UNIVERSITÀ DEGLI STUDI DI MILANO

Dottorato di Ricerca in Scienze della Terra
Ciclo XXXII

DIPARTIMENTO DI SCIENZE DELLA TERRA

TESI DI DOTTORATO DI RICERCA

EARLY CARNIAN AMMONOIDS FROM NEVADA: REVISED TAXONOMY, EVOLUTIONARY TRENDS AND USEFULNESS FOR THE DEFINITION OF THE LATE TRIASSIC TIME SCALE

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Anno Accademico 2018-2019

Abstract

The aim of this research is the study of the Lower Carnian (Upper Triassic) ammonoid faunas from Nevada, which have contributed to the definition of the North American Triassic chronostratigraphic scale in the 1960s. These faunas, however, have never been described in detail, both in terms of taxonomy and in terms of stratigraphic distribution in bed-by-bed sampled sections. This research is a contribution for the revision and improvement of the Late Triassic chronostratigraphic time scale.

A revised zonation is proposed for the sedimentary succession within the middle member of the Augusta Mountain Formation at South Canyon (New Pass Range, Nevada), type locality of the Desatoyense Zone of the North American chronostratigraphic scale. New Lower Carnian ammonoid faunas from China Mountain (Tobin Range, Nevada) are also described.

Silberling & Tozer (1968) introduced the Desatoyense Zone to replace the "*Joannites* zone" of Johnston (1941), with *Trachyceras desatoyense* Johnston, 1941, as the index species. The fauna described by Johnston (1941) was collected without accounting for the stratigraphic position of the specimens, and consequently, a range chart could not be provided for the 24 taxa attributed to this zone. An intensive sampling program in the type locality was begun in 2002 by Marco Balini and James Jenks and continued intermittently with other occasional collaborators over a period of several years. Bed by bed collection efforts from 103 fossiliferous beds in six stratigraphic sections have yielded ~3900 specimens, of which 3130 ammonoids, that allow the construction of range charts and recognition of the bioevents on which this revision is based. The systematic study has led to the recognition of 29 taxa, 10 of which are new. These taxa belong to 18 genera, two of which are new: *Neoclypites*, *Sageceras*, *Perrinoceras*, *Badiotites*, *Procladiscites*, *Arcestes*, *Joannites*, *Silenticeras*, *Frankites*, *Daxatina*, *Trachyceras*, Genus A, Genus B, *Clionitites*, *Hannaoceras*, *Sympolycyclus*, *Lobites* and *Coroceras*. Ammonoids of the Subfamily Trachyceratinae are the most abundant, and provide all the zonal indexes.

Frankites sutherlandi and *Daxatina* occur in the lower part of the succession (sections A and B). The middle-upper part of the succession (section D2, E and lower part of section F) exhibits a different faunal composition and *Trachyceras* co-occurs with Genus A and Genus B (both Trachyceratinae), which are confined to two narrow stratigraphic intervals. The upper part of section F is characterized by another major faunal change, the onset of *Trachyceras* with highly indented suture lines that co-occur with *Coroceras*. With the new data it is possible to subdivide the former Desatoyense Zone into three parts, which are in stratigraphic order: the *Daxatina* sp. A range zone, the *Trachyceras desatoyense* interval zone and the *Trachyceras* sp. B range zone. The *Daxatina* sp. A zone is correlated with the Canadian Sutherlandi Zone and with the Tethyan Canadensis Subzone. The *T. desatoyense* and the *T.* sp. B zones are correlated with the Canadian Desatoyense Zone and with the Tethyan Aon Subzone.

The Desatoyense Zone is reported also from China Mountain (Tobin Range, Nevada). This area was investigated in the early 1970s as part of the PhD work of K.M. Nichols (1972). Nichols collected ammonoids from two sites (localities #1251 and #1311, Nichols, 1972), but did not report bed-by-bed collection data, nor described the collection. Nichols & Silberling (1977), referred to the locality and assigned the ammonoid faunas to the Desatoyense Zone. During the 2018 field campaign we visited the area, and noted the location of the fossiliferous interval in the uppermost part of the Smelser Pass Member of the Augusta Mountain Formation, a few meters below the erosional base of the Cane Spring Formation. Two new fossiliferous sites were located and sampled bed-by-bed from exposed beds, and float specimens were collected from the two sites, taking careful note of their stratigraphic position. Stratigraphic sections were measured, and a total of 758 specimens were collected from these two new localities. An attempt was made to find locality #1251 (Nichols, 1972), but was unsuccessful due to the lack of precise locality information.

Ammonoids by far make up the majority (+95%) of the specimens, with the remaining 5% consisting of bivalves and brachiopods. The ammonoid faunas are dominated by two new species of Genus B, that are not documented in South Canyon. The occurrence of Genus B and very rare *Perrinoceras*, *Silenticeras*, *Clionitites* and ?*Trachyceras* suggests a correlation with the *Trachyceras desatoyense* zone recognized at South Canyon.

Chapter 1

Introduction to the biochronostratigraphy of the Upper Ladinian and Lower Carnian

1.1 - Basic concepts

This thesis deals mainly with the revision of the North American Lower Carnian Desatoyense Zone, which is an example of Oppel zone defined without a bed-by-bed sampling approach (Johnston, 1941; Silberling & Tozer, 1968). This type of zone is no longer considered valid, and needs to be replaced with modern zones. Some basic concepts need to be explained in order to better understand these important aspects of the thesis.

1.1.1 – Modern and old biozones

There are many types of zones, defined in very different ways in the literature. The conceptual and practical way in which a zone is defined affects its precision, resolution, recognisability and hence its utility during practical geological work.

Modern biozones are based on range charts, which are used to clearly show the distributions, appearances and disappearances of fossil taxa in the rock successions.

The oldest zones erected in the early days of Triassic biostratigraphy up to the 1960's are Oppel zones (see Hedberg, 1976; Balini et al., 2010; Balini et al., 2017), named for the German geologist Albert Oppel, who applied his revolutionary method (see Balini et al., 2017) to subdivide the Jurassic successions. In the old Triassic literature (e.g. Mojsisovics, 1882) Oppel zones were constructed by grouping together all taxa found in the same facies (=lithologic unit) into a single fauna, without regard for the stratigraphic position (Balini et al., 2010). However, in the modern approach a fauna is intended as a fossil assemblage considered representative of a living community of the past, in other words organisms that lived together at the same time and in the same place. Each Oppel zone was accompanied by a list of characteristic taxa, including the one selected as zone index (Balini et al., 2017). A zone could also include other taxa present in underlying and overlying zones. Local identification of a zone was based on the identification of one of its characteristic species. Such an approach was good in the 19th century, but does not conform with the high resolution required by modern standards. Hedberg (1976) was the first who emphasized that the boundaries of the Oppel zones are not univocally defined, as bed-by-bed sampling inevitably reveals that the FOs and LOs of the characteristic species are not coeval and their ranges overlaps only in part. The drawing of Oppel zone boundaries is therefore highly subjective on range charts, as their position depends on which taxa are selected for this purpose (Balini et al., 2017).

Ammonoids are useful in stratigraphy because of their extremely high evolutionary rate, so their faunas can radically change from bed to bed. With the Oppel zone approach the high resolution potential of ammonoids is not fully exploited.

The zones of the first Tethyan Triassic chronostratigraphic scale (Mojsisovics, 1882; Mojsisovics et al., 1895) were all Oppel zones. Many of them have been revised to match the modern standards. The zones of the current North American chronostratigraphic scale (Tozer, 1994) are very similar to Oppel zones, as they are "*bodies of rock characterized by a fauna*" (Tozer, 1967, p. 10) and were not defined with a bed-by-bed sampling approach.

Since Salvador (1994), Oppel zones are no longer considered valid because, as explained above, they do not provide the kind of precision required for modern biochronostratigraphic work. They need to be bed-by-bed reinvestigated, possibly in their type area, and replaced with modern zones based on range charts. The revision of the North American Lower Carnian Desatoyense Zone is one example of this kind of problems, and is one of the aims of this thesis.

1.1.2 - The bond between classification and zonation

There is a strict relationship between classification of an ammonoid group and biostratigraphy of the successions where this group is documented. Classifications, based on specimens collected without a precise stratigraphic position do not take into account the stratigraphic variations of the morphological characteristics of the taxa identified. Evolutionary bonds between taxa classified with this approach can only be speculatively hypothesized, as the chronologic sequence is not known or is very approximate.

The recognition of evolutionary trends and relationships based on reproducible data is possible only taking into account the precise stratigraphic position of the specimens. The modern approach considers the fossils coming from the same bed, without any evidence of reworking, as a fauna. The faunas are studied with the stratophenetic method of Gingerich (1979). At first, each ammonoid fauna is studied as a distinct unit, to identify the populations of specimens present. The next step consists in the linking between populations from beds in stratigraphic succession based on overall similarity (phenetic linking). The range charts and zonation schemes obtained with this approach provide useful tools for more precise biochronostratigraphic correlations.

1.1.3 - The role of ammonoids in modern integrated stratigraphy

Modern stratigraphy apply several biostratigraphic tools to the same section, and integrates also other tools like magnetostratigraphy and stable isotope analysis to calibrate the correlations with other sections. Among the biostratigraphic tools, ammonoids are the fossil group with the highest power of stratigraphic and chronologic resolution within Triassic marine environments (Balini et al., 2010; Jenks et al., 2015). Ammonoids are used to calibrate the bioevents of other taxonomic groups to the ammonoid biochronostratigraphic scale. For this reason the refinement of ammonoid taxonomy through bed-by-bed studies is crucial for improving the Triassic Geologic Time Scale.

1.2 - Evolution of the Tethyan and North American upper Ladinian – Lower Carnian chronostratigraphic scale

In this introductory chapter a brief history of the uppermost Ladinian and Lower Carnian biostratigraphic scale is summarized. Detailed information about the historical evolution of the entire Triassic scale can be found in Zittel (1901), Silberling & Tozer (1968), Tozer (1984), Lucas (2010), Balini et al. (2010) and Jenks et al. (2015).

Ammonoids belonging to the Family Trachyceratidae provide all the zone index for the upper Ladinian and Lower Carnian. *Daxatina* Strand, 1929 and *Trachyceras* Laube, 1869 are the most important genera for the Lower Carnian. According to the literature (Arkell et al., 1957; Tozer, 1994; Mietto et al., 2008) they differ mainly by the suture line, ceratitic in *Daxatina*, ammonitic in *Trachyceras*.

1.2.1 - Beginnings of the Tethyan scale

The Austrian paleontologist Edmund von Mojsisovics was the first to establish a biostratigraphic scale of the Tethyan Triassic based on ammonoids. All of the zones introduced by Mojsisovics were typical Oppel zones (Balini et al., 2010). In 1869, he introduced the term Carnian Stage, composed of one single zone, the *Trachyceras aonoides* Zone. Initially, he erroneously regarded the Carnian as younger than the Norian. After several steps Mojsisovics (1874; 1879; 1882) differentiated the Lower Carnian and divided it into two zones: the already present *T. aonoides* Zone plus the underlying *T. aon* Zone. Mojsisovics (1882) divided his Norisch (the future Ladinian) into two zones: the *T. reitzi* Zone and the *T. archelaus* Zone. The final version (Mojsisovics, 1892; 1893) provided the separation between the Lower Carnian and the Middle Carnian including, respectively, the *T. aon* Zone and the *T. aonoides* Zone. These two zones were based respectively on the San Cassiano fauna (Italian Dolomites) and on the Feuerkogel fauna (Austria) (Krystyn, 1978). Mojsisovics (1892) recognized that the Carnian was older than the Norian, placing the corresponding zones in the correct order. However, he moved the term Norisch to refer to pre-Carnian zones and coined the term Juvavisch Stage for the post-Carnian zones. This caused the debate with Bittner (see Tozer, 1984) who introduced the term Ladinian (referred to the Buchenstein and Wengen beds, with possible inclusion of the San Cassiano beds), still used today, to replace Mojsisovics' Norisch. In Mojsisovics et al. (1895) the authors defined Substages, Stages and Series for the first complete chronostratigraphic scale of the Triassic System. Longobardian, Cordevolian and Julian Substages were defined respectively for the *P. archelaus* Zone (referred to the Wengen beds), *T. aon* Zone (referred to the San Cassiano beds) and *T. aonoides* Zone (referred to the Raibl beds). The revised Longobardian and Julian Substages are still used in the present version of the Standard Global Chronostratigraphic Scale for the Triassic.

The definition of the ammonoid zonal succession required much time because of the relatively complex tectonic setting of the Alpine Triassic successions and their facies, that now are known to be strongly condensed (e.g. Krystyn, 1970; 1973; 1974; 1980; Tozer, 1971; Zapfe, 1983; Balini et al., 2010).

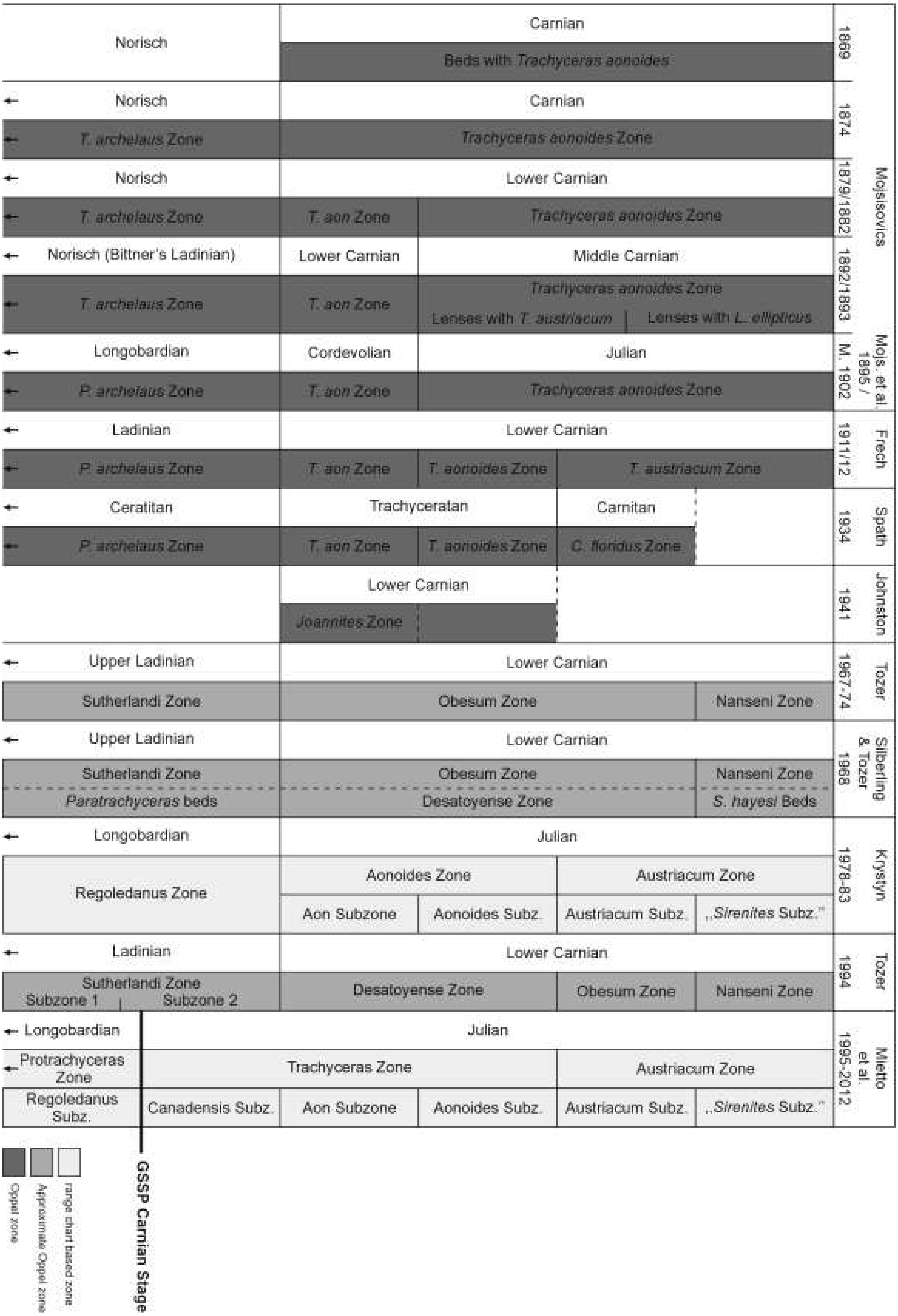


Fig. 1.1 *– Evolution of the uppermost Ladinian to Lower Carnian chronostratigraphic scale (sources: Krystyn, 1978; 1983; Mojsisovics et al., 1895; Johnston, 1941; Tozer, 1967; 1994; Silberling & Tozer, 1968; Mietto & Manfrin, 1995; Mietto et al., 2012).*

As explained in Balini et al. (2010), at the beginning of the twentieth century the ammonoid record was recognized as being discontinuous, and some authors (e.g. Arthaber, 1905 and Pia, 1930) integrated the ammonoid zones with bivalve, brachiopod and crinoid zones, filling the gaps between ammonoid zones, or replacing them. This approach, however, was not followed in the post WWII literature.

Spath (1934) proposed a new subdivision of the Triassic, based on a biochronologic approach. His approach did not take into consideration the rock successions, but only the fossil "faunas" studied in museums and collected by other persons. Spath subdivided the entire Triassic into "ages", named from the most important ammonoid family and hierarchically equivalent to substages. For the Ladinian and Carnian Spath recognized the Ceratitan, Trachyceratan and Carnitan ages, further divided into zones based on fauna, almost equivalent to Mojsisovics' Oppel zones. No one, however, accepted and continued this approach.

1.1.2 - The North American scale

The pioneering studies on American Triassic ammonoids started in the nineteenth century by Alpheus Hyatt and James Perrin Smith, who published important monographs (Hyatt & Smith 1905; Smith 1914; 1927; 1932) on the taxonomy of the Western U.S. ammonoid faunas. They tried to apply the Tethyan biochronostratigraphic scale to the North American successions (Tozer, 1984; Balini et al., 2010). Francis N. Johnston (1941) described the Lower Carnian fauna documented in the new locality of South Canyon (New Pass Range, Nevada). He introduced the *Joannites* Zone (a typical Oppel zone) for his "*Trachyceras* beds" of South Canyon, correlating them with the *T. aon* Zone or the *T. aonoides* Zone of the European Alps. In the U.S. the school of Hyatt and Smith continued by S.W. Muller and N.J. Silberling. In Canada the school of F.H. McLearn continued by E.T. Tozer, who proposed (Tozer, 1967) the first complete biostratigraphic scale of the Canadian Triassic, totally based on ammonoids and constructed with a hybrid biochronologic/chronostratigraphic approach (Tozer, 1971; Balini, 2008). For the uppermost Ladinian he recognized the Sutherlandi Zone, and for the Lower Carnian the Obesum and Nanseni Zones. Silberling & Tozer (1968) presented a biostratigraphic correlation chart of the most important North American marine successions. South Canyon was recognized as the best record of the North American Lower Carnian. They introduced the Desatoyense Zone to replace Johnston's *Joannites* Zone, selecting as index species *Trachyceras desatoyense* Johnston, 1941. The Desatoyense Zone was still based on the taxonomy of Johnston (1941). In the last version of the North American scale, Tozer (1994) introduced some improvements. He differentiated the Sutherlandi Zone into two subzones, recognizing two different faunas in sequence. For the Lower Carnian he recognized the correct sequence of the Desatoyense, Obesum and Nanseni Zones.

1.1.3 - Refinement of the Tethyan scale

Biostratigraphic studies of the Tethyan successions restarted during the 1960's (Balini et al., 2010). Leopold Krystyn (Vienna) restarted investigations of the Upper Triassic condensed successions of the Northern Alps with a bed-by-bed approach. In 1978 he proposed a new zonal scheme for the Lower Carnian, demonstrating the equivalence of Cordevolian and Julian. The Julian was subdivided into two ammonoid zones (Aonoides Zone and Austriacum Zone) each with two subzones (Aon and Aonoides; Austriacum and "*Sirenites*"). Krystyn (1983) proposed also a subdivision of the Upper Ladinian based on bed-by-bed data from the Hallstatt-like condensed succession of Epidaurus (Greece). He subdivided the *P. Archelaus* Zone of Mojsisovics into three zones (Gredleri Zone, Archelaus Zone and Regoledanus Zone). He also worked on the Triassic of Himalayas (Krystyn, 1982; Krystyn et al., 2004). Krystyn was the first who integrated the use of ammonoids with conodonts (e.g. Krystyn, 1970; 1973; 1974; 1980). His approach consists of documenting their simultaneous occurrences, but keeping the ammonoid and conodont biostratigraphic scales separated (Balini et al., 2010).

Urlichs (1974; 1977; 1994; 2004; 2017) revised the ammonoid faunas of the Aon and Aonoides Subzones in the Dolomites (Southern Alps), based on bed-by-bed data. Balini et al. (2000) presented an integrated stratigraphic study of some classical Upper Ladinian - Lower Carnian successions in Lombardy (Italy). Their results allowed the revision of both chronostratigraphic schemes and paleogeographic history of the Lombardian Southern Alps during Ladinian-Carnian time.

The research group of University of Padova (Italy) studied with a bed-by-bed integrated approach the successions of the uppermost Ladinian and basal Lower Carnian of the Dolomites (Mietto & Manfrin, 1995; Broglio Loriga et al., 1999; Mietto et al., 2008; Mietto et al., 2012). These successions had never been studied in detail, and were considered Ladinian in age. They proposed (Mietto & Manfrin, 1995) a subdivision of the Julian in two zones: the Trachyceras Zone, composed of three subzones (Canadensis, Aon and Aonoides) and the Austriacum Zone (sensu Krystyn, 1978). They subdivided the Longobardian into five subzones (Margaritosum, Gredleri, Longobardicum, Neumayri and Regoledanus), included in the Protrachyceras Zone. They documented (Broglio Loriga et al., 1999; Mietto et al., 2008) the occurrence of *Daxatina* Strand and *Trachyceras* Laube below the occurrence of *Trachyceras aon* Münster, 1834 in the Canadensis Subzone. With this scheme, based on bed-by-bed data, they placed the Ladinian/Carnian boundary inside of the classical uppermost Ladinian Regoledanus Zone.

1.3 - Carnian Stage GSSP and open problems

The GSSP for the base of the Carnian Stage has been ratified in 2008 (Gaetani, 2009). The selected marker bioevent is the FO (First Occurrence) of the ammonoid *Daxatina canadensis* (Whiteaves, 1889) in bed SW4 of the Prati di Stuores section in the Dolomites, Italy (Mietto et al., 2008; 2012). The secondary marker bioevent is the FO of the conodont *Paragondoloella polygnathiformis* (Budurov & Stefanov, 1965), which occurs 70 cm above the FO of *Daxatina canadensis*. The FO of *Trachyceras muensteri* (Wissmann in Wissmann & Münster, 1841) is reported by Mietto et al. (2008; 2012) to be less than 34 meters above the FO of *Daxatina canadensis*. These two species co-occur for about 80 meters of the succession.

This thick co-occurrence of *Daxatina* and *Trachyceras* is documented only in the Dolomites. In the successions of Spiti in the Himalayas (Krystyn et al., 2004), Canada (Tozer, 1994), and South Canyon (Balini et al., 2012) the co-occurrence of *Daxatina* and *Trachyceras* is not documented or it is very limited. Recently the occurrence of *Trachyceras* in the Canadensis Subzone of the Dolomites has been strongly questioned by Urlichs (2017).

The lack of consensus on the taxonomy of the early *Trachyceras* might be also due to the rather poor ammonoid record of the upper Canadensis Subzone in the Tethys and of the Desatoyense Zone in Canada. For instance, few specimens of *Daxatina* and *Trachyceras* have been reported by Mietto et al. (2008) and less than 10 specimens of *Daxatina* have been collected by Krystyn et al. (2004) from Spiti. The succession of South Canyon, type locality of the Desatoyense Zone, is instead extremely fossiliferous and rich in ammonoids belonging to the Subfamily Trachyceratinae, to which both *Daxatina* and *Trachyceras* are attributed. The study of these ammonoid faunas, based on a bed-by-bed approach and focused on the study of the suture line, can clarify the supposed evolutionary relationships between *Daxatina* and *Trachyceras*. These relationships have never been described in literature. The results of this study can help the interpretation of the incomplete record of other successions. The taxonomy developed for South Canyon ammonoid faunas is crucial for the revision of the Lower Carnian of the North American chronostratigraphic scale. This in turn leads to the calibration of the North American scale with the Tethyan scale where the GSSP of the Carnian Stage is defined.

