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Geologic Map of the Eastern Flank of the Northern Cortez Mountains, Eureka County, Nevada

by

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INTRODUCTION

The Cortez Mountains are located in north-central Nevada, southwest of Carlin (fig. 1). Previous geologic mapping in this region (Smith and Ketner, 1978) and previous stratigraphic studies (e.g., Smith and Ketner, 1976; Suydam, 1988) have defined an extensive exposure of the Early Cretaceous Newark Canyon Formation (NCF) on the eastern flank of the northern Cortez Mountains. In this region of Nevada, there have been differing interpretations of the timing and style of contractional deformation associated with construction of the Cordilleran mountain belt, as well as the potential relationship of the NCF to this deformation. Smith and Ketner (1977) did not observe evidence for contractional deformation in the NCF, and interpreted that regional Mesozoic contractional deformation must have taken place prior to NCF deposition.

Alternatively, Vandervoort (1987) and Suydam (1988) interpreted that the NCF was deposited in isolated basins that formed in response to regional tectonism along the 'Eureka thrust belt' (also known as the Central Nevada thrust belt of Taylor et al. (1993, 2000)). The goal of this study is to present map data that illustrate field relations between the NCF and surrounding rock units. We present a new 1:20,000-scale geologic map of the eastern flank of the northern Cortez Mountains that covers ~42 km^2 (a ~13 km north–south by ~4 km east–west distance), which covers the extent of exposure of the NCF (fig. 1). To illustrate the deformation geometry of the NCF relative to underlying and overlying rock units, we also present two retro-deformable cross sections. This report is meant to accompany Di Fiori et al. (2021), which characterizes the stratigraphic architecture, deposition timing, and deformation history of three NCF exposures in central Nevada, including the Cortez Mountains exposure. The following report provides descriptions of all rock and surficial units in the map area, with a focus on intraformational members of the NCF that we defined in our mapping, as well as the structural framework and geologic history of the map area and surrounding region.

STRATIGRAPHY

The oldest rocks exposed in the map area are Late Jurassic volcanics of the Frenchie Creek Rhyolite (Jfu), which are part of the Pony Trail Group (Muffler, 1964). The Pony Trail Group consists of three formations, each of which are separated by unconformities. These formations, from oldest to youngest, are the Big Pole Formation, the Sod House Tuff, and the Frenchie Creek Rhyolite (Muffler, 1964; Smith and Ketner, 1976; 1977; 1978). The Frenchie Creek Rhyolite consists of black to red-brown rhyolite lava flows with interstitial whitish-green volcaniclastic breccia. Smith and Ketner (1976) obtained an emplacement age of 151 ± 3 Ma for the Frenchie Creek Rhyolite (K–Ar on biotite).

The NCF in the Cortez Mountains is nearly continuously exposed in an ~11-km-long, NNE-trending exposure (fig. 1). The NCF overlies Late Jurassic volcanics across a disconformity, which locally exhibits as much as ~10° of dip difference. We defined five intraformational NCF members (Knc$_{1-5}$, from oldest to youngest), which

