

# Taxonomy and stratigraphic significance of *Trachyceras silberlingi* n. sp., from the Lower Carnian of South Canyon (New Pass Range, central Nevada, USA)

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**KEY WORDS** - Upper Triassic, Carnian Stage, Desatoyense Zone, Ammonoids, Taxonomy, Nevada.

**ABSTRACT** - New intensive bed-by-bed ammonoid collecting efforts conducted in 2010 and 2011 at South Canyon, the type locality of the lowest Carnian Desatoyense Zone of the North American chronostratigraphic scale, have led to the recognition of a new species of *Trachyceras* that is herein described. The new species is dedicated to Norman J. Silberling (1928-2011), who was widely recognized as the leading authority on marine Triassic stratigraphy in western US for over 50 years. *T. silberlingi* n. sp. is characterized by a peculiar ornamentation consisting of two spiral rows of bullae on the flank (first row on umbilical shoulder and second row at about 70% of whorl height) and by ribs frequently looped in pairs at the lateral bulla.

The new species, from South Canyon site F, the stratigraphically highest level of the fossiliferous succession of the middle member of the Augusta Mountain Formation, represents the first definite occurrence of the genus *Trachyceras* Laube, 1869 in this succession. For this reason *T. silberlingi* n. sp. is of great importance for the revision of the Desatoyense Zone, a unit defined on the basis of a large collection of ammonoids described in 1941 from the lower part of the middle member of the Augusta Mountain Formation, without regard for the number and position of fossil bearing levels. We herein propose the subdivision and replacement of the former Desatoyense Zone with two biostratigraphic units: the lower unit referred to as the Daxatina beds, is an informal biozone characterized by the occurrence of *Daxatina* and *Frankites sutherlandi*, and the overlying *Trachyceras silberlingi* biozone is a range zone characterized by the occurrence of *Trachyceras*, based on the new species. The chronostratigraphic potential of this proposed subdivision is briefly outlined, but it will be more accurately defined upon completion of the taxonomic revision of the South Canyon ammonoid faunas.

**RIASSUNTO** - [Tassonomia e significato stratigrafico di *Trachyceras silberlingi* n. sp., del Carnico Inferiore di South Canyon (New Pass Range, Nevada centrale, Stati Uniti d'America)] - South Canyon, località tipo della Zona a Desatoyense, la prima zona del Carnico nella scala cronostratigrafica nordamericana, nel 2010 e 2011 è stata oggetto di campionamenti strato-per-strato che hanno permesso di individuare una specie nuova di *Trachyceras*, che viene descritta in questo lavoro. La specie è dedicata a Norman J. Silberling (1928-2011) che per 50 anni è stato l'autorità indiscussa per la stratigrafia del Triassico marino nella parte occidentale degli Stati Uniti. *Trachyceras silberlingi* n. sp. è caratterizzato da un'ornamentazione molto particolare, che consiste in due serie spirali di bullae sul fianco, una in posizione vicina al margine ombelicale e una a circa il 70% di altezza del fianco, e da coste che spesso si congiungono a coppie alla bulla laterale.

La nuova specie è stata raccolta dal sito F, il sito stratigraficamente più alto del membro medio della Augusta Mountain Formation di South Canyon, ove rappresenta la prima sicura presenza del genere *Trachyceras* Laube, 1869. Per questo motivo la nuova specie *T. silberlingi* è estremamente utile per una prima revisione della Zona a Desatoyense, basata originariamente su raccolte di ammonioidi effettuate nella parte inferiore del membro medio della Augusta Mountain Formation, senza distinzione sui livelli di raccolta. Si propone quindi la sostituzione della Zona a Desatoyense con due unità biostratigrafiche. I Daxatina beds sono una biozona informale caratterizzata dalla presenza di *Daxatina* e *Frankites sutherlandi*, e sono seguiti dalla biozona a *Trachyceras silberlingi*. Quest'ultima è una zona di distribuzione formalmente istituita in questo lavoro, caratterizzata dalla presenza di *Trachyceras*. Viene delineato il significato cronostratigrafico delle due biozone, ma il completamento della revisione del Carnico Inferiore della scala nordamericana sarà possibile solo dopo il completamento della revisione tassonomica di tutte le faune raccolte.

## INTRODUCTION

Efforts to define the GSSP of the Carnian Stage (Upper Triassic Series) during the past fourteen years have involved considerable research by numerous bio-chronostratigraphers on Upper Triassic ammonoids, conodonts and pelagic bivalves, as well as specialists on palynology and physical stratigraphy. This search for the optimal section and events to mark the base of the Carnian has led these specialists to reconsider and re-examine a few promising Tethyan and North American Upper Ladinian-Lower Carnian fossil-rich successions that have not been studied for many tens of years. The Working Group of the Subcommittee on Triassic Stratigraphy (STS) eventually selected Prati di

Stuores/Stuores Wiesen in Italy, Spiti in India and South Canyon in Nevada (USA) for further scrutiny. Following a thorough discussion of the strengths and weaknesses of these possible candidates during the 2007 “Global Triassic” conference in Albuquerque, NM, the FO (First Occurrence) of the ammonoid *Daxatina canadensis* at level SW4 of Prati di Stuores was ultimately selected as the GSSP, and eventually ratified by the STS and IUGS in 2008. Since the formal definition of this GSSP, many of these specialists have become involved with the Carnian/Norian boundary Working Group, and consequently, the completion of the taxonomic and bio-chronostratigraphic revision of the three above designated successions has been delayed. The presentation of the GSSP is now ready (Mietto et al., 2012) and the bio-chronostratigraphy of the

Spiti and South Canyon successions is nearly finished. Herein we provide the description of a new ammonoid species recently discovered in the upper levels of the South Canyon Lower Carnian succession. Although the formal description of this new taxon would normally be included in the forthcoming taxonomic revision of the South Canyon ammonoids, we choose to document its existence now as a tribute to Norman J. Silberling (1928-2011), who was a pillar of the Triassic scientific community for over 50 years. Norm Silberling was widely recognized as the leading authority for Triassic ammonoid palaeontology and biostratigraphy in the western United States.

STRATIGRAPHIC IMPORTANCE OF SOUTH CANYON

South Canyon, a ~3.0-km-long, west trending valley located near the southern end of the New Pass Range (central Nevada; Fig. 1), has played a crucial role in the definition of the North American Triassic bio-chronostratigraphic scale (Silberling & Tozer, 1968; Fig. 2), which is generally accepted as the most detailed marine Triassic scale in the world. The middle member of the Augusta Mountain Formation of the Star Peak Group (Silberling, 1956; Nichols & Silberling, 1977) has provided vital ammonoid faunas that are generally missing or poorly preserved within the fossil-rich successions of British Columbia (Fig. 2), which has abundant Upper Ladinian ammonoids, but a relatively poor Lower Carnian ammonoid record (Tozer, 1967, 1981b: p. 412). F.N. Johnston (1941) first described the ammonoids of the middle member but he did not utilize the bed-by-bed collecting method and instead, treated the taxa as a single fauna. Later, Silberling (1956) examined the South Canyon section and recognized the position of Johnston’s taxa in the lower part of the middle member. Then in 1968, Silberling & Tozer correlated the ammonoid “fauna” of the middle member with the British Columbia ammonoid succession and designated the Desatoyense Zone at South Canyon (Fig. 2) as the base of the Carnian stage of the North American scale.

