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1 Latest Triassic onset of the Central Atlantic Magmatic Province (CAMP) volcanism in
2 the Fundy Basin (Nova Scotia): new stratigraphic constraints

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24 **Abstract**

25 In this paper we investigate the stratigraphic relationship between the emplacement of the
26 CAMP basalts and the Triassic-Jurassic (Tr-J) boundary in the Fundy basin (Nova Scotia,

27 Canada), one of the best exposed synrift basins of eastern North America (ENA) formed
28 as a consequence of the rifting that led to the formation of the Atlantic Ocean. The
29 Triassic palynological assemblages found in the sedimentary rocks below (uppermost
30 Blomindon Formation) and just above the North Mountain Basalt (Scots Bay Member)
31 indicate that CAMP volcanism, at least in Nova Scotia, is entirely of Triassic age,
32 occurred in a very short time span, and may have triggered the T-J boundary biotic and
33 environmental crisis. The palynological assemblage from the Blomindon Formation is
34 characterised by the dominance of the Circumpolles group (i.e. *Gliscopollis meyeriana*,
35 *Corollina murphyae*, *Classopollis torosus*) which crosses the previously established Tr-J
36 boundary. The Triassic species *Patinasporites densus* disappears several centimetres
37 before the base of the North Mountain basalt, near the previously interpreted Tr-J
38 boundary. The lower strata of the Scots Bay Member yielded a palynological assemblage
39 dominated by Triassic bisaccate pollens (e.g. *Lunatisporites acutus*, *L. rhaeticus*
40 *Lueckisporites* sp., *Alisporites parvus*) with minor specimens of the Circumpolles group.
41 Examination of the state of preservation and thermal alteration of organic matter
42 associated with the microfloral assemblages precludes the possibility of recycling of the
43 Triassic sporomorphs from the older strata. Our data argue against the previously
44 definition of the Tr-J boundary in the ENA basins, based mainly on the last occurrence of
45 *P. densus*. Consequently, it follows that the late Triassic magnetostratigraphic
46 correlations should be revised considering that chron E23r, which is correlated with the
47 last occurrence of *P. densus* in the Newark basin, does not occur at the Tr-J boundary but
48 marks rather a late Triassic (probably Rhaetian) reversal.

49

50 Keywords: CAMP, ENA synrift basins, Nova Scotia, palynology, organic matter,
51 Triassic-Jurassic boundary

52

53 **1. Introduction**

54 The Triassic-Jurassic (Tr-J) boundary, most recently dated by U/Pb 201.6 +/- 0.3 Ma
55 (Schaltegger et al., 2008) is characterized by the well known end-Triassic extinction,
56 (Sepkoski, 1996; Hallam, 2002; Tanner et al., 2004). According to several authors, the
57 severity of the Tr-J event at the genus and family level is higher than for the end-
58 Cretaceous extinction, and second only to the end-Permian extinction. Other authors,
59 however, have documented that this extinction is characterized by a progressive, and
60 possibly punctuated, reduction of diversity from the Late Triassic to the Early Jurassic
61 (Hallam, 2002; Tanner et al., 2004; Lucas and Tanner, 2007). Notably, the record of
62 turnover among continental flora remains unclear (Hallam, 2002). For example, in most
63 of the European domain, the Tr-J boundary seems to be characterized by only a minor
64 extinction/turnover of the macroflora and microflora, against a background of more
65 gradual change (e.g. Schuurman, 1979; Hallam, 2002; Warrington, 2002; Tanner et al.,
66 2004; Lucas and Tanner, 2007, 2008; Traverse, 2008). In contrast, an abrupt floral
67 change has been documented for eastern North America (ENA) and Greenland (Fowell
68 and Olsen, 1993; Fowell et al., 1994; Fowell and Traverse, 1995; McElwain et al., 1999;
69 2007; Olsen et al., 2002; Whiteside et al., 2007). A marked negative carbon isotope
70 ($\delta^{13}\text{C}$) anomaly in both carbonate and sedimentary organic matter (OM) observed in
71 marine and terrestrial Tr-J boundary strata, e.g. from Hungary, Canada, Spain, Italy,
72 Austria, and England (Pálfy et al., 2001; Hesselbo et al., 2002; Guex et al., 2004; Ward et
73 al., 2004; Gomez et al., 2007; Kuerschner et al., 2007; Williford et al., 2007).
74 Additionally, an apparently synchronous decrease of the stomatal index of fossil leaves
75 (McElwain et al., 1999) has suggested a disruption of the global carbon cycle, potentially
76 involving some combination of global warming, productivity decline and methane

77 hydrate release (Pálffy et al., 2001; Tanner et al., 2004; Ward et al., 2004; Lucas and
78 Tanner, 2008).

79 In summary, there is a general consensus that a biotic and environmental
80 perturbation occurred during the latest Triassic and spanned the Tr-J boundary (Tanner et
81 al., 2004; Lucas and Tanner, 2008). Some of the forcing mechanisms that have been
82 invoked to explain this disruption of the ecosystem include: (1) rapid sea-level change
83 and/or anoxia (Hallam and Wignall, 1999); (2) bolide impact (Olsen et al., 2002; Ward et
84 al., 2004); and (3) atmospheric loading by CO₂ and SO₂ related to eruptions of the
85 Central Atlantic Magmatic Province (CAMP), which potentially caused atmospheric
86 warming of up to 3-4 °C or acidic atmospheric pollution (Marzoli et al., 1999, 2004;
87 McElwain et al., 1999; Hesselbo et al., 2002; Guex et al., 2004; Knight et al., 2004;
88 Cohen and Coe, 2007; Tanner et al., 2007; Schaltegger et al., 2008; Van de Schootbrugge
89 et al., 2008).

90 Emplacement of the voluminous tholeiitic dikes, sills, and flood basalts of CAMP
91 occurred in North and South America, Africa and Europe over a total surface area
92 potentially in excess of 10 million km² (Marzoli et al. 1999, 2004; Olsen et al., 2003;
93 Verati et al., 2007) (Fig.1). The available ⁴⁰Ar/³⁹Ar plateau ages for the basalts suggest
94 brief durations (< 1 Ma) of peak eruptive activity at specific locations (Deckart et al.,
95 1997; Marzoli et al., 1999; 2004; Knight et al., 2004; Nomade et al., 2007; Verati et al.,
96 2007), although the main interval of emplacement across the entire CAMP may have had
97 a duration of 2 ± 1 Ma centered at ca. 199 Ma (Jourdan et al., in press). These ⁴⁰Ar/³⁹Ar
98 ages conform to the U-Pb age of the Tr-J boundary (201.6 ± 0.3 Ma, single zircon;
99 Schaltegger et al., 2008) considering the well established ca. 1% bias between the two
100 isotopic dating methods (Min et al., 2000; Kuiper et al., 2008). However, taking into
101 account analytical and intercalibration uncertainties, as well as the short duration of the

102 eruptive events, the published radio-isotopic ages indicate proximity, but cannot
103 ultimately define the relative timing of CAMP volcanism and the Tr-J boundary crisis.
104 Therefore, correlation of the biotic turnover from the marine realm, where the boundary
105 is defined by ammonites (Guex et al., 2004) with the continental CAMP volcanism is
106 required. Various analytical methods have been applied, including palynology,
107 magnetostratigraphy and geochemistry. However, multidisciplinary studies applied to the
108 North American and African Tr-J sediments and interlayered CAMP basaltic flows have
109 produced contrasting interpretations.

110 Since the 1970s the palynological Tr-J boundary in the ENA continental rift-
111 basins has been placed in the strata immediately beneath the lowest CAMP basalt flow
112 (e.g. the Orange Mt. Basalt in the Newark basin). Thus, all the strata overlying and
113 interlayered with the CAMP lava flows were assigned to the Jurassic. This boundary is
114 defined, according to both older and more recent studies (e.g. Cornet and Traverse, 1975;
115 Cornet and Olsen, 1985; Fowell and Olsen, 1993; Fowell et al., 1994; Fowell and
116 Traverse, 1995; Whiteside et al., 2007), by a marked palynological turnover event
117 recognized on the basis of the following: (1) some last appearances of certain species
118 (*Ovalipollis ovalis*, *Vallasporites ignacii*, and *Patinasporites densus*); (2) an increase in
119 *Corollina* spp. (= *Classopollis* and *Gliscopollis*) percentage; (3) and a bloom of trilete
120 spores (fern spike), considered as the expression of a renewed palynoflora after the Tr-J
121 mass extinction. These palynostratigraphic criteria for placing the Tr-J boundary have
122 been criticised (Gradstein et al., 1994; van Veen, 1995; Lucas and Tanner, 2007) because
123 locally (e.g., the European domain) the disappearance of the vesiculate forms (i.e. *V.*
124 *ignacii*, and *P. densus*) took place during the late Norian and occasionally early Rhaetian
125 (e.g., Morbey, 1978; Schuurman, 1979; Krystyn et al., 2007; Kuerschner et al, 2007).
126 Notably, Kozur and Weems (2005), relying on conchostracan assemblages from the

127 Culpeper and Newark basins, concluded that the Tr-J boundary in the Newark
128 Supergroup must occur above the lowest CAMP basalt.

129 In the Newark and Fundy basins, the putative Tr-J boundary is also characterized
130 by a moderate Ir anomaly, the origin of which is disputed (Olsen et al., 2002; Tanner and
131 Kyte, 2005; Tanner et al., 2008); more importantly, the Ir anomaly is immediately
132 preceded by a magnetic reversal (chron E23r; Olsen et al., 2002). Indeed, the most
133 complete Late Triassic to earliest Jurassic magnetic polarity time scale has been
134 calibrated on the non-marine section of the Newark basin (e.g. Kent and Olsen, 1999),
135 which is anchored to the palynologically defined Tr-J boundary (see Lucas and Tanner,
136 2007 for an historical review), and thus represents a potentially powerful tool for global
137 correlations. The E23r reversal has been correlated by Whiteside et al. (2007) to one of
138 the brief reversals (chrons SA5n.3r and SA5r) of the marine St. Audrie's Bay section
139 (England), which corresponds to the Tr-J boundary in the upper part of the Penarth Group
140 (Hounslow et al., 2004). Recently, Gallet et al. (2007) noticed discrepancies between the
141 Newark magnetostratigraphy and that of the Tethyan realm (e.g., the Oyuklu section of
142 south-western Turkey), which suggests either a higher position of the Norian-Rhaetian
143 boundary and/or a lack of the lowermost part of the Rhaetian in the Newark sequence.

144 The cyclostratigraphy of the Newark basin suggests that the onset of CAMP
145 volcanism postdated the Tr-J boundary by 20-40 ky and that the entire basalt pile was
146 erupted in the Early Jurassic during normal polarity chron E24n (Kent and Olsen, 1999,
147 2008; Olsen et al., 2003). The next reversal, chron E24r, occurred about 1.6 Ma after the
148 supposed Tr-J boundary, and above the youngest CAMP lava flow (Hampden Basalt), as
149 recorded in the Hartford basin (Kent and Olsen, 2008). This reversal tentatively has been
150 correlated with reversals detected in Jurassic strata from the Paris basin, France (Yang et
151 al., 1996).

152 In contrast to the interpretation that all CAMP volcanism postdated the Tr-J
153 boundary, multidisciplinary data suggest a latest Triassic onset of the volcanism in
154 Morocco (Knight et al., 2004; Marzoli et al., 2004). This conclusion is based on: (1)
155 evidence that the first lava flows erupted were synchronous with sediments bearing a
156 Triassic palynological assemblage dominated by *P. densus*, *C. murphyae*, *G. meyeriana*
157 and *C. torosus*; (2) the presence of a paleomagnetic reversal within the lava pile (i.e.
158 approximately halfway between the base and top) that has been correlated with the Tr-J
159 boundary reversal from the marine St. Audrie's Bay section, and possibly with chron
160 E23r from the Newark basin; (3) geochemical correlations of the basalts between basins,
161 suggesting that CAMP volcanism started slightly earlier in Morocco than in the Newark
162 basin. However, the data for the Moroccan CAMP have been questioned (Whiteside et
163 al., 2007, 2008; *contra* Marzoli et al., 2008), which means that the relationship between
164 the age of CAMP volcanism and the Tr-J boundary remains an unresolved question. This
165 problem mainly results from the absence of a generally accepted chronostratigraphic
166 definition of the Tr-J boundary, the disputed biostratigraphic value of the palynological
167 assemblages, and the lack of a well constrained age for the sediments interlayered with or
168 covering the CAMP lava flows.

169

170 2. Study Area

171 In this paper we investigate the relationship between the emplacement of the CAMP
172 basalts and the Tr-J boundary in the Fundy basin (Nova Scotia, Canada), one of the best
173 exposed ENA synrift basins,. These basins, collectively referred to as the Newark
174 Supergroup, are more or less continuously exposed on the east coast of North America,
175 from Nova Scotia to South Carolina (Tollo and Gottfried, 1992; Olsen and Schlische,

176 1990; Olsen et al., 2003; Whiteside et al., 2007). Formational nomenclature and the
177 group-level stratigraphy used in this paper are after Weems and Olsen (1997) (Fig.2).

