Research Article

HALOBIA AUSTRIACA IN NORTH AMERICA WITH A REAPPRAISAL OF ITS DISTRIBUTION ACROSS THE CARNIAN-NORIAN BOUNDARY INTERVAL AT BLACK BEAR RIDGE (NORTHEASTERN BRITISH COLUMBIA, CANADA)

Christopher A. McRoberts

Geology Department, State University of New York at Cortland, Cortland, NY 13045, USA;
Email: mcroberts@cortland.edu

Abstract – The pelagic pterioid bivalve *Halobia austriaca* occurs most commonly in earliest Norian deep-marine facies in the Tethyan and circum-Panthalassan realms, including the candidate GSSPs at the Pizzo Mondello (Sicily) and at Black Bear Ridge (British Columbia, Canada) and other localities in Haida Gwaii (western British Columbia), southern Alaska, California and Oregon and questionably in Arctic Alaska. Reported occurrences of *H. austriaca* from other North American localities are shown to be either misidentifications or based on specimens too poorly preserved for identification. Previous work on the halobiid biostratigraphy at Black Bear Ridge suggested a first occurrence of *H. austriaca* from bed 18f, at a position coinciding with a major conodont turnover between the lower and middle subdivisions of the *Metapolygnathus parvus* Subzone of the *Primatella primitia* conodont Zone, and several meters below the traditionally Norian ammonoid zone of *Stikinoceras kerri*. Reappraisal of *H. austriaca* from Black Bear Ridge now places the lower occurrence of the species from bed 22. This revised datum integrated with ammonoids and conodonts, provides for a more parsimonious correlation with the basal-Norian GSSP candidate section at Pizzo Mondello and elsewhere across Panthalassa and Tethys.

INTRODUCTION

The Carnian-Norian boundary is one of several stage boundaries of the Triassic System that remains to be defined with a Global Stratotype Section and Point (GSSP). Following years of activity within the Subcommission on Triassic Stratigraphy (STS) and its base-Norian Working Group, several base-Norian GSSPs have been variously proposed. Recent proposals include: (1) the first occurrence datum (FOD) of the conodont of *Metapolygnathus parvus* Kozur, 1972 as supported by Mazza et al. (2018), (2) the last occurrence (LOD) of the same conodont species as supported by Mazza et al. (2012) and Orchard (2019), and (3) the FOD of the pelagic bivalve *Halobia austriaca* Mojsisovics (1874) as supported by Krystyn (2010), Levera and McRoberts (2010), McRoberts & Krystyn (2011), Balini et al. (2012) and Levera (2012). These datums are recognized in the two proposed GSSP stratigraphic sections: Pizzo Mondello (Siciani Basin, Sicily) and Black Bear Ridge (Western Canada Sedimentary Basin, British Columbia, Canada). Quite recently (July, 2021), the base-Norian Working Group completed the preliminary rounds of balloting selecting the FOD of the bivalve *Halobia austriaca* from bed 135 at the Pizzo Mondello section of Sicily. If the FOD of *Halobia austriaca* at Pizzo Mondello is ultimately chosen, it would represent only the third Phanerozoic GSSP defined by a bivalve mollusc, the others being Cretaceous inoceramids *Platyceramus undulatoplicatus* defining the base of the Santonian (Lamolda et al., 2014) and *Cremnoceramus deformis erectus* which was recently approved by the Subcommission on Cretaceous Stratigraphy to define the base of the Conacian Stage and is currently being evaluated by the International Commission on Stratigraphy.

The initial advocation of *Halobia austriaca* as a defining datum for the basal Norian (Krystyn, 2010, Levera and McRoberts 2010) did not proffer any particular stratotype. In a poster presentation at the Canadian Paleontology Conference, McRoberts and Krystyn (2011) proposed the FOD of *Halobia austriaca* at the Black Bear Ridge section along the north shore of Williston Lake (British Columbia, Canada) as a potential datum for the basal Norian GSSP. This proposal was largely based on the recently completed monograph of Late Triassic Bivalvia

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from the Williston Lake area (McRoberts, 2011). McRoberts (2011) and McRoberts and Krystyn (2011) proposed the first occurrence *Halobia austriaca* in bed 18f of the Black Bear Ridge section as the primary marker defining the basal Norian GSSP. Since 2011, work on the halobiids from the Williston Lake area and elsewhere from North America has continued at a slow pace, yet has resulted in a re-evaluation on the taxonomic status and occurrence of *H. austriaca*. This report, therefore, provides a summary of the current status of *H. austriaca* in light of new and revised findings from Black Bear Ridge and other North American localities that have direct bearing on the position and choice of *H. austriaca* for a basal Norian GSSP.

