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GEOCHRONOLOGIC AND PETROLOGIC CONTEXT FOR DEEP CRUSTAL METAMORPHIC CORE COMPLEX DEVELOPMENT, EAST HUMBOLDT RANGE, NEVADA

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INTRODUCTION

Ruby Mountains-East Humboldt Range (RM-EHR) in northeastern Nevada is the western most example of a metamorphic core complex within the hinterland of the Late Cretaceous to early Tertiary Sevier orogenic belt (Snoke, 1980; Hudec, 1992; McGrew and Snee, 1994; McGrew et al., 2000). The northern East Humboldt Range, just north of the proposed and debated boundary between Archean Wyoming Province and the southern Proterozoic Mojave Province, exposes the oldest rocks in Nevada as well as the westernmost high grade Precambrian rocks in the Cordillera (Lush, 1988; Wright and Snoke, 1993; Sullivan and Snoke, 2007; Premo, 2008). The region underwent Paleozoic to Mesozoic contractional episodes followed by Cenozoic extension with major extension taking place in the middle Miocene (Henry, 2011). The age relationships and deformational history of these oldest rocks may inform the early development of the complex including the role of Cretaceous extension in the exhumation (Miller and Snoke, 2009).

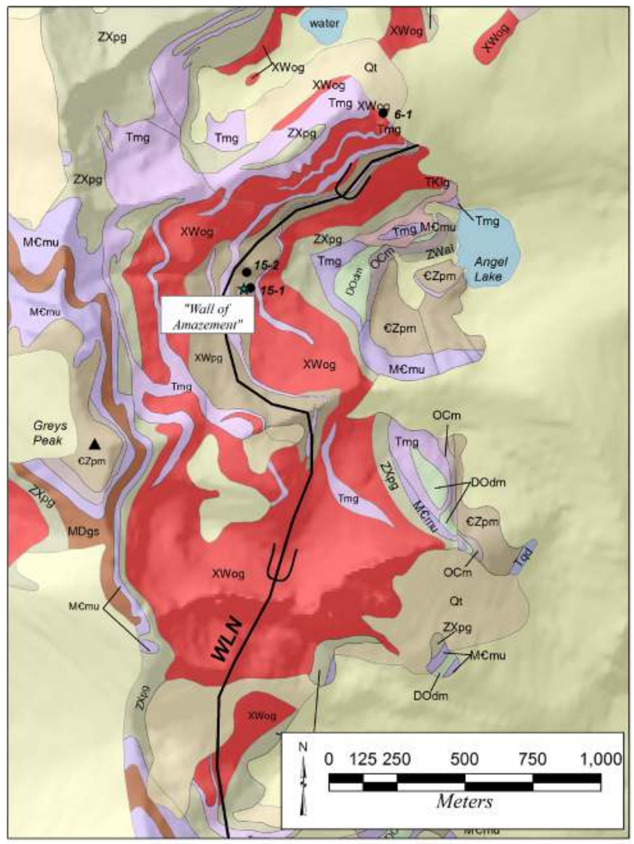

Figure 1. Map centered on Angel Lake cirque at the northern end of the East Humboldt Range, NE Nevada. Black dots are amphibolite sample localities (6-1, 15-1, 15-2). Key structural locality, "Wall of Amazement," is demarked with a green star; note that it lies near the black hinge line of the south-verging recumbent isoclinal Winchell Lake Nappe, exposing the deepest part of the section. Qy: Youngest alluvium (upper Holocene), Qt: Talus deposit (Holocene), MCmu: Mississippian to Cambrian carbonates, calc-metasediments, and metaquartzite, DOdm: Devonian to Ordovician dolomitic marble, CZpm: Cambrian to Neoproterozoic Prospect Mtn. quartzite and McCoy Creek Group, XWpg: Paleoproterozoic to Neoarchean paragneiss of Angel Lake, XWog: Paleoproterozoic to Neoarchean orthogneiss of Chimney Rock, Tmg: Mid-Oligocene to mid-Eocene bt-monzogranite orthogneiss (McGrew and Snoke, 2015).