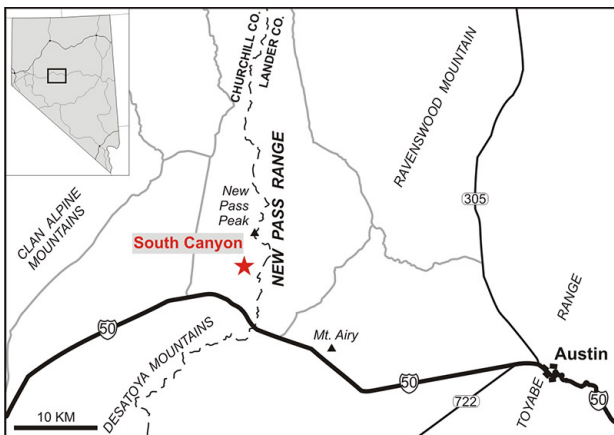


Fig. 1 - Location map of South Canyon in the New Pass Range, central Nevada, USA. A detailed road log with access information for this locality is provided in Lucas et al. (2007). Black: main roads; grey: unpaved roads.

		Index species	Type locality
CARNIAN	Lower	<i>Sirenites nanseni</i>	Ewe Mountain, BC
		<i>Austrotrachyceras obesum</i>	Ewe Mountain, BC
		<i>Trachyceras desatoyense</i>	South Canyon, Nevada
LADINIAN	Upper	<i>Frankites sutherlandi</i>	Boiler Canyon, BC
		<i>Maclearnoceras maclearni</i>	Fossil Gate, BC
		<i>Meginoceras meginiae</i>	Boiler Canyon, BC

Fig. 2 - The Upper Ladinian-Lower Carnian ammonoid zones of the North American Triassic bio-chronostratigraphic scale (Silberling & Tozer, 1968; Tozer, 1981b, 1994). All the zones were defined in British Columbia (BC), except for the Desatoyense Zone, defined in Nevada.

Basically, the ammonoid succession at South Canyon has not been studied since the works of Johnston and Silberling, and for all practical purposes, the Desatoyense Zone may as well be an Oppel zone, *sensu* Hedberg (1976). Because of its importance to the definition of the North American bio-chronostratigraphic scale, this locality attracted the interest of the Ladinian/Carnian boundary Working Group of the STS about ten years ago and new extensive collections were made following a strict bed-by-bed approach from 2003 to 2007, mostly by MB and JJ, but also by M. Orchard for conodonts and C. McRoberts for pelagic bivalves. This investigation, which focused on the lowermost part of the middle member of the Augusta Mountain Formation (Fig. 3) at six sites (A, B, D1, D2, E and F), has led to the following summarized results, some of which were unexpected:

1. As reported by Silberling & Tozer (1968), ammonoids replicating the “fauna” described by Johnston (1941) were collected from several levels (Balini et al., 2007) over some tens of meters of the lowermost part of the middle member of the Augusta Mountain Formation;
2. These ammonoid bearing levels are mostly concentrated within two intervals (Fig. 3). The lowermost is about 25 m thick at sites A and B, and the uppermost occurs about 50 m above the base of the middle member at sites D2, E and F. Johnston’s fauna occurs in both intervals;
3. Ammonoids, conodonts and bivalves typical of the Sutherlandi Zone of British Columbia were discovered within the lower interval (Balini et al., 2007; Balini, 2008). This fauna included *Frankites sutherlandi*, the index ammonoid of the Sutherlandi Zone (Fig. 2), which was not reported by Johnston;
4. *Trachyceras*-like ammonoids from the lower interval were found to have ceratitic suture lines and were referred to *Daxatina* Strand, 1929 (Balini & Jenks, 2007). *Daxatina* Strand, 1929 can be separated from *Trachyceras* Laube, 1869 only by its suture line, the former being ceratitic and the latter characterized by an ammonitic suture. *Daxatina* is another component of the *Frankites sutherlandi* Zone (*sensu* Tozer, 1967; Silberling & Tozer, 1968; Tozer, 1981b, 1994) of British Columbia;
5. The occurrence of *Trachyceras* Laube, 1869 at site F in the uppermost ammonoid bearing interval was

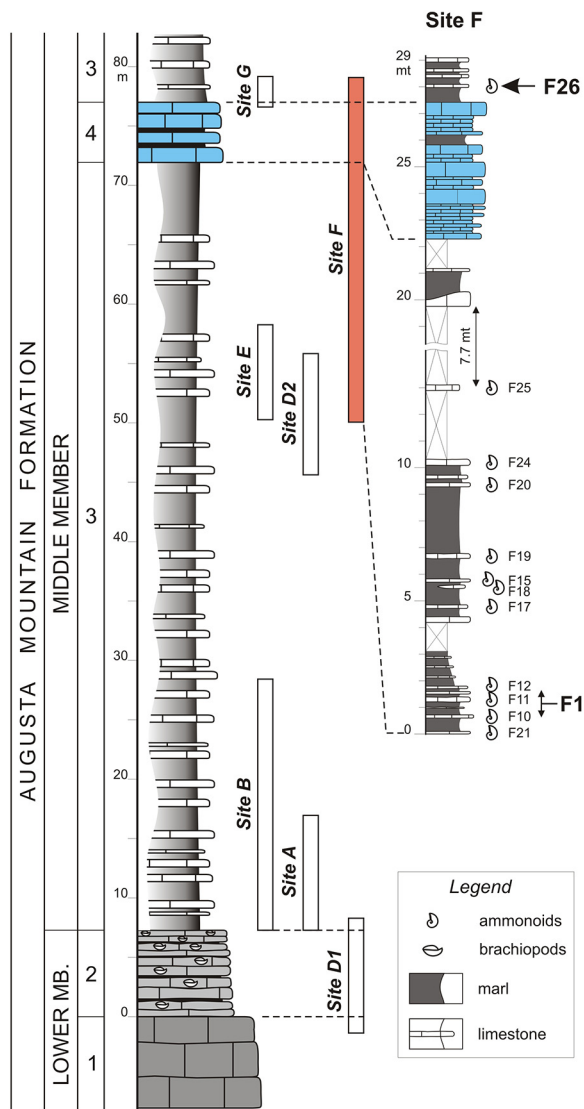


Fig. 3 - Composite section of the lower part of the middle member of the Augusta Mountain Formation, as exposed on the northern slope of South Canyon (New Pass Range, central Nevada, USA). Sites A, B, D1, D2, E and F are distributed over a distance of about 500 m along strike. Logs are described in Balini et al. (2007) and Balini & Jenks (2007). Bedding of the composite log is not to scale, but bedding shown at site F represents actual field measurements. GPS (WGS84) coordinates of F1: 39°36'48.0"N; 117°30'09.5"W. Coordinates of F26: 39° 36' 47.6" N; 117° 30' 12.6" W.

documented on the basis of few specimens with ammonitic suture lines (Balini & Jenks, 2007).