Chapter 2

Studied localities: geological and structural setting

2.1 - Regional geological and structural setting

2.1.1 - The Triassic of north western Nevada

During the Triassic Period western Nevada represented the active margin of the North American tectonic plate. An eastward subduction was active west of the region under examination. The principal elements that constituted this margin (shelf, retroarc and arc) have been subsequently deformed and thrusted. For this reason in literature they are referred to as terranes (Speed, 1978; Wyld, 2000; 2002), although the displacement is small. The Triassic successions of north western Nevada (Fig. 2.1) are assigned to a shelf terrane to the east, a magmatic arc terrane (Black Rock terrane) to the west and a basinal retroarc terrane between the two. The basement of these terranes is formed by Paleozoic rocks involved in the latest Permian to earliest Triassic Sonoma orogeny (Wyld, 2000 and references therein). The integrated study of the stratigraphic record (Speed, 1978; Wyld, 2000; 2002) suggest a common evolution of the volcanic arc, the basinal and the shelf terranes within an extensional tectonic setting during the Triassic. The model proposed by Wyld (2000; 2002) provides an Early Triassic to mid-Ladinian incipient extension (Fig. 2.2a), characterized by differential uplift and subsidence and by

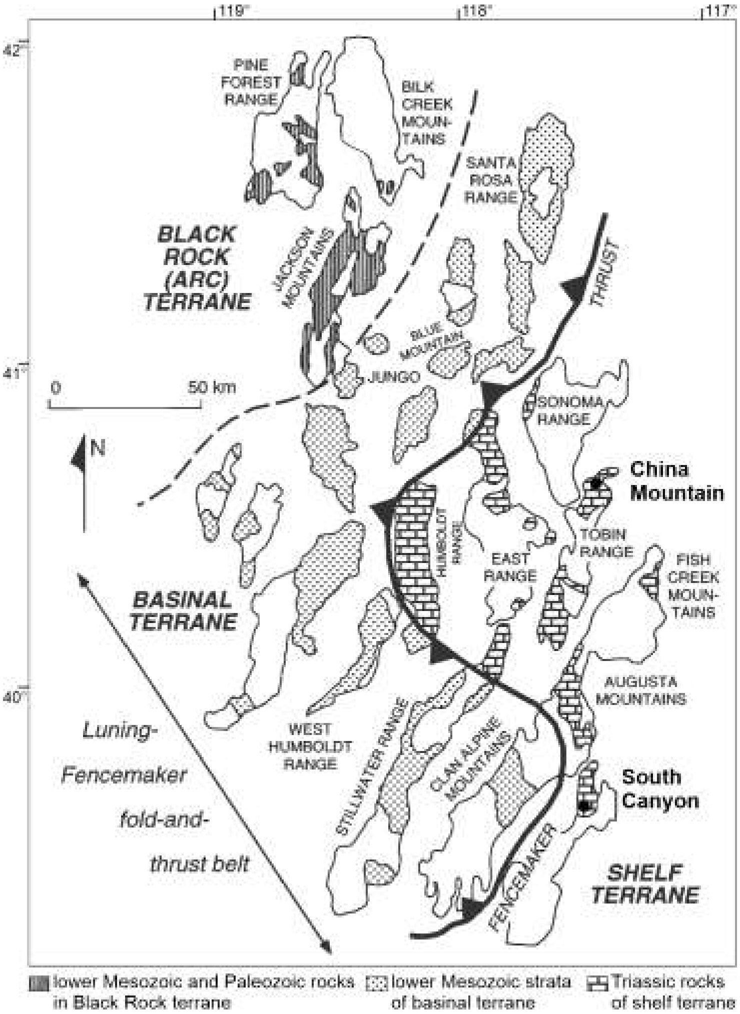


Fig. 2.1 – *Location map of the north western Nevada showing mountain ranges and Mesozoic rocks of the arc, basinal and shelf terranes (slightly modified from Wyld, 2000).*

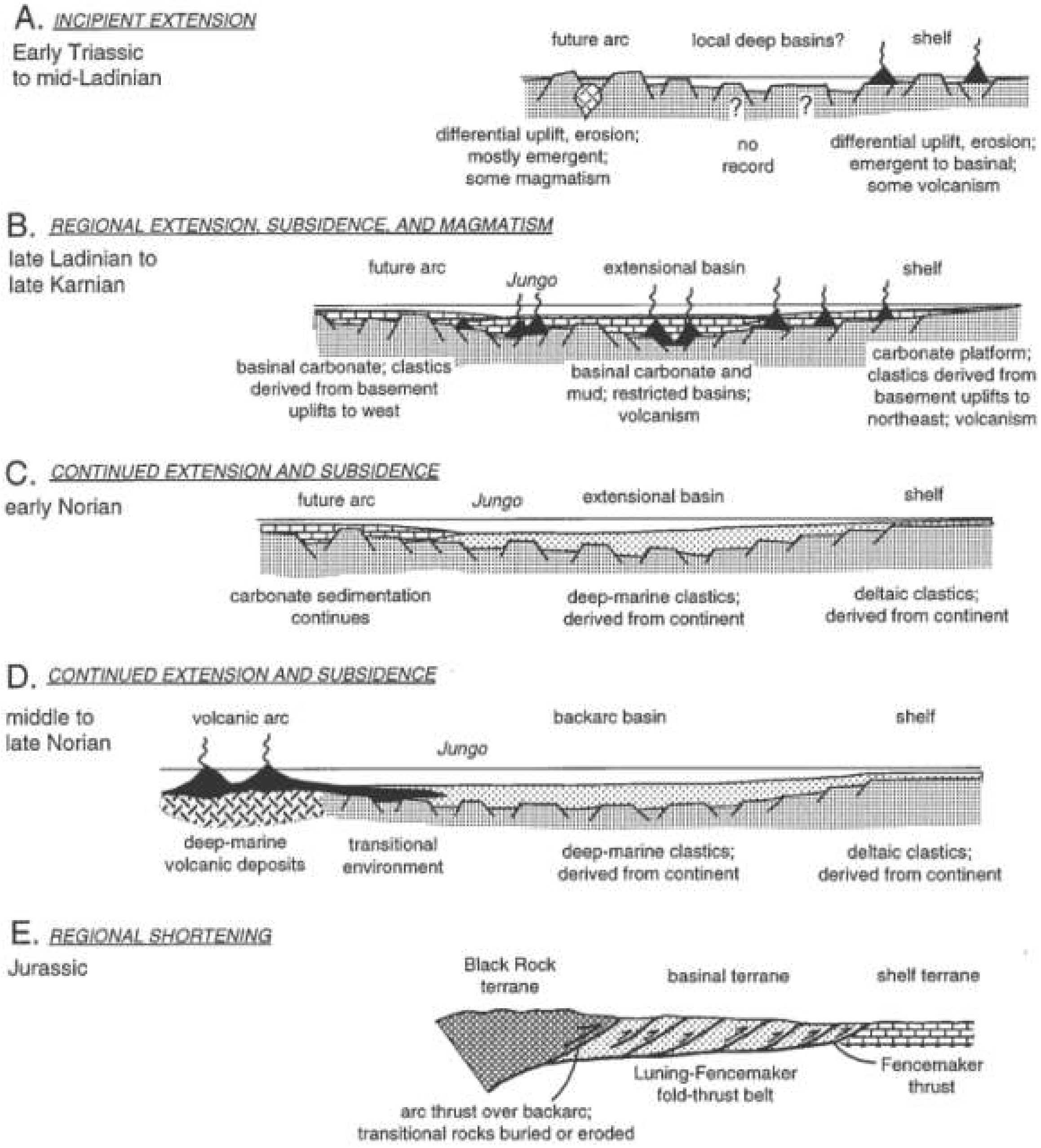


***Fig. 2.2** – Interpretative model for the early Mesozoic evolution of arc, basinal and shelf terranes of northwestern Nevada (from Wyld, 2000).*

episodic magmatism in the shelf and arc terranes. During the Late Ladinian to Late Carnian (Fig. 2.2b) regional subsidence led to widespread carbonate deposition in all areas, with coarse siliciclastic input in the shelf and arc terranes derived from nearby eroded basement. Volcanism affects the basinal and shelf terrane, and in the basinal terrane stratigraphic evidences suggests deposition in restricted anoxic conditions.

During the Norian (Fig. 2.2c-d) thick clastic sequences were deposited in the shelfand basinal terranes,while the Black Rock terrane is characterized by continued carbonate deposition in the Early Norian and marine volcanic deposits in the Middle to Late Norian. The absence of transitional rocks between the arc and basinal terranes is probably due to burial or erosion during the subsequent tectonic deformation (Wyld, 2000). During the Jurassic (Fig. 2.2e) regional shortening led to the structural closure of the backarc basin. The development of the Luning-Fencemaker fold-thrust belt was confined to the basinal terrane, which was thrusted over the shelf terrane. The Fencemaker thrust was the frontal thrust of the belt. The Black Rock arc terrane was thrusted over the basinal terrane (Wyld, 2000).

2.1.2 – Triassic stratigraphy of the northern shelf terrane

The following description is based on Nichols & Silberling (1977) and on the synthetic study of Wyld (2000). The basement of the Triassic shelf terrane succession is composed by Paleozoic rocks of the Golconda allochton, deformed during the Sonoma orogeny (Wyld, 2000). The post-orogenic sediments are represented by the Lower Triassic Koipato Group (Fig. 2.3), a thick (> 3 km) volcanic sequence deposited in a shallow marine to continental environment probably during a first episode of regional extensional tectonism (Wyld, 2000). During the latest Early Triassic a major episode of uplift caused the erosion of part and locally all of the Koipato Group.

The Home Station Member of the Augusta Mountain Formation records the deposition of a carbonate platform. A mid-Ladinian tectonic episode probably caused the erosion of basement rocks, and the sediments derived were deposited on the carbonate platform (Wyld, 2000).

Subsequently, a period of regional subsidence allowed the extensive development of carbonate platforms, which prograded toward the western part of the shelf. The platform successions are represented by the Upper Ladinian to Lower Carnian Panther Canyon and Smelser Pass Members of the Augusta Mountain Formation, and by the Upper Carnian Cane Spring Formation. These successions arecomposed mainly of shallow marine to supratidal carbonates (Nichols & Silberling, 1977; Wyld, 2000). During the mid-Carnian a period of relative uplift interrupted briefly the carbonate deposition and produced a regional unconformity at the top of the Smelser Pass Member (Wyld, 2000). Episodic input of coarse siliciclastic sediments occurred in this period, and were derived from basement sources to the north and east (Nichols & Silberling, 1977; Wyld, 2000). The two most important siliciclastic events occur at the top of the Panther Canyon Member and at the base of the Cane Spring Formation. Widespread presence of mafic lavas, breccias and tuffs in the upper Smelser Pass Member and uppermost Prida Formation documents volcanic activity in the shelf region during this time period (Nichols & Silberling, 1977; Wyld, 2000).

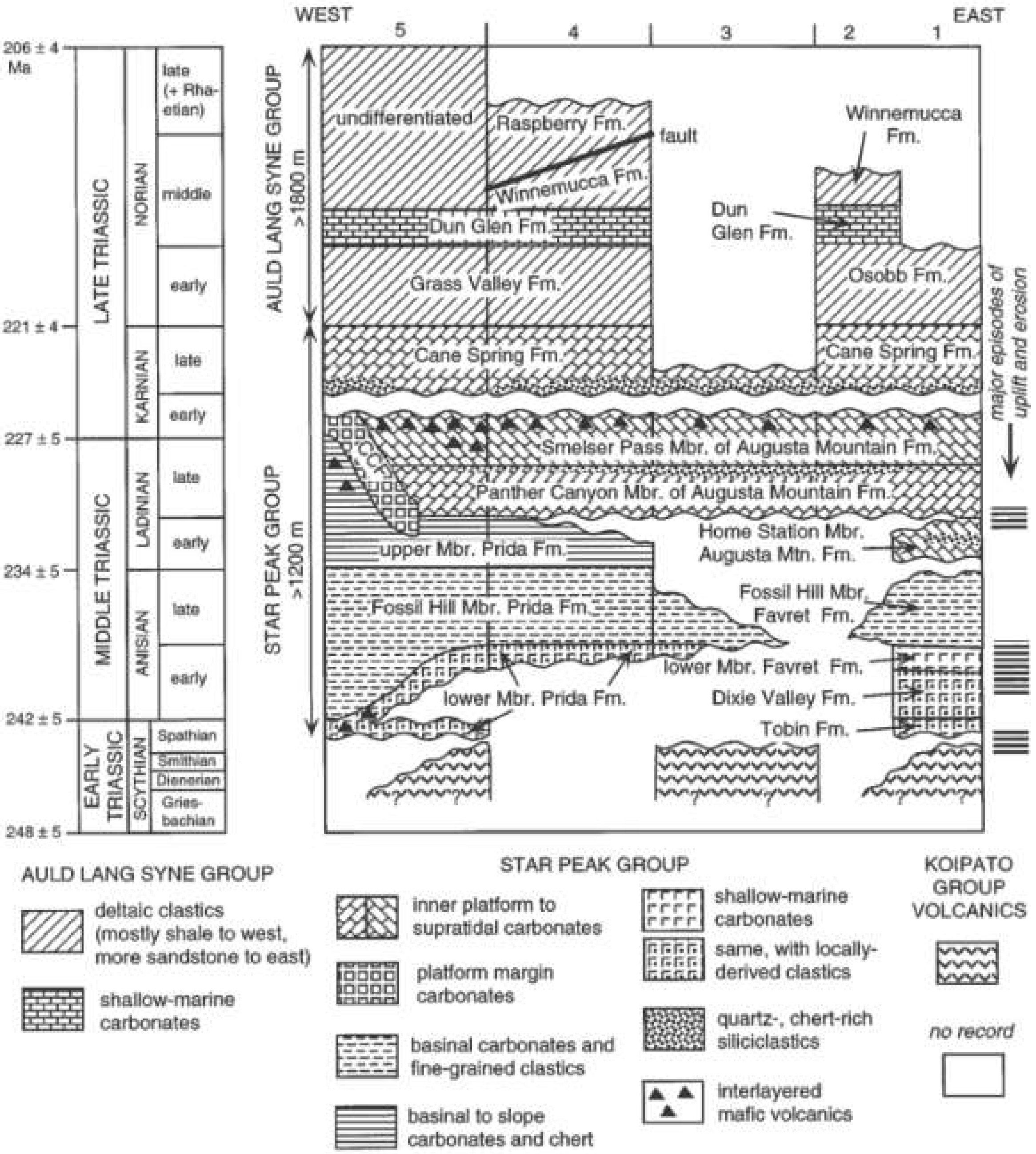


Fig. 2.3 *– Stratigraphic chart of the northern shelf terrane. CFF is Congress Canyon Formation. Locations of columns: 1) Augusta Mountains; 2) southern Tobin Range; 3) China Mountain; 4) Northern East Range; 5) Humboldt Range (from Wyld, 2000).*

The Norian siliciclastic successions of the Auld Lang Syne Group document a substantial change in the depositional processes affecting the shelf region (Wyld, 2000). Regional subsidence and increased siliciclastic input resulted in uniform patterns of sedimentation across the shelf. The deposition of the Auld Lang Syne Group began in the earliest Norian and continued into the Early Jurassic (Wyld, 2000). These units consists mainly of shale and subordinate quartz sandstone derived from the continent and transported to the shelf, where they form deltaic successions. (Wyld, 2000). The input of clastic sediments and the strong decrease in carbonate deposition is interpreted as a reorganization of the drainage patterns that created unfavourable conditions for carbonate production (Wyld, 2000).

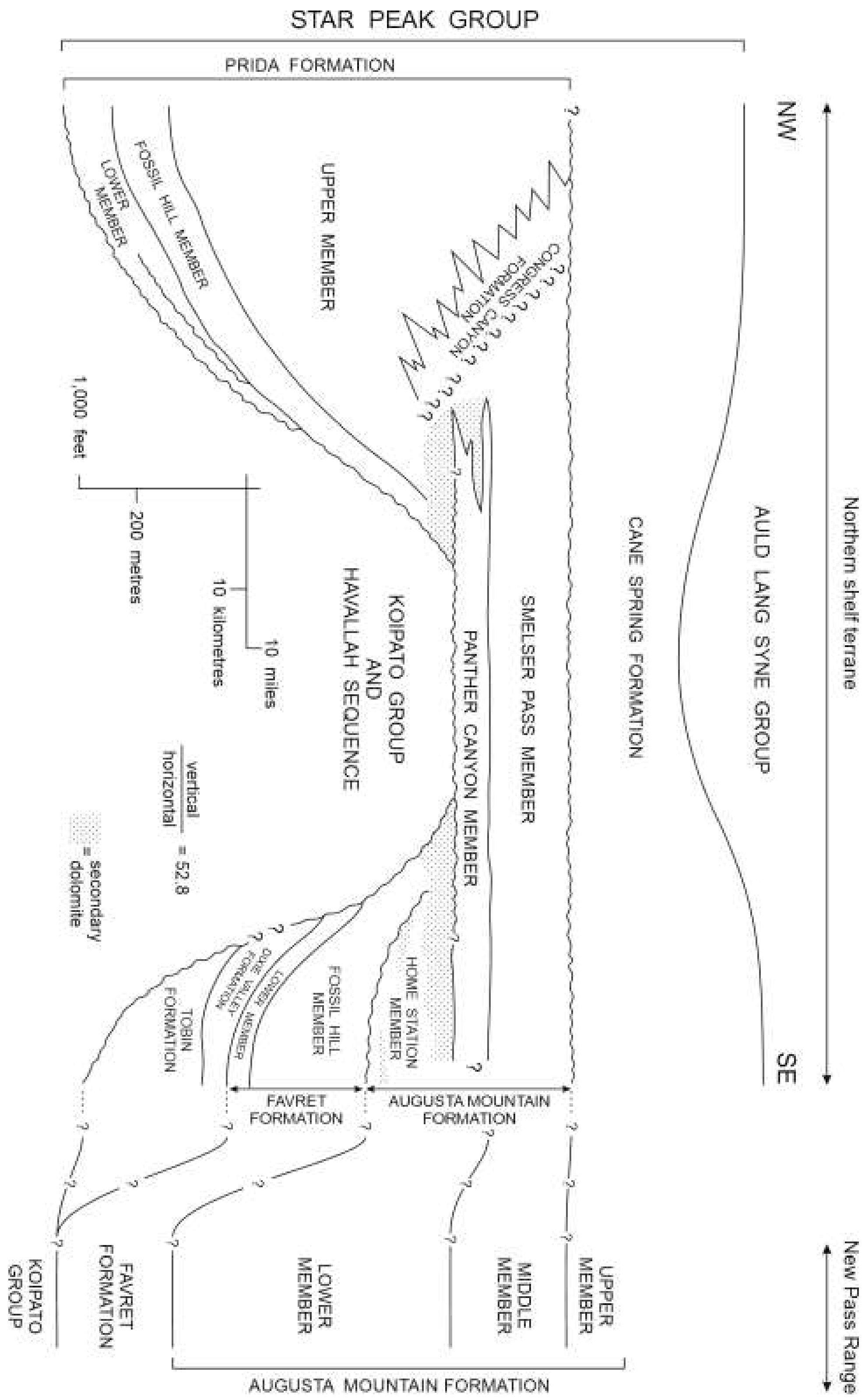


Fig. 2.4 *– Schematic NW-SE cross section of the Star Peak Group from the northern Humboldt Range to the Augusta Mountains, with a tentative correlation with the lithologically different succession outcropping in the New Pass Range, south of the Augusta Mountains (modified from Nichols & Silberling, 1977).*

2.1.3 - Triassic stratigraphy of the New Pass Range area

The sedimentary succession in the New Pass Range is characterized by a thick Triassic succession, best exposed in the South Canyon area (Fig. 2.5). This section is correlative with the typical Star Peak Group that crops out just 20 to 30 km to the north, in the Augusta Mountains (Nichols & Silberling, 1977). Correlation of the South Canyon section with the characteristic Star Peak Group is difficult, due to the lack of intervening exposures (Fig. 2.4). The only formation that is recognized with certainty is the Middle to Upper Anisian Favret Formation, which represents the older part of the Star Peak Group in the area (Nichols & Silberling, 1977). The Favret Formation yields ammonoids (Bucher, 1988) and daonellids. The clastic and tuffaceous rocks underlying the Favret Formation are probably counterparts of the upper Koipato Group (Nichols & Silberling, 1977). The Favret Formation is overlain by about 500 meters of gray limestones that constitute the lower member of the Augusta Mountain Formation. The lower half of the member contains intercalations of siltstones and conglomerates, and could be an undolomitized equivalent of the Home Station Member (Nichols & Silberling, 1977). The upper half of the member consists mostly of massive limestones, locally bioclastic or oolitic, with rare intercalations of shales and siltstones (Nichols & Silberling, 1977; Balini et al., 2007). Cnidarians are locally rich (Roniewicz & Stanley, 1998; Waller & Stanley, 2005), and the shales and siltstones yield bivalves and rare ammonoids (Silberling & Tozer, 1968; Waller & Stanley, 2005). The uppermost part of the member is rich in brachiopods, and documents a deepening episode. The brachiopod rich layers are unconformably overlain by basinal marlstones and limestones alternations of the middle member of the Augusta Mountain Formation. The lower part of the member is so rich in ammonoids, bivalves and brachiopods (Johnston, 1941; Silberling, 1956; Silberling & Tozer, 1968; Balini et al., 2007; Balini & Jenks, 2007), that this stratigraphic interval was selected by Silberling& Tozer (1968) as type locality of the Lower Carnian Desatoyense Zone, the first zone of the Carnian in North America. In the upper part of the member bioherms are locally present, and contain brachiopods and a wide variety of bioclasts. The middle member can be correlated at least in part with the Smelser Pass Member of the

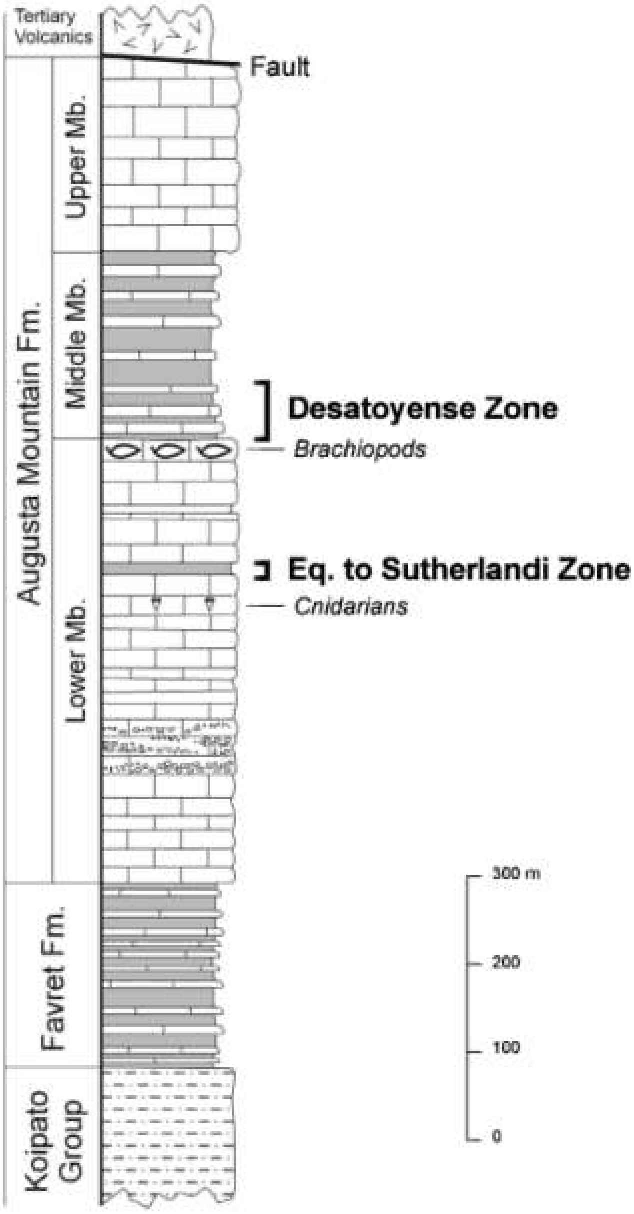


Fig. 2.5 – The South Canyon (New Pass Range) stratigraphic section (from Balini et al., 2007, slightly modified from Silberling, 1956).

Augusta Mountain Formation (Nichols & Silberling, 1977; this thesis). The middle member is overlain by the massive cliff-forming limestones of the Upper Member, which are probably correlative with the Cane Spring Formation (Nichols & Silberling, 1977).

2.2 - South Canyon

2.2.1 - Geographic position

South Canyon is located in the New Pass Range, central Nevada. The locality is situated in the Churchill County, near the eastern boundary with Lander County. The nearest populated area is the town of Austin, located about 40 km to the east. The best way to reach South Canyon is from the Interstate 50, then by the gravel road to McCoy Mine, to the North.

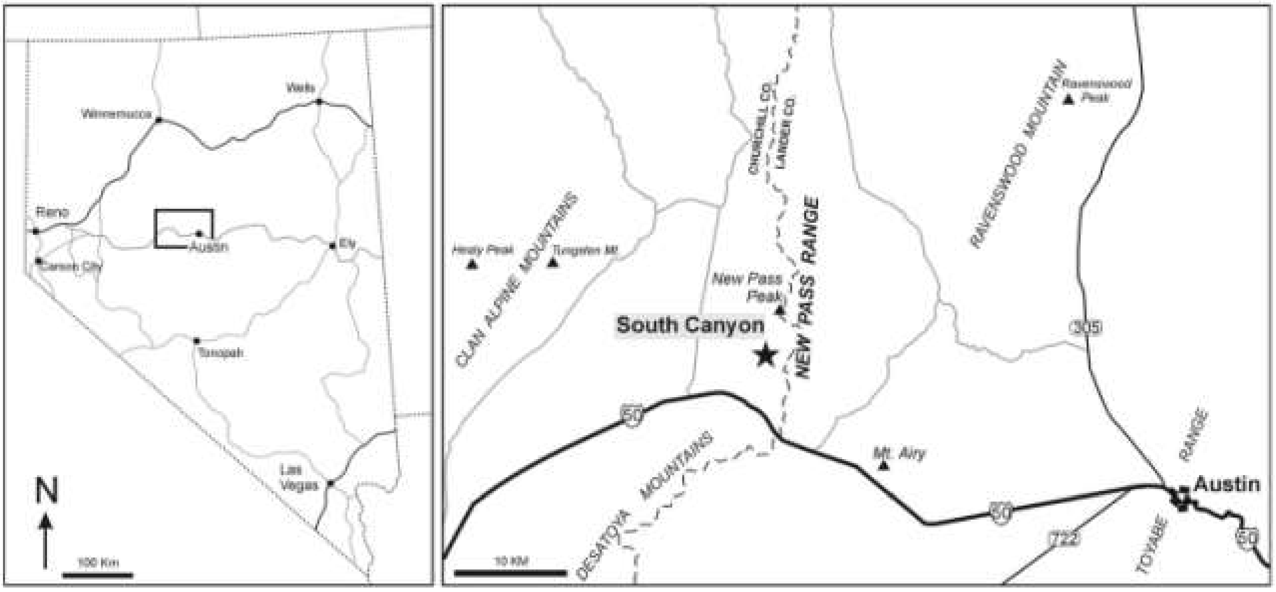


Fig. 2.6 – Geographic position of South Canyon (from Balini et al., 2007).

2.2.2 - History of studies

The history of early paleontological investigations in South Canyon is exhaustively summarized in Balini et al. (2007). Geological interest for the area started in 1864-65, when early-day prospectors discovered gold near a diorite intrusion located on the west side of the New Pass Range (Johnston, 1930). The first geological reports (Raymond, 1869; White, 1869) pointed out the presence of fossiliferous limestone beds in the area. Later, in the reports of the Fortieth Parallel Survey (Emmons, 1877; King, 1878) these beds were recognized as being of marine origin and of Triassic age. These successions were correlated with rocks later assigned to the Star Peak Group. J. P. Smith examined the fossils listed in Emmons (1877) and recognized their age as Middle Triassic, *Daonella dubia* Zone. Smith included these fossils in his monograph on the Middle Triassic of North America (Smith, 1914). In 1929 Francis N. Johnston, following a suggestion of Smith, visited twice the area of the New Pass Range to carry out geological studies (Johnston, 1930). He collected a new ammonoid fauna in the locality of South Canyon, from beds now included in the middle member of the Augusta Mountain Formation, which lie stratigraphically above the Middle Triassic *Daonella dubia* Zone. Johnston (1930 MA thesis) recognized the presence of *Halobia* and, among various other ammonoids, several species of *Trachyceras*. He attributed the new fauna to the Late Ladinian or the Early Carnian, recognizing that it was older than the Late Carnian *Tropites subbullatus* Zone of California (Johnston, 1930). In 1936, Muller briefly described the Ladinian coral beds occurring in the lower member of the Augusta Mountain Formation. Few years later Johnston (1941) formally described several new ammonoid species, correlating this fauna with the Lower Carnian *Trachyceras aon* or *Trachyceras aonoides* Zones of the Tethys. Johnston introduced the *Joannites* Zone for the "*Trachyceras* beds" of South Canyon, as the term "*Trachyceras* subzone" was already used by Smith for a subdivision of the *Tropites subbullatus* Zone of northern California.