Angel Lake cirque in the northern part of the East Humboldt Range exposes a folded fault within the Winchell Lake Fold nappe (WLN) (Fig. 1). This is a key tectonic contact recording age relationships from the early evolution of the deep RM-EHR architecture for which syntectonic U-Pb zircon ages 84.8 ± 2.8 Ma from the WLN hinge-zone and peak P-T conditions of 800 °C and >9 kbar (McGrew, 2000). Recent work that reports prograde metamorphism beginning by 82.8 ± 1.3 Ma with cooling and zircon, monazite crystallization from 77.4 ± 12.4 to 58.9 ± 3.6 Ma (Hallett, 2015). This implies a duration of 2.1 to 6.1

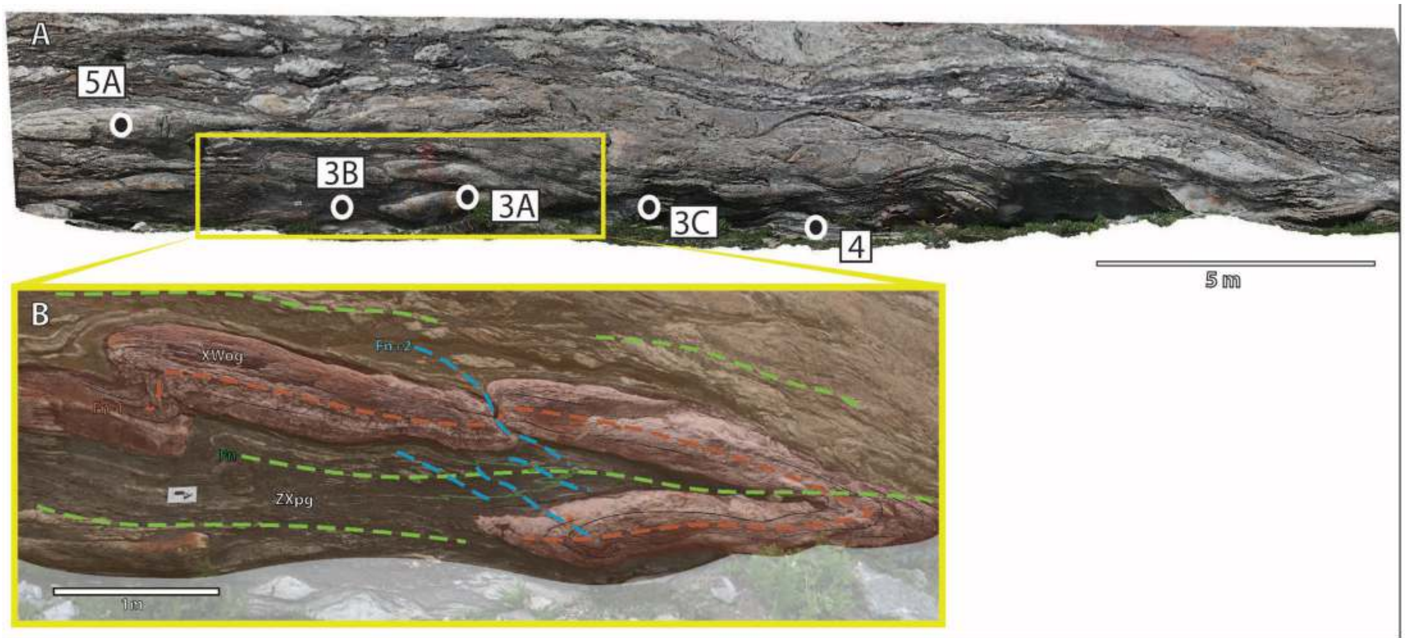

Figure 2. (A) Composite field photograph of the "Wall of Amazement" outcrop within the core of the WLN with sample localities demarcated. (B) Inset illustrates fold transposition of the Chimney Rock orthogneiss and Grey's Peak paragneiss (3A and 3B). Units are consistent with Figure 1. Three generations of deformation are inferred. Pre-nappe F_{n-1} foliation is in black with isoclinal fold axis demarcated in dashed red. The F_n hinge line synkinematic with nappe emplacement is in dashed green forming Ramsey Type 3 interference with parasitic folds in dark green. Cenozoic F_{n+1} shearing in blue overprint refolds the previous generations (McGrew and Snoke, 2015).

