Divergence Time Estimation & Paleobiogeography of the Salamander Subgenus *Plethopsis*

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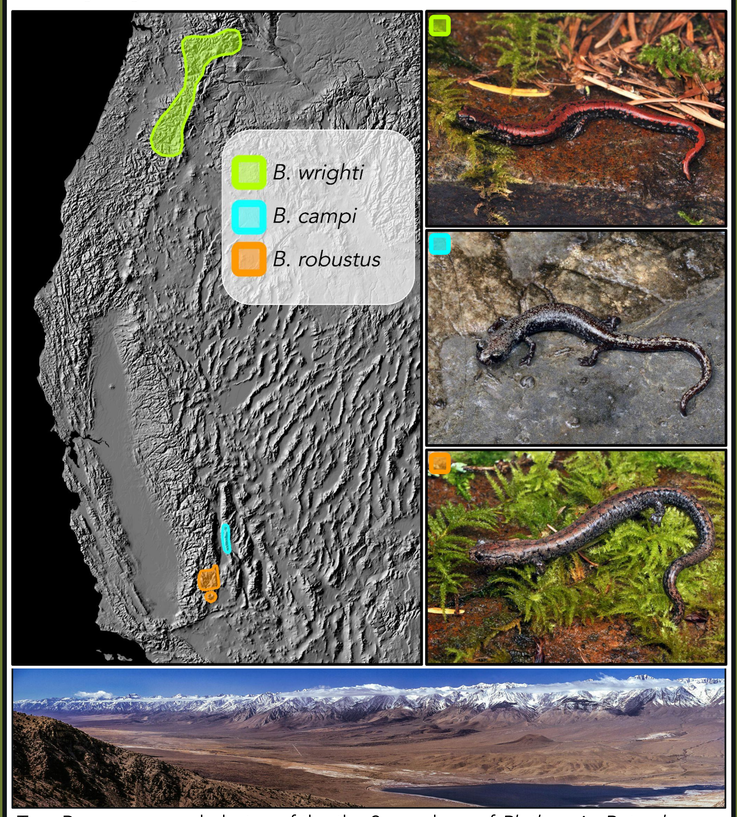
Abstract

The disparate global range of Plethodontid salamanders in the *Batrachoseps* subgenus *Plethopsis* is unique, and implicates perplexing historical biogeographic scenarios. Using uncorrelated relaxed molecular clock methods and fossil-calibrated divergence estimates from Shen et al. (2016), we present a time-scaled phylogeny for the genus *Batrachoseps* in order to test hypotheses concerning the diversification of the subgenus *Plethopsis*. Our estimated divergence time intervals detract support from a hypothesis that *Batrachoseps robustus* diverged as the flow of the Owens river changed course at ca. 3.2 Ma, as evidenced by sediment deposits at Searles Lake (Phillips, 2008). Instead, our estimates support that diversification of the known *Plethopsis* species began earlier, in the late Miocene to early Pliocene, as extensional activity formed the proto-Owens Valley and led to ensuing hydrological and climatic changes, driving vicariance between populations in the proto-southern Sierra Nevada and Inyo Mountains. Moreover, our estimates support a scenario wherein *B. campi* and *B. wrighti* diverged in the Pliocene as ancestral populations of *B. wrighti* expanded northward to Oregon via a corridor of relatively mesic habitat in the western Great Basin.

Research Goal

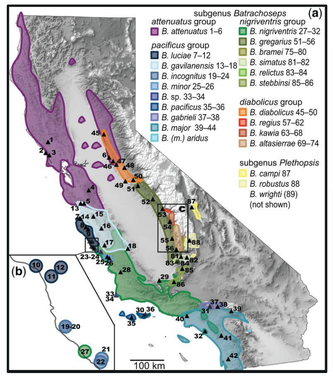
Understand the timing of diversification in *Plethopsis* to explore possible historical biogeographic scenarios and geologic events driving speciation.

Study System



Top: Range map and photos of the 3 members of *Plethopsis*: *Batrachoseps wrighti, campi,* and *robustus*. Photos courtesy of Robert Hansen
Bottom: The Owens Valley and the eastern escarpment of the Sierra Nevada viewed from the Inyo Mountains.

