

Further adventures in the phylogenetics of Boechereae (Brassicaceae).

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• Löve and Löve (1976) created the genus in honor of Tyge Böcher, based on chromosome numbers:

Boechera: n=7
Arabis: n=8

• Split of the two genera has been confirmed by molecular phylogenetics.





- 110 species, all but one (*Boechera falcata*) endemic to North America;
- divergent sexual diploid species as well as diploid and triploid hybrid lineages;
- Boechera comprises most of the tribe Boechereae, which also includes:
 - Anelsonia
 - Borodinia
 - Cusickiella
 - Nevada

- Phoenicaulis
- Polyctenium
- Sandbergia



- Due in part to a close relationship to *Arabidopsis*, *Boechera* has become a model system for a wide variety of studies, including:
 - evolution of genes & gene families
 - local adaptation
 - plant/pathogen interactions

- polyploid hybrid speciation
- apomixis

• However, poor understanding of the taxonomy and phylogeny of *Boechera*

imposes a constraint on these studies.





Resolving phylogeny of Boechera

- Present efforts focus on divergently related diploid species;
- triploids are excluded based on pollen morphology (Windham & Al-Shehbaz 2006);
- diploid hybrids are excluded based on microsatellite data (Dr. Beck, Tuesday).
- Once the underlying phylogenetic framework of diploid *Boechera* species is established, the superstructure of hybridization can be laid on top of it.



Methods

- Phylogenetic analyses include ± 60 of the ± 70 divergent diploid *Boechera*, and representatives of all other genera of Boechereae.
- Ten loci used, ±95% coverage overall:
- two chloroplast loci:
 - trnL-F
 - trnK-rps16
- one nuclear ribosomal locus:
 - ITS

- •seven low-copy nuclear loci:
- alcohol dehydrogenase
- chalcone synthase
- *dpa*I
- luminidependens
- mps35
- · nuo
- pistillata.

• Compared to results presented at Botany 2009, ±25 taxa & ±500 sequences have been added.

Methods

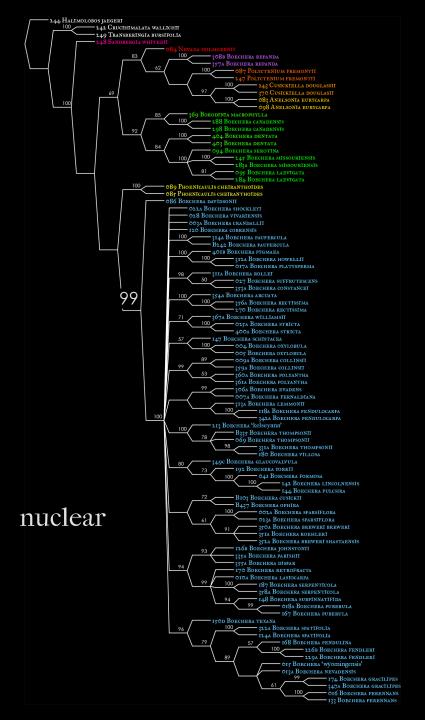
- Prior to phylogenetic analysis, gaps were coded as characters using simple indel coding of Simmon & Ochoterena (2000) as implemented in SeqState;
- including gaps, parsimony-informative characters per locus are as follows:

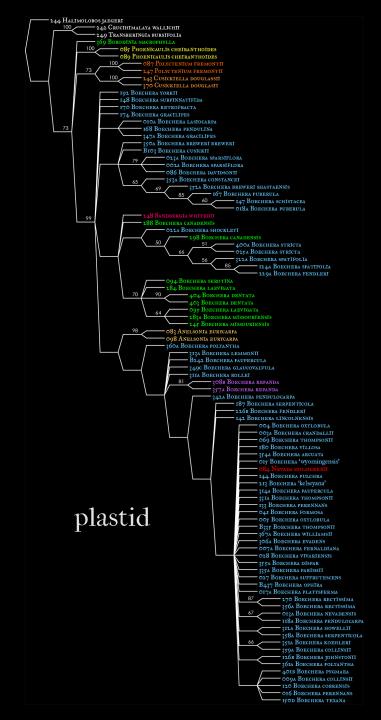
• trnL-F	146
• trnK-rps16	IIO
• ITS	120
 alcohol dehydrogenase 	130
 chalcone synthase 	149
$\bullet dpaI$	I20
 luminidependens 	114
• mps35	137
• nuo	50
• pistillata	25I
• plastid	256
nuclear	1071
• total	1327

