

Supplement of Foss. Rec., 20, 201–213, 2017
<https://doi.org/10.5194/fr-20-201-2017-supplement>
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Fossil Record museum für
naturkunde
Open Access berlin

Supplement of

A Burmese amber fossil of *Radula* (Porellales, Jungermanniopsida) provides insights into the Cretaceous evolution of epiphytic lineages of leafy liverworts

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Table S1. Taxa used in this study with their corresponding GenBank accession numbers.

Taxon	Isolate	<i>atpB-rbcL</i>	<i>psbT-psbH</i>	<i>psbA-trnH</i>	<i>rps4</i>	<i>trnG</i>	<i>trnL-F</i>
<i>Frullania</i> sp.	L1535	KF852046	JF513426	AY507480	AY507439	-	-
<i>Lejeunea tuberculosa</i>	E24	KF852094	KF852247	KF851964	KF851488	-	-
<i>Lepidolaena clavigera</i>	IBC39	KF851996	JF513410	JF513394	JF513472	-	-
<i>Porella navicularis</i>	IBC163	KF852000	KF852118	KF851826		-	-
<i>Radula acuminata</i>	ND_227	HM992384	HM992127	HM992463	HM992295	HM992034	HM992208
<i>Radula acuta</i>	NSW890194	KF495334		KX827524	KX827553	KF495272	KF495393
<i>Radula acutiloba</i>	NSW976716	KM220231		KX827544	KX827585	KM220093	KM220162
<i>Radula allisonii</i>	NSW896403	KF495342			KX827557	KF495280	KF495397
<i>Radula aneurismalis</i>	ND_126	HM992358	HM992100	-	HM992269	HM992007	-
<i>Radula ankefinensis</i>	ND_222	HM992382	HM992125	HM992461	HM992293	HM992032	HM992207
<i>Radula antilleana</i>	ND_088	HM992343	HM992085	HM992429	HM992254	HM991992	HM992175
<i>Radula apiculata</i>	ND_339	-	HM992143	HM992478	HM992311	HM992050	-
<i>Radula appressa</i>	ND_229	HM992386	HM992129	HM992465	HM992297	HM992036	HM992209
<i>Radula aquilegia</i>	ND_078	HM992341	HM992083	HM992427	HM992252	HM991990	HM992173
<i>Radula australiana</i>	ND_119	HM992356	HM992098	HM992442	HM992267	HM992005	HM992183
<i>Radula australis</i>	ND_299	HM992395	HM992138	HM992473	HM992306	HM992045	HM992217
<i>Radula boryana</i>	ND_178	HM992375	HM992117	-	HM992285	HM992024	HM992200
<i>Radula brunnea</i>	ND_001	HM992315	HM992054	HM992403	-	HM991961	HM992147
<i>Radula buccinifera</i>	ND_127	HM992359	HM992101	HM992444	HM992270	HM992008	HM992185
<i>Radula campanigera</i>	ND_042	HM992330	HM992070	-	HM992239	HM991977	HM992160
<i>Radula carringtonii</i>	ND_018	HM992323	HM992062	HM992409	HM992231	HM991969	HM992153
<i>Radula complanata</i>	ND_311	HM992396	HM992139	HM992474	HM992307	HM992046	HM992218
<i>Radula constricta</i>	ND_004	HM992317	HM992056	-	HM992225	HM991963	-
<i>Radula cubensis</i>	ND_068	HM992337	HM992078	HM992422	HM992247	HM991985	HM992168