178 The Fundy basin, which was located at 24° N palaeolatitude at the close of the
179 Triassic (Kent and Tauxe, 2005), is the northernmost of the Mesozoic rift basins of ENA
180 (Fig.3d), and its sedimentary and volcanic sequence is well exposed on the shores of the
181 Bay of Fundy in western Nova Scotia and eastern New Brunswick. The Fundy Basin,
182 including the Minas, Fundy, and Chignecto structural sub-basins (Olsen and Schlische,
183 1990), consists of a thick siliciclastic succession, of which about 1 km of fluvial,
184 lacustrine and eolian sediments crops out in Nova Scotia and New Brunswick, and 4 km
185 are submerged beneath the Bay of Fundy (Olsen et al., 2005). The Blomidon Formation
186 of the Fundy Group, which is assigned to the middle-late Norian and possibly Rhaetian
187 on the basis of magneto-cyclostratigraphy (Kent and Olsen, 2000; Olsen et al., 2005),
188 comprises 200-300 m of cyclically interbedded sandstone and mudstone of mostly
189 lacustrine, playa, eolian and fluvial origin deposited during an interval of semi-arid to
190 arid climate (Tanner, 2000; Tanner and Kyte, 2005). The uppermost Blomidon Formation
191 (Partridge Island Member) contains the turnover event cited by Fowell and Traverse
192 (1995) as the Tr-J palynological boundary.

193 The Blomidon Formation is overlain by the tholeiitic North Mountain Basalt,
194 which is overlain in turn by the McCoy Brook Formation. The North Mountain Basalt
195 (about 400 m thick) crops out on the north and south shores of the Minas Basin, along the
196 western coast of Nova Scotia and on Grand Manan Island (New Brunswick). It is
197 subdivided into three lava flow units, which are distinguished in the field by
198 volcanological features (Papezik et al., 1988; Kontak, 2008). The lowermost unit, the
199 East Ferry Member, is composed of a single massive basalt flow up to 180 m thick,
200 which in its upper part locally contains sheets ($\leq 1-2$ m) of coarse-grained mafic

201 pegmatite and granophyre. The middle unit, the Margaretsville Member, is formed by up
202 to 16 individual inflated, pahoehoe-type flows, up to 10 m thick, that are heavily
203 vesiculated and altered. The uppermost unit, the Brier Island Member, consists of one to
204 two massive basalt lava flows that are similar to the lowermost flow unit. Significant
205 sedimentary intercalations are absent between the lava units or flows, although flow tops
206 commonly are oxidized, suggesting only brief hiatuses between volcanic events. U/Pb
207 and $^{40}\text{Ar}/^{39}\text{Ar}$ ages are available for the North Mountain Basalt. A single-zircon U/Pb age
208 of 201.3 ± 0.3 Ma was obtained on a granophyric matrix in a mafic pegmatite sheet in
209 the upper part of the East Ferry Member (Schoene et al., 2006). $^{40}\text{Ar}/^{39}\text{Ar}$ plateau ages on
210 plagioclase from lower and upper unit lava flows range from 198.6 ± 1.1 to 201.0 ± 1.4
211 Ma (Jourdan et al., in press), supporting a duration of the peak eruptive event on the order
212 of, or shorter than ~ 1 Ma. These ages overlap with the U/Pb age of Schoene et al. (2006),
213 and with the U/Pb age of the Tr-J boundary (Schaltegger et al., 2008), if analytical and
214 intercalibration uncertainties are considered. Furthermore, the ages are indistinguishable
215 from high-quality isotopic ages for basalts from other areas of the northern CAMP (i.e.,
216 Morocco and the U.S.A. Knight et al., 2004; Marzoli et al., 2004; Nomade et al., 2007;
217 Verati et al., 2007). The North Mountain Basalt flows show broad geochemical
218 similarities with other CAMP basalts, but in detail the geochemical correlation with those
219 flows is not straightforward (Marzoli et al., 2008).

220 The McCoy Brook Formation is the youngest unit in the Fundy rift basin and is
221 mainly composed of red beds and abundant sand-rich fluvial deposits, gypsiferous sand
222 patch playa/lacustrine cycles and local eolian sandstones (De Wet and Hubert, 1989;
223 Tanner and Hubert, 1992; Tanner, 2000; Olsen et al., 2005). The basal member, the Scots
224 Bay Member, generally lies directly on the North Mountain basalt.

225

226 3. Previous Work

227 The entire sedimentary succession of the Fundy Basin has been dated mainly on
228 the basis of palynology (Bujak, 1977; Fowell and Traverse, 1995; Whiteside et al., 2007),
229 vertebrate fossils and cyclostratigraphic correlations with the Newark Supergroup (Olsen
230 et al., 2005 for references). Bujak (1977) located the Tr-J boundary within the McCoy
231 Brook Formation based on palynological data from the Chinampas N-37 well (Bay of
232 Fundy). Subsequently, new palynological data from the Minas sub-basin (at Partridge
233 Island) resulted in placement of the Tr-J boundary in the uppermost meter of the
234 Blomidon Formation (Fowell and Traverse, 1995; Whiteside et al., 2007), where the
235 palynological assemblage exhibits a transition from dominantly *Corollina torosa* and *P.*
236 *densus* to mainly *Corollina* spp. (*C. meyeriana*, *C. torosa*, *C. simplex*, *C. murphyae*).
237 Whiteside et al. (2007), on the basis of new palynological data, placed the Tr-J boundary
238 at less than 20 cm below the contact with the North Mountain Basalt (i.e. near the top of
239 the Blomidon Formation), between the bed that contains the highest occurrence of *P.*
240 *densus*, and the overlying sample, which lacks *P. densus* or abundant bisaccates. The
241 stratigraphic position of this presumed turnover is similar to that observed in the Newark
242 and Hartford basins (Fowell et al., 1994; Olsen et al., 2002).

243 As in the Newark basin (Kent and Olsen, 2000; Olsen et al., 2002), a moderate Ir
244 (maximum measured value > 400 pg/g) and PGE (Platinum Group elements) enrichment
245 occurs in multiple grey-coloured mudstone layers within the uppermost meter of the
246 Blomidon Formation in the Partridge Island section, which is roughly coincident with the
247 presumed palynological transition (Tanner and Kyte 2005; Tanner et al., 2008). In
248 contrast to the Newark basin, no magnetic reversal (equivalent to E23r) and no fern spike
249 (Kent and Olsen, 2000; Olsen et al., 2002), have been found in this section. The spike in
250 fern spores would be produced by *Clathropteris meniscoides*, which occurs in well-

251 preserved specimens in some localities of the Hartford basin (Cornet and Traverse, 1975).
252 In the Fundy basin, the only recorded *Clathropteris* has been found in the Scots Bay
253 Member, while the species *C. meniscoides* has not been reported (Olsen et al., 2005). The
254 McCoy Brook Formation contains a large variety of fossils which are mostly considered
255 to be of early Jurassic age (De Wet and Hubert, 1989; Shubin et al., 1994; Olsen et al.,
256 2005). Lucas and Tanner (2007) suggested that the Tr-J boundary in the Fundy Basin
257 occurs within the McCoy Brook Formation, based on the presence of only one CAMP
258 extrusive unit in the Fundy basin (compared to the three units present in the Newark and
259 Hartford basins).

260

261 **4. Research methods**

262 4.1 Lithostratigraphy of the sampled section

263 The section sampled at Partridge Island is a cliff face partially covered by
264 colluvium (Fig. 3a). The uppermost 1.0 m of the Blomidon Formation was exposed in a
265 trench and sampled at 5-10 cm intervals (Fig. 4a, 6). The lower part of the exposed
266 section consists of interbedded red and grey mudstones. The red mudstone is thinly to
267 medium bedded (2–15 cm thick) and composed mostly of hematite-stained clays and silt
268 to sand-size immature arenite grains. The coarser components consist mostly of quartz
269 and minor micas and feldspars. Grey mudstones are mostly thin-bedded (2–5 cm in
270 thickness) and contain a higher proportion of sand-size grains, including quartz and rock
271 fragments (igneous and metamorphic), intercalated with organic-rich dark clay beds.
272 Finely laminated mudstone containing dark organic-rich laminae interlayered with grey
273 to reddish laminae are also present in the lower part of the sampled section. The clay
274 fraction of the mudstones comprises mostly illite, smectite and chlorite, with lesser
275 amounts of kaolinite and mixed-layer clays and an abundance of chlorite in a greenish-

276 grey mudstone 20 cm below the contact with the base of the North Mountain Basalt, the
277 East Ferry Member (Tanner and Kyte, 2005).

278 At Scots Bay, the outcropping strata of the Scots Bay Member are in direct
279 stratigraphic contact with the Margaretsville Member of the North Mountain Basalt (the
280 Brier Island Member is not present here; Fig. 3b,c). The Scots Bay strata here consist of a
281 basal carbonate-rich sequence of two white, green, purple, and red lacustrine cycles. The
282 basal portion contains coarse immature sandstone with ostracod- and peloid-bearing
283 carbonate matrix. Clastic grains mostly consist of quartz, mottled carbonate mudstone,
284 siltstone and volcanic debris.

285

286 4.2 Sampling and analysis

287 Twelve samples were selected for organic matter (OM) analysis. Of these
288 samples, nine are from the uppermost Blomidon Formation beneath the North Mountain
289 Basalt (East Ferry Member) at the Partridge Island section (Fig.3a,d). The Tr-J boundary
290 identified at this location in earlier palynological studies (Fowell and Traverse, 1995;
291 Whiteside et al, 2007) was sampled in the interval represented by sample PI-30 (i.e., 30–
292 35 cm below the basalt Fig.4a). The three remaining samples are from the lower Scots
293 Bay Member, which overlies the North Mountain Basalt, and are from the section at
294 Scots Bay (Fig.3).These three samples were also analyzed for palynological assemblage
295 (Fig. 4, 5), palynofacies (Fig.6) and thermal maturity (see supporting online material, Fig.
296 S1, Fig. S2).

297

298 5. Results

299 5.1 Palynological assemblage

300 The palynological content of the sampled section at Partridge Island (Fig. 5) is

301 characterised by a dominance of Circumpolles group species, represented in order of
302 decreasing abundance by *G. meyeriana* (Fig. 5d,f), *C. murphyae* (Fig. 5l,m), *C. torosus*
303 (Fig. 5g, h, j, k), and *C. simplex* (in this paper, the generic name *Classopollis* is used
304 instead of *Corollina* or *Circulina*, as recently formally proposed by Traverse (2004), for
305 *Classopollis torosus*). The total abundance of the Circumpolles group varies slightly
306 through the section (Fig.4a). Generally, a lower abundance occurs in the most oxidized
307 beds (i.e. red mudstones), as demonstrated by the state of preservation of the palynofacies
308 (Fig. 6), which is mostly dominated by inertinite and strongly oxidized vitrinite. At these
309 low levels of preservation, degraded, oxidized, and badly preserved sporomorphs prevail
310 (i.e. PI-70, PI-5, PI-0). The low total content of Circumpolles also correlates with a low
311 total OM concentration, which is poorly preserved in oxidized beds.

312 As shown in the Fig.4a, Circumpolles cross the Tr-J boundary previously
313 established by previous workers (Fowell and Traverse, 1995; Whiteside et al., 2007)
314 without a marked decline in abundance. *P. densus* (Fig. 5a,b,c) is present from the base of
315 the sampled section at Partridge Island up to sample PI-45, which is near the presumed
316 Tr-J boundary. The percentage of this vesiculate pollen is rather low when compared with
317 the other sporomorphs, comprising at most 10%-15% of the association. Among
318 bisaccates, *Alisporites parvus* (Fig. 5p, r), *A. tenuicarpis*, *Ovalipollis septimus* and other
319 undetermined bisaccates are generally quite common, particularly *Alisporites*. The
320 bisaccates are absent in the 20-cm interval below the basalt, but are again present in the
321 Scots Bay Member above the North Mountain Basalt. Less common are *Calamospora*
322 *mesozoica* (Fig. 5n), *Conbaculatisporites mesozoicus* (Fig. 5e), *Porcellispora*
323 *longdonensis*, *Todisporites rotundiformis*, *Kraeuselisporites sp.*, *Carnisporites spiniger*
324 (Fig. 5q) and *Cycadopites sp.* (Fig. 5i), all of which are present in only a few samples.
325 Noteworthy is the presence of a group of trilete spores, such as *Converrucosisporites*

326 *cameroni* (Fig. 5o), *Dictyophyllidites harrisii* and *Dictyophyllidites* sp., and other trilete
327 spores below the presumed Tr-J boundary. In the other sections of the ENA basins, these
328 fern spores characterize the fern spike just above the palynological boundary that has
329 been interpreted as the floral turnover after mass-extinction.

330 Three samples of the Scots Bay Member (Fig. 4b) collected about 1 meter above
331 the top of the Margaretville member basalt flow (the Brier Island Member is not present
332 here) proved to be palynologically productive. Sample SB2 yielded the best preserved
333 and most significant assemblage. The three samples yielded a palynological assemblage
334 dominated by bisaccate pollens, e.g *Lunatisporites acutus* (Fig.5w), *L. rhaeticus* (Fig. 5t),
335 *Lueckisporites* sp., *A. parvus* (Fig.5s), *Klausipollenites* sp., *Platysaccus* sp. (Fig. 5u) and
336 other bisaccates in association with *C. mesozoica* and minor specimens of *G. meyeriana*,
337 *C. torosus* and other circumpolloid (Fig. 5x). In general, the Circumpolles group is less
338 abundant in the Scots Bay samples than in the Blomidon Formation samples.