Several years later Silberling (1956) measured the entire Triassic succession of the northern side of South Canyon, trying to apply the stratigraphic nomenclature of the Star Peak Group developed by Muller et al. (1951) and Ferguson et al. (1951a; 1951b; 1952). He reported the occurrence of Late Ladinian *Protrachyceras* species above the coral beds and below the *Trachyceras* beds. He also demonstrated that the ammonoids of the Upper Carnian "*Trachyceras* subzone" of northern California are morphologically different from true *Trachyceras*. Silberling & Tozer (1968) reported the occurrence of *Frankites sutherlandi* (McLearn) several hundred feets below the *Trachyceras* beds. They also introduced the *Trachyceras desatoyense* Zone to replace Johnston's *Joannites* Zone (Silberling & Tozer, 1968). Mosher (1968) described a conodont fauna from the *Trachyceras* Zone, including several new species. Foraminifers, cnidarians and bivalves were reported by Gazdzicki & Stanley (1983), Roniewicz & Stanley (1998) and Waller & Stanley (2005).

An intensive sampling program of part of the middle member utilizing the bed-by-bed method was begun in 2002 by Marco Balini and James Jenks and continued intermittently with other occasional collaborators over a period of several years. The writer participated in the last 2018 field campaign. Preliminary results (Balini et al., 2007; Balini & Jenks, 2007; Orchard & Balini, 2007; Balini, 2008), published in view of the discussion and selection of the GSSP of the Carnian Stage, pointed out the occurrence of *Daxatina* and *Frankites sutherlandi* in the type locality of the Desatoyense Zone. Baliniet al. (2012) described a new ammonoid species, *Trachyceras silberlingi*, and replaced the Desatoyense Zone with two biostratigraphic units: the lower, an informal biozone termed the *Daxatina* beds and the upper, the formal *Trachyceras silberlingi* range zone.

2.2.3 - Studied sections

The Triassic succession outcropping in South Canyon strikes 120°-140° SE and dips 40°-60° SW. Beds dip with the slope on the northern side of the canyon (Fig. 2.7), whereas they dip against the slope on the southern side (Balini et al., 2007). The lowermost part of the middle member is poorly exposed. Unfavorable conditions for exposure are due to various factors: soft weathering lithology, structural setting with beds dipping with the slope, gentle topography of the northern side of the canyon (slope dips 14°-25°), presence of debris produced by erosion of the lower member outcropping higher on the slope. However, the debris cover is generally thin and small fossiliferous outcrops are common.

Fig. 2.7 *– Panoramic view of the northern side of South Canyon. The middle member is poorly exposed in the lower part of the slope, whereas the limestones of the lower member crop out in the higher part of the slope.*

Six fossiliferous sections have been measured and bed-by-bed sampled (Fig. 2.8, sites A, B, D2, E, F, G). The sections are distributed over a distance of less than 500 meters on the northern side of the canyon. Natural outcrops were enlarged by excavation and trenching of the debris cover (Balini et al., 2007). The succession exposed is subdivided into four stratigraphic intervals (Fig. 2.8). Interval 1 belongs to the lower member and is composed by gray crinoidal packstones in 20 to 50 cm thick beds. Interval 2 (thickness of about 7 m) constitutes the uppermost part of the lower member and is formed by brachiopod rich gray bioclastic packstones in 10 to 20 cm thick beds, with rare marly interbeds. Interval 3 (thickness of about 65 m) belongs to the middle member and is constituted by monotonous alternation of light gray to dark gray bioclastic marly mudstones and wackestones with gray marlstones. The most common macrofossils found in the mudstones-wackestones are cephalopods, brachiopods and bivalves. The better exposed interval 4 (thickness of about 5 m) is dominated by gray mudstones in 30 to 50 cm-thick beds, with intercalations up to 60 cm thick of marly mudstones/calcareous marlstones in 1cm-thick beds (Balini et al., 2007).

Section D(1) is rich in brachiopods and was not bed-by-bed sampled. It represents the best natural exposure of the stratigraphic interval 2. Section A is almost equivalent to USGS Mesozoic locality M2560 (Balini et al., 2007) cited in Silberling & Tozer, 1968. Section B is located about 230 meters to the east. All beds exposed in sections A and B have been bed-by-bed sampled, and conodont samples were collected from the most significant fossiliferous beds (see Orchard & Balini, 2007). Sections D(2), E and F are stratigraphically higher, and they start about 40 meters above the base of the middle member (Balini et al., 2007). The stratigraphic succession between the top of sections A and B and the base of sections D(2), E and F is more marly. This lithologic character is not favorable for the preservation of specimens, which are strongly deformed by compaction.

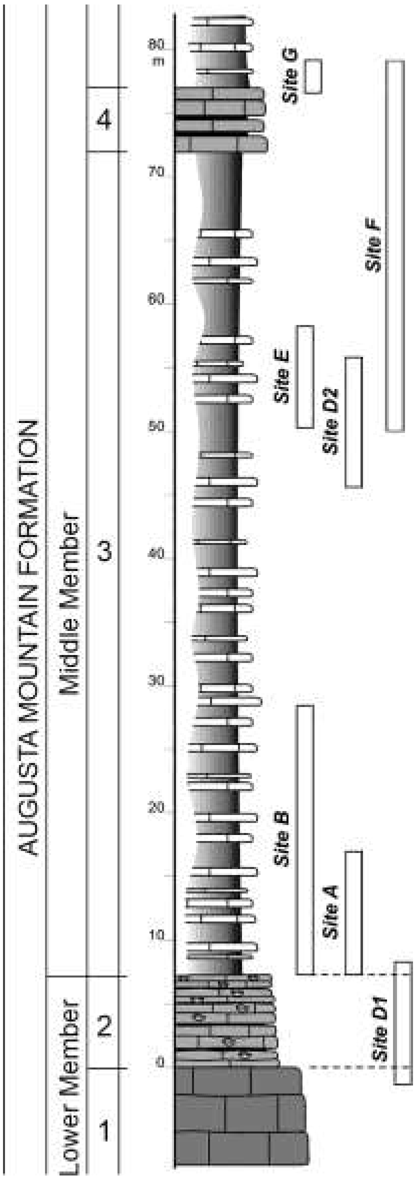


Fig. 2.8 – *Synthetic section of the upper part of the lower member and the lower part of the middle member of the Augusta Mountain Formation; sites correspond to the studied sections (slightly modified from Balini et al., 2012).*

2.3 - China Mountain

2.3.1 - Geographic position

China Mountain is located in the northern Tobin Range, north western Nevada (Fig. 2.9). The locality is situated in the eastern Pershing County, near the boundary with Lander County to the east and Humboldt County to the north. The nearest cities are Battle Mountain, about 45 km to the east, and Winnemucca, about 50 km to the northwest. The area is also of mining interest (e.g. Silver lead mine, Ferguson et al., 1952). The studied locality can be reached from the Interstate 80, continuing along the Pumpernickel valley until reaching the Smelser Pass, where a jeep trail leads to the outcrops.

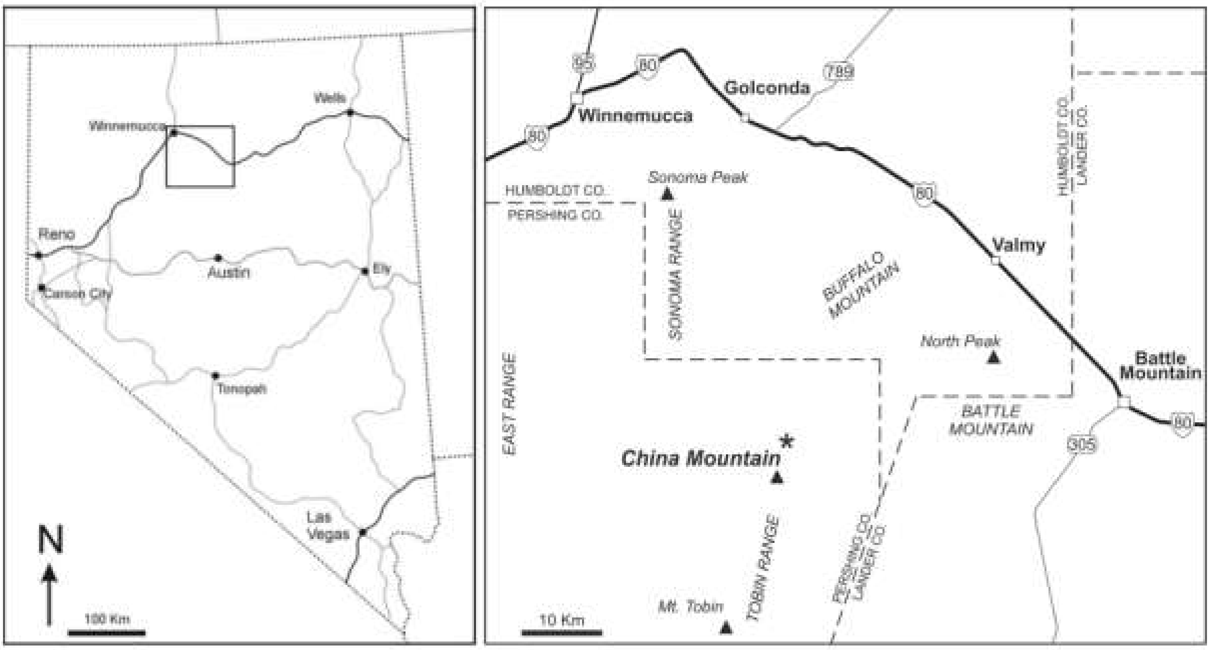


Fig. 2.9 *– Geographic position of China Mountain. The asterisk indicate the approximate position of the studied locality.*

2.3.2 - History of studies

Previous studies on the China Mountain area were crucial for understand the stratigraphy of the type Star Peak Group. The type localities of several formations are located in this area, for example the China Mountain Formation (Ferguson et al., 1952) belonging to the Koipato Group, the Panther Canyon Member of the Augusta Mountain Formation (described and mapped at the rank of formation by Ferguson et al., 1952) and the Smelser Pass Member of the Augusta Mountain Formation (Nichols & Silberling, 1977). The area was investigated in the early 1970s as part of the PhD work of K.M. Nichols (1972). Part of her work is published in Nichols (1974) and Nichols & Silberling (1977). Nichols collected ammonoids from two sites located in the Smelser Pass Member of the Augusta Mountain Formation (localities #1251 and #1311, Nichols, 1972), but did not report bed-by-bed collection data. These collections are presently stored at the USGS Core Research Center (Lakewood,

CO), but they have not been described. Nichols & Silberling (1977), referred to the locality and assigned the ammonoid faunas to the Desatoyense Zone.
In 2017 Marco Balini, the writer and James Jenks visited the collections stored in Lakewood, noting the abundance (163 specimens) and the good preservation of the specimens collected in locality #1251. We visited the area in October 2018 and identified the fossiliferous interval in the uppermost part of the Smelser Pass Member of the Augusta Mountain Formation, a few meters below the erosional base of the Cane Spring Formation. Two new fossiliferous sites were located and sampled for macrofossils. The beds exposed were sampled with bed-by-bed approach. However, due to the importance of the fossil-bearing interval and the lack of information in literature, we collected also float specimens from the two sites, after taking careful note of their ex-situ stratigraphic position. Stratigraphic sections were measured and a total of 758 specimens were collected from these two new localities. An attempt was made to find locality #1251 (Nichols, 1972), but was unsuccessful due to the lack of precise locality information. Results of the study of the collected material are presented in this thesis.

2.3.3 – Studied sections

During the 2018 field campaign we measured the first composite section from the upper part of the Panther Canyon Member to the lowermost part of the Cane Spring Formation (Fig. 2.10, 2.11).

Fig. 2.10 *– The upper part of the Panther Canyon Member and part of the Smelser Pass Member exposed on the northern end of China Mountain.*

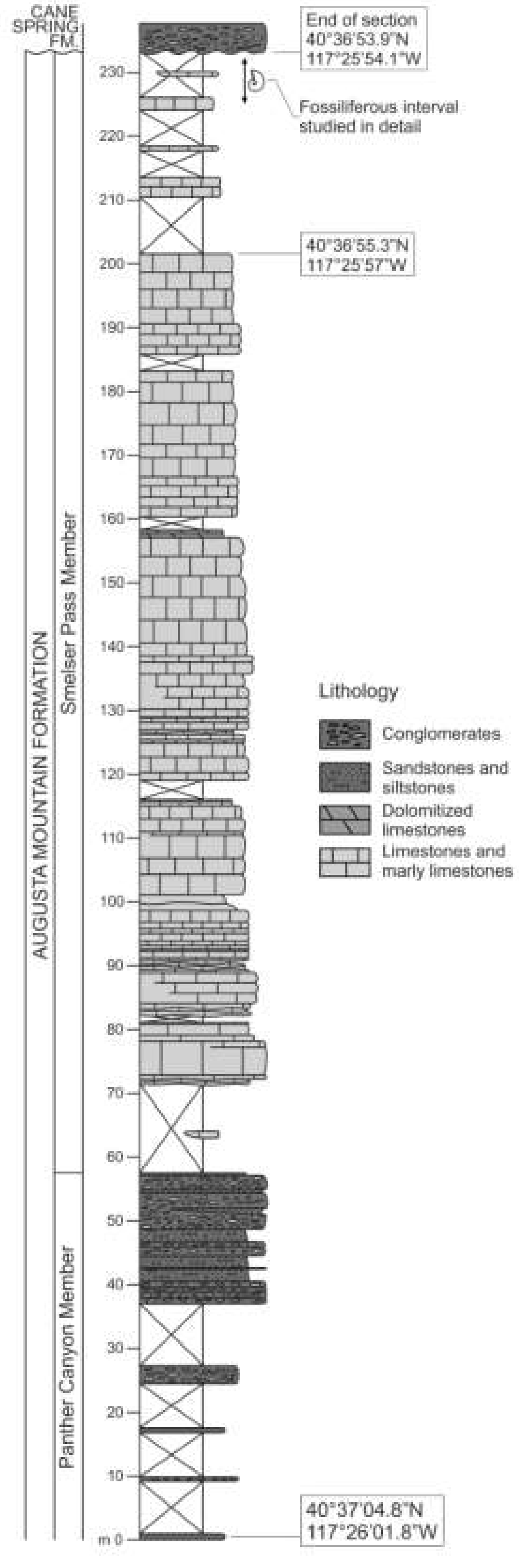


Fig. 2.11 *– Compositesection of the upper part of the Panther Canyon Member and the Smelser Pass Member of the Augusta Mountain Formation.*

The Triassic beds outcropping in the northern end of China Mountain strike 155°-185° S and dip16°-24° E. The exposed upper part of the Panther Canyon Member is about 57 m thick, and is mostly composed by red-brown conglomerates, sandstones and siltstones. The lower 35 meters are dominated by fine grained lithologies, with red sandstones in about 1 meter thick beds. Less abundant are the red conglomerates and microconglomerates in 0.7-2.75 m thick beds, composed by rounded non-spherical quartz grains. The conglomerates are more abundant in the upper part and occur often in thick subdivided beds with granules-small pebbles grain-size (2-6 cm). Red sandstones and siltstones are intercalated with the conglomerates. The uppermost part of the Panther Canyon Member is characterized by a red-brown conglomerate main cliff with thin beds and lenses of red sandstones, for a total thickness of about 8.5 meters. The basal part is characterized by an abrupt change from sandstones to grain-supported conglomerates, whose grain size range from very coarse sand to pebbles (1-10 cm). The majority of the sub-rounded grains are composed by quartz, but red-brown siltstone grains are also present.

The boundary between the clastic rocks of the Panther Canyon Member and the limestones of the Smelser Pass Member is covered by debris, that forms a walkable ledge. The total measured thickness of the Smelser Pass Member is about 175 meters. The lowermost 14 meters are poorly exposed, and only few grey limestone beds crop out. This interval is overlain by twenty meters of the exposed cliff-forming limestones, which are clearly subdivided into two banks. The first bank begins with 50cm of bioturbated gray nodular limestones in cm-thick levels, overlain by massive gray bioturbated limestones in beds of increasing thickness from decimetric to metric. This succession is overlain by decimetric beds of bioturbated limestone. The bioturbation is dolomitized, and consists mainly of complex networks of burrows horizontally developed along the bed surface. The second bank is

lithologically similar to the first. The remaining part of the cliff-forming succession is composed again by nodular limestones and massive beds of varying thickness, but it is less clearly subdivided into banks. A 1.2 m thick dolomitized interval occurs about 100 meters from the base of the member.
The uppermost part of the member measured along the mountain ridge is poorly exposed, but includes the ammonoid-bearing levels first found by Nichols. These levels are documented just below the erosional unconformity of the red-brown conglomerates of the Cane Spring Formation resting on the Smelser Pass Member. The fossiliferous succession has been studied in four localities with the measurement of stratigraphic sections (Fig. 2.12; 2.13).

Fig. 2.12 *– Satellite map showing the position of the studied localities and the measured composite section (image from Google maps).*

Localities A and D. At these sites, the last seven meters of the Smelser Pass Member document a deepening trend. About 2.8 meters of gray to dark gray bioclastic limestones in decimetric beds contain silicized bivalves and brachiopods. These limestones are overlain by 40cm of slightly nodular limestones with intercalated red sediment, which pass to more nodular limestones and finally to yellow-light brown cherty limestones. Only one silicified brachiopod (sample CHM2) has been found from debris one meter below the base of Cane Spring Formation. In locality D some brachiopods have been found in debris between 10 and 15 meters below the Cane Spring Formation.
Localities B and C. These sites are located on the opposite side of the small valley (Fig. 2.12), where the succession is tectonically lowered by a fault. In these localities a thicker part of the Smelser Pass Memberis documented. The measured sections begin in correspondence of dark gray bioclastic limestones, similar to the one observed at locality A. At localities B and C these limestonesare overlain by some tens of meters (about 23 m in locality B, about 45 m in locality C) of poorly exposed, soft

weathering, marls, limestones and marly limestones. The ammonoid faunas have been collected from few in situ exposed limestone and marly limestone beds and from debris. In locality C few beds of volcanic origin are also exposed.

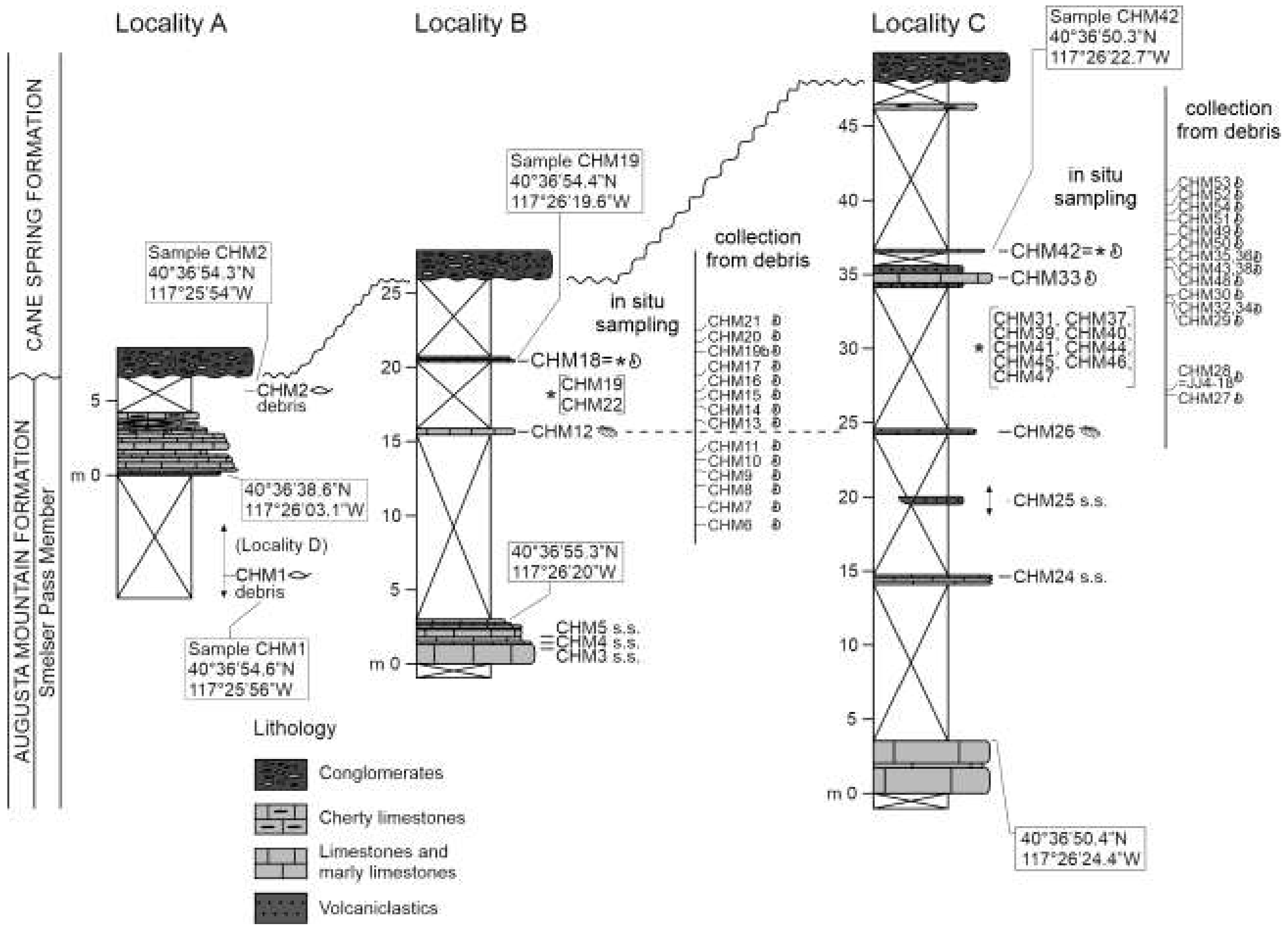


***Fig. 2.13** – Stratigraphic sections measured in the fossiliferous localities, showing the position of in situ samples and the ex-situ stratigraphic position of debris samples.*

Chapter 3

Materials and methods

3.1 - General approach to the study of ammonoids

The material studied has been collected with a bed-by-bed approach. This makes possible the application of the stratophenetic method (Gingerich, 1979) to the study of ammonoids. This method is mentioned in Chapter 1.1.2.

Particular attention is deserved to the suture line, the most important feature for the classification of the early Trachyceratinae. The potential of the suture line for the reconstruction of the phylogeny of Triassic ammonoids has never been developed in literature. However, we have demonstrated (Balini & Marchesi, 2018) that this study might be the best approach, especially for the study of ammonitic suture.

The development of a population-based and phylogeny-oriented taxonomy requires an integrated study of historical type specimens (collected without information as to their stratigraphic position in the section) and newly collected (bed-by-bed) topotypes. The study of type specimens allows one to clarify the various combination features of a species. The study of bed-by-bed collected topotypes allows the recognition of population variability and evolutionary trends of the species.

3.2 - Preparation and study of the specimens

At the beginning of the PhD work the South Canyon collection consisted of about 3000 specimens. A first preparation of this material has been done during previous master's degree thesis by Paola Taiana and Riccardo Martin. During the PhD work the writer added about 900 newly prepared specimens to the initial collection. This new specimens comes from unprepared material present in the Department and from the material collected during the 2018 field campaign. The refined preparation of South Canyon specimens and preparation of the China Mountain ammonoid collection, consisting of 758 specimens, have been done by the writer.

The main tools used for the preparation are two pneumatic micro-chisels equipped with custom made needles (Chicago Pneumatic CP9361; Desoutter HP2 7DR; needles crafted by Reinhart Veit † and CRM Utensili Speciali S.r.l.). The test surface of few specimens has been prepared by hand with needles mounted on pin vises. The preparation has been done with the help of a stereomicroscope Wild Heerbrugg M3 at magnifications of 6.4x – 16x.

Biometry parameters have been measured by means of two vernier calipers, one of which modified with an external jaw extension to facilitate the whorl height measurement. Measurements have been reported in tables and graphs, with the identification number of the corresponding specimens. Graphs have been realized with the software OriginPro.

Photographs of all the specimens have been taken by the writer, apart from Johnston's types (taken by Marco Balini), after coating the ammonoids with ammonium chloride. Management of photographs and composition of the plates have been done with the software Photoshop.

3.3 - Drawing of suture lines

Suture lines have been drawn mainly with a stereomicroscope Wild Heerbrugg M5A Apochromat, equipped with a Motic K400 Drawing Tube, at magnifications of 6x – 25x (smallest sutures at 50x). The drawing process is explained below. Initially the sutures are drawn on normal paper with a 0.2mm or 0.3mm mechanical pencil. The specimen is oriented in such a way that the portion of suture to be drawn is as planar as possible; the drawing is performed avoiding the peripheral zone of the stereomicroscope's field of view, to reduce at minimum the distortion produced by the lens system. For this reason the specimen needs to be reoriented several times, and the suture is drawn in separate portions. Usually each suture is divided into a ventral portion, a ventrolateral portion and three to five portions for each flank. Each portion is then traced and united on a tracing paper sheet. To facilitate this operation each portion is drawn so as it partially overlaps the adjacent portions. The tracing paper sheet is then scanned and imported in the software CorelDRAW for the vectorial digitalisation. Once digitized, the suture line is reduced to the desired scale and inserted in the final figure.

For many specimens, the suture lines required additional preparation before the actual drawing. Often it was necessary to carefully remove test fragments that partially covered the sutures, with particular attention to avoid the artificial simplification of the suture (see Balini, 1998, fig.13). This has been done mechanically by hand with needles mounted on pin vises or with fine pneumatic micro-chisel, with the support of a stereoscope at various magnifications (6x - 25x). Sometimes a very careful chemical preparation (HCl 2.5%) has been necessary for the removal of the remaining test. This has been done with the help of a small syringe under stereoscope magnification of 25x, with water at hand to stop the reaction when needed.

