GEOLOGY | THE GEOLOGICAL SOCIETY OF AMERICA®

https://doi.org/10.1130/G52614.1

Manuscript received 29 July 2024
Revised manuscript received 18 September 2024
Manuscript accepted 25 September 2024

Published online 11 October 2024

Orogen-scale inverted metamorphism during Cretaceous–Paleogene terminal suturing along the North American Cordillera, Alaska, USA

Sean P. Regan[1,2,*], Mark E. Holland[3], Trevor S. Waldien[4], McKenzie Miller[1,2], Peter Taylor[5], Andrew Kylander-Clark[6], Sean Marble[1,2], and Florian Hofmann[1]

[1]Geophysical Institute, University of Alaska Fairbanks, 1930 Yukon Drive, Fairbanks, Alaska 99775, USA
[2]Department of Geosciences, University of Alaska Fairbanks, 1930 Yukon Drive, Fairbanks, Alaska 99775, USA
[3]Geology Department, St. Lawrence University, 23 Romoda Drive, Canton, New York 13617, USA
[4]Department of Geology and Geologic Engineering, South Dakota School of Mines and Technology, 501 E. Saint Joseph Street, Rapid City, South Dakota 57701, USA
[5]P.O. Box 22290, Juneau, Alaska 99802, USA
[6]Department of Earth Sciences, University of California–Santa Barbara, 1006 Webb Hall, Santa Barbara, California 93106, USA

ABSTRACT

The northern North American Cordilleran margin has been active for >200 million years, as recorded by punctuated phases of crustal growth and deformation. Accretion of the exotic Wrangellia Composite Terrane (Insular Belt) is considered the largest addition of juvenile crust to the Cordilleran margin, though margin-parallel translation during the Cenozoic has obscured much of the accretionary history. Three zones of inverted metamorphism spatially correspond to the Insular–North American suture zone from north to south: (1) Clearwater Mountains; (2) Kluane Lake; and (3) Coast Mountains, each preserving kinematics indicative of thrusting of North American–derived rocks over Insular-derived assemblages. We performed in situ monazite petrochronology on samples collected across strike in both the Clearwater and Coast Mountain regions. New and recently published data from these three metamorphic belts indicate that thrust-sense deformation accompanied the formation of inverted metamorphic isograds from 72 to 56 Ma. We leverage recent estimates of Denali fault offset to reconstruct a >1000-km-long zone of inverted metamorphism and interpret it as the Insular–North America terminal suture.

INTRODUCTION

The North American Cordillera is an archetypal accretionary orogen recording >200 m.y. of superimposed terrane assembly, magmatism, and orogenesis (Busby et al., 2023). Discontinuous exposures of shortened Jurassic–Cretaceous metasedimentary assemblages along the Cordillera, commonly associated with inverted metamorphism, record closure of a marginal marine basin system during accretion of the Insular Belt to western North America (Erdmer and Mortensen, 1993; Ridgway et al., 2002; Monger et al., 1982). Although accretion of the Insular Belt has been credited as the most profound crustal growth event in the Phanerozoic record of North America (Trop and Ridgway, 2007), aspects of this event remain contentious due to conflicting data sets informing the age and polarity of accretionary structures (Pavlis et al., 2019; Tikoff et al., 2023). Complicating matters further, syn- to post-accretionary margin-parallel strike-slip translation and differential exhumation have dissected the orogen, obfuscating much of the earlier accretionary history (e.g., Enkin, 2006; Waldien et al., 2021).

Three vestiges of inverted metamorphic field gradients distributed along the northern Cordillera broadly correspond to the Insular–North America boundary: (1) the Clearwater Mountains in south-central Alaska; (2) the Kluane Lake area in the Yukon Territory; and (3) the Coast Mountains in southeastern Alaska (Fig. 1). Each locality preserves an ∼5-km-thick thrust-sense zone dipping toward North America that exhibits an increase in metamorphic grade from Insular-affinity rocks in the footwall structurally upward into rocks of North American provenance. Erdmer and Mortensen (1993) correlated these metamorphic domains based on multi-grain thermal ionization mass spectrometry analysis of monazite. However, the strength of this correlation has degraded as subsequent geochronologic investigations applied different techniques in each site (e.g., Stowell and Goldberg, 1997). Here, we present detailed in situ U-Pb monazite petrochronology from two traverses across inverted metamorphic field gradients within the Coast and Clearwater Mountains of Alaska (Fig. 1). We synthesize our data with data from the Kluane Lake region of southwestern Yukon (McKenzie et al., 2024) and a recent palinspastic reconstruction of the Denali fault (Waldien et al., 2021) to argue that the three metamorphic domains represent along-strike equivalents of a single zone of Cretaceous–Paleogene inverted metamorphism that formed during terminal suturing of the Insular Belt to the North American margin.