Ma for transport from ~400 °C, above the kyanite-sillimanite isopleth, to deeper magmatic conditions recorded in an orthogneiss melted around the nose of the WLN.

GEOLOGIC SETTING

The Great Basin consists of Neoproterozoic-early Proterozoic metamorphic basement constructed from the sediments and metasediments from western Laurentia overlain by a cratonal sequence of siliclastic sediments accumulated through sequential orogenies (DeCelles, 2004.) Metamorphic core complexes are windows into the deep crust of this region that record iterative deformational events within sedimentary strata, igneous, and metamorphic rocks. The primary structural geometry of the northern area of the RM-EHR is the Winchell Lake Fold Nappe (WLN), a south-verging recumbent fold with a WNW-trending hinge line that is approximately parallel to the mineral elongation lineation. The nappe is a map-scale feature exposed within Winchell Lake and Angel Lake cirques that records a pre-metamorphic tectonic contact that is supported by zircon ages with multiple episodes of overprinted folding and foliation within the Angel Lake gneiss complex consisting of an orthogneiss and two paragneisses (Fig. 1).

A folded thrust fault separates the metasediments of the eastern Great Basin miogeoclinal sequence from the Archean basement of the Angel lake gneiss complex (Lush 1988). This a key tectonic contact records age relationships from the early evolution of the deep RM-EHR architecture that is interpreted as low-angle, though its age and pre-folding geometry are poorly constrained (Lush 1988). The Neoproterozoic to early Paleozoic metasedimentary sequence is inverted atop the Paleoproterozoic to Archean rocks with oldest material at the core of nappe (Lush, 1988; McGrew, 1992; Snoke, 1993). Nappe emplacement has been interpreted as synkinematic with migmatization through compositional and spatial variability of an attenuated, folded schistose unit (Fig. 2).

METHODS

Field Relationships

The key relationship at the Wall of Amazement outcrop is near the hinge zone of the Winchell Lake fold-nappe in an area where the Neoarchean to earliest Paleoproterozoic orthogneiss of Chimney Rock is tectonically interdigitated with the paragneiss of Angel Lake (Fig. 2).

Petrography

Optical mineralogic and microstructural analysis was performed on uncovered double-polished thin sections, 30 mm in thickness, prepared by Spectrum Petrographics.

U-Pb Geochronology

Six samples were selected for geochronology to evaluate the timing of intrusive and metamorphicevents within gneissic suites of Angel Lake cirque. Zircons were separated from samples, mounted in epoxy, and imaged by cathodoluminescence and backscatter on a scanning electron microscope to elucidate internal zoning and chemical composition (Fig. 3). Samples were analyzed for zircon U-Pb geochronology by laser ablation–inductively coupled plasma mass spectrometer (LA-ICPMS) following spot analysis protocol of Kylander-Clark et al. (2013).

RESULTS

Amphibolites

Amphibolite samples yielded metamorphic ages of 60-89 Ma. The two garnet amphibolite bodies collected near the core of the Winchell Lake Fold nappe (15-1 and 15-2; Fig. 1) within the Archean gneiss complex represented mean ages of 86.5 and 85.3 Ma (Table 1). The stratigraphically lower of these two (15-1) also has inheireted core values ranging from 2459.8±43.5 to 546.2±11.6 converging on mid-Paleoproterozoic age of 2080.13±379.6. The younger amphibolite body (6-1) was collected higher in the section within the upper limb of the WLN and yielded a mean of 72.5 Ma, maximum of 77.7 Ma and one anomalously low age of 60.0 Ma.