3.4 - Other preparation activities

Eight specimens have been selected an prepared in the Department's Thin Section Lab for the study of the test structure by SEM images. The preparation method used is described in Crippa et al. (2016). Each specimen has been cutted in the desired orientation, and the flat surface obtained has been grounded with fine grade silicon carbide (Mesh 1000). After washing in water, the surface has been etched in diluted hydrocloridric acid; the best results have been achieved with a diluition of 2.5% for 25 seconds.

Sixty-six acetate peels of the most important fossiliferous beds have been made for a first study of the sedimentologic characteristics of the succession.

Chapter 4
Taxonomy

4.1 - Introductory notes

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

Repository of specimens. The collection studied will be registered and housed at the following institutions: Museo di Paleontologia (acronym MPUM), Dipartimento di Scienze della Terra "Ardito Desio", Universitàdegli Studi di Milano, Via Mangiagalli 34, I-20133 Milano, Italy;

New Mexico Museum of Natural History & Science (acronym NMMNHS), 1801 Mountain Road NW, Albuquerque, New Mexico 87104, USA; The cited types of Johnston (1941) are currently housed at the Smithsonian National Museum of Natural History (acronym USNM), 1000 Constitution Avenue NW, Washington D.C., USA. The cited types of Tozer (1994) are housed at the Geological Survey of Canada (acronym GSC), 601 Booth Street, Ottawa, Ontario K1A 0E8, Canada.

Numbering of specimens. Every specimen is identified by the collection number, indicating the stratigraphic level of collection and the individual number of the specimen (e.g. South Canyon specimen D10-70: section D, bed number 10, 70th specimen; China Mountain specimen CHM37-1: sample number 37, 1st specimen). For the specimens already published in other works, the museum number is also reported (e.g., MPUMxxxxx.).

Measurements. Acronyms: D=diameter (mm), H=whorl height in D (mm), U=umbilical diameter (mm); W=whorl width (mm).

Suture line terminology. We follow the lobe nomenclature of Wedekind (1916) for the lobe in the ventral position (E) and the 1st one on the external part of the flank (L); In the descriptions that follow, the saddles are numbered beginning with the external part of the flank, e.g., the 1st saddle is between the lobes E and L.

In order to better characterize and compare suture lines, we follow the method proposed by Balini & Marchesi (2018), consisting in the comparison between the total depth of the external lobe (TDE) in respect to the total depth of the first lateral lobe (TDL). The measurement of the lobe's depth is taken between the top of the 1st saddle and the end of the deepest denticle of the lobe.

Nomenclature for bio- and chronozones. The nomenclature used in this thesis is from Salvador (1994).

Nomenclature and description of new taxa. The International Code of Zoological Nomenclature (Article 7, 8, 9) establish that any nomenclatural act must be done on a published work. Since a PhD thesis is not considered a published work, it is not possible to assign new specific names in it. For this reason in the thesis new genera and species are named with alphabetical letters (e.g. Genus A; Genus B; Genus A sp. A). Descriptions and diagnoses of new taxa are presented in an informal way, and the possible holotype is indicated with the wording "best representative specimen".

4.2 - Remarks on taphonomy

Taphonomic observations has been made for assessing the presence of reelaborated ammonoids, which must be treated separately (see Fernandez Lopez, 1991 for concepts regarding the utilization of reelaborated fossils).

Fernandez Lopez (1985; 2011) summarizes and exemplifies various criteria for the recognition of accumulated, resedimented and reelaborated fossils. These criteria are summarized in the following table.

Accumulated ammonoids	Accumulated landing mark and accumulated shell.
Resedimented ammonoids	Shell and internal mold with ooids produced in high energy environments.
	Shells and internal molds showing structural continuity between infill and matrix.
Reelaborated ammonoids	Phosphatized, concretionary internal molds, enclosed in marly limestones.
	Micritic concretionary internal mold, enclosed in limestone with ferruginous ooids. Ferruginous encrusting of internal mold.
	Structural discontinuity between internal mold and sedimentary matrix. Coating by iron crusts.
	Structural discontinuity between internal mold and sedimentary matrix.
	Reverse geopetal sedimentary infill.
	Several phases of sedimentary filling and cementation.
	Disarticulation surface of internal mold.
	Truncation facet of internal mold.
	Ellipsoidal abrasion facet on the last third of the last preserved whorl.
	Annular abrasion furrow.
	Fracture surface of internal mold.
	Bioerosion traces on internal mold.
	Ferruginous encrusting of internal mold.
	Microbial encrusting on a flank of internal mold.
	Remains of bryozoan and oyster encrusting the internal mold.

None of the listed diagnostic criteria for reelaborated ammonoids have been observed in the succession of South Canyon and China Mountain. However, resedimented ammonoids have been recognized. Shells and internal molds show always structural continuity between the infill and the external matrix, and in some cases the presence of ooids produced in high energy environments has been observed, as in bed F26 (Fig. 4.1). Ammonoids of bed F26 rarely show a preserved body chamber, while in other beds, like bed E5, body chambers are usually well preserved and in some cases nearly complete. Other indications of transport, like isooriented nautiloid orthocones on bed surfaces, have been observed in bed D10 and correlatives.

The sedimentary succession between Section A and B and Sections D, E and F is generally more marly. This lithology is not favorable for the preservation of specimens, which are always extremely deformed and fractured by compaction.

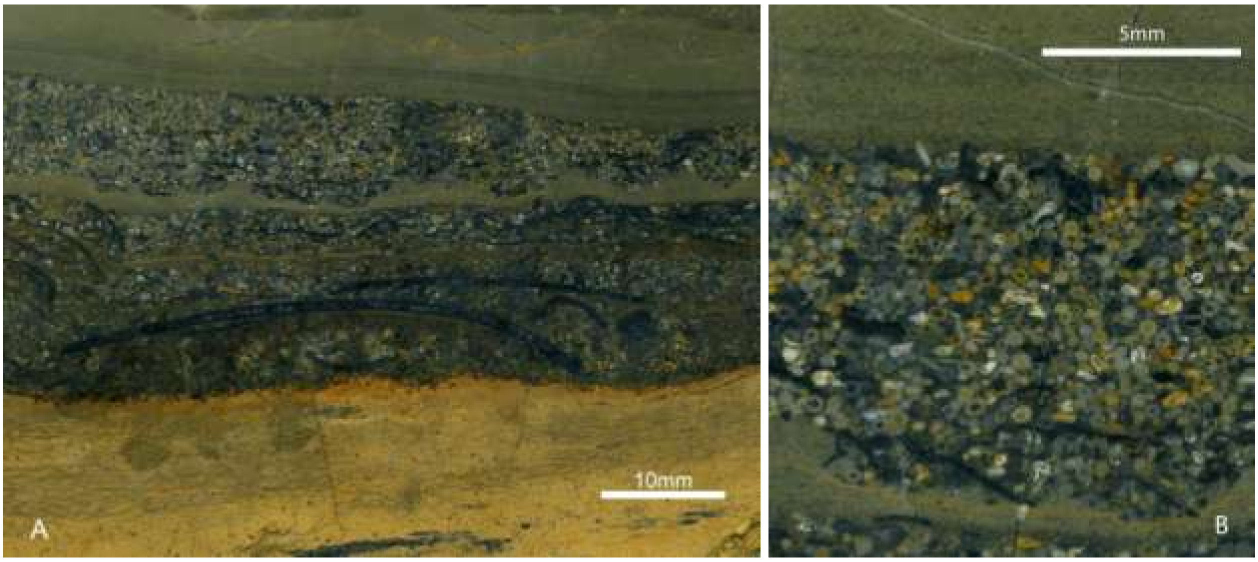


Figure 4.1. *Photographs of the lower part of bed F26.* ***A*** *- Resedimented bed composed by grain supported oolitic and bioclastic packstones and grainstones, with intercalations of laminated mudstones;* ***B*** *– enlarged detail of A.*

4.3 - Systematic descriptions

Order Ceratitida Hyatt, 1884
Superfamily Noritoidea Mojsisovics, 1879
Family Noritidae Karpinsky, 1889
Genus *Neoclypites* Spath, 1951
Type species: *Metahedenstroemia*? *desertorum* Johnston, 1941

Neoclypites desertorum (Johnston, 1941)
Pl. 1, fig. 1-3; Textfig. 1

v 1941. *Metahedenstroemia*? *desertorum* n. sp. Johnston; p. 460, pl. 60, fig. 6-8; pl. 61, fig. 1-4; pl. 63, fig. 3; textfig. 1g, 1h, 2a.

Type series. Holotype: USNM 77518f; six figured paratypes: USNM 77518a, USNM 77518b, USNM 77518c, USNM 77518d, USNM 77518e, USNM 77518g. Johnston, 1941 reported eleven studied specimens and fifteen fragments. Only the figured holotype and six paratypes are housed at the USNM.
Topotypes. Fifty-four specimens. Twenty-seven specimens from Section A (A11-26; A16-1; A21-3, -37, -44, -45, -61, -103, -123, -125, -132, -135; A22-6, -10; A23-7, -8, -19, -20, -22; scan3-21, -62, -63, -64, -65, -66, -73; AA1-18); twenty-seven specimens from Section B (B10-18, -21; -15, -42, -48, -50, -58, -97, -123, -131, -141, -159, -174; B13-11; B18.1-10; B18.2-11; scan16-8, -75, -116, -117, -197, -229, -391, -469, -538, -591; scan16b-12)

Type locality. *Joannites* zone, South Canyon, New Pass or Desatoya Range, Nevada (Johnston, 1941).

Measurements. See Table 1.

Description. Specimens range from about 22mm to 75mm in diameter, and are preserved as internal molds often with complete parts of test on the flanks. All the populations show consistent ontogeny, and the juvenile stage is well documented in the scan16 population. The general shape is oxycone, with a very narrow umbilicus and a gradational umbilical margin. Whorl section is very compressed (H/W=2.33÷2.78), with almost flat flanks. The maximum width is located near the periumbilical margin. The venter is tabulate or grooved at all growth stages, and the venter width increases very slowly during ontogeny. The venter width/whorl height ratio is higher in juvenile specimens (spec. scan16-591, H=13.3, venter width=2mm; spec. A21-37, H=46.5, venter width=2mm).
Ornamentation consists of sinuose to falcoid growth lines, more accentuated at 2/3 of the flanks from the umbilicus. In this same position sometimes are visible very low and spaced ribs which follow the same trend of the growth lines.

The adult suture line is ceratitic, with at least six elongated saddles. The denticulation of lobes is well developed, in particular the external lobe is complex and shows terminations with numerous and long denticles. Often the right side of the external lobe is slightly different in respect of the left side. The juvenile suture line (e.g. spec. scan16-197, H=7mm) is relatively more simple in respect of the adult suture, with less indented lobes.

Discussion. The resemblance with the Lower Triassic species *Metahedenstroemia kastriotae* (Arthaber, 1911), already pointed out by Johnston (1941, p. 461-462), may be a case of evolutionary convergence. *Neoclypites desertorum* differs from *Metahedenstroemia kastriotae* by the wider whorl section, the wider and more grooved venter and the higher number of elements of the suture line at a comparable whorl height. These morphological differences, and the lack of similar species in the Middle Triassic, exclude the possibility that they represent a long lived chronospecies, and justify the attribution to a different genus.

Neoclypites desertorum is probably the ancestor of *Perrinoceras novaditum* Johnston, 1941 for the reasons explained in the discussion of the latter species.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Superfamily Sageceratoidea Hyatt, 1884
Family Sageceratidae Hyatt, 1884
Genus *Sageceras* Mojsisovics, 1873
Type species. *Goniatites haidingeri* Hauer, 1846

Sageceras cf. *haidingeri* (Hauer)
Pl. 2, fig. 1-2

Synonymy.
1941. *Sageceras* cf. *S. haidingeri* (Hauer) – Johnston; p. 462; pl. 60, fig. 9-10.

Material. One specimen from Section E (E5-53); Four specimens from Section F (F1bis-40, -133, -134, -135).

Description. Specimens can reach large sizes (H=about 50mm), but none is complete. Coiling is very involute, with a small umbilicus and angular umbilical margin. Whorl section is compressed, with almost flat flanks and a rounded venter. The few parts of test show low radial ribs on the flanks, and two small keels that mark the ventrolateral margin. The suture line is ceratitic, with numerous tall and narrow saddles and bifid lobes.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Superfamily Ceratitoidea Mojsisovics, 1879
Family Hungaritidae Waagen, 1895
Genus *Perrinoceras* Johnston, 1941
Type species: *Perrinoceras novaditum* Johnston, 1941

Perrinoceras novaditum Johnston, 1941
Pl. 1, fig. 4-7; Textfig. 2.1-.5

v 1941. *Perrinoceras novaditus* n. gen. et n. sp. Johnston; p. 460, pl. 60, fig. 3-5; textfig. 1f.

Type series. Holotype: USNM 77516a, one paratype USNM77516b.
Topotypes. Twenty-four specimens conserved as internal molds often with some test. 3 from section D (D14-31, -42, -53), 1 from section E (E18.1-59), 18 from section F (F1-46; F26-16, -28, -29, -32, -57, -74, -100, -142, -143, -144, -205, -241, -243, -245, -262, -302), 2 from section G (G1-73, -84).
Other material. Nine specimens from China Mountain, loc. C (CHM49-12, -13, -14, -15; CHM52-1, -5, -6, -7, -8).

Type locality. *Joannites* zone, South Canyon, New Pass or Desatoya Range, Nevada (Johnston, 1941).

Measurements. See Table 1.

Description. Specimens can reach a diameter of about 80mm, and are preserved as internal molds often with complete parts of test still attached. Specimens collected in China Mountain and from the highest stratigraphic positions in South Canyon (bed F26 and G1) fit closely with the descriptions and figures of Johnston, 1941. General shape is oxycone with a very narrow umbilicus and a gradational umbilical margin. Whorl section is very compressed ($H/W=2.65\div3.37$) and flanks are almost flat or slightly lanceolate. The maximum whorl width is located near the periumbilical margin. The inner whorls (spec. F26-143, $\sim H<10$mm,) show a narrow tabulate venter (spec. F26-143, $H\approx6$mm, venter width= 0.7mm) with marked shoulders. The venter narrows quickly and becomes acute already at $H\approx15$mm (spec. F26-302).
Ornamentation consists of falcoid growth lines. Spaced and wide falcoid ribs are more in marked on adult specimens only at 2/3 of the flanks, in correspondence of the crescent part of the falcoid trend.
Suture line is ceratitic, with eight lobes and saddles in adult specimens. A characteristic feature of all the visible suture from bed F26 and G1 of South Canyon and from China Mountain is the simple

denticulation of the external lobe, which usually ends with a single pointed denticle on each side. This feature is visible also in the inner whorls (spec. F26-143, H≈6mm).
Specimens collected from lower stratigraphic positions of South Canyon (beds E18.1, F1, D14) show variations in the suture line and venter in respect of specimens from bed F26. The venter remains tabulate and very narrow with marked shoulders even at H=30mm (spec. D14-41, venter width=1mm). On the test are visible two slightly rised keels. The suture line shows slightly more complex denticulation, in particular the external lobe terminal denticles are two-pointed or three-pointed. The single pointed terminal denticle is never observed in the stratigraphically lower specimens.

Discussion. Comparing the populations in stratigraphic order, two evolutionary trends are observed. The first regards the venter and the second regards the suture line. The venter tends to become from tabulate to acute progressively earlier during ontogeny. Regarding the suture line, the external lobe denticulation tends to become slightly more simple. These trends suggest a possible evolutionary relationship with *Neoclypites desertorum*, which occurs in the lower sedimentary succession of sections A and B and is characterized by a tabulate venter and a more complex ceratitic suture line at all growth stages. The variation in venter type can be explained with a case of acceleration, with the appearance of the acute venter progressively earlier during ontogeny. This evolutionary relationship is suggested also by the fact that the suture line of adult *Perrinoceras novaditum* shows similarities with the suture of juvenile *Neoclypites desertorum*.
The resemblance with the Lower Triassic genus *Parahedenstroemia* Spath, 1934, already pointed out by Johnston (1941, p. 459-460), may be a case of evolutionary convergence.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation; China Mountain (northern Tobin Range, northern Nevada), upper part of the Smelser Pass Member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Family Badiotitidae Hyatt, 1900
Genus *Badiotites* Mojsisovics, 1879
Type species: *Ammonites eryx* Münster, 1834

Badiotites trauthi (Johnston, 1941)
Pl. 2, fig. 3-5; Textfig. 2.6

Synonymy.
v 1941. *Lecanites trauthi* n. sp. Johnston; p. 455, pl. 59, fig. 17-20.

Type series. Holotype: USNM 77515c; two figured paratypes: USNM 77515a, USNM 77515b. Johnston, 1941 reported nine studied specimens. Only the figured holotype and two paratypes are housed at the USNM.
Topotypes. Ten specimens from Section D (D10-12, -80, -112; D10bis-22, -32; D13-2; D3-3, -4, -12; D4-7); two specimens from Section E (E3-35; E15-12); Twenty-two specimens from Section F (F15-7, -11, -13, -14, -19, -21, -22, -31, -32, -33, -37, -38, -39, -40, -41, -42, -43, -45, -46; F17-2; F25-3, -4).

Type locality. *Joannites* zone, South Canyon, New Pass or Desatoya Range, Nevada (Johnston, 1941).

Description. Specimens range from about 10mm to 17mm in diameter, and are preserved as internal molds, often with complete parts of test attached. Coiling is evolute at all growth stages, with a shallow umbilicus and a gradational umbilical margin. The whorl section is compressed elliptical, with a well rounded venter. Ornamentation consists of delicate slightly sinuous primary ribs, which are abruptly projected orad on the ventrolateral margin. Bifurcations are very rare, and occur on the periumbilical margin in the adult stage. Suture line is goniatitic, with short saddles and lobes.

Discussion. *Badiotites trauthi* (Johnston) differs from *Badiotites scapulatus* Tozer for the more fine and delicate ribs and for the rounded venter. Specimens of *B. trauthi* with slightly more accentuated ribs are close to the robust *Badiotites* aff. *scapulatus*, which occurs in the same stratigraphic interval at South Canyon.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Badiotites aff. *scapulatus* Tozer
Pl. 2, fig. 6-9

Best representative specimen: D10-76
Other material: Twenty-two specimens from Section D (D10-11, -14, -15, -17, -66, -73, -75, -77, -79, -106, -117, -132, -171, -176, -177, -178; D10bis-38, -64, -52a, -95; D13-4, -6); Two specimens from Section E (E2-18; E3bis-11); Seventeen specimens from Section F (F15-2, -5, -8, -9, -10, -18, -20, -23, -24, -29, -30, -44, -47; F24-7, -10, -15; F25-2). Two specimens from China Mountain, loc. C (CHM34-17; CHM47-16).

Locus typicus and stratum typicum. South Canyon (New Pass Range, central Nevada, USA), Augusta Mountain Formation, middle member, section D, bed D10.

Description. Specimens range from about 12mm to 19mm in diameter, and are preserved as internal molds, often with complete parts of test attached. Coiling is always evolute, with a gradational umbilical margin. The whorl section is compressed elliptical, with a smooth rounded venter in the juvenile and intermediate stage. On the adult body chamber angular shoulders are developed, and the venter appears more flat. Ornamentation consists of robust sinuous primary ribs, which are abruptly projected orad on the ventrolateral margin. The shoulders developed on the adult body chamber are formed by the prominent projected ribs, which also seems to cross the venter. Suture line is goniatitic, with short saddles and lobes.

Discussion. *Badiotites scapulatus* Tozer shows a flat smooth venter, with angular shoulders. At comparable whorl height *Badiotites* aff. *scapulatus* shows instead a more rounded venter, without angular shoulders. The latter are developed only on the adult body chamber of the largest specimen, but here the ribs seem also to cross the venter.
Badiotites aff. *scapulatus* differs from *Badiotites trauthi* only for the more robust ornamentation at all growth stages.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation; China Mountain (northern Tobin Range, northern Nevada), upper part of the Smelser Pass Member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Superfamily Arcestoidea Mojsisovics, 1875
Family Cladiscitidae Zittel, 1884
Genus *Procladiscites* Mojsisovics, 1882
Type species. *Procladiscites brancoi* Mojsisovics, 1882

Procladiscites mulleri Johnston, 1941
Pl. 2, fig. 10-11

Synonymy.
v 1941. *Procladiscites mulleri* n. sp. Johnston; p. 480; pl. 65, fig. 4-7; textfig. 3f-g.

Type series. Holotype: USNM 77530a; four figured paratypes: USNM 77530b, USNM 77530c, USNM 77530d, USNM 77530e. Johnston, 1941 reported thirteen studied specimens, but only the figured holotype and four paratypes are housed at the USNM.
Topotypes. One specimen from Section A (A20.18-1); One specimen from Section B (B11-79); One specimen from Section D (D10bis-7); Twelve specimens from Section E (E13-36, -53, -68; E13bis-3; E5-9, -26, -42, -69, -117, -118, -119, -120); four specimens from Section F (F1bis-41, -88, -89, -90).

Type locality. *Joannites* zone, South Canyon, New Pass or Desatoya Range, Nevada (Johnston, 1941).

Description. Specimens reach a maximum diameter of about 50mm, and are preserved as internal molds, often with complete parts of test attached. Coiling is very involute, and the umbilicus is very narrow, with a gradational umbilical margin. Whorl section is compressed elliptical, with a well rounded venter. Ornamentation consists of fine and dense spiral striae, developed on the whole surface of test. The suture line is ammonitic, characterized by a curved trend and with about eleven lobes on the flanks. The saddles are composed of one main part, not bifid as on for example *Joannites*.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Family Arcestidae Mojsisovics, 1875

Genus *Arcestes* Suess, 1865

Type species. *Arcestes galeati* Mojsisovics, 1873

Arcestes sp. ind.

Pl. 3, fig. 1-2

Material. Five specimens from Section A (A21-65, -133; scan3-3; scan3det-6; A20.18-2); seventeen specimens from Section B (B11-72, -102, -110; scan16-114, -119, -120, -121, -140, -159, -244, -274, -340, -389, -486, -489, -506, -510); one specimen from Section D (D4-24); two specimens from Section E (E15-5; E5-30); three specimens from Section F (F1-114; F1bis-5, -44).

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Genus *Joannites* Mojsisovics, 1875

Type species. *Nautilus cymbiformis* Wulfen, 1793

Joannites jacobus Johnston, 1941

Pl. 3, fig. 3

Synonymy.
v 1941. *Joannites jacobus* n. sp. Johnston; p. 477; pl. 62, fig. 6-9; pl. 63, fig. 4; pl. 64, fig. 1-7; pl. 65, fig. 1-3; pl. 69, fig. 6; pl. 70, fig. 1-2; pl. 71, fig. 1-2; textfig. 3a-e.

Type series. Holotype: USNM 77528i; eleven figured paratypes: USNM 77528a, USNM 77528b, USNM 77528c, USNM 77528d, USNM 77528e, USNM 77528f, USNM 77528g, USNM 77528h, USNM 77528j, USNM 77528k, USNM 77528l. Johnston, 1941 reported over one hundred studied specimens, but only the figured holotype and eleven paratypes are housed at the USNM.

Topotypes. Thirty-seven specimens from Section A (A20-4, -5; A21-7, -8, -9, -28, -47, -56, -58, -59, -113, -114, -115, -116, -117, -118, -120, -121; A23-3, -12; A24-3, -5, -6, -7, -8; scan3-1, -13, -25, -69, -70, -71, -74, -81; AA1-19, -20, -21, -47); eighty specimens from Section B (B11- 3, -12, -13, -17, -20, -22, -24, -32, -34, -39, -45, -46, -52, -74, -75, -77, -80, -82, -87, -89, -90, -91, -92, -93, -96, -98, -99, -101, -104, -106, -107, -108, -109, -122, -128, -129, -145, -147, -148, -155, -164, -170, -172; B12-8; B13-2, -5, -10; B5-51; B8-4, -6; B9-10; scan13-12; scan15-45, -60, -68, -80; scan16-5, -18, -89, -113, -122, -199, -304, -395, -402, -428, -466, -488, -548; scan16b-13, -14, -15, -16, -17; B18.2-3, -4, -6, -7, -19; B18.1-2, -8); one specimen from Section D (D13-1); one specimen from Section E (E14a-2).

Type locality. *Joannites* zone, South Canyon, New Pass or Desatoya Range, Nevada (Johnston, 1941).

Description. Specimens can reach large dimensions, up to 90mm in diameter. The majority of specimens are preserved as internal molds, often with parts of test still attached. Coiling is very involute, with a narrow and deep umbilicus and a gradational umbilical margin. The whorl section is compressed subelliptical, with a rounded venter. The external surface of test is almost smooth. Sinuose periodic constrictions are visible on the internal mold. Their number vary during growth. At a diameter of 70mm the constrictions are developed every 60°-70° of volution. At larger diameters the constrictions become weaker. The suture line is ammonitic, with about eleven lobes. The saddles are divided into two parts by minor lobes. The suture follow a curved trend along the flanks.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Superfamily Clydonitoidea Hyatt, 1877 (in Meek, 1877)
Family Trachyceratidae Haug, 1894

Remarks on the composition of the Family. The structure of the Family Trachyceratidae adopted in this thesis follows that of Tozer (1994), with the addition of the Subfamily Haoceratinae introduced by Zou et al. (2015). The Family Trachyceratidae is subdivided into five subfamilies: Protrachyceratinae Tozer, 1971, Arpaditinae Hyatt, 1900, Haoceratinae Zou et al., 2015, Trachyceratinae Haug, 1894 and Sirenitinae Tozer, 1971.

Subfamily Arpaditinae Hyatt, 1900

Genus *Silenticeras* McLearn, 1930

Type species: *Daphnites* (*Silenticeras*) *hatae* McLearn, 1930

Silenticeras schencki (Johnston, 1941)

Pl. 3, fig. 4-7; Textfig. 2.7-.8

Synonymy.
v 1941. *Arpadites schencki* n. sp. Johnston; p. 458; pl. 60, fig. 1-2; textfig 1e.

Type series. Holotype USNM 77517.
Topotypes. Seventy-three specimens, conserved as internal molds often with some test. Five specimens from Section D2 (D4-4, -25, -40, -41, -42); Thirty-three specimens from Section E (E4-9; E5-66, -71, -86, -87, -102, -108, -125, -126, -127, -128, -129, -130, -131, -132, -133, -162, -163, -164; E11-9; E13-26, -32, -54, -58, -67; E13bis-7, -9, -10, -12, -13, -14; E13c-1; E14-31); Thirty-five specimens from Section F (F1bis-18, -105, -106, -107, -108, -109, -110, -112, -113, -114, -115, -116, -146, -147, -148, -149, -150; F16-9; F17-11; F18-3, -4, -8, -13, -15, -16, -17, -18, -19, -20, -21, -22, -23, -24, -26, -28).
Other attributed material. One specimen from China Mountain, loc. C (JJ4-18-25).