339

340 5.2 Palynofacies

341 Palynofacies analysis addresses the potential for depositional and diagenetic
342 control of OM preservation in the vicinity of the previously interpreted Tr-J boundary;
343 i.e. rather than resulting from a catastrophic mass extinction event, is the observed
344 palynological turnover an artifact of preservation? The type and amount of organic debris
345 in the Blomidon Formation were measured quantitatively (Fig. 6). The lower total OM
346 content of the Scots Bay Member prevented a detailed quantitative analysis, although a
347 semi-quantitative estimation was possible. The palynofacies consist of terrestrial
348 elements with high concentrations of palynomacerals, including debris of higher plants
349 with minor amorphous organic matter (AOM). The type and amount of organic debris
350 show consistent variations through the Blomidon Formation (Fig. 6). Despite the

351 expected oxidizing conditions, the OM preservation and content are quite high, except in
352 several samples. The peak abundances of inertinite (Fig. 6a), occur in the lower and
353 upper parts of the sampled section (PI-10 and PI-70), coinciding with lower amounts of
354 AOM. Vitrinite, , varies slightly within the section, ranging from 25% to 50% of the OM
355 content.

356 Sporomorphs are present in varying abundances through the entire section, with
357 the exception of sample PI-10 (which was barren), a mottled limestone (Fig. 6b) just
358 above the previously interpreted Tr-J boundary. The sedimentary structures within this
359 latter sample may reflect bioturbation, a process that is typically detrimental to OM
360 preservation. Strongly degraded and oxidized sporomorphs occur in samples PI-70, PI-05
361 and PI-00; notably, the coarse and/or oxidized lithologic character of these samples was
362 not conducive for OM preservation (i.e., interlayered grey-reddish laminated mudstone,
363 grey coarser sandstone, and coarse siltstone at the contact with basalt, respectively). This
364 inference is supported by their high content of inertinite, which is the product of strong
365 degradation-oxidation processes. The highest abundance of sporomorphs occurs within a
366 dark grey mudstone (PI-45) (Fig. 6b), which was likely deposited in low-oxygen
367 conditions that favoured preservation of OM. The overall scarcity of AOM (Fig. 6c),
368 however, except in a few samples as noted, supports the interpretation of generally
369 strongly oxidizing conditions during deposition of the sedimentary section, as is typical
370 in many continental environments.

371 The three samples from the Scots Bay Member contain low concentrations of total
372 OM. The dominant palynomacerals are inertinite, and minor vitrinite. Several yellow to
373 dark orange cutinite debris are also present.

374 Variations in the palynofacies through the studied section are consistent with a
375 depositional environment that varied from playa/lacustrine to fluvial in the uppermost

376 Blomidon Formation, and perennial lacustrine in the basal Scots Bay Member. The
377 presence of abundant AOM within the darker intervals of the Blomidon Formation
378 indicates that rarely transient conditions of very temporary nature made higher OM
379 preservation possible.

380

381 5.3 Thermal alteration index (TAI)

382 Colour and degree of preservation of the OM were studied in order to determine
383 the thermal history of the sampled section and to evaluate the possibility that the
384 sporomorph content was recycled from older, thermally overmature strata (see online
385 material). Given the nature of the depositional environment of the studied succession
386 (i.e., fluvial-lacustrine), the potential for concentrating reworked palynomorphs from
387 older strata was considered high. Fortunately, the transported or reworked fraction of
388 OM can be distinguished by its opacity and darker colour (Traverse, 2008).

389 The Partridge Island section affords the opportunity to examine colour changes
390 over a relatively short stratigraphic/time interval, thus minimizing evolutionary and/or
391 environmentally driven changes in the sporomorph associations, and yielding an
392 internally consistent dataset. The TAI does not reveal a significant trend in colour
393 variation for most of the studied section (Fig. 6). The colour of the sporomorphs ranges
394 from orange to brown down section, which corresponds to a TAI value of approximately
395 2+ to 3- (on a five point scale), suggesting a medium thermal maturity (about 60°-65° for
396 this type of OM). Closer to the section top (the basalt flow), from sample PI-05 to sample
397 PI-00, a modest increase occurs, with TAI values around 3 to 3+ (about 70°-80°). Thus,
398 sampling indicates a mild increase in thermal alteration that is easily attributed to thermal
399 overprint during the basalt emplacement.

400 The three samples of Scots Bay Member contain Triassic sporomorphs in which colour
401 ranges from dark yellow to orange (TAI from 2 to 2+) (around 60°-55°). The fact that
402 these sporomorphs are generally lighter in colour (i.e. less mature) than those in the
403 Blomidon Formation strongly suggests that they were not recycled from the older
404 Blomidon strata. (see online material, Fig.S2)

405

406 **6. Discussion**

407 The hypothesis that CAMP eruptions triggered the end-Triassic climatic and
408 biotic perturbations requires that the basaltic eruptions commenced before and temporally
409 overlapped the Tr-J boundary. This issue is debated in regards both to the ENA basins, as
410 well as other CAMP localities (i.e. Morocco). Some authors (e.g. Fowell and Traverse,
411 1995; Whiteside et al., 2007) placing the Tr-J boundary below, hence before, the earliest
412 basalt eruptions define the boundary location based on the following observations: (1) the
413 disappearance of several Triassic sporomorphs (i.e., *P. densus*); (2) compositional
414 variation of the Circumpolles group; and (3) a bloom of fern spores in the overlying
415 strata, which is interpreted as a pronounced palynofloral turnover after the Tr-J mass
416 extinction. However, the data presented in this study do not support a significant
417 palynological turnover before emplacement of the oldest CAMP lava flows. In the
418 following discussion we focus on five points that address specifically the end-Triassic
419 age of CAMP volcanism in the Fundy basin and how it relates to the Tr-J boundary.

420

421 6.1 Is the last occurrence of *Patinasporites densus* a marker of the Tr-J boundary?

422 In the ENA basins, including the Fundy basin of the present study, the Tr-J
423 boundary is currently defined, in part, based on the last occurrence of the Triassic
424 sporomorph *P. densus*. However, the last appearance of *P. densus*, as well as other

425 vesiculate sporomorphs, is considered to occur at the upper Norian - lowermost Rhaetian
426 boundary of the Late Triassic rather than at the Tr-J boundary, as documented in
427 numerous independently dated key sections (see online material, Fig. S3). The last
428 occurrence of this sporomorph in the Northern and Southern Hemispheres in the late
429 Norian to Early Rhaetian (Sevatian-Rhaetian boundary) suggests a late Norian-early
430 Rhaetian age for the palynological event in the Newark Basin rather than a Tr-J boundary
431 age, as proposed by some (Gradstein et al., 1994; Van Veen, 1995, Lucas and Tanner,
432 2007). The possibility of a floral provincialism controlling a diachronous distribution in
433 North American and Tethyan domains of the parent plants (Fowell and Olsen, 1993) does
434 not seem to be valid given the large distribution of these taxa in different palaeoclimate
435 belts (Buratti and Cirilli, 2007). Furthermore, the updated palaeogeographic
436 reconstructions based on palaeomagnetism (Kent and Tauxe, 2005) discount the
437 possibility of explaining the discrepancy by a latitudinal floral gradient. *P. densus* is
438 present in numerous Triassic sections located in similar palaeoclimatic and
439 palaeogeographic belts (e.g.: Carnian formations in Worcester, Tewkesbury and Reddick
440 districts, Barclay et al., 1997). It is notable that in Northern Italy (Southern Alps) the last
441 occurrence of *P. densus* is recorded (Jadoul et al., 1994) several hundred meters below
442 the Tr-J boundary based on biostratigraphic, stratigraphic and geochemical constraints
443 (Galli et al., 2007). Correlation of the palynological assemblage across the putative Tr-J
444 boundary in the Fundy and Newark basins (Whiteside et al., 2007) with the section at St.
445 Audrie's Bay (Hounslow et al., 2004) indicates that these sections are quite different, in
446 particular at the latter section where *P. densus* is absent in the Triassic portion of the
447 section below the Tr-J boundary. Clearly, this lack of correlation cannot be explained by
448 a provincialism of this taxon.

449

450 6.2 Does the compositional variation of Circumpolles group reflect an early Jurassic
451 palynological assemblage?

452 The miospores from the extinct conifer family Cheirolepidiaceae (*Classopollis*,
453 *Gliscopollis*, *Corollina*) first appeared in the Late Triassic and became major elements in
454 Jurassic and Cretaceous palynoflora. The widespread distribution of *G. meyeriana* and *C.*
455 *torosus* commences in the Norian and continues into the Rhaetian and the Jurassic, as
456 documented in several locations in the Northern and Southern Hemispheres (e.g. Cornet
457 and Traverse, 1975; Schuurman 1979; ; Batten and Koppelhaus 2002; Warrington, 2002;
458 Hounslow et al. 2004; Barron et al., 2006; Buratti and Cirilli, 2007). Recent geochemical
459 and biostratigraphic constraints document that *C. torosus* and *G. meyeriana* were already
460 abundant within the Rhaetian (Rhaetipollis-Limbosporites zone of Kuerschner et al.,
461 2007; Barron et al. 2006; Gomez et al., 2007). Thus, the presence or relative abundance
462 of these Circumpolles taxa does not justify assigning a Jurassic age to the host strata, so
463 long as they are not part of an assemblage with only other Jurassic forms. Furthermore, a
464 valid biozone should be defined by one or more first occurrences rather than solely by
465 disappearances. In the Blomidon Formation, as well as in the Scots Bay Member, a
466 distinctly Hettangian species has not yet been recorded. Also significant is the absence of
467 *Cerebropollenites thiegarthi*, which is considered a marker for the basal Jurassic in
468 numerous palynological zonations that also are age-constrained by ammonoids,
469 conodonts and geochemical data (Kuerschner et al., 2007; von Hillebrandt et al., 2007;
470 Gomez et al., 2007).

471

472 6.3 Does the presumed palynological turnover and related fern spike mark the Tr-J
473 boundary?

474 It is essential to emphasize that the sediments investigated in this study were
475 deposited in continental environments (e.g. fluvial and lacustrine), which are
476 unfavourable to OM preservation. Consequently, the OM likely was subjected to strong
477 and episodic oxidizing conditions, as indicated by the palynofacies analysis. In the
478 Partridge Island section, for example, sporomorph abundance varies as a function of OM
479 preservation, which itself is associated with variable conditions of depositional/diagenetic
480 oxidation. Correlation of the sporomorph distribution with the palynofacies and TAI
481 variations demonstrates that the low percentage or absence of sporomorphs is coincident
482 with higher thermal indices and/or with more degraded-oxidized palynofacies (Fig.4,6).
483 Therefore, no significant palynological decline or turnover occurs below the North
484 Mountain Basalt that can be attributed to a mass extinction event. This observation is also
485 reinforced by the fact that except for *P. densus* and few other sporomorphs (Fig. 4) no
486 other last occurrences of Triassic sporomorphs have been recorded at the presumed Tr-J
487 boundary. A few last appearances (i.e. *C. cameronii*, *D. harrisii* and *Dictyophyllidites*
488 sp.) are only local most likely and palaeoecologically controlled, since they are present
489 above the putative Tr-J boundary as important elements of the so-called fern spike in
490 other ENA basins (Fowell and Olsen, 1993; Fowell et al., 1994). Although a true fern
491 spike is absent at the Partridge Island site, a level enriched in fern spores is recorded
492 within a dark clay mudstone (Fig. 4) located 15 cm below the putative Tr-J boundary, but
493 not above the boundary as in the Newark Basin. The co-occurrence of climate sensitive
494 facies (dark clay) with abundant fern spores could be related to local, more humid climate
495 conditions rather than to a re-colonization after mass-extinction. During the Mesozoic,
496 ferns developed easily in warm and humid environments (i.e. coal swamps, river banks),
497 preferring sheltered areas under the forest canopy, along creeks and streams and other
498 sources of permanent moisture (Abbink et al., 2004).

499

500 6.4 Are the Triassic sporomorphs in the Scots Bay Member reworked?

501 One of our most significant findings is the presence of a palynological assemblage
502 dominated by bisaccates, such as *L. acutus*, *L. rhaeticus*, *Lueckisporites* sp. with minor
503 Circumpolles, within the Scots Bay Member. The presence of specimens considered as
504 Triassic taxa (e.g. Schuurman, 1979; Batten and Koppelhous, 2002; Warrington, 2002;
505 Jadoul et al 1994, Hounslow et al., 2004) led to assigning these strata to the Triassic,
506 although they overlie the East Ferry and Margaretsville Members of the ~201 Ma North
507 Mountain Basalt. The colour of these sporomorphs, which are comparable to and often
508 slightly lighter than sporomorphs from the underlying Blomindon Formation, excludes
509 the possibility that they might be recycled from older strata. Therefore, while we can not
510 constrain the age of the Brier Island Member (one or two basalt flows) which is
511 discontinuously present along the Bay of Fundy and has not been observed in contact
512 with the Scot's Bay sediments, palynostratigraphy convincingly constrains the age of the
513 East Ferry and Margaretsville Members of the North Mountain Basalt to the Late
514 Triassic.

