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New biostratigraphic constraints for the Martin Bridge Formation (Upper Triassic, Wallowa terrane, Oregon, U.S.A.)

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Abstract

The stratigraphic relationships between the thick carbonate deposits of the Martin Bridge Formation and contiguous clastic lithologies are poorly understood. Biostratigraphic markers are almost absent in the shallow-water Triassic limestones and, in places where deeper, fossiliferous-rich carbonate rocks occur, incomplete exposures, metamorphism and structural complexity have obscured most stratigraphic contacts. We have investigated two deep-water localities in the eastern and southern Wallowa Mountains, in which transitional contacts are preserved. There, rich assemblages of *Halobia* bivalves have been found, including *H. ornatissima*, *H. radiata* or *H. septentrionalis*, and *Halobia* spp. aff. *H. beyrichi*. The short temporal range of these taxa designate a precise timing constraints of lithological transitions, at the base and at the top of the Martin Bridge Formation.

Keywords

Martin Bridge Formation, *Halobia*, Wallowa terrane, Upper Triassic, Oregon.

1. INTRODUCTION

In the Wallowa Mountains of northeastern Oregon (Fig. 1A), Upper Triassic rocks are represented by a thick (plurikilometric) sequence of volcaniclastic rocks, sandstones, shales, argillites, and limestones. The lower part of the succession is predominantly made of volcaniclastic rocks and volcanic flows of the Seven Devils Group (Nolf, 1966; Vallier, 1974). These rocks are overlaid by widely distributed, 0.3 to 1.1 km-thick, lagoonal, reef, slope and basinal carbonate deposits of the Martin Bridge Fm. (Smith *et al.*, 1941; Nolf, 1966; Follo, 1994; Stanley *et al.,* 2008), which are conformably overlaid by (and supposedly laterally interfingered with) deep, argillaceous sediments of the Hurwal Fm. (Smith *et al.*, 1941; Nolf, 1966; Follo, 1986).

The Martin Bridge Fm. is the most conspicuous carbonate succession of the Wallowa terrane (NE Oregon, USA). The type locality of the Martin Bridge Fm., located at the confluence of Eagle and Paddy creeks, has been formally described by Smith *et al.* (1941), where Smith (1912, 1927) discovered rich fossil assemblages. Subsequent paleontological studies were carried out in this area (e.g. Kristan-Tollmann & Tollmann, 1983; Orr, 1986; Stanley, 1986; McRoberts, 1990, 1993; Rigaud, 2012), some increased the stratigraphic precision of the section, which would, based on deep-water fauna reported by McRoberts (1993), extend from the upper Carnian (*T. dilleri* and/or *T. welleri* ammonoid zone) to the lower middle Norian (*D. rutherfordi* zone).

However, the formational boundaries between the volcaniclastic (Seven Devils Group), limestone (Martin Bridge Fm.) and argillite (Hurwal Fm.) units are not exposed at the type locality and are poorly constrained in other areas of the Wallowa terrane. Regional and contact metamorphisms, together with structural complications,

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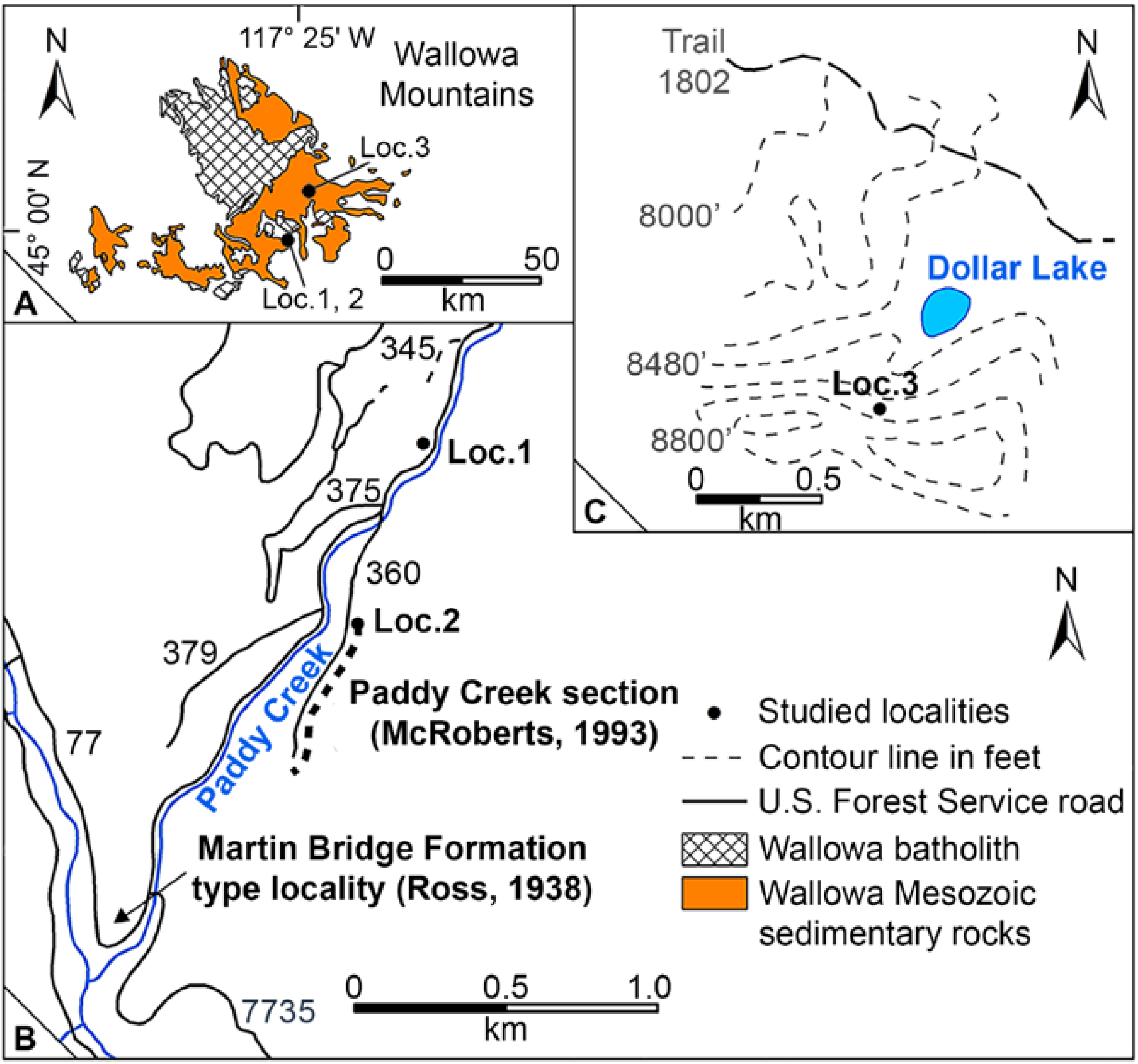