Metasediments

A migmatitic biotite sillimanite schist (3B) from the Archean gneiss complex yielded detrital zircon ages with a wide array of ages that are broken into two suites at ~2500 Mya (see Fig. 3 d,e). These mostly Archean ages have an upper and lower intercepts of 4129±210 and 2021±380 Ma. The maximum of 3353.7±63.7 Ma is one of if not the oldest reported in Nevada (Table 1). Most of the younger array are between 1200 and 2600 an upper intercept of 2515±110 Ma and lower intercept of 789±290 Ma. The three lowest ages, averaging 88.0 Ma, are metamorphic Cretaceous zircon.

Orthogneisses

Two orthogneisses from the Angel Lake gneiss complex were dated. The first (5A) a leucosomatic garnet orthogneiss, yielded ages intercepts of 1826±22 and 243±92 Ma not including four much older Paleoproterozoic core ages that converge on 2424±150 and 579±110 Ma. The refolded orthogneiss (3A) has two concordia, the older with intercepts at 2468±43 and 436±260 Ma while the younger at 1815±22 and 101±47 Ma. Only two younger rim ages were dated, one each Cretaceous and Oligocene.

Sample	Rock Description	2σ Age	Error	Group #	Interval %	Wt'd Mean Age	Error	MSWD				Max Inheireted
15-1	garnet amphibolite	84.6	1.0	3	75.0	85.3	4.1	19.0				2459.8
15-2	garnet amphibolite	88.4	2.2	3	75.0	86.5	2.2	11.9				
6-1	garnet amphibolite	74.0	0.9	6	96.9	65.0	8.9	-				
		Metamorphic Age 1					Metamorphic Age 2					
		Lower Intercept	Error	Upper Intercept	Error	MSWD	Lower Incercept	Error	Upper Intercept	Error	MSWD	
3B	migmatitic bt-sill schist	786	290	2615	110	75	2021	380	4129	210	173	3353.7
3A	orthogneiss	148	59	1826	22	4.3	1066	630	2502	67	7.6	2482.4
5A	garnet orthogneiss	243	92	1826	22	6.6	579	110	2424	150	14	2494.5

Table 1. LASS-ICP-MS U-Th-Pb geochronologic analytical data for zircon in ampbiolites, metasediments and orthogneisses from Angel Lake, East Humboldt Range, NE Nevada. Sample site locations denoted in Figures 1 and 2. Errors are 2σ.

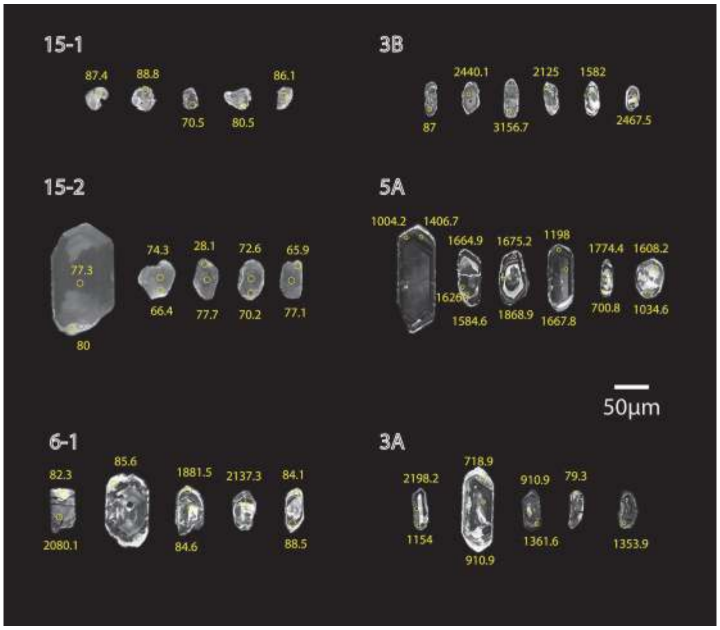

Figure 3. Cathodoluminescence images of zircon separates from a schist and two orthogneisses. Circles indicate locations of spot analyses 12 μm in diameter. Note the oscillatory zoning within 3A and 5A, indicative of their magmatic origins. Highly luminescent interiors have early to mid-Proterozoic ages.