BACKGROUND

The Alaska Range suture zone is a wedge of variably deformed supracrustal and plutonic rocks between the Denali and Talkeetna faults in south-central Alaska (Fig. 1). Within the Alaska Range suture zone, the Valdez Creek shear zone (VCsz) is an ∼4-km-thick north-

Sean P. Regan https://orcid.org/0000-0002-8445-5138
*sregan5@alaska.edu

CITATION: Regan, S.P., et al., 2024, Orogen-scale inverted metamorphism during Cretaceous–Paleogene terminal suturing along the North American Cordillera, Alaska, USA: Geology, v. XX, p. , https://doi.org/10.1130/G52614.1

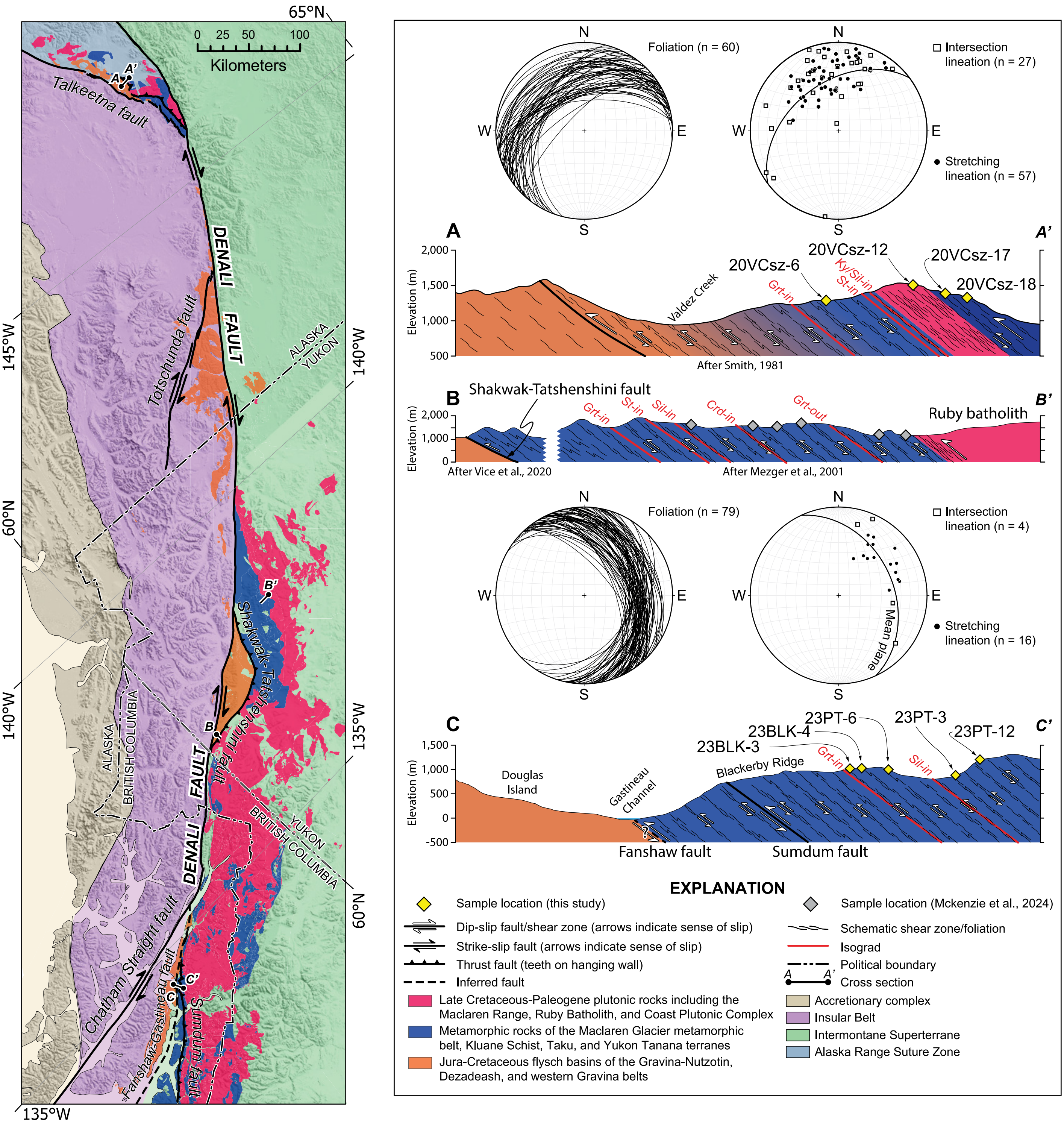

Figure 1. (A) Simplified geologic map of the northern Cordillera highlighting inverted metamorphic belts associated with the Insular-North American suture. (B) Cross sections of inverted metamorphic belts with sample locations and structural measurements from this study.

dipping thrust-sense shear zone (Smith, 1981; Davidson et al., 1992; Davidson and McPhillips, 2007) that formed along the inboard margin of the Insular Belt during terminal suturing (Ridgway et al., 2002). The VCsz preserves a complete inverted metamorphic field gradient ranging from sub-greenschist facies slate in the south to upper amphibolite-facies sillimanite-garnet gneisses in the north (Smith, 1981). The boundary between Insular Belt–derived and peri-Laurentian–derived metasediments is transposed within the shear zone (Link, 2017).

