

Text and references to accompany Nevada Bureau of Mines and Geology Map 125

GEOLOGY OF THE LAMOILLE QUADRANGLE

ELKO COUNTY, NEVADA

by

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The Ruby Mountains and adjoining East Humboldt Range form one of more than a score of North American Cordilleran metamorphic core complexes (Crittenden and others, 1980). The Lamoille 7.5-minute Quadrangle includes part of the core complex where the Ruby Mountains are accessible by car via Lamoille Canyon, as described in several field guides (Snoke and Howard, 1984; Howard, 1987; Snoke and others, 1997). The quadrangle lies within the area of a geologic map of the Ruby Mountains (Howard and others, 1979, 1:125,000-scale). Geologic maps of adjacent quadrangles can be found in Howard (1966, 1:24,000), Smith and Howard (1977, 1:62,500), and MacCready and others (1997, ~1:45,500).

In brief, the core complex in the quadrangle exposes Neoproterozoic and lower Paleozoic miogeoclinal strata that were thrust-faulted, deeply buried, metamorphosed, recumbently folded, and intruded pervasively by Cretaceous

to Oligocene granitoids. Cenozoic unroofing accompanied footwall rise below an inclined down-to-the-west extensional fault system. That fault system imprinted a ductilely sheared mylonitic carapace on the now-exposed deep footwall in Oligocene and Miocene time, and has continued into Holocene time to move as a gently dipping near-surface brittle fault (Howard, 1992).

METAMORPHIC AND INTRUSIVE ROCKS

Metamorphosed sedimentary rocks are correlated on the basis of lithologic sequence with unmetamorphosed Neoproterozoic to Devonian strata of the Cordilleran miogeocline in nearby mountain ranges (Howard, 1971). The strata are tectonically thinned from original thicknesses (table 1).

Table 1. Thickness of metamorphosed stratigraphic units compared to original thickness.

Map unit	Structural thickness in Lamoille Quadrangle	Approximate stratigraphic thickness of unmetamorphosed correlatives
Dm, marble of Snell Creek	≤50 m, top not exposed	300 m (Guilmette Formation)
DOd, dolomite	0–60 m	1000 m (Simonson, Sevy, Laketown, and Fish Haven Formations)
Oe, metamorphosed Eureka Quartzite	0–3 m	0–100 m
Ocm, marble of Verdi Peak	20–1000 m	3000 m (Pogonip Group and Cambrian limestone and shale units)
czp, metamorphosed Prospect Mountain Quartzite	12–400 m, base not exposed	>1000 m

They are metamorphosed to amphibolite facies. Sillimanite appears in muscovite-K-feldspar-bearing metaquartzite in the sillimanite zone east of and structurally below a mapped sillimanite isograd. Sillimanite is found in pelitic schist locally outside the host-rock-defined sillimanite zone, and sillimanite occurs in granitic rocks mostly only well inside the sillimanite zone.

Migmatitic networks of Late Cretaceous to Oligocene granite form more than half of the rock volume within the Ruby Mountains in the quadrangle, and intimately inject a framework of relics or rafts of the metamorphosed strata (Howard and others, 1979; Wright and Snoke, 1993; MacCready and others, 1997). Remarkably, these relics outline ghost stratigraphy that traces out large coherent structures even where granitic rocks greatly predominate. Pegmatitic granite intrusions assigned a Cretaceous age are the most abundant, and consist of sills, dikes, and irregular bodies as thick as 100 m. Overprint patterns on the mapped metasedimentary units indicate the proportion of pegmatitic granite in the resulting migmatite. The pegmatite granite becomes proportionally more voluminous toward structurally deep levels, and is mapped separately in canyon bottoms where metasedimentary relics are lacking.

A separate overprint pattern indicates areas where undated small gabbro bodies occur. The distinctive granite gneiss of Thorpe Creek (dated as late Eocene) and the undated granodiorite gneiss of Seitz Canyon each form a mapped sheet in the core or along the upper limb of the Lamoille Canyon fold nappe. Their shapes mimic that of the nappe (Howard, 1966, 1980; MacCready and others, 1997). Younger, less voluminous intrusions are biotite monzogranite (Oligocene, 29 Ma) and the youngest intrusive rock, basalt dikes (Miocene).