515

516 6.5 Is chron E23r at the Tr-J boundary and how long is the Rhaetian?

517 The Newark magnetostratigraphy shows that the reverse chron E23r occurs just
518 below the interval previously interpreted as the Tr-J boundary (Kent and Olsen, 2000;
519 Olsen et al., 2002). The new data from Partridge Island do not support this interpretation,
520 given the presence of Triassic sporomorphs in strata overlying the North Mountain
521 Basalt, hence above the supposed Tr-J boundary. Unless the Newark magnetostratigraphy
522 is missing several chrons (cf. Gallet et al., 2007), E23r must actually occur well before
523 the end of the Rhaetian. Hounslow et al. (2004), in fact, noted the ambiguity in

524 correlating palaeomagnetic records of the Newark basin and the St. Audrie's Bay marine
525 section, and suggested that E23r might correlate with SA5.2r, below the base of the
526 Lilstock Formation, rather than to SA5r, in the lower Blue Lias. In addition, it is
527 significant that the terrestrial components of the palynological assemblage at St. Audrie's
528 Bay (e.g. lack of *P. densus* and presence of typical uppermost Triassic taxa) are quite
529 different from the microflora found at the Partridge Island and also at the presumed Tr-J
530 boundary in the Newark basins.

531 This interpretation of the magnetostratigraphy is in good agreement with recent
532 biogeochemical and magnetostratigraphic data that indicate the supposed Tr-J boundary
533 of the Newark basin actually coincides with the Sevatian-Rhaetian boundary (Gallet et
534 al., 2007). However, this correlation and the results of the present biostratigraphic study,
535 as well as radio-isotopic ages, raise problems regarding the duration of the Rhaetian.
536 Considering that the age of the North Mountain Basalt is constrained to ~201 Ma
537 (Schoene et al., 2006; Jourdan et al., in press), i.e. indistinguishable from the age of the
538 marine Tr-J boundary (Schaltegger et al., 2008), the time which elapsed between the last
539 occurrence of *P. densus*, the eruption of CAMP basalts and the Tr-J boundary would be
540 extremely short. Although at face value the U/Pb age of the North Mountain Basalt
541 (201.3 ±0.3 Ma) predates that (201.6 ±0.3 Ma) for the Tr-J boundary only at relatively
542 low probability, we note that the former (obtained on a mafic pegmatite sheet in the upper
543 part of the East Ferry Member) may not date the earliest North Mountain Basalt
544 eruptions, and the latter (being determined from a silicic tephra) is more likely to be
545 affected by pre-eruptive residence time of the zircons, which can produce apparent age
546 bias of several hundred ka (Simon et al., 2008). Furthermore, if the last occurrence of *P.*
547 *densus* can be considered as a Norian-Rhaetian or very early Rhaetian event, this would
548 imply a very short Rhaetian (<1 Ma). A short Rhaetian event suggested here concurs with

549 that proposed by Krystyn et al. (2007) and Gallet et al. (2007), but contrasts markedly
550 with conclusions of Channell et al. (1993), and Muttoni et al. (2004) who consider that
551 the Rhaetian had a duration of 6Ma. Alternatively, it might be considered that the
552 stratigraphic record of the Newark and Fundy basins are incomplete and that the Rhaetian
553 is partly or wholly missing, as suggested by Kozur and Weems (2005).

554

555 **7. Conclusions**

556 New palynological data from the Fundy Basin of Nova Scotia, Canada, constrain
557 the age of the sedimentary rocks below and just above the ~201 Ma North Mountain
558 Basalt, part of the widespread CAMP event, to the Late Triassic. In particular, this is
559 documented in the Fundy Basin by the presence of Triassic sporomorphs in the Scots Bay
560 Member, which overlies East Ferry and Margaretsville Members of the North Mountain
561 Basalt. Significantly, examination of the state of preservation and thermal alteration of
562 OM associated with the fossil assemblage precludes the possibility of recycling of the
563 Triassic sporomorphs from the older Blomidon Formation strata, which underlies the
564 basalt. From these new data, we draw the following conclusions:

565 1. Because the last occurrence of *P. densus* occurs 40 cm below the North Mountain
566 Basalt, and strata above the basalt (e.g. the Scots Bay Member) are clearly Triassic, it
567 follows that the palynological definition of the Tr-J boundary based on the last
568 occurrence of *P. densus* is not valid. Consequently, it appears that the occurrence of a
569 fern spike in the Newark Basin probably reflects a regional environmental perturbation ,
570 e.g. an abrupt but short-lived episode of climate change, rather than a global event.

571 2. Given that the previously accepted definition of the Tr-J boundary in the Newark Basin
572 cannot be supported palynologically, it follows that chron E23r, which is correlated with
573 the last occurrence of *P. densus* in the Newark Basin, also cannot be considered as a

574 marker of the Tr-J boundary. Instead, the chron E23r event merely marks a Late Triassic
575 (probably Rhaetian) reversal. This is an important point to consider correlating the Late
576 Triassic magnetostratigraphic data from marine sections (Hounslow et al., 2004; Gallet et
577 al., 2007) to the Newark continental section.

578 3. The occurrence of clearly Triassic strata in sharp contact with underlying North
579 Mountain Basalt lava flows clearly indicates that CAMP volcanism, at least in Nova
580 Scotia, is entirely of Triassic (Rhaetian) age. Significantly, this temporal relationship
581 must also apply to other areas of CAMP. In Morocco, for example, initiation of the
582 basaltic eruptions was coeval with deposition of sedimentary containing *P. densus*.
583 Cyclostratigraphy constrains the onset of CAMP volcanism elsewhere in the ENA (e.g.
584 the Fundy and Newark basins) to about 20-40 ky after the last occurrence of *P. densus*.

585 4. Because the eruption of the basalt plus deposition of at least the first few meters of the
586 Scots Bay Member occurred in a time span shorter than analytical resolution of the
587 geochronological data, emplacement of the basalt took place in a very short span of time.

588

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598 **References**

599

600 Abbink, O.A., Van Konijnenburg-Van Cittert, J.H.A., Visscher, H., 2004. A
601 sporomorph ecogroup model for the NW European Jurassic-Lower Cretaceous:
602 concepts and framework. *Netherlands Jour. Geos./Geol. En Mijnb.*, 83, 17-38.

603 Barclay, W.J., Ambrose, K., Chadwick, R.A., Pharaoh, T.C., 1997. Geology of the
604 country around Worcester. Memoir for 1:50,000 geological sheet 199 (England
605 and Wales). British Geological Survey, HMSO, London.

606 Barrón, J.J. Gómez, A., Goy, A., Pieren, A.P., 2006. The Triassic-Jurassic boundary
607 in Asturias (northern Spain): palynological characterization and facies. *Rev.*
608 *Palaeobot. Palynol.*, 138, 187–208.

609 Batten, D.J., Koppelhus, E.B., 2002. Biostratigraphic significance of uppermost
610 Triassic and Jurassic miospores in Northwestern Europe. In: Jansonius, J.,
611 McGregor, D.C. (Eds.), *Palynology: Principles and Applications*, 2, 2nd edition,
612 AASP Foundation, pp. 795–806.

613 Bujak, J.P., 1977. Palynological Analysis of Mobil-Gulf Chinampas N-37, Bay of
614 Fundy. Mobil Oil Corp. Rep. EPGs-PAL. 3-79JPB (technical report).

615 Buratti, N., Cirilli, S., 2007. Microfloristic provincialism in the Upper Triassic
616 Circum- Mediterranean area and palaeogeographic implication. *Geobios*, 40, 133-
617 142.

618 Channell, J.E.T., Kozur, H., Sievers, T., Mock, R., Aubrecht, R., Sykora, M., 1993.
619 Carnian–Norian biomagnetostratigraphy at Silická Brezová (Slovakia): correlation
620 to other Tethyan sections and to the Newark Basin. *Palaeogeogr. Palaeoclimatol.*
621 *Palaeoecol.*, 122, 65–109.

Formatted: Spanish (International Sort)

- 622 Cohen, A.S., Coe, A.L., 2007. The impact of the Central Atlantic magmatic province
623 on climate and on the Sr- and Os-isotope evolution of seawater. *Palaeogeogr.*
624 *Palaeoclimatol. Palaeoecol.*, 244, 374–390.
- 625 Cornet, B., Olsen, P.E., 1985. A summary of the biostratigraphy of the Newark
626 Supergroup of eastern North America with comments on provinciality, in: Weber
627 III, R. (Ed.), *Congreso Latinoamericano de Paleontología Mexico, Simposio Sobre*
628 *Floras del Triasico Tardio, su Fitogeografía y Paleología, Memoria. UNAM*
629 *Instituto de Geología, Mexico City*, pp. 67–81.
- 630 Cornet, B., Traverse, A., 1975. Palynological contributions to the chronology and
631 stratigraphy of the Hartford basin in Connecticut and Massachusetts. *Geosci. Man.*,
632 11, 1–33.
- 633 Deckart, K., Feraud, G., Bertrand, H., 1997. Age of Jurassic continental tholeiites of
634 French Guyana, Suriname, and Guinea: implications for the initial opening of the
635 Central Atlantic Ocean. *Earth Planet. Sci. Lett.*, 150, 205–220.
- 636 | De Wet, C.B., Hubert, J.H., 1989. The Scots Bay Formation, Nova Scotia, Canada: a
637 Jurassic lake with silica-rich hydrothermal springs. *Sedimentology*, 36, 857-874.
- 638 Fowell, S.J., Olsen, P.E., 1993. Time calibration of Triassic–Jurassic microfloral
639 turnover, eastern North America. *Tectonophysics*, 222, 361–369.
- 640 Fowell, S.J., Traverse, A., 1995. Palynology and age of the upper Blomidon
641 Formation, Fundy basin, Nova Scotia. *Rev. Palaeobot. Palynol.*, 86, 211–233.
- 642 Fowell, S.J., Cornet, B., Olsen, P.E., 1994. Geologically rapid Late Triassic
643 extinctions: Palynological evidence from the Newark Supergroup, in Klein, G.D.
644 (Ed.), *Pangea: Paleoclimate, Tectonics, and Sedimentation During Accretion,*
645 *Zenith and Break-up of a Supercontinent, Geol. Soc. Am. Spec. Pap.*, 288, pp. 197-
646 206.

Formatted: German (Germany)

647 | [Gallet, Y., Krystyn, L., Marcoux, J., Besse, J., 2007. New constraints on the end-](#)
648 | Triassic (Upper Norian–Rhaetian) magnetostratigraphy. *Earth Planet. Sci. Lett.*,
649 | 255, 458–470.

Formatted: Norwegian (Bokmål)

650 | [Galli, M., Jadoul, F., Bernasconi, S.M., Cirilli, S., Weissert, H., 2007. Stratigraphy](#)
651 | and paleoenvironmental analysis of the Triassic–Jurassic transition in Western
652 | southern Alps (Northern Italy). *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 244 ,
653 | 52–70.

Formatted: Italian (Italy)

654 | Gómez, J.J., Goy, A., Barrón, E., 2007. Events around the Triassic–Jurassic
655 | boundary in northern and eastern Spain: a review. *Palaeogeogr. Palaeoclimatol.*
656 | *Palaeoecol.*, 244, 89–110.

657 | Gradstein, F.M., Agterberg, F.P., Ogg, J.G., Hardenbol, J., van Veen, P., Thierry, J.,
658 | Huang, Z., 1994. A Mesozoic time scale. *J. Geophys. Res.*, 99, 24051–24074.

659 | [Guex, J., Bartolini, A., Atudorei, V., Taylor, D., 2004. High-resolution ammonite](#)
660 | and carbon isotope stratigraphy across the Triassic–Jurassic boundary at New York
661 | Canyon (Nevada). *Earth Planet. Sci. Lett.*, 225, 29–41.

Formatted: Italian (Italy)

662 | Hallam, A., 2002. How catastrophic was the end-Triassic mass extinction? *Lethaia*,
663 | 35, 147–157.

664 | Hallam, A., Wingall, P.B., 1999. Mass extinction and sea-level changes. *Earth-Sci.*
665 | *Rev.*, 48, 217–250.

666 | Hesselbo, S.P., Robinson, S.A., Surlyk, F., Piasecki, S., 2002. Terrestrial and marine
667 | extinction at the Triassic–Jurassic boundary synchronized with major carbon-cycle
668 | perturbation: a link to initiation of massive volcanism. *Geology*, 30, 251–254.

669 | [Hillebrandt, A., von, Krystyn, L., Kürschner, W.M., 2007. A candidate GSSP for the](#)
670 | base of the Jurassic in the Northern Calcareous Alps (Kuhjoch section, Karwendel
671 | Mountains, Tyrol, Austria). *ISJS Newsletter*, 34, 2–20.

