Oblique Convergence as a Driving Mechanism for Protracted Exhumation, Basin Development, and Sedimentation during Island Arc Collision: A Case Study from Southern Alaska*

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Search and Discovery Article #30100 (2009)
Posted September 8, 2009

*Adapted from oral presentation at AAPG Annual Convention, Denver, Colorado, June 7-10, 2009

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Abstract

Late Cenozoic examples of island arc collision (e.g., Taiwan, Trinidad, Venezuela) have aided in our understanding of exhumation, basin development, and sediment dispersal in moderately- to highly-oblique convergent margin settings. However, in older mountain belts, often the timing, location, and duration of collision can only be inferred from stratigraphic and provenance trends from sedimentary basin that developed during suturing events. In the case of the North American Cordillera, Mesozoic island arc collision is recorded in a discontinuous belt (>2000-km-long) of clastic strata that are exposed inboard (cratonward) of the allochthonous Wrangellia composite terrane (composite island arc) from southern Alaska to Washington State. In southern Alaska, synorogenic strata of the Upper Jurassic-Cretaceous Kahiltna assemblage are located in the suture zone between the Wrangellia composite terrane and pericratonic Intermontane belt. Stratigraphic constraint and provenance trends from the Kahiltna assemblage, including U-Pb detrital zircon geochronology, reveal distinct temporal and spatial trends in regional exhumation and basin development during Jurassic-Cretaceous arc collision. U-Pb detrital zircon geochronology from base-to-top of the Kahiltna assemblage reveal an age distribution of primarily Mesozoic-age grains (Mz-74%) with less abundant Paleozoic (Pz-11%), and Precambrian (Pc-15%) age grains. A comparison of detrital zircon ages from older to younger stratigraphic intervals within the Kahiltna assemblage reveals three distinct stages of exhumation and basin development that are interpreted to represent: (1) An initial Late Jurassic-Early Cretaceous stage during which detritus was derived almost solely from Middle-Late Jurassic igneous sources of the Wrangellia composite terrane (Mz-100%-Pz-0%-Pc-0%) and deposited in a retroarc foreland basin, (2) An Early Cretaceous stage that reflects a transition to sedimentation in a remnant ocean basin setting and the first introduction of Paleozoic and Precambrian age detritus from pericratonic source areas (Mz-84%-Pz-11%-Pc-5%; Mz-59%-Pz-12%-Pc-29%), and finally, (3) An Early to Late Cretaceous stage that reflects a transition to a collisional foreland basin that was characterized by continued detrital contributions from inboard and outboard source areas and a relative decrease in Mesozoic arc source areas and increase in Precambrian and Paleozoic pericratonic sources (Mz-46%-Pz-16%-Pc-38%).

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Talk Overview

1) Introduction – Tectonic configuration of the North American Cordillera
   - Current models for Mesozoic island arc accretion

2) Modern Example – Oblique arc collision in the Pacific (Luzon arc, Taiwan)
   - Ocean basin closing and along-strike (axial) sediment transport
   - Models for three-part stratigraphy (pre-, syn-, and post-collision)

3) Geologic Case Study – Alaska Range suture zone, southern Alaska
   - Stratigraphy and provenance of the Jurassic–Cretaceous Kahiltna assemblage
   - Provenance comparison from base-to-top of strata to get at the timing of exhumation and basin development
Tectonic configuration of the N.A. Cordillera
Collisional model for Mesozoic accretion of the Wrangellia Island Arc

- Late Jurassic–Early Cretaceous island-arc accretion
- Late Cretaceous suturing of arc to margin and subsequent strike-slip faulting (~95 Ma)
- Syntectonic strata preserved in a linear trend along N. American margin
Modern Examples of Island Arc Generation/Accretion
Example: Oblique Island Arc Accretion

**Diagnostic characteristics:**

- Rapid uplift/exhumation; extreme sedimentation rates
- Along-strike (axial) sediment transport parallel to plate margin

Modified from Stephan et al. (1986)
Spatial and temporal stratigraphic trends during oblique convergence

Phase 1: Sediment starved
- Oceanic crust
- "basement"
- Abyssal plain

Phase 2: Rapid sedimentation
- Submarine fans
- Submarine phase

Phase 3: Sedimentation and deformation
- Delta
- Nonmarine fluvial deposits

From Graham et al. (1975)
Case Study: Mesozoic Arc Accretion – Southern Alaska

Diagnostic characteristics:

- Highest topography in North America

- Jr–K Kahiltna assemblage is part of a discontinuous belt (>2000 km long) exposed along the western margin of North America
Alaska Range Suture Zone – Generalized Geology

- Pericratonic accreted terranes (Pc-Mz)
- Kahiltina assemblage (Mz)
- Wrangellia Island arc (Pz-Mz)
Alaska Range Suture Zone – Stratigraphic and Provenance Overview

From Hampton et al. (2007)
Alaska Range Suture Zone – Kahiltna Assemblage

- Pericratonic accreted terranes (Pc-Mz)
- Kahiltna assemblage (Mz)
- Wrangellia Island arc (Pz-Mz)
Alaska Range Suture Zone – Kahiltna Assemblage
Alaska Range Suture Zone – Kahiltna assemblage
Provenance: U-Pb Detrital Age Dating

Collection

Separation

LA-ICP-MS

\[ \frac{^{206}\text{Pb}}{^{238}\text{U}} \]

\[ \frac{^{207}\text{Pb}}{^{235}\text{U}} \]

Sink - Sample - Age
Bulk U-Pb Age Distribution – Kahiltna Assemblage

Wrangellia island arc
continental margin

Total grains - n=714
74% Mesozoic
11% Paleozoic
15% Precambrian
Summary of Pz-Mz magmatic sources inboard and outboard of the Kahiltna basin
Bulk U-Pb Age Distribution – Kahiltna Assemblage

Wrangellia island arc

continental margin

Total grains - n=714

74% Mesozoic
11% Paleozoic
15% Precambrian

Current slide is a scatter plot showing the distribution of U-Pb ages for the Kahiltna Assemblage. The x-axis represents the $^{206}Pb/^{238}U$ ratio, while the y-axis shows the $^{207}Pb/^{206}Pb$ ratio. The data points are distributed across a range of ages, with a notable peak in the Mesozoic era. The slide also highlights the Wrangellia island arc and the continental margin.
Majority of detrital contributions from the inboard margin; decreased arc contributions

First detrital contribution from the inboard margin; still primarily from the Wrangellia composite terrane

Detrital contributions almost entirely from the exhuming Wrangellia composite terrane
Conclusions: Stage 1 – Exhumation of Wrangellia Island Arc

**STAGE 1**: Late Jurassic
(Oxfordian–Tithonian)
161.2–145.5 Ma
**STAGE 2**: Early Cretaceous
(Barremian–Aptian)
130–112 Ma

Conclusions: Stage 2 – Exhumation of Arc (primary) and Inboard Margin
Conclusions: Stage 3 – Exhumation of Inboard Margin (primary) and arc

**STAGE 3: Early Cretaceous**
(Albian)
112–199.6 Ma

Wrangellia island arc
continental margin

Kahiltna assemblage
Acknowledgments

Dwight Bradley *(USGS)*
George Gehrels *(U. of Arizona)*
Ken Ridgway *(Purdue U.)*
Jeanine Schmidt *(USGS)*

Basin Research Lab *(at MSU)*:
- Michael Ackerson *(MSU)*
- Jenifer Deloge *(MSU)*
- Matthew Malkowski *(MSU)*

**National Science Foundation**

**U.S. Geological Survey**

**Michigan State University**
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http://jan.ucc.nau.edu/~rcb7/nam.html

