (1979), based in part on Jurassic radiolarians from the western part of the unit (Irwin and others, 1978). Unit is considered by Barnes and others (1993) to be equivalent to the Middle Jurassic western Hayfork terrane of Wright and Fahan (1988) (the Hayfork Bally meta-andesite of Irwin, 1972). Olive-green hornblende separated from metagrawacke gave a $^{40}Ar/^{39}Ar$ age of 173 ± 1 Ma. Brown hornblende from a weakly metamorphosed dike crosscutting this metagraywacke yielded a $^{40}Ar/^{39}Ar$ age of 156 ± 1 Ma. Equivalent to unit vsci of Donato (1992)

mmt **Marble Mountain terrane (Jurassic or older)**—Lithologically diverse unit consisting predominantly of amphibolite, siliceous argillite, quartzite, and metaserpentinite. Elsewhere also includes metachert, volcaniclastic metasedimentary rocks, siliceous and semipelitic metasedimentary rocks, and marble, but these lithologies are uncommon in the Squaw Lakes quadrangle. Metamorphic grade is amphibolite facies. Argillites commonly have phyllitic sheen due to incipient growth of micaceous minerals such as biotite and chlorite and commonly contain sulfide minerals. Contacts between the various rock types are difficult to map for extended distances due to poor exposure and intricate structural and depositional interlayering; therefore lithologic variants are undifferentiated on this map. Unit, together with unit mmsp, is correlated with the Marble Mountain terrane of Blake and others (1982) and interpreted as metamorphosed tectonic mélange, based on similarity to rocks described by Donato (1987) in the Marble Mountains in northern California, 45 km to the south. Green hornblende from sample of amphibole schist near southern arm of Applegate Lake yielded $^{40}Ar/^{39}Ar$ cooling age of 151 ± 2 Ma. Equivalent to unit gam of Donato (1992)

mmsp **Metaserpentinite**—Tectonically emplaced lensoidal bodies of metamorphosed serpentinite within the Marble Mountain terrane. Chlorite-talc-magnetite reaction rinds (blackwalls) are present at many contacts. Serpentinite textures (e.g. bladed antigorite pseudomorphs after olivine), the presence of blackwall, and idioblastic olivine + amphibole metamorphic assemblages indicate that the serpentinites were regionally metamorphosed along with the surrounding sedimentary and volcanic rocks after tectonic emplacement. Only larger bodies are shown

cmas **Actinolite schist (Jurassic or older)**—Well-foliated and lineated, fine- to medium-grained schist composed predominantly of actinolite, chlorite, quartz, epidote, and albite, with accessory sphene and rarely, garnet. Sodic amphibole has been reported elsewhere in this unit, hence metamorphic grade is transitional between greenschist and blueschist facies (Helper, 1986). Represents marginal facies of Condrey Mountain Schist of Helper (1986) and is the "greenschist" unit of Coleman and others (1983)

cmgs **Graphite schist (Jurassic or older)**—Black, extremely fissile, siliceous graphite schist containing quartz, chlorite, white mica, albite, graphite, and locally, pyrite cubes up to 1 cm. Strongly foliated, with foliation marked by mm-scale quartz laminae; locally foliation is contorted in complex folds. Variation in amount and proportion of quartz, feldspar, and mica are observed locally. Unit is very prone to landslides. Forms core of Condrey Mountain Schist and is the "black schist" unit of Coleman and others (1983)

cmsp **Metaserpentinite**—Fault-bounded lensoidal bodies of metasomatized, metamorphosed serpentinite within the graphite schist. Consist mainly of talc schist with chlorite-rich selvages. Larger bodies contain nearly pure steatite talc. Many smaller bodies are not shown

Contact—Dashed where approximately located; dotted where concealed; queried where uncertain. Shown as solid lines in cross-sections

Fault—Dashed where approximately located; dotted where concealed; queried where uncertain. Shown as solid lines in cross-sections

Normal fault—Dashed where approximately located. Hatchures on downthrown side

24 **Bedding**—Showing strike and dip

56 **Metamorphic foliation or schistosity**—Showing strike and dip

12 **Metamorphic mineral lineation**—Showing azimuth and plunge. May be combined with symbol for metamorphic foliation or schistosity

Zone of strongly deformed rocks

Sedimentary layering—Used in cross-section A-A' only

❖ 156 ± 1 **$^{40}Ar/^{39}Ar$ sample locality**—Showing age in millions of years

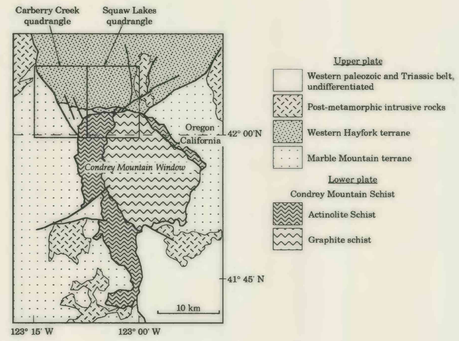


Figure 1. Simplified geologic map of the north-central Klamath Mountains, showing the location of the Squaw Lakes quadrangle.