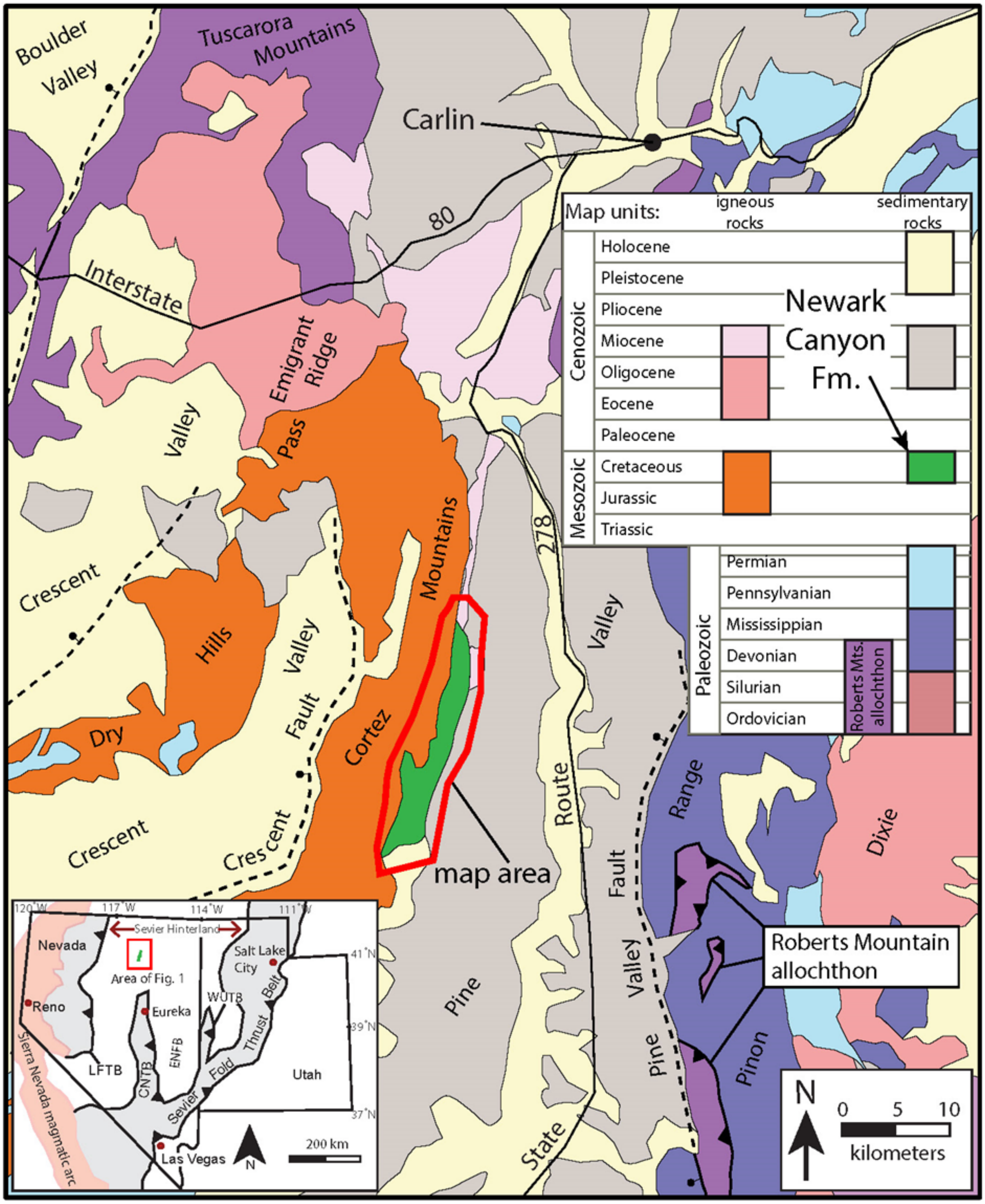

Figure 1. Simplified geologic map of part of north-central Nevada (modified from Crafford, 2007); the map area is highlighted in red. Inset map in lower left shows major components of the Cordilleran mountain belt (modified from Long et al., 2014). The approximate spatial extents of Cordilleran thrust systems are shaded light gray and the Sierra Nevada magmatic arc is shown in red. CNTB = Central Nevada thrust belt; ENFB = Eastern Nevada fold belt; LFTB = Luning–Fencemaker thrust belt; WUTB = Western Utah thrust b

were delineated on the basis of the dominant correlative lithofacies and the composition of conglomerate clasts. The basal member (Knc_1) is dominated by weakly consolidated, clast-supported, pebble to cobble conglomerate. Knc_2 consists of poorly indurated, massive mudstone with lenses of sandstone and pebble conglomerate. Knc_3 is predominately ridge-forming, red-brown, cross-bedded pebble-conglomerate, which is interbedded with cross-bedded sandstone. Knc_4 is dominated by cross-stratified sandstone and pebble conglomerate, with interstitial siltstone and carbonaceous mudstone. Knc_5 is similar to Knc_4, but contains a significantly greater abundance of calcareous mudstone, siltstone, and pedogenic horizons. U–Pb zircon geochronology from horizons that we interpret to represent minimally reworked waterlain tuffs help bracket the timing of deposition of Knc_1 and Knc_5 (supporting data and details on methods can be found in Di Fiori et al., 2021). Euhedral zircons were hand-picked from the separates in an effort to select the youngest zircon age group from the sample. Two samples collected near the base of Knc_1 yielded weighted mean ages of 118.8 ± 2.5 Ma from the southern part of the exposure (n = 8) (defined by the youngest population of zircons that overlap within error) and 119.0 ± 1.8 Ma from the northern part of the exposure (n = 11). A sample collected near the top of Knc_5 yielded a weighted mean age of 110.4 ± 2.2 Ma (n = 24) (Di Fiori et al., 2021). Because these three samples were collected from minimally reworked waterlain tuffs, we interpret these weighted mean ages to represent actual ages of deposition. Therefore, the timing of deposition of the NCF in the Cortez Mountains can be bracketed between ~123 and ~108 Ma (Aptian and Albian stages).