<i>Radula cuspidata</i>	ND_111	HM992353	HM992095	HM992439	HM992264	HM992002	-
<i>Radula decora</i>	ND_026	HM992327	HM992066	HM992413	HM992235	HM991973	-
<i>Radula demissa</i>	ND_053	HM992332	HM992072	HM992417	HM992241	HM991979	HM992162
<i>Radula eggersii</i>	ND_058	HM992334	HM992075	HM992420	HM992244	HM991982	HM992165
<i>Radula episcia</i>	ND_148	HM992366	HM992108	HM992449	HM992277	HM992015	HM992191
<i>Radula fendleri</i>	ND_074	HM992339	HM992080	HM992424	HM992249	HM991987	HM992170
<i>Radula floridana</i>	ND_323	HM992379	HM992122	HM992458	HM992290	HM992029	HM992204
<i>Radula forficata</i>	NSW878032	KF440561	KX827458		KX827552	KF440626	KF440490
<i>Radula formosa</i>	NSW979086	KX827519	KX827487	KX827545	KX827586	KX827496	KX827508
<i>Radula frondescens</i>	ND_091	HM992345	HM992087	HM992431	HM992256	HM991994	HM992177
<i>Radula fulvifolia</i>	ND_215	HM992379	HM992122	HM992458	HM992290	HM992029	HM992204
<i>Radula gottscheana</i>	ND_060	HM992335	HM992076	-	HM992245	HM991983	HM992166
<i>Radula grandis</i>	ND_212	-	HM992121	HM992457	HM992289	HM992028	HM992203
<i>Radula hicksiae</i>	ND_120	HM992357	HM992099	HM992443	HM992268	HM992006	HM992184
<i>Radula holtii</i>	ND_281	HM992394	HM992137	HM992472	HM992305	HM992044	HM992216
<i>Radula husnotii</i>	ND_015	HM992322	HM992061	HM992408	HM992230	HM991968	HM992152
<i>Radula imposita</i>	NSW875821	KF432252	KX827456	KX827523	KX827550	KF432338	KF440419
<i>Radula inflexa</i>	ND_039	-	HM992069	-	HM992238	HM991976	HM992159
<i>Radula iwatsukii</i>	ND_076	-	HM992082	HM992426	HM992251	HM991989	HM992172
<i>Radula japonica</i>	ND_353	HM992402	HM992146	HM992481	HM992314	HM992053	HM992223
<i>Radula javanica</i> I	AK323599	KM220207	KX827454	KX827521	KX827547	KM220070	KM220137
<i>Radula javanica</i> II	ND_220	HM992381	HM992124	HM992460	HM992292	HM992031	HM992206
<i>Radula jonesii</i>	ND_267	HM992393	HM992136	-	HM992304	HM992043	-
<i>Radula jovetiana</i>	NSW896752	KF440596	KX827463	KX827529	KX827560	KF440660	KF440530
<i>Radula kegelii</i>	ND_012	HM992320	HM992059	HM992406	HM992228	HM991966	HM992150
<i>Radula kojana</i>	ND_137	HM992364	HM992106	HM992447	HM992275	HM992013	-
<i>Radula lindenbergiana</i>	ND_063	HM992336	HM992077	HM992421	HM992246	HM991984	HM992167

<i>Radula loriana</i>	NSW970882	KF440604	KX827474	KX827538	KX827573	KF440668	KF440538
<i>Radula macrostachya</i>	ND_007	HM992318	HM992057	HM992404	HM992226	HM991964	HM992148
<i>Radula madagascariensis</i>	ND_232	HM992387	HM992130	HM992466	HM992298	HM992037	HM992210
<i>Radula marojezica</i>	ND_233	HM992388	HM992131	HM992467	HM992299	HM992038	HM992211
<i>Radula mazarunensis</i>	ND_081	HM992342	HM992084	HM992428	HM992253	HM991991	HM992174
<i>Radula mittenii</i>	NSW897201	KF432391	KX827467	KX827533	KX827565	KF432391	KF440473
<i>Radula multiamentula</i>	ND_108	HM992352	HM992094	HM992438	HM992263	HM992001	HM992182
<i>Radula myriopoda</i>	NSW970376	KF440611	KX827471	KX827536	KX827570	KF440675	KF440545
<i>Radula neotropica</i>	ND_160	HM992371	HM992113	HM992452	HM992281	HM992020	HM992196
<i>Radula notabilis</i>	NSW909500	KF432293	KX827469	KX827535	KX827568	KF432378	KF440458
<i>Radula novae-hollandiae</i>	NSW896816	KF495348		KX827530	KX827561	KF495286	KF495403
<i>Radula nudicaulis</i>	ND_020	HM992325	HM992064	HM992411	HM992233	HM991971	HM992155
<i>Radula nymanii</i>	NSW898712	KF432310		KX827534	KX827566	KF432396	KF440478
<i>Radula obtusiloba subsp. polyclada</i>	ND_315	HM992378	HM992120	-	HM992288	HM992027	-
<i>Radula ocellata</i>	ND_116	HM992354	HM992096	HM992440	HM992265	HM992003	-
<i>Radula oreopsis</i>	NSW970377	KM220174	KX827472		KX827571	KM220042	KM220104
<i>Radula perrottetii</i>	ND_158	HM992369	HM992111	-	HM992279	HM992018	HM992194
<i>Radula physoloba</i>	ND_211	HM992378	HM992120	-	HM992288	HM992027	-
<i>Radula plicata</i>	ND_103	HM992351	HM992093	HM992437	HM992262	HM992000	-
<i>Radula plumosa</i>	ND_011	HM992319	HM992058	HM992405	HM992227	HM991965	HM992149
<i>Radula pocsii</i>	ND_150	HM992367	HM992109	HM992450	-	HM992016	HM992192
<i>Radula pseudoscripta</i>	NSW895495	KX827511	KX827459	KX827525	KX827554	KX827490	KX827499
<i>Radula psychosis</i>	NSW970878	KF440592	KX827473	KX827537	KX827572	KF440656	KF440526
<i>Radula pugioniformis</i>	NSW870344	MF346528	-	MF346529	-	MF346530	MF346531
<i>Radula pulchella</i>	ND_219	HM992380	HM992123	HM992459	HM992291	HM992030	HM992205
<i>Radula quadrata</i>	ND_225	HM992383	HM992126	HM992462	HM992294	HM992033	-