Formatted: German (Germany)

- 672 Hounslow, M.H., Posen, P.E., Warrington, G., 2004. Magnetostratigraphy and
673 biostratigraphy of the Upper Triassic and lowermost Jurassic succession, St.
674 Audrie's Bay, UK. *Palaeogeogr. Palaeoclimat. Palaeoecol.*, 213, 331–358.
- 675 Jadoul, F., Masetti, D., Cirilli, S., Berra, F., Claps, M., Frisia, S., 1994. Norian-
676 Rhaetian and paleogeographic evolution of the Lombardy Basin. (Bergamasc
677 Alps). 15th IAS Reg. Meet., Ischia, 1-38.
- 678 Jourdan, F., Marzoli, A., Bertrand, H., Cirilli, S., Tanner, L., Kontak, D.J., McHone, G.,
679 Renne P.R., Bellieni, G. 40 Ar/39Ar ages of CAMP in North America: implications
680 for the Triassic-Jurassic boundary and the 40K decay constant bias. *Lithos*,
681 [doi:10.1016/j.lithos.2008.12.011](https://doi.org/10.1016/j.lithos.2008.12.011)
- 682 Kent, D.V., Olsen, P.E.. 1999. Astronomically tuned geomagnetic polarity time scale
683 for the Late Triassic. *J.Geophys. Res.*, 104, 12831-12841.
- 684 Kent, D.V. Olsen, P. E., 2000. Magnetic polarity stratigraphy and paleolatitude of the
685 Triassic--Jurassic Blomidon Formation in the Fundy basin (Canada): implications
686 for early Mesozoic tropical climate gradients. *Earth Planet. Sci. Lett.*, 179, 311-
687 324.
- 688 Kent, D.V., Olsen, P.E., 2008. Early Jurassic magnetostratigraphy and paleolatitudes
689 from the Hartford continental rift basin (eastern North America): Testing for
690 polarity bias and abrupt polar wander in association with the central Atlantic
691 magmatic province. *J. Geophys. Res.*, 113, B06105, doi:10.1029/2007JB005407.
- 692 Kent, D.V., Tauxe, L., 2005. Corrected Late Triassic latitudes for continents adjacent
693 to the North Atlantic. *Science*, 307, 240–244.
- 694 Knight, K.B., Nomade, S., Renne, P.R., Marzoli, A., Bertrand, H., Youbi, N., 2004.
695 The Central Atlantic Magmatic Province at the Triassic–Jurassic boundary:
696 paleomagnetic and 40Ar/39Ar evidence from Morocco for brief, episodic

- 697 volcanism. *Earth Planet. Sci. Lett.*, 228, 143–160.
- 698 Kontak, D.J., 2008. On the edge of CAMP: Geology and volcanology of the Jurassic
699 North Mountain Basalt, Nova Scotia. *Lithos*, 101, 74-101.
- 700 Kozur, H.W., Weems, R.E., 2005. Conchostracan evidence for a late Rhaetian to
701 early Hettangian age for the CAMP volcanic event in the Newark Supergroup, and
702 a Sevatian (late Norian) age for the immediately underlying beds. *Hallesches
703 Jahrbuch Geowissenschaften*, B27, 21–51.
- 704 Krystyn, L., Bouquerel, H., Kuerschner, W., Richoz, S., Gallet, Y., 2007. Proposal
705 for a Candidate GSSP for the base of the Rhaetian Stage, in Lucas, S.G.,
706 Spielmann, J.A. (Eds.), *The Global Triassic*, New Mexico Museum of Natural
707 History and Science Bulletin 41, pp. 189-199.
- 708 Kuerschner, W.M., Bonis, N.R., Krystyn, L., 2007. Carbon-isotope stratigraphy and
709 palynostratigraphy of the Triassic–Jurassic transition in the Tiefengraben section—
710 Northern Calcareous Alps (Austria). *Palaeogeogr. Palaeoclimatol. Palaeoecol.*,
711 244, 257–280.
- 712 Kuiper, K.F., Deino, A., Hilgen, F.J., Krijgsman, W., Renne, P.R., Wijbrans,
713 J.R. 2008. Synchronizing Rock Clocks of Earth History. *Science*, 302,
714 500-504.
- 715 Lucas, S.G., Tanner, L.H., 2007. The nonmarine Triassic–Jurassic boundary in the
716 Newark Supergroup of eastern North America. *Earth-Science Reviews*, 84, 1–20.
- 717 | Lucas, S.G., Tanner, L.H., 2008. Reexamination of the end-Triassic mass extinction. In:
718 | Elewa, A.M.T. (ed.) *Mass Extinction*. Springer Verlag, pp. 66-103.
- 719 Marzoli, A., Renne, P.R., Piccirillo, E.M., Marcia, E., Bellieni, G., De Min, A., 1999.
720 Extensive 200-Million-Year-Old Continental Flood Basalts of the Central Atlantic
721 Magmatic Province. *Science*, 284, 616-618.

Formatted: Swedish (Sweden)

- 722 Marzoli, A., Bertrand, H., Knight, K.B., Cirilli, S., V rati, C., Nomade, S., Martini,
723 R., Youbi, N., Allenbach, K., Neuwerth, R., Buratti, N., Rapaille, C., Zaninetti, L.,
724 Bellieni, G., Renne, P.L., 2004. Synchrony of the Central Atlantic magmatic
725 province and the Triassic-Jurassic boundary climatic and biotic crisis. *Geology*,
726 32, 973-976.
- 727 Marzoli, A., Bertrand, H., Knight, K., Cirilli, S., Nomade, S., Renne, P., V rati, C.,
728 Youbi, N., Martini, R., Bellieni, G., 2008. Comment on ‘‘Synchrony between the
729 Central Atlantic magmatic province and the Triassic–Jurassic mass-extinction
730 event? By Whiteside et al. (2007)’’. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 262,
731 189–193.
- 732 McElwain, J.C., Punyasena, S., 2007. Mass extinction events and the plant fossil
733 record. *Trends in Ecology and Evolution*, 22, 548-557.
- 734 McElwain, J.C., Beerling, D.J., Woodward, F.I., 1999. Fossil Plants and Global
735 Warming at the Triassic-Jurassic Boundary. *Science*, 285, 1386-1390.
- 736 | Min, K., Mundil, R., Renne, P.R., Ludwig, K.R., 2000. A test for systematic errors in
737 40Ar/39Ar geochronology through comparison with U–Pb analysis of a 1.1 Ga
738 rhyolite. *Geochimica Cosmochimica Acta*, 64, 73–98.
- 739 Morbey, J.S., 1978. Late Triassic and Early Jurassic subsurface palynostratigraphy in
740 northwestern Europe. *Palinologia*, 1, 355–365.
- 741 Muttoni, G., Kent, D.V., Olsen, P., Di Stefano, P., Lowrie, W., Bernasconi, S.,
742 Martin, F., Hernandez, F.M. 2004. Tethyan magnetostratigraphy from Pizzo
743 Mondello (Sicily) and correlation to the Late Triassic astrochronological polarity
744 time scale. *Geol. Soc. Amer. Bull.*, 116, 1043–1058.
- 745 Nomade, S., Knight, K.B., Renne, P.R., Verati, C., F raud, G., Marzoli, A., Youbi,
746 N., Bertrand, H., 2007. The chronology of CAMP: relevance for the central

Formatted: Norwegian (Bokm l)

747 Atlantic rifting processes and the Triassic-Jurassic biotic crisis. *Palaeogeogr.*
748 *Palaeoclimatol. Palaeoecol.*, 244, 326-344.

749 Olsen, P.E., Schlische, R.W., 1990. Transtensional arm of the early Mesozoic Fundy
750 rift basin: penecontemporaneous faulting and sedimentation. *Geology*, 18, 695-
751 698.

752 Olsen, P.E., Koerberl, C., Huber, H., Montanari, A., Fowell, S.J., Et-Touhami, M.,
753 Kent, D.V., 2002. The continental Triassic–Jurassic boundary in central Pangea:
754 recent progress and discussion of an Ir anomaly, in: Koerberl, C., MacLeod, K.G.
755 (Eds.), *Catastrophic Events and Mass Extinctions: Impacts and Beyond*. Boulder,
756 Colorado, Geological Society of America Special Paper, 356, pp. 505–522.

757 Olsen, P.E., Kent, D.V., Et-Touhami, M., Puffer, J.H., 2003. Cyclo-,magneto-, and
758 bio-stratigraphic constraints on the duration of the CAMP event and its
759 relationship to the Triassic–Jurassic boundary, in: Hames, W.E., McHone, J.G.,
760 Renne, P.R., Ruppel, C. (Eds.), *The Central Atlantic Magmatic Province: Insights*
761 *from Fragments of Pangea*. Geophysical Monograph Series, 136, pp. 7–32.

762 Olsen, P.E., Whiteside, J.H., Fedak, T., 2005. Field Trip A7: the Triassic–Jurassic
763 faunal and floral transition in the Fundy Basin, Nova Scotia. Geological
764 Association of Canada, Mineralogical Association of Canada, Canadian Society of
765 Petroleum Geologists, Canadian Society of Soil Sciences Joint Meeting, Halifax,
766 May 2005, AGS Special Publication Number 26.

767 Pálffy, J., Demény, A., Haas, J., Hetényi, M., Orchard, M.J., Veto, I., 2001: Carbon
768 isotope anomaly and other geochemical changes at the Triassic-Jurassic boundary
769 from a marine section in Hungary. *Geol.*, 29, 1047-1050.

Formatted: German (Germany)

- 770 Papezik, V.S., Greenough, J.D., Colwell, J.A., Mallinson, T.J., 1988. North
771 Mountain Basalt from Digby, Nova Scotia; models for a fissure eruption from
772 stratigraphy and petrochemistry. *Canadian Journal of Earth Sciences*, 25, 74-83.
- 773 | Schaltegger, U., Guex, J., Bartolini, A., Schiene, B., Ovtcharova, M., 2008. Precise
774 U–Pb age constraints for end-Triassic mass extinction, its correlation to volcanism
775 and Hettangian post-extinction recovery. *Earth Planet. Sci. Lett.*, 267, 266–275.
- 776 Schoene, B., Crowley, J.L., Condon, D.J., Schmitz, M.D., Bowring, S.A., 2006.
777 Reassessing the uranium decay constants for geochronology using ID-TIMS U–Pb
778 data. *Geochimica et Cosmochimica Acta*, 70, 426–445.
- 779 Schuurman, W.M.L., 1979. Aspects of Late Triassic palynology: 3. Palynology of
780 latest Triassic and earliest Jurassic deposits of the northern limestone Alps in
781 Austria and southern Germany, with special reference to a palynological
782 characterization of the Rhaetian stage in Europe. *Rev. Palaeobot. Palynol.*, 27, 53–
783 75.
- 784 Sepkoski, J.J.Jr. 1996. Patterns of the Phanerozoic extinction: a perspective from
785 global data bases, in: Walliser, O.H. (Ed.), *Global Events and Event Stratigraphy*
786 *in the Phanerozoic*, Springer, Berlin, pp. 35-51.
- 787 Shubin, N.H., Olsen, P.E., Sues, H.-D., 1994. Early Jurassic small tetrapods from the
788 McCoy Brook Formation of Nova Scotia, Canada, in: Fraser, N.C., Sues, H.D.
789 (Eds.), *In the Shadow of Dinosaurs: Early Mesozoic Tetrapods*, Cambridge
790 University Press, Cambridge, pp. 242–250.
- 791 Simon, J.I., Renne, P.R., and Mundil, R., 2008. Implications of pre-eruptive
792 magmatic histories of zircons for U-Pb geochronology of silicic extrusions: Earth
793 and Planetary Science Letters 266: 182-194. doi:10.1016/j.epsl.2007.11.014

Formatted: Italian (Italy)

- 794 Tanner, L.H., 2000. Triassic–Jurassic lacustrine deposition in the Fundy rift basin,
795 eastern Canada, in: Gierlowski-Kordesch, E., Kelts, K. (Eds.), *Lake Basins*
796 *Through Space and Time*, Am. Assoc. Petrol. Geol. Studies in Geology, 46, pp.
797 481–490.
- 798 Tanner, L.H., Hubert, J.F., 1992. Depositional environments, palaeogeography and
799 palaeoclimatology of the Lower Jurassic McCoy Brook Formation, Fundy basin,
800 Nova Scotia: Palaeogeog., Palaeoclimatol., Palaeoecol. 96, 261-280.
- 801 Tanner, L.H., Kyte, F.T., 2005. Anomalous iridium enrichment in sediments at the
802 Triassic–Jurassic boundary, Blomidon Formation, Fundy basin, Canada. *Earth*
803 *Planet. Sci. Lett.*, 240, 634–641.
- 804 Tanner, L.H., Lucas, S.G., Chapman, M.G., 2004. Assessing the record and causes of
805 Late Triassic extinctions. *Earth-Science Reviews*, 65, 103–139.
- 806 | Tanner, L.H., Smith, D.L., Allan, A., 2007. Stomatal response of swordfern to
807 volcanogenic CO₂ and SO₂ from Kilauea volcano, Hawaii. *Geophysical Research*
808 *Letters* 34: L15807, doi:10.1029/2007GL030320
- 809 Tanner, L.H., Kyte, F.T., Walker, A.E., 2008. Multiple Ir anomalies in uppermost
810 Triassic to Jurassic-age strata of the Blomidon Formation, Fundy basin, eastern
811 Canada. *Earth and Planetary Science Letters* 274, 103-111.
- 812 Tollo, R.P., Gottfried, D., 1992. Petrochemistry of Jurassic Basalt from eight cores,
813 Newark Basin, New Jersey: implications for the volcanic petrogenesis of the
814 Newark Supergroup, in: Puffer, J.H., Ragland, P.C. (Eds.), *Eastern North*
815 *American Mesozoic Magmatism*, Geological Society of America Special Paper,
816 268, pp. 233–259.
- 817 Traverse, A., 2004. Proposal to conserve the fossil pollen morphogeneric name
818 *Classopollis* against *Corollina* and *Circulina*. *Taxon*, 53, 847-848.