Cenozoic rocks in the map include late Eocene to late Oligocene rhyolitic volcanic rocks and mafic shallow intrusive rocks, and deeply incised Miocene to Pliocene alluvial-fan deposits. Volcanic rocks in the map include the Indian Well Formation (map units Tiwt and Twt), which overlies the NCF across a low-angle unconformity with ~5–10° of dip difference, and consist of ash-flow tuff, lapilli tuff, and volcaniclastic breccias. The Indian Well Formation has yielded an emplacement age of 34.9 ± 0.7 Ma from a sample collected from the Piñon Range to the east (K-Ar sanidine; McKee et al., 1971). In the northern part of the NCF exposure, two mafic to intermediate plug-like bodies (Tmi) intrude the NCF. These shallow intrusive rocks were dated at 31.9 ± 1.1 Ma (whole rock K-Ar; Smith and Ketner, 1976). The Indian Well Formation is disconformably overlain by lake and alluvial-fan deposits of the gently east-dipping Miocene Humboldt Formation (Th) and approximately horizontal alluvial-fan sediments of the Pliocene Hay Ranch Formation (QThr). Drainages in the map area contain alluvium (Qal) and hillslope colluvium (Qc), whereas elevated, beveled, piedmont surfaces are overlain by a veneer of older gravel and silt (Qg).

STRUCTURAL FRAMEWORK

Contractional deformation in the region between ~45–75 km to the east and northeast of the map is indicated by NNE-striking folds and thrust faults. To the northeast in the Adobe Range, the NNE-striking, SE-vergent Garamendi anticline and Adobe Range syncline (and associated small-scale thrust faults) deform sedimentary rocks as young as Triassic. This anticline-syncline pair projects along-trend to the southwest to the northern Cortez Mountains (e.g., Smith and Ketner, 1977; Ketner and Ross, 1990; Ketner and Alpha, 1992). Within the map area, the axial traces of these folds are interpreted to be concealed beneath the Jurassic Pony Trail Group volcanic suite. Each of the three formations in the Pony Trail Group are separated by angular unconformities, including a high-angle (~40–60° of dip difference) unconformity between the Big Pole Formation and the overlying Sod House Tuff and Frenchie Creek Rhyolite (Muffler, 1964). Therefore, the three formations of the Pony Trail Group define contemporaneously active volcanism, volcaniclastic sedimentation, and folding. The disconformity between the Frenchie Creek Rhyolite and the overlying NCF indicates that folding pre-dated the deposition of the Early Cretaceous NCF. This folding may be correlative with the E–vergent folding observed in the Adobe Range to the northeast (Smith and Ketner, 1977).

The northern Cortez Mountains lie within the Basin and Range extensional province (e.g., Dickinson, 2002). The bedrock comprising the Cortez Mountains is interpreted here to be part of an east-tilted crustal block, with the ~25° average eastward dip of the Jurassic Frenchie Creek Rhyolite and the Early Cretaceous NCF, as well as the slightly shallower (~5–15°) eastward dip of the late Eocene Indian Well Formation and middle Miocene Humboldt Formation, attributed to rotation resulting from motion on top-down-to-west, range-bounding normal faults. The range-bounding normal faults likely responsible for much of this tilting include the northeast-striking Crescent fault on the western flank of the Cortez Mountains, and the north-striking Pine Valley fault to the east, which bounds the western flank of the Piñon Range (fig. 1). The middle Miocene Humboldt Formation is interpreted to represent the deposits of a half-graben that filled present-day Pine Valley and is bound on the east by the Pine Valley fault (Wallace et al., 2008). The slightly greater eastward tilt of the NCF compared to the Humboldt Formation likely indicates that initial extension was underway before Humboldt Formation deposition had begun (Smith and Ketner, 1976). Additionally, several north- to east-striking normal faults with meter-scale to decameter-scale offset magnitudes were identified within the map area. West of Devils Gate, along cross section A–A′, a N-striking, down-to-the-west normal fault juxtaposes the Jurassic Frenchie Creek Rhyolite in the footwall against Knc_1 in the hanging wall. Another NW-striking, down-to-the-southwest normal fault observed in the southern NCF exposure places Knc_3 in the hanging wall against Jurassic volcanics in the footwall. Based on crosscutting relationships, these normal faults can only be bracketed as Cretaceous or younger; however, we interpret that they are likely related to Miocene and younger Basin and Range extension (Colgan and Henry, 2009).

