

Early Coarse Clastic Deposition in the Western Elko Basin, Piñon Range, Northeastern Nevada: Implications for Basin Evolution and Petroleum Potential

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Elko Basin and Similar Eocene Lacustrine Basins of the Great Basin

The Elko Basin is one of several middle to late Eocene high-elevation lacustrine, or more aptly, lacustrine-volcanic basins, that developed in the Sevier hinterland of the northern Great Basin. The White Sage, Sheep Pass, Nanny, and Copper basins, among others, formed in the same region (Figures 1 and 2; Potter et al., 1995; Brooks et al., 1996; Henry, 2008; Druschke et al., 2011). The Elko Basin contains hydrocarbon resources that have been exploited in the Blackburn and Tomera Ranch oil fields located on the west flank of the Piñon Range, as well as explored for oil shale in the 1970s by the U.S. Bureau of Mines and for fracking potential as recently as 2013-2015 by Noble Energy.

Eocene sedimentary basins in the Great Basin largely developed from ~50-37 Ma progressing from early conglomerate, to a variable succession of algal limestone, limy shale, organic shale, and siltstone; ~45-40 Ma volcanic rocks mostly preceded lacustrine deposition in the north, whereas lacustrine rocks largely preceded ~40-38 Ma volcanics in the south (Henry, 2008). In general, the age of Eocene sedimentary basins parallels the southwestward sweep of arc magmatism due to slab rollback (e.g., Ressel and Henry, 2006; Figures 1 and 2).

This study examines the western margin of the Elko basin (Figures 3 and 4), which reflects early, coarse clastic alluvial-fluvial deposition into and on the western flank of incipient Elko Basin prior to establishment of a lacustrine setting. Between ~0 and 150 m of conglomerate was deposited on the west flank of the Elko Basin in the Piñon Range. Conglomerates are mainly comprised of moderate- to well-rounded cobbles of chert, argillite, siltstone, and quartzite derived from sources in the Roberts Mountains allochthon to the immediate west. However, Jurassic volcanic rocks, mainly rhyolite and some andesite, along with ~45-44 Ma porphyritic rhyolite clasts, constitute smaller but important percentages of clasts. The Jurassic volcanic rocks are almost certainly derived from the Frenchie Creek Volcanics, located in the Cortez Mountains about 20 km to the west of the Piñon Range (Figures 4 and 5). The Eocene clasts are enigmatic, however, as no Eocene igneous activity in the immediate region predates ~41 Ma, thereby suggesting fluvial transport from at least the Copper Basin area (Figure 1) ~150 km to the north or from the Challis area of central Idaho.

Eocene Geologic Setting of the Northern Great Basin

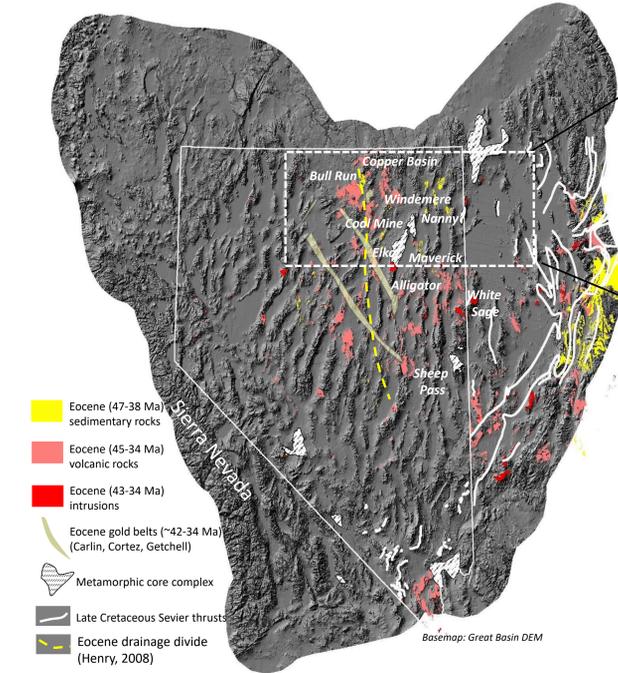


Figure 1. Great Basin DEM showing distribution of Eocene basinal sedimentary rocks, Eocene volcanic and intrusive rocks, metamorphic core complexes, major Eocene gold deposit belts, approximate late Eocene drainage divide, and late Cretaceous Sevier thrust faults. Eocene high-elevation basins of Nevada developed proximal to the regional drainage divide and core complexes.