Formatted: Swedish (Sweden)

- 819 Traverse, A., 2008. Paleopalynology. Second Edition Series: Topics in Geobiology,
820 28, 2nd ed. 2007. Corr. 2nd printing, 2008, XVIII.
- 821 Van de Schootbrugge, B., Payne, J.L., Tomasovych, A., Pross, J., Fiebig, J.,
822 Benbrahim, M., Föllmi, K.B., Quan, T.M., 2008. Carbon cycle perturbation and
823 stabilization in the wake of the Triassic-Jurassic boundary mass-extinction event.
824 *Geochem. Geophys. Geosyst.*, 9, Q04028, doi:10.1029/2007GC001914.
- 825 Van Veen, P.M., 1995. Time calibration of Triassic/Jurassic microfloral turnover,
826 eastern North America—comment. *Tectonophysics*, 245, 93–95.
- 827 Verati, C., Rapaille, C., Féraud, G., Marzoli, A., Bertrand, H., Youbi, N., 2007.
828 $^{40}\text{Ar}/^{39}\text{Ar}$ ages and duration of the Central Atlantic Magmatic Province volcanism
829 in Morocco and Portugal and its relation to the Triassic–Jurassic boundary.
830 *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 244, 308–325.
- 831 Ward, P.D., Garrison, G.H., Haggart, J.W., Kring, D.A., Beattie, M.J. 2004. Isotopic
832 evidence bearing on Late Triassic extinction events, Queen Charlotte Islands,
833 British Columbia, and implications for the duration and cause of the Triassic-
834 Jurassic mass extinction. *Earth and Planetary Science Letters* 224, 589–600.
- 835 Warrington, G., 2002. Triassic spores and pollen, in: Jansonius, J., McGregor, D.C.
836 (Eds.), 2nd edition. *Palynology: Principles and Applications*, 2. American
837 Association of Stratigraphic Palynologists Foundation, pp. 755–766.
- 838 Weems, R.E., Olsen, P.E., 1997. Synthesis and revision of groups within the Newark
839 Supergroup, eastern North America. *North America. Geol. Soc. America Bull.*,
840 109, 195–209.
- 841 Whiteside, J.H., Olsen, P.E., Kent, D.V., Fowell, S.J., Et-Touhami, M., 2007.
842 Synchrony between the Central Atlantic magmatic province and the Triassic–

Formatted: French (France)

843 Jurassic mass-extinction event? *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 244,
844 345–367.

845 Whiteside, J.H., Olsen, P.E., Kent, D.V., Fowell, S.J., Et-Touhami, M., 2008.
846 Synchrony between the Central Atlantic magmatic province and the Triassic–
847 Jurassic mass-extinction event? Reply to comment of Marzoli et al. 2008,
848 *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, 262, 194–198.

849 Williford, K. H., Ward, P. D., Garrison, G. H., Buick, R. 2007. An extended organic
850 carbon-isotope record across the Triassic–Jurassic boundary in the Queen Charlotte
851 Islands, British Columbia, Canada. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 244,
852 290–296.

853 Yang, Z., Moreau, M-G., Bucher, H., Dommergues, J-L., Trouiller, A., 1996.
854 Hettangian and Sinemurian magnetostratigraphy from Paris basin. *Journal of*
855 *Geophysical Research*, B101, 8025–8042.

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857

858 **Figure captions**

859 Fig. 1 Distribution of the CAMP in the lower Mesozoic. Eu: Europe (Southern Portugal
860 and Spain); Af: Africa (from Morocco to Ivory Coast); SA: Southern America (Brazil,
861 Bolivia and Guyana); ENA: Eastern North America (USA and Canada); (left) distribution
862 of the main rift basins in eastern North America and Morocco. Ne: Newark; Hr: Hartford;
863 De: Deerfield; Fu: Fundy; Ar: Argana; HA: High Atlas; Ou: Oujda

864

865 Fig. 2 Stratigraphic correlations, compiled from literature, among the main Newark
866 Super Group basins in the eastern North America (USA and Canada). These elongated
867 asymmetric basins, formed as a consequence of the rifting that led to the formation of the

868 Atlantic Ocean, filled with very thick successions of continental sediments interlayered
 869 with tholeiitic basalts and intruded by sills and dykes. HMDN BSLT: Hampden basalt;
 870 TLCT : Talcott S.B. Mb: Scots Bay Memberformational nomenclature and the group–
 871 level stratigraphy are referred to Weems and Olsen (1997). Not to scale

872

873 Fig. 3 Study area in the Fundy basin (Nova Scotia); a) the studied section at Partridge
 874 Island: the Blomidon Formation is overlain by the North Mountain basalt with a
 875 stratigraphic contact; b) The Scots Bay section: the stratigraphic boundary between the
 876 North Mountain basalt (bottom) and the lacustrine deposits of the Scots Bay Mb.; c) the
 877 North Mountain basalt ; d) Geologic sketch of the Fundy basin area and location of the
 878 studied sections: Partridge Island section (45.22.09 N; 64.20.11. W) (star); Scots Bay
 879 (rhombus).

880

881 Fig. 4 Distribution range of the main sporomorphs. 4a)palynological assemblage from
 882 Blomidon Formation at Partridge Island section; 4b) palynological assemblage from the
 883 lowermost part of the Scots Bay Member; the dotted line indicates the previous
 884 established Tr-J boundary (Fowell and Traverse, 1995; Whiteside et al, 2007).

885

886 Fig. 5 Palynological assemblage from the Blomidon Formation (PI) and Scots Bay
 887 Member (SB); A) *Patinasporites densus* (Leschik) Scheuring 1970, sample PI45(4)
 888 England Finder coordinates (E.F.c.) S36(1), B) *P. densus*, PI55(4) E.F.c. W36(3), C) *P.*
 889 *densus*, PI55(4) E.F.c. K42, D) *Glyscopollis meyeriana* (Klaus) Venkatachala 1966,
 890 PI45(4) E.F.c. R33, E) *Conbaculatisporites mesozoicus* Klaus 1960, PI30(2) E.F.c. P34,
 891 F) *G. meyeriana*, PI45(4) E.F.c. O24(1), G) *Classopollis torosus* (Reissinger) Couper
 892 1958, PI45(4) E.F.c. S46, H) *C. torosus*, PI45(4) E.F.c. R29(4), I) *Cycadopites* sp.,

893 PI55(3) E.F.c. N44(1), J) *C. torosus*, PI55(3) E.F.c. H28(4), K) *C. torosus*, PI45(4)
894 E.F.c. L42(1), L) *Corollina murphyae* Cornet et Traverse 1975, PI45(4) E.F.c. L50, M)
895 *C. murphyae*, PI45(4) E.F.c. X38(1), N) *Calamospora mesozoica* Couper 1958, PI45(4)
896 E.F.c. P38(1), O) *Converrucosporites cameroni* (de Jersey) Playford and Dettmann
897 1965, PI45(4) E.F.c. U40(3), P) *Alisporites parvus* de Jersey 1962, PI45(4) E.F.c. J31,
898 Q) *Carnisporites spiniger* (Leschik) Morbey 1975, PI20(4) E.F.c. V33, R) *A. parvus*,
899 PI45(3) E.F.c. V52(2), S) *A. parvus*, SB2(2) E.F.c. H40(3), T) *Lunatisporites rhaeticus*
900 Leschik, 1955, SB2(1) E.F.c. G47(1), U) *Platysaccus* sp., SB2(2) E.F.c. F33(3/4); V) cf.
901 *Lunatisporites acutus*, SB2(2) E.F.c. L34(1); W) *Lunatisporites acutus*, Leschik, 1956
902 emend. Scheuring, 1970, SB2(2) E.F.c. E44(3/4); X) undetermined circumpolloid, SB2(2)
903 E.F.c. L39(2).

904

905 Fig. 6 Quantitative analysis of the palynofacies across the Blomidon Formation. Type and
906 amount of organic debris show sensible variations through the section: palynofacies
907 enriched in amorphous organic matter (c) are scarce and present only in the basal gray
908 mudstone; sporomorphs (b) are present, although in different percentage, in the whole
909 succession with a peak in correspondence of a dark grey mudstone, few centimetre below
910 the presumed Tr-J boundary of Whiteside et al., 2007; palynofacies dominated by
911 intertinite (a) are common, showing a peak in abundance in the lower and upper part of
912 the sampled section, where sporomorphs are absent and/or strongly degraded and
913 oxidised.

914

Figure

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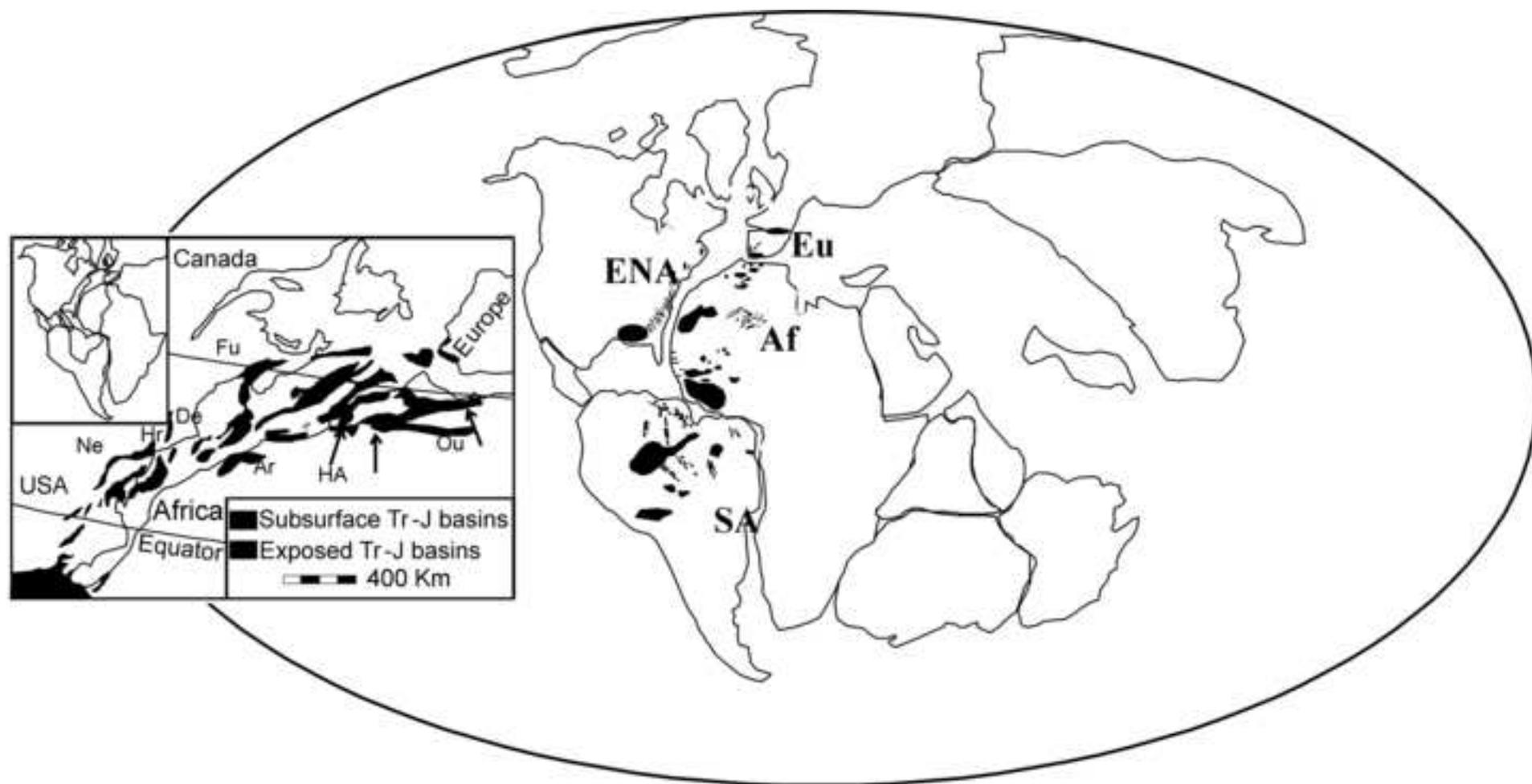
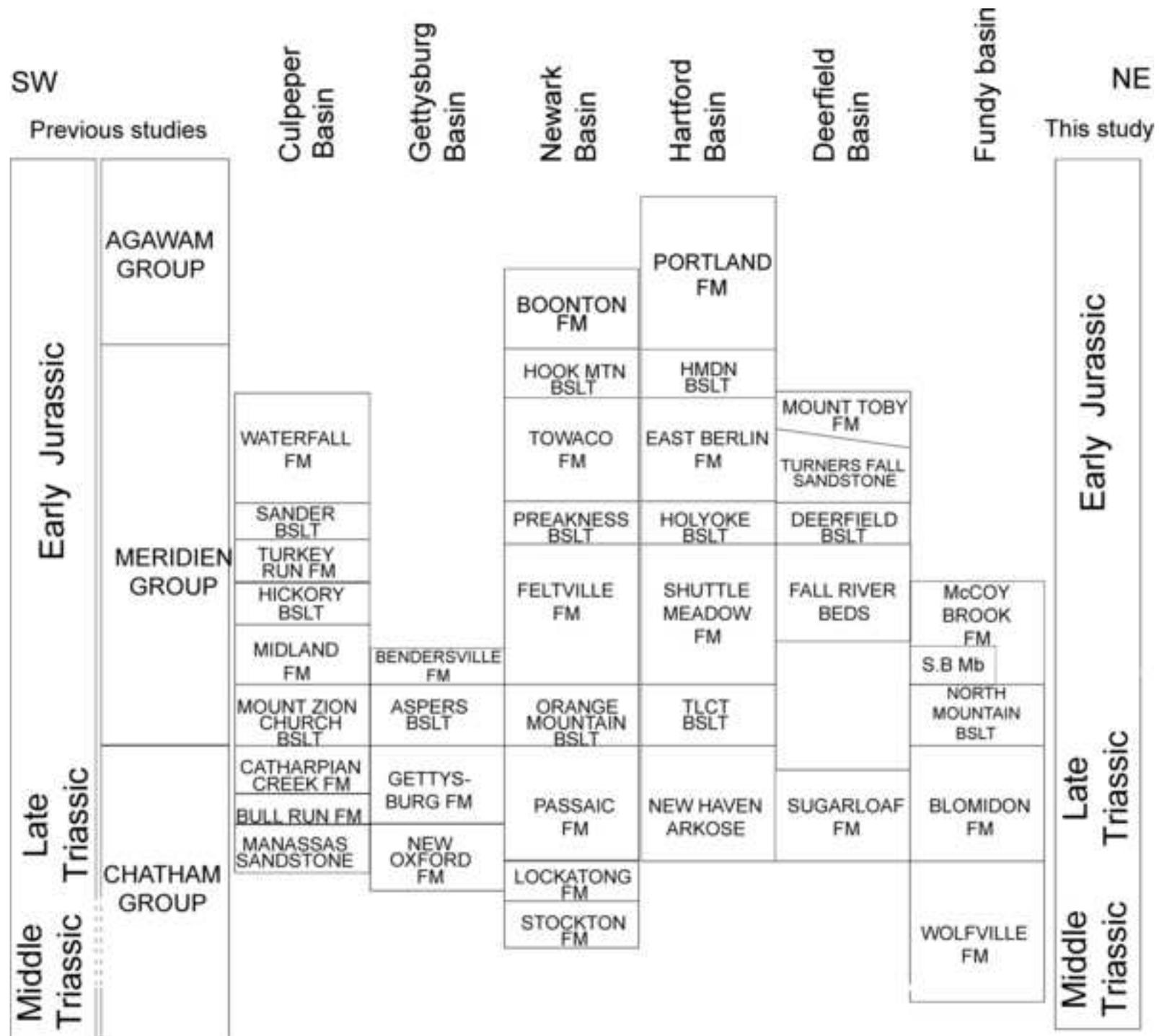