Methods



Divergence time estimates from Shen et al. (2016) used as calibrations:

Split	Divergence Time (95% HPDI)
B. robustus – B. attenuatus	39.2 Ma (32.3 - 46.2)
B attenuatus – B. major	16.8 Ma (12.0 - 22.1)

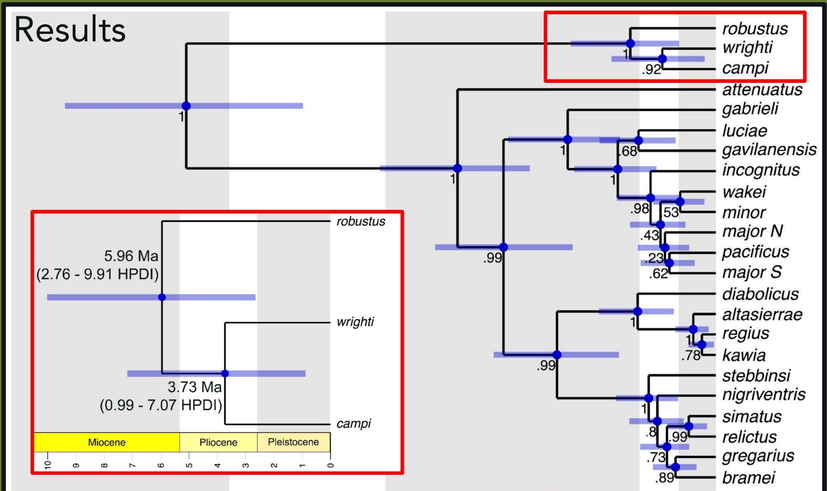
Beast2
Bayesian evolutionary analysis by sampling trees

CIPRES Cyberinfrastructure for Phylogenetic Research

Molecular dataset from Jockusch et al. (2015)
- 3 intronic nuclear loci (pvalb, ilf3, mylpf)
- 2 exonic nuclear loci (RAG1 & POMC)
- 1 mitochondrial locus (CytB)

- Species tree inference in BEAST v.2.7.3 using StarBEAST3.
- Relaxed clock model
- MCMC chain ~40,000,000 iterations
- Analyses run on ACCESS supercomputer via CIPRES

Results



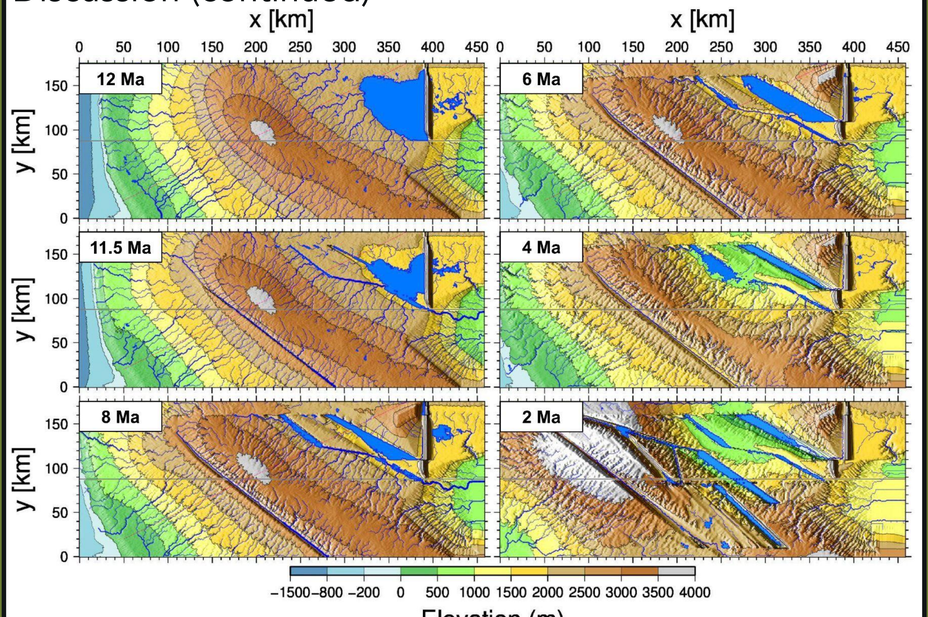
Node	Divergence Time (95% HPDI)
robustus divergence	5.96 Ma (2.76 - 9.91)
campi - wrighti	3.73 Ma (0.99 - 7.07)