Fig. 1: Location map of the studied localities 1-3, in the Eastern and Southern Wallowa Mountains, Oregon. Mesozoic rocks in the Wallowa Mountains (A); Studied localities along Paddy Creek (B) and Dollar Lake (C).

have obscured most transitional contacts (see Smith *et al.,* 1941; Wetherell, 1960; Prostka, 1963; Nolf, 1966; Vallier, 1977; Brooks & Vallier, 1978; Follo, 1986; Stanley *et al.,* 2008; Rigaud, 2012) and no paleontological record allowed adequate age resolution.

The aims of this paper are 1) to better assess the age resolution of the Triassic sedimentary succession of the Wallowa terrane based on some key fossil occurrences and 2) to better constrain the timing of growth and demise of the Martin Bridge carbonate platform. We investigated transitional lithologies at the top and the base of this carbonate Formation in distinct localities and here provide new paleontological discoveries.

2. GEOLOGICAL SETTINGS

The Wallowa terrane is an allochthonous, composite Permian-Triassic island arc system, which accreted onto the North American Craton during the Mesozoic (e.g. Vallier *et al.,* 1977; Vallier & Batiza, 1978; Kays *et al.,* 2006; Stanley *et al.,* 2008). Largely intruded by Mesozoic batholiths (e.g., Armstrong *et al.,* 1977; Walker, 1989; Taubeneck, 1995; Johnson *et al.,* 1997), it is thickly covered by Tertiary volcanic rocks of the Columbia River Basalt (Follo, 1986, 1992, 1994). No complete sequence was ever recorded there and Mesozoic rocks mostly crop out as erosional inliers, in four main areas: (i) The Southern Wallowa Mountains; (ii) The Northern Wallowa Mountains; (iii) Hells Canyon and (iv) the Seven Devils Mountains. In the Wallowa Mountains, carbonate rocks of the Martin Bridge Fm. are found between a thick sequence of Triassic volcanic and volcaniclastic sedimentary products of the Seven Devils Group (Smith *et al.*, 1941; Vallier, 1977) and deep-water, starved basinal argillites of the Hurwal Fm. (Smith *et al.*, 1941; Nolf, 1966; Follo, 1992).

2.1. The Lower Sedimentary Series (LSS)

The name Lower Sedimentary Series (LSS) was proposed by Smith *et al.* (1941) for a low grade metamorphic volcaniclastic sequence found in the Southern Wallowa Mountains. The LSS is in part correlative with the upper part of the Seven Devils Group (Vallier, 1967, 1977; Follo, 1986). The LSS, of reddish, purple or green color, is mainly made of fine to coarse, possibly brecciated or bedded sandstone, siltstone, and calcareous argillites (Follo, 1986). No marker fossils have been found in the Southern Wallowa Mountains but biostratigraphic studies of lateral equivalent in Hells Canyon (Vallier, 1977) and in the Northern Wallowa Mountains (Smith *et al.*, 1941) have provided *Halobia oregonensis* Smith (1927), which indicates a Middle Carnian age (*Tropites* zone of Smith, 1927) for part of the succession.

2.2. The Martin Bridge Fm. (MB)

The Martin Bridge Fm. includes different units of carbonate to argillaceous rocks indicative of reefal, shoal, lagoonal, slope, and basinal depositional environments (Stanley *et al.,* 2008). It records a complex depositional history and is known as one of the most fossiliferous Early Mesozoic shallow water tropical succession in North America.