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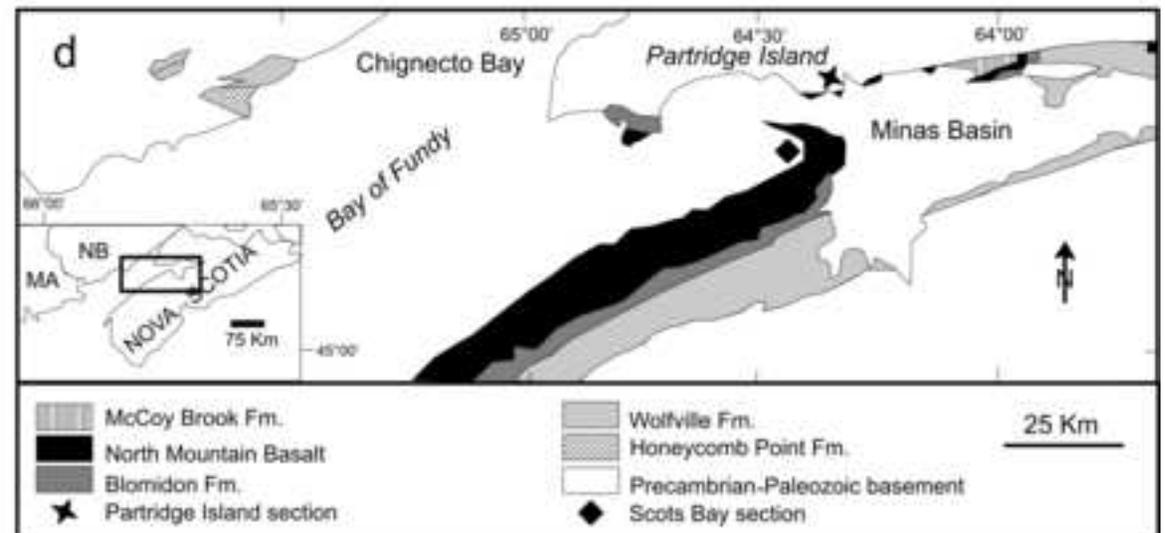


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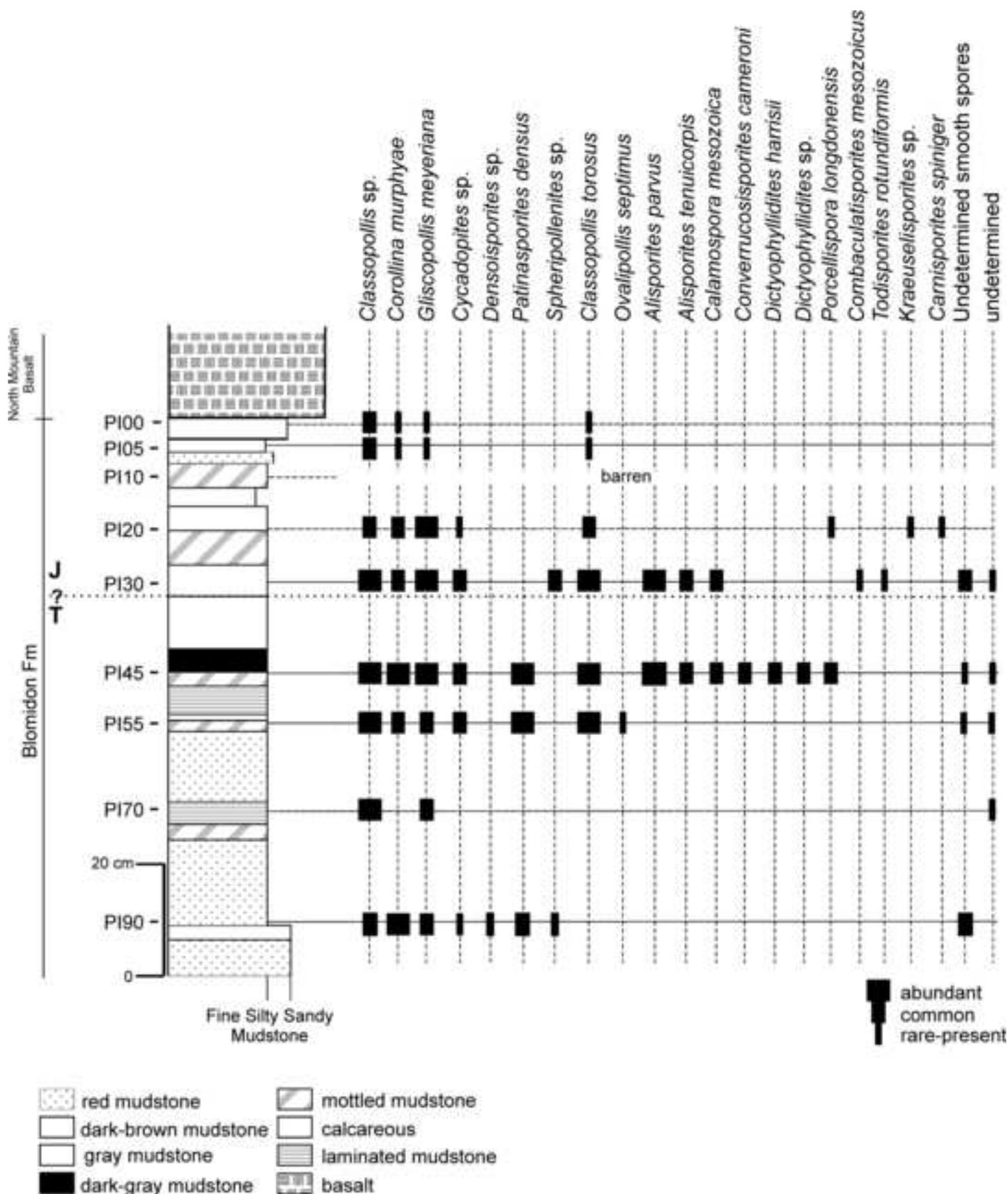


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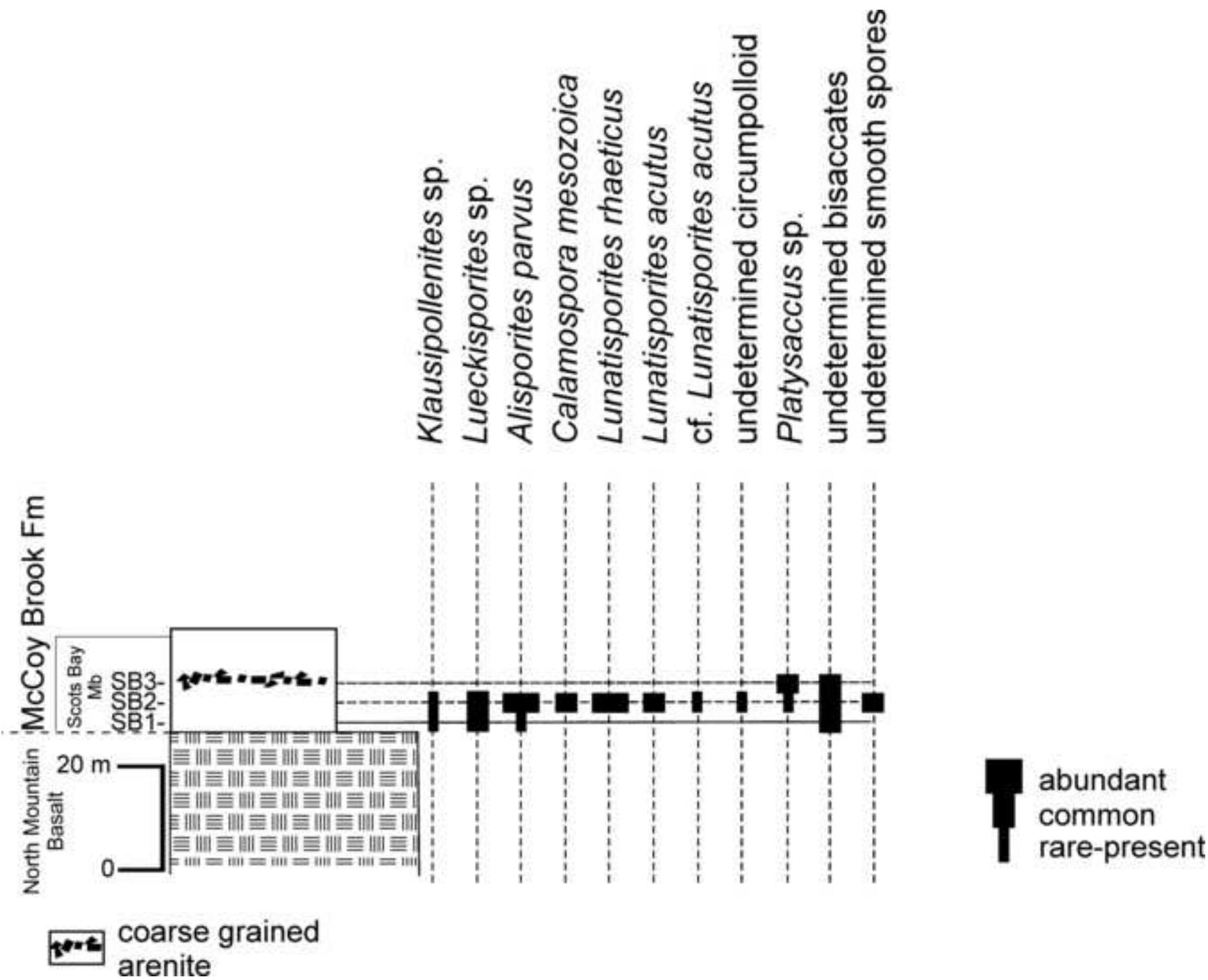