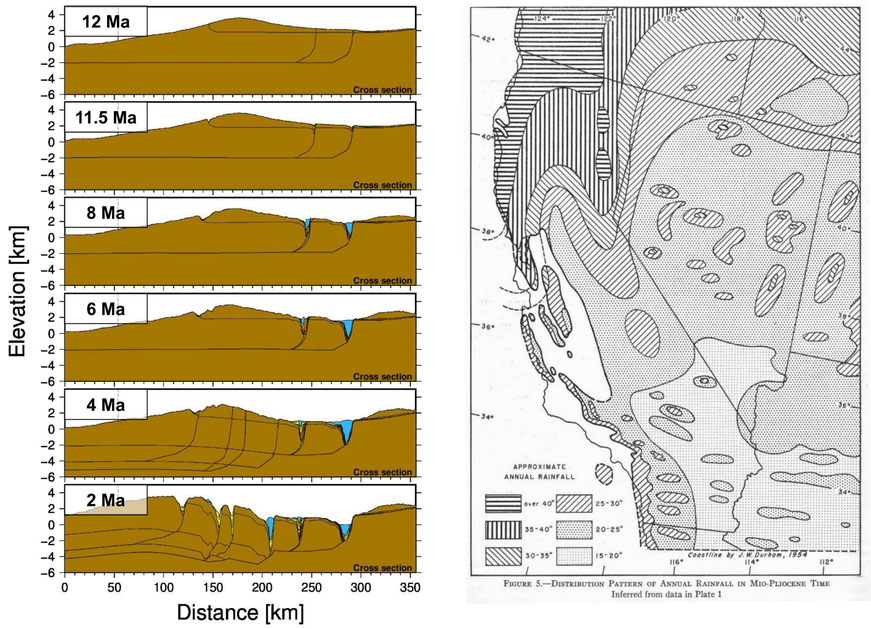
Top: Time tree for *Batrachoseps* with posterior probabilities and node bars representing divergence time HPD intervals. Inset shows the time-scaled phylogeny for subgenus *Plethopsis*. Bottom: Divergence times and 95% HPD intervals for the 2 *Plethopsis* nodes.

Discussion

- Estimated time interval for *B. robustus* divergence coincides with the development of the early Owens Valley, and breakup of a continuous highland linking the southern Sierra and proto Inyo Mountains (Jayko, 2009; Monastero et al., 2002; Phillips, 2008). Climatic and hydrologic changes in this valley likely fractured intermediate populations, leading to divergence of *B. robustus* via allopatric vicariance.
- A plausible biogeographic explanation for the *B. campi - B. wrighti* split is that ancestral populations migrated north to Oregon via a corridor of comparatively moist habitat that existed on the western margin of the Great Basin. Population genetic work by Miller et al. (2005) suggests *B. wrighti* reached Oregon by the late Pliocene.

Discussion (continued)





Top: Preliminary TISC paleogeographic reconstructions of the Southwestern Great Basin from Han, K., Berry, M., & Phillips, F., 2023. Unpublished model results.
Bottom Left: TISC estimated paleoelevation profiles of the Sierra Nevada and Southwestern Great Basin from Han, K., Berry, M., & Phillips, F., 2023. Unpublished model results.
Bottom Right: Mio-Pliocene precipitation map of western North America inferred from paleoflora data, from Axelrod (1957).

Future directions

- Compare *B. robustus* divergence time to paleoclimatic models of the Owens Valley
- Historical demography & interspecific divergence time estimation of *Batrachoseps wrighti*
- Conduct divergence date estimation with expanded molecular dataset
- Find relictual populations of *Plethopsis* in the Great Basin