Methods

- Preliminary phylogenetic analyses are as follows:
 - heuristic parsimony searches conducted in NONA spawned from WinClada (500 random addition replicates; 20 trees per replicate; swapping to 10001 trees);
 - support is estimated with 1000 jackknife replicates in TNT (courtesy of Willi Hennig Society; JK replicates conducted with "new technology search" including parsimony ratchet, sectorial search, tree drift, and tree-fusing).



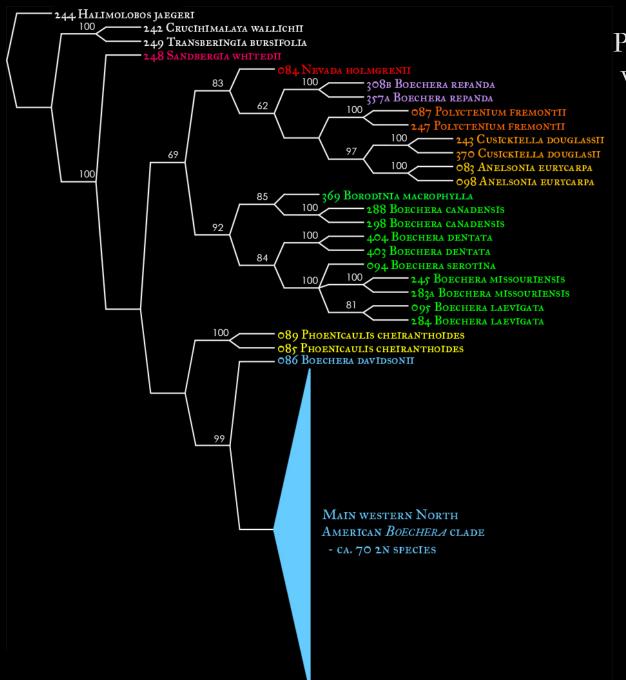




Nuclear/plastid incongruence

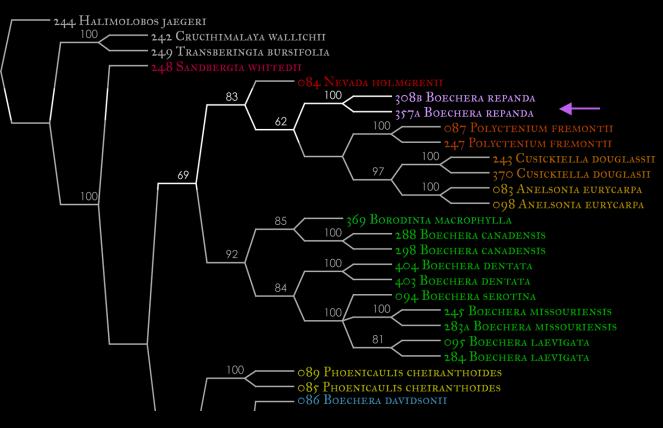
- Patterns of plastid divergence decoupled from species divergence in Boechereae & related tribes:
 - Arabidopsis: Koch & Matschinger 2007, PNAS;
 - Boechera: Kiefer et al. 2009, MPE
- ancestral polymorphism & incomplete lineage sorting?
- hybridization / chloroplast capture?





Plastid data is excluded; we'll focus on *Boechera*.