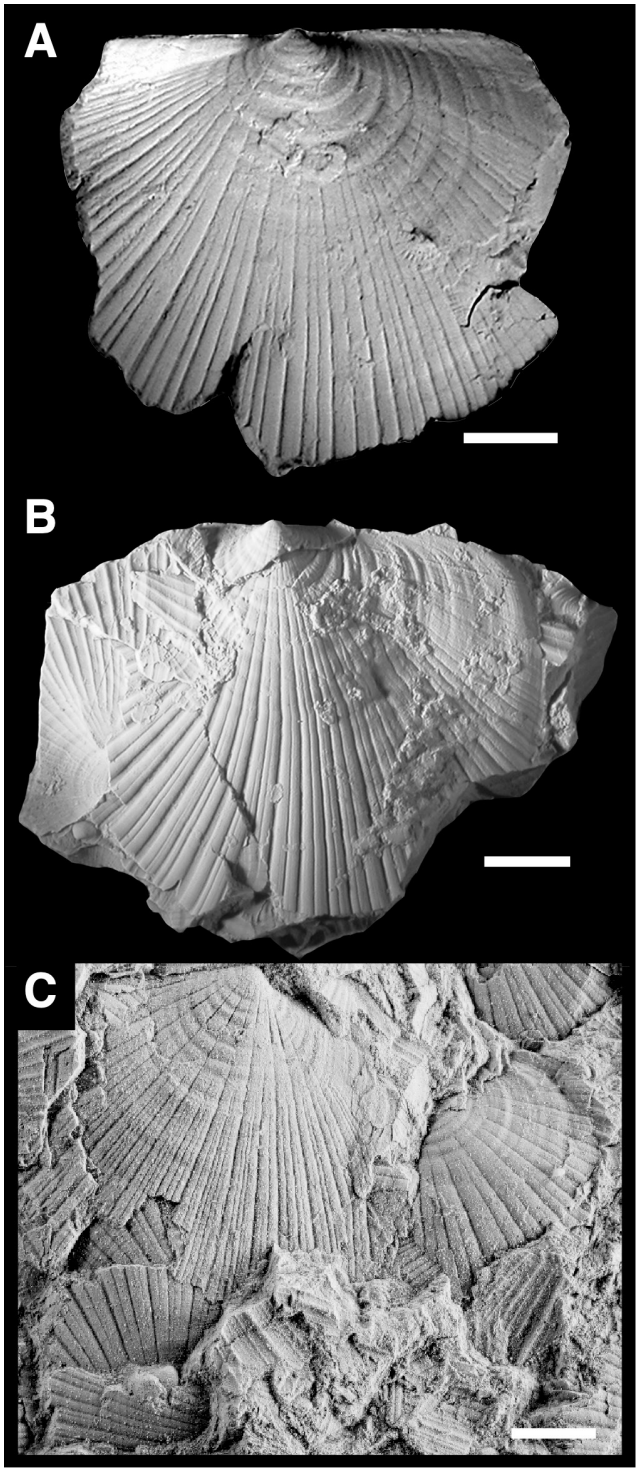

Figure 1 – **A**, *Halobia austriaca* Lectotype, a RV, from Mojsisovics (1874, pl. 4, fig. 3), Raschberg, Austria; **B**, *Halobia austriaca* Paratype, Mojsisovics, (1874, pl. 4, fig. 1), Raschberg, Austria; **C**, slab of *Halobia austriaca* from Feuerkogel Section F1-E, Austria (McRoberts unpubl. collection). Scale bars = 1 cm.

On the taxonomic status of *Halobia austriaca* and implications for regional and global correlation

Halobia austriaca is one of the most ubiquitous halobiid species, with significant occurrences reported from across the western Tethys (e.g., Austria, Italy, Bosnia-Herzegovina) and in both eastern and western Panthalassa (e.g., China, New Zealand, Timor, Japan, Canada, USA). The species was introduced by Mojsisovics (1874) who described and illustrated four specimens from what is now considered lower Norian (Lac 1) strata of the Hallstatt Limestone of Raschberg, Pötschenstein, and Röthelstein, Styria Austria. Although no type specimen was originally identified, Campbell (1994) designated one of Mosjsisovics' original specimens (GBA 1874/01/3; Mojsisovics, 1874, pl. 4, fig. 3) from Raschberg as the lectotype. Mojsisovics' (1874) types of *H. austriaca* and additional specimens from the nearby Feuerkogel locality are illustrated in Figure 1.

Since Mojsisovics introduced the species, *Halobia austriaca* has been described from more than 50 localities and seen several major taxonomic reviews and revisions. Although a complete review of all available literature of on the taxonomic position and stratigraphic and geographic distribution of *H. austriaca* is beyond the scope of this report, it is relevant to mention some of the major publications which impact on the taxonomic status of the species and its geographic and temporal distribution within biostratigraphically-controlled stratigraphic sections. Following introduction of the species by Mojsisovics (1874), several significant taxonomic works on *H. austriaca* have been published from Western Tethys including: Austria (Kittl, 1912; Gruber 1977); Bosnia-Herzegovina (Gruber, 1975); Italy, including the Apennines (De Capoa Bonardi, 1970) and Sicily (Cafiero and De Capoa Bonardi, 1982; Levera, 2010, 2012). In the eastern Tethys and western Panthalassa, *H. austriaca* is known from Timor (Krumbeck, 1924), and New Zealand (Campbell, 1994). From northeastern Russia, several early publications (e.g., Kiparisova, 1947; Vozin and Tikhomirova, 1964; Bychkov et al., 1976) noted and discussed the occurrence of *H. austriaca*. In North America, *H. austriaca* was first reported and reviewed by Smith (1927) from localities in California and Alaska and more recently by McRoberts (2011) from northeastern British Columbia.

Beginning with Mojsisovics (1874) and prior to the 1970s, *H. austriaca* was most often considered to be of late Carnian age. This was in part due to Mojsisovics' (in Mojsisovics et al., 1885) temporal inversion of the Carnian and Norian stages in the Hallstatt area of Austria, and also in part due to lack of co-occurring ammonoids in *H. austriaca*-bearing strata across the western Tethy's. More recent publications (e.g., Gruber, 1975, 1976, 1977; Cafiero and De Capoa Bonardi, 1982; Levera, 2010, 2012; McRoberts, 2010, 2011) the species is considered to

straddle a Carnian-Norian boundary or positioned it within the basal Norian (within the *Guembelites jandianus* or *Stinkinoceras kerr*i ammonoid zones and equivalents).

At present, a species-level phylogenetic series including *Halobia austriaca* has not been demonstrably determined by authorities in part because morphologic traits used to define and describe halobiid species appear to exhibit mosaic and homoplastic tendencies across the history of the genus. Gruber (1977) proposed that *H. austriaca* was descendant from an as yet unknown species (itself derived from *Halobia bithynica*) sometime in the Late Carnian. Given a lack of likely immediate ancestor for *H. austriaca* in the western Tethys where *H. austriaca* may be an immigrant, it is plausible that potential ancestors could be found in the Panthalassic realm. One possible candidate ancestor is *Halobia selwyni* whose numerous similarities with *H. austriaca* are striking (see below) and is known to occur in an appropriate stratigraphic position immediately below and co-occurring with *H. austriaca* in the Black Bear Ridge section of Williston Lake. Other potential ancestors of *H. austriaca* are certainly possible and can be chosen from within the several species groups that include *H. austriaca* (e.g., Gruppe der *Halobia rarestriata* of Mojsisovics (1874); Gruppe der *Halobia austriaca* of Kittl, 1912; Reihe der *Halobia austriaca* of Gruber 1977). Even other Halobia species outside of these informal groups, including those that possess a growth-stop (deflection in ribs), such as *H. brooksi*, cannot be ruled out.