The first to investigate the carbonate succession of the Wallowa terrane was Lindgren (1901). A description of the limestone, limy shales and their fossil content in the Southern Wallowa Mountains was later published by Smith (1912, 1927). The type locality, described by Ross (1938), is situated at the confluence of Eagle Creek and Paddy Creek, in the Southern Wallowa Mountains. The name Martin Bridge was introduced for an Upper Triassic sequence made of limestone, shale, basalt and tuff in the Southern Wallowa Mountains (Chaney, 1932) but Ross (1938) limited its use to Upper Triassic carbonate rocks. The Martin Bridge Formation hosts a variety of fossiliferous assemblages (e.g. Smith 1912, 1927; Nolf, 1966; Stanley, 1979, 1986; Stanley & Senowbari-Daryan, 1986; Follo, 1986; Newton, 1986; Orr, 1986; McRoberts & Stanley, 1991; McRoberts, 1993; Yancey & Stanley, 1999; Blodgett *et al.,* 2001; Nützel & Erwin, 2001; Nutzel *et al.,* 2003; Stanley *et al.,* 2008; Rigaud & Martini, 2016; Rigaud *et al.*, 2012, 2013a, b, 2015a, b, 2016) and has been dated as upper Carnian (*T. welleri*?, *T. dilleri* zone) to Middle Norian (*M. columbianus*?, *D. rutherfordi* zone) at the type locality (McRoberts, 1993).

The relationship between the Martin Bridge Fm. and surrounding lithologies is not well understood, leading to diverted perspectives regarding the formational boundaries and their definition. Noteworthy, the basal part of the Martin Bridge Fm. along Hells Canyon and in the Northern Wallowa Mountains documents shallow water, restricted peritidal environments, whilst in the Southern Wallowa Mountains it represents an open, slope to basinal environment (Stanley *et al.,* 2008).

2.2.1. Hells Canyon

The most complete and well-preserved section of the Martin Bridge Fm. is found on the west side of the Snake River at Kinney Creek (Vallier, 1967, 1977), but even there the top of the formation is not exposed. Vallier studied another section in Spring Creek, where he assigned an early Norian age to the Martin Bridge Fm. based on bivalves found by Jones *et al.* (1977). Subsequently retrieved corals, bivalves and gastropods (Stanley, 1986; Newton *et al.,* 1987; Nützel *et al.,* 2003) suggested a Late Carnian? (*K. macrolobatus* zone) to Early Norian (*S. kerri* zone) age for the formation. At the Spring Creek section on the west side of the Snake River, the basal contact of the Martin Bridge may be faulted (low-angle fault), but intercalations of thin beds of volcaniclastic siltstone in the lower part indicate a probable gradational contact with the underlying Doyle Creek Fm., of the Seven Devils Group (Lund *et al.,* 1983; Whalen, 1988). The Doyle Creek Fm. was assigned by Vallier (1967) to the Carnian, as the formation is bracketed between the Ladinian-Carnian Grassy Ridge Fm. and the latest Carnian-?earliest Norian Martin Bridge Fm. Vallier (1977) mentioned that the Kurry Creek member of the Doyle Creek Fm., in which Late Carnian to Middle Norian ammonites and *Halobia* were retrieved, is probably correlative to the Lower Sedimentary Series of Smith *et al.* (1941) and the upper part of Nolf's Clover Creek Greenstone (Prostka, 1963). The upper part of the carbonate succession is marked by an erosional surface and the Martin Bridge is directly overlain by the Neogene Columbia River Basalt (Vallier, 1977; Whalen, 1988). The only known lithology in Hells Canyon that could resemble the Hurwal Fm. is an isolated metamorphosed succession of shales and calcareous argillites (of unknown age) that crops out locally near the mouth of the Grand Ronde River (Glerup, 1960; Follo, 1986).

2.2.2. Northern Wallowa Mountains

The Martin Bridge Fm. was defined by Smith *et al.* (1941) as a crystalline limestone, which grades upward into argillaceous sediments of the Hurwal Fm. They assigned the formation to the upper Carnian based on retrieved nautiloids and ammonoids; an age extended by Nolf (1966) who dated the upper part of the formation (Scotch Creek member) to the upper Carnian - lower Norian (*S. kerri* zone), based on ammonoids fauna (Nolf, 1966, pl. 4). According to Nolf (1966), the age of the lower part of the Martin Bridge Fm. is unknown and could be either Late Carnian or earliest Norian, the underlying volcaniclastic sequence being dated as upper Carnian based on *Halobia oregonensis* Smith (1927) of the *Tropites* zone (Smith *et al.,* 1941; Nolf, 1966; Vallier, 1967, 1977). At Hurricane Creek, Nolf found and identified in the Martin Bridge Fm. a variety of ammonoids and halobiid bivalves of Lower-Middle Norian age (Silberling & Tozer, 1968, p. 41).

2.2.3. Southern Wallowa Mountains

The type locality of the Martin Bridge Fm. poorly reflects the assortment of carbonate facies found in the Wallowa terrane (Stanley *et al.,* 2008). Based on a rich association of halobiid bivalves and on scarce ammonoid findings, McRoberts (1990, 1993) assigned an upper Carnian (*T. dilleri* and/or *T. welleri* ammonoid zone) to lower Middle Norian (*D. rutherfordi* zone) to the type locality, as a very good *Halobia halorica* indicative of the lower Middle Norian was recovered (in a brecciated level) near the top of the ridge (McRoberts, 2011). The age of the overlying Hurwal Fm. is poorly constrained. It was reported in Follo (1986) based on the ammonite *Malayites* cf. *M. dawsoni* found at the base of the Excelsior Gulch conglomerate, 2 km south of Forks Forest Camp, as middle Lower Norian.