GEOLOGIC SUMMARY

Structural setting

The Squaw Lakes 7.5' quadrangle straddles an important structural boundary in the Klamath Mountains Province. The boundary, which trends east-west in this area, divides the quadrangle approximately in half and comprises a complex zone of faulted and highly deformed rocks at the northern margin of a domal structure known as the Condrey Mountain Window (Fig. 1). The rocks in the northern part of the quadrangle are part of the upper plate of the dome and are predominantly weakly metamorphosed volcaniclastic sandstones and argillites correlative with the middle Jurassic western Hayfork terrane, unit wht (Barnes and others, 1993). Limited exposures of high-grade metamorphic rocks assigned to the Marble Mountain terrane, unit mmt (Blake and others, 1982) also occur structurally beneath the western Hayfork terrane within the faulted zone at the northern margin of the window. The southern part of the quadrangle lies within the Condrey Mountain Window and is underlain primarily by the two metamorphic units which make up the Condrey Mountain Schist: actinolite schist (unit cmas) and graphite schist (unit cmgs). Rocks in the upper plate are tilted radially away from the center of the dome, as documented in demonstrably tilted plutons at its southern and eastern margins (Barnes and others, 1986). The effects of doming may extend up to 30- to 50-km radially from the center of the dome (Mortimer and Coleman, 1984).

On the northern flank of the dome, the upper plate constitutes a broad, northward-widening graben bounded on the east and west by northeast- and northwest-trending high-angle fault systems, respectively. The Squaw Lakes quadrangle lies between the two graben-bounding fault systems (Figure 1). In the graben, the volcaniclastic rocks predominate in the upper plate, whereas southeast and southwest of the graben, the upper plate is composed mainly of rocks of the Marble Mountain terrane. The graben-bounding faults are interpreted as part of a system of radial faults that accommodated doming, the age of which is believed to be between 15 Ma and 4 Ma (Mortimer and Coleman, 1984).

The boundary between the Condrey Mountain Schist and the rocks of the upper plate in the Squaw Lakes quadrangle is a complex zone of steep north-dipping faults, along which upper-plate rocks have been displaced downward and to the north relative to the Condrey Mountain Schist. It is inferred that this motion occurred along normal faults during doming of the schist. One of these faults probably displaced an earlier contact within the upper plate between the western Hayfork terrane and the underlying Marble Mountain terrane. The geometry of the faults is such that in some places the western Hayfork terrane is directly in contact with the Condrey Mountain schist, whereas in other places, a thin sliver of Marble Mountain terrane is present between these two units. The most topographically pronounced of these faults, here called the French Gulch fault, trends east-west across the quadrangle. Based on apparent cross-cutting relationships at the surface, the French Gulch fault is interpreted to postdate the fault between the western Hayfork terrane and the Marble Mountain terrane, but merges with it along strike near Applegate Dam (and possibly at depth; see cross sections B-B', C-C' and D-D'). In the adjacent Carberry Creek quadrangle to the west, a series of northwest-trending en echelon faults associated with doming is interpreted to postdate the western extension of the French Gulch fault, offsetting it stepwise to the north (Donato, 1992). Although relative ages of faults can in some cases be inferred from cross-cutting relationships, it is likely that both the graben-bounding faults and the faults defining the Condrey Mountain Window are related to doming. Thus time intervals between faulting episodes may not have been significant.

The upper plate is intruded by numerous Jurassic plutons (unit Jqd) which range from gabbro to granodiorite in composition. The pluton whose western margin is exposed in the northeastern part of the Squaw Lakes quadrangle is here referred to as the Squaw Mountain pluton. Preliminary $^{40}Ar/^{39}Ar$ data indicate a late middle Jurassic age (see below). Another small intrusive body exposed near Applegate Lake intrudes the Marble Mountain terrane; no radiometric age data are available, and its age is inferred to be Jurassic.