Boechera outliers: Boechera repanda

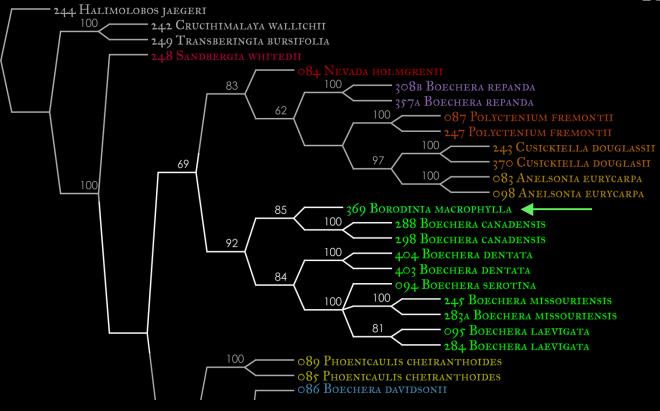






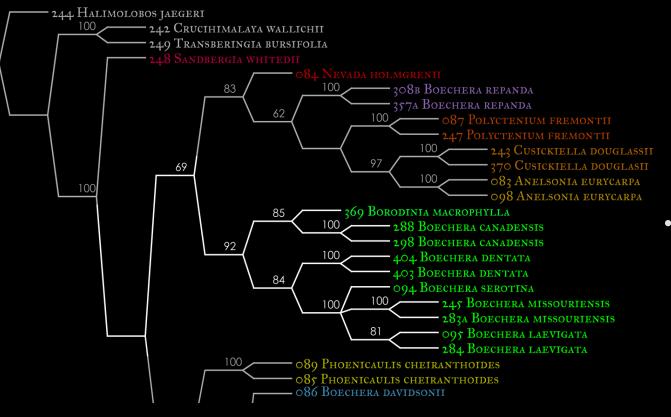
Boechera outliers: Borodinia + eastern N.A. Boechera

- Borodinia macrophylla
- monotypic genus
- Russian Far East

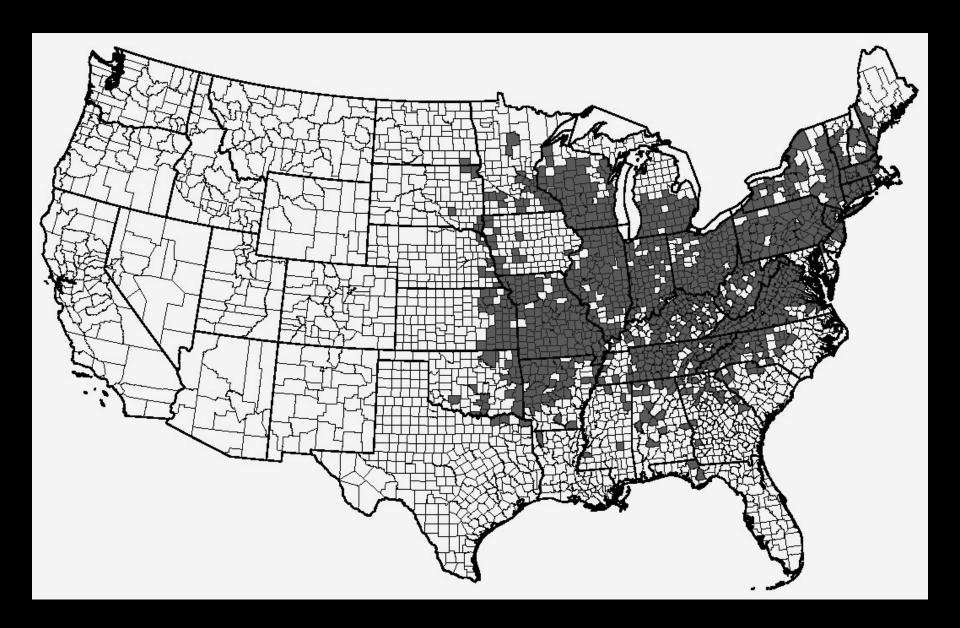


Boechera outliers: Borodinia + eastern N.A. Boechera

- eastern North American clade:
 - B. canadensis
 - B. dentata
 - B. laevigata
 - B. missouriensis
 - B. serotina
 - ? B. burkii
 - ? B. perstellata
 - eastern North
 America / eastern
 Asia disjunction