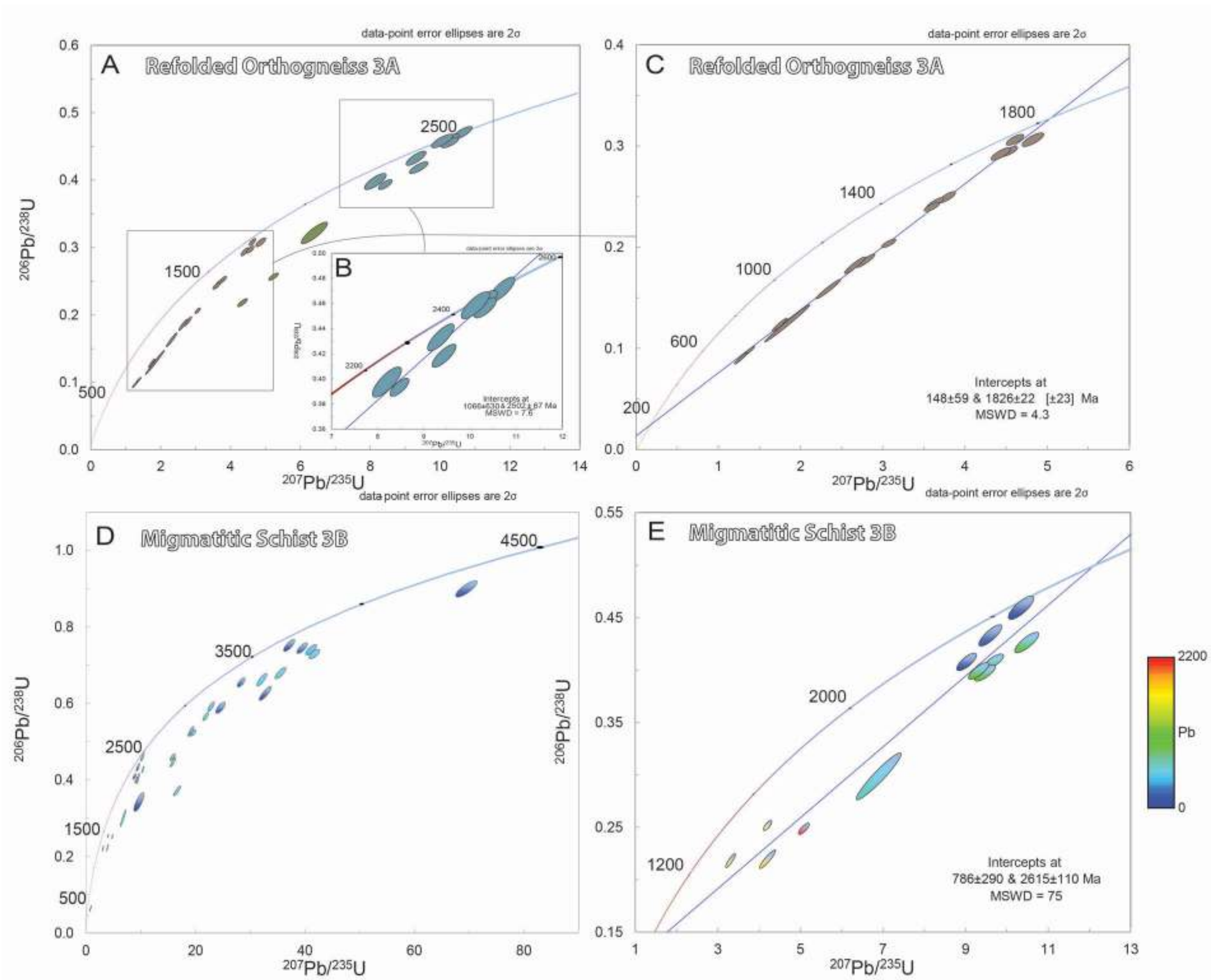

Figure 4. (A) Conventional concordia plot showing LA-ICP-MS data (ellipses) for sample 3A, refolded as illustrated in Figure 2. Blue ellipses denote the older population with regression calculated in inset (B). (C) The brown ellipses denote the younger population with its regression. The three points in green have been excluded as they increase the MSWD tenfold and are potentially xenocrystic. (D) All zircon ages present in the Grey's Peak Paragneiss 3B, a biotite-sillimanite migmatitic schist. Ellipses are shaded for Pb content. (E) A lower Concordia excludes four Cretaceous as they are metamorphic zircons.

DISCUSSION

The ages for the garnet amphibolites are broadly consistent with a late Cretaceous metamorphic event 85 to 88 Ma during the peak metamorphic conditions (McGrew, 2000; Hallett, 2015). The older two amphibolites (15-1, 15-2) collected near the center of the WLN are interpreted to have protoliths that intruded the Chimney Rock orthogneiss. The Paleoproterozoic ages of 15-1 are from both metamorphic zircon and oscillatory-zoned igneous zircon with recrystallized Cretaceous cores. The Cretaceous ages may be from migmatized leucosome from surrounding rock as they are from euhedral igneous zircon as opposed to metamorphic zircon. The younger ages of the highest stratigraphic amphibolite (6-1) indicates that it intruding the Neoproterozoic gneiss complex and are in keeping with the 60 to 80 Ma ages in zircon and monazite reported by Hallett (2015.)

The schist from the core of the WLN (3B) has detrital zircons with Archean to Early Paleoproterozoic and Mesoproterozoic cores, mostly 2100 to 2500 Ma, and small overgrowth of Late Cretaceous rims. These crystals record two distinct periods of magmatism with and late Cretaceous metamorphic overprint; the younger source material lies within error of the age of the orthogneissic protoliths while its lower Neoproterozoic intercept is consistent with previous metasedimentary ages (Premo, 2008). The Precambrian grains show lead loss (Fig. 4) and their abundance suggests a Wyoming Province source.

