THE TRACHYCYRATIDAE FROM SOUTH CANYON (CENTRAL NEVADA): RECORD, TAXONOMIC PROBLEMS AND STRATIGRAPHIC SIGNIFICANCE FOR THE DEFINITION OF THE LADINIAN-CARNIAN BOUNDARY

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Abstract—South Canyon, type locality of the Lower Carnian Trachyceras desatoyense Zone of the North American Standard Scale, has been extensively sampled utilizing a bed-by-bed approach. The ammonoid rich Middle Member of the Augusta Mountain Formation (Star Peak Group) has been sampled at five sites, and preliminary data are presented. Suture line analysis permits the identification of the genus Daxatina from the lower part of the Middle Member and subsequently, this genus is reported for the first time from South Canyon. Trachyceras, also identified on the basis of its suture line, definitely occurs in the higher part of the studied interval, about 50 m from the base. This discovery of Daxatina, a genus almost identical to Trachyceras except for its carotitic suture line, brings into question the definite taxonomical position of Trachyceras desatoyense Johnston, 1941, a species whose suture line is not known. Taxonomical analysis of South Canyon Trachyceratidae is also complicated by the very common occurrence in both Daxatina and Trachyceras of a preseptal layer, an inner layer of the test that tends to smooth the internal mold with respect to the outer surface of the test. The occurrence of Daxatina, in conjunction with conodont and daonellid faunal analyses, support the correlation of the lower part of the Middle Member with the Upper Ladinian Frankites sutherlandi Zone of British Columbia.

INTRODUCTION

By tradition, the chronostratigraphy of the Triassic is mostly based on ammonoids, which provide the highest power of biochronologic resolution for the study of marine successions. This distinctive advantage of the ammonoids also holds true for resolving one of the major chronostratigraphic problems of the Upper Triassic Series, i.e., the definition of the GSSP of the Carnian Stage. Up till now only one candidate marker for this boundary has been suggested, and this is the appearance of the ammonoid Daxatina cf. canadensis at Prati di Stuores-Stuores Wiesen, in the Dolomites, Italy (Broglio Loriga et al., 1999). The correlatability of this particular bioevent and its calibration with conodont and bivalve events are still under evaluation. South Canyon (central Nevada, Fig. 1) is one of the three most interesting areas for the definition of the GSSP of the Carnian Stage, and the other site is the Spiti Valley (Tethys Himalaya, northern India; Balini et al., 1998, 2001). South Canyon is of great interest because it is the key-locality for intercontinental correlation with North America. However, ammonoids from this site were never studied with a bed-by-bed approach. Because of the great importance of this site, a joint research program based on bed-by-bed sampling of ammonoids, conodonts (M.J. Orchard) and bivalves (C.A. McRoberts) was started in 2002. A summary of the new data is presented in the Field Trip Guidebook (Balini et al., 2007), and the conodonts are described by Orchard and Balini (this volume). Herein, we present in more detail certain facts and taxonomic problems concerning a key group for the definition of the Ladinian-Carnian boundary, i.e., the ammonoids of the Family Trachyceratidae Haug, 1894.

IMPORTANCE OF SOUTH CANYON FOR THE NORTH AMERICAN TRIASSIC

For more than 60 years South Canyon has been regarded as the best locality for the Lower Carnian in North America. It is the type locality of the Trachyceras desatoyense Zone, the first zone of the Lower Carnian of the North American Standard Scale (Silberling and Tozer, 1968; Tozer, 1994; Fig. 2), that is based on the ammonoid “fauna” described by Johnston in 1941. This “fauna” is of high diversity, consisting of 13 genera, 17 new species (among them Trachyceras desatoyense), and 5 taxa in open nomenclature, but until the work of Tozer (1994) it had not been recognized elsewhere in North America. Its position within the North American Standard Scale was not easy to define, and a few refinements were required (see also Balini et al. 2007, fig. 3). Johnston (1941) correlated the “fauna” with the Lower Carnian Trachyceras aon or Trachyceras aonoides zone of the Tethyan Triassic, but its position with respect to the typical Upper Ladinian ammonoid zones was not recognized until 1968, when Silberling and Tozer discovered elements of the Frankites sutherlandi Zone, the uppermost zone of the Upper Ladinian, several hundreds of feet below the Trachyceras desatoyense “fauna”. The position of the Trachyceras desatoyense zone with respect to the other Carnian ammonoid zones was even more difficult to clarify. In 1968 Silberling and Tozer suggested time equivalence with the Trachyceras obesum Zone of British Columbia, a poorly documented zone also containing Trachyceras s.s. ammonoids (Tozer, 1967; Silberling and Tozer, 1968). This poorly defined zone was later revised by Tozer (1981 and 1994); Trachyceras obesum was moved to Austrotrachyceras Krystyn, 1979, and the discovery in British Columbia of a few Trachyceras desatoyense specimens below the Austrotrachyceras obesum
Zone, definitively established the position of the \textit{T. desatoyense} Zone as lowermost Carnian, below the \textit{A. obesum} Zone.