Data from the 2003-2007 sampling program at South Canyon greatly contributed to the selection of *Daxatina* as marker for the GSSP of the Carnian stage. Unfortunately, these collections were not sufficiently adequate to allow for the revision of the "fauna" described by Johnston (1941) because of a combination of two unexpected conditions. First, the type specimens of *Trachyceras desatoyense* Johnston, 1941 as well as most of the other species he attributed to the genus *Trachyceras*, are preserved with test and do not show the suture line, whereas our new collections consist of specimens from hard, un-weathered limestone that usually separate

from part of the test during preparation, and thus show only incomplete suture lines and outer ornamentation. Second, and even more important, the internal molds of Trachyceratinae with exposed suture lines from South Canyon are very difficult to compare to the type specimens of *T. desatoyense* because the internal mold of this group of ammonoids very commonly exhibits a "weakening or dampening effect" with respect to the ornamentation on outer surface of the test (Balini & Jenks, 2007). This effect, first recognized in the early 1970s (Tozer, 1972, 1994; Howarth, 1975), is known to occur in some genera of the family Trachyceratidae Haug, 1894, and is supposedly caused by the development of a secondary inner test ("preseptal layer" of Guex, 1970 and Tozer, 1972, 1994) on the inside of the body chamber.

### TOWARDS THE REVISION OF THE DESATOYENSE "FAUNA"

The occurrence of this "preseptal layer" in the South Canyon Trachyceratinae has not prevented the revision of Johnston's taxonomy, but it certainly has hindered its progress, because relatively few new specimens can be prepared with the entire test still attached. Thus, it can be difficult to compare our material with Johnston's type specimens. These specimens are generally quite rare with respect to the frequency of those found as internal molds; therefore, it became necessary to increase the overall collection in order to better understand the outer ornamentation of a population sample consisting mainly of inner molds. For this reason collecting efforts at South Canyon resumed in 2010 and were mainly focused on the upper ammonoid bearing interval at site F, where very few *Trachyceras* s.s. were collected in 2006.

Among the new specimens collected in 2010 and 2011, some are characterized by a well indented ammonitic suture line and the peculiar occurrence of two lateral rows of large sized bullae-like nodes. The first row is positioned on or just slightly above the umbilical shoulder, while the second row is located higher on the flank at 70% of whorl height. These ammonoids belong to a rare assemblage of *Trachyceras* that Mojsisovics (1893) described as the group of "*Trachycerata acanthica*". This group, based on specimens from the classic Carnian Hallstatt Limestone localities at Feuerkogel and Raschberg (Northern Alps, Austria), has never been reported from anywhere else in the world. The differences between our South Canyon specimens and the Alpine species, while not great, do justify the erection of the new species, *Trachyceras silberlingi*. Since this new species is the first belonging to *Trachyceras* s.s., this identification then is of great interest for its bio-chronostratigraphic implications. For this reason, we provide in the next chapters a detailed lithostratigraphic setting for the new specimens and a discussion of their bio-chronostratigraphic significance.

### LITHOSTRATIGRAPHIC SETTING

At South Canyon, the Augusta Mountain Formation is divided into three members (Silberling, 1956). While the lower and upper members consist of medium to thick

bedded shallow water carbonates, the middle member was deposited in a significantly deeper environment. The middle member, which yielded the rich ammonoid faunas described by Johnston (1941) and Silberling (1956), is about 280 m thick (Balini et al., 2007) and consists of a monotonous alternation of dark grey marl and marly limestone beds. The boundary between the lower and middle members is transitional, which documents the drowning of the carbonate platform of the lower member (Fig. 3). Its topmost part, consisting of medium bedded crinoidal packstones (Fig. 3, lithofacies 1), is overlain by medium to thin bedded brachiopod-rich packstones with a few very thin marly intercalations (lithofacies 2). The middle member consists of monotonous alternation of light grey to dark grey bioclastic marly mudstones and wackestones with grey marls (lithofacies 3). Included in the upper part is a ~5 m-thick interval dominated by grey mudstones up to 50 cm thick (lithofacies 4).

Structurally, the beds of the entire Augusta Mountain Formation at South Canyon dip to the south, and the middle member crops out only on the northern side of the canyon, where the beds dip with the slope. In general, outcrops of the ammonoid-rich middle member (lithofacies 3) are rather poor and scattered because of 1) the unfavorable dip/slope relationship of the bedding, 2) the soft weathering attitude of the grey marl-marly limestone alternations, and 3) the amount of covering debris produced by carbonates of the lower member, which are well exposed higher up on the northern slope of the canyon. Because of these unfavorable conditions, continuous exposures of the middle member are virtually non-existent. Extensive bed-by-bed sampling has been conducted at six sites (Balini et al., 2007; Balini & Jenks, 2007; Orchard & Balini, 2007; Balini, 2008), either on natural exposures on the side of small gullies cutting the slope of the canyon, or in hand-dug trenches. Two trenches were dug within the lowermost ammonoid bearing interval at sites A and B in the lower 20-30 m of the middle member, while the uppermost ammonoid bearing interval (from 50 to 80 m from the base) was sampled at sites D2, E and F. The successions at the different sites are correlated (Fig. 3) by using the top of lithofacies 2 and the well exposed lithofacies 4 as marker levels. Fossils occur in laterally continuous beds and to a lesser extent, in lenses that are more difficult to follow along strike.

Site F is a natural exposure on the eastern side of a small gully, where a ~28 m-thick section (Fig. 3) was sampled in 2006, 2010 and 2011. This exposure includes

about 5 m of the normally well exposed marker level designated as lithofacies 4. Twelve fossil bearing levels were sampled along the section (Fig. 3), but unfortunately, the most fossiliferous level at site F is the large-sized lens F1 (~1.5 m diameter) that was exposed a few tens of meters east of the section (GPS WGS84 coordinates: 39° 36' 48.0" N, 117° 30' 09.5" W). Lateral tracing based on strike and dip of F1 (barring any covered faults) suggests a correlation with the lowermost part of the section (levels F10-F12).

The new species *Trachyceras silberlingi* is based on four specimens from levels F1 and F26. The best specimen of the type series, designated as holotype, is from F26.

## SYSTEMATIC PALAEOLOGY

Family-group taxonomy follows that of Tozer (1981a and 1994).

Specimens described in this contribution are housed in the Museo di Paleontologia (MPUM), Dipartimento di Scienze della Terra "Ardito Desio", Università degli Studi di Milano, Via Mangiagalli 34, 20133 Milano, Italy.

Each specimen is identified by both museum number (e.g., MPUM xxxxx) and collection number. The latter, in parentheses or dashes, indicates site, bed of collection and the individual number of the specimen (e.g., F26-1: site F, bed number 26, 1<sup>st</sup> specimen).

Order CERATITIDA Hyatt, 1884

Superfamily CLIDONITACEAE Hyatt, 1877 (in Meek, 1877)

Family TRACHYCERATIDAE Haug, 1894

Subfamily TRACHYCERATINAE Haug, 1894

Genus *Trachyceras* Laube, 1869

Type species *Ammonites (Ceratites) aon* Münster, 1834

*Trachyceras silberlingi* n. sp.