Boechera outliers: eastern N.A. Boechera





Eastern North American clade: Boechera laevigata



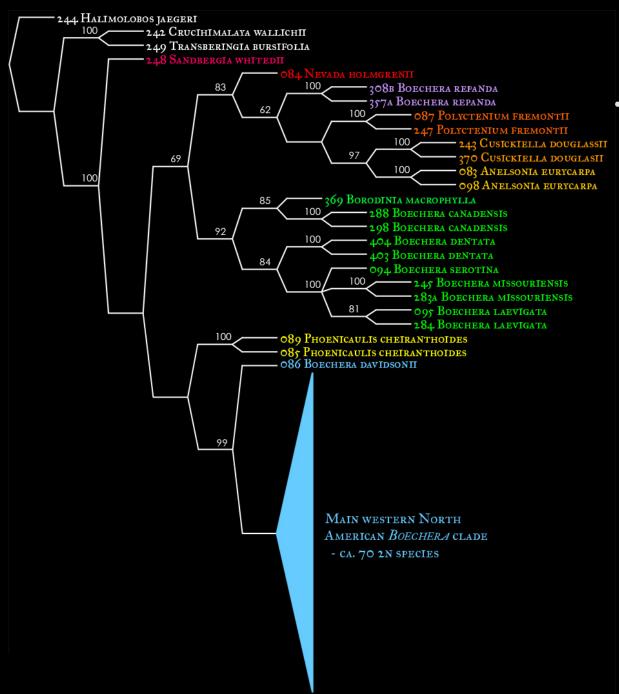




Eastern North American clade: Boechera dentata



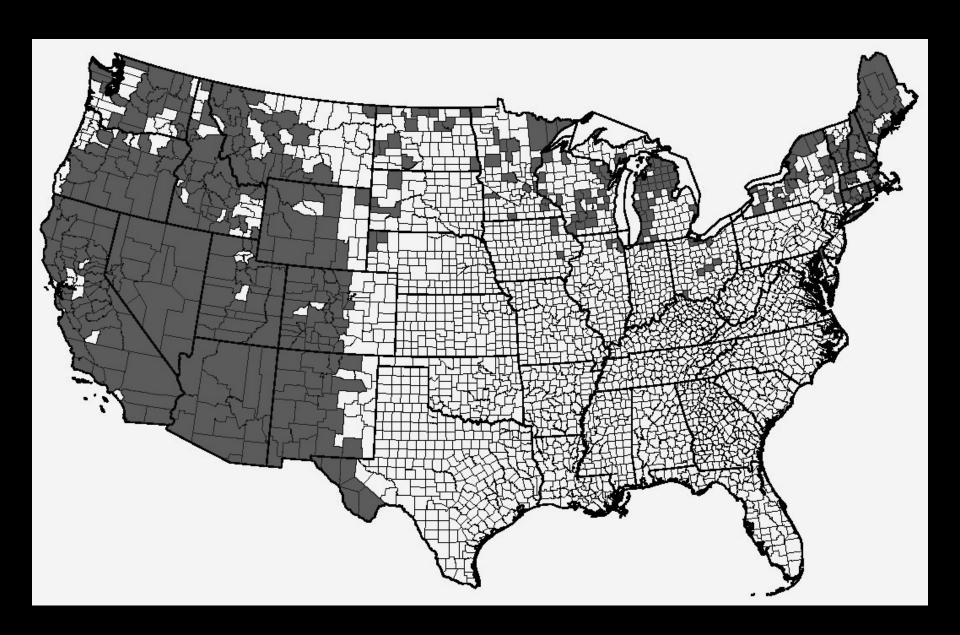




Main Boechera clade

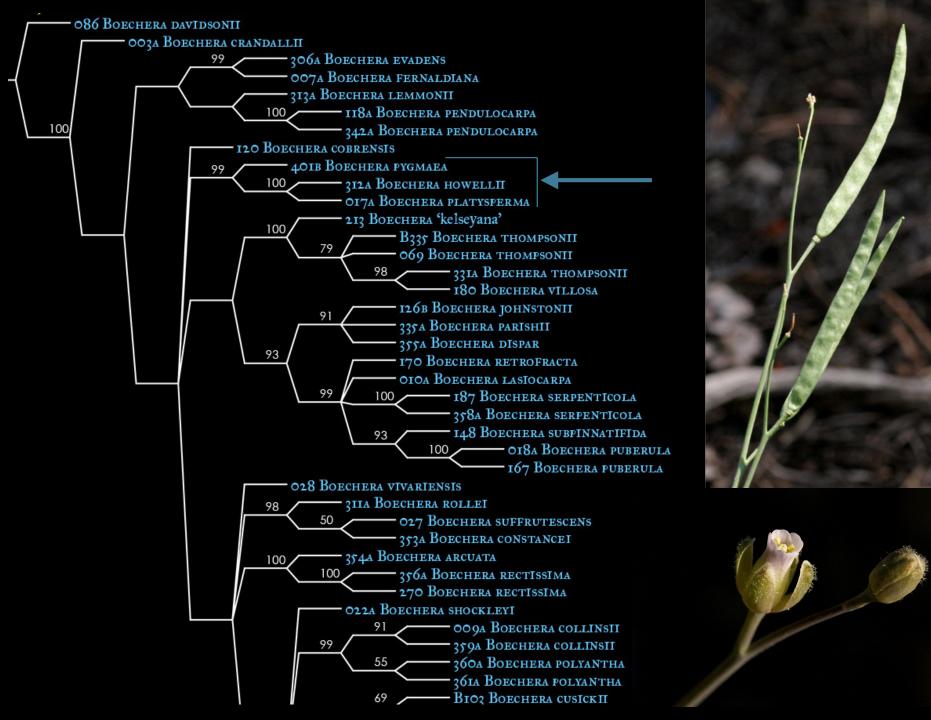
- Boechera, main clade:
 - ± 100 spp.
 - largely allopatric from the eastern N.A. clade