<i>Radula queenslandica</i>	ND_118	HM992355	HM992097	HM992441	HM992266	HM992004	-
<i>Radula ratkowskiana</i>	ND_102	HM992350	HM992092	HM992436	HM992261	HM991999	HM992181
<i>Radula recubans</i>	ND_092	HM992346	HM992088	HM992432	HM992257	HM991995	HM992178
<i>Radula retroflexa</i>	ND_228	HM992385	HM992128	HM992464	HM992296	HM992035	-
<i>Radula robinsonii</i>	NSW875795	KF440568	KX827455	KX827522	KX827548	KF440634	KF440501
<i>Radula saccatiloba</i>	ND_075	HM992340	HM992081	HM992425	HM992250	HM991988	HM992171
<i>Radula sainsburiana</i>	ND_098	HM992347	HM992089	HM992433	HM992258	HM991996	HM992179
<i>Radula scariosa</i>	NSW895626	KX827512	KX827460	KX827527	KX827556		KX827500
<i>Radula schaefer-verwimpii</i>	ND_019	HM992324	HM992063	HM992410	HM992232	HM991970	HM992154
<i>Radula</i> sp. I	ND_142	HM992365	HM992107	HM992448	HM992276	HM992014	HM992190
<i>Radula</i> sp. II	ND_234	HM992389	HM992132	HM992468	HM992300	HM992039	HM992212
<i>Radula</i> sp. III	ND_045	HM992331	HM992071	HM992416	HM992240	HM991978	HM992161
<i>Radula squarrosa</i>	NSW896832	KX827514	KX827464	KX827531	KX827562		KX827502
<i>Radula stenocalyx</i>	ND_235	HM992390	HM992133	HM992469	HM992301	HM992040	HM992213
<i>Radula strangulata</i>	ND_099	HM992348	HM992090	HM992434	HM992259	HM991997	HM992180
<i>Radula subinflata</i>	ND_030	HM992328	HM992067	HM992414	HM992236	HM991974	HM992157
<i>Radula sullivanii</i>	ND_321	-	HM992121	HM992457	HM992289	HM992028	HM992203
<i>Radula tasmanica</i>	ND_101	HM992349	HM992091	HM992435	HM992260	HM991998	-
<i>Radula tenax</i>	ND_129	HM992360	HM992102	-	HM992271	HM992009	HM992186
<i>Radula tenera</i>	ND_022	HM992326	HM992065	HM992412	HM992234	HM991972	HM992156
<i>Radula thiersiae</i>	NSW897007		KX827465		KX827563	KX827492	KX827503
<i>Radula tjibodensis</i>	ND_055	-	HM992073	HM992418	HM992242	HM991980	HM992163
<i>Radula tokiensis</i>	ND_003	HM992316	HM992055	-	HM992224	HM991962	-
<i>Radula voluta</i>	ND_014	HM992321	HM992060	HM992407	HM992229	HM991967	HM992151
<i>Radula weymouthiana</i>	NSW895586	KF495340		KX827526	KX827555	KF495278	KF495396
<i>Radula wichurae</i>	ND_057	HM992333	HM992074	HM992419	HM992243	HM991981	HM992164

Table S2. Coding matrix used for the ancestral character state reconstruction.