On the relationship between *Halobia austriac*a and potential synonymous species

As introduced above, the taxonomic status of *Halobia brooksi* and its potential affinity to *Halobia austriaca* is of significance in the position of potential halobiid datums in the selection of a basal Norian GSSP and inter-regional correlations. Smith (1927, pl. 99, figs. 7–9) described and illustrated three specimens from the Kuskulana River area of the Wrangell Mountains of southern Alaska which served as the basis for his new species *Halobia brooksi*. The primary criterion for differentiation between the two species as stated by Smith (1927) is the presence of a deflection in the radial ribs (here termed growth-stop) in *Halobia brooksi* whereas in *H. austriaca*, the ribs run relatively straight or are only slightly curved anterior in their course. The illustrated *H. brooksi* of Smith (1927, pl. 99, figs. 7–9) show an apparent growth-stop positioned approximately 20–25 mm from the beak. While the specimens exhibit some signs of taphonomic crushing/fracture, the growth stop in these specimens is apparently not an artifact. Apart from the possible growth-stop, the types *H. brooksi* appear superficially similar to *H. austriaca* in outline, posterior and anterior triangular fields, auricles, and radial rib profile. These similarities, however, fail to be confirmed upon closer inspection in finer details. McRoberts (2011) concluded that *H. brooksi* differs from H. austriaca in possessing a shallower anterior triangular field (23° for *H. brooksi* versus about 30° for *H. austriaca*) and perhaps more importantly in the rib bundling. The external ribbing of *H. brooksi* is strongly bundled by up to 10 fine riblets whereas *H. austriaca* generally maintains simple division into secondary and sometimes tertiary ribs of somewhat equal strength. Furthermore, Smith (1927) stated that ribbing was somewhat coarser in *H. brooksi* than in *H. austriaca*, although such a claim is not borne out in his illustrated specimens given that the holotype of *H. brooksi* (Smith, 1927, pl. 99, fig. 7) has demonstrably finer and more densely-packed ribs than several of his specimens assigned to *H. austriaca* (pl. 99, figs. 11, 12) as well as from the original *H. austriaca* of Mojsisovics (1874). Even though knowledge on the range of morphologic variation of *H. brooksi* in North America is poorly known, this species possesses a distinctive morphology and is maintained as a separate species distinct from *H. austriaca*.

Gruber (1975, 1977) synonymized several previously named species possessing a growth-stop, including *Halobia brooksi*, into an expanded concept of *H. austriaca*. By doing so (and explicitly stated in Gruber 1976) Gruber concluded that the presence of a growth-stop by itself should not be considered a character of species-level significance. Gruber (1975) synonymized *H. ocevljana* of Kittl (1912, text-fig. 36 and pl. 7, fig. 22) from the Ocevlja locality in Bosnia-Herzegovina into *H. austriaca*. This was reaffirmed in his 1977 thesis in which he also included *H. brooksi* in his synonymy of *H. austriaca*. Both synonymies were followed by Cafiero and De Capoa Bonardi (1982) and later Campbell (1994) without comment. Gruber (1975, pl. 3, figs. 1-4), illustrated four specimens assigned to *H. austriaca* from the lower Norian (Lac 1) in the Dragulac and Ocevlja sections in Bosnia-Herzegovina of which one was Kittl's original specimen of *H. ocevljana* (Kittl, 1912 pl. 7, fig. 22). These specimens appear to show a growth-stop and deflection of radial ribs in spite of signs of taphonomic fracture and deformation. As with North American *H. brooksi*, it is here maintained that synonymy of *H. ocevljana* into *H. austriaca* is not warranted.

Additional consideration of *Halobia austriaca* and its potential synonymies in northeastern Russia are also relevant. As noted by Alexey Konstantinov (communication to the base Norian task group, August 2020), *H. austriaca* has been cited to occur in northeastern Russia multiple times with occurrences in the Yana, Indigirka, and Kolyma River basins. Of particular importance is that the species has been assigned to the upper Carnian *Sirenites yakutensis* ammonoid Zone (e.g., Kiparisova, 1947; Vozin and Tikhomirova, 1964; Bychkov et al., 1976), but has not been confirmed by more recent publications (e.g., Polubotko, 1984, 1986, 1988, 2005; Polubotko et al., 1990). It is relevant that Polubotko (1986, p. 68) synonymized northeast Russian *H. austriaca* that was previously illustrated in Bychkov et al. (1976, p. 44, figs. 6-8) into her new species *Indigirohalobia kilganaensis*. In her zonal chart, Polubotko (1986, p. 65) listed both *Indigirohalobia kilganaensis* and *Zittelihalobia brooksi* (= *Halobia brooksi* herein) as occurring in the lower subzone of the *Sirenites yakutensis* ammonoid zone below the upper subzone of *Sirenites yakutensis* which was deemed equivalent to *Anatropites* bearing strata of North America. In Polubotko (2005), both *Primahalobia kilganaensis* (presumably the same taxon as *H. austriaca* of Bytchkov et al., 1976) and *Indigirohalobia* (*Popowihalobia*) *brooksi* (= *Halobia brooksi* herein) were listed as indices of the *Indigirohalobia* (*Popowihalobia*) *asperella* zone which spans a Carnian-Norian boundary interval and is the equivalent to the *Sirenites yakutensis*, *Striatosirenites kedonensis* and *Striatosirenites*

kinasovi ammonoid zones. This position (in Polubotko, 2005) appears to extend into somewhat younger ages than that suggested by earlier zonal schemes (e.g., Polubotko, 1986) which relegated *H. austriaca*-like forms to the just the *Sirenites yakutensis* zone.

NORTH AMERICAN *HALOBIA AUSTRIACA*

Given the importance of *Halobia austriaca* in global correlation and particularly its well documented occurrence in candidate GSSP sections, this section provides an assessment and re-evaluation of occurrences of *H. austriaca* as it is known or reported from western North America and in particular its occurrence in the candidate GSSP and likely auxiliary section in western Canada. Across North America, *H. austriaca* has been reported to occur in numerous tectonic settings from tectonostratigraphic terranes to strata affiliated with the Triassic North American craton (Fig. 2). Notably, many of the reported occurrences of *H. austriaca* in North America have not been re-evaluated in light of revised systematic validity since their initial descriptions, and nor have been carefully vetted with respect to stratigraphic position.