**THE STRATIGRAPHIC SUCCESSION AT SOUTH CANYON**

The Triassic succession at South Canyon was briefly described by Silberling (1956). In 1977 Nichols and Silberling discussed lithostratigraphic classification and correlation, and they slightly modified the lithostratigraphy of the section. Figure 3 shows the synthetic log of the Triassic succession (see Balini et al., 2007, for descriptions of the lithofacies). Basically, the Augusta Mountain Formation is subdivided into three members. The Lower Member consists of thick-bedded to massive coral limestones, with intercalations of conglomerates in the lower part, and of shales in the upper part. The top of the Lower Member is very peculiar and consists of well bedded coquina-like brachiopod limestone beds, which testify to the drowning of the carbonate platform. The Middle Member, consisting of alternating marls and limestones, is capped by massive limestones of the Upper Member, which record the onset of carbonate platform conditions.

The Augusta Mountain Formation is rather fossiliferous. Foraminifers (Gazdzicki and Stanley, 1983), cnidarians (Roniewicz and Stanley, 1998) and bivalves (Waller and Stanley, 2005) were reported mostly from the Lower Member. Brachiopods are very abundant at the top of the member, but they have not been studied. Conodonts were reported from the Middle Member by Mosher (1968). Ammonoids occur in two fossil bearing intervals (Silberling and Tozer, 1968). The lower occurrence, recorded within the Lower Member (USGS Locality M2559), provided ammonoids representative of the \textit{Frankites sutherlandi} Zone, while the upper occurrence, documented in the lower part of the Middle Member (USGS Locality M2560), is the \textit{stratum typicum} of the \textit{Trachyceras desatoyense} Zone. New data regarding ammonoids, conodonts and bivalves from the lower part of the Middle Member are briefly described by Balini et al. (2007) and by Orchard and Balini (this volume).

**THE STUDIED SECTIONS**

**Sections**

South Canyon is oriented approximately W-E and the Triassic succession strikes 120°-140° SE and dips 40°-60° SW. The beds dip with the slope on the northern side of the canyon, whereas they dip against the slope on the southern side. Details on the distribution of the outcrops are illustrated in Balini et al. (2007), but here we simply summarize that the Middle Member is soft weathering and is not very well exposed. The best outcrops are located on the northern side of the canyon (WGS84 coordinates 39°36' N, 117°30' W) because the debris cover is thinner than on the southern side. Natural outcrops are scattered, and bed-by-bed sampling of the stratigraphic section usually requires the removal of debris. Five sites were sampled during four field excursions from 2001 to 2006. These sites (labelled A, B, D, E and F) are distributed over a distance of less than 500 m along strike. The stratigraphic intervals exposed at the five sites are shown in Figure 4. Site A is more or less equivalent to USGS locality M2560 (N.J. Silberling, personal commun. to MB and JJ, 2001).

**Lithology**

The upper part of the Lower Member and the lowermost 70 m of the Middle Member can be subdivided into the following four lithologic intervals (see also Balini et al., 2007; Fig. 4):

1) Lower Member. Gray crinoidal packstones in 20 to 50 cm thick beds.

2) Lower Member. Gray bioclastic, brachiopod rich, packstones in 10 to 20 cm thick beds, with rare marly interbeds. Thickness about 7 m.

3) Middle Member. Monotonous alternation of light gray to dark gray bioclastic marly mudstones and wackestones with gray marls. The mudstones-wackestones usually contain varying amounts of ammonoids, and sometimes brachiopods and bivalves. Brachiopods are more common in the lowermost part. Thickness about 65 m.