Taxa	Lobule insertion	Leaf apex	Gemmae	Female bract pairs
	0=transverse	0=round	0=absent	0=1
	1=longitudinal	1=acute	1=present	1=2
<i>Porella navicularis</i>	0	0	0	0
<i>R. acuminata</i>	1	0	1	0
<i>R. acuta</i>	1	1	1	1
<i>R. acutiloba</i>	1	0	1	0
<i>R. allisonii</i>	1	0	0	0
<i>R. aneurismalis</i>	1	0	0	0
<i>R. ankefinensis</i>	1	0	0	0
<i>R. antilleana</i>	1	0	0	0
<i>R. apiculata</i>	1	1	0	1
<i>R. appressa</i>	1	0	0	0
<i>R. aquilegia</i>	1	0	0	0
<i>R. australiana</i>	1	0	0	0
<i>R. australis</i>	1	0	0	0
<i>R. boryana</i>	0	0	0	0
<i>R. brunnea</i>	0	0	0	0
<i>R. buccinifera</i>	1	0	0	0
<i>R. campanigera</i>	0	0	0	0
<i>R. carringtonii</i>	1	0	0	0
<i>R. complanata</i>	1	0	1	0
<i>R. constricta</i>	1	0	1	0
<i>R. cubensis</i>	1	0	0	0
<i>R. cuspidata</i>	1	1	0	1
<i>R. decora</i>	1	0	0	0

<i>R. demissa</i>	1	0	0	0
<i>R. eggersii</i>	1	0	0	0
<i>R. episcia</i>	1	0	0	0
<i>R. fendleri</i>	1	0	0	0
<i>R. floridana</i>	1	0	0	0
<i>R. forficata</i>	1	0	0	0
<i>R. formosa</i>	1	0	0	0
<i>R. frondescens</i>	1	0	0	0
<i>R. fulvifolia</i>	1	0	0	0
<i>R. gottscheana</i>	0	0	0	0
<i>R. grandis</i>	1	0	1	0
<i>R. hicksiae</i>	1	0	0	0
<i>R. holtii</i>	1	0	0	0
<i>R. husnoti</i>	1	0	0	0
<i>R. imposita</i>	1	0	0	0
<i>R. inflexa</i>	1	0	0	0
<i>R. iwatsukii</i>	1	0	0	0
<i>R. japonica</i>	1	0	0	0
<i>R. javanica I</i>	1	0	0	0
<i>R. javanica II</i>	1	0	0	0
<i>R. jonesii</i>	1	0	0	0
<i>R. jovetiana</i>	1	0	0	0
<i>R. kegelii</i>	1	0	0	0
<i>R. kojana</i>	1	1	1	1
<i>R. lindenbergiana</i>	1	0	1	0
<i>R. loriana</i>	1	0	0	0
<i>R. macrostachya</i>	1	0	0	0

<i>R. madagascariensis</i>	1	0	0	0
<i>R. marojezica</i>	1	0	0	0
<i>R. mazarunensis</i>	1	0	0	0
<i>R. mittenii</i>	1	0	0	0
<i>R. multiamentula</i>	1	0	0	0
<i>R. myriopoda</i>	1	0	0	0
<i>R. neotropica</i>	1	0	0	0
<i>R. notabilis</i>	1	0	0	0
<i>R. novaehollandiae</i>	1	1	1	1
<i>R. nudicaulis</i>	1	0	0	0
<i>R. nymanii</i>	1	0	1	0
<i>R. obtusiloba</i> subsp. <i>polyclada</i>	1	0	0	0
<i>R. ocellata</i>	1	1	0	0
<i>R. oreopsis</i>	1	0	0	0
<i>R. physoloba</i>	1	0	0	0
<i>R. plicata</i>	1	0	0	0
<i>R. plumosa</i>	1	0	0	0
<i>R. pocsii</i>	1	0	0	0
<i>R. pseudoscripta</i>	1	0	0	0
<i>R. psychosis</i>	1	0	0	0
<i>R. pugioniformis</i>	1	0	0	1
<i>R. pulchella</i>	1	1	0	0
<i>R. quadrata</i>	1	0	0	0
<i>R. queenslandica</i>	1	1	0	0
<i>R. ratkowskiana</i>	1	0	0	0
<i>R. recubans</i>	1	0	0	0
<i>R. retroflexa</i>	1	0	0	0