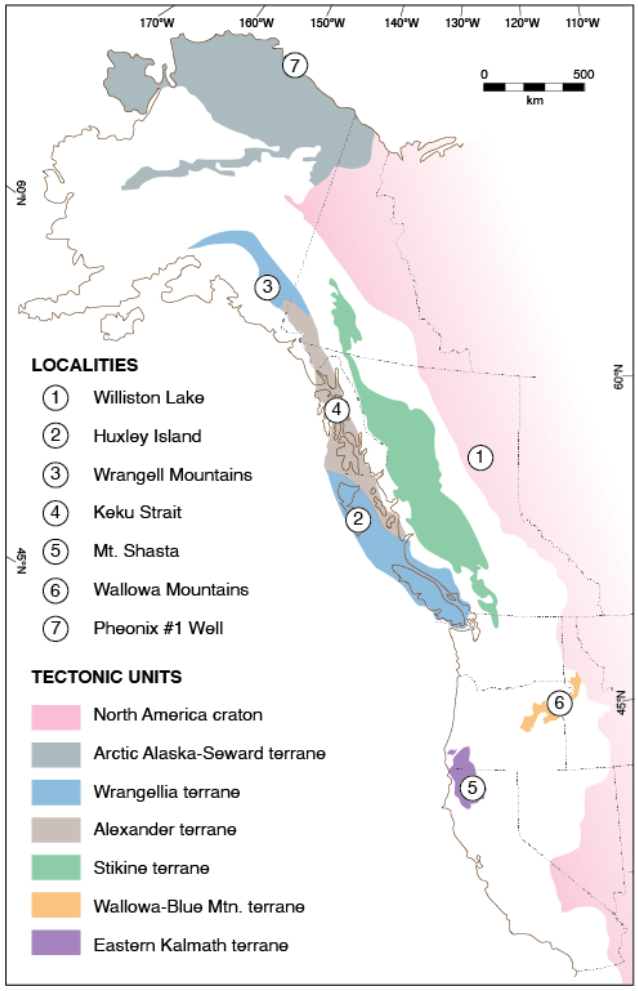

Figure 2 – Simplified map of western North America showing the distribution of several tectonostratigraphic terranes and halobiid localities discussed in text.

Re-evaluation of *Halobia austriaca* from Black Bear Ridge and other localities on Williston Lake

The Black Bear Ridge section lies on the north shore of Williston Lake (Figs. 2–5), 4 km northeast of the mouth of Nabesche River (NTS Map 94 B/3; zone 10, UTM 497670E, 6215500N). The halobiid-bearing Carnian-Norian boundary interval lies within the lower part of the Pardonet Formation and consists of thin to medium-bedded carbonaceous silty limestone, calcareous and dolomitic siltstone and shale likely deposited below fair-weather wave base in deep water setting slope well off the western margin of Pangaea (Zonneveld et al., 2010). Although stratigraphical, sedimentological and geochemical attributes of Carnian-Norian interval part of the Black Bear Ridge section and those of the nearby Pardonet Hill and Brown Hill sections can be found elsewhere (e.g., Orchard et al., 2001; Williford et al., 2007; Zonneveld et al., 2010; Onoue et al., 2016; Lei et al., 2021), a summary of section and important biostratigraphical horizons are illustrated in Figure 4.

In McRoberts (2007, 2011) and McRoberts and Krystyn (2011), the lowest occurrence (FOD) of *Halobia austriaca* was listed as occurring in bed 18f in the Black Bear Ridge section. It should be noted that in the Black Bear Ridge section (see Orchard, 2014, 2019), bed 18f occurs approximately 1.7 m above the highest occurrence of the ammonoid *Anatropites* in bed 17, and 30 cm above of the lowest occurrence of *Pterosirenites* sp., a single occurrence of *Griesbachites* and the highest occurrence of *Tropiceltites* sp. in bed 18d. Bed 18f falls within the range of several occurrences of *Gonionotites* sp. Furthermore, this datum also occurs 3.8 meters below the first occurrence of *Guembelites clavatus*, a proxy for the lower part of the *Stikinoceras kerri* Zone sensu Silberling and Tozer (1968) and Tozer (1994). Additionally, a large number of conodont species occur in bed 18f which is within 5 cm above the boundary between the lower and middle subdivisions of the *Metapolygnathus parvus* Subzone of the *Primatella primitia* conodont Zone (Orchard, 2014, 2019). Correlations of the conodont and ammonoid record (Orchard, 2014, 2019) suggest that the *Metapolygnathus parvus* Subzone is equivalent to the uppermost part of the *Klamathites macrolobatus* ammonoid zone — the youngest zone of the traditionally recognized Upper Carnian. Thus, the original determination from Black Bear Ridge (McRoberts, 2011) placed the FOD of *H. austriaca* within beds of the upper part of the *K. macrolobatus* ammonoid zone confirmed with both conodonts and ammonoids.

In the nearly 10 years since the publication of McRoberts (2011) and McRoberts and Krystyn (2011), the author has re-examined the original halobiid material from Black Bear Ridge and studied additional material of *Halobia austriaca* and other halobiid bivalves from the Black Bear Ridge locality and other localities on Williston Lake and elsewhere in North America and Europe. These studies have led me to re-evaluate the stated occurrences and provide a revised succession of the Black Bear Ridge halobiid occurrences.