2.3. The Hurwal Fm. (HWL)

The Hurwal Fm. was originally defined by Smith *et al.* (1941) in the Northern Wallowa Mountains, where it demonstrably overlies the Martin Bridge Fm. In the Southern Wallowa Mountains, no clear contact between Hurwal and underling Martin Bridge can be identified, due to limited exposure and structural complications (Follo, 1986). Hurwal sediments are mainly made of dark grey to red-brown argillites (due to oxidation). Follo (1986) reported the Upper Triassic trace fossil *Chondrites* near Excelsior Gulch with some unidentified halobiid molds, along with ammonoid *Malayites* cf. *M. dawsoni* index for middle lower Norian from south of Forks Forest camp. Other retrieved fauna (Flügel *et al.,* 1989; Rosenblatt, 2010) yield no significant age.

3. STUDIED LOCALITIES AND STUDIED MATERIAL

The present study covers two localities of the Wallowa Mountains: Paddy Creek and Dollar Lake (Fig. 1B-C). These localities were investigated for their lithofacies (Del Piero, 2016) as well as their fossils content (Khalil, 2016), in order to improve the sedimentological and biostratigraphic resolution of the formational boundaries.

3.1. The Paddy Creek Locality

Paddy Creek is partly running along the US forest service road (77), northeast of the Martin Bridge Fm. type locality. The volcaniclastic rocks, informally named Lower Sedimentary Series (Smith *et al.*, 1941), represent the dominant lithology along the upper road. The area is rich in slightly flattened and sheared *Halobia*. At locality 1, some limy interbedded levels start to appear, indicating the beginning of the carbonate production. Up in the road 77, scattered lenticular levels (?slope channelized gravitational deposits) of limestone breccia can be observed. East of Paddy Creek, an outcrop exposed on the east side of the service road 360, shows a transition between calcareous siltstones and marly limestones, rich in metamorphosed *Halobia*. This locality (loc. 2) is at the beginning of McRoberts' (1993) section, informally named "Paddy Creek section". Locality (1) and (2) display a transition from Seven Devils' rock types into more calcareous rocks (Del Piero, 2016) and have delivered diverse halobiid species (Fig. 4).

3.2. The Dollar Lake Locality

The Dollar Lake locality is only 0.4 km off the trail 1802, which starts from the end of road 39, in the eastern part of the Wallowa Mountains. The section is located about 300 meters S-SW of Dollar Lake, where the alternations between deep-water clayey limestones and more or less limy argillite beds end and pure argillites of the Hurwal Fm. take over. A ca 2.5 m transitional zone between the alternated predominantly calcareous levels of the Martin Bridge Fm. and fully argillaceous levels of the Hurwal Fm. has been deeply investigated. This transition is rich in moderately preserved, flattened and slightly metamorphosed *Halobia* spp. (Fig. 4). The outcrop has been mapped by Follo (1986), and initially studied by Rigaud (2012).

The bivalve *Halobia* is known for its diversity, abundance, and broad distribution in rocks of Tethys, Panthalassa, and Arctic seas during Carnian and Norian stages. These characteristics, along with its high speciation and extinction rates, make this genus a valuable biostratigraphic index for Upper Triassic rocks worldwide (McRoberts, 1993, 2010). For this study, a number of 29 molds have been selected. These molds were white coated using ammonium chloride (NH_4Cl), to highlight areas of high topographic relief (see Hegna, 2010 for details). They were examined based on number of characteristic features (McRoberts, 1993, 2007, 2011) including: S, shape; L, total length; H, total height; BP, beak position (anterior hinge length/total length); ATF, anterior triangular field (anterior auricle); PTF, posterior triangular field (posterior auricle); R, ribs (plicae or costae) shape and division (furrows); CR, commarginal rugae shape; GS, presence or absence of growth-stops.

4. RESULTS

In the Paddy Creek section (lower volcaniclastic part in Fig. 5C), all recovered *Halobia* molds (Fig. 2: A-G) are incomplete and strongly strained, but show distinctive characteristics of *Halobia ornatissima* Smith (1927) (i.e. greater ATF, more pronounced costation, initial growth-stop at a shorter distance from the beak, and increase in subsequent growth-stops to produce a wavy appearance along the posterior margin). The age range of this species is upper Carnian, *T. dilleri*?, *T. welleri* - *K. macrolobatus* zone; it is rare in the Norian but may occur in the lowermost part of the *S. kerri* zone (McRoberts, 2011).

In the Paddy Creek section (upper jointed calcareous claystone part in Fig. 5C), *Halobia* molds (Fig. 2: H-I) are poorly preserved. The mold in Fig. 2I is strained. It may represent *Halobia radiata* (Gemmellaro, 1882), ranging from lower part of the *K. macrolobatus* zone