(Pl. 1, figs 1-4; Fig. 4)

*Etymology* - The species is dedicated to the memory of Norman J. Silberling (1928-2011), who, for over 50 years, was the recognized authority on the Triassic of the western United States.

*Locus typicus and stratum typicum* - South Canyon (New Pass Range, central Nevada, USA), Augusta

## EXPLANATION OF PLATE 1

Type specimens of *Trachyceras silberlingi* n. sp.

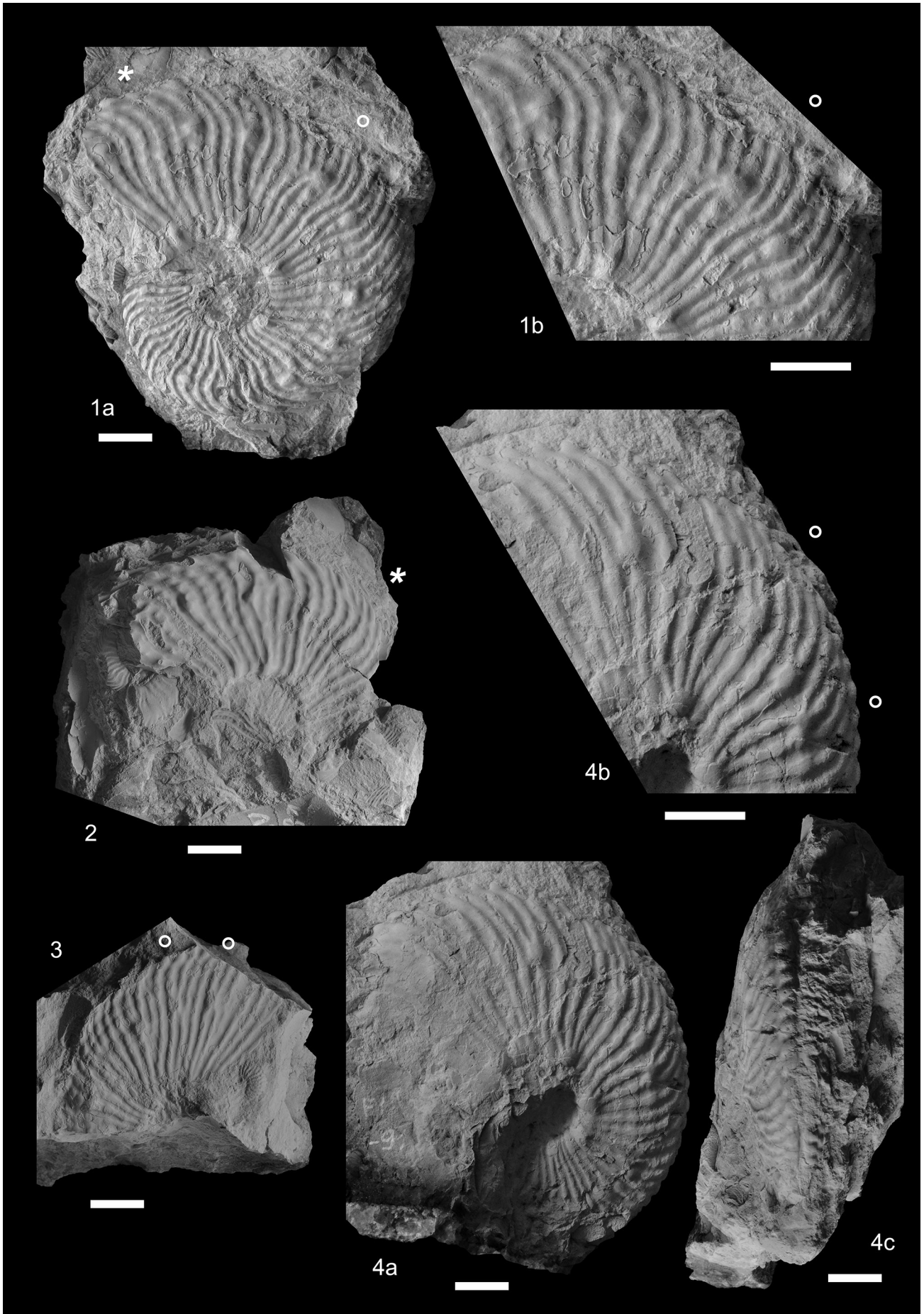
Fig. 1 - Holotype MPUM 11061 (F26-14). a) lateral view; b) enlarged lateral view showing detail of the ornamentation.

Fig. 2 - Paratype MPUM 11062 (F26-2), lateral view.

Fig. 3 - Paratype MPUM 11064 (F1-144), phragmocone, lateral view.

Fig. 4 - Paratype MPUM 11063 (F1-91), phragmocone. a) lateral view; b) enlarged lateral view showing detail of the ornamentation; c) ventral view.

Asterisk marks the last suture line; white circle marks the ribs looped at the lateral bulla. All scale bars = 1 cm.



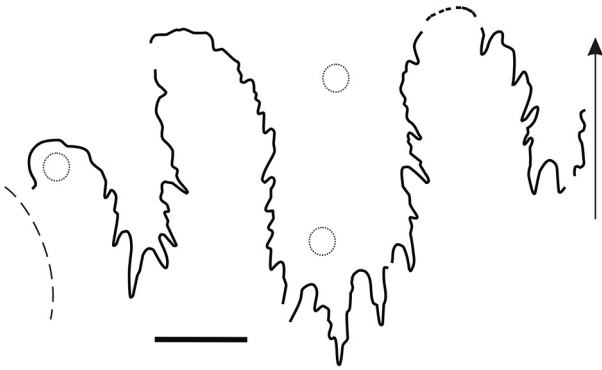


Fig. 4 - Suture line of *Trachyceras silberlingi* n. sp., paratype MPUM 11063 (F1-91), at about 26 mm of whorl height. The position of the bullae is shown with dotted circles. Scale bar is 5 mm.

Mountain Formation, middle member, section F, level F26, with GPS coordinates (WGS84) 39° 36' 47.6"N, 117° 30' 12.6"W.

*Type series* - Holotype MPUM 11061 (F26-14). Three paratypes: MPUM 11062 (F26-2), MPUM 11063 (F1-91), MPUM 11064 (F1-144).

*Diagnosis* - Large sized *Trachyceras* characterized by eleven rows of nodes and two rows of bullae, the first located just slightly above the umbilical shoulder and the second on the flank at about 70% of whorl height. Some ribs dividing at umbilical bullae, into two or sometimes three ribs. Occasionally, the ribs divided at the umbilical bulla are looped at the lateral bulla, and then divided again on their remaining course to the venter. Cross section of the ribs is symmetrical.

*Description* - The four available specimens are of medium to large size. Two specimens (MPUM 11062 and MPUM 11064) are preserved only as a quarter whorl. All specimens are preserved as internal molds, with a few small patches of test still attached. The largest most complete specimen, which is selected as the holotype, consists of a phragmocone with only a very small portion of the body chamber.

Shell characterized by involute coiling (U/D ~ 25% for holotype), a compressed whorl section with slightly convex flanks and a convex, furrowed venter.