The results indicate that the two lowest original data points for

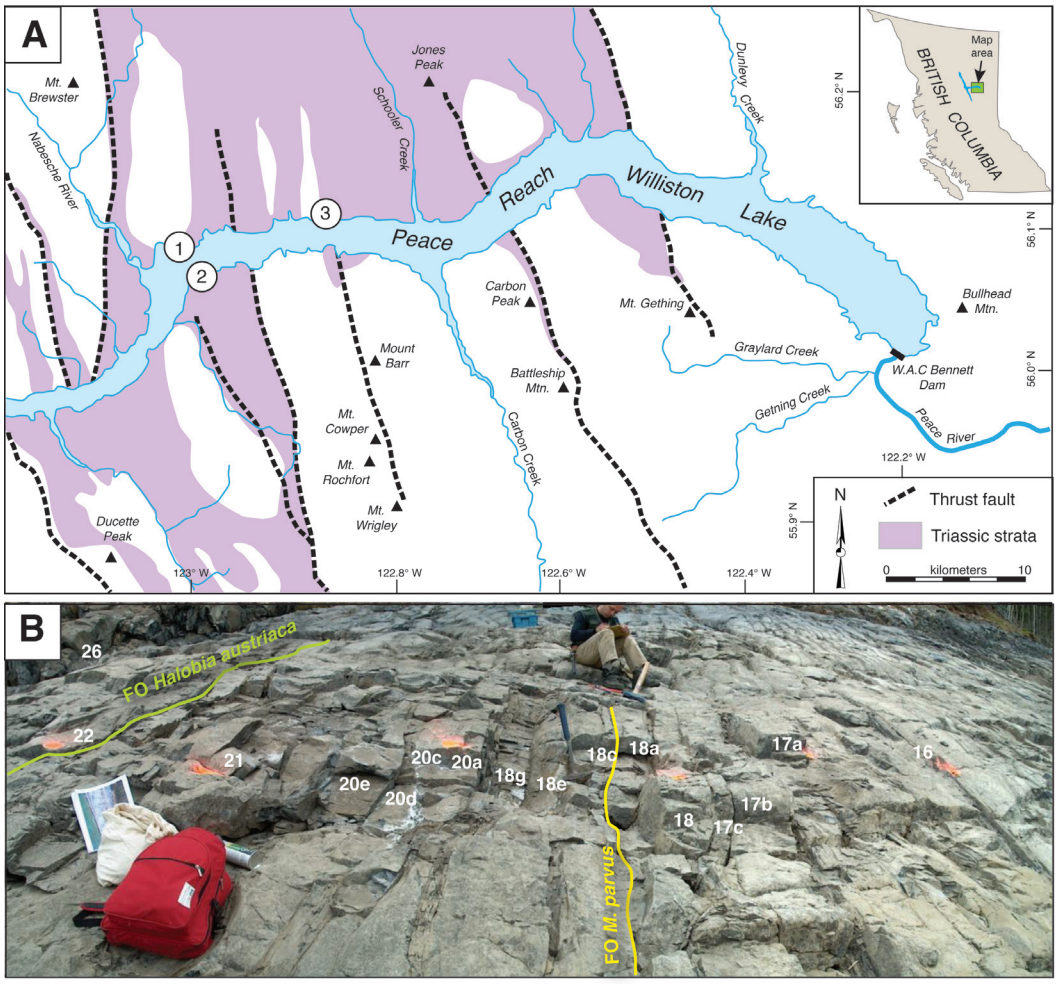

Figure 3 – **A**, Map of eastern Williston Lake area showing localities discussed in text. Numbered localities include 1, Black Bear Ridge; 2, Pardonet Hill East; 3, Borwn Hill. Modified from Zonneveld et al. (2010); **B**, Outcrop map of Black Bear Ridge Carnian-Norian boundary interval. Refer to stratigraphic log (Fig. 4) for bed numbers.

Halobia austriaca from McRoberts (2011), C-307815 (bed 18f) and CM01BBR-4 (bed 21), are based on incomplete specimens that, although shareing similarities with true *H. austriaca*, likely belong to a different *Halobia* species – most likely *H. selwyni*. An undescribed halobiid specimen collected by Mike Orchard from bed 20f (GSC loc. C-307823) within the *Metapolygnathus parvus* Subzone (see attached figure) is typical of the two aforementioned adjacent occurrences (beds 18f and 21), albeit these fragments are somewhat larger and better preserved and suggest closer affinity to *H. selwyni* but with broader and less curved ribs. It should also be noted that there are other confirmed *H. selwyni* from bed 18f (McRoberts, 2011, fig. 18.11) and several additional levels both below and above (beds 18d–24).

Based on the current understanding of halobiids at BBR, the lowest *Halobia austriaca* that can be identified with confidence occurs in bed 22 (McRoberts, 2011, fig. 18.2 and reproduced in Figure 5). It should be further noted that the *H. austriaca* occurrence in bed 22 was listed in McRoberts (2011, figs. 9, 18.2, and Appendix 5) but not included in the range chart of Orchard (2019, fig. 2). Bed 22 occurs approximately 35 cm above base of the *Primatella asymmetrica-Norigondolella* conodont Subzone above the *Metapolygnathus parvus* Subzone and 15 cm below the first occurrence of ammonite *Guembelites clavatus* in bed 22b. It is therefore likely that this level (bed 22) occurs within the lower *S. kerri* ammonoid zone. The revised stratigraphic distribution of halobiid bivalves and key ammonoid and conodont events are shown in Figure 4.

Apart from the Black Bear Ridge section, additional occurrences of *Halobia austriaca* in Williston Lake outcrops provide insight into the first occurrence of this species and possible synonymies. McRoberts (2011, fig. 18.3) illustrated a single small specimen attributed to *H. austriaca* from Brown Hill. Upon re-evaluation, this specimen, is indeed quite similar to *H. austriaca* in many of its features, but possess finer and more densely-packed ribs in its posterior sector atypical of the species and suggest placement into *H. selwyni*. Based this revision, *H. austriaca* remains to be identified from the Brown Hill section.

McRoberts (2011, figs. 18.5, 18.6) illustrated two specimens attributed to *Halobia austriaca* from beds 3 and 4 in Pardonet Hill East section. Although clearly juveniles, these specimens are only questionably assigned to *H. austriaca* and may be better placed into *H. selwyni*. According to Orchard (2014, 2019),