4) Middle Member. Interval dominated by gray mudstones in 30 to 50 cm thick beds, with some intercalations of up to 60 cm thick intervals of marly mudstones/calcareous marls in 1 cm thick beds and...
ammonoids have been collected thus far.

Ammonoids are found from the uppermost bed of the brachiopod packstones (interval 2) to the Middle Member. Faunal composition of the cephalopod assemblages is shown in Figure 4. Ammonoids belong to the families Trachyceratidae, Joannitidae, Clionitidae, Lobitidae, Arcestidae and Noritidae. Family indeterminate mainly includes rather incomplete specimens of small size with almost evolute coiling, which could be referred to other Clionitites (family Clionitidae) or Hannaoceras (family Trachyceratidae).

Trachyceratidae are undoubtedly the most frequent group of ammonoids, and they represent a little more than the 50% of the overall collection. Their dominance normally ranges between 50 to 80%. Only rarely it is lower than 40%, but on occasion they represent 100% of the assemblage. Faunal diversity at the family rank may change from bed to bed, and does not seem to be influenced by sample size. The faunas with the highest diversity are A21, B11, and F1, with 5 to 6 families, but sample D10 yielded the largest number of specimens, and includes only Trachyceratidae, as well as Nautiloids and specimens in open position (family indet.).

**Family Composition**

Although taxonomic analysis is still in progress, we do present some qualitative and semiquantitative data. Ammonoid families are represented by few to very few genera. Joannitidae, Clionitidae, Lobitidae and Noritidae are represented by only one genus each, Joannites, Clionitites, Lobites and Neoclypitites, respectively. No definite examples of Perrinoceras (family Hungaritidae) and Coroceras (family Lobitidae) were collected even though these two genera were reported from South Canyon by Johnston (1941). The Trachyceratidae are only slightly more diversified. Most belong to the group of Daxatina and Trachyceras (Figs. 5-6), while Hannaoceras is much rarer. Silenticeras is represented by only one specimen from level D4, but the occurrence of Frankites sutherlandi from levels SCAN 14 and SCAN 15 is noteworthy (Fig. 5, Balini, in press). The first report of Frankites from South Canyon is of great bio- and chronostratigraphical significance, but it is treated in a separate contribution (Balini, in press). Here we focus on another group of Trachyceratidae very important for bio-chronostratigraphy, i.e., the group of Daxatina and Trachyceras.

**TAXONOMIC PROBLEMS AFFECTING THE TRACHYCERATIDAE**

Among the Trachyceratidae, the genera Daxatina Strand, 1919, and Trachyceras Laube, 1869 are morphologically very close. Both genera are characterized by a ventral furrow, dense ribs, several spiral rows of nodes and two rows of double-pointed ventral nodes bordering the furrow. Although Daxatina sometimes has triple pointed ventral nodes (e.g., Daxatina canadensis Whiteaves, 1889: Tozer, 1994, pl. 85, fig. 7), the only clear distinguishing difference between the two genera is the suture line, which is ammonitic in Trachyceras, and ceratitic in Daxatina, with occasional wrinkles on the external saddle (Tozer, 1994, p. 166, fig. 68e).

Taking into account that Daxatina is traditionally regarded as a latest Ladinian genus in North America, and that Trachyceras is accepted everywhere in the world as a typically Carnian ammonoid, the morphological similarities between the two genera suggest possible phyllogenetic relationships. However, up till now bed-by-bed analysis of these relationships has not been done.

Even if the morphological similarities of Daxatina and Trachyceras may suggest intriguing and stimulating hints for future phyllogenetic investigations, there is, however, a direct and somewhat depressing consequence: for specimens retaining the test, the separation of Daxatina and Trachyceras may be nearly impossible.

Given this complex background, it is clear that the South Canyon ammonoid record is of great interest. This is probably the only site in the...
FIGURE 5. Stratigraphic sections sampled at sites A and B, with the distribution of some ammonoid taxa. Daonellid and conodont faunas are described in Balini et al. (2007).
world with a very rich and uncondensed record of well preserved Trachyceratidae, in particular of the group of *Daxatina* and *Trachyceras*. At the present stage of work, the taxonomic revision of the ammonoid faunas of South Canyon is not yet complete. However, we present herein a few facts which are useful for the discussion on the GSSP of the Carnian Stage. We also illustrate some problems in order to show the direction of ongoing investigations.