Ornamentation consists of spiral rows of nodes and bullae, as well as radial ribs. Quite often, ornamentation is weakened by the "preseptal layer". This weakening more commonly affects the nodes rather than the ribs. The bullae, if not damaged during preparation - e.g., MPUM 11064 (F1-144) - are always well visible.

Eleven rows of nodes are present on the flank from the umbilical shoulder to the ventral shoulder. This feature is most visible on paratype MPUM 11062 (F26-2). The nodes between the first and the second row of bullae are very weak, while the others are much stronger. A single ventral node is visible at the end of the preserved part of the body chamber of specimen MPUM 11062, and shows a double pointed termination. The nodes are very weak and much less obvious on the other type specimens. The

single row of ventral nodes, exposed only on paratype MPUM 11063 (F1-91), is significantly subdued by effect of the "preseptal layer".

The bullae, organized into two rows, are situated at nearly the same position on all type specimens. The first row is located on or just slightly above the umbilical shoulder, while the second row is located higher on the flank at about 70% of whorl height. Bullae frequency changes slightly from specimen to specimen. The holotype exhibits on one half whorl between four and five bullae in the umbilical row and eight in the lateral row. Each umbilical bulla is usually paired with a corresponding lateral bulla, but unpaired (no corresponding umbilical bullae) lateral bullae are occasionally positioned between these paired bullae. Umbilical and lateral bullae are all paired on paratype MPUM 11062 (F26-2), whereas the ratio is four umbilical for five lateral per half whorl on paratype MPUM 11063 (F1-91). The umbilical bullae on paratype MPUM 11064 (F1-144) were damaged during preparation and cannot be counted.

Ribbing is visible only on the internal molds, and the few patches of test remaining on the surface of the specimens do not allow for the understanding of the cross section of the ribs on the outer surface of the test. On the internal mold, the ribs in cross section are top-rounded and symmetrical.

The organization of the ribs is very similar for all type specimens. Most ribs are primary and start at the umbilical shoulder, but some actually begin at the umbilical bullae, in groups of two or even three. Primary ribs independent of the umbilical bulla may bear a lateral bulla, and some of these may divide at this point. Intercalary ribs are rare (about one or two per half whorl) and appear only between the first and second row of bullae. A peculiar feature of this species is the looping of the ribs at the lateral bullae, which then is often accompanied by a further division of the looped ribs on their course to the venter (Pl. 1, figs 1a-b, 3, 4b). This feature is present on all type specimens except MPUM 11062 (F26-2).

A slight difference exists in the course of the ribs among the type specimens. The holotype and paratype from F26 exhibit an almost falcooid-type of ribbing, while the ribbing style of specimens from F1 varies from more sinuous - MPUM 11064 (F1-144) - to almost concave - MPUM 11063 (F1-91) -. However, this feature is considered of secondary importance since the two specimens from F1 are slightly deformed (elliptical), while the specimens from F26 are normal.

The ammonitic suture line is visible on all type specimens, with that of specimen MPUM 11063 (F1-91) (Fig. 4) being the most complete. The saddles are indented and rather spirally elongated.

*Discussion* - None of the specimens attributed to *Trachyceras* by Johnston (1941) and Silberling (1956) can be attributed to the new species. This conclusion is based on information contained in both papers and the direct examination (by MB) of both collections at the National Museum of Natural History (Smithsonian Institution, Washington).

The combination of the lack of test and the occurrence of the "preseptal layer" does not allow for the understanding of the cross section of the ribs on the outer surface of the

test. This cross section is flat topped and symmetrical in the *Trachyceras* of the Aon Zone - group of *T. brotheus* (Münster, 1834), including also *T. medusae* (Mojsisovics, 1893), *T. fontanesi* (Mojsisovics, 1893) and ?*T. jannuarius* (Mojsisovics, 1893) - whereas it is asymmetrical in the *Trachyceras* of the Aonoides Zone (Krystyn, 1978 and personal communication 2012). The types of *T. silberlingi* consist of internal molds affected by “preseptal layer”, but show a symmetrical section, that suggest a connection of this species with the group of *T. aon*.

The spiral ornamentation, on the contrary, suggests a close similarity of *Trachyceras silberlingi* n. sp. to an assemblage of very rare Trachyceratinae, the group of “*Trachycerata acanthica*”, that thus far is known only from its original description by Mojsisovics (1893). This group, consisting of 15 species from the Hallstatt Limestone of Salzkammergut (Northern Alps, Austria), is characterized by frequent large sized nodes of varying intensity that accompany the typical small sized nodes of *Trachyceras*. Mojsisovics’ type specimens are beautifully preserved in a manner typical of the well-known Hallstatt style, and their illustration in hand drawn plates represents an amazingly high quality never again reached in the history of Triassic ammonoid taxonomy. Unfortunately the suture line of Mojsisovics’ species is not known (Mojsisovics, 1893) because all specimens retain the test. The 15 species of this group are all based on relatively few type specimens, and their stratigraphic position is difficult to determine because of their occurrence in the highly condensed Hallstatt Limestone facies at the type localities of Feuerkogel and Raschberg in the Salzkammergut, Northern Alps (Tozer, 1971; Krystyn, 1973, 1978, 1980; Balini et al., 2012, figs 10 and 12). Mojsisovics reported his 15 species from three marker levels with *Lobites ellipticus*, *Trachyceras aonoides* and *Trachyceras austriacum*, which at that time (Mojsisovics, 1893: p. 793; Mojsisovics et al., 1895) were included within the *Trachyceras aonoides* Zone.

Eight of the 15 species described by Mojsisovics in the “*Trachycerata acanthica*” group have two rows of bullae-like nodes in the same position as *Trachyceras silberlingi* n. sp. These are *Trachyceras uraniae*, *T. ariae*, *T. thaliae*, *T. semiramis*, *T. stenonis*, *T. griseldis*, *T. supremum* and *T. scaphitoides*. Several of these species also exhibit the alternation of paired and unpaired bullae that is equivalent to the organization of the bullae in *T. silberlingi* n. sp. However, none of Mojsisovics’ species have ribs looped at the lateral bulla. This feature is thus the most significant diagnostic characteristic of *T. silberlingi* n. sp.

With regard to the number of rows of small sized nodes, *Trachyceras silberlingi* with its 11 rows, falls within the range of the above mentioned eight species, which vary from nine rows (*T. uraniae* and *T. ariae*) to 13 rows (*T. supremum*). A rather common feature in Mojsisovics’ species is the occurrence of two rows of very closely spaced nodes that resemble a single row of double pointed nodes. This row of “double pointed” nodes, located in the next to last position, adjacent to the ventral shoulder, are best developed in *T. uraniae*, *T. ariae*, *T. thaliae*, *T. semiramis*, *T. stenonis*, *T. griseldis* and *T. supremum*. The type specimens of *T. silberlingi* do not exhibit these “double pointed” nodes. However, these specimens are preserved as internal molds and it is very unlikely that this feature of the outer surface of the

test would be visible on the internal mold, especially on specimens with the “preseptal layer”.