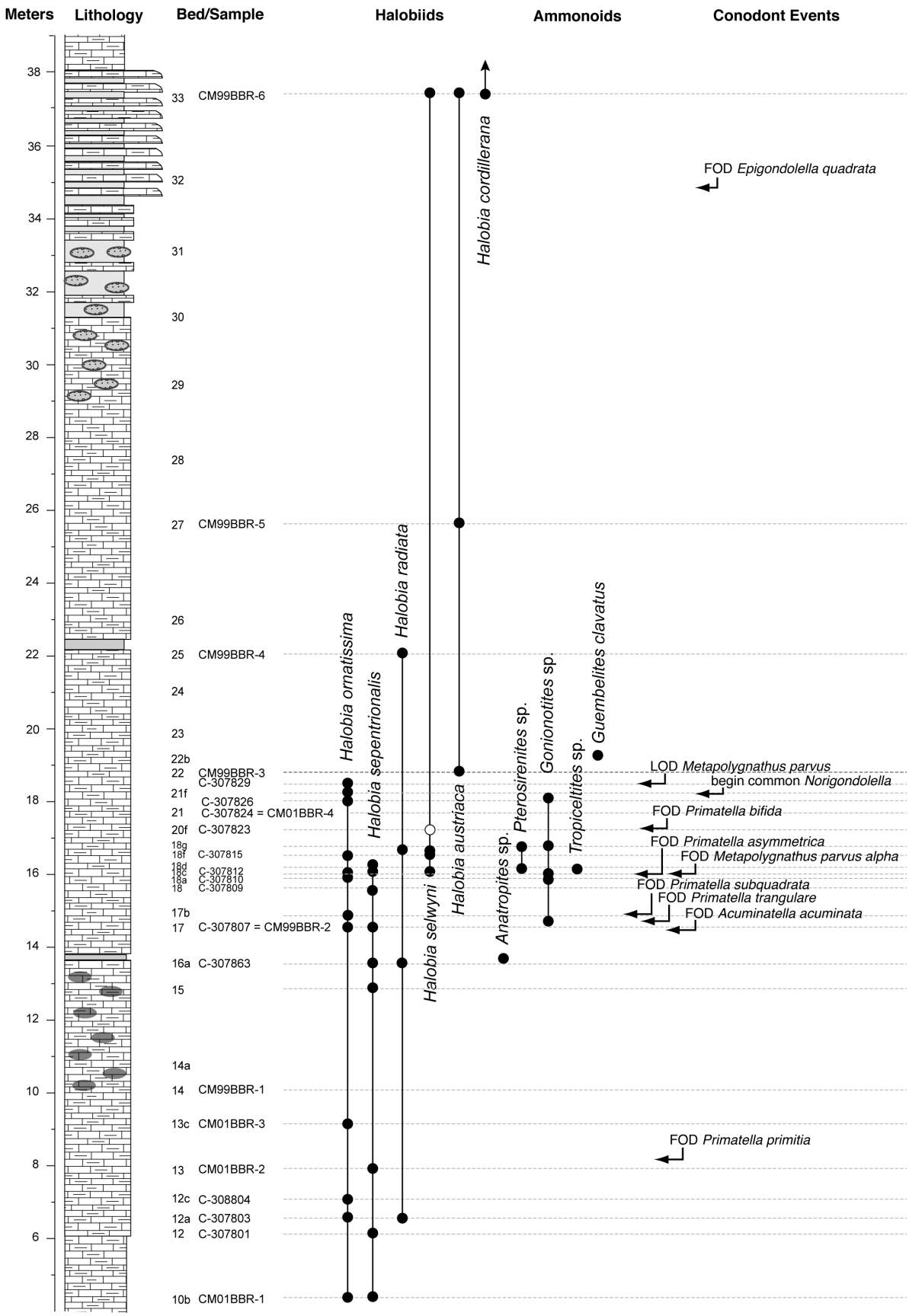

Figure 4 – Revised halobiid biostratigraphy at Black Bear Ridge. Ammonoid ranges and conodont bioevents from Orchard (2014, 2019). FOD = first occurrence datum, FAD = last occurrence datum.

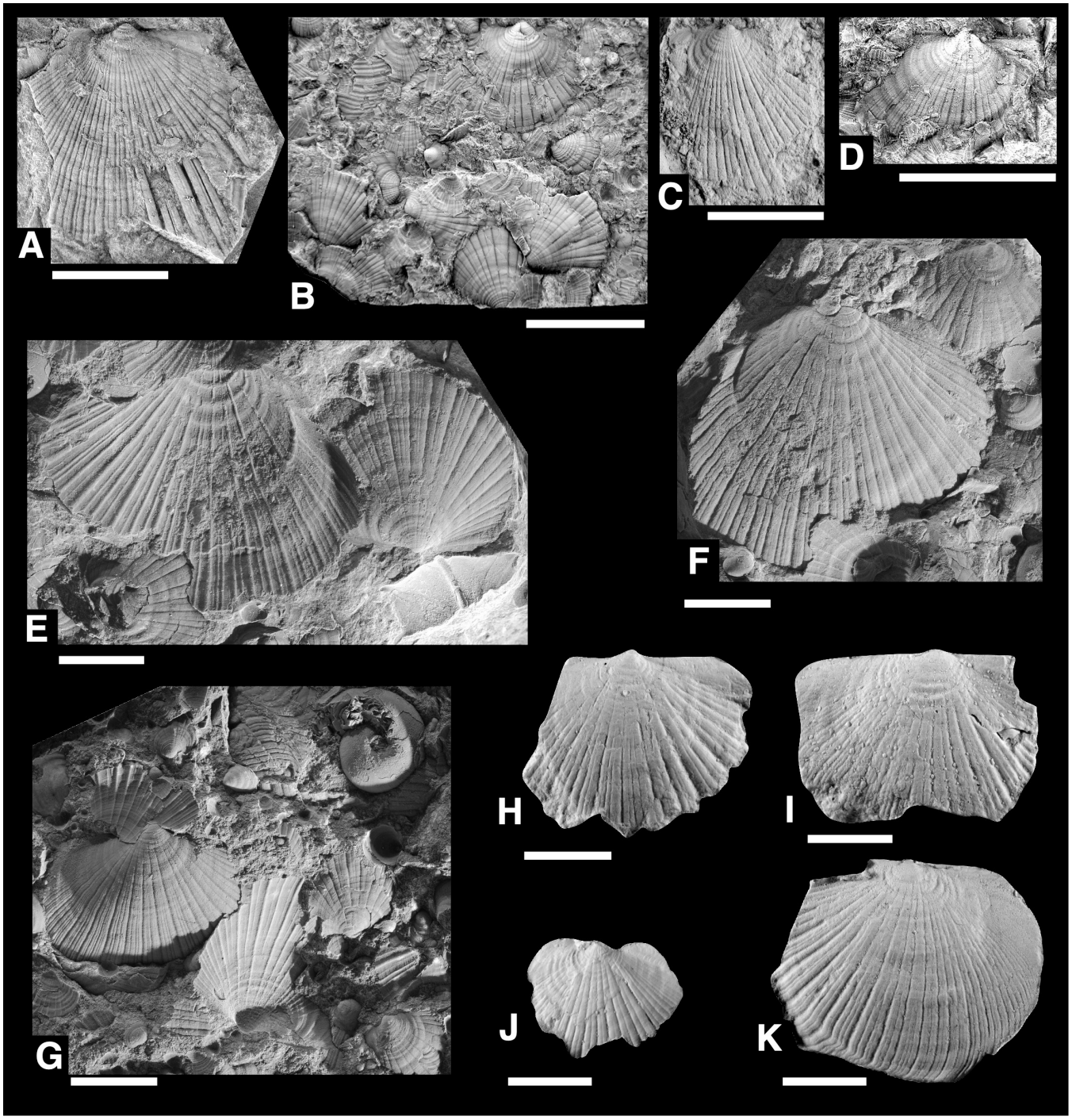

Figure 5 – **A**, *Halobia austriaca*, GSC 132229; Black Bear Ridge bed 27 (from McRoberts, 2011, fig. 18.1); **B**, *Halobia austriaca*, GSC 132230, Black Bear Ridge bed 22 (from McRoberts, 2011, fig. 18.2); **C**, *Halobia austriaca*, GSC 132232, Black Bear Ridge bed 33 (from McRoberts, 2011, fig. 18.4); **D**, *Halobia selwyni*, GSC 132231, Brown Hill, loc. CM99BRH-2 (from McRoberts, 2011, fig. 18.3); **E**, *Halobia austriaca*, GSC loc. 157119, Huxley Island, British Columbia; **F**, *Halobia austriaca*, GSC loc. 157119, Huxley Island, British Columbia; **G**, *Halobia austriaca*, GSC loc. C-157123, Huxley Island, British Columbia; **H**, *Halobia austriaca*, USNM 74190, Copper River area, Alaska (from Smith, 1927, pl. 99, fig. 12); **I**, *Halobia austriaca*, USNM 74190, Copper River area, Alaska (from Smith, 1927, pl. 99, fig. 10); **J**, *Halobia austriaca*, USNM 74189, Admiralty Island, Alaska (from Smith, 1927, pl. 99, fig. 13); **K**. *Halobia brooksi*, Holotype, USNM 74188, Copper River area, Alaska (from Smith 1927, pl. 99, fig. 7). Scale bars = 1 cm.

these two levels (beds 3 and 4), are separated by approximately 4 cm, contain the ammonoids *Gonionotites*? sp. and *Pterosirenites auritus* and are close to the boundary between the *Acuminatella acuminata-Parapetella prominens* and the lower subdivision *Metapolygnathus parvus* Subzone — approximately 1.7 m below *Guembelites* cf. *jandianus* and *Stikinoceras* cf. *kerri*. It should be noted that *Anatropites* sp. has not been recovered from the Pardonet Hill East section, but has been reported from a nearby

locality on the west side of Pardonet Hill (Tozer, 1994). There were no other occurrences of similar taxa that can confidently be attributed to *H. austriaca* recovered from the Pardonet Hill East section.