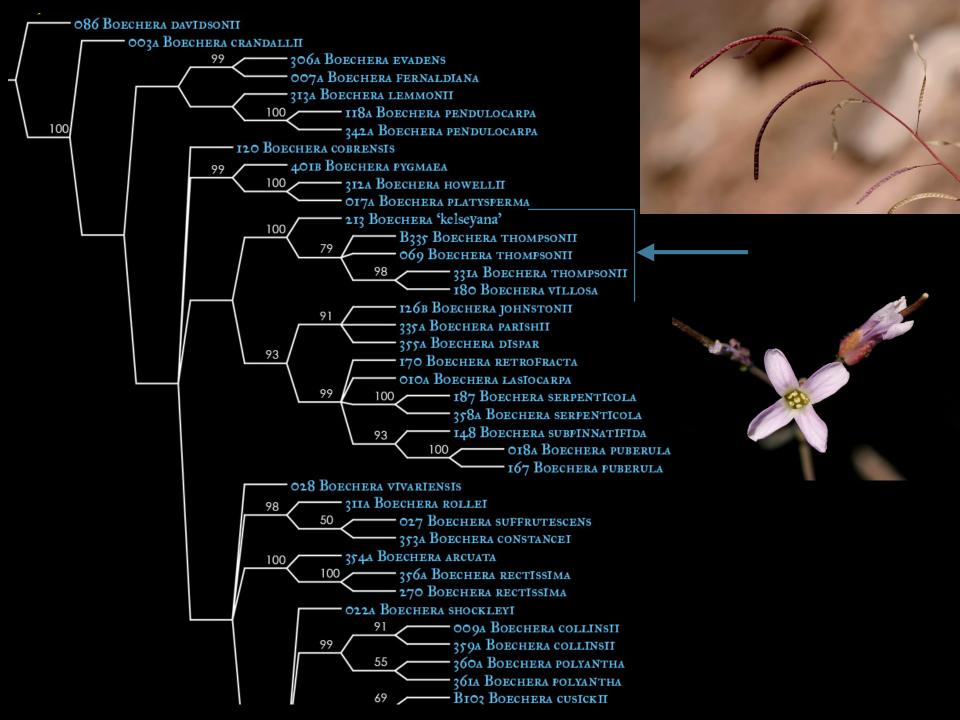
Main Boechera clade

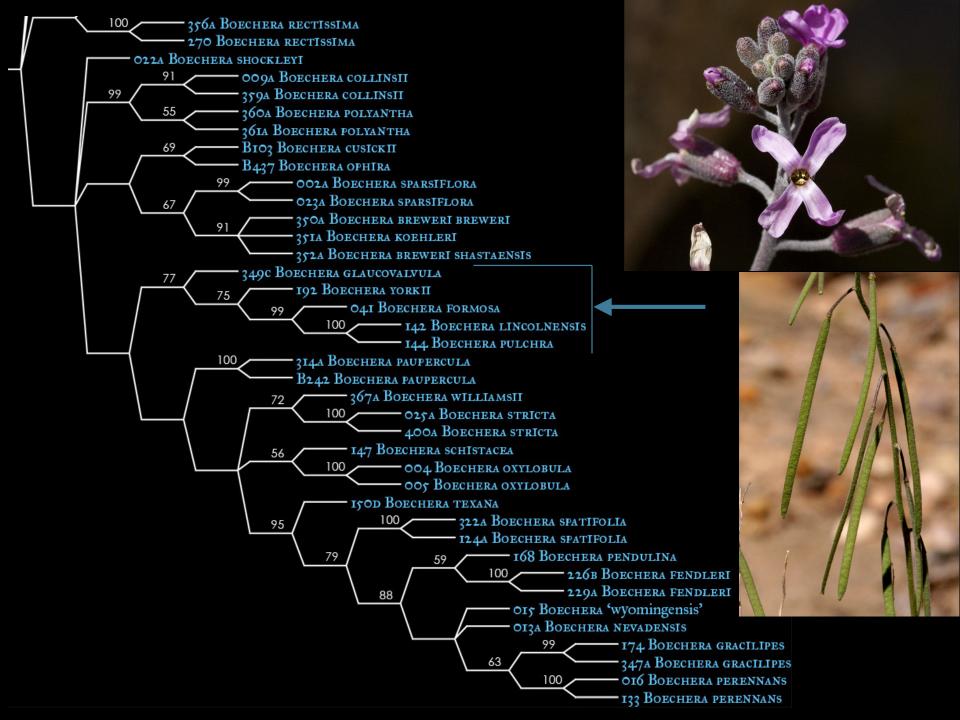


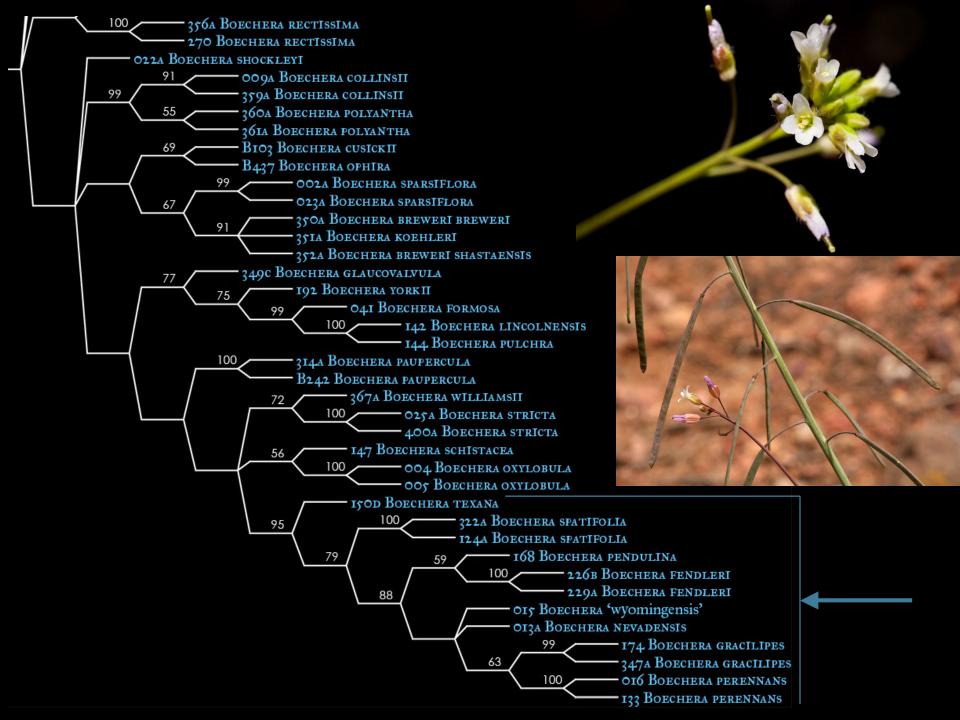
089 PHOENICAULIS CHEIRANTHOIDES - 086 Boechera davidsonii OO2A BOECHERA CRANDALLII · 306a Boechera evadens 007a Boechera Fernaldiana - 2124 Boechera Lemmonii - 118a Boechera pendulocarpa 100 - 24.2 A Boechera pendulocarpa 120 Boechera cobrensis 4018 Boechera pygmaea - 312A BOECHERA HOWELLII 017a Boechera platysperma - 213 Boechera 'kelseyana' B225 Boechera thompsonii 069 Boechera thompsonii 221A BOECHERA THOMPSONII 180 Boechera VIllosa - 1268 Boechera Johnstonii 225a Boechera parishii 255A BOECHERA DISPAR 93 170 Boechera retrofracta OIOA BOECHERA LASIOCARPA 187 Boechera serpenticola 358a Boechera serpenticola 148 Boechera subpinnatifida O18a Boechera puberula 167 Boechera puberula 028 Boechera vivariensis - 211A BOECHERA ROLLEI 027 Boechera suffrutescens 353a Boechera constancei 254A BOECHERA ARCUATA 256a Boechera rectissima - 270 Boechera rectissima O22A BOECHERA SHOCKLEYI OO9A BOECHERA COLLINSII 3594 Boechera collinsii 260a Boechera polyantha 261a Boechera polyantha B103 BOECHERA CUSICKII B437 Boechera ophīra 002a Boechera sparsiflora 023a Boechera sparsiflora 250a Boechera breweri breweri 3514 Boechera koehleri 252A BOECHERA BREWERI SHASTAENSIS 349c Boechera Glaucovalvula 192 Boechera yorkii - 04.1 Boechera formosa 142 Boechera Lincolnensis - 144. Boechera pulchra 214A BOECHERA PAUPERCULA B242 Boechera Paupercula 367a Boechera Williamsii - 025a Boechera stricta 400a Boechera stricta 147 Boechera schistacea -004 Boechera oxylobula - 00° Boechera oxylobula 1500 Boechera texana 222a Boechera spatifolia 124A BOECHERA SPATIFOLIA 168 Boechera pendulina 226B Boechera Fendleri - 2294 Boechera Fendleri OIS BOECHERA 'wyomingensis' O13A BOECHERA NEVADENSIS - 174 Boechera gracilipes 347A Boechera gracilipes 016 Boechera perennans 122 Boechera perennans