Type locality. *Joannites* zone, South Canyon, New Pass or Desatoya Range, Nevada (Johnston, 1941).

Measurements. See Table 1.

Description. *Silenticeras* attaining a maximum diameter of 25 mm (specimen F18-8). Involute ($U/D \approx 0.30$) with a shallow umbilicus and a sharp umbilical edge. Umbilical egression is observed in medium and large sized specimens (e.g. F18-8) from $H \approx 6$ mm. Inner whorls (specimen F18-147, $D < \sim 5$ mm) are depressed and globular, with arched flanks which curve into the well rounded venter. From $D > 5$ mm the whorl section becomes gradually more compressed (spec. F18-8, $H/W=1.07$; spec. E13bis-14, $H/W=1.26$), with slightly arched flanks, rounded ventrolateral margins and rounded venter. Some specimens (e.g. F18-3, F16-9) shows more flat flanks and venter, with a subrectangular whorl section; the ventrolateral margin remains rounded and shoulders are not present.
A marked and deep ventral furrow is present at all growth stages except for the innermost whorls ($D<2$ mm in specimen F18-147). In medium-large sized specimens the furrow is bordered by two slightly rised keels.
Ornamentation consists of growth lines less visible on the internal mould. They are radial for the first 2/3 of the flanks from the umbilicus, and near the ventrolateral margin they are markedly projected orad. Slight periodic depressions are sometimes visible in the first 1/3 of the flanks, e.g. specimen F1bis-105 with 6 depressions in 90°. They follow the same trend of the growth lines.
The suture line is ceratitic, with two slightly indented lobes.

Discussion. *Silenticeras schencki* differs from all Ladinian *Silenticeras* species by its more involute coiling. *S. involutum* Tozer, 1994 differs from *S. schencki* by its more involute coiling and wider whorl section.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation; China Mountain (northern Tobin Range, northern Nevada), upper part of the Smelser Pass Member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Subfamily Trachyceratinae Haug, 1894

Remarks on the composition of the Subfamily. The structure of the Subfamily Trachyceratinae follows that of Tozer (1994), and shows a wide composition. Ten genera are attributed to the Subfamily Trachyceratinae: *Anolcites* Mojsisovics, 1893, *Zestoceras* Tozer, 1994, *Maclearnoceras* Tozer, 1963, *Asklepioceras* Renz, 1911, *Muensterites* Mojsisovics, 1893, *Frankites* Tozer, 1971, *Daxatina* Strand, 1929, *Trachyceras* Laube, 1869, *Austrotrachyceras* Krystyn, 1978, *Trachysagenites* Mojsisovics, 1893.

Genus *Frankites* Tozer, 1971

Type species. *Paratrachyceras sutherlandi* McLearn, 1947

Frankites sutherlandi (McLearn, 1947)

Pl. 3, fig. 8-9; Textfig. 2.9

Synonymy.
1947. *Paratrachyceras sutherlandi* n. sp. McLearn; p. 22; pl. 5, fig. 9.
1967. *Paratrachyceras sutherlandi* McLearn – Tozer; p. 30, 65, 66; pl. 8, fig. 9-12.
1970. *Paratrachyceras sutherlandi* McLearn – Tozer; pl. 17, fig. 22a-b.
1971. *Frankites sutherlandi* (McLearn) – Tozer; p. 1029.
1972. *Frankites sutherlandi* (McLearn) – Tozer; p. 640; pl. 128, fig. 5-9.
1994. *Frankites sutherlandi* (McLearn) – Tozer; p. 165; pl. 82, fig. 10; pl. 83, fig. 8-12; fig. 66b-d.
v 2005. *Frankites sutherlandi* (McLearn) – Waller & Stanley; fig. 3.1-.2.
v 2008. *Frankites sutherlandi* (McLearn) – Balini; p. 177; fig. 5.5-.8; fig. 6.

Material. Twelve specimens from Section A (MPUM 9275 [scan15-1], MPUM 9276 [scan15-6], MPUM 9277 [scan15-16], MPUM 9278 [scan15-3], MPUM 9279 [scan15-2], MPUM 9280 [scan15-7], MPUM 9281 [scan17-1], MPUM 9282 [scan14-1], MPUM 9283 [scan15-4, -5, -10, -12]).

Description. See Balini, 2008, p. 177.

Occurrence. Northeastern British Columbia (Canada), Toad and Liard formations; GSC locs. 9797, 9806, 9811, 36484, 40084, 42297, 42351, 42352, 42354, 49998, 68232, 68233, 68266, 68267, 68269, 68278, 68279, 74773, 82645, 84262, 84265, 89783. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Ladinian, Sutherlandi Subzone 2 of British Columbia (Canada). Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Genus *Daxatina* Strand, 1929

Type species. *Trachyceras canadense* Whiteaves, 1889

Remarks on the genus. The systematics of the genus *Daxatina* Strand has been developed by Tozer (1994), and is based on specimens collected in British Columbia, Canada. *Daxatina* is characterized by a ceratitic to wavy ceratitic suture line. Tozer (1994) described four species of *Daxatina* and figured a total of eight suture lines. Seven of them are ceratitic and only one attributed to *Daxatina canadensis* (Whiteaves) is wavy ceratitic, showing small wrinkles on the first saddle (Tozer, 1994, fig. 68e). The holotype of *Daxatina canadensis* (Whiteaves), type species of the genus, shows a ceratitic suture line (Tozer, 1994, fig. 68c). The specimens from South Canyon attributed here to *Daxatina* show ceratitic to subammonitic suture lines, with great abundance of wavy ceratitic saddles. On average these sutures are more complex in respect of those of the Canadian specimens. Considering the strong external morphologic similarities with the Canadian *Daxatina*, the specimens from South Canyon are attributed to the same genus, and the differences in suture line are used for the distinction at the species level. This involves a small extension of the genus diagnosis to include also subammonitic suture lines.

Daxatina sp. A

Pl. 4, fig. 1-8; Pl. 5, fig. 1-5; Textfig. 3-9

Synonymy.
v pars 1941. *Trachyceras* (*Trachyceras*) cf. *T. aonoides* Mojsisovics – Johnston; p. 482; pl. 67, fig. 7-9; ? textfig. 3h-i [lost specimens].
v 1956. *Trachyceras* (*Trachyceras*) cf. *T. aonoides* Johnston – Silberling; p. 1152; textfig. 2a.
v 2007. *Daxatina* – Balini & Jenks; fig. 7a-b; fig. 8a, c.
v 2007. *Daxatina* – Balini et al.; fig. 8a-c.
v 2007. *Trachyceras desatoyense* Johnston – Jenks et al.; pl. 26, fig. e-f.
? pars 2008. *Trachyceras muensteri* (Wissmann in Wissmann & Münster) – Mietto et al.; pl. 8, fig. 10; fig. 9g.

Best representative specimen: JJ1-97-8
Other material: 111 specimens from Section A (JJ1-97-1, -4, -5, -7; A1-1, -6, -11, -16, -33; A1.2-6; A10-6, -7, -8; A11-1, -2, -5, -6, -7, -10, -11, -17, -23, -24, -30, -31, -41, -46; A12-5, -6, -9; A14-6; A15-3, -5, -6, -8, -13; A16-4, -6, -8, -9, -10, -11, -14, -15, -16, -17, -21, -24; A17-1, -2, -3, -15, -16, -

17, -21; A19-1, -2, -3, -4, -8, -8bis, -9, -10, -13, -14, -16, -19, -21, -23, -25, -26, -28, -31, -33; A20-3, -6; A21-1, -14, -20, -21, -22, -29, -33, -38, -40, -41, -43, -46, -69, -71, -76; A22-4, -8; A23-1, -6, -9, -10, -11, -21; A24-2; A8-3; scan3-1, -14, -15, -23, -30, -38; scan3det-2, -3, -4, -7).
229 specimens from Section B (B10-14, -16, -17, -19, -22; B11-18, -19, -29, -36, -37, -40, -43, -68, -78, -81, -114, -117, -125, -132, -140, -156; B12-5; B13-3, -4, -7, -9; B4-14, -28, -29, -30;B5-6,-9, -13, -15, -17, -24, -27, -29, -49; B5D-8; B5E-1, -5; B6-2, -3, -4, -8; B8-8; B9-3, -9, -32; scan13-1, -2, -9, -14, -15; scan14-7, -11, -12, -13, -16; scan15-14, -21, -23, -42, -58, -67, -93, -100, -101, -102; scan16-1, -2, -10, -11, -13, -17, -19, -24, -25, -26, -27, -28, -29, -53, -63, -67, -69, -70, -72, -76, -80, -81, -90, -93, -96, -97, -101, -102, -104, -105, -106, -109, -111, -112, -128, -130, -131, -132, -133, - 135, -137, -138, -139, -152, -153, -158, -161, -162, -174, -182, -184, -191, -218, -219, -220, -221, - 222, -225, -226, -227, -230, -231, -232, -233, -234, -240, -243, -247, -249, -251, -252, -257, -258, - 59, -266, -267, -268, -269, -270, -271, -276, -284, -286, -287, -289, -293, -294, -297, -300, -301, - 303, -309, -311, -338, -344, -352, -353, -354, -356, -357, -358, -365, -368, -371, -377, -383, -392, -393, -397, -408, -410, -414, -415, -420, -422, -424, -425, -426, -440, -442, -447, -451, -453, -455, -462, -471, -472, -473, -475, -476, -480, -482, -483, -490, -492, -496, -499, -500, -523, -524, -527, -530, -531, -534, -536, -537, -540, -549, -552, -557, -578, -579, -580, 581, -582, -585, -589;

Locus typicus and stratum typicum. South Canyon (New Pass Range, central Nevada, USA), Augusta Mountain Formation, middle member, section B, bed scan16.

Measurements. See Table 1-2.

Diagnosis. *Daxatina* characterized by very dense and fine ribs, with 17-20 spiral rows of very small nodes. Intermediate and adult specimens show 20 to 30 ribs to a quadrant at the venter. The ventral nodes are usually double-pointed, but in large adult specimens they can be triple-pointed. The venter is rounded and the ventral furrow is narrow at all growth stages. The umbilicus is small and the whorl height can increase very rapidly. Suture line vary from ceratitic to subammonitic, the majority of the specimens show wavy ceratitic saddles.

Description. Specimens range from about 23mm to 75mm in diameter, and are preserved mostly as internal molds, sometimes with parts of test still attached on the flanks and venter. In higher stratigraphic positions the adult specimens are generally larger than specimens found in lower stratigraphic positions. Coiling is involute from H=3mm (spec. scan16-1) up to the adult stage. The umbilicus is small and deep at all growth stages, and a slight umbilical egression is sometimes present at H>20mm (e.g. spec. scan16-581). The periumbilical margin is angular and the tall umbilical wall is overhanging. The whorl section is semielliptical compressed already at H=3mm. The flanks are gently arched and the venter is rounded. The maximum width is located near the periumbilical margin. The whorl height can increase very fast in the intermediate and adult stage. The ventral furrow is always narrow and well defined.
Ornamentation consists of very dense and fine sinuose to falcoid ribs, with 17 to 20 spiral rows of small nodes equally spaced along the flanks. Bifurcations and intercalations of ribs are numerous, and occur more often in the lower half of the flanks or near the ventrolateral margin. In intermediate and

adult specimens there are 20 to 30 ribs to a quadrant at the venter. The number of ventral ribs is more than three times the number of umbilical ribs. In the parts where the whorl height increase very fast the ribs are markedly prorsiradiate. The height and width of the ribs are almost equivalent, and the intercostal spaces are less wide than the ribs. The nodes are very small, conic shaped and less wider than the ribs. The ventral nodes usually are double pointed, and on the internal mold they are slightly separated from the lateral nodes by a narrow spiral depression. The largest adult specimen (A21-76) shows triple-pointed ventral nodes preserved at the beginning of the body chamber. The ventral nodes meet the ventral furrow at an angle between 105° and 116° in intermediate and adult stages.

The complex test structure called in literature "preseptal layer" (Tozer, 1972; Balini & Jenks, 2007; Balini et al., 2007) cause a smoothing effect on the internal mold in respect of the external test surface. On the internal mold of phragmocone and at least the first part of the body chamber the ribs appears rounded and the nodes are weakened or totally absent.

The suture line range from ceratitic to subammonitic, and usually is characterized by wavy ceratitic first and second saddles. Subammonitic sutures are shown only by the largest adult specimens. The second saddles are often narrow and elongated. The lobes often show relatively long denticles, sometimes with secondary indentations. The external lobe is generally deep. Some suture lines show a slightly spiral elongation.

Discussion. *Daxatina* sp. A closely resemble *Daxatina laubei* Tozer, 1994 in almost all morphological features. Distinction of these two species is based on the suture line. *Daxatina laubei* Tozer shows a simple ceratitic suture line (Tozer, 1994, fig. 68a), with well rounded saddles and small, simple denticles on the lobes. *Daxatina* sp. A shows a generally more complex suture line, with large specimens that show subammonitic sutures.

Daxatina sp. A differs from the other species of *Daxatina* for the denser and finer ribs, the smaller umbilicus in the adult stage and the faster increase of whorl height.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Daxatina bispinosa (Johnston, 1941)

Pl. 6, fig. 1-5; Textfig. 10

Synonymy.

v 1941. *Trachyceras* (*Trachyceras*) *bispinosum* n. sp. Johnston; p. 487; pl. 69, fig. 1-3.

v 1941. *Trachyceras* (*Trachyceras*) *trispinosum* n. sp. Johnston; p. 488; pl. 68, fig. 1-3.

v 2007. *Daxatina* – Balini & Jenks; fig. 7c-d, fig. 8b.

v 2007. *Daxatina* – Balini et al.; fig. 8l-m.

Type series: Holotype USNM 77537; USNM 77538, type of *Trachyceras* (*Trachyceras*) *trispinosum* Johnston.
Representative topotypes: B11-95; A21-84; JJ1-97-2, -6; A22-4, -7; A23-5.
Other attributed topotypes: A1.2-1; A10-9; A12-4, -10, -12; A16-2; A21-42, -68. B11-54; B12-6; B13-1; B4-14, -28; B8-2, -5; scan16-85, -134, -146, -168, -186, -223, -237, -349, -360, -362, -400, -449, -450, -461, -484, -504, -507, -525, -541.

Type locality. *Joannites* zone, South Canyon, New Pass or Desatoya Range, Nevada (Johnston, 1941).

Measurements. See Table 1-2.

Diagnosis.
Daxatina characterized by a wide whorl section and a very robust ornamentation. There are 9 to 14 ribs to a quadrant at the venter. Eight to nine spiral rows of nodes are developed on the ribs. On the test the ventral nodes can be double- or triple-pointed, and the ventrolateral nodes are double-pointed. The umbilicus is relatively wide. The ventral furrow is always narrow and very deep. Suture line is ceratitic to wavy ceratitic.

Description. Specimens range from about 15mm to 60mm in diameter, and are preserved mostly as internal molds. Parts of test are visible on the types and in few other topotypes. The largest adult specimens occur in the upper stratigraphic positions (beds B11 and scan3=A21), while in lower stratigraphic positions the adult specimens are generally small sized.
Coiling is involute from the late juvenile up to the adult stage. Umbilicus is deep and relatively wide, with angular umbilical margin and overhanging umbilical wall. In the juvenile stage the whorl section is depressed up to about H=20mm (B11-95). The adult specimens show a wide and very slightly compressed whorl section. The flanks are slightly arched and the rounded venter is wide. The maximum width is located near the periumbilical margin. The ventral furrow is very well defined, deep and narrow.
Ornamentation is very robust at all growth stages, and consists of slightly sinuous to falcoid prominent ribs, which have a sub-quadrate equidimensional cross section on the test. Nine to fourteen ribs to a quadrant are present at the venter. Intercostal spaces are relatively wide. Eight to nine spiral rows of nodes are developed on the ribs. The ventral, ventrolateral and umbilical nodes are the most prominent, and can become long spines (e.g. A23-5; inner whorls of B11-95).Ventral nodes can be double- or triple-pointed (visible on USNM 77538 and in JJ1-97-6), and meet the ventral furrow at an angle of 122° to 131° (B11-95, respectively at H=12.4 and H=19.5). The ventrolateral nodes are double-pointed (visible on the Holotype and on spec. A22-4). Ribs are usually bifurcated and trifurcated in correspondence of the prominent umbilical nodes. Rare bifurcations and intercalations also occur on mid flanks and on the ventrolateral margin. On the majority of specimens the ventral nodes are separated from the ventrolateral nodes by a narrow spiral depression (e.g. JJ1-97-6) visible on the internal mold. The "preseptal layer" cause a strong attenuation of the ornamentation. On the internal mold the ribs are rounded or very slightly sub-quadrate, and the nodes are very attenuated or absent. Ventral and ventrolateral nodes are single pointed, and spines are replaced with prominent

rounded tubercles. In correspondence of the strongest ornamentation elements a complex test structure with internal cavities is observed.
Suture line is ceratitic to wavy ceratitic, composed by three lobes on the flanks (E, L, U1) and two and a half saddles, as the third saddle is placed in correspondence of the periumbilical margin. The external lobe is deep.

Discussion. *Daxatina bispinosa* Johnston shows a wider whorl section in respect of the other *Daxatina* species. The double-pointed ventrolateral nodes are characteristic of this species. The coarsely ribbed variants of *Daxatina canadensis* (Whiteaves) shows a comparable number of ribs and spiral rows of nodes, but the whorl width is smaller and the ribs are less prominent. *Daxatina megabrotheus* Tozer is comparable with the inner whorls of *Daxatina bispinosa* Johnston, but maintain a coarser ornamentation during growth. The suture line of *D. megabrotheus* shows well rounded saddles (Tozer, 1994, fig. 65e) which are simpler in respect of that of *Daxatina bispinosa*.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Daxatina sp. B
Pl. 7, fig. 1-5; Textfig. 11

Synonymy.
? pars 1994. *Daxatina canadensis* (Whiteaves) – Tozer; p. 165; pl. 85, fig. 4; fig. 68e; non pl. 85, fig. 2-3, 5-9; fig. 68b-d
v 2007. Trachyceratidae – Balini & Jenks; fig. 11e-f.
v 2007. *Trachyceras* gr. *desatoyense* Johnston – Balini et al.; fig. 8d-h.
v 2008. *Trachyceras desatoyense* Johnston – Balini; fig. 5.1-.4.

Best representative specimen: scan3-12.
Other representative specimens: JJ1-97-3, scan16-361, MPUM 8440 (scan16-253), scan16-129.
Other attributed material: 22 specimen from Section A (A11-40, -44; A12-11; A14-5; A15-4, -9; A16-5; A16-5, -24, -29; A21-32; A22-5 [MPUM 8438]; scan3-10, -26, -28, -32, -36, -53, -57, -58; scan3det-1). 36 specimens from Section B (B10-23; B11-28, -44, -47, -105, -154, -160; B9-35; scan14-2, -8 [MPUM8439], -26; scan16-6 [MPUM8441], -7, -23, -64, -66, -71, -86, -91, -224, -264, -290, -347, -351, -405, -406, -421, -477, -503, -518, -546, -554, -584).

Locus typicus and stratum typicum. South Canyon (New Pass Range, central Nevada, USA), Augusta Mountain Formation, middle member, section A, bed scan3=A21.

Measurements. See Table 1-2.

Diagnosis. Compressed *Daxatina* characterized by a relatively robust ornamentation. Intermediate and adult specimens show 12 to 18 ribs to a quadrant at the venter, and 12-15 spiral rows of nodes. The venter is rounded and the ventral furrow is deep and narrow at all growth stages. The whorl height increase steadily during growth, without fast accelerations. Adult specimens show an evident umbilical egression. Suture line vary from ceratitic to subammonitic, the majority of the specimens show wavy ceratitic saddles.

Description. Specimens range from about 25mm to 83mm in diameter, and are preserved mostly as internal molds of phragmocones and parts of body chambers. Sometimes small parts of test are still attached on the flanks. Coiling is involute at all visible growth stages. The umbilicus is relatively small in juvenile specimens, but tends to widen during growth. Adult specimens show an evident umbilical egression at H>25mm. The whorl section is compressed and semielliptical, with a rounded and relatively large venter. The whorl height increase relatively slowly and steadily. The ventral furrow is deep and very narrow at all growth stages. Specimen JJ1-97-3 shows a pathological condition, as the ventral furrow is dislocated on the left flank (Pl. 6, fig. 2a).

Ornamentation consists of well spaced and well defined sinuose to falcoid ribs, which have an equidimensional cross section. The intermediate and adult specimens show 12 to 18 ribs to a quadrant at the venter. Bifurcations and intercalations occur more often in the lower half of the flanks. In correspondence of the periumbilical margin the ribs are bifurcated or trifurcated. In intermediate and adult growth stages 12 to 15 spiral rows of relatively small and conic nodes are equally spaced on the flanks. In the juvenile stage (H<12mm) only nine spiral rows of nodes are developed. The ventral nodes are separated from the ventrolateral nodes by an evident and narrow spiral depression. The ventral nodes meet the ventral furrow at an angle between 114° and 131°. This angle tends to become more obtuse during growth.

The internal mold of phragmocone and part of the body chamber is smoothed due to the “preseptal layer”, present also in other species. The extent of the “preseptal layer” on the body chamber is difficult to measure, as only parts of the body chambers are preserved.

Suture lines can vary from ceratitic to subammonitic in the largest specimens, and sutures with wavy ceratitic saddles are abundant.

Discussion. *Daxatina* sp. B differs from *Daxatina* sp. A for the coarser ornamentation with less numerous ribs and less spiral rows of nodes. Intermediate and adult specimens shows also a wider umbilicus, with an evident umbilical egression. In *Daxatina* sp. B the whorl height increase more steadily in respect of *Daxatina* sp. A. On average, the angle between the ventral nodes and the ventral furrow is more obtuse in *D.* sp. B in respect of *D.* sp. A.

Daxatina sp. B differs from *Daxatina bispinosa* mainly for the more compressed whorl section and the finer ornamentation.

Daxatina sp. B differs from *Daxatina limpida* Tozer for the more obtuse angle between the ventral nodes and the ventral furrow, and for the more complex suture line.

Daxatina sp. B shares similarities with *Daxatina canadensis* (Whiteaves). The two species differs mainly for the suture line. *Daxatina canadensis* shows a simple ceratitic suture line (Tozer, 1994, fig. 68b-d), while *Daxatina* sp. B shows generally wavy ceratitic saddles. *Daxatina* sp. B seems also to

have more marked narrow spiral depressions that slightly separate the ventral nodes from the ventrolateral nodes.
The specimen attributed by Tozer (1994) to *Daxatina canadensis* showing small wrinkles on the first saddle (Tozer, 1994, pl. 85, fig. 4; fig. 68e) is the only *Daxatina* specimen found in GSC loc. 42335, and could be attributed to *Daxatina* sp. B due to the similar suture line.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

?*Daxatina* sp. A

Pl. 8, fig. 1-4; Textfig. 12

Best representative specimen: F1-89
Other representative specimens: E5-19, -23, -34, -54, -65, -81, -83; F1-3, -4, -22, -32, -33, -55, -66, -67, -68, -139, -145;

Locus typicus and stratum typicum. South Canyon (New Pass Range, central Nevada, USA), Augusta Mountain Formation, middle member, section F, bed F1.

Measurements. See Table 1-2.

Diagnosis. Trachyceratid with a robust ornamentation, characterized by eight to nine spiral rows of nodes. The juvenile and intermediate stage is sculptured like the robust forms of *Daxatina*, with a deep and narrow ventral furrow. The adult body chamber is more similar to *Trachyceras*, as the furrow widens and the ventral nodes are separated from the two closely spaced ventrolateral spiral rows of nodes. The suture line shows a wide variability from ceratitic to ammonitic, characterized by short and wide saddles.

Description. Specimens range from about 25mm to 55mm in diameter, and are preserved mostly as internal molds, sometimes with small pieces of test still attached. Coiling is involute at all visible growth stages. The whorl section is relatively wide, with a rounded venter and slightly arched flanks. Ornamentation is robust, and consists of sinuose to falcoid ribs upon which are developed eight to nine spiral rows of nodes. The intercostal spaces are relatively wide. The more robust variants shows also a wider whorl section. Bifurcations and intercalations are numerous, and occur more often on the periumbilical margin and on the lower half of the flanks. The more robust forms show prominent umbilical tubercles from which depart two or three ribs.
The juvenile and intermediate stages show a deep and narrow ventral furrow, and the ventrolateral nodes are separated from the ventral nodes by a narrow spiral depression. The adult body chamber (visible on spec. F1-89) show two closely spaced well defined spiral rows of nodes that marks the

ventrolateral margin. The ventral nodes are well separated from the ventrolateral nodes, and the ribs are clearly projected in the space between.
The suture line is composed by three lobes and two and a half or three saddles. The external lobe is deep. The variability is very wide, from ceratitic to ammonitic. The saddles are short and wide, and they are not spirally elongated.

Discussion. This species is of difficult classification mostly because of the wide variability of the suture line. The external morphology of the adult specimens (e.g. spec. F1-89) suggest an affinity with *Trachyceras desatoyense*, mainly because of the marked projection of ribs between the ventral and ventrolateral nodes and the ventral furrow that tends to widen. However the juvenile and intermediate specimens show similarities with *Daxatina* sp. B and *Daxatina bispinosa*.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Genus *Trachyceras* Laube, 1869
Type species. *Ammonites* (*Ceratites*) *aon* Münster, 1834

Remarks on the genus. The most updated diagnosis for the genus *Trachyceras* is given by Urlichs (1994). The diagnosis report double and triple pointed ventral nodes for *Trachyceras*. Triple pointed ventral nodes are known only in *Trachyceras* (*Trachyceras*) *trispinosum* Johnston, but this species is here attributed to *Daxatina*. A small emendation is then necessary, to include only double pointed ventral nodes in *Trachyceras*. *Trachyceras* differs clearly from *Daxatina* by its more deeply indented ammonitic suture line, which is considerably more complex than the ceratitic and subammonitic sutures attributed here to *Daxatina*. Another substantial difference between the early *Trachyceras* species, as *Trachyceras desatoyense*, and *Daxatina* is the morphology of the venter. In the early *Trachyceras* the ventrolateral margin is marked by two closely spaced spiral rows of nodes, and the ventral nodes are segregated from the ventrolateral nodes. The ribs are clearly projected in the space between ventral and ventrolateral nodes.