Tozer (1994, pl. 108, fig. 14a) illustrated a halobiid specimen from the west side of Pardonet Hill embedded in the umbilicus of an *Anatropites* that superficially appears to be a juvenile *Halobia austriac*a. This halobiid is, unfortunately, too small for confident identification and could potentially belong to a number of halobiid species, including *H. selwyni*. It should be noted that Tozer's locality/section at Pardonet Hill West is different than the Pardonet Hill East section logged in Orchard (2014, figs. 29, 30) and discussed above.

Thus, the re-evaluation of *Halobia austriaca* from Williston Lake suggests that the lowest occurrence identified with confidence remains in the Black Bear Ridge from bed 22 (*S. kerri* ammonoid and *Primatella asymmetrica-Norigondolella* conodont zones). A potentially lower occurrence from beds 3 and 4 in the Pardonet Hill East section (lower subdivision *Metapolygnathus parvus* Subzone) is also not confirmed and may belong to *H. selwyni*.

Halobia austriaca from Haida Gwaii, western British Columbia (Wrangellia terrane)

The Carnian-Norian boundary interval is likely represented in numerous localities across Haida Gwaii within deep-water successions of the Peril Formation rich in radiolarians, conodonts, ammonoids, and halobiid bivalves (e.g., Carter and Orchard, 2000, 2013). *Halobia austriaca*, however, is only confirmed from the section at Huxley Island (Figs. 2, 5E–5G).

Tozer (1994, pl. 104, fig. 12b) illustrated a small halobiid in the same piece as a poorly preserved *Anatropites* sp. from a locality (GSC C-157119) on Huxley Island, British Columbia, Canada. This halobiid specimen, like that from Pardonet Hill West (see above) is too small for identification and could belong to a number of different *Halobia* species. However, additional, previously unstudied specimens provided by Michael Orchard for examination from GSC C-157119 (= bed 8, Huxley B section of Orchard, 1991) and a second specimen from a likely slightly higher level GSC C-157123 (= bed 10A, Huxley B section of Orchard, 1991) appear to agree with the current understanding of *H. austriaca* (Fig. 5). The precise relationship between these levels GSC 157119 and GSC C-157123 and that of the aforementioned Tozer specimens are unclear. According to Orchard (personal communication, 2019), there is a small fault that separates C-157119 and C-157123, even though Tozer suggested that C-157123 and C-157119 were considered as probably the same bed. The possibility they are of different ages may be supported by both the ammonoid and conodont assemblages (see Orchard, 2019, fig. 5) with the *H. austriaca*-bearing GSC C-157123 occurring with the ammonoids *Styrites dawsoni*, *Gonionotites* sp. and *Thisbites* sp. Conodonts from this level (Orchard, 1991, 2019; Carter and Orchard, 2013) suggest that GSC C-157123 is just above the upper division of the *Metapolygnathus parvus* Subzone and within the lower division of the *Primatella asymmetrica-Norigondolella* conodont Subzone.

Halobia austriaca in southern Alaska (Wrangellia terrane)

Also from the Wrangellia terrane, Smith (1927, pl. 99, figs. 10-12) illustrated two specimens attributed to *Halobia austriaca* from a locality (USGS loc. 9935) along Rock Creek in the Copper River area (Chitina River District, Wrangell Mountains) of southern Alaska. Smith (1927) assigned these specimens (reproduced in Fig. 5) to his Upper Carnian *Juvavites* subzone of *Tropites subbulatus* ammonoid zone without providing evidence. While these specimens appear to be valid *H. austriaca*, their age remains in question as they are not independently collaborated by co-occurring ammonoids or other biostratigraphically informative species.

From a nearby locality (USGS loc. 8153) in the Kuskulana River area of the Wrangell Mts., Smith (1927, pl. 99, figs. 7-9) described and illustrated three specimens attributing it to his new species *Halobia brooksi*. Silberling (1963, pl. 2, figs. 14-15) also illustrated a *H. austriaca* from the same locality. The holotype of *H. brooksi* Smith (1927, pl. 99, fig. 7; USNM 74188) is listed as upper Carnian or more likely lower Norian, Roadhouse Creek (USGS loc. 8153); however, the age of the type specimens remains questionable as no ammonoids, conodonts, or other age-diagnostic fossils are known from this locality. As previously mentioned, Gruber (1977, pl. 6, fig. 2), considered *H. brooksi* as a junior subjective synonym of *H. austriaca*, and re-illustrated Smith's type (USNM 74188). It should be further noted that in his plate explanation, Gruber incorrectly listed its occurrence as Thompson's Cove on Gravina Island Alaska (which is a different locality from the Alexander terrane) and not that from where the specimen was collected.

In addition to the above-mentioned specimens, Silberling (1963, pl. 2, fig. 11) illustrated an additional specimen from the Wrangell Mountains at Canyon Creek (USGS loc. M1709) attributed to *Halobia austriaca* from the basal McCarthy Formation. This specimen is interesting as it is associated with *Anatropites* sp; and evidentially late Carnian in age. However, this single valve exhibits very thin and tightly packed radial ribs of nearly all equal strength and straightness are much more reminiscent of *H. radiata* rather than *H. austriaca*. It is possible that this illustrated specimen is similar those mentioned, but not illustrated, in a taxonomic list of fauna identified by N.J. Silberling from the Ninza Limestone from three nearby localities (USGS locs. M1792, M1793, M1794) listed in MacKevett (1970, 1971). One additional mention worth noting is the presence of *Halobia brooksi* in beds transitional between the Chitistone and overlying Ninza limestones from USGS loc. M1706 as noted by Silberling and Tozer (1968, p. 48) co-occurring with a rich bivalve and gastropod fauna that the authors suggest is of earliest Norian or latest Carnian age.