The boundary between North American affinity rocks and the accreted Insular Belt in the Coast Mountains near Juneau (Alaska) is an east-dipping package of strongly deformed supracrustal rocks with an inverted metamorphic gradient (Himmelberg et al., 1991). The structurally lowest package belongs to Jurassic–Cretaceous overlap assemblage of the Gravina belt (Yokelson et al., 2015) structurally beneath polydeformed allochthonous Laurentian-affinity Taku (Saleeby, 2000), Yukon-Tanana (Gehrels, 2001), and Coast Gneiss Complex (Gehrels

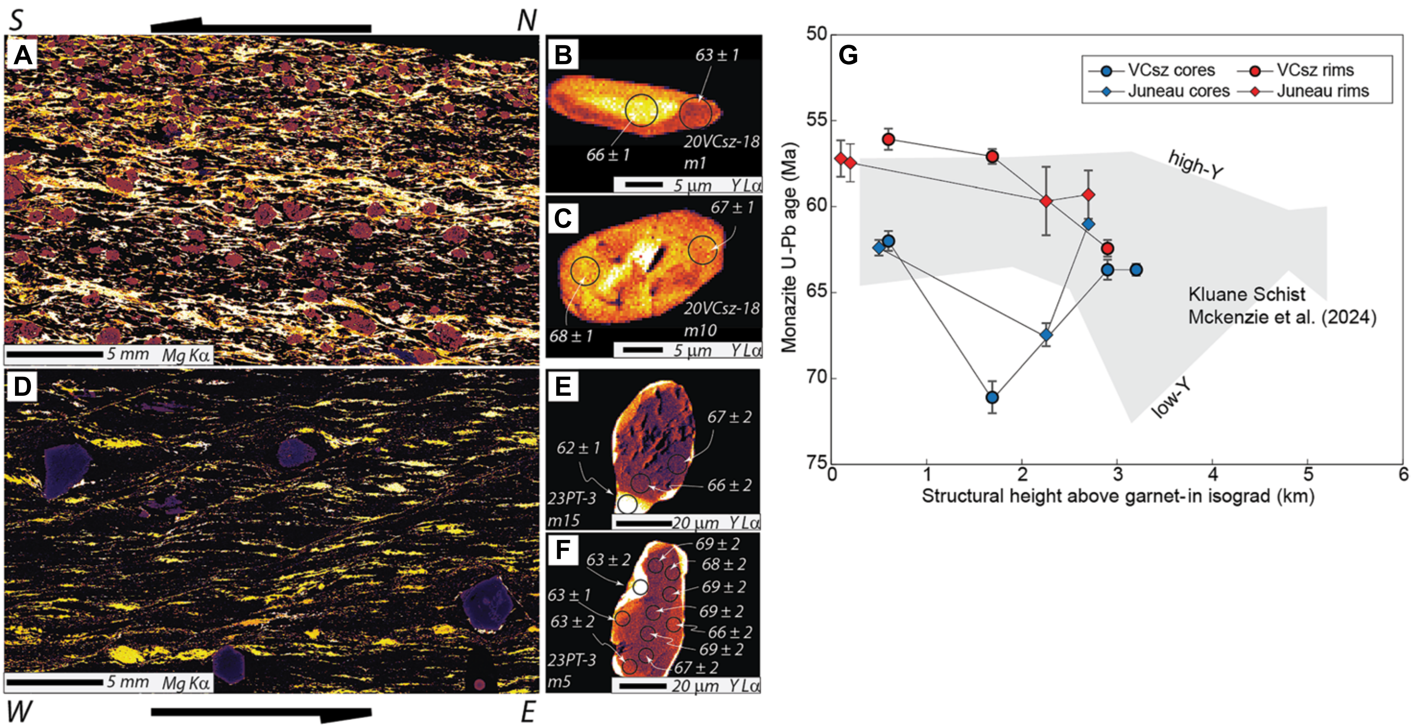

Figure 2. Representative structural and petrochronologic results from this study. All uncertainties listed are provided at the 2σ level. (A) Full thin section Mg Kα map from sample 20VCsz-12 with S-C geometries and σ-type asymmetries indicating south-vergent deformation. (B, C) Y Lα X-ray maps of monazite from sample 20VCsz-18 displaying high-Y cores surrounded by low-Y rims both of which are parallel to host rock folia. (D) Full thin section Mg Kα map from sample 23PT-6 displaying west-vergent shear bands. (E, F) Y Lα X-ray maps of monazite from sample 23PT-3 displaying characteristic low-Y cores and high-Y rims with distinctive age populations. (G) Summary of monazite U-Pb results from the Kluane Schist (McKenzie et al., 2024) and this study split into low-Y and high-Y populations plotted along structural height relative to the garnet-in isograd. VCsz—Valdez Creek shear zone.

et al., 2009) panels. Although parallel to the Coast shear zone, defined as a ca. 65–57 Ma east-side-up contractional structure (Gehrels et al., 2009), Stowell and Goldberg (1997) interpreted the inverted metamorphic belt to have formed at ca. 90 Ma based on Sm-Nd garnet geochronology. Subsequent interpretations of the Coast shear zone in southeastern Alaska have been relegated to discrete structures inferred between lithotectonic packages with disparate provenance, or drawn within variably deformed 70 Ma tonalitic rocks (Hollister and Andronicos, 1997; Stowell and Crawford, 2000).

CLEARWATER MOUNTAINS

We conducted a south-to-north transect across the VCsz from sub-greenschist facies Clearwater metasedimentary rocks to amphibolite-facies gneisses of the Laurentian-derived Maclaren Glacier metamorphic belt (Fig. S1 in the Supplemental Material[1]). At the base of the phyllite zone (Smith, 1981) deformation is localized into thrust faults, which we interpret as the base of the VCsz. Rocks in the VCsz exhibit a strong west-striking foliation with moderate north dip and a pervasive down-dip stretching lineation (Fig. 1). Intersection lineations are predominately oblique to stretching lineations, though locally parallel to stretching lineations near meta-intrusive rocks. Reverse-sense kinematic indicators including σ-clasts and S-C asymmetries are present throughout the shear zone (Fig. 2A).