Trachyceras desatoyense Johnston, 1941
Pl. 8, fig. 5-7; Pl. 9, fig. 1-9; Textfig. 13

Synonymy.
v 1941. *Trachyceras* (*Trachyceras*) *desatoyense* n. sp. Johnston; p. 483; pl. 66, fig. 3-4; pl. 67, fig. 4-6; pl. 68, fig. 4-7.
v 1941. *Trachyceras* (*Trachyceras*) *desatoyense* var. Johnston; p. 484; pl. 66, fig. 1-2.
? 1994. *Trachyceras desatoyense* Johnston – Tozer; p. 168; pl. 89, fig. 4-7; pl. 90, fig. 1; fig. 72c.

Type series. Holotype USNM 77535C; three figured paratypes: USNM 77535A, 77535B, 77535D. Johnston reported eight studied specimens, but only four of them are figured and housed in the USNM.
Topotypes. 147 specimens. 19 from site D (D4-9, -10, -13, -15, -16, -18, -27, -28, -29, -31, -32, -34, -36; D5-3, -4, -5 ,-6, -7, -8). 119 from site E (E5-1, -3, -4, -5, -6, -8, -11, -12, -13, -14, -15, -16, -17, -18, -20, -22, -24, -25, -29, -31, -33, -35, -36, -37, -38, -39, -40, -41, -43, -44, -46, -47, -48, -49, -51, -52, -55, -56, -58, -60, -61, -62, -63, -64, -67, -68, -72, -73, -74, -75, -76, -77, -78, -79, -80, -82, -84, -85, -90, -92, -94, -100, -174; E14-1, -2, -4, -5, -8, -9, -10, -11, -12, -13, -14, -15, -16, -19, -26, -32, -33, -35, -37, -40; E14bis-1, -2, -3, -8; E4-1, -2, -3, -4, -6, -7, -8, -10, -11, -12, -13, -14, -16; E13-1, -4, -6, -9, -10, -14, -15, -16, -18, -21, -23, -24, -28, -37, -38, -40, -44, -49, -59; E13bis-1, -2, -6, -8). 8 from site F (F10-5, -6, -7; F11-1, -2, -3; F1-10, -56, -85, -90; F1bis-1)

Type locality. *Joannites* zone, South Canyon, New Pass or Desatoya Range, Nevada (Johnston, 1941).

Measurements. See Table 1-2.

Diagnosis. Compressed *Trachyceras* with nine to eleven spiral rows of small conic nodes. The sinuose to falcoid ribs shows frequent bifurcations and intercalations. The ventral nodes are rised and segregated from the two closely spaced ventrolateral spiral rows of nodes. The ribs are projected orad between ventral and ventrolateral nodes. The ventral furrow is flat floored and relatively wide. The spiral rows are well spaced on the first three quarters of the flanks, starting from the umbilicus. On adult specimens the ribs are wide and flat topped, with a symmetric cross section on the test. Suture line is ammonitic with relatively short saddles.

Description. The specimens are preserved as internal molds, often with complete parts of test on the flanks. Specimens range from about 33mm to about 93mm in diameter. The body chamber is at least 270° long. Coiling is involute from the early juvenile stage (spec. E5-72, H=2mm) up to the adult stage. The umbilicus is narrow, the umbilical margin is angular and the umbilical wall is vertical to overhanging. In the early juvenile stage the whorl section is oval and slightly depressed (spec. E5-72, H≈2mm), with a rounded venter and a faintly incised ventral furrow. From the juvenile up to the adult stage the whorl section becomes progressively more compressed, with slightly arched flanks. The maximum width is located near the periumbilical margin. The ventral furrow is flat and relatively wide, especially in large sized specimens.

In the early juvenile stage (H≈2mm) ornamentation consists of falcoid primary ribs and five spiral rows of nodes. The ventral nodes seem to be single-pointed on the internal mold. Bifurcations occur at the first and second spiral row, rare intercalations occur between the third and fourth spiral row. From the late juvenile up to the adult stage ornamentation consists of dense sinuose to falcoid ribs, upon which are developed nine to eleven spiral rows of small conic nodes. The nodes can be very weak, and in extreme forms they are hardly visible on the middle part of the flanks, even on the test. Frequent bifurcations and intercalatory ribs occur often near the periumbilical margin and between the fifth and the sixth spiral row of nodes. On the test the ribs have a symmetric cross section, with steep margins and a wide nearly flat top; the intercostal spaces are narrow. The spiral rows of nodes are well spaced on the flanks, while in correspondence of the ventrolateral margin there are two closely spaced spiral

rows of nodes, which are slightly spirally elongated. Between the ventrolateral margin and the rised ventral nodes the ribs are markedly projected orad. This feature is well developed on the adult specimens (H>15mm). The ventral nodes meet the ventral furrow at an angle between 107° (spec. E5-100, H=12.5mm) and 120° (e.g. spec. E5-13, H=26mm), measured on the internal molds.
The internal mold shows a slightly attenuated ornamentation in respect of the external surface of test. This attenuation is caused by a complex test structure called "preseptal layer" in literature (Tozer, 1972; Balini & Jenks, 2007; Balini et al., 2007). On the internal mold the ribs appear slightly more rounded, the nodes are less marked but still visible, and the ventral nodes appear single pointed. The attenuation affects the whole phragmocone and at least the first 60° of the body chamber.
Suture line is ceratitic in the early juvenile stage (spec. E5-72, H=2mm). During ontogeny the suture quickly develops marked indentations and already in the late juvenile stage becomes ammonitic. The adult suture is characterized by moderately deep and well indented lobes. The saddles are clearly indented and are relatively short.

Discussion. *Trachyceras desatoyense* differs from the other North American species by its combination of low number of spiral rows of nodes, the marked projection of ribs between ventral and ventrolateral nodes and the relatively wide ventral furrow. The whorl section of *Trachyceras desatoyense* differs from the discoidal *Trachyceras* sp. B. The suture line of *Trachyceras desatoyense* is less elongated and less spirally bended in respect of *Trachyceras* sp. A and B.
Trachyceras desatoyense possess a similar number of spiral rows of nodes in respect of *Trachyceras aon* (Münster), however *Trachyceras desatoyense* has a more compressed whorl section, and bifurcations and intercalations of ribs are more frequent.
The ceratitic suture line in the early juvenile stage suggests an evolutionary relationship with *Daxatina*. The marked projection of ribs combined with the rised ventral nodes give to this species a far resemblance with the genus *Sirenites*.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Trachyceras sp. A

Pl. 10, fig. 1-5; Textfig. 14

Synonymy.
v 1941. *Trachyceras* (*Trachyceras*) cf. *T. aon* Münster – Johnston; p. 481; pl. 67, fig. 1-3.
v 2007. *Trachyceras* – Balini & Jenks; fig. 9a-b; fig. 10a.
v 2007. *Trachyceras*? – Balini et al.; fig. 8n-o.

Material. 46 specimens, 12 from site D, 8 from site E, 26 from site F. Best representative specimen: E3-9. Other representative specimens: E3-33, -37, -59; D10bis-42; F1-44, -54; F26-11. Other attributed material: D10-2, -30, -42bis; D10bis-10, -18, -57; E3 -29, -36; E3bis-4, -7; F1-24, -26, -31, -86, -134, -138, -141; F1bis-3, -8, -11, -14, -19, -23, -25, -28, -35, -36, -43; F16-3, -13; F16b-23, -28; F26-77.

Locus typicus and stratum typicum. South Canyon (New Pass Range, central Nevada, USA), Augusta Mountain Formation, middle member, section E, bed E3 (correlative of bed D10).

Measurements. See Table 1-2.

Diagnosis. Densely ribbed *Trachyceras* with at least 14 spiral rows of small nodes and a semielliptical cross section with a rounded venter. The ventral furrow is relatively narrow and deep also in the adult stage. The ribs are projected orad in the narrow space between the ventral nodes and the ventrolateral nodes. Suture line is ammonitic with a triangular shaped first saddle and a moderate spiral elongation.

Description. Specimens are preserved as internal molds, sometimes with big parts of test still attached on the flanks (e.g. spec. E3-9). Specimens range from 30mm to 85mm in diameter, and are mostly phragmocones. Coiling is involute at all visible growth stages. Umbilicus is relatively narrow, with angular umbilical margin and vertical to overhanging umbilical wall. The whorl section is semielliptical, with a rounded U shaped venter at all growth stages. The maximum width is located near the periumbilical margin. The ventral furrow is well defined and relatively deep. It remains narrow up to the adult stage.

Ornamentation consists in dense sinuose to falcoid ribs, which have a symmetric cross section and are nearly flat topped on the test. Bifurcations and intercalations are numerous and occur more often in the first three quarters of the flanks. At least 14 spiral rows of small conic nodes are developed on the ribs. The spiral rows are more closely spaced in proximity of the ventrolateral margin, while near the periumbilical margin they are more widely spaced. The space between the double pointed ventral nodes and the ventrolateral nodes is rather narrow. The ribs are projected orad between these two spiral rows of nodes. The ventral nodes meet the ventral furrow at an angle of about 116° at a whorl height of 20-27 mm (spec. E3-9; F1-44), measured on the internal mold.

This species possess the “preseptal layer” too. Ornamentation on the phragmocone is attenuated, with rounded ribs and weaker nodes. The double-pointed ventral nodes appear single pointed on the internal mold, and the nodes on the flanks are sometimes difficult to count. The extent of the “preseptal layer” on the body chamber is difficult to estimate, as specimens are mostly phragmocones.

Suture line is ammonitic, with relatively deep indentations on the saddles and long denticles on the lobes. The first saddle is triangular shaped and the suture is rather spirally elongated.

Discussion. *Trachyceras* sp. A shares similarities with *Trachyceras desatoyense*, but differs from the latter by the higher number of spiral rows of nodes, the more gently arched flanks and the more indented and spirally elongated suture line. *Trachyceras* sp. A differs from *Trachyceras* sp. B by the semielliptical whorl section and the U shaped venter, while *Trachyceras* sp. B is discoidal shaped with a narrower venter.

Like *Trachyceras desatoyense*, *Trachyceras* sp. A share similarities with *Trachyceras* gr. *aon* of the Tethyan realm, but differs by the more compressed whorl section at all growth stages.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Trachyceras silberlingi Balini et al., 2012
Pl. 12, fig. 1-2; Textfig. 15

Synonymy.
v 2012. *Trachyceras silberlingi* n. sp. Balini et al.; p. 130; pl. 1, fig. 1-4; fig. 4.

Type series. Holotype: MPUM 11061 (F26-14). Three paratypes: MPUM 11062 (F26-2), MPUM 11063 (F1-91), MPUM 11064 (F1-144).
Other attributed material. Two specimens from bed F26: F26-281, -284.

Locus typicus and stratum typicum. South Canyon (New Pass Range, central Nevada, USA), Augusta Mountain Formation, middle member, section F, level F26.

Measurements. See Table 1-2.

Description. The detailed description of the type series is given by Balini et al. (2012, p. 132-133). Two newly prepared juvenile to intermediate specimens from bed F26 show that the lateral bullae are slightly less prominent than the umbilical bullae in the juvenile stage, and the rib looping is rare. Umbilical bullae are already prominent at H= 12mm, and they are also visible in the umbilicus of spec. F26-281. The suture line is ammonitic, with relatively shallow indentations on the saddles.

Discussion. *Trachyceras silberlingi* differs from *Trachyceras* sp. A and sp. B by a more robust ornamentation that persists from juvenile up to the adult stage. Prominent bullae at all growth stages with occasional rib looping is characteristic of this species. Juvenile and intermediate specimens of *T. silberlingi* show a relatively large and rounded venter, that differs from the very narrow venter of *Trachyceras* sp. B at comparable whorl height (e.g. spec. F26-282). The suture line of *Trachyceras silberlingi* is less deeply indented and less triangular shaped than that of *Trachyceras* sp. B.
The relations between *T. silberlingi* and the Tethyan species are discussed in Balini et al. (2012, p. 132-133).

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Trachyceras sp. B

Pl. 11, fig. 1-5; Textfig. 16-17

Synonymy.
v 1956. *Trachyceras* (*Trachyceras*) cf. *T. desatoyense* Johnston – Silberling, textfig. 2b.

Material. 28 specimens from bed F26. Best representative specimen: F26-6. Other representative specimens: F26-1, -8, -282, -283; F26-9, -13, -291. Other attributed material: F26-3, -4, -10, -15, -36, -37, -62, -79, -149, -154, -159, -160, -166, -174, -178, -180, -182, -184, -188, -286, -287.

Locus typicus and stratum typicum. South Canyon (New Pass Range, central Nevada, USA), Augusta Mountain Formation, middle member, section F, level F26.

Measurements. See Table 1-2.

Diagnosis. Discoidal shaped *Trachyceras* with a fine ornamentation consisting in dense sinuose to falcoid ribs and 13 to 16 spiral rows of nodes. The venter is narrow, and the ventral furrow remains narrow up to the adult stage. Extreme variants show a slightly more robust ornamentation only in the juvenile and medium growth stages, sometimes with weak bullae in umbilical and lateral position. Suture line is highly indented ammonitic.

Description. The specimens are mostly preserved as internal molds, often with small parts of the test preserved. The body chamber is not known, as the majority of specimens are phragmocones. Specimens range from about 30mm to about 90mm in diameter. The early juvenile stage is not visible. At least from about H=7mm (spec. F26-283) up to the adult stage coiling is involute, with a narrow and deep umbilicus. The umbilical margin is angular, and the umbilical wall is overhanging. The general shape is discoidal, with a compressed subtrapezoidal whorl section. Flanks are slightly arched, and the maximum width is located near the periumbilical margin. The venter is very narrow, the ventral furrow is deep and remains narrow up to the adult stage.
Ornamentation consists of dense sinuose to falcoid ribs, upon which are developed 13 to 16 spiral rows of nodes, counted on the internal mold. Bifurcations are numerous, and occurs more often in the first three quarters of the flanks, creating a complex pattern which is sometimes difficult to follow on the internal mold. The number of ventral ribs in 90° of volution can vary from 20 in medium growth stage (spec. F26-283, final H=17.4mm) to 28 in adult stage (spec. F26-6, final H=44mm). On the test the ribs have a symmetric cross section, with steep margins and a flattened top. The small nodes have a conic shape, sometimes slightly spirally elongated especially near the ventrolateral margin. The ventral rows of nodes are double-pointed and meet the ventral furrow at an angle between 108° (spec. F26-282, H=13.5mm) and 121° (spec. F26-6, H=40mm). This angle tends to become more obtuse during growth.

Some specimens, considered extreme variants, show a more robust ornamentation in the juvenile and intermediate growth stages (spec. F26-291, up to H=27mm). The ribs are more wide and the spiral rows of nodes more prominent. The ribs are markedly projected orad between the ventrolateral margin and the venter. In some cases (e.g. spec. F26-291) periodic bullae are present in umbilical and lateral position. However in the adult stage (e.g. spec. F26-291, H>27mm) the ornamentation gradually become more fine, with dense ribs and weaker bullae.

This species also possess the "preseptal layer". Ornamentation on the phragmocone is slightly attenuated, with rounded ribs and weaker nodes. The ventral nodes appear single pointed on the internal mold, while on the test they are clearly double pointed (Pl. 11, fig. 5c). Unfortunately it is not possible to define the extent of the "preseptal layer" on the body chamber, as specimens are only phragmocones.

The suture line is highly indented ammonitic, with a marked spiral curvature. The saddles are elongated and triangular shaped. The lobes are deep, with numerous denticles which are long and usually thin.

Discussion. *Trachyceras* sp. B differs from the other North American species by the marked discoidal shape, the narrow venter and the highly indented ammonitic suture line. Ornamentation pattern and number of spiral rows of nodes can be very similar to *Trachyceras* sp. A, but the latter species shows a more large U shaped venter. The extreme variants showing a more robust ornamentation with weak bullae suggest an affinity with *Trachyceras silberlingi*, but in the latter species ribs and bullae are more prominent up to the adult stage.

Among the tethyan species *Trachyceras* sp. B shares similarities with *Trachyceras* gr. *aonoides* because of the discoidal shape and the well indented suture line. However the ribs of *T. aonoides* Mojsisovics possess an asymmetric cross section (Krystyn, 1978; Urlichs, 1994; Balini et al. 2012; Krystyn, pers. comm. 2019), while *Trachyceras* sp. B shows a symmetric cross section. The suture line of *T. aonoides* Mojsisovics and *T. fissinodosum* (Mojsisovics) are more deeply indented, with numerous secondary denticles (Mojsisovics, 1893, pl. 191, fig. 2; Krystyn, pers. comm. 2019), while *T.* sp. B shows more shallow indentations and fewer secondary denticles.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

?*Trachyceras* sp. ind.
Plate 12, fig. 3

Material. One specimen from locality C, bed CHM42 (CHM42-7)

Locus typicus and stratum typicum. China Mountain, upper part of the Smelser Pass Member, Augusta Mountain Formation, locality C, bed CHM42.

Description. The specimen consists of a quarter of whorl of the body chamber. The test is not preserved and the internal mold is exposed. Coiling is involute, with a deep umbilicus. Whorl section is compressed (H=22.30mm, W=18.20mm, H/W=1.23). The venter is rounded and relatively large, with a deep and well defined ventral furrow. Ornamentation consists of marked falcoid to sinuose ribs, upon which are developed at least thirteen spiral rows of nodes. The ribs bifurcate on the umbilical margin or near the ventrolateral margin. Two spiral rows of bullae are well visible on the flanks, one in umbilical position and one in lateral position. Suture line is not preserved.

Discussion. The ornamentation pattern suggest an affinity with the species *Trachyceras silberlingi* Balini et al., 2012. Unfortunately the suture line is not preserved, so the attribution to the genus *Trachyceras* Laube, 1869 is doubtful.

Occurrence. China Mountain (northern Tobin Range, northern Nevada), upper part of the Smelser Pass Member of the Augusta Mountain Formation.

Age. Lower Carnian of China Mountain, see biostratigraphy for the discussion on its stratigraphic position.

Genus A

Type species. Genus A sp. A

Composition of the genus. The type species Genus A sp. A

Diagnosis. Very involute trachyceratid showing a discoidal shape in the medium and adult growth stage. Ornamentation is very weak and consists of low ribs with a rounded cross section and eight to nine spiral rows of rounded nodes. The ventral furrow is well defined, and is bordered by two narrow ventral rows of low nodes. Suture line shows a wide variability, from subammonitic to ammonitic.

Discussion. Genus A is close to *Trachyceras* Laube. Separation of the genus is based on the combination of very weak ornamentation, smaller umbilicus and wider variability of the suture line. In *Trachyceras* the ornamentation is always well defined, characterized by sinuose to falcoid flat topped ribs on the test, well separated from intercostal spaces. In Genus A the ornamentation is very weak both on internal mold and on test. The ribs have a low and well rounded cross section. The suture line of *Trachyceras* is always ammonitic, while in Genus A it is more variable, both in terms of indentation depth and in terms of general shape of saddles and lobes, even in specimens belonging to the same population.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Genus A sp. A

Pl. 12, fig. 4-7; Textfig. 18

Synonymy.

? 1994. *Protrachyceras*(?) sp. indet. – Tozer, p. 339; pl. 88, fig. 13.

v 2007. *Trachyceras* – Balini & Jenks, fig. 10b.

Material. Seven specimens from section F, four from level F1, three from level F1bis. Best representative specimen: F1-2. Other representative specimens: F1-1, -116, -119; Fibis-34, -37, -48.

Locus typicus and stratum typicum. South Canyon (New Pass Range, central Nevada, USA), Augusta Mountain Formation, middle member, section F, bed F1.

Measurements. See Table 1.

Diagnosis. Genus A species characterized by a discoidal shape only in the medium and adult stage. The juvenile stage is much less compressed, with a rounded venter and gently arched flanks. The umbilicus is very narrow. Ornamentation is very weak, and is characterized by slightly sinuose rounded ribs and eight-nine spiral rows of low and wide nodes. The venter is narrow, with a well defined ventral furrow bordered by narrow and low ventral nodes. Suture line is variable from subammonitic to ammonitic.

Description. The specimens are preserved as internal molds, often with parts of test still attached. Specimens range from about 30mm to about 80mm in diameter. Coiling is very involute at all visible growth stages (U/D= 0.13-0.16), with a narrow and deep umbilicus, angular umbilical margin and overhanging umbilical wall. In the juvenile stage (H<10mm) the whorl section is sub-oval slightly compressed, with a well rounded venter and gently arched flanks (e.g. spec. F1bis-48). During growth the whorl height increase quickly, and the intermediate and adult specimens become discoidal, with a subtrapezoidal whorl section and slightly arched flanks (e.g. spec. F1-1). The maximum width is located near the periumbilical margin. The ventral furrow is well defined and more deep than the intercostal spaces.

Ornamentation is weak and consists in slightly sinuose prorsiradiate ribs, which are projected orad near the ventrolateral margin. The ribs are low and wide, with a rounded cross section both on the internal mold and on the test. Eight to nine spiral rows of low and rounded nodes are developed on the ribs. In adult specimens the primary ribs are banded in groups of two or more at the prominent umbilical nodes. Two closely spaced weak spiral rows of spirally elongated nodes mark the ventrolateral margin. (e.g. spec. F1bis-37). The test is thin and the smoothing effect of the "preseptal layer" is weak. Cavities inside the test structure are not observed. The ventral nodes are relatively

narrow and seem single-pointed also on the test. This feature is unsurely visible on few specimens with small parts of test preserved on the venter. Marked growth lines are visible only on the test.
The suture line is variable from subammonitic to ammonitic. The more deeply indented sutures are characterized by relatively short and wide saddles.

Discussion. See the discussion on the genus for an explanation of the major differences in respect of the genus *Trachyceras* Laube. The single-pointed ventral nodes are a relevant feature at the genus level, but since their presence is uncertain it is not cited in the diagnosis.
The similarity between the discoidal adult specimens of Genus A sp. A and the discoidal *Trachyceras* sp. B is interpreted as a case of evolutive convergence. The juvenile whorl section of these two species differs substantially. *Trachyceras* sp. B shows a discoidal shape with a narrow venter already at a small whorl height, while Genus A sp. A is much less compressed and shows a well rounded venter with gently arched flanks. Genus A sp. A shows also a narrower umbilicus in respect of *Trachyceras* sp. B.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Genus B

Type species. Genus B sp. A

Composition of the genus. Genus B sp. A, Genus B sp. B, Genus B *compressum* (Johnston, 1941).

Diagnosis. Involute trachyceratids characterized by a shallow ventral furrow, which is less deep than the intercostal spaces. The suture line is characterized by an external lobe that is much shallower than the lateral lobe L. The outline of the saddle range from wavy ceratitic to weakly indented ammonitic. The test structure is complex and similar to that of the Family Dactylioceratidae, with the development of an Inner shell in addition to the Main shell. Due to the structure of the test, the surface of the internal mold is much smoother than the external surface of the test. The ornamentation smoothing is developed on the phragmocone and beginning of the body chamber. The external ornamentation consists of sinuous to falcoid ribs that cross the venter. The ribs are usually flat topped, with a subrectangular cross section. The number of spiral rows of nodes ranges from seven to ten, and is characteristic at the species level. The ventral nodes are double-pointed.

Discussion. Genus B is undoubtedly very close to *Daxatina* Strand, 1929 and *Trachyceras* Laube, 1869. The separation of the new genus is based on combination of the ventral furrow shape, with the relative proportion of the external and lateral lobes and the outline of the saddles.
The ventral furrow of Genus B is shallower than the space between ribs in a way that the venter is crossed by the ribs. This feature is not related to the preservation of the test, because it is visible on

both the internal mold and outer surface of the test. *Daxatina* and *Trachyceras* are both characterized by a well defined ventral furrow, which is deeper than the space between the ribs. In *Daxatina* and *Trachyceras* the ribs do not cross the ventral furrow but end at the ventral node.

The suture line of *Daxatina* is characterized by a very deep external lobe (e.g. holotype of *D. canadensis*: Tozer, 1994, p. 518, fig. 68c; holotype of *D. laubei*, Tozer, 1994, fig. 68a; holotype of *D. megabrotheus*: Tozer, 1994, p. 512, fig. 65e; *D. limpida*: Tozer, 1994, p. 524, fig. 71c-d) and saddles that are well rounded. The occurrence of slightly wavy first lateral saddles (Tozer, 1994, p. 518, fig. 68e) is reported by Tozer as very rare. In addition to the suture line, *Daxatina* differs from Genus B also in the cross section of the ribs, that in Genus B is subrectangular, flat-topped.

The suture line of *Trachyceras* is usually characterized by a deeper external lobe and by more elongated, slightly spirally-bended, more deeply indented saddles (e.g. Urlichs, 1994, textfig. 5a-l; Mojsisovics, 1882, pl. 21, fig. 20; Mojsisovics, 1893, pl. 174, fig. 4; pl. 187, fig. 7c; pl. 191, fig. 2). The suture line variability is higher in Genus B in respect to the other two genera.

Occurrence. China Mountain (northern Tobin Range, northern Nevada), upper part of the Smelser Pass Member of the Augusta Mountain Formation; South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Genus B sp. A

Plate 13, fig. 1-11; Textfig. 19

Best representative specimen: CHM37-1.

Other material: 137 specimens, preserved as internal molds often with some parts of test. 21 specimens from locality B (CHM15-1, -3, -9, -11; CHM16-1; CHM17-1, -5, -6, -7, -55, -58, -59; CHM18-4, -13; CHM19-1, -2, -5, -8; CHM20-7, -10; CHM22-3). 116 specimens from locality C (CHM28-12, -15; CHM31-1, -5; CHM32-2, -3, -4; CHM33-1, -2, -10; CHM34-1, -2, -3, -5, -6, -7, -9, -10, -11, -14, -21; CHM36-1; CHM37-1, -2, -3; CHM42-1, -2, -3, -4, -5, -6, -8, -9, -10, -12, -13, -15, -17, -18, -23, -24, -35; CHM43-1, -2; CHM44-1, -2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -14, -16, -18, -19, -22, -23, -33; CHM45-1, -2, -3, -4, -7, -10, -11, -12, -13, -14, -16, -17, -18, -21, -23, -24, -29, -30, -31, -32, -43, -45, -47, -48, -50; CHM46-1; CHM47-1, -2, -3, -4, -5, -7, -8, -13, -14; CHM48-7; CHM49-1, -2, -4, -8; CHM50-6, -9; CHM51-1; JJ4-18-1, -3, -4, -5, -6, -8, -9, -11, -12, -13, -16).

Locus typicus and stratum typicum. China Mountain, upper part of the Smelser Pass Member, Augusta Mountain Formation, locality C, bed CHM42.

Measurements. See Table 1-2.