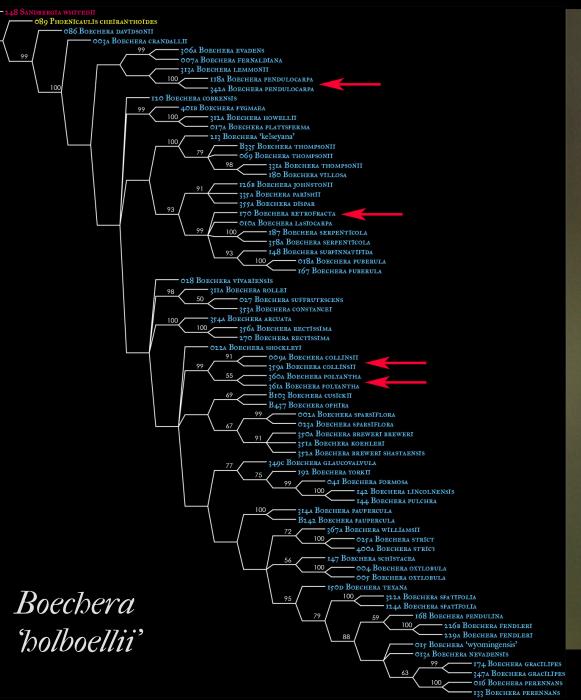
Main Boechera clade







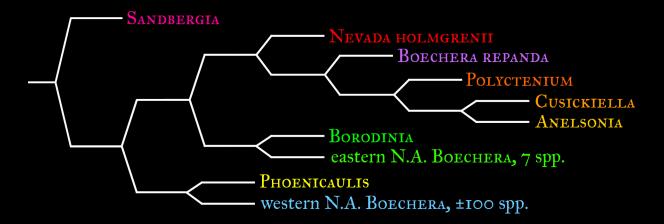






Conclusions

• Relationships within Boechereae are as follows:



- eastern North American *Boechera* should be united with *Borodinia*;
- Boechera repanda requires a new genus.
- A number of small clades are highly supported within the remaining, predominately western North American, *Boechera* clade, but deeper nodes are not supported.