Four samples (Table S1) from above the garnet-in isograd were collected for in situ U-Th-Pb monazite petrochronology (Table S2; Fig. 3). The structurally lowest sample, 20VCsz-06, is a garnet-biotite schist with garnet that displays sharp compositional zonation and inclusion trails parallel to the external foliation. Monazite exhibits mottled chemical zonation with minor intra-grain variability in Y and Th. ^{206}Pb/^{238}U ages range continuously from 63 to 55 Ma and preserve an increase in heavy rare earth element dispersion with decreasing age. Sample 20VCsz-12 was collected from the structural base of the gneiss unit (mapping of Smith, 1981) immediately beneath the tonalitic sill and is a granoblastic garnet-biotite-staurolite gneiss (Fig. 2A). Monazite grains contain low-Y cores (71.1 ± 0.9 Ma; mean squared weighted deviation [MSWD]: 1.39) and high-Y rims (57.1 ± 0.4 Ma; MSWD = 0.58). Sample 20VCsz-17 is a sillimanite-garnet gneiss with a pronounced down-dip lineation. Monazite from sample 20VCsz-17 exhibits three concentric compositional domains (low Y-cores, high-Y inner rims, and low-Y outer rims). Resulting ^{206}Pb/^{238}U weighted averages for each compositional domain are 66.9 ± 0.5 Ma (MSWD: 1.48), 63.7 ± 0.6 Ma (MSWD: 1.48), and 62.4 ± 0.5 Ma (MSWD: 2.15), respectively. Sample 20VCsz-18 is a garnet protomylonitic gneiss containing monazite with low-Y cores, elongated high-Y rims, and rare irregular outer rims with scalloped margins interpreted to reflect post-kinematic fluid-mediated dissolution-reprecipitation (Figs. 2B and 2C). Elongate cores and rims yield a ^{206}Pb/^{238}U weighted average of 67.6 ± 0.4 Ma (MSWD: 2.29) and 63.7 ± 0.3 Ma (MSWD: 1.6), respectively. We interpret these data to reflect progressive contractional deformation that decreases in age from ca. 72 Ma to 56 Ma structurally downward within the VCsz (Fig. 3).

COAST MOUNTAINS

We conducted a transect along Blackerby Ridge outside of Juneau from greenschist-facies Gravina belt rocks into the amphibolite-facies Yukon-Tanana Terrane (Fig. S2). Rocks exhibit a pervasive east-dipping cleavage to gneissosity and strong down-dip stretching lineation (Fig. 1). Asymmetric features including σ-type

[1]Supplemental Material. Methods, sample locations, and laser ablation split stream data. Please visit https://doi.org/10.1130/GEOL.S.27156984 to access the supplemental material; contact editing@geosociety.org with any questions.

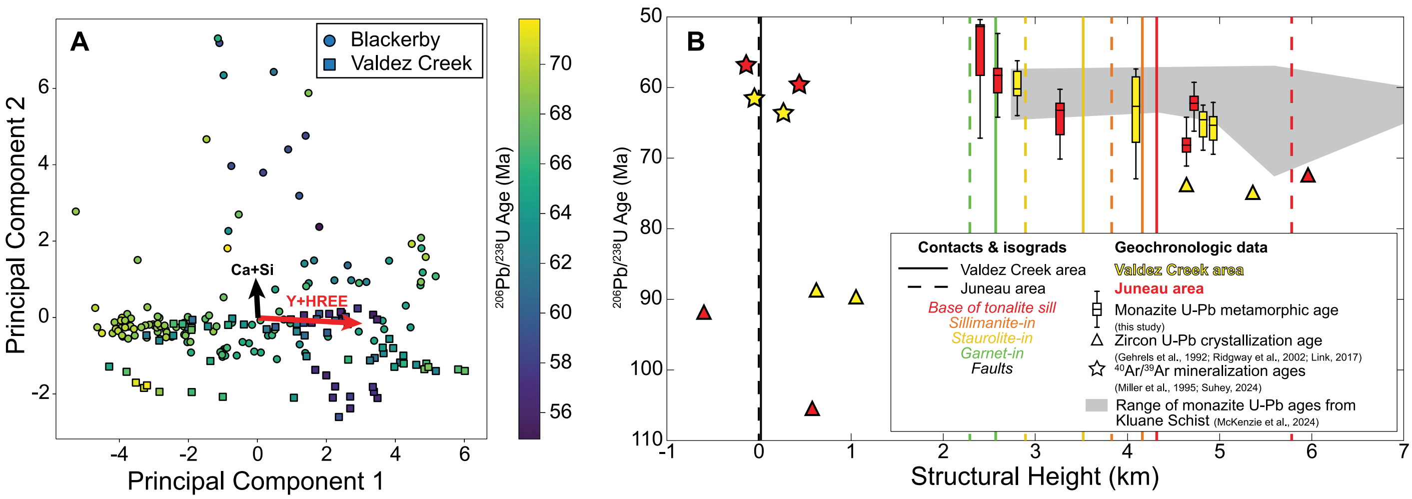

Figure 3. (A) Bivariant principal component analysis of monazite composition and loading vectors for Y + HREE, which covary with reported $^{206}Pb/^{238}U$ age. (B) Summary of geochronologic data from Clearwater and Coast Mountain regions plotted against structural height. New monazite data is presented as box plots. Note similar U-Pb zircon crystallization ages from the tonalite sill near the top of the inverted metamorphic belts as well as granitoids in footwall rocks. Mineralization ages are white mica $^{40}Ar/^{39}Ar$ analyses from gold-bearing quartz veins. Structural heights for the Valdez Creek shear zone and Juneau area are relative to basal faults of each inverted metamorphic belt.

garnet porphyroblasts and shear bands are consistent with east-side-up reverse sense motion throughout the traverse (Fig. 2D). Intrafolial folds and well-defined strike-parallel intersection lineations in the structurally lowest rocks indicate that the predominant fabric formed from transposition of older cleavage(s). Metamorphic isograds identified in this study match those mapped by Ford and Brew (1973) and extend through the sillimanite isograd over a map distance of 7 km. The predominant foliation is also present within ca. 70 Ma tonalitic rocks in the upper reaches of the traverse, indicating that this phase of deformation post-dated or accompanied emplacement of tonalite sills (Himmelberg et al., 1991).