The two orthogneissic samples plot onto two concordia, each interpreted as a separate event. Both samples have an igneous signature around the Archean-Proterozoic. The older population of crystals in has a poorly defined lower intercepts though 3A yields an Early Mesoproterozoic age not previously observed in the region. The younger zircon population is more precisely dated with Paleoproterozoic crystal ages ~1800 Ma with Mesozoic overprint. The younger concordia for the refolded orthogneiss (3A, Fig. 2) has a lower intercept that is well within error of a late Cretaceous metamorphic event while the garnet orthogneiss has a concordia related to heating in the early to mid-Triassic. The refolded orthogneiss may have little to no mixed source population instead Paleoproterozoic to Neoarchean in age with later Proterozoic migmatization to account for the age trends. A Proterozoic magmatic event has been previously observed in orthogniesses regionally (Premo, 2008). However, the dearth of older zircons in the garnet orthogneiss 5A brings this interpretation into question, instead pointing to a mid-Proterozoic protolith that inheireted Neoarchean crystals. This may be resolved through bulk rock geochemical and trace element analysis to assess whether the two orthogneisses share a protolith, and the extent of migmatization.

CONCLUSION

New U-Pb zircon data from the East Humboldt Range for metasedimentary and igneous ages from the core of the WLN suggest Archean sources that may be from allochthonous basement. Orthogneissic ages record multiple ages, metamorphic and igneous, notably a Proterozoic metamorphic age.