Eocene Lacustrine Basins, Northeast Nevada

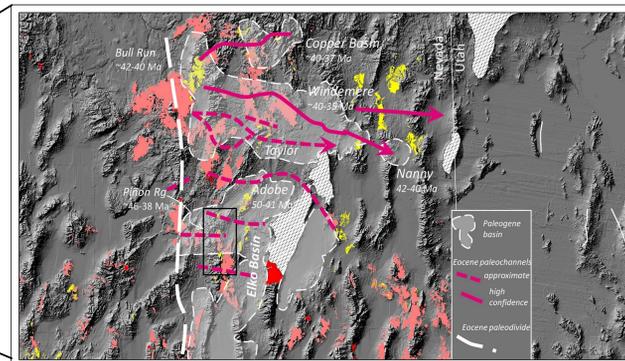


Figure 2. Inset of northeast Nevada showing features from Figure 1 in addition to outlines of Paleogene basins (lacustrine and volcanic inputs; Smith et al., 2017; white dashed) with approximate ages of main lacustrine sedimentation. Also shown are Eocene paleochannels with arrows indicating regional flow directions where possible (modified from Henry, 2008; C.D. Henry, 2018, AAPG abstract). The Piñon study area is located in the lower-central part of the figure in the Elko Basin (black rectangle), which was active from about 46 to 38 Ma. Widespread volcanism starting at ~38 Ma effectively terminated sedimentary input into the Elko Basin in the study area.



Eocene basal conglomerate Piñon Range, Nevada

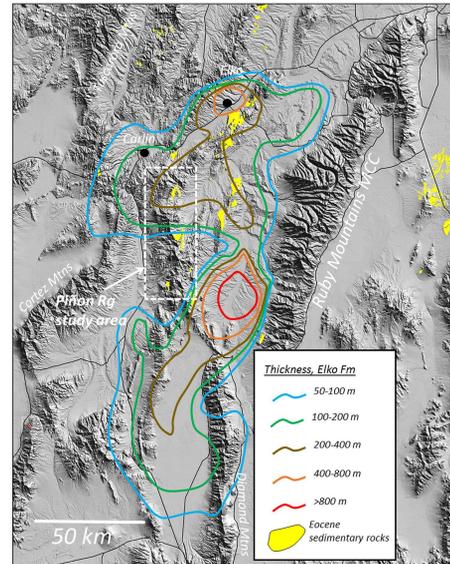


Figure 3. Estimated thickness contours of the Elko Formation (Smith et al., 2017) based on seismic data, well logs, and field measurements. The greatest accumulation of Elko lacustrine facies rocks occurs in a corridor immediately west of the Ruby Mountains metamorphic core complex ("MCC" on map). Other areas, including in the Piñon Range, accumulated much less Eocene sedimentary strata.

Abstract

The Eocene Elko Formation of northeast Nevada consists of highly variable siliciclastic, carbonate, and volcanoclastic rocks, which are commonly interpreted to have accumulated in a half-graben, lacustrine setting resulting from early extension of the Ruby Mountains metamorphic core complex. Black shales in this succession are potential petroleum sources. Despite recent interest in Elko Basin hydrocarbons, controversy remains about the basin's age, shape, and extent. Recent mapping and U/Pb detrital zircon dating of conglomerates around the Piñon Range reveal that many units mapped as Mississippian-Permian Antler foreland and overlap sequences contain Eocene zircons (youngest age populations of ~45.3-43.7 Ma; one 38.6 Ma) and are part of the lowermost Elko Basin. One Eocene conglomerate in the western Piñon Range extends the basin beyond its previously interpreted southwestern limits. The oldest Eocene conglomerates rest almost exclusively on Upper Paleozoic clastic strata, whereas the youngest rests on Devonian carbonate. However, bedding in these conglomerates is mostly parallel to bedding in underlying units. These data indicate varying degrees of pre-Eocene folding, uplift, and erosion to ultimately form Eocene topographic highs that bound and underlie the developing Elko Basin.

45-44 Ma zircons probably derive from reworked tephra from northern sources as magmatism in and near the Piñon Range was exclusively ~38 Ma. However, 3-4 cm, subrounded, porphyritic igneous clasts from one sample were hand-picked and dated separately from matrix material. Results reveal Eocene (45.2 Ma) and Jurassic (158.2 Ma) zircon populations that likely represent contributions from two distinct ages of felsic igneous clasts. Jurassic clasts almost certainly were sourced from the Frenchie Creek Volcanics exposed 20km to the west in the Cortez Mountains, but nearby sources for the 45 Ma clasts are unknown.

Conglomerate dominates the Elko Formation rocks in our refined western basin. Thick shale is restricted to one area in the northern Piñon Range, although published thicknesses differ significantly and drilling has encountered major shale sequences just 25 km to the east. The rock type distributions suggest the basin was partly fed by drainages from the west and the western part of the basin has lesser volumes of potential source rocks and thus lesser petroleum potential than areas farther east.