Five samples (Table S1) from the traverse were targeted for in situ monazite petrochronology. Samples 23BLK-3 and -4 were collected immediately above the garnet-in isograd (Table S3; Fig. 1). The two samples contain very fine-grained (<15 μm) monazite. The analyzed grains lack zoning and likely formed as prograde products of allanite, typical of the transition from greenschist to amphibolite facies (Gasser et al., 2012). Owing to the fine grain sizes it was difficult to avoid imperfections during analysis, and results are mostly discordant. A subset of analyses not flagged for compositional issues yields a ^{207}Pb-corrected weighted mean age from the 11 most concordant analyses of 57.8 ± 1.0 Ma (MSWD: 7.5). Sample 23PT-6 is an S-C-C′ mylonite with coarse garnet porphyroblasts with top-to-the west shear bands (Fig. 2D). Monazite grains are small (~5–25 μm), exhibit mottled Y and Th zonation, and yield a range of $^{206}Pb/^{238}U$ ages from 68 to 58 Ma. Sample 23PT-3 is a garnet-biotite-sillimanite protomylonitic gneiss. Monazite exhibits low-Y cores often aligned in the plane of the foliation and sporadic high-Y rims (Figs. 2E and 2F). Low-Y cores yield a $^{206}Pb/^{238}U$ weighted mean of 67.5 ± 0.5 Ma (MSWD: 0.7) whereas high-Y rims yield a weighted mean age of 59.7 ± 2.0 Ma (MSWD: 3.4). Sample 23PT-12 is a fine-grained garnet-biotite gneiss with abundant garnet. Monazite grains display mottled low-Y cores with local high-Y rims with $^{206}Pb/^{238}U$ weighted means of 61.0 ± 0.7 (MSWD: 0.97) and 59.3 ± 1.4 (MSWD: 0.59). These results link deformation to the development of inverted metamorphic isograds during west-directed contractional uplift of the Coast Mountains metamorphic complex over the Insular Belt from 72 to 56 Ma. In addition, all samples aside from 23PT-12 show a systematic decrease in age structurally downward (Fig. 3B).

RECONSTRUCTION OF THE INSULAR–NORTH AMERICA SUTURE

Our new monazite results indicate that the inverted metamorphism in the Coast Mountains near Juneau and the Clearwater Mountains was contemporaneous. Near Juneau, inverted metamorphism formed within a thick (~5 km) ductile shear zone from 72 to 56 Ma during underthrusting of Insular-derived western Gravina belt beneath peri-Laurentian rocks of the Taku and Yukon-Tanana terranes. Similarly, inverted metamorphism within the VCsz formed during thrusting of North America–derived Maclaren schist over the Insular-derived Clearwater metasediments from 72 to 56 Ma. A third site of inverted metamorphism between the Coast and Clearwater Mountains, the Kluane schist, was also the focus of recent monazite petrochronology (McKenzie et al., 2024). There, inverted metamorphism was demonstrated to have formed from 72 to 56 Ma through underthrusting of Insular-derived metasediments beneath the peri-Laurentian Yukon-Tanana Terrane. The systematic decrease in monazite U-Pb ages structurally downward (Fig. 2G), a hallmark of other inverted metamorphic systems (e.g., Mottram et al., 2014), is now documented in each locality and is consistent with the incorporation of footwall rocks into the base of the propagating shear zone during progressive deformation, syn-kinematic prograde metamorphism of footwall affinity rocks, and extrusion of the thermally weakened hanging wall where 72–58 Ma plutons are abundant (Davidson et al., 1992; Gehrels et al., 2009; Waldien et al., 2021). The new petrochronology data presented here suggest that inverted metamorphism in the northern Cordillera resulted from orogen-scale thrust-sense ductile shearing along the Insular–North American boundary at ca. 72–56 Ma. We interpret metamorphic inversion as a consequence of advective heating (Pavlis, 1986; Davidson et al., 1992) during non-coaxial flow.