*Age* - The species is known only from the Early Carnian of Nevada. See biostratigraphy for the discussion on its stratigraphic position.

## BIOSTRATIGRAPHY

The original definition of the Desatoyense Zone by Silberling & Tozer (1968: p. 35), based on the investigation of Johnston (1941) and complemented by additional data by Silberling (1956), is no longer consistent with new data provided by recent studies at South Canyon, which adhered to a strict bed-by-bed approach. Taxa described by Johnston are documented in the lower 80 m of the middle member of the Augusta Mountain Formation, but the succession has also yielded some taxa that either were not found by Johnston, or were not correctly classified.

We here propose the subdivision of the Desatoyense Zone into two units (Fig. 5) that for now are considered as local biozones. The first unit is provisionally informal, while the second is formally described. Their chronostratigraphic potential will be more fully understood as soon as the ongoing taxonomic revision of South Canyon ammonoids is completed.

### *Daxatina* beds

This biostratigraphic unit is documented at sites A and B, and its fauna is very close to the *Frankites sutherlandi* subzone 2 of Tozer (1994). The most typical taxon of this unit is *Daxatina* Strand, 1929, which probably also occurs in the lower part of the overlying *Trachyceras silberlingi* biozone (see below). For this reason we regard this unit as an interval zone based on the FO of *Daxatina* and FO of *Trachyceras*, rather than a biostratigraphic unit based on faunal content as was done by Tozer (1994). We choose not to formalize this unit because currently there is not a taxonomically well defined species to designate as the index ammonoid.

The ammonoid faunas of this biostratigraphic unit are dominated by the Trachyceratidae (Balini & Jenks, 2007, fig. 4) and in particular by *Daxatina* Strand, 1929, but the occurrence of *Trachyceras* Laube, 1869 (quoted in Balini, 2008, submitted long before Balini & Jenks, 2007) has not yet been confirmed by the discovery of specimens with an ammonitic suture line. In fact, it is highly probable that most of the species attributed by Johnston (1941) to *Trachyceras*, including *T. desatoyense* Johnston, 1941, actually belong to *Daxatina*. *Frankites sutherlandi* (McLearn, 1947), a taxon not found by Johnston, is quite common in a certain part of the succession (site B, beds SCAN 14 and 15; Balini, 2008).

Besides Trachyceratidae, the taxa of the *Daxatina* beds includes several components of Johnston’s Desatoyense “fauna”, such as *Clionitites* Strand, 1929, *Joannites* Mojsisovics, 1879, *Lobites* Mojsisovics, 1875 and *Neoclypites* Spath, 1951.

The co-occurrence of *Frankites sutherlandi* and *Daxatina* as well as the apparent lack of *Trachyceras* demonstrates the correlation of this part of the succession with the *Frankites sutherlandi* subzone 2 of British

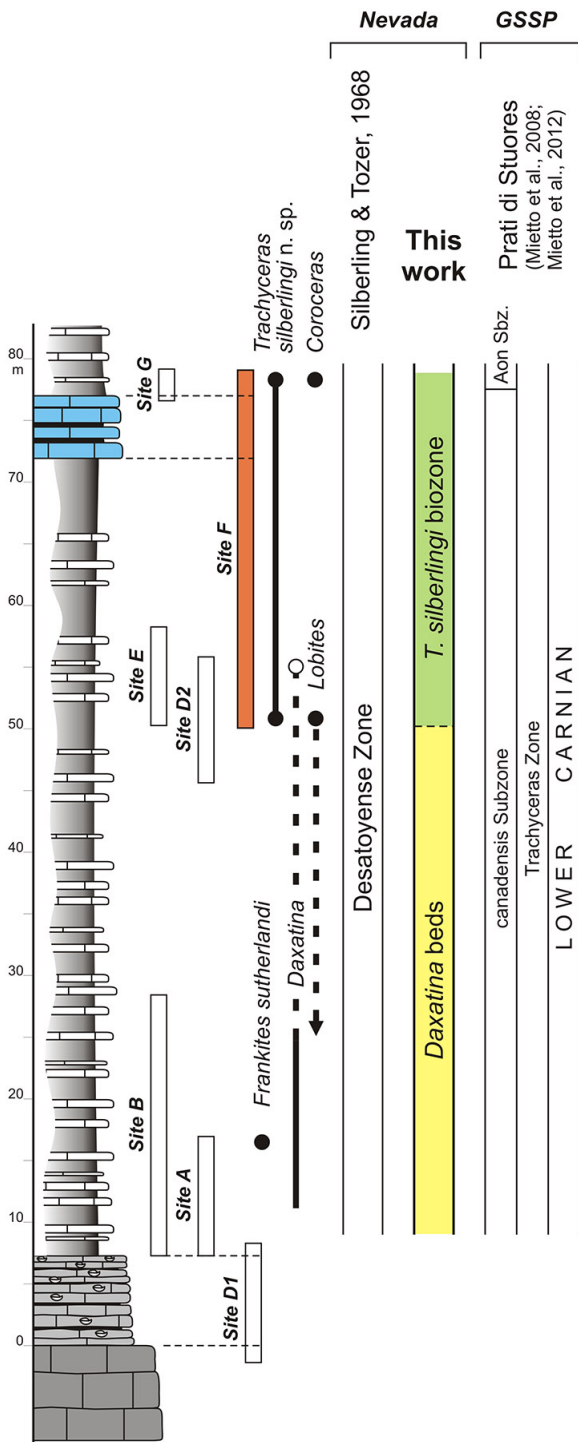


Fig. 5 - Revision of the Lower Carnian zonation at South Canyon, and its correlation with the Prati di Stuores/Stuores Wiesen GSSP (Tethys). Since bed F1 is actually located few tens of meters from the measured section, the position of the FO of *Trachyceras silberlingi* n. sp., documented from this bed is correlated to levels F10-F12 on the basis of strike and dip (see text). The LO of *Daxatina* is recorded in level D10 of section D2, but thus far, it has not been found at site F. Its projected position on the succession exposed at site F is marked with white circle.

Columbia as implied by Tozer (1994), i.e., with the upper part of the Sutherlandi zone, characterized by the occurrence of *Daxatina*.

*Trachyceras silberlingi* biozone (new)

INDEX AMMONOID OF THE BIOZONE - *Trachyceras silberlingi* n. sp.

TYPE - Range zone.

TYPE LOCALITY AND BOUNDARIES - South Canyon (New Pass Range, central Nevada), site F. The lower boundary is recorded in level F1, correlated with F10-F12. The last bed assigned to the zone is F26.

FAUNAL COMPOSITION - At the type locality *Trachyceras silberlingi* n. sp., *Trachyceras* div. sp. and *Perrinoceras novaditum* Johnston, 1941 occur throughout the entire zone. *Clionitites callazonensis* Tozer, 1994, *Silenticeras* aff. *schencki* (Johnston, 1941) and *Lobites* Mojsisovics, 1875 are limited to the lower part of the zone. *Coroceras* Hyatt, 1887 is rather common in bed F26, the uppermost fossil bearing bed of the section. Thus far, *Daxatina* Strand, 1929 has not been identified at site F (Fig. 5), but representatives of this genus are common in level D10 of section D2, whose stratigraphic position most probably is above the FO of *T. silberlingi* n. sp. at site F (F10-F12; see correlation chart in Balini & Jenks, 2007, fig. 6).