GEOLOGIC HISTORY

The map area contains evidence for multiple depositional and tectonic events that span from the Jurassic to the present day. From the Neoproterozoic to the Devonian, Nevada was the site of deposition of a ~10 km-thick section of clastic and carbonate rocks in a passive margin setting (e.g., Stewart and Poole, 1974; Poole et al., 1992; Dickinson, 2006). During the Late Devonian-Mississippian Antler orogeny, Ordovician-Devonian deep-water sedimentary rocks were thrust eastward and emplaced above shallow-marine rocks of the continental shelf (e.g., Speed and Sleep, 1982; Burchfiel et al., 1992). The map area is proximal to the leading edge of the basal thrust fault of the Antler orogeny (the Roberts Mountains thrust), which is exposed in the Piñon Range ~8 km to the east (fig. 1) (Smith and Ketner, 1977; 1978).

During the Jurassic, western and north-central Nevada underwent spatially isolated contractional deformation and accompanying magmatism (e.g., Miller and Hoisch, 1995; Wyld, 2002). This is attributed to the Jurassic amalgamation of the western margin of North America into an Andean-style subduction margin, which initiated the contractional deformation that constructed the North American Cordilleran orogenic belt (e.g., Allmendinger, 1992; Burchfiel et al., 1992; DeCelles, 2004; Yonkee and Weil, 2015). The map area lies within a broad retroarc region commonly referred to as the 'Sevier hinterland' of the Cordilleran orogen (e.g., Armstrong, 1968; DeCelles, 2004). Contractional deformation surrounding the map area is characterized by north- to northeast-trending, east-vergent, large-scale folds (e.g., Smith and Ketner, 1978; Ketner and Alpha, 1992; Colgan et al., 2010). Within and proximal to the map area, folding must have been completed by the Late Jurassic, as indicated by intraformational unconformities within the Pony Trail Group and the disconformity between the Frenchie Creek Rhyolite and the NCF, which indicates a lack of tilting after emplacement of the Frenchie Creek Rhyolite (Smith and Ketner, 1977; Ketner and Alpha, 1992).

The combination of the lack of evidence for syn- or post-depositional thrust faulting or folding of the NCF and the disconformity between the NCF and the underlying Frenchie Creek Rhyolite indicates that contractional deformation was likely completed before deposition of the NCF. Thus, we speculate that the most likely scenario for generating erosion and the accommodation for NCF deposition is an Early Cretaceous (~123–108 Ma) thrusting and/or folding event to the west.

The Late Eocene (~35 Ma; McKee et al., 1971) felsic ash-flow tuffs of the Indian Well Formation and the Oligocene (~32 Ma; Smith and Ketner, 1976) shallow intrusive rocks in the map area are related to the Late Eocene-Oligocene 'Great Basin ignimbrite flare-up', a north to south sweep of felsic magmatism that affected most of Nevada (e.g., Best et al., 2009; Henry and John, 2013). This migration of volcanism is hypothesized to have been generated by the steepening of the subduction angle of the Farallon slab (e.g., Humphreys, 1995; Smith et al., 2014).