Erdmer and Mortensen (1993) postulated that the three localities discussed here formed a single ~1200-km-long metamorphic-plutonic belt that was dissected by the Denali fault. We leverage a recent palinspastic restoration of the Denali fault (Waldien et al., 2021; Fig. 4) and the new monazite data to test this hypothesis. The restoration of Waldien et al. (2021) uses detrital zircon U-Pb age spectra and regional map patterns to argue that the Maclaren schist, Clearwater metasediments, and associated plutonic rocks (Clearwater Mountains, Alaska; A–A′ on Fig. 1) correlate with the Kluane schist, Dezadeash Formation, and associated plutonic rocks (Kluane Lake, YT; B–B′ on Fig. 1). We contend that the identical U-Pb monazite petrochronology between these two localities strengthens the interpretation that they represent a single metamorphic belt dissected by ~480 km of

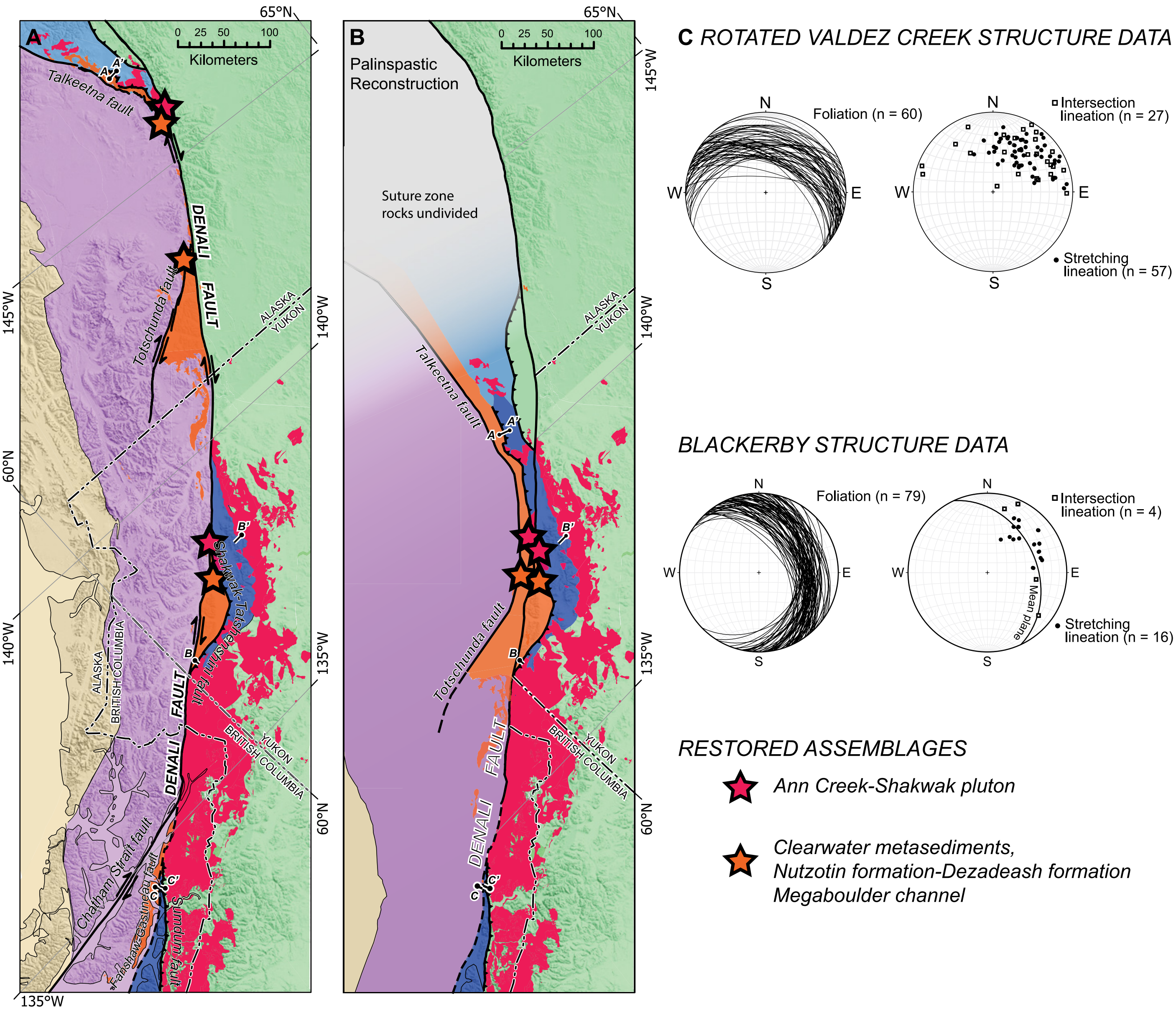

Figure 4. Palinspastic reconstruction of the Denali fault based on key offset markers (red and orange stars) from Waldien et al. (2021). (A) Modern configuration; same as Figure 1. (B) Configuration at ca. 52 Ma after 480 km of Denali fault slip is restored and the Clearwater Mountains and Kluane Lake zones of inverted metamorphism are reconnected. (C) Stereograms comparing structural data from Valdez Creek shear zone (VCsz) and Blackerby traverses. A 50° clockwise vertical axis rotation was applied to the VCsz data to account for restoration along the curved Denali fault, displaying parallel stretching lineations compatible with formation along the same structure.

displacement on the Denali fault since 52 Ma (Fig. 4) (Waldien et al., 2021). Critically, the Coast Mountains and Kluane Lake localities both lie northeast of the Denali fault and host synchronous inverted metamorphism where Insular-derived metasediments were thrust beneath the Yukon-Tanana Terrane. In each of the three localities considered here, inverted metamorphism formed between the Insular Belt and North America at 72–56 Ma within a thick ductile shear zone that uplifted melt-weakened North American rocks over the Insular Belt. Reconstruction of this structural system through Denali fault restoration reveals a >1000-km-long shear zone (Fig. 4) that represents the terminal suture of the most profound crustal growth event in the Phanerozoic record of the northern North American Cordillera.