REMARKS - The occurrence of *Trachyceras* at South Canyon in the upper ammonoid bearing succession (site F) was previously reported by Balini & Jenks (2007), but at that time the taxonomic analysis of *Trachyceras* was in a very preliminary stage and no specific name was available to distinguish this part of the succession. The formal description of *Trachyceras silberlingi* n. sp., with its peculiar and easily recognizable spiral ornamentation provides a well defined reference for this biozone.

With regard to faunal composition we emphasize the occurrence of taxa already described by Johnston, such as *Lobites*, *Coroceras* and *Perrinoceras novaditum* together with taxa reported for the first time from South Canyon, such as *Silenticeras*, *Clionitites callazonensis* and *Trachyceras silberlingi* n. sp.

CORRELATION - The *Trachyceras silberlingi* n. sp. biozone is here regarded as a local biozone. Calibration of its chronostratigraphic position with respect to the Tethyan scale must await the completion of the taxonomic revision of South Canyon *Trachyceras*. The Tethyan scale is based mainly on species of *Trachyceras* that are quite well known due to the revisions of Krystyn (1978) and Urlichs (1994) and complemented by the recent description of the earliest Carnian species from the GSSP section at Prati di Stuores/Stuores Wiesen (Mietto et al., 2008). Aside from the systematics of *Trachyceras*, the occurrence of *Coroceras* in the uppermost part of the *Trachyceras silberlingi* biozone suggests the correlation of this portion of the biozone with the Aon Zone of the Tethyan scale (Fig. 5), as this genus is known from the Aon and Aonoides zones of the Tethys (cf. Krystyn, 1973, 1980; Urlichs, 1994; Bizzarini, 2000). The occurrence of *Coroceras* in British Columbia (localities GSC 45745 and 83824; Tozer, 1994) is not significant for calibration of the South Canyon biostratigraphy because Tozer (1994) dated this occurrence, based on the taxon's occurrence in



the Desatoyense Zone *sensu* Silberling & Tozer (1968), thus leading to a circular reasoning.

## CONCLUSIONS

The study of recently collected *Trachyceras* from the type locality of the lowermost Carnian Desatoyense Zone of Silberling & Tozer, 1968 provides a number of known facts pointing in the direction of the revision of this zone that can be summarized as follows:

1. The new species *Trachyceras silberlingi* is described. This species is characterized by a peculiar and easy to distinguish feature, consisting of two rows of spiral lateral bullae, in addition to 11 rows of small sized spiral nodes, and by ribs looped at the lateral bulla.

2. None of the specimens collected by Johnston, presently housed in the National Museum of Natural History (Smithsonian Institution, Washington), are referable to the new species, and our new species is also quite rare in our new collections. Notwithstanding the present stage of the revision of the South Canyon fauna, *T. silberlingi* n. sp. represents a good, well defined marker for the subdivision of the former Desatoyense Zone into two parts.

3. These two units for the moment are considered as local biostratigraphic units. The *Daxatina* beds are characterized by *Daxatina* and *Frankites*, while the overlying *T. silberlingi* biozone is a range zone characterized by the occurrence of *Trachyceras*.

4. The chronostratigraphic significance and potential of the two biostratigraphic subdivisions will be demonstrated only after the completion of the taxonomic revision of the South Canyon ammonoid faunas. However, the subdivision of the former Desatoyense Zone into two parts appears to be worthwhile not only from a local perspective, but also on a broader scale. At South Canyon as in Spiti (Krystyn et al., 2004), the FO of *Daxatina* and the FO of *Trachyceras* are in stratigraphic sequence, but with a very limited overlap of the two genera. At the GSSP section of Prati di Stuoeres/Stuoeres Wiesen (Mietto et al., 2008, 2012) about 2/3 of the range of *Daxatina* actually overlaps the range of *Trachyceras*, and Mietto et al. (2008, 2012), have preferred to keep *Daxatina* and the first representative of *Trachyceras* together in the same subzone. This solution emphasizes the FO of *Daxatina* that is very useful for long distance correlations (Mietto et al., 2012), but on the other hand it diminishes the stratigraphic potential of the FO of *Trachyceras*, the genus that provides the markers for a major part of the Lower Carnian. This potential is also weakened by the attribution of the beds yielding *Daxatina* to the *Trachyceras* Zone (Mietto & Manfrin, 1995: p. 558; Mietto et al., 2008, 2012), even though they underlie the FO of *Trachyceras*.

5. The chronostratigraphic significance of *Trachyceras silberlingi* n. sp. has yet to be defined. This species shows a spiral ornamentation similar to the rare group of *Trachycerata acanthica* described by Mojsisovics in 1893 from the western Tethys of the Northern Alps (Austria), and at the same time it shows some similarity to the group of *T. aon* with respect to its ribbing cross section. Therefore this discovery from Nevada is of great interest in terms of its potential contribution to the reconstruction of the phylogeny of *Trachyceras* Laube, 1869.

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## REFERENCES

- Balini M. (2008). Discovery of Upper Ladinian ammonoids at the type locality of the Lower Carnian Desatoyense Zone (South Canyon, New Pass Range, Nevada). *Journal of Paleontology*, 82(1): 162-168.
- Balini M. & Jenks J.F. (2007). The Trachyceratidae from South Canyon (central Nevada): Record, taxonomic problems and stratigraphic significance. In Lucas S.G. & Spielmann J.A. (eds), *The Global Triassic. New Mexico Museum of Natural History and Science Bulletin*, 41: 14-23.
- Balini M., Jenks J.F., McRoberts C.A. & Orchard M.J. (2007). The Ladinian-Carnian boundary succession at South Canyon (central Nevada). In Lucas S.G. & Spielmann J.A. (eds), *The Triassic of American West. New Mexico Museum of Natural History and Science Bulletin*, 40: 127-138.
- Balini M., Krystyn L., Levera M. & Tripodo A. (2012). Late Carnian-Early Norian ammonoids from the GSSP candidate section Pizzo Mondello (Sicani Mountains, Sicily). *Rivista Italiana di Paleontologia e Stratigrafia*, 118(1): 47-84.
- Bizzarini F. (2000). Studio biostratigrafico delle tanatocenosi a cefalopodi della Formazione di S. Cassiano (Valle d'Ampezzo, Dolomiti orientali). *Lavori della Società Veneziana di Scienze Naturali*, 25: 15-28.
- Gux J. (1970). Sur les moules internes des Dactyloceratidae. *Bulletin des Laboratoires de géologie, minéralogie, géophysique et du Musée géologique de l'Université de Lausanne*, 182: 1-7.
- Haug E. (1894). Les Ammonites du Permien et du Trias. *Bulletin de la Société Géologique de France*, ser. 3, 22: 385-412.
- Hedberg H. (Ed.) (1976). *International stratigraphic guide*. 200 pp. John Wiley & Sons. New York.
- Howarth M.K. (1975). The shell structure of the Liassic ammonite family Dactyloceratidae. *Bulletin of the British Museum Natural History, Geology*, 26(2): 45-67.
- Hyatt A. (1884). Genera of fossil cephalopods. *Proceedings of the Boston Society of Natural History*, 22: 253-338.
- Johnston F.N. (1941). Trias at New Pass, Nevada (new Lower Carnian ammonoids). *Journal of Paleontology*, 15(5): 447-491.
- Krystyn L. (1973). Zur Ammoniten- und Conodonten-Stratigraphie der Hallstätter Obertrias (Salzkammergut, Österreich). *Verhandlungen Geologischen Bundesanstalt*, 1973(1): 113-153.
- Krystyn L. (1978). Eine neue Zonengliederung im alpin mediterranen Unterkarn. In Zapfe H. (ed.), *Beiträge zur Biostratigraphie der Tethys-Trias. Schriftenreihe der erdwissenschaftlichen Kommission, Österreichische Akademie der Wissenschaften*, 4: 37-75.
- Krystyn L. (1980). Stratigraphy of the Hallstatt region. In Schönlaub H.P. (ed.), *Second European Conodonts Symposium (ECOS II)*, Guidebook, Abstracts, *Abhandlungen der Geologischen Bundesanstalt*, 35: 69-98.