STRUCTURE

The Paleozoic strata in this migmatitic terrain are tectonically layered as a result of thrust faulting and later recumbent folding. The oldest deformational structure recognizable is the pre-metamorphic, now recumbently folded Ogilvie thrust fault (Smith and Howard, 1977). This thrust doubles a section of the metamorphosed Prospect Mountain Quartzite and the marble of Verdi Peak; the section in the allochthon continues upward into the Devonian. As seen in this and adjacent quadrangles, the thrust-repeated sequence folds around the Lamoille Canyon fold nappe, resulting in a layering of alternating Prospect Mountain Quartzite and the marble of Verdi Peak. The thrust surface lacks recognizable cataclastic rocks or outcrop-scale discordance, a lack that can be attributed to post-thrusting metamorphism and deformation. Wedgelike slivers of interfingered metaquartzite and marble are mapped northwest and southwest of Thomas Canyon Campground (as well as elsewhere outside the quadrangle), and are interpreted as structural horses bound by splays of the thrust. When restored to prefolding position the shapes of these mapped slivers suggest an originally westward thrust imbrication,

indicative of westward-directed thrusting (Howard and others, 1979). The thrusting may relate to west-verging folds and thrusts of Jurassic or Early Cretaceous age 50 km to the west in the Piñon Range area that were described by Ketner and Smith (1974) and Smith and Ketner (1977).

The Lamoille Canyon fold nappe has an overturned limb 5–10 km long in the direction of east-southeastward vergence. The nappe plunges gently north-northeastward, and hinge lines can be traced for 20 km through this and adjacent quadrangles (Howard, 1980; Howard and others, 1979). Parasitic folds and mineral lineations parallel the north-northeastward-trending nappe throughout the sillimanite zone. Development of these fabrics evidently spanned a long sequence of intrusions. Many individual bodies of the pegmatitic granite are mesoscopically folded parallel to the nappe, yet other bodies, or even parts of the same bodies, locally cut across the mesoscopic folds. Also, the pegmatitic granite is more abundant on the nappe's inverted lower limb and so does not evidence gross folding around the nappe. These relations suggest that nappe folding mostly predated but overlapped in age with Late Cretaceous pegmatitic granite intrusion. Locally, Paleogene intrusions exhibit lineation of the same nappe-parallel north-northeastward strike, for instance in the granite gneiss of Thorpe Creek 3.5 km north of the southeast corner of the quadrangle. This suggests that flow in the infrastructure, geometrically related to the nappe, continued through Paleogene time (MacCready and others, 1997).

The nappe shape shown in cross section is based on down-plunge projection from this and adjacent mapped areas. Locally, units of Devonian to Cambrian age are inverted and structurally disrupted above the nappe on the northwest flank of the range east of Snell Creek. They may be part of the higher west-facing Soldier Creek nappe that is mapped northeast of this quadrangle by Howard (1966, 1980), Snoke (1980), and MacCready and others (1997). The opposite vergences of the Lamoille Canyon and Soldier Peak nappes exemplify an extraordinary variety in fold-nappe facing directions in the Ruby Mountains (Howard and others, 1979; Howard, 1980).

Mesozoic thrusting and recumbent folding probably resulted in deep tectonic burial. Hodges and others (1992) studied petrologic barometry in part of the core complex northeast of the Lamoille Quadrangle, and concluded that Neoproterozoic strata were buried to 35-km depths, probably in Jurassic or Early Cretaceous time. Adjacent to this quadrangle, hornblende barometry on a facies of the biotite monzogranite from upper Lamoille Canyon suggest the depth was still 20–25 km when that unit intruded in late Oligocene time (Snoke and others, 1999).