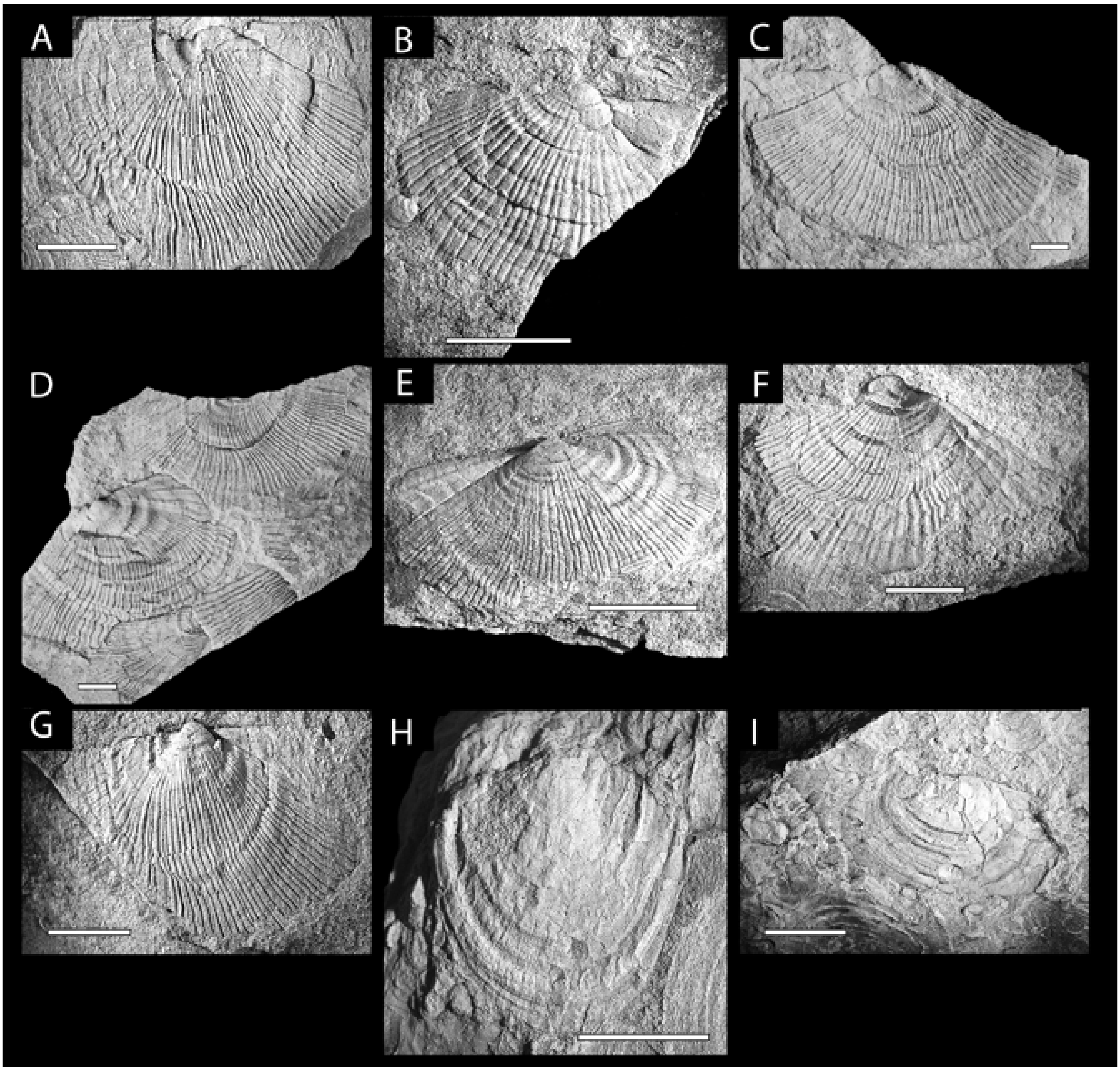

Fig. 2: Characteristic halobiids from localities along Paddy Creek. Location 1, (lower part of Paddy Creek section). A-G: *Halobia ornatissima*, upper Carnian (*T. dilleri*- *K. macrolobatus* zones to, very rarely, *S. kerri* zone); Location 2, (Upper part of Paddy Creek section). H, I: *Halobia radiata* or *H. septentrionalis*, (*K. macrolobatus*-lower part of the *S. kerri* zone); scale bar 5 mm.