New dates broadly confirm the age of peak late Cretaceous metamorphic conditions as previously recorded, but are generally a few million years older than previous metapelitic dates. This implies that the Precambrian gneiss complex at the core of the WLN was not yet juxtaposed with the younger Paleozoic metapelites that it overlies during peak metamorphism. The thrusting of the Precambrian basement over Paleozoic units may be the younger age recorded in the Paleozoic rocks, perhaps synchronously with the pre-Winchell Lake folding (F_1) event. The WLN (F_2) postdates thrusting as the contact between Archean and Paleozic is folded. The cretaceous ages reported here support prograde burial occurred ~80 Mya and exhumation beginning by 75 Ma (Hallett and Spear, 2015).

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REFERENCES

Dickinson, W. R. 2006, Geotectonic evolution of the Great Basin: Geosphere, v. 2, no. 7, p. 353-368.

DeCelles, P.G., 2004, Late Jurassic to Eocene evolution of the Cordilleran thrust belt and foreland basin system, western USA: American Journal of Science, v. 304, p. 105-168.

Hallett, B.W., Spear, F.S., 2015, Monazite, zircon, and garnet growth in migmatitic pelites as a record of prograde and retrograde metamorphism and partial melting in the East Humboldt Range, Nevada: American Mineralogist, v. 100, p. 951–972

Kylander-Clark, A.R.C., Hacker, B.R., and Cottle, J.M., 2013, Laser-ablation split-stream ICP petrochronology: Chemical Geology, v. 345, p. 99–112.

Lush, A.P., McGrew, A.J., Snoke, A.W., and Wright, J.E., 1988, Allochthonous Archean basement in the northern East Humbodt Range, Nevada: Geology, v. 16, p. 349-353.

Miller, R. B., Snoke, A. W., 2009, The utility of crustal cross sections in the analysis of orogenic processes in contrasting tectonic settings, in Miller and Snoke eds. Crustal Cross Sections from the Western North American Cordillera and Elsewhere: Implications for Tectonic and Petrologic Processes: Geological Society of America Special paper 456, p 1-38..

McGrew, A. J., Peters, M. T., and Wright, J. E., 2000, Thermobarometric constraints on the tectonothermal evolution of the East Humboldt Range metamorphic core complex, Nevada. Bulletin of the Geological Society of America, v. 112(1), 45-60.

McGrew, A.J., 1992, Tectonic evolution of the northern East Humboldt Range, Elko County, Nevada [Ph.D. thesis]: Laramie, University of Wyoming.

McGrew, A. J., and Snoke, A. W., 2015, Geologic Map of the Welcome and adjacent part of the Wells quadrangle, Nevada, Nevada Bureau of Mines and Geology Map M-184.

McGrew, A.J., and Snee, L.W., 1994, 40Ar/39Ar thermochronologic constraints on the tectonothermal evolution of the northern East Humboldt Range, Tectonophysics.

Premo, W. R., Castineiras, P., Wooden, J. L. 2008. SHRIMP-RG U-Pb isotopic systematics of zircon from the Angel Lake orthogneiss, East Humboldt Range, Nevada: Is this really Archean crust?: Geosphere, v. 4, n. 6, p. 963–975.

Snoke, A.W., Hudec, M.R., Hurlow, H.A., and McGrew, A.J., 1990, The anatomy of a Tertiary extensional shear zone, Ruby Mountains–East Humboldt Range, Nevada: Geological Society of America Abstracts with Programs, v. 22, no. 3, p. 85.

Sullivan, W.A., and Snoke, A. W. 2007. Comparative anatomy of core-complex development in the north-eastern Great Basin, U.S.A., Rocky Mountain Geology, v 42, no 1, p, 1-29.

Wright, J.E., and Snoke, A.W., 1993, Tertiary magmatism and mylonitization in the Ruby–East Humboldt metamorphic core complex, northeastern Nevada: U-Pb geochronology and Sr, Nd, Pb isotope geochemistry: Geological Society of America Bulletin, v. 105, p. 935–952.