During the middle Miocene (starting at ~17 Ma), the inception of regional extension that constructed the Basin and Range Province is attributed to the reorganization of the western North American plate boundary and the corresponding growth of the San Andreas fault system (e.g., Atwater, 1970; Dickinson, 2002; 2006). To the west and east of the map, large-offset, range-bounding normal faults bound the western sides of the Cortez Mountains (Crescent fault) and Piñon Range (Pine Valley fault). The Crescent fault cuts middle Miocene sedimentary rocks, which brackets movement along the fault to be younger than ~15 Ma. (Colgan and Henry, 2009). A ~9 Ma apatite (U-Th)/He age from the western flank of the Cortez Mountains, within the footwall of the Crescent fault, requires a minimum of ~2 km of vertical displacement since ~9 Ma in order to exhume the rocks from the depth equivalent to a closure temperature of 60 °C (Colgan and Henry, 2009). The Crescent fault also cuts Quaternary alluvial-fan deposits (Muffler, 1964). The Pine Valley fault is interpreted to have been active from the middle Miocene to the Pleistocene, during and after the deposition of the Humboldt and Hay Ranch Formations (Wallace et al., 2008). Motion on the Crescent and Pine Valley faults is interpreted to have produced the ~20–25° eastward dips of the Jurassic, Cretaceous, and Miocene rocks in the map area. The Miocene Humboldt Formation is interpreted to represent half-graben fill deposited in the hanging wall of the Pine Valley fault (e.g., Smith and Ketner, 1976; Wallace et al., 2008).

DESCRIPTION OF MAP UNITS

Quaternary Deposits

Qal Alluvium in active channels Poorly sorted, active alluvial sediments. Size ranges from boulders to silt. Deposited in active washes and ephemeral stream channels.

Qc Colluvium Veneer of poorly sorted, angular, slope-covering sediment deposited over steep slopes, mainly below ridge- and cliff-forming bedrock outcrops. Clasts range in size from silt to boulders.

Qg Gravel Includes weakly consolidated to unconsolidated gravel, sand, silt, and clay. Clasts and grains range in size from boulder to clay. Deposits found on topographically elevated, beveled piedmont interfluvial benches. Rare outcrops of calcareous cement.

Alluvial-fan deposits

QThr Hay Ranch Formation (Pliocene) Coarse-grained, semi-indurated alluvial-fan sediment. Consists of tuffaceous conglomerate and sandstone with minor amounts of thin-bedded to massive limestone. Clast sizes range from boulders (up to ~2 m.) to silt and clay, exhibiting a size distribution gradient that fines towards the valley. Depositional age determined from vertebrate fossils (Regnier, 1960).

Tertiary Rocks

Th Humboldt Formation (late Miocene) Gray to tan siltstone, sandstone, and pebble-cobble conglomerate consisting of clasts of tuffaceous sandstone, ash, diatomite, and fine-grained carbonate. Sandstone weathers orange to red, and locally exhibits cross stratification. Also contains interstitial, thin-bedded silty micrite. Lies above volcanic and sedimentary rocks across a low-angle (~5°) unconformity. Depositional age determined from invertebrate and vertebrate fossils and a 9.5 ± 1.9 Ma zircon fission-track age (written comm. C.W. Neaser in Smith and Ketner, 1976) that likely represents a maximum depositional age. ~400 m minimum thickness.

Tmi Mafic to intermediate intrusive rocks (Oligocene) Dark-brown to black, aphanitic intrusive plugs exhibiting crude columnar jointing. Hornfels rinds define weak contact metamorphism with surrounding Knc_2 mudstone. Forms cliffy outcrops and erodes as large blocks. Emplacement age is 31.9 ± 1.1 Ma (whole-rock K-Ar; Smith and Ketner, 1976).

Twt Rhyolitic welded tuff (Oligocene) Dark-gray to pinkish-gray, strongly to moderately welded ash-flow tuff. Rare, disseminated, ~2–5 mm smoky quartz and white plagioclase feldspar phenocrysts. Strongly welded horizons exhibit local devitrification. Disconformably overlies the Newark Canyon Formation. Thickness is ~80 m.

Tiwt Indian Well Formation (Oligocene to late Eocene) Gray, light-gray, or cream-colored rhyolitic to dacitic ash-flow tuff, with lesser abundance of lapilli tuff and volcanic breccia horizons. Varies from nonwelded to densely welded. Groundmass consists mainly of glass and mm-scale fragments of pumice. Phenocrysts include sanidine, quartz, biotite, and hornblende, with rare pyroxene. Disconformably overlies the Newark Canyon Formation. Emplacement age is 34.9 ± 0.7 Ma (K-Ar sanidine; McKee et al, 1971). ~220 m thick.