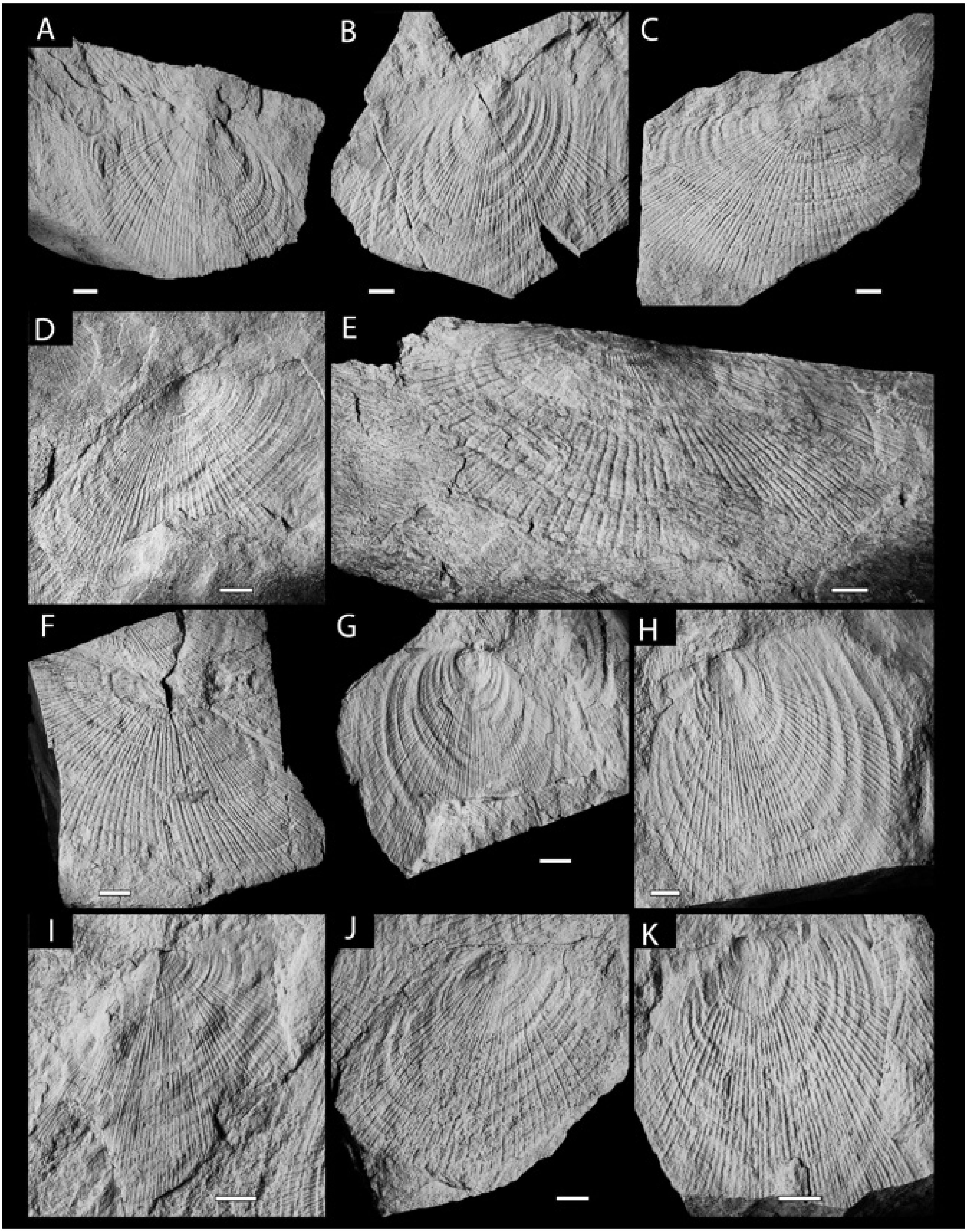

Fig. 3: Characteristic halobiids from Dollar Lake. Location 3- Martin Bridge. A-D: *Halobia* aff. *H. beyrichi*. E: *Halobia* aff. *H. beyrichi*?, lower Norian (*S. kerri* zone); Location 3-transition. F-J: *Halobia* aff. *H. beyrichi*, lower Norian (*S. kerri* Zone); Location 3-Hurwal. K: *Halobia* aff. *H. beyrichi*?, lower Norian (*S. kerri* Zone-lower *M. dawsoni* zone); scale bars 5 mm.

to the lower part of the *S. kerri* zone, or *Halobia septentrionalis* (Smith, 1927), which total range is within the *K. macrolobatus* zone. The later resembles *H. radiata* in most of the characteristics described by Smith (1927) and McRoberts (2011), but differs slightly from it in having an elongated posterior part of the shell (Fig. 2I), even though the rib density of the two species is roughly equal. In our material, it is not clear whether growth-stops are present or absent due to compaction (flattened shells). We also observed a small disruption in the ribs direction but without any shape-like zigzag ornamentation, a criterion more indicative of *H. septentrionalis*. The likely age interval for this intermediary form is uppermost Carnian-lowermost Norian (*K. macrolobatus* zone-lower part of the *S. kerri* zone).

In Dollar Lake (Fig. 5C), molds of *Halobia* aff. *H. beyrichi* (Mojsisovics, 1874) were collected within the interval between the Martin Bridge Fm. and the Hurwal Fm. (Figs 3-4). This taxon was originally listed as *Halobia beyrichi* (Mojsisovics, 1874) in McRoberts (1993), but it differs slightly by its more numerous, narrower, sharper costae from true *H. beyrichi*. Very closely related to *Halobia beyrichi*, the herein illustrated taxon differs from *H. radiata* by its coarser costation and larger size. The mold illustrated in Fig. 3E, incomplete and strongly strained, represents a very large specimen. The likely range for this form is lower Norian (*S. kerri* zone), as for *H. beyrichi*. *Halobia* molds from the argillaceous levels of the Hurwal Fm are all quite strained/deformed rendering their original shape and features indeterminate.