Diagnosis. Genus B showing a whorl section relatively wide. An umbilical egression characterizes the adult stage. Ornamentation is usually robust, but variations are present in the juvenile and intermediate stages, where parts up to a quarter of whorl can show more dense and delicate ribs. Specimens usually show eight spiral rows of nodes, with variations between seven and nine. The ventral nodes are double-pointed. Suture line is wavy ceratitic, characterized always by a shallow external lobe.

Description. Ontogenetic reconstruction is based on specimens belonging to the same population (sample CHM42 and correlatives). Specimens collected in other beds, debris and ex situ blocks show perfectly consistent ontogenetic development with the CHM42 population, and help to better characterize the ontogeny of the intermediate growth stage (D=40÷48mm).

Specimens range from 20 to 70 mm in diameter. Coiling is slightly evolute in the innermost whorls (H<1mm, spec. CHM34-21). At a whorl height ranging from about 3 mm up to the adult stage coiling is involute, with angular umbilical margin and overhanging umbilical wall.

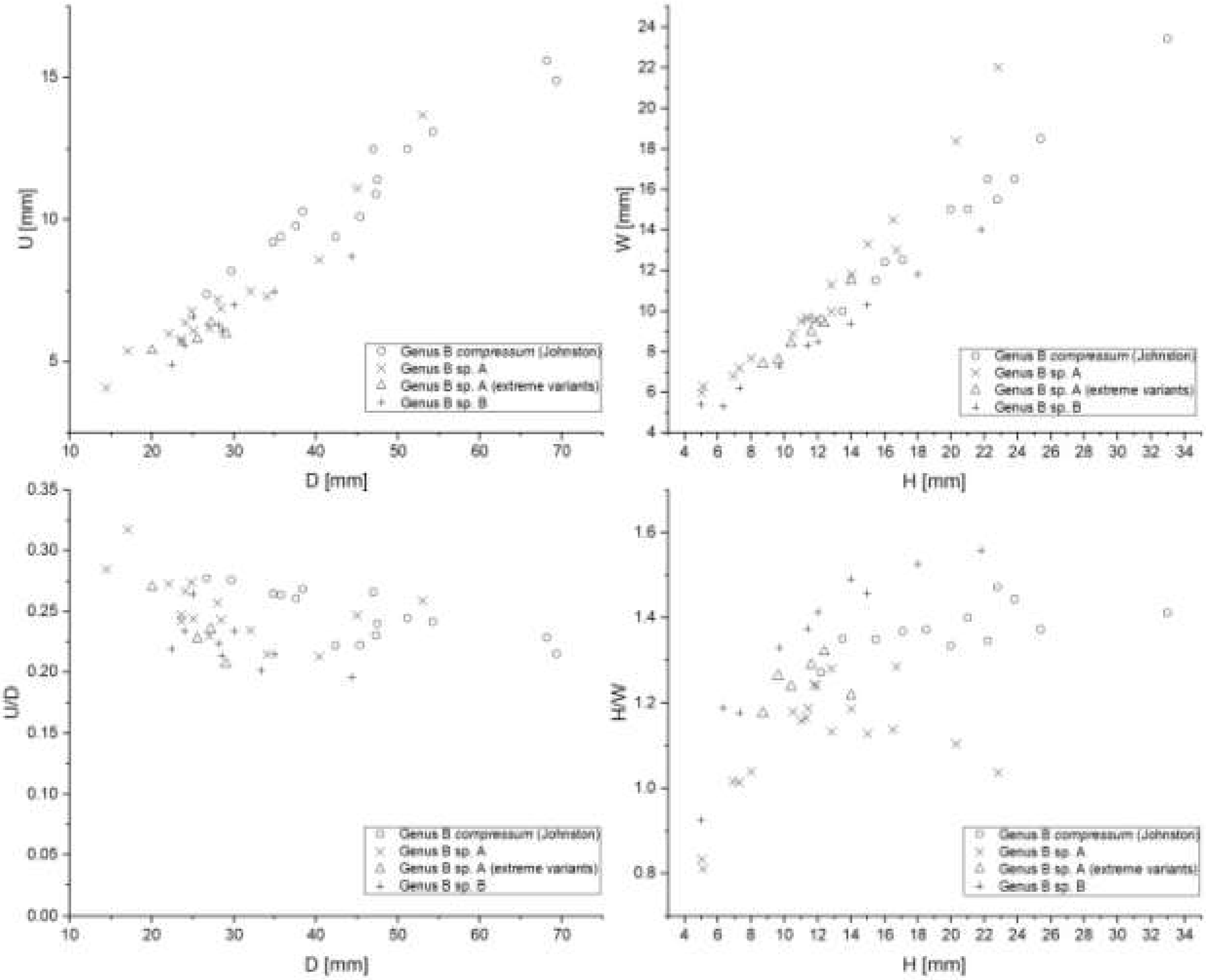


Fig. 4.2. U-D, W-H, U/D-D and H/W-H biometry graphs for Genus B sp. A, sp. B and sp. C. Data are shown in Table 1.

An umbilical egression is developed in the adult stage at about D=40mm (Fig. 4.2). During the juvenile growth stage up to H≈7mm (e.g., spec. CHM34-21, CHM44-1) the whorl section is slightly depressed with rounded venter and progressively less arched flanks. Starting from a whorl height of about 8 mm up to the adult stage the whorl section is compressed; the whorl width increases relatively fast and the venter becomes progressively more wide (Fig. 4.2). The adult body chamber is slightly compressed (spec. CHM37-1, CHM34-1). Maximum width is located near the periumbilical margin.

The innermost whorls (H<1mm) are completely smooth. The early juvenile stage (H≈1÷3mm, spec. CHM34-21) is characterized by primary and intercalate ribs on which are developed at least four spiral rows of nodes. The ventral nodes seem to be single-pointed, and there is no trace of ventral furrow. From the late juvenile stage (H≈5mm) up to the adult stage ornamentation is robust and consists of marked sinuose ribs with a subrectangular cross section. On the umbilical wall the ribs are attenuated and projected orad. On the flanks bifurcated and intercalatory ribs are frequent (Fig. 4.3). The majority of specimens show eight spiral rows of small conic nodes, which are developed on the ribs. There can be variations between seven and ten spiral rows, even on the same specimen (e.g. nine spirals in spec. CHM37-3, CHM37-2, CHM45-17,with an extra row situated between the second and third spiral; spec. CHM37-2 shows eight spirals on the right flank and nine on the left flank; spec. CHM42-1 shows seven spiral rows on the right flank and eight on the left flank). The double-pointed ventral rows of nodes border a shallow and narrow ventral furrow which is less deep than the intercostal spaces, so the ribs seem to cross the venter. In juvenile stage the primary ribs are more pronounced near the periumbilical margin, with prominent first and second spiral rows of nodes. In this growth stage bifurcation of the ribs is frequent and occurs in correspondence of the second, third and fourth spiral row of nodes. In medium and adult stages intercalatory ribs are numerous, and they occur more often between the third and fifth spiral row of nodes, while less numerous are the intercalations between the second and third spiral row. Intercalatory ribs near the ventrolateral margin are rarely observed (e.g., spec. CHM42-1).

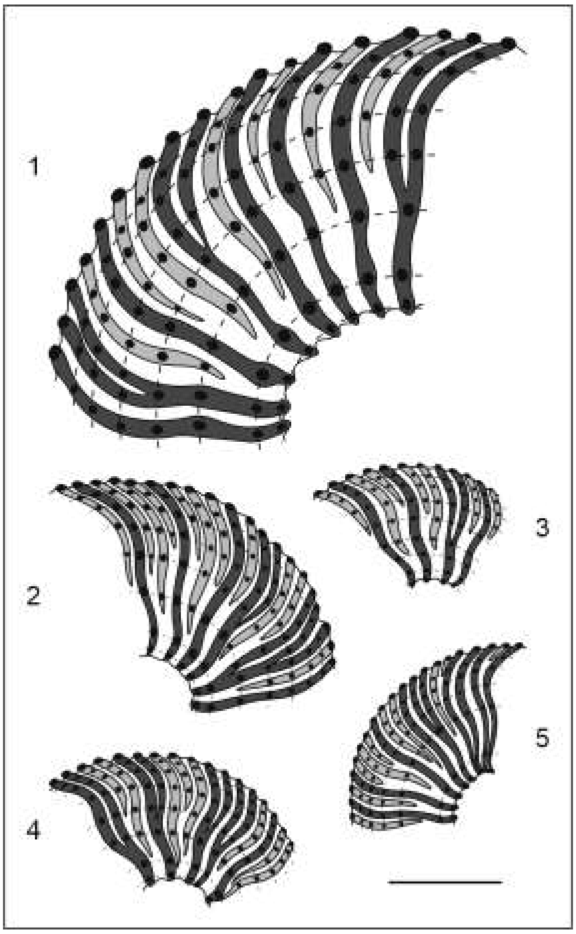


Fig. 4.3. *Ornamentation schemes of Genus B sp. A.* ***1*** *– Based on CHM37-1.* ***2*** *– Based on CHM45-10.* ***3*** *– Based on CHM37-3.* ***4*** *– Based on CHM45-1.* ***5*** *– Based on CHM42-1. Bar scale is 10mm.*

Some juvenile and intermediate specimens (e.g., spec. CHM45-1, CHM45-17), interpreted as extreme variants, show parts up to a quarter whorl long where the ribs become very thin and dense and the nodes are much less pronounced, with the ventral nodes showing slightly more spaced double-points. These specimens sometimes show also a slightly more compressed whorl section and a slightly narrower umbilicus (Fig. 4.2).

The shell structure is similar to the inner shell wall of the Dactylioceratidae, described by Howarth (1975). Ornamentation of the phragmocone and part of the body chamber differs considerably between external shell surface and internal mold, being extremely attenuated on the latter. At about 50-60° from the last septum the internal mold ornamentation abruptly changes and becomes very similar to that of the external shell surface.

Suture line is generally wavy ceratitic (Textfig. 19). Two and a half to three saddles are present on the flanks, the latter is situated on the periumbilical margin. The lobes have very small and short denticles. During ontogeny the external lobe progressively becomes more shallow in respect of the first lateral lobe, which tends to deepen more quickly (Textfig. 19.8). The adult suture has always a shallow external lobe.

Discussion. Genus B sp. A differs from the other species by its larger whorl section. The whorl height/whorl width increase slower than Genus B sp. B and Genus B *compressum*, and in the adult stage tends even to decrease, approaching H/W=1 (Fig. 4.2). Genus B sp. A has a larger umbilicus in the adult stage, due to the onset of the umbilical egression (Fig. 4.2). Suture line is generally simpler and less variable than that of Genus B *compressum*.

Occurrence. China Mountain (northern Tobin Range, northern Nevada), upper part of the Smelser Pass Member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Genus B sp. B
Pl. 14, fig. 1-8; Textfig. 20.1-.4

Best representative specimen: CHM15a-1.

Other representative specimens: 31 specimens, conserved as internal molds often with small parts of test. 18 specimens from locality B (CHM15A-2; CHM17-2, -3, -8, -92; CHM19-3, -4, -6, -7, -18; CHM19b-4, -5; CHM20-1, -2, -3, -4, -5, -6).13 specimens from locality C (CHM41-1, -2, -3, -4, -5; CHM50-1, -8, -10, -11, -14; JJ4-18-2, -7, -18).

Locus typicus and stratum typicum. China Mountain, upper part of the Smelser Pass Member of the Augusta Mountain Formation, locality C, bed CHM41 (=CHM42).

Measurements. See Table 1-2.

Diagnosis. Genus B species showing evanescent ribs on the flanks and eight spiral rows of nodes. The first four spiral rows are less developed and consists of fewer nodes. The whorl height/whorl width ratio tends to increase quickly during all growth stages, and the umbilicus tends to become narrower in proportion to the diameter. The venter remains narrow during all growth stages. Suture line is wavy ceratitic, characterized always by a shallow external lobe.

Description. Ontogenetic reconstruction for whorl height from 6mm to 17mm is based on specimens belonging to the same population (sample CHM41=CHM42). Specimens collected in debris and ex situ blocks show perfectly consistent ontogenetic development with the CHM41 population, and permits the ontogenetic reconstruction of the adult and early juvenile stage.

Specimens range from 17 to 47 mm in diameter. Coiling is slightly evolute in the innermost whorls (H<1mm, spec. CHM20-1). At a whorl height ranging from about 3 mm up to the adult stage coiling is involute, with angular umbilical margin and overhanging umbilical wall. During growth the umbilicus tends to become narrower in proportion to the diameter up to the adult stage (Fig. 4.2). During the early juvenile growth stage (H<4mm, specs. CHM20-1) the whorl section is subelliptical and slightly depressed, with a well rounded venter. Already at a whorl height of about 5mm the whorl section is compressed, and so it remains up to the adult stage. The whorl width increases relatively slow and the adult body chamber is compressed (Fig. 4.2), with a relatively narrow venter (e.g., spec. CHM15-a1). The maximum whorl width is located near the periumbilical margin.

The innermost whorls (H<1mm) are smooth. From the juvenile stage up to the adult stage ornamentation consists of sinuose ribs with a subrectangular cross section. They are well visible only on the upper part of the flanks and on the venter. On the lower and middle part of the flanks the ribs are evanescent and sometimes difficult to follow (Fig. 4.4). Often they consists only of more pronounced growth lines. Eight spiral rows of small conic nodes are well developed only where the ribs are pronounced, that is near the ventrolateral margin and on the venter. The first four spiral rows are less developed, and consists of fewer nodes. Apparently bifurcated ribs are very rare, and in juvenile stage they occur in correspondence of the second, third and fourth spiral row of nodes. Intercalated ribs are abundant, and occurs more often between the fourth and the sixth spiral row. The double-pointed ventral rows of nodes border a shallow and narrow ventral furrow which is less deep than the intercostal spaces, so the ribs seem to cross the venter. In juvenile stage the primary ribs are more pronounced near the periumbilical margin, with prominent first and second spiral rows of nodes.

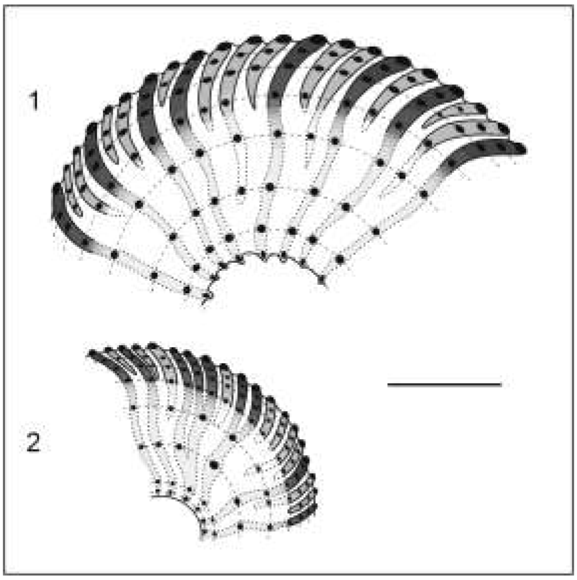


Fig. 4.4. *Ornamentation schemes of Genus B sp. B.* ***1*** *– Based on CHM15-A1.* ***2*** *– Based on JJ4-18-2. Bar scale is 10mm.*

The shell structure is similar to the inner shell wall of the Dactylioceratidae, described by Howarth (1975). Ornamentation of the phragmocone and part of the body chamber differs considerably between external shell surface and internal mold, being extremely attenuated on the latter.At about 50-60° from the last septum the internal mold ornamentation quickly changes and becomes very similar to that of the external shell surface.

Suture line is wavy ceratitic (Textfig. 20.1-.4), always with a shallow external lobe and two other lobes which shows very small and short denticles.

Discussion. Genus B sp. B differs markedly from the other species by its evanescent ribs and sparse nodes on the flanks. During all the growth stages Genus B sp. B shows a more compressed whorl section (Fig. 4.2), always with a narrow venter. In the adult stage Genus B sp. B shows a narrower umbilicus in respect of Genus B sp. A and Genus B *compressum* (Fig. 4.2). The suture line of Genus B sp. B is less variable than that of Genus B *compressum*, and is generally less complex.

Occurrence. China Mountain (northern Tobin Range, northern Nevada), upper part of the Smelser Pass Member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Genus B *compressum* (Johnston, 1941)

Pl. 14, fig. 10; Pl. 15, fig. 1-3; Pl. 16, fig. 1-6; Pl. 17, fig. 1-6; Textfig. 21-22

Synonymy.
v 1941. *Trachyceras (Trachyceras) desatoyense* var. *compressum* nov. sp. et var. Johnston, p. 484, pl. 68, fig. 6-7.
v 2007. *Daxatina* sp. ind. – Balini & Jenks, fig. 7e.
v 2007. *Daxatina* sp. ind. – Balini et al., fig. 8i-k.
v 2007. Trachyceratidae ind. – Balini & Jenks, fig. 11a-d.

Type series: Holotype USNM 77536.
Representative topotypes: 29 specimens, preserved as internal molds often with parts of the shell. 22 specimens from section D, bed D10=D10bis=JJ5-05(D10-3, -10, -27, -32, -69, -70, -91, -95, -118; D10bis-5, -8, -15, -16, -49, -77, -79, -83, -92; JJ5-05-2, -3, -4, -5). 7 specimens from Section E, bed E3 =JJ6-05 (E3-5, -65, -74; JJ6-05-1, -2, -4, -7).
Other attributed topotypes: 105 specimens from Section D (D9-6, -10; D10-5, -7, -8, -9, -21, -28, -29, -31, -37, -38, -40, -41, -42, -43, -45, -46, -48, -49, -51, -52, -54, -57, -58, -59, -61, -62, -63, -64, -65, -71, -72, -82, -84, -85, -90, -93, -96, -98, -99, -100, -103, -104, -105, -110, -114, -115, -119, -121, -122, -123, -124, -126, -130, -138, -139, -141, -144, -145, -146, -152, -154, -155, -157, -162, -173, -174, -175; D10bis-1, -13, -14, -17, -20, -24, -30, -33, -35, -40, -43, -44, -47, -48, -50, -51, -52, -54, -55, -58, -61, -62, -68, -69, -71, -72, -73, -74, -75, -76, -78, -80, -85, -94). 126 specimens from Section E (E10-3, -4, -6, -7, -8, -9, -16, -17, -18, -19, -20, -22, -23, -25, -26, -27, -28; E11-1, -2, -3, -6, -7, -8, -10, -11, -12, -13, -14, -16; E15-1, -2, -4, -6, -8, -9; E3-1, -3, -4, -6, -7, -8, -10, -11, -12, -13, -14, -15, -16, -17, -19, -20, -21, -22, -24, -25, -26, -27, -28, -30, -31, -32, -34, -39, -40, -41, -42, -43, -44, -45, -46, -47, -48, -49, -50, -51, -52, -54, -55, -56, -57, -58, -60, -61, -63, -67,-68, -69, -70, -71, -73, -75, -76, -77, -78, -79, -80; E3bis-1, -2, -3, -5, -6, -8, -9, -10, -12, -13, -14, -15, -16, -17, -18, -19, -20; E3ter-2, -3, -4; JJ6-05-3, -5, -6). 29 specimens from Section F (F15-1, -3, -4, -6, -17, -25; F16-1, -2, -4, -5, -6, -7, -8, -10, -11, -12, -14, -16, -17, -18; F16b-1, -2, -5, -6, -9, -11, -18, -25, -26).

Type locality. *Joannites* zone, South Canyon, New Pass or Desatoya Range, Nevada (Johnston, 1941).

Measurements. See Table 1-2.

Diagnosis. Genus B species showing always a robust ornamentation with well defined and prominent ribs. Specimens usually show nine spiral rows of nodes, with variations between seven and ten. The ventral nodes are double-pointed. Whorl section is compressed, and the whorl height/whorl width ratio tends always to increase during ontogeny. The venter remains narrow up to the adult body chamber. Suture line has a wide variability and range from wavy ceratitic to ammonitic.

Description. The ontogenetic reconstructions are based on specimens belonging to the same population (bed D10=D10bis and the lateral correlative bed E3).

Specimens range from 28 to 80 mm in diameter. The early juvenile stage (H<6mm) is not visible. At least from H=6mm up to the adult stage coiling is involute, with angular umbilical margin and overhanging umbilical walls. The whorl section is compressed (spec. D10-32 at H=6mm is slightly compressed) and the whorl height/whorl width ratio tends to increase during ontogeny (Fig. 4.2). The maximum width is located near the periumbilical margin. The venter is rounded and remains narrow up to the adult body chamber.

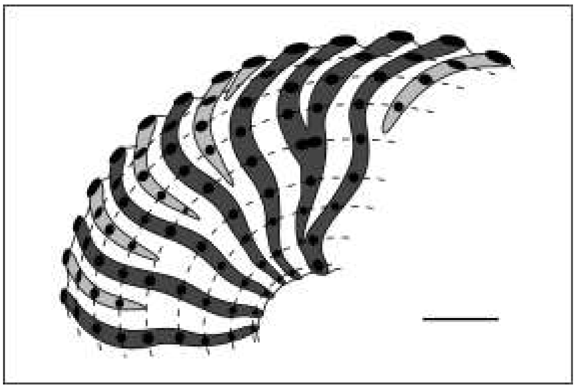


Fig. 4.5. *Ornamentation scheme of Genus B compressum (Johnston, 1941) based on specimen JJ6-05-7. Bar scale is 10mm.*

Ornamentation is always robust and consists of marked sinuose to falcoid ribs which can be relatively wide and well spaced (e.g. spec. JJ6-05-7) (Fig. 4.5). Growth lines are well visible on the test, and follow the ribs trend. The ribs have a flat top, and their cross section is subrectangular. This feature is well visible on the test. On the umbilical wall the ribs are attenuated and projected orad. Bifurcations are relatively rare, and usually occur in correspondence of the fourth or the fifth spiral row of nodes. Intercalatory ribs are more frequent and usually occur between the fourth and the sixth spiral row. The majority of specimens shows nine spiral rows of nodes, but there can be variations between seven and ten, even on the same specimen (e.g., spec. JJ5-05-2 shows seven spirals on right flank and nine spirals on left flank; specs. D10-69 and D10bis-83 show nine spirals on both flanks; spec. D10bis-77 shows eight spirals on right flank; spec. JJ6-05-4 shows eight spirals on left flank). The nodes, developed on the flat topped ribs, are conic-shaped with a subcircular base; often they show a slight spiral elongation near the ventrolateral margin. The double-pointed ventral rows of nodes border a shallow ventral furrow, which is less deep than the intercostal spaces. This feature is visible on the internal mold and is even more accentuated on the test (e.g. on specs.JJ6-05-4, D10-69, JJ5-05-3, E3-65), where the ribs clearly cross the venter, and the deepest depressions correspond to the intercostal spaces. Only on the adult body chamber (from H=28mm) of specimen JJ6-05-7 the ventral furrow seems to be more defined, although marked depressions in correspondence of the intercostal spaces are still present. Divergences from the common ornamentation pattern, interpreted as pathologies, are relatively frequent (e.g. spec. D10-70, H=22mm; JJ6-05-4, H=25mm; E3-74, H=15mm; D10-69, H=18mm). In these cases the ornamentation is no longer symmetrically developed and the ventral nodes are dislocated on one flank near the ventrolateral margin. Often a pronounced rib that truncate the other ribs marks the beginning of the dislocation on the flank where the ventral nodes lies. The dislocation can last only a few degrees of volution (e.g. spec. E3-74) before returning to normal.

Ornamentation on the phragmocone and part of the body chamber up to 50-60° from last septum differs considerably between external shell surface and internal mold. On the latter the nodes are extremely attenuated or completely absent, and the ribs from mid-flanks to the venter becomes very low with flat roofs. The ventral furrow is replaced by a slight depression, and the ribs cross the venter. At about 50-60° from the last septum the internal mold ornamentation quickly changes and becomes very similar to that of the external shell surface, showing the previously described features. These characteristics suggest a shell structure very similar to the inner shell wall of the Dactylioceratidae described by Howarth (1975). When the inner shell surface is exposed, the intercostal spaces are very well defined by sharp edges that separate them from the perfectly flat ribs.

Suture line has a wide variability, from wavy ceratitic to ammonitic (Textfig. 21-22). The adult suture is formed by three lobes with relatively small and short denticles. On each flank there are three saddles, of which the third is just before or in correspondence of the periumbilical margin. Common characteristics are a stocky first lateral saddle and a relatively shallow external lobe.

Discussion. Genus B *compressum* shows a more robust ornamentation in respect of Genus B sp. A and Genus B sp. B. The ribs are generally wider and always well defined on the test and on the not attenuated internal mold. Usually Genus B *compressum* shows nine spiral rows of nodes, one more in respect of the other two species that usually show eight spiral rows. Pathologic variations of the ornamentation are more frequent in Genus B *compressum* than in the other species. Variation of the coiling parameters (Fig. 4.2) follow a more linear trend in respect of Genus B sp. A and Genus B sp. B. At diameters lower than 40mm the umbilicus of Genus B *compressum* is generally wider than that of Genus B sp. A and Genus B sp. B. Only in the adult stage (D>40mm) Genus B sp. A shows an umbilicus wider than that of Genus B *compressum*. Whorl height/whorl width ratio tends to increase during all growth stages (Fig. 4.2) but slower in respect of Genus B sp. B.

The suture line of Genus B *compressum* has a wider variability and is generally more complex in respect of the other species.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Genus B sp. ind.
Pl. 14, fig. 9; Textfig. 20.5

Material. Two specimens from locality B, ex situ samples CHM14 (CHM14-14) and CHM20 (CHM20-11).

Type locality and horizon. China Mountain, upper part of the Smelser Pass Member, Augusta Mountain Formation, locality B, ex situ sample CHM20.

Description. The two juvenile fragments found in debris are incomplete internal molds of the first part of the body chamber, showing only one third of whorl. Coiling is slightly involute, and the umbilical margin is rounded. The whorl section is considerably depressed, with a wide and slightly rounded venter. Ornamentation is very robust, with marked sinuose ribs that cross the venter. At least three spiral rows of nodes are developed on the ribs. The ventral nodes seem long and triple-pointed, and the ventral furrow is very shallow. The primary ribs are bifurcate or trifurcate in correspondence of the second spiral row. Intercalated ribs are present on the upper half of the flanks. The nodes on the primary ribs are very prominent.
Ornamentation on the first part of the body chamber is very attenuated, with low and wide ribs showing completely flat tops on the venter.
Specimen CHM20-11 shows a wavy ceratitic first lateral saddle top of the last septum (Textfig. 20.5).

Discussion. This species is attributed to Genus B by the combination of shallow ventral furrow, attenuated ornamentation on the internal mold and wavy ceratitic saddle tops. This species differs from the others by a much more robust ornamentation, combined with a considerably depressed whorl section. Unfortunately medium and adult specimens have not been found, so the species is left in open nomenclature.