Cretaceous Rocks

Knc Newark Canyon Formation

Knc_5 Newark Canyon Formation member 5 Well-bedded red, brown, tan, yellow, and gray, medium- to coarse-grained, horizontally and low-angle cross stratified sandstone. Brown to red trough cross stratified, chert pebble conglomerate is also common. Chert dominates the conglomerate clast composition. Abundant interstitial, cm- to decameter scale gray to brown micrite and silty micrite horizons are common. Pedogenic carbonate nodules are also present in the fine-grained horizons. Forms ledges and cliffs and erodes as blocks. U-Pb zircon geochronology from a waterlain tuff horizon indicates a depositional age of 110.4 ± 2.2 Ma (Di Fiori et al., 2021). Thickness ~50 m.

Knc_4 Newark Canyon Formation member 4 Red, red-brown, gray and tan, massive to trough cross-bedded, pebble to cobble conglomerate with medium-grained sandstone matrix. Interlayered with less abundant, trough and low-angle cross-bedded and laminated red, brown, to tan, medium- to coarse-grained sandstone. Interstitial light gray, cm-scale micrite and silty micrite beds increase in abundance towards the top of the member. Forms ridges and ledges and erodes into blocky float. Thickness ~65 m.

Knc_3 Newark Canyon Formation member 3 Brown to red, poorly sorted, crudely to cross-bedded, clast-supported, pebble to cobble conglomerate and medium- to coarse-grained sandstone. Sandstone and conglomerate are massive to cross-bedded with lenses of interstitial siltstone and mudstone. Dominant conglomerate clast lithology consists of light-gray, coarse-grained carbonate likely sourced from erosion of upper Paleozoic rocks. Conglomerate matrix consists of red to tan, medium- to coarse-grained sand. Base of member is dominated by red and tan siltstone and sandstone. Siltstone to clay matrix-supported pebble conglomerates are rare but present throughout the section as laterally discontinuous lenses. Forms steep slopes and ledges near the top of the member where sandstone is more dominant. Thickness ~145 m.

Knc_2 Newark Canyon Formation member 2 Weakly indurated, dark-brown to dark-gray massive calcareous mudstone intercalated with laterally discontinuous, lens-shaped, cross-bedded, clast-supported, pebble-cobble conglomerate and massive to cross-bedded sandstone. Conglomerate clast lithologies are dominated by Jurassic volcanics. Gradually grades upwards into gray-brown, tan, or red siltstone and sandstone. This member has yielded abundant Cretaceous ankylosaurian dinosaur fossils (personal comm. from E. Lewis in Smith and Ketner, 1976). Gradational contact with Knc_3 above and sharp contact with Knc_1 below. Thickness ~65 m.

Knc_1 Newark Canyon Formation member 1 Light-gray, tan, to brown, poorly consolidated, massive to cross stratified, clast-supported pebble to cobble conglomerate defined by an abundance of sub-angular, aphanitic, light-colored volcanic clasts. The basal contact with Jfc is sharp and is an unconformity with <5–10° of difference in dip. U-Pb zircon geochronology from a minimally reworked, waterlain tuff indicates depositional ages of 118.8 ± 2.5 Ma and 119.0 ± 1.8 Ma (Di Fiori et al., 2021). ~35 m.

Jurassic Rocks

Jfc Frenchie Creek Rhyolite of the Pony Trail Group (Late Jurassic). Black to red-brown rhyolite flows and lesser amounts of rhyodacite flows with interstitial white and green altered volcanic breccia. Common phenocrysts include mm-scale plagioclase, smoky quartz, and biotite. Rare accessory minerals include titanite and apatite. Well-developed compaction foliation. Commonly altered and strongly devitrified. Local opalized vugs and miarolitic cavities are common. Forms ledges, cliffs, and ridges, and erodes as blocks or as large plates where foliation is thin. A rhyolite flow yielded a 151 ± 3 Ma emplacement age (K-Ar biotite; Smith and Ketner, 1976). Thickness ranges between ~1200 m (Muffler et al., 1964) and ~2000 m (Smith and Ketner, 1976).

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