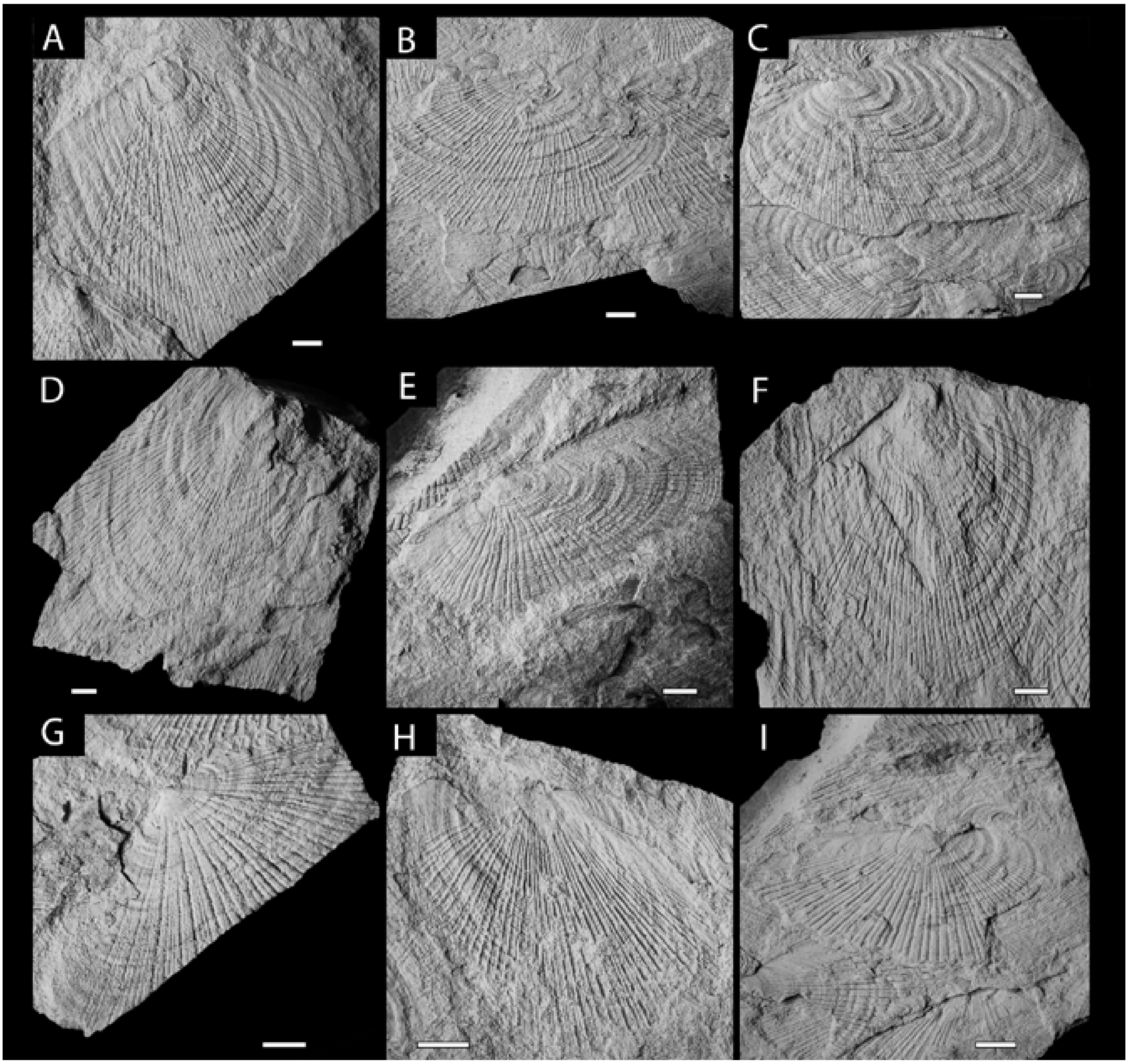

Fig. 4: Characteristic halobiids from Dollar Lake (Fig. 3C). Location 3-Hurwal. A-I: *Halobia* aff. *H. beyrichi*?, lower Norian (*S. kerri* Zone-lower *M. dawsoni* zone); scale bars 5 mm.