<i>R. robinsonii</i>	1	0	0	0
<i>R. rottetii</i>	0	0	0	0
<i>R. saccatiloba</i>	1	0	0	0
<i>R. sainsburiana</i>	1	0	0	0
<i>R. scariosa</i>	1	0	0	0
<i>R. schaefer-verwimpii</i>	1	0	0	0
<i>R. sp. I</i>	1	0	0	0
<i>R. sp. II</i>	1	0	0	0
<i>R. sp. III</i>	1	0	0	0
<i>R. spicata</i>	1	0	0	0
<i>R. squarrosa</i>	1	0	0	0
<i>R. stenocalyx</i>	1	0	1	0
<i>R. strangulata</i>	1	0	0	0
<i>R. subinflata</i>	1	0	0	0
<i>R. sullivantii</i>	1	0	0	0
<i>R. tasmanica</i>	1	0	0	0
<i>R. tenax</i>	0	0	0	0
<i>R. tenera</i>	1	0	0	0
<i>R. thiersiae</i>	1	0	0	0
<i>R. tjibodensis</i>	1	0	1	0
<i>R. tokiensis</i>	1	0	0	0
<i>R. voluta</i>	1	0	1	0
<i>R. weymouthiana</i>	1	0	0	0
<i>R. wichurae</i>	1	0	0	0

Table S3. Summary of molecular dating studies including *Radula*.

Reference	Study system	Stem age estimates of <i>Radula</i> in Ma [95%HPD]	Calibration approach	Program used: BEAST (Drummond et al., 2012), r8s (Sanderson, 2003)
Heinrichs et al. (2007)	Dataset I: liverworts (Marchantiophyta)		<ul style="list-style-type: none"> – minimum age constraints: 8 fossil calibrations – fixed age constraint: earliest split of vascular plants (430 Ma) – maximum age constraint: oldest fossil of land plants (475 Ma) 	penalized likelihood r8s
	Dataset II: leafy liverworts (Jungermanniopsida)	179.4 (“139.4”, typing error) ± 13.1 (MAX) 185.9 ± 12.1 (MIN)	<ul style="list-style-type: none"> – minimum age constraints: 10 fossil calibrations split Metzgeriidae and Jungermanniidae obtained in dataset I – minimum (MIN) and maximum (MAX) borders of confidence intervals (obtained with dataset I) used to calibrate split Metzgeriidae and Jungermanniidae 	
Fiz-Palacios et al. (2011)	Land plants	230 [not given]	<ul style="list-style-type: none"> – minimum constraint: age of eudicots, tricolpate pollen gain (121 Ma) – 16 additional minimum age constraints – maximum age for root of tree (725 Ma) 	penalized likelihood r8s
Cooper et al. (2012)	Liverworts (Marchantiophyta)	247 [204-285]	<ul style="list-style-type: none"> – 9 fossil calibrations following Heinrichs et al. (2007) using a uniform distribution with minimum age of fossil and maximum age of root (475 Ma) – maximum age constraint on root: normal distribution, mean of 475 Ma (SD 12.5 Ma) 	uncorrelated relaxed clock, BEAST
Feldberg et al. (2014)	Liverworts (Marchantiophyta)	264.76 [not given]	<ul style="list-style-type: none"> – 20 fossil calibrations: uniform distribution with minimum age of fossil and maximum age of root (475 Ma) 	uncorrelated relaxed clock, BEAST

			– maximum age constraint: liverworts, oldest known cryptospores (475 Ma)	
Laenen <i>et al.</i> (2014)	Liverworts (Marchantiophyta)	97.34 [52.55-150.94] (I) 98.33 [47.3-174.6] (II) 122.44 [51.56-200.22] (III)	25 fossil calibrations: log-normal distribution using 3 different approaches: (I) timespan of the geological era attributed to the fossil (II) fossil age to age of oldest non-ambiguous fossil of land plants (475 Ma) (III) fossil age to upper limit of most ancient inferred estimate of the origin of land plants (815 Ma)	uncorrelated relaxed clock, BEAST
Patino <i>et al.</i> (2017)	<i>Radula</i>	175 [not given]	nucleotide substitution rate based on Laenen <i>et al.</i> (2014) using log-uniform prior distribution: 5.273×10^{-4} (SD 6.463×10^{-6}) subst./site/My	uncorrelated relaxed clock, BEAST