Halobia austriaca in southeastern Alaska (Alexander terrane)

Smith (1927, pl. 99, fig. 13) illustrated a single specimen attributed to *Halobia austriaca* from a locality (USGS loc. 8847) at Herring Bay, on Admiralty Island in the Keku Strait area of southeastern Alaska. Although this single specimen

(reproduced in Fig. 5J) is a small and incomplete right valve, it clearly exhibits shape/outline and ribbing characteristic of *H. austriaca*. Unfortunately, however, it was apparently not collected within a stratigraphic succession nor was it collected with other age-diagnostic fossils. Other possible occurrences of *H. austriaca* from the Keku Strait area are mentioned (e.g., Muffler, 1967; Katvala, 2004) but not illustrated. Likewise, other mentions of *Halobia austriaca* from both Bostwick Inlet and Nehenta Bay at Gravina island (e.g., Berg and Cruz, 1982) were never illustrated and are difficult to assess. Based on the above known occurrences, it can be confirmed that *H. austriaca* does indeed occur within the Alexander terrane, but for lack of ancillary biostratigraphic control, the precise age or stratigraphic position remains ambiguous.

Halobia austriaca from northern California (Eastern Kalamath terrane)

Smith (1927) illustrated *Halobia austriaca*, from the Hosselkus Limestone from the Shasta District, North Fork of Squaw Creek, 3 miles N of Kelley's Ranch (USGS loc. 15676). Smith assigned this locality to the Upper Carnian Juvavites subzone of *Tropites subbulatus* ammonoid zone, but it is distinct from a locality 2 miles NE of Madison's Ranch (USGS loc. 15678) which is the type locality of the *Tropites welleri* zone of Silberling and Tozer (1968). Smith (1927) broadly considered the ammonoid and bivalve fauna of the *Juvavites* subzone to include the entire strata, without subdivision or stratigraphic section, above the *Trachyceras*-bearing beds (= *Tropites dilleri* zone of Silberling and Tozer, 1968) and a 'coral zone' of Norian age. It is also notable that, although a species of the ammonoid *Klamathites* is known to occur in the *Juvavites* subzone of Smith at USGS loc. 15676, the *K. macrolobatus* zone has not yet been recognized from here or elsewhere in Shasta County California (see Silberling and Tozer, 1968; Tozer, 1994). According to Smith (1927), USGS loc. 15676 is reported to be many meters thick and the reported fauna of ammonoids (e.g., *Juvavites*, *Tropites*, *Gonionotites*, and *Metasibirites*) includes both upper Carnian and possible Norian taxa at different levels. Without precise stratigraphic control, the level from which *H. austriaca* was collected and its age cannot be determined.

Halobia austriaca from northeastern Oregon (Wallowa terrane)

Smith (1912, p. 95) noted the occurrence of *Halobia* cf. *austriaca* together with *H.* cf. *superba*, and *H.* cf. *salinaria* from the type locality of the Martin Bridge Formation in the southern Wallowa Mountains of northeast Oregon (Fig. 2, loc. 6). Unfortunately, little can be said of this occurrence as the specimen was never illustrated nor recorded in the known Triassic collections of J. P. Smith. From the same locality, McRoberts (1990, fig. 6.6.9) illustrated a single specimen obtained from float and provisionally assigned it to *H. austriaca*. Although this locality spans a Carnian-Norian boundary (e.g., McRoberts, 1993), it is not possible to determine the precise stratigraphic level from which the loose specimen may have come from. A second possible occurrence of *H. austriaca* was recovered from float (McRoberts, undescribed collections cited in Stanley et al., 2008) within the Martin Bridge Formation at Hells Canyon several meters below USGS loc. M2672 (the well-known and demonstrably lower Norian shallow-water silicified fauna described by Newton et al. , 1987). Without precise stratigraphic control of these two talus specimens and independent biostratigraphic evidence little can be said of their potential relationship.

Nevada (Black Rock terrane)

In an unpublished thesis, Fuller (1986, pl. 5) illustrated a specimen attributed to *Halobia* cf. *H. austriaca* from Alaska Canyon, Jackson Mountains, Humboldt Co., Nevada. The specimen in question occurs several meters below a level containing the ammonite *Discotropites* and is confidently placed in the Upper Carnian. While this specimen exhibits signs of significant tectonic shear deformation, it cannot be confused with true *H. austriaca* as it possesses much finer ribs, a distinctive growth-stop and disruptive waviness of ribs more indicative of *H. superba* or *H. ornatissima*.

North Slope Alaska (Arctic Alaska terrane)

From the Phoenix #1 drill core off-shore Arctic Alaska, McRoberts et al. (2021) illustrated three specimens attributed to *Halobia* cf. *H. austriaca* from two depth levels, situated approximately 5 m above the highest occurrence of *Halobia ornatissima* and immediately above a presumable sequence boundary. The small sample size and condition of the Phoenix #1 specimens dictate only provisional assignment to *H. austriaca.* The age of these *H.* cf. *H. austriaca* beds is not confirmed with ammonoids, conodonts or radiolarians and is only provisionally assigned as basal Norian based on broadly ranging ostracod and foraminifera species regional correlations and sequence stratigraphy.

IMPLICATIONS AND CONCLUSIONS

Based on the new specimens and a re-evaluation of existing specimens from Williston Lake and elsewhere in North America, it can be concluded that *Halobia austriaca,* while present from many localities only demonstrably occurs in few stratigraphic sections in North America with ammonoid and conodont biostratigraphic control. The lowest occurrence of *H. austriaca* from the Black Bear Ridge section, at a higher level (bed 22) than previously reported, is closely associated with the ammonoid *Guembelites clavatus* (bed 22b) as is within centimeters of the base of the recognized *Stikinoceras kerri* ammonoid zone and the *Primatella asymmetrica-Norigondolella* conodont subzone. With this report, a revised primary datum of the first occurrence of *H. austriaca* from bed 22 in the Black Bear Ridge section of Williston Lake provides a robust datum integrated with ammonoids and conodonts to correlate a basal-Norian GSSP. This revised position of *Halobia austriaca* from Black Bear Ridge also provides for a more parsimonious correlation to other sections within the western Tethys, including the candidate Pizzo Mondello GSSP and other sections in Austria, Turkey, and Slovakia. Although a

full and complete discussion on the biochronology and correlation of *H. austriaca* and potential secondary markers (ammonoids, conodonts, geochemical signatures and a geomagnetic polarity) to other regions is beyond the scope of this preliminary report and is partially available elsewhere (e.g., Krystyn and Gallet, 2002; McRoberts and Krystyn, 2011; Balini et al., 2012; Levera 2012), and will be more formally discussed in the formal proposal being prepared for the Subcommisssion on Triassic Stratigraphy on *H. austriaca* as primary datum at the Pizzo Mondello section of Sicily (Balini pers. comm., 2021).

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