Strongly deformed intermediate to granitic intrusive rocks (unit Ji) are present within the faulted contact zone between the upper and lower plates. These bodies are mapped separately from the generally undeformed, more mafic intrusive bodies described above. They form irregular, sinuous bodies along the outer margin of the window within the upper plate and are distinctive both in their style of deformation and in their mineralogy (K-feldspar, biotite and no hornblende, muscovite, and accessory garnet are characteristic; quartz and plagioclase are also present). They clearly intrude the Marble Mountain terrane but have not been observed in direct contact with the Condrey Mountain Schist, although contact-metamorphosed graphite schist float has been observed in one locality. The rocks have a strong north- to northeast-dipping planar (locally gneissic) fabric defined by micas and feldspar. Locally the rocks develop a strong northeast-southwest-trending lineation. Textures observed in thin section and outcrop, including stretched and elongate feldspar and quartz grains, mica "fish" and incipient S-C fabrics, are consistent with high-temperature ductile deformation. Oriented samples yielded ambiguous sense of shear. Although the rocks contain abundant zircon, an earlier attempt to date them isotopically yielded discordant ages (M. Helper, written commun., 1992). Zircon separates from a second locality are currently being prepared. The strongly deformed character and the spatial restriction of these rocks to the margin of the window suggests that they were intruded synchronously with juxtaposition of the Condrey Mountain Schist with the upper plate rocks. Note that this event may have significantly predated domal uplift and activation of the window-bounding normal faults.

Metamorphism

Metamorphic grade in the upper plate ranges from low greenschist facies to middle- amphibolite facies. Unit wht is mainly greenschist facies (a typical assemblage is actinolite-epidote-albite-sphene ± chlorite) except near the margin of the Squaw Mountain pluton, where contact metamorphism produced hornblende and plagioclase, indicating hornblende hornfels facies. Recrystallized volcaniclastic rocks seen only in float on the south slope of Iron Knob become more strongly deformed, pale green amphibole becomes increasingly dark in color, and biotite joins the assemblage as the contact with the Condrey Mountain Schist is approached, suggesting local increase in metamorphic grade from greenschist to upper greenschist or lower amphibolite facies at the structural base of the unit. Unit mmt and the associated metaserpentinite (mmsp) of the Marble Mountain terrane within the Squaw Lakes quadrangle are amphibolite grade, as they are in adjacent quadrangles (Donato, 1992).

An abrupt change in metamorphic grade occurs locally at the margin of the Condrey Mountain window, where the Marble Mountain terrane is in contact with the Condrey Mountain Schist. A typical metamorphic assemblage in unit cmas is actinolite + chlorite + epidote + albite, indicating greenschist facies conditions, whereas rocks immediately structurally above the contact in unit mmt display amphibolite-facies assemblages. A more quartzofeldspathic (and Fe-rich?) variety of unit cmas located about 0.7 km west of Stein Butte contains abundant sheafs of late-growing stilpnomelane crosscutting the main foliation. Minor pale garnet is locally present in the unit. Outside the map area unit cmas locally contains sodic amphibole and displays metamorphic assemblages transitional between blueschist- and greenschist-facies (Helper, 1986). The metamorphic grade of the graphite schist (unit cmgs) is greenschist facies, indicated by the presence of chlorite, albite, and white mica.

Age

Hornblende separates from three samples within the Squaw Lakes quadrangle have been dated by the $^{40}Ar/^{39}Ar$ incremental heating method. Sample localities of dated samples are shown on the map. In addition, a fourth sample, representative of the Squaw Mountain pluton, was collected in the Sterling Creek quadrangle (northeast of the Squaw Mountain quadrangle). All ages reported are preliminary but final ages probably will not differ from the reported ages by more than about 1 or 2%. These isotopic ages represent the elapsed time since the mineral cooled below its closure temperature for Ar diffusion (estimated to be about 500° to 550°C for hornblende(McDougall and Harrison, 1988)) and therefore are interpreted as cooling ages.

Two samples from the western Hayfork terrane (unit wht) were dated. Detrital olive-green hornblende of igneous origin was separated from a sample of metagraywacke near Applegate Dam. This separate yielded a $^{40}Ar/^{39}Ar$ age of 173 ± 1 Ma (weighted mean plateau age—WMPA). Based on the slight degree of metamorphic recrystallization, the temperature of the metagraywacke during metamorphism probably did not exceed the hornblende closure temperature. Therefore this age is interpreted as the eruptive age of the volcanic source rock which provided the detritus for the metagraywacke's protolith. Brown hornblende phenocrysts from a lightly metamorphosed dike at the same locality gave a WMPA of 156 ± 1 Ma; this age is interpreted as the dike's igneous cooling age.