**Fact #1: *Daxatina* is Documented in the South Canyon Sections**

At sites A and B, *Daxatina* is quite common and is represented by at least two groups. The first group exhibits a rather involute coiling and is very densely and finely ribbed (Fig. 7A-B). It includes some of the specimens classified by Johnston as *Trachyceras cf. T. aonoides*. The other group is more strongly ornamented and is probably represented by more than two species (Fig. 7C-E). The suture lines (Fig. 8) are clearly ceratitic, or just slightly crenulated.

*Daxatina* has been also found in the 2nd marker bed sampled at sites D(2) and E (Fig. 7E).

**Fact #2: *Trachyceras* is also Documented in the South Canyon Sections**

The sections sampled at sites D(2), E and F (Fig. 6) are characterized by two rather rich fossil bearing levels, which can be easily correlated, especially sites D(2) and E (Fig. 6). The lower level (levels D4= E14, E4 and E5) yields involute, compressed and densely ribbed Trachyceratidae, while the upper level (D10= E15, E3, E11, E12, E13) yields not only compressed and densely ribbed Trachyceratidae, but also the above mentioned coarsely ornamented *Daxatina* (Fig. 7E). These two marker beds are also probably exposed at site F (Fig. 6). The search for preserved suture lines has not met with much success in the 1st marker bed, while in the 2nd marker bed *Daxatina* (level D10 and E3) and two groups of ammonoids with an ammonitic suture have been identified (Figs. 9-10). The first group (Figs. 9-10A) exhibits a suture that is undoubtedly ammonitic, even if it is not as deeply indented as in typical *Trachyceras aon*. This group fits much better with *Trachyceras* than with *Daxatina* because the latter never displays true indentations of the saddles. The second group possesses a more indented suture (Fig. 10B) and is conspecific with the specimen classified as *Trachyceras cf. T. desatoyense* Johnston by Silberling (1956, fig.2B). However, this second group of *Trachyceras* does not agree with the types of *Trachyceras desatoyense*, since it exhibits a narrow venter and an almost subtriangular whorl section (M.B. pers. observation of specimens housed at NMNH, Washington).
Question #1 and #2: Where is and What is *Trachyceras desatoyense* Johnston, 1941?

These questions cannot be answered at the present time. The type specimens of *Trachyceras desatoyense* retain the test, and their suture lines are unknown. Moreover, Johnston did not select as the holotype one of his beautifully preserved, relatively large sized specimens such as pl. 68, fig. 4, but instead, chose one of the smallest specimens (pl. 67, fig. 4-5), which is a juvenile.

The preservation of the test should not represent a problem for the understanding of the internal mold, because for ammonoids the internal mold normally reflects almost exactly the morphology of the outer surface of the test. Unfortunately, this is not true for the South Canyon Trachyceratidae. *Frankites, Daxatina*, and *Trachyceras* specimens in the collection exhibit, almost as a rule, a thick and well developed preseptal layer (Fig. 11) in the innermost part of the body chamber, as well as on the phragmocone. This structure of the shell was described by Tozer (1972) for *Frankites*, but this is the first report for *Daxatina* and *Trachyceras*. Figure 11 includes some examples of specimens possessing a preseptal layer. In some specimens (Fig. 11A-B) two layers can be recognized, while other specimens apparently have three layers (Fig. 11C-D). Further investigation is necessary to clarify the structure and ontogenetic meaning of this double or multilayered feature.

From a taxonomic point of view, the preseptal layer precludes a direct comparison between the internal mold and outer surface of the test because the internal mold may be much smoother than the outer surface (Fig. 11D). When the preseptal layer is present, the septa are imprinted onto it, and not on the (outer) test. This structural feature does not have a “smoothing” influence on the indentations of the suture lines. Specimen F1-54 (Fig. 10A) possesses a preseptal layer, and its suture line was drawn from the surface of the internal mold. Notwithstanding this feature, its suture line is definitely ammonitic.