ACKNOWLEDGMENTS

Funding for this work was supported through a U.S. Geological Survey EdMap award to Regan and National Science Foundation awards 2336081 and 2336082 to Regan and Waldien, respectively. We acknowledge constructive reviews from S. Johnston, C. Davidson, and T. Pavlis in addition to editorial handling by R. Strachan.

REFERENCES CITED

Busby, C.J., Pavlis, T.L., Roeske, S.M., and Tikoff, B., 2023, The North American Cordillera during the Mesozoic to Paleogene: Selected questions and controversies, *in* Whitmeyer, S.J., Williams, M.L., Kellett, D.A., and Tikoff, B., eds., Laurentia: Turning Points in the Evolution of a Continent: Geological Society of America Memoir 220, p. 635–658, https://doi.org/10.1130/2022.1220(31).

Davidson, C., and McPhillips, D., 2007, Along strike variations in metamorphism and deformation of the strata of the Kahitna basin, south-central Alaska, *in* Ridgway, K.D., Trop, J.M., Glen, J.G.M., and O'Neill, J.M., eds., Tectonic Growth of a Collisional Continental Margin: Crustal Evolution of Southern Alaska: Geological Society of America Special Paper 431, p. 439–453, https://doi.org/10.1130/2007.2431(17).

Davidson, C., Hollister, L.S., and Schmidt, S.M., 1992, Role of melt in the formation of a deep-crustal compressive shear zone: The Maclaren Glacier metamorphic belt, southcentral Alaska: Tectonics, v. 11, p. 348–359, https://doi.org/10.1029/91TC02907.

Enkin, R.J., 2006, Paleomagnetism and the case for Baja British Columbia, *in* Haggart, J.W., Enkin, R.J., and Monger, J.W.H., eds., Paleogeography of the North American Cordillera: Evidence for and against Large-Scale Displacements: Geological Association of Canada Special Paper 46, p. 233–253.

Erdmer, P., and Mortensen, J.K., 1993, A 1200-km-long Eocene metamorphic-plutonic belt in the northwestern Cordillera: Evidence from southwest Yukon: Geology, v. 21, p. 1039–1042, https://doi.org/10.1130/0091-7613(1993)021<1039:AKLEMP>2.3.CO;2.

Ford, A.B., and Brew, D.A., 1973, Preliminary geologic and metamorphic-isograd map of the Juneau B-2 Quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map 527, 1 sheet, scale 1:31,680.

Gasser, D., Bruand, E., Rubatto, D., and Stüwe, K., 2012, The behavior of monazite from greenschist facies phyllites to anatectic gneisses: An example from the Chugach Metamorphic Complex, southern Alaska: Lithos, v. 134–135, p. 108–122, https://doi.org/10.1016/j.lithos.2011.12.003.

Gehrels, G.E., 2001, Geology of the Chatham Sound region, southeast Alaska and coastal British Columbia: Canadian Journal of Earth Sciences, v. 38, p. 1579–1599, https://doi.org/10.1139/e01-040.

Gehrels, G.E., McClelland, W.C., Samson, S.D., Patchett, P.J., and Orchard, M.J., 1992, Geology of the western flank of the Coast Mountains between Cape Fanshaw and Taku Inlet, southeastern Alaska: Tectonics, v. 11, p. 567–585, https://doi.org/10.1029/92TC00482.

Gehrels, G., Rusmore, M., Woodsworth, G., Crawford, M., Andronicos, C., Hollister, L., Patchett, J., Ducea, M., Butler, R., Klepeis, K., Davidson, C., Friedman, R., Haggard, J., Mahoney, B., Crawford, W., Pearson, D., and Girardi, J., 2009, U-Th-Pb geochronology of the Coast Mountains batholith in north-coastal British Columbia: Constraints on age and tectonic evolution: Geological Society of America Bulletin, v. 121, p. 1341–1361, https://doi.org/10.1130/B26404.1.

Himmelberg, G.R., Brew, D.A., and Ford, A.B., 1991, Development of inverted metamorphic isograds in the western metamorphic belt, Juneau, Alaska: Journal of Metamorphic Geology, v. 9, p. 165–180, https://doi.org/10.1111/j.1525-1314.1991.tb00512.x.

Hollister, L.S., and Andronicos, C., 1997, A candidate for the Baja British Columbia fault system in the Coast Plutonic Complex: GSA Today, v. 7, p. 1–7.

Link, B.J., 2017, From deposition to deformation within an accretionary suture zone: An example from the Clearwater and Talkeetna Mountains, Alaska Range suture zone [MSc. thesis]: West LaFayette, Indiana, USA, Purdue University, 70 p.

McKenzie, W.F., Dyck, B., Gibson, H.D., and Larson, K., 2024, A record of Late Cretaceous to early Paleogene Insular terrane accretion within the northern Cordillera: Insights from monazite petrochronology across the Kluane Schist, southwest Yukon, Canada: Geological Society of America Bulletin, v. 136, p. 3510–3526, https://doi.org/10.1130/B37198.1.

Mezger, J.E., Chacko, T. and Erdmer, P., 2001, Metamorphism at a late Mesozoic accretionary margin: A study from the Coast Belt of the North American Cordillera: Journal of Metamorphic Geology, v. 19, p. 121–137, https://doi.org/10.1046/j.0263-4929.2000.00300.x.

Miller, L.D., Goldfarb, R.J., Snee, L.W., Gent, C.A., and Kirkham, R.A., 1995, Structural geology, age, and mechanisms of gold vein formation at the Kensington and Jualin deposits, Berners Bay District, southeast Alaska: Economic Geology, v. 90, p. 343–368, https://doi.org/10.2113/gsecongeo.90.2.343.