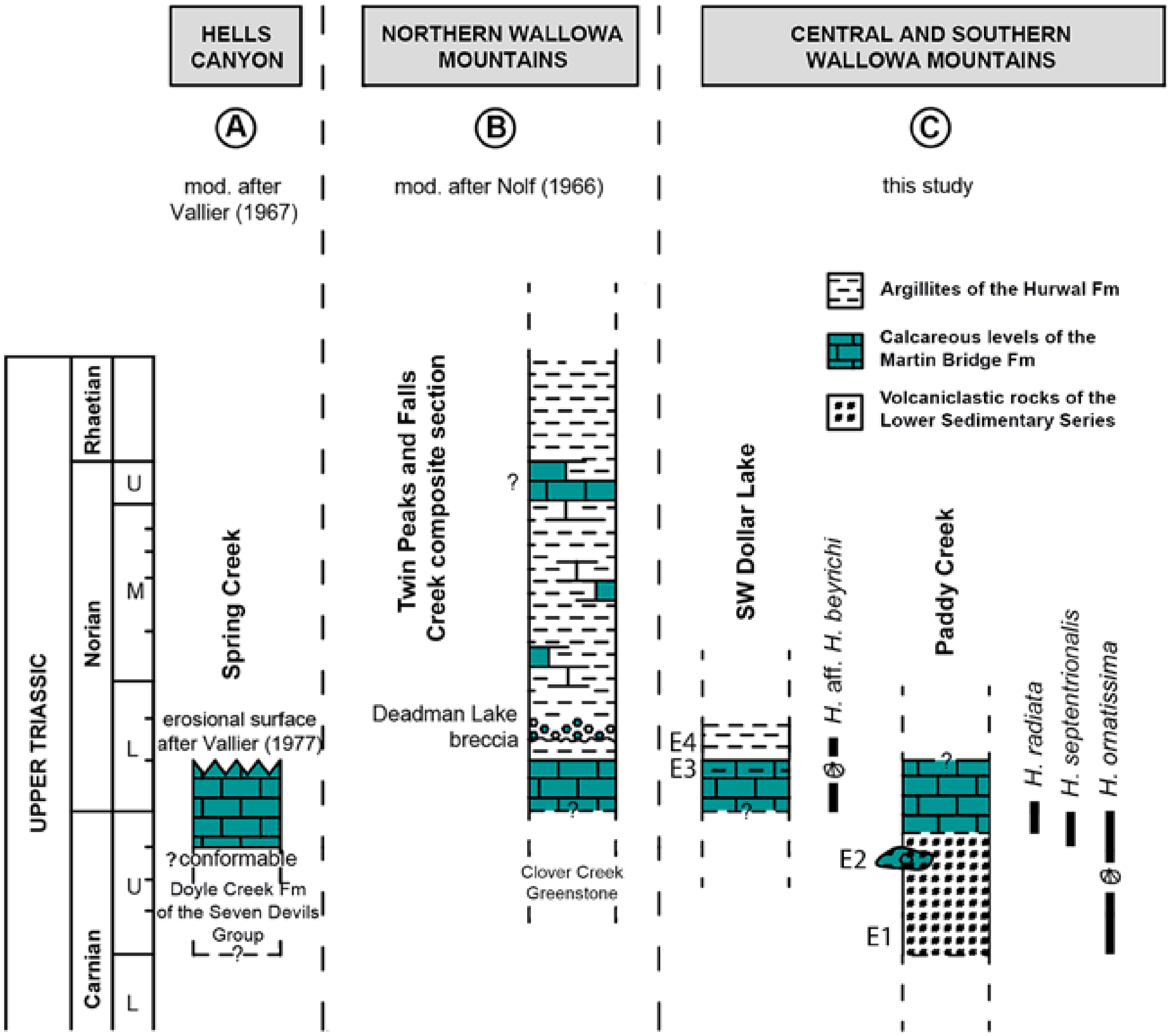

Fig. 5: Important sections of the Martin Bridge Fm., showing possible synchronicity at the terrane scale. E1, calcareous siltstone beds interfingering with volcaniclastics of the Lower Sedimentary Series (L.S.S.); initiation of the carbonate production; E2, limestone breccia lenses; E3, more or less calcareous argillite levels interfingering with clayey limestones of the Martin Bridge Fm. (Khalil, 2016); E4, Hurwal-type argillite levels; end of the carbonate production.

They have some similarities to those referred above as *Halobia* aff. *H. beyrichi* but are slightly different in their more pronounced costae. *Halobia beyrichi* is known from several early Norian (*S. kerri* zone) localities in North America under a variety of names (e.g., *H. alaskana* Smith, 1927). Nolf (1966, pl. 4) reported *H. beyrichi* as "*H. halorica* Mojsisovics or *H. dilatata* Kittl of Smith" in association with *Stikinoceras kerri* from the Hurwal Formation of the northern Wallowa Mountains (McRoberts, 1993). The likely range for this form is, as for *H. beyrichi*, lower Norian (*S. kerri* zone). However due to its stratigraphic position (within argillites of the Hurwal Fm), the presence of this *beyrichi*-like form in the lower *M. dawsoni* zone cannot be excluded.

5. DISCUSSION

The age (upper Carnian: *Tropites* zone) of the volcaniclastics interval in Hells Canyon (Vallier, 1967, 1977), and in the Northern Wallowa Mountains (Smith *et al.,* 1941; Nolf, 1966; Vallier, 1967, 1977) is perfectly consistent with that of the Lower Sedimentary Series section that we studied in the Southern Wallowa Mountains (*Tropites dilleri-welleri* zone) (Fig. 5). The sedimentary transition at the base of the Martin Bridge Fm. occurred during the uppermost Carnian-lowermost Norian in different localities of the Wallowa terrane. Prostka (1963) noted that the boundary between LSS and Martin Bridge could be slightly diachronous along Paddy Creek but our data do not allow confirming or refuting this statement. Our data allow refining the transition between volcaniclastics and carbonate rocks to the *K. macrolobatus*-lower *S. kerri* interval.

In the Southern Wallowa Mountains, the levels of argillites within the Martin Bridge carbonates started to appear after the complete disappearance of coarse volcaniclastics, and are clearly interfingered with carbonate deposits. Our data from Dollar Lake, based on lithology and halobiids, show that the upper portion of the Martin Bridge Fm. may not be diachronous contrary to Follo's (1986) hypothesis. At the terrane scale, a lower Norian age (*S. kerri* zone) is found for the top of the Martin Bridge Fm. in Dollar Lake, Spring Creek (Hells Canyon) and in the Northern Wallowa Mountains, and the contact is gradational over few meters. However, some enigmatic levels of carbonates (mostly breccias) of the Wallowa terrane date younger (Nolf, 1966; Follo, 1986; Stanley *et al.,* 2008), and may have a distinct origin. The same is true for the brecciated carbonate level found by McRoberts (1991, 1993) at the top of the Martin Bridge type locality and dated as Middle Norian.

6. CONCLUSIONS

This study is an effort to improve the paleontological resolution at the formational boundaries between the volcaniclastic rocks of the Seven Devils Group, the Upper Triassic Martin Bridge Fm. and the Hurwal Fm. in the Wallowa terrane. Three morphotypes of the genus *Halobia* have been identified and studied. By integrating the observations made in the field, along with the dating of the retrieved fauna, as well as the data of previous authors findings, we conclude that (i) the transition from Lower Sedimentary Series to the Martin Bridge Formation likely occurred during the uppermost Carnian-lowermost Norian (*K. macrolobatus* zone-lower part of the *S. kerri* zone), and (ii) the Martin Bridge Fm. fully grades into argillites of the Hurwal Fm. within the lower Norian interval (*S. kerri* zone).

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