**STRATIGRAPHIC SIGNIFICANCE OF THE NEW DATA**

Results from the recent investigations conducted at South Canyon on ammonoids, conodonts and bivalves, in cooperation with M.J.
Orchard and C.A. McRoberts (Balini, in press; Balini et al., 2007; Orchard and Balini, this volume), necessitate a modification in the correlation of the South Canyon succession with British Columbia. The lower part of the Middle Member of the Augusta Mountain Formation exposed at site A and B is now correlated with the upper part of the Fraktites sutherlandi Zone of British Columbia. With regard to ammonoids, the facts in support of this new correlation are:

1) The occurrence of Fraktites sutherlandi at site B, level SCAN 14 and 15 (Balini, in press).
2) The occurrence of Daxatina from the lower part of site A to the top of site B, and in level D10.
3) The occurrence of Trachyceras rather high in the succession (site F, level F1).

Ongoing investigations are focused in three directions:

a) To complete the study of the Trachyceratidae at site A and B in order to determine if Daxatina occurs together with Trachyceras. As shown in Figure 5, some ammonoids resemble the external morphology of T. desatoyense Johnston (Fig. 11E-F) from the top of the Lower Member to the top of Site B. The suture line of these specimens is unknown.

b) To test whether the F.O. of Trachyceras is recorded in the 2nd marker level or in the 1st marker level. The suture line of specimens from level D4 (=E14) is not known.

c) To study the beds overlying F1 in order to determine where the main faunal change occurs.

Given that in North America the Ladinian-Carnian boundary traditionally has been placed at the first occurrence of Trachyceras (Tozer, 1967; Silberling and Tozer, 1968; Tozer, 1981 and 1994), the identification of Trachyceras s.s. only from higher levels at South Canyon strongly suggests that the Ladinian-Carnian boundary should be moved from the ammonoid barren shallow water limestones of the Lower Member to the fossil rich limestones of the Middle Member. This relocation of the boundary improves the overall significance of the South Canyon succession since the Ladinian-Carnian boundary would not be influenced by a facies change. However, the practical difficulties in the separation of Daxatina from Trachyceras would suggest the re-evaluation of Trachyceras as a guide fossil for the base of the Carnian Stage. The final decision on the selection of the boundary marker event will depend on the possibility of having the support of additional marker events for identification and correlation. The experience with the South Canyon succession (Balini et al., 2007) demonstrates that for the definition of the base of the Carnian Stage, no single bio-chronostratigraphic tool prevails over the others for the power of resolution and correlatability.

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Since 2001 South Canyon has been visited several times by MB and JJ. In 2002 the sections at Sites A and B were sampled together with M.J. Orchard and C.A. McRoberts with the help of C. Larghi (Milano University), T. Beattie (Simon Fraser University, Vancouver) E. Hopkin (at that time at SUNY, Cortland), and V. Atudorei (University of New Mexico). Sites D and E were sampled in 2005 with the help of A. Nicora and P. Taiana (Milano University). Site F was investigated in October 2006.

This study is a contribution to IGCP 467 “Triassic Time and trans-Panthalassan Correlations” (M. J. Orchard). The 2006 field sampling was carried out within the field activity of the Museo di Paleontologia, Dipartimento di Scienze della Terra (Milano University).

REFERENCES


FIGURE 11. Trachyceratidae from sites B and D, showing some examples of development of preseptal layer. A-B, specimen D10-91. A, the arrows indicate the position of the internal mold. B, in this view two layers are visible. I: outer layer (?test), II: preseptal layer. C-D, specimen D10bis-77, body chamber. C, natural size. D, enlarged view showing multilayer structure. I: outer layer, II: intermediate layer, III: inner layer (preseptal layer). Asterisk marks the position of a row of nodes which are visible on both external and the intermediate layers. Stars indicate two rows of nodes, which are visible on the intermediate layer, but not on the internal mold. E-F, specimen SCAN16-6. E, natural size. F, enlarged view. Arrows indicate the part of the internal mold “smoothed” by the preseptal layer. Scale bar for all specimens is 1 cm.


Orchard, M.J. and Balini, M., in press, Conodonts from the Ladinian-Carnian boundary beds of South Canyon, New Pass Range, Nevada, USA. New Mexico Museum of Natural History and Science, Bulletin 41.