Mottram, C.M., Warren, C.J., Regis, D., Roberts, N.M.W., Harris, N.B.W., Argles, T.W., and Parrish, R.R., 2014, Developing an inverted Barrovian sequence: Insights from monazite petrochronology: Earth and Planetary Science Letters, v. 403, p. 418–431, https://doi.org/10.1016/j.epsl.2014.07.006.

Monger, J.W.H., Price, R.A., and Tempelman-Kluit, D.J., 1982, Tectonic accretion and the origin of two major metamorphic and plutonic welts in the Canadian Cordillera: Geology, v. 10, p. 70–75, https://doi.org/10.1130/0091-7613(1982)10<70:TAATOO>2.0.CO;2.

Pavlis, T.L., 1986, The role of strain heating in the evolution of megathrusts: Journal of Geophysical Research, v. 91, p. 12,407–12,422, https://doi.org/10.1029/JB091iB12p12407.

Pavlis, T.L., Amato, J.M., Trop, J.M., Ridgway, K.D., Roeske, S.M., and Gehrels, G.E., 2019, Subduction polarity in ancient arcs: A call to integrate geology and geophysics to decipher the Mesozoic tectonic history of the Northern Cordillera of North America: GSA Today, v. 29, no. 11, p. 4–10, https://doi.org/10.1130/GSATG402A.1.

Ridgway, K.D., Trop, J.M., Nokleberg, W.J., Davidson, C.M., and Eastham, K.R., 2002, Mesozoic and Cenozoic tectonics of the eastern and central Alaska Range: Progressive basin development and deformation in a suture zone: Geological Society of America Bulletin, v. 114, p. 1480–1504, https://doi.org/10.1130/0016-7606(2002)114<1480:MACTOT>2.0.CO;2.

Saleeby, J.B., 2000, Geochronologic investigations along the Alexander-Taku terrane boundary, southern Revillagigedo Island to Cape Fox areas, southeast Alaska, *in* Stowell, H.H., and McLelland, W.C., eds., Tectonics of the Coast Mountains, Southeastern Alaska and British Columbia: Geological Society of America Special Paper 343, p. 107–144, https://doi.org/10.1130/0-8137-2343-4.107.

Smith, T.E., 1981, Geology of the Clearwater Mountains, south-central Alaska: Alaska Division of Geological and Geophysical Surveys Geologic Report 60, 72 p., 3 sheets, scale: 1:63,360.

Stowell, H.H., and Crawford, M.L., 2000, Metamorphic history of the Coast Mountains orogen, western British Columbia and southeastern Alaska, *in* Stowell, H.H., and McClelland, W.C., eds., Tectonics of the Coast Mountains, Southeastern Alaska and British Columbia: Geological Society of America Special Paper 343, p. 257–284, https://doi.org/10.1130/0-8137-2343-4.257.

Stowell, H.H., and Goldberg, S.A., 1997, Sm-Nd garnet dating of polyphase metamorphism: northern Coast Mountains, south-eastern Alaska, USA: Journal of Metamorphic Geology, v. 15, p. 439–450, https://doi.org/10.1111/j.1525-1314.1997.00025.x.

Suhey, J., 2024, Exploring competing gold system models in the Valdez Creek region, Clearwater Mountains, Alaska: Fairbanks, AK [MSc. thesis]: University of Alaska Fairbanks, Alaska, USA, 124 p.

Tikoff, B., Housen, B.A., Maxson, J.A., Nelson, E.M., Trevino, S., and Shipley, T.F., 2023, Hit-and-run model for Cretaceous–Paleogene tectonism along the western margin of Laurentia, *in* Whitmeyer, S.J., Williams, M.L., Kellett, D.A., and Tikoff, B., eds., Laurentia: Turning Points in the Evolution of a Continent: Geological Society of America Memoir 220, p. 659–705, https://doi.org/10.1130/2022.1220(32).

Trop, J.M., and Ridgway, K.D., 2007, Mesozoic and Cenozoic tectonic growth and southern Alaska: A sedimentary basin perspective, *in* Ridgway, K.D., Trop, J.M., Glen, J.M.G., and O'Neill, J.M., eds., Tectonic Growth and a Collisional Continental Margin: Crustal Evolution of Southern Alaska: Geological Society of America Special Paper 431, p. 55–94, https://doi.org/10.1130/2007.2431(04).

Vice, L., Gibson, H.D., and Israel, S., 2020, Late Cretaceous to Paleocene tectonometamorphic evolution of the Blanchard River Assemblage, Southwest Yukon: New insight into the terminal accretion of Insular Terranes in the Northern Cordillera: Lithosphere, v. 2020, https://doi.org/10.2113/2020/2298288.

Waldien, T.S., Roeske, S.M., and Benowitz, J.A., 2021, Tectonic underplating and dismemberment of the Maclaren-Kluane schist records late Cretaceous terrane accretion polarity and $\sim$480 km of post-52 Ma dextral displacement on the Denali fault: Tectonics, v. 40, https://doi.org/10.1029/2020TC006677.

Yokelson, I., Gehrels, G.E., Pecha, M., Giesler, D., White, C., and McClelland, W.C., 2015, U-Pb and Hf isotope analysis of detrital zircons from Mesozoic strata of the Gravina belt, southeast Alaska: Tectonics, v. 34, p. 2052–2066, https://doi.org/10.1002/2015TC003955.

Printed in the USA