The third sample is from the Marble Mountain terrane (unit mmt). The protolith age of the Marble Mountain terrane is not well established but its unmetamorphosed equivalent, the Rattlesnake Creek terrane, is reported to be no younger than early Jurassic (Wright and Wyld, in press). Numerous determinations of the cooling age of metamorphic hornblende from the Marble Mountain terrane consistently yield ages in the 148- to 152-Ma range (Donato, 1992; Hacker and others, 1993). In this case, metamorphic hornblende from a well-lineated amphibole schist collected near the southern arm of Applegate Lake yielded 151 ± 2 Ma (WMPA).

The hornblende separate from a sample of hornblende-biotite quartz diorite of the Squaw Lakes pluton in the Sterling Creek quadrangle gave a $^{40}Ar/^{39}Ar$ WMPA age of 164 ± 1 Ma.

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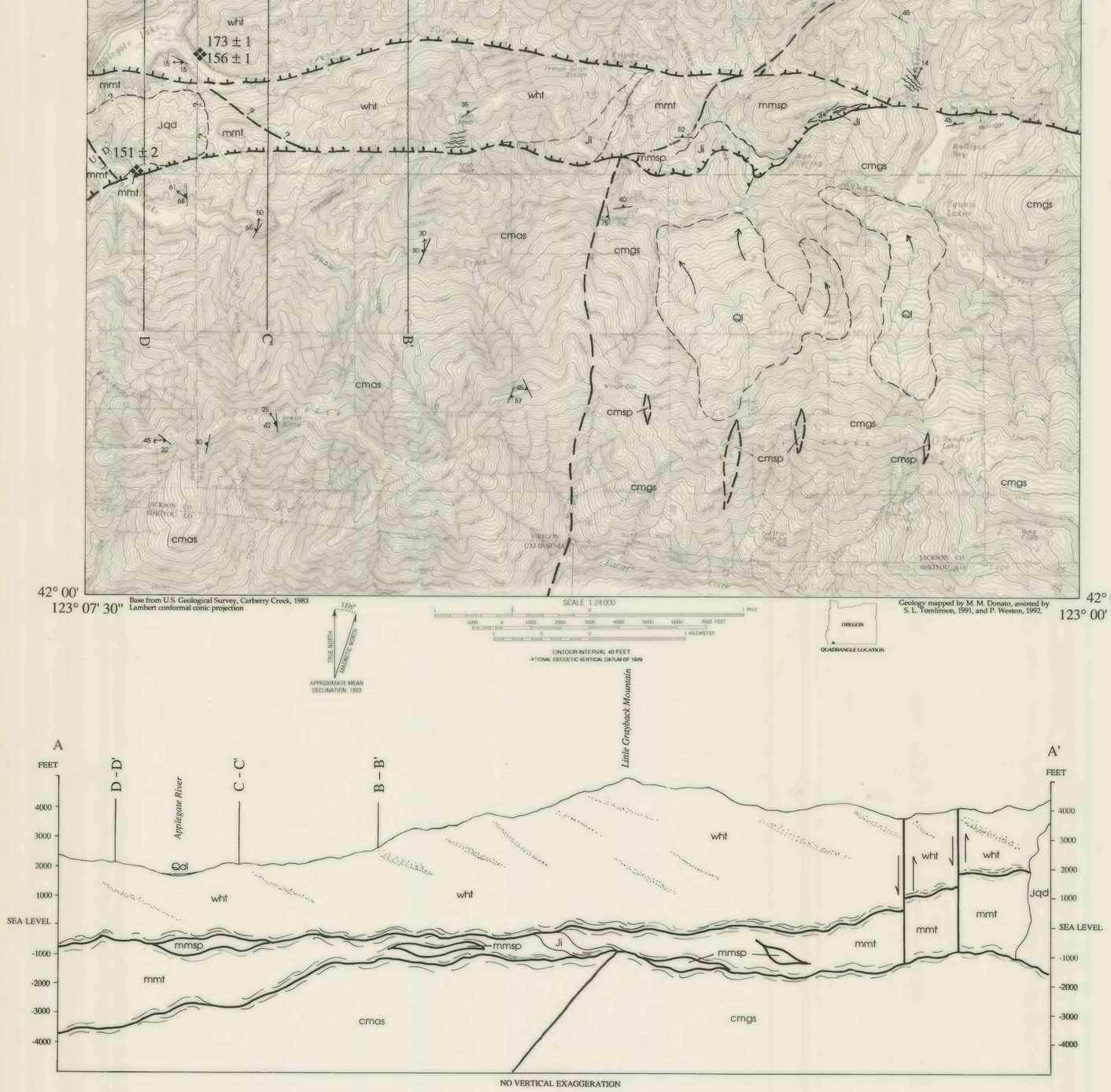

PRELIMINARY GEOLOGIC MAP OF THE SQUAW LAKES QUADRANGLE, OREGON AND CALIFORNIA

By
Mary M. Donato

1993