A gently northwestward-dipping mylonitic carapace on the order of 1 km thick dominates the west flank of the Ruby Mountain. The base of the carapace dies out downward into higher grade, coarser-grained, nonmylonitic rocks of the metamorphic infrastructure. Rock units within the carapace are attenuated to as little as 5 percent of original thickness. The mylonitic zone is superposed on the Lamoille

Canyon nappe, for it attenuates both the upper and lower limbs of the nappe. Mylonitic foliation dips 10–30° northwestward, and generally exhibits strong stretching lineation trending west-northwestward. The sillimanite isograd approximates the boundary between mylonitic carapace, exhibiting lineations striking west-northwest, and the higher-grade infrastructure, exhibiting a nearly orthogonal azimuth of folds and lineations. A top-to-the-west shear sense for the mylonitic zone is indicated by S-C fabrics (Lister and Snoke, 1984; Snoke and Lush, 1984) and is also suggested by the azimuth of drag sense determined by slip-line analysis of diversely oriented disharmonic folds (Howard, 1968), as indicated on this map. Hacker and others (1990) and Erskine and others (1993) analyzed microstructures in the mylonites. Mylonitization began before intrusion of the Oligocene biotite monzogranite unit, and some biotite monzogranite (as well as older rocks) contains the west-trending mylonitic lineation (Wright and Snoke, 1993). Biotite K-Ar and $^{40}\text{Ar}/^{39}\text{Ar}$ cooling ages as low as 20 Ma suggest the lower age limit for mylonitic deformation (Kistler and others, 1981; Dallmeyer and others, 1986; MacCready and others, 1997).

The mylonitic zone is considered to represent a deep expression of middle Tertiary extensional shearing that led to unroofing of the middle crust (Snoke and Lush, 1984; Snoke and Howard, 1984; Howard, 1987). Patterns of Oligocene to middle Miocene cooling ages from fission-track and biotite $^{40}\text{Ar}/^{39}\text{Ar}$ studies on the metamorphic and granitic rocks suggest that much of the footwall was at elevated temperatures, typical of midcrustal levels, until it was rapidly cooled in the early Miocene (Kistler and others, 1981; Dokka and others, 1986; Dallmeyer and others, 1986). Stratigraphic evidence from surrounding areas as well as the geochronologic and structural evidence supports a model that ascribes this cooling to extensional unroofing during progressive rise of the footwall.

The stratigraphic evidence derives from conglomerates of the Miocene Humboldt Formation southwest of the Lamoille Quadrangle in Huntington Valley and the Piñon Range. The lowest conglomerates contain limestone clasts. Higher beds contain increasing proportions of metamorphic and granitic rocks derived from the Ruby Mountains, which form nearly all the clasts in the uppermost beds. Smith and Ketner, following Sharp (1939), concluded that the Humboldt Formation records removal of a now-gone limestone source from above the crystalline rocks of the Ruby Mountains.

Gently dipping, top-to-the-west, brittle extensional faults overprint the mylonite carapace northeast of the quadrangle in Secret Pass (Snoke, 1980; Snoke and others, 1990). These faults can be inferred to represent later stages of faulting in the shear zone at progressively higher crustal levels as the rising footwall was denuded. Four seismic reflection profiles have been published off the west flank of the East Humboldt Range and Ruby Mountains beyond the quadrangle. All show evidence for normal fault systems dipping moderately to gently west from the margin of the

adjoining ranges, and for eastward-thickening late Cenozoic depocenters (Effimoff and Pinezich, 1981; Anderson and others, 1983; Smith, 1984; Reese, 1986).

Exposed normal faults of Pleistocene and Holocene age flank the northwestern foot of the Ruby Mountains in the quadrangle. The faults cut Lamoille-stage moraines and Angel Lake-stage outwash. The fault scarps strikingly follow map patterns in the mylonitic zone, across and beyond the quadrangle. This parallelism suggests that the exposed Quaternary faults dip gently northwest along the mylonitic zone. That fault geometry, together with evidence from the seismic profiles, supports the idea that the broad range-flanking valleys are underlain by hanging-wall blocks riding on a still-active major west-dipping fault system. If so, the inferred Miocene extensional unroofing continues today, and the Ruby Mountains footwall is still moving out from under the valleys to the west.

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