- Krystyn L., Balini M. & Nicora A. (2004). Lower and Middle Triassic stage and substage boundaries in Spiti. *Albertiana*, 30: 39-52.
- Laube G.C. (1869). Über *Ammonites Aon* Münster und dessen Verwandte. *Sitzungsberichte der Akademie der Wissenschaften Mathematisch-naturwissenschaftliche Klasse, Wien*, 59: 7-16.
- Lucas S.G., Silberling N.J., Jenks J.F., Balini M., Bucher H., Spielmann J.A. & Rinehart L.F. (2007). Second day: Middle and Upper Triassic stratigraphy and ammonite biostratigraphy: McCoy mine and South Canyon, Nevada. In Lucas S.G. & Spielmann J.A. (eds), *The Triassic of American West. New Mexico Museum of Natural History and Science Bulletin*, 40: 16-22.
- McLearn F.H. (1947). The Triassic *Nathorstites* fauna in Northeastern British Columbia. *Geological Survey of Canada, paper*, 47-24: 1-29.
- Meek F.B. (1877). Paleontology (Trias). In U.S. Geological Exploration of the 40th Parallel. 4(1): 1-197.
- Mietto P. & Manfrin S. (1995). A high resolution Middle Triassic ammonoid standard scale in the Tethys Realm. A preliminary report. *Bulletin de la Société Géologique de France*, 166(5): 539-563.
- Mietto P., Manfrin S., Preto N. & Gianolla P. (2008). Selected ammonoid fauna from Prati di Stuoeres/Stuoeres Wiesen and related sections across the Ladinian/Carnian boundary (Southern Alps, Italy). *Rivista Italiana di Paleontologia e Stratigrafia*, 114 (3): 377-429.
- Mietto P., Manfrin S., Preto N., Rigo M., Roghi G., Furin S., Gianolla P., Posenato R., Muttoni G., Nicora A., Buratti N., Cirilli S., Spötl C., Ramezani J. & Bowring S.A. (2012). The Global Boundary Stratotype Section and Point (GSSP) of the Carnian Stage (Late Triassic) at Prati di Stuoeres/Stuoeres Wiesen Section (Southern Alps, NE Italy). *Episodes*, 35 (3): 414-430.
- Mojsisovics E.v. (1873-1902). Das Gebirge um Hallstatt I. *Abhandlungen der kaiserlich und königlich Geologischen Reichsanstalt*, 6/1, part 1(1873): 1-82, part 2 (1875): 83-174, part 3 (1902): 175- 356, 6/2 (1893): 1-835.
- Mojsisovics E.v. (1879). Vorläufige kurze Übersicht der Ammoniten-Gattungen der mediterranen und juvavischen Trias. *Verhandlungen der kaiserlich und königlich Geologischen Reichsanstalt*, 7: 133-143.
- Mojsisovics E.v., Waagen W. & Diener C. (1895). Entwurf einer Gliederung der pelagischen Sedimente des Trias-Systems. *Sitzungsberichte der Akademie der Wissenschaften Mathematisch-naturwissenschaftliche Klasse, Wien*, 104(1): 1271-1302.
- Münster G.G. (1834). Ueber das Kalkmergellager von St. Cassian in Tyrol und die darin vorkommenden Ceratiten. *Neues Jahrbuch für Mineralogie, Geognosie und Petrefactenkunde*. Heidelberg, Stuttgart, 1834: 1-15.
- Nichols K.M. & Silberling N.J. (1977). Stratigraphy and Depositional History of the Star Peak Group (Triassic), Northwestern Nevada. *Geological Society of America, Special Paper*, 178: 1-73.
- Orchard M.J. & Balini M. (2007). Conodonts from the Ladinian-Carnian boundary beds of South Canyon, New Pass Range, Nevada, USA. In Lucas S.G. & Spielmann J.A. (eds), *The Global Triassic. New Mexico Museum of Natural History and Science Bulletin*, 41: 333-340.
- Silberling N.J. (1956). "Trachyceras Zone" in the Upper Triassic of the western United States. *Journal of Paleontology*, 30(5): 147-153.
- Silberling N.J. & Tozer E.T. (1968). Biostratigraphic Classification of the Marine Triassic in North America. *Geological Society of America, Special Papers*, 110: 1-63.
- Spath L.F. (1951). The Ammonoidea of the Trias. *Catalogue of the Fossil Cephalophoda in the British Museum, part 5, The Ammonoidea of the Trias (II)*. 228 pp. London.
- Strand E. (1929). Zoological and palaeontological nomenclatorial notes. *Acta Universitatis Laviensis*, 20: 1-29.
- Tozer E.T. (1967). A standard for Triassic time. *Geological Survey of Canada Bulletin*, 156: 1-103.
- Tozer E.T. (1971). Triassic time and ammonoids: Problems and proposals. *Canadian Journal Earth Sciences*, 8(8): 989-1031, 1611.
- Tozer E.T. (1972). Observation on the shell structure of Triassic ammonoids. *Palaeontology*, 15(4): 637-654.
- Tozer E.T. (1981a). Triassic Ammonoidea: Classification, Evolution and Relationship, with Permian and Jurassic Forms. In House M.R. & Senior J.R. (eds), *The Ammonoidea. The Systematic Association special volume* 18: 65-100, Academic Press, London, New York.
- Tozer E.T. (1981b). Triassic Ammonoidea: Geographic and Stratigraphic Distribution. In House M.R. & Senior J.R. (eds), *The Ammonoidea. The Systematic Association special volume* 18: 397-432, Academic Press, London, New York.
- Tozer E.T. (1994). Canadian Triassic ammonoid faunas. *Geological Survey of Canada Bulletin*, 467: 1-663.
- Urlichs M. (1994). *Trachyceras* Laube 1869 (Ammonoidea) aus dem Unterkarn (Obertrias) der Dolomiten (Italien). *Stuttgarter Beiträge zur Naturkunde*, ser. B, 217: 1-55.

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