Simplified Geologic Map of the Piñon Range

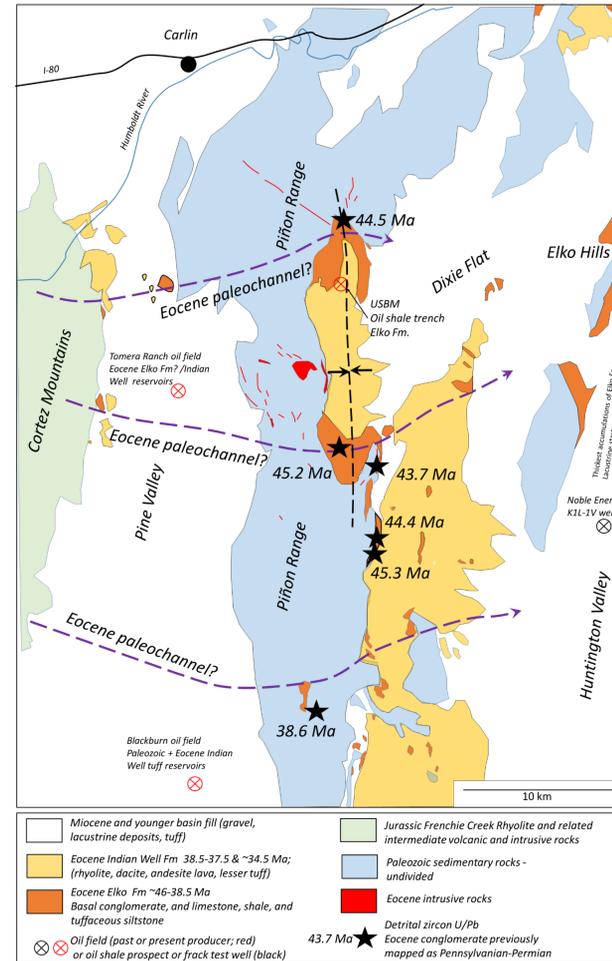


Figure 4. Simplified geologic map of the Piñon Range, north-central Nevada. Shown is the wide distribution of Eocene fluvial and lacustrine rocks of the Elko Formation and overlying Eocene volcanic rocks of the Indian Well Formation. Also shown are youngest concordant U/Pb age populations of detrital zircons (this study) from Eocene conglomerates that were previously mapped as Paleozoic (Pennsylvanian through Permian). Locations of oil fields and oil shale resources are also depicted.

The Piñon Range largely lacks the lacustrine facies of the Elko Formation. Instead, basal conglomerates that rest unconformably on Pennsylvanian-Permian strata give youngest detrital zircon age populations of between ~45 and 43 Ma, dominate. In the south, however, a basal conglomerate containing 38.6 Ma detrital zircons rests on older (Devonian) strata.

The Elko Formation at the USBM oil shale trench is the only exposure of thick lacustrine sedimentary rocks, with estimates of either 700 m or 1300 m total thickness (Horne, 2015; Haynes, 2003). A significant component of igneous clasts together with major Jurassic detrital zircon populations indicate derivation of a major part of the Elko Fm. conglomerates from the immediate west, in the modern Cortez Mountains area.

The Piñon Range: A Conglomeration of Conglomerates

Compositionally similar conglomerates of widely differing age and tectonic derivation are common in the Piñon Range of northeast Nevada. These include:

- Late Mississippian turbidite, flysch-type sandstone and fine conglomerate (Chainman and Melandco Fms) developed in the Antler foreland basin
- Early to Middle Pennsylvanian overlap sequence or molasse-type conglomerate, with westerly allochthon sources (Tonka or Diamond Peak Fm)
- Late Pennsylvanian-Early Permian platform edge debris flow conglomerates with mixed carbonate and siliciclastic provenance reflecting eastern and western sources (Tomera and Moleen Fms)
- Late Cretaceous coarse pebble conglomerate developed in Sevier "piggyback" basins (Newark Canyon Fm)
- Late Eocene coarse pebble conglomerates developed in hanging wall of Ruby-East Humboldt metamorphic core complex – incipient extensional basin (Elko Fm)
- Mid- to late Miocene fanglomerates developed in major extensional basins and reflecting more recent Basin and Range extension since ~17 Ma.

Paleozoic Becomes Eocene

Six conglomerates in the Piñon Range previously mapped as Paleozoic overlap sequence conglomerate gave Eocene youngest concordant zircon age populations from bulk rock using U/Pb LA-ICP-MS dating. The methods for dating included standard magnetic and heavy liquid mineral separation, mounting, cathodoluminescence imaging, and mass spectrometry. Figure 4 shows the extent of dated Eocene conglomerates.