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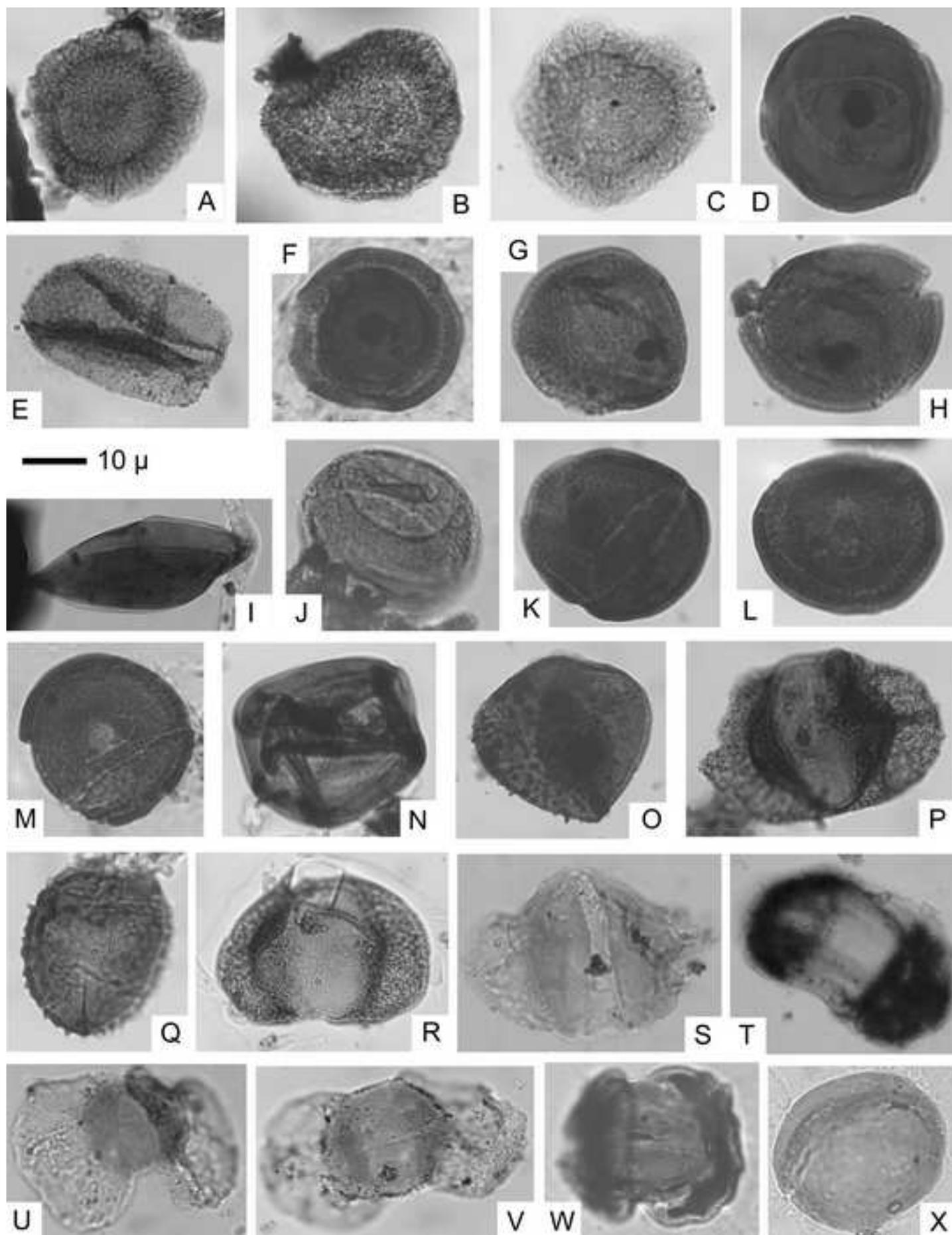
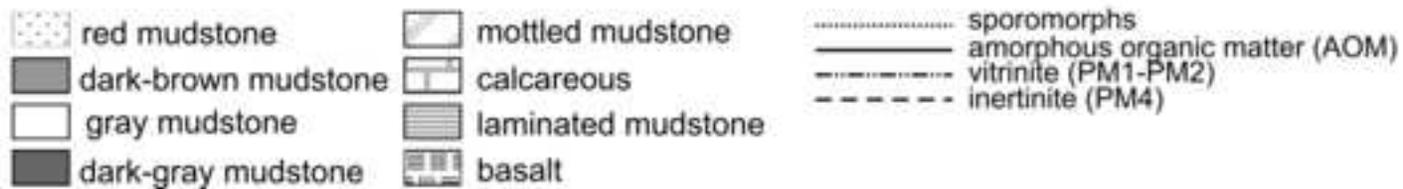
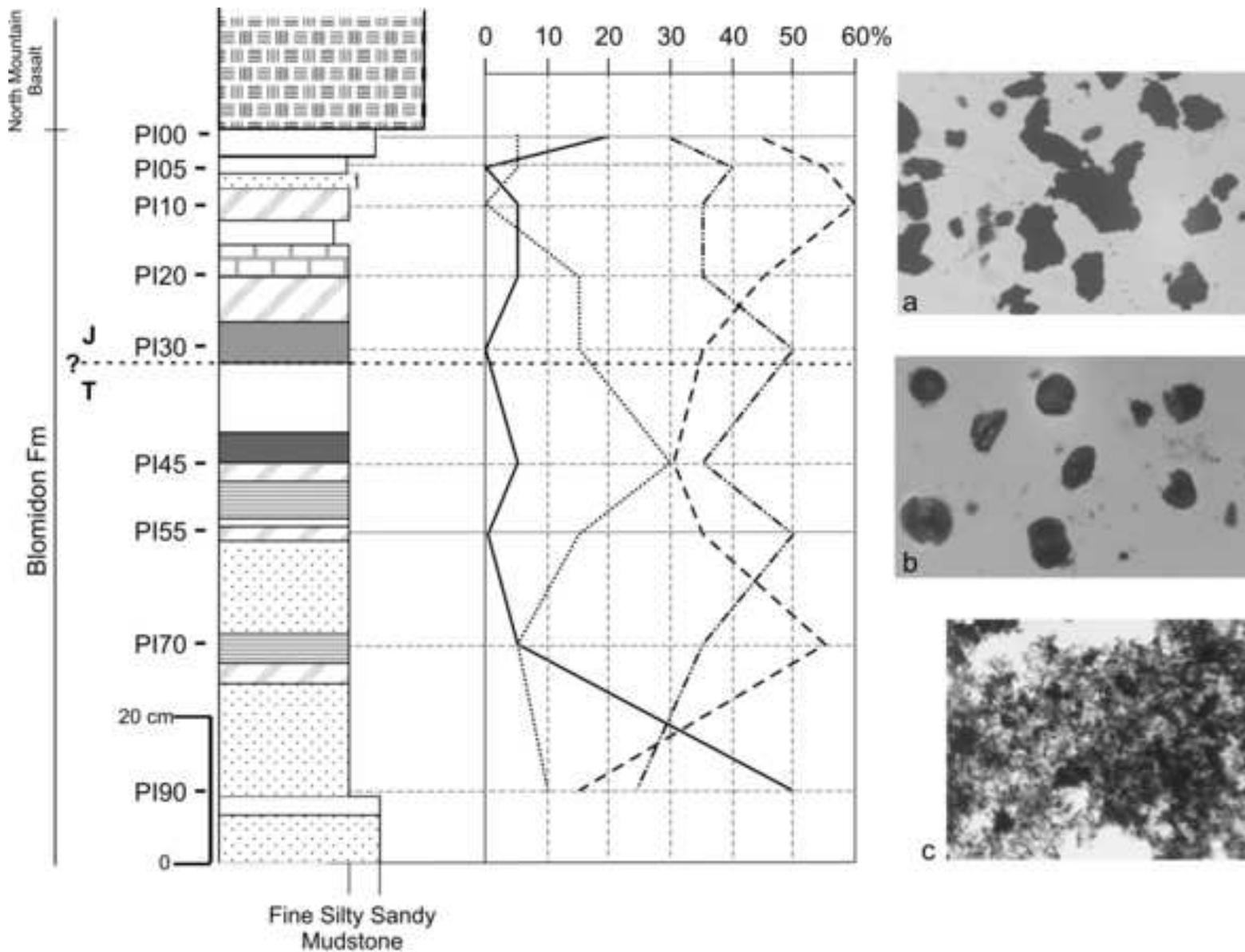


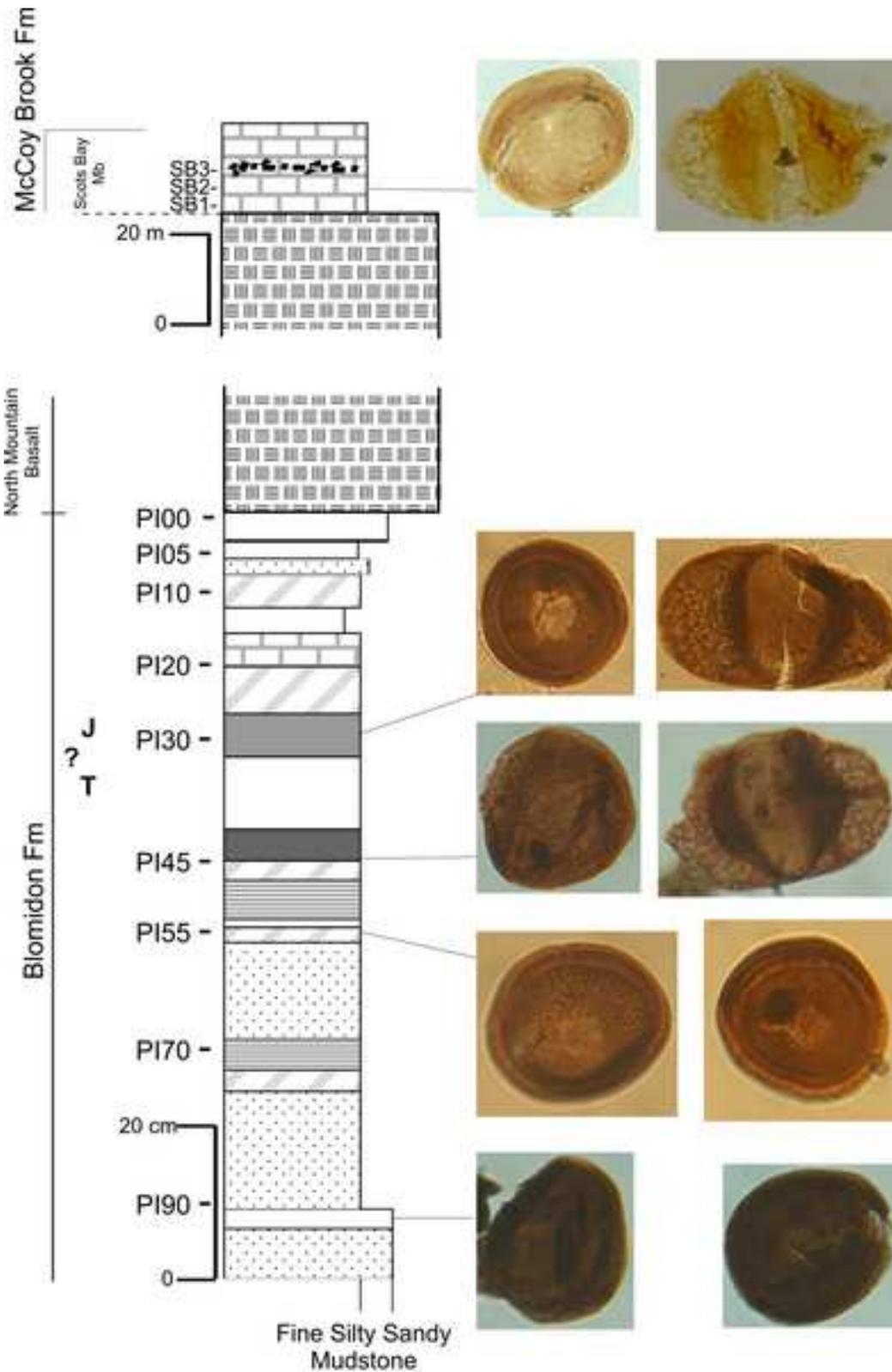
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	origin	group	constituent	approx. coal maceral equiv.
ALLOCHTHONOUS CONTINENTAL FRACTION	higher plant debris	phytoclads	PM4	Inertinite
			PM1-PM2	Vitrinite
			PM3	Cutinite
	pollen and spores	sporomorphs	saccates	Sporinite
			non-saccates	
	degraded plant debris	amorphous phytoclads	non-fluorescent AOM	Vitrinite
		amorphous organic matter (AOM)		



- | | | | |
|--|------------------------|--|--------------------|
| | red mudstone | | mottled mudstone |
| | dark-brown mudstone | | calcareous |
| | gray mudstone | | laminated mudstone |
| | dark-gray mudstone | | basalt |
| | coarse grained arenite | | |