Similarities among conglomerates have led to misinterpretation of some conglomerates. Several conglomerates previously mapped as Paleozoic Antler orogeny overlap are now established as Eocene based on 1) recognition of sparse siliceous, porphyritic igneous clasts that preclude a Paleozoic age, and 2) abundant detrital zircon U/Pb dating. New mapping significantly expands the distribution of the Eocene Elko Basin in the Piñon Range, and in particular, better defines the early, western margin of the basin (Figures 2 and 5).

Eocene conglomerates almost certainly are more extensive than those dated and occur in both the flanks and interior of the range. The Eocene conglomerates resemble Paleozoic conglomerates, because the bulk of clasts in both are derived from similar Paleozoic sources, and moderate silicification has indurated Eocene conglomerate.

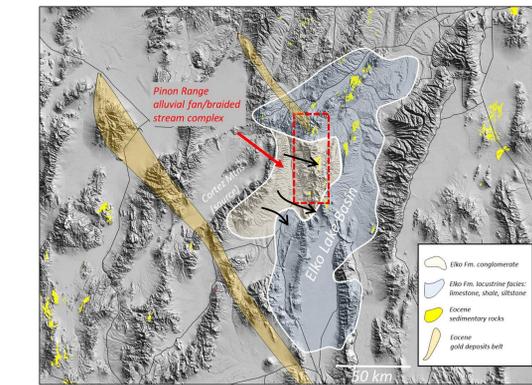
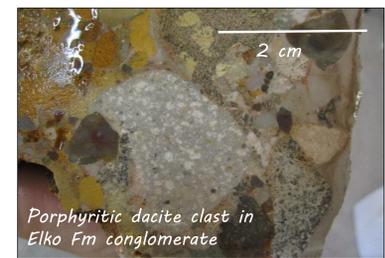
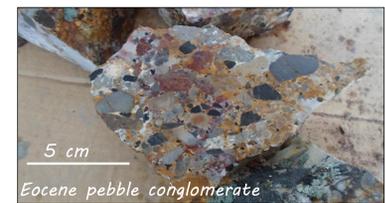


Figure 5. Elko lake basin modified from Smith et al. (2017) showing extent of the alluvial fan and/or braided stream complex that comprises most of the Elko Formation in the Piñon Range. Major Carlin-type gold deposits formed during and just after sedimentation, coeval with the start-up of arc magmatism at ~38 Ma in the Piñon Range.



Porphyritic dacite clast in Elko Fm conglomerate



Eocene pebble conglomerate

Conclusions: Western Alluvial-Fluvial Flank of the Elko Basin

Most of the Elko Formation exposed in the Piñon Range consists of alluvial fan and/or braided stream deposits composed of conglomerate. Conglomerates record the earliest history of the Elko Basin prior to lacustrine deposition. Detrital U/Pb zircon ages place maximum constraints on basal conglomerates of ~45.3-43.7 Ma. This older group of conglomerates generally rests concordantly on the youngest Paleozoic strata in the area, which are Pennsylvanian through Permian. One conglomerate from the south end of the study area has a youngest concordant zircon population of about 38.6 Ma and rests on Devonian strata, indicating mid-Paleozoic strata were locally exposed by the late Eocene perhaps due to extension-related uplift and erosion, or were previously exposed as a result of Sevier orogeny contractional deformation. Outcomes of this study include:

- The Elko Formation in the Piñon Range mostly contains conglomerate; conglomerate units are generally thin, mostly 0-150 meters total thickness. These conglomerates were previously mapped as Paleozoic overlap. Overlying lacustrine limestone, tuffaceous siltstone, and shale are rare but increase northward along the easternmost flank of the Piñon Range.
- The farthest east exposure within the study area contains a lacustrine sequence estimated to be 700-1300 meters thick (Horton, 2015; Haynes, 2003) and is the only known major exposure of Elko lacustrine strata in the northern Piñon Range.
- Conglomerates contain mostly coarse clasts of chert, quartzite, and argillite that are distinctive of the Paleozoic Roberts Mountains allochthon located to the immediate west. Limestone clasts that reflect probable derivation from Paleozoic autochthonous sources are absent, suggesting these units were not widely exposed during earliest basin development.
- Felsic igneous clasts in conglomerate are locally common and most are likely derived from ~20 km west in the Jurassic Frenchie Creek volcanic field of the Cortez Mountains. However, an enigmatic porphyritic rhyolite clast yielded a U/Pb zircon age of ~45-44 Ma, which suggests sourcing from areas >150 km north.
- Thinner Eocene sections (<100m) dominated by conglomerate indicate lower potential for Eocene hydrocarbon source rocks in the northern Piñon Range.
- Major arc magmatism starting at ~38 Ma in the Piñon Range effectively ended Elko lacustrine deposition. Some lacustrine deposition may have ended earlier after ~40.1 Ma ash-flow tuff inundated major paleochannels where lakes were focused.

References and Acknowledgements

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