Occurrence. China Mountain (northern Tobin Range, northern Nevada), upper part of the Smelser Pass Member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Family Clionititidae Arabu, 1932

Genus *Clionitites* Strand, 1929

Type species: *Clionites angulosus* Mojsisovics, 1893

Clionitites barwicki (Johnston, 1941)

Pl. 18, fig. 1-4; Textfig. 23.1-.5

Synonymy.
v 1941. *Clionites barwicki* n. sp. Johnston; p. 450, pl. 58, fig. 9-18; textfig. 1a.
? 2008. *Zestoceras barwicki* (Johnston) – Mietto et al.; p. 396, pl. 1, fig. 12; pl. 2, fig. 3-9; textfig. 9a.

Type series. Five figured sintypes: USNM 77512a, USNM 77512b, USNM 77512c, USNM 77512d, USNM 77512e. Johnston, 1941 do not mention the number of studied specimens and do not provide a holotype for this species. The best representative sintype is USNM 77512b.

Topotypes. Twenty-nine specimens from Section A (A21-4, -10, -12, -23, -24, -25, -55, -57, -62, -72, -85, -86, -87, -89, -90, -91, -92; scan3-2, -24, -29, -37, -40, -46, -47, -48, -49; AA1-22; A22-1, -9). Forty specimens from Section B (scan16-9, -15, -88, -118, -164, -180, -302, -413, -430, -452, -463, -508; B11-4, -5, -8, -10, -31, -33, -33, -35, -41, -49, -55, -57, -59, -60, -61, -66, -71, -83, -94, -103, -115, -121, -135, -150, -151, -153, -158, -163).

Type locality. *Joannites* zone, South Canyon, New Pass or Desatoya Range, Nevada (Johnston, 1941).

Measurements. See Table 1.

Description. Specimens range from about 20mm to 48mm in diameter, and are preserved as internal molds, sometimes with most of the test attached. Coiling is evolute at all growth stages, the umbilical wall is very short and the umbilical margin is rounded. The whorl section is compressed elliptical. Ornamentation consists in slightly sinuose rounded ribs that cross the venter. In the ventrolateral region the ribs are only slightly bended forward. Regular bifurcations and intercalations occurs at mid flanks. The number of ventral ribs is two times the number of umbilical ribs. Two rows of small spirally elongated ventral nodes are usually developed on the ribs, and create the suggestion of a ventral furrow. The nodes are generally more marked in juvenile and intermediate stages. The intensity of nodes vary also from specimen to specimen, and they can be absent on the final part of the adult body chamber. Specimens with stronger and persistent nodes show also a narrower venter, with more straight flanks in the ventrolateral region.

The suture line is always ceratitic, with well rounded saddles and lobes with very small and simple denticles.

Discussion. *Clionitites barwicki* (Johnston) differs from the other South Canyon *Clionitites* species by the venter that is clearly crossed by the ribs. The ventral nodes gives only the suggestion of a ventral furrow, and no depression is observed on the venter.

Clionitites barwicki differs from *Clionitites reesidei* (Johnston) also for the much less projected ribs in the ventrolateral region and for the more simple always ceratitic suture line.

C. barwicki shares similarities with the Canadian species attributed to the genus *Zestoceras* Tozer, 1994, but in *C. barwicki* the ventral rows of nodes can persist also on part of the adult body chamber (e.g. spec. A21-86).

Specimens from Prati di Stuores (Dolomites), attributed by Mietto et al. (2008) to *Zestoceras barwicki* (Johnston) are difficult to compare with *C. barwicki* from South Canyon, as their whorl section and ventral morphology is not recognizable (Mietto et al., 2008; p. 397; pl. 2, fig. 3-9). However, the ornamentation on the flanks and the suture line (Mietto et al., 2008; fig. 9a) are very similar.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Clionitites aff. *wheeleri* (Johnston)

Pl. 18, fig. 5-8; Textfig. 23.6

Best representative specimen: F1-99

Other material: Three specimens from Section D (D4-3, -31; D5-9); Twenty-two specimens from Section E (E13-34, -61, -63; E14-3, -6, -34, -41; E14a-1; E14bis-5, -7; E5-7, -27, -28, -50, -70, -122, -123, -124, -160, -161; E18.1-20, -21); Thirty-nine specimens from Section F (F1-11, -12, -13, -14, -16, -27, -30, -38, -47, -53, -58, -69, -71, -75, -78, -79, -80, -81, -83, -95, -97, -101, -102, -103, -104, -106, -109, -121, -132, -133, -135, -150; F1bis-97, -145; F16b-14, -30, -33, -34; F21-2).

Locus typicus and stratum typicum. South Canyon (New Pass Range, central Nevada, USA), Augusta Mountain Formation, middle member, section F, bed F1.

Measurements. See Table 1.

Description. Specimens range from 13mm to 25mm in diameter, and are preserved mostly as internal molds. Few specimens show parts of test attached. Coiling is evolute from the juvenile up to the adult stage, and the umbilical margin is rounded, with a short vertical umbilical wall. The whorl section is oval and slightly compressed, with a wide and relatively flat venter. Ornamentation consists of sinuous ribs that stops on the venter, and sometimes the rib ending is similar to a node. Relatively rare bifurcations and intercalations occur on the periumbilical margin or at mid flanks. Sometimes a slight depression resembling a ventral furrow is visible only in the first part of the last whorl.

Suture line is ceratitic, with slightly wavy saddles and short and simple denticles on the lobes.

Discussion. This species shares similarities with *Clionitites wheeleri* (Johnston), mostly because of the similar whorl section and the rib termination resembling a node in the more robust forms. However the majority of the specimens attributed to *C.* aff. *wheeleri* show more fine and dense ribs, with more numerous bifurcations and intercalations. On the ventrolateral margin the ribs are not as wide as those of *C. wheeleri*. Only the body chamber of the holotype of *C. wheeleri* shows an ornamentation similar to *Clionitites* aff. *wheeleri*.

Clionitites callazonensis Tozer shows a similar ornamentation pattern, but it has a goniatitic suture line, way simpler than the ceratitic suture of *C.* aff. *wheeleri*.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Clionitites reesidei (Johnston, 1941)

Pl. 18, fig. 9-13; Textfig. 23.7-.10

Synonymy.
v 1941. *Clionites reesidei* n. sp. Johnston; p. 451, pl. 58, fig. 19-25; pl. 59, fig- 1-9; textfig. 1b-c.
1994. *Clionitites reesidei* (Johnston) – Tozer; p. 175, pl. 88, fig. 4-8.

Type series. Holotype: USNM 77513d; nine figured paratypes: USNM 77513a, USNM 77513b, USNM 77513c, USNM 77513e, USNM 77513f, USNM 77513g, USNM 77513h, USNM 77513i, USNM 77513j. Johnston, 1941 do not mention the total number of studied specimens.
Topotypes. Nine specimens from Section D (D10-18; D10bis-4; D14-15, -16, -24, -33, -34, -36, -51); Thirteen specimens from Section E (E11-4; E18.1-13, -14, -15, -16, -17, -18, -19, -22; E18.2-18, -19, -20, -22; Sixty-five specimens from Section F (F1-20, -42, -48, -65, -70, -73, -77, -94, -107, -111, -127, -136; F1bis-12, -13, -24, -26, -30, -31, -39, -49, -84, -85, -91, -93, -94, -95, -96, -98, -99, -100, -101, -102, -104, -117, -118, -119, -120, -121, -122, -123, -124, -125, -126, -127, -129, -131, -132; F10-2, -3, -4, -17, -18, -19, -25, -26, -27, -28, -29, -30, -31, -32, -34, -35; F16b-27; F18-6).
Other attributed material. One specimen from China Mountain, loc. C (JJ4-18-26).

Type locality. *Joannites* zone, South Canyon, New Pass or Desatoya Range, Nevada (Johnston, 1941).

Measurements. See Table 1.

Description. Specimens range from about 10mm to 35mm in diameter, and are preserved as internal molds often with complete parts of test still attached. Coiling is always evolute, with rounded umbilical margin and a short vertical umbilical wall. The whorl section is subelliptical compressed, with a rounded venter. The more compressed forms show also more straight flanks near the ventrolateral region. Ornamentation consists of sinuose to falcoid rounded ribs, which are markedly projected orad in proximity of the ventrolateral margin. The ribs are more accentuated in correspondence of the ventrolateral projection. Bifurcations and intercalations are relatively abundant, and occur at mid flanks. The ribs stop on the venter, in correspondence of two rows of small and elongated nodes that create the suggestion of a ventral furrow. This ventral depression is not well defined, and does not sink below the level of the intercostal spaces.
Suture line is variable from simple ceratitic to wavy ceratitic, with small wrinkles on the saddles.

Discussion. *Clionitites reesidei* (Johnston) differs from *Clionitites barwicki* (Johnston) for the combination of the marked peripheral projection of ribs that stops on the venter and the more variable suture line, which can be wavy ceratitic.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation; China Mountain (northern Tobin Range, northern Nevada), upper part of the Smelser Pass Member of the Augusta Mountain Formation; north eastern British Columbia (Canada), Liard Formation, GSC locs. 45751, 83824, 84271 (Tozer, 1994).

Age. Early Carnian of Nevada (see biostratigraphy for the discussion on its stratigraphic position); Desatoyense Zone, Early Carnian of British Columbia (Tozer, 1994).

Clionitites sp. A

Pl. 18, fig. 14-17; Textfig. 24.1-.2

Best representative specimen: F26-295
Other material: 37 specimens from Section F (F26-39, -40, -41, -42, -43, -45, -66, -92, -135, -136, -137, -138, -139, -140, -141, -194, -198, -203, -224, -225, -226, -227, -228, -229, -230, -231, -232, -233, -234, -247, -258, -259, -267, -296, -299, -300, -301).

Locus typicus and stratum typicum. South Canyon (New Pass Range, central Nevada, USA), Augusta Mountain Formation, middle member, section F, bed F26.

Measurements. See Table 1.

Description. Specimens range from about 15mm to 27mm in diameter. They are preserved as internal molds, often with parts of test attached on flanks and venter. Coiling is slightly evolute, with an abrupt rounded umbilical margin and a short vertical umbilical wall. The whorl section is compressed, with a relatively narrow and rounded venter and slightly arched flanks. The maximum width is located near the periumbilical margin. The venter is always characterized by a true well defined ventral furrow, which is deeper than the intercostal spaces. Ornamentation consists of very fine and dense sinuose to falcoid ribs, which shows a slightly asymmetric cross section. Ribs are markedly projected orad on the ventrolateral margin. Bifurcations and intercalations are numerous, and occurs in the lower three quarters of the flanks. The rib pattern is complex, as in addition to bifurcations and intercalations sometimes two or more ribs merge before the ventrolateral projection.
Suture line is ceratitic, with simple and small denticles on lobes.

Discussion. *Clionitites* sp. A differs markedly from the other South Canyon *Clionitites* species for the presence of a well defined ventral furrow, the smaller umbilicus and the finer and denser ribs.
A direct comparison with the Tethyan *Clionitites* species is difficult, as the latter are all large sized in respect of the South Canyon species, which are all small sized.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Genus *Hannaoceras* Tomlin, 1931
Type species. *Ammonites nasturtium* Dittmar, 1866

Hannaoceras newpassense Johnston, 1941
Pl. 18, fig. 18-19; Textfig. 24.3

Synonymy.
v 1941. *Hannaoceras newpassense* n. sp. Johnston; p. 454; pl. 59, fig. 10-16; textfig. 1d.

Type series. Holotype USNM 77514c, two figured paratypes USNM 77514a, USNM 77514b. Johnston, 1941 reported twenty-nine studied specimens, but only the figured holotype and two paratypes are housed at the USNM.
Topotypes. Thirteen specimens from Section A (A1.2-5; A21-6, -13, -19, -88; A23-14, -15; A24-4; scan3-35, -50, -51, -52); One specimen from Section B (scan16-577).

Type locality. *Joannites* zone, South Canyon, New Pass or Desatoya Range, Nevada (Johnston, 1941).

Measurements. See Table 1.

Description. Specimens range from about 12mm to 25mm in diameter, and are preserved as internal molds often with pieces of test attached. Coiling is evolute at all visible growth stages, the umbilical margin is rounded and the umbilical wall is short and vertical. The whorl section is compressed subelliptical, with a well rounded venter. Ornamentation consists of well defined radial or slightly prorsiradiate primary ribs that cross the venter without any interruption. Bifurcations and intercalations are rare, and occur near the umbilical margin or near the ventrolateral margin. The ribs are slightly bended forward on the ventrolateral margin. Suture line is goniatitic.

Discussion. *Hannaoceras newpassense* differs from *Sympolycyclus antiquus* Tozer mainly for the less evolute coiling, the more compressed whorl section and the denser ribs.
Hannaoceras newpassense differs from *Clionitites barwicki* (Johnston) for the absence of ventral nodes, the less numerous bifurcations and intercalations, the more defined ribs and the simpler goniatitic suture line, which is ceratitic in *C. barwicki*.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Genus *Sympolycyclus* Spath, 1951

Type species. *Polycyclus nodifer* Hyatt & Smith, 1905

Sympolycyclus antiquus Tozer, 1994

Pl. 18, fig. 20

Synonymy.
1994. *Sympolycyclus antiquus* n. sp. Tozer; p. 176; pl. 82, fig. 1a-b; fig. 65c

Material. One specimen from Section A (A22-2).

Type locality. North eastern British Columbia (Canada), Toad Formation, GSC loc. 42335 (Tozer, 1994).

Description. Very evolute specimen with a subcircular whorl section and rounded shoulders. The umbilicus is very wide, and the umbilical margin is gradational. Ornamentation consists of marked and well spaced rounded primary ribs, which cross the venter and are slightly projected on the ventrolateral margin. Suture line is goniatitic.

Discussion. *Sympolycyclus antiquus* Tozer differs from *Hannaoceras newpassense* Johnston for the more evolute coiling, the less dense ribs and the subcircular whorl section, which is more compressed in *Hannaoceras newpassense*.

Occurrence. North eastern British Columbia (Canada), Toad Formation; GSC loc. 42335 (Tozer, 1994). South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Ladinian, Sutherlandi Subzone 2 of British Columbia (Tozer, 1994); Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Superfamily Lobitoidea Mojsisovics, 1882
Family Lobitidae Mojsisovics, 1882
Genus *Lobites* Mojsisovics, 1875

Type species. *Clydonites ellipticus* Hauer, 1860

Lobites carinatus Johnston, 1941

Pl. 19, fig. 2-5

Synonymy.
v 1941. *Lobites (Lobites) carinatus* n. sp. Johnston; p. 466; pl. 61, fig. 5-9; textfig. 2b.

Type series. Holotype: USNM 77520c; two figured paratypes: USNM 77520a, USNM 77520b. Johnston, 1941 reported eight studied specimens, but only the figured holotype and two paratypes are housed at the USNM.
Topotypes. Fifteen specimens from Section A (A11-45; A19-12; A21-2, -27, -31, -48, -93, -94, -95); Seventeen specimens from section B (B11-7, -9, -11, -14, -21, -23, -30, -73, -88, -112, -120, -134, -169, -171, -173; B18.2-5, -9); Three specimens from Section E (E13-27, -35, -62); three specimens from Section F (F1-6, -7, -8).

Type locality. *Joannites* zone, South Canyon, New Pass or Desatoya Range, Nevada (Johnston, 1941).

Description. Specimens range from about 15mm to 25mm in diameter, and are preserved as internal molds often with complete parts of test attached. The general shape is globose and slightly compressed on the adult body chamber, which is slightly more than 360° long. The umbilicus is closed on the inner whorls, while on the body chamber an umbilical egression is developed. At the beginning of the last whorl the venter is rounded, and it is crossed by very faint radial ribs. During growth the ribs quickly become more marked in the upper half of the flanks. On the sharpened venter the ribs end at a regular series of small nodes, which give the suggestion of a keel. Approaching the aperture the ribs and the nodes becomes weaker, until the venter returns smooth and rounded just before the aperture. Suture line is goniatitic, with four rounded saddles and pointed lobes.

Discussion. *Lobites carinatus* Johnston differs from *Lobites gargantua* Johnston for the much smaller dimensions and for the ornamentation with marked ribs and small ventral nodes. *Lobites carinatus* is relatively more compressed than the Tethyan species. *Lobites benekei* Mojsisovics shows a similar keel, but the ribs are weaker.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Lobites gargantua Johnston, 1941
Pl. 19, fig. 1

Synonymy.
v 1941. *Lobites (Lobites) gargantua* n. sp. Johnston; p. 466; pl. 62, fig. 1-5.

Type series. Holotype: USNM 77521b; two paratypes: USNM 77521a, USNM 77521c.
Topotypes. One specimen from Section A (A11-28); One specimen from Section F (F1-17).

Type locality. *Joannites* zone, South Canyon, New Pass or Desatoya Range, Nevada (Johnston, 1941).

Description. Specimens are large sized, reaching about 60mm in diameter. The inner whorls are globose, with a closed umbilicus and a rounded venter. The last whorl of the living chamber the whorl section becomes slightly more compressed, and an umbilical egression is developed. Ornamentation consists of very weak radial ribs, visible only on the upper half of the flanks of the body chamber. Suture line is goniatitic.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

Genus *Coroceras* Hyatt, 1877

Type species: *Clydonites monilis* Laube, 1869

Coroceras zephyrum Johnston, 1941

Pl. 19, fig. 6-9; Textfig. 24.4

Synonymy.
v 1941. *Lobites (Coroceras) zephyrus* n. sp. Johnston; p. 468, pl. 61, fig. 10-14; textfig. 2c.

Type series. Holotype: 77522b; two paratypes: USNM 77522a, USNM 77522c.
Topotypes. Forty-seven specimens from Section F (F26-17, -18, -19, -20, -21, -22, -23, -52, -59, -60, -75, -76, -84, -87, -103, -104, -105, -106, -107, -109, -110, -111, -112, -113, -114, -115, -116, -117, -118, -119, -120, -121, -122, -123, -146, -147, -201, -202, -206, -207, -208, -209, -210, -212, -213, -214, -298); six specimens from Section G (G1-1, -8, -9, -66, -67, -77).

Type locality. *Joannites* zone, South Canyon, New Pass or Desatoya Range, Nevada (Johnston, 1941).

Description. Specimens reach a diameter of about 35mm, and are preserved as internal molds often with complete parts of test attached. The general shape is globose in the inner whorls, with a closed umbilicus. In the last whorl of the adult body chamber the whorl section becomes more compressed, and an umbilical egression is developed. The characteristic outer hood is a whorl constriction developed about 50° of revolution before the aperture. The corresponding inner hood is developed on the whorl next inside, and marks the beginning of the adult body chamber. The inner whorls are almost smooth, while ornamentation of the body chamber consists of marked radial ribs visible on the upper half of the flanks. The ribs attenuate approaching the aperture, and disappear in correspondence of the outer hood. Suture line is goniatitic, with six rounded saddles and pointed lobes.

Occurrence. South Canyon (New Pass Range, north western Nevada), middle member of the Augusta Mountain Formation.

Age. Early Carnian of Nevada, see biostratigraphy for the discussion on its stratigraphic position.

4.4 - Remarks on the test structure of the Family Trachyceratidae

Many representatives of the Family Trachyceratidae in the South Canyon and China Mountain collections show a complex test structure that is responsible of the strong difference between the ornamentation of the internal mold in respect to the external surface of the test. This unusual feature was first noticed at South Canyon by Balini & Jenks (2007) and Balini (2008). The external test surface is usually more ornamented than the internal mold, which is smoother on the phragmocone and on the first part of the body chamber.

This complex test structure is known only in the Triassic Family Trachyceratidae and in the Jurassic Family Dactylioceratidae (Howarth, 1975), and has been called in literature as “preseptal layer”. This term was introduced by Guex (1970) for the Jurassic Family Dactylioceratidae and adopted by Tozer (1972) for Triassic ammonoids. Tozer (1972) described the “preseptal layer” with the example of *Frankites sutherlandi* (McLearn). He interpreted the test structure as composed by an Outer Test, corresponding to the Outer Prismatic Layer, and an Inner Test, corresponding to the Nacreous and Inner Prismatic Layers. The Inner Test is always in contact with the Outer Test, but shows a variable thickness in a way that the internal surface results smoother than the external surface. The interpretation by Tozer followed the traditional knowledge on the two- or three-layer structure of ammonoid test, and was based on direct observation on specimens under stereomicroscope, and on few thin sections.

In Triassic literature (Tozer, 1972; 1994; Balini & Jenks, 2007; Balini et al. 2007; Balini, 2008; Balini et al., 2012) the occurrence of the “preseptal layer” is reported within the Family Trachyceratidae in the Subfamily Protrachyceratinae (in *Eoprotrachyceras* and *Protrachyceras*) and in the Subfamily Trachyceratinae (in *Anolcites*, *Zestoceras*, *Maclearnoceras*, *Muensterites*, *Frankites*, *Daxatina* and *Trachyceras*). Apart from the Family Trachyceratidae, the “preseptal layer” is reported by Tozer (1994) only in the Family Tibetitidae (genus *Sirenotibetites*) and in the Family Thetiditidae (genus *Eothetidites*).

The test structure of the Jurassic Family Dactylioceratidae was described in detail by means of Scanning Electron Microscope images by Howarth (1975). His work shows that the test structure of this group of ammonoids is more complex than previously thought (Fig. 4.6). It consists of a Main Shell, an Inner Shell and a Septal Prismatic Layer. The Main Shell (Fig. 4.6) consists of a normal sequence of Outer Prismatic, Nacreous and Inner Prismatic Layers, as in all ammonoids. The Inner Shell, composed by an Outer Prismatic and an Inner Nacreous Layer, is added to the inside of the Main Shell, and appears as soon as strong ornamentation is developed. In the ornamented portion of the shell (e.g. ribs) the Inner Shell is not in contact with the Main Shell, leaving characteristic flat floored cavities (CA in fig. 4.6). The internal surface of the Inner Shell is covered by the Septal Prismatic Layer, of which the septa are a direct development. The Inner Shell and Septal Prismatic Layer are present only in the first part of the adult body chamber, while on the last part they are absent.

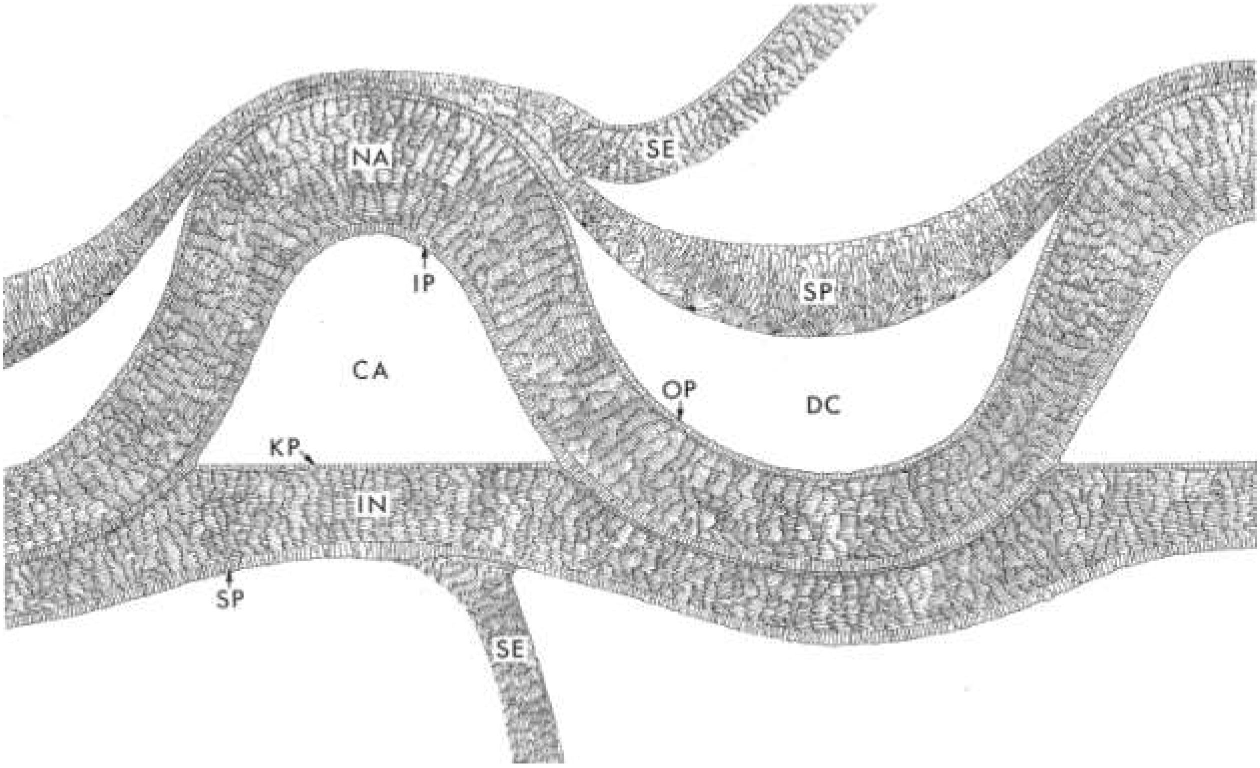


Fig. 4.6 *– Schematic illustration of the test structure observed in ammonoids of the Family Dactylioceratidae (from Howarth, 1975). Main Shell = Outer Prismatic Layer (OP) + Nacreous Layer (NA) + Inner Prismatic Layer (IP). Inner Shell = Outer Prismatic Layer (KP) + Inner Nacreous Layer (IN). SP = Septal Prismatic Layer, SE = Septum, CA = flat floored cavity between Main and Inner Shell, DC = cavity between dorsal SP and Main Shell of the previous whorl (from Howarth, 1975, p. 51, fig. 1).*

4.4.1 – The “preseptal layer” in the Trachyceratinae of South Canyon and China Mountain

Ammonoids attributed to the new Genus B are certainly those that show a more evident smoothing of the internal mold. This feature occurs in the 100% of complete specimens e.g. in bed D10, E3 and CHM42, and is best shown by specimens ranging in diameter from 20 mm to 80 mm showing the phragmocone and/or the first part of the body chamber. Therefore this smoothing cannot be interpreted as pathology, but as a normal feature that was part of the ontogenetical development of a population.

The test of all the specimens of Genus B is heavily recrystallized. However, stereomicroscope observations of 3D specimens and few SEM images allow to identify a layered test structure that can be interpreted as the Main Shell, the Inner Shell and the Septal Prismatic Layer, although the internal structure of these layers is not recognizable (Fig. 4.7; 4.8). The typical flat floored cavities (CA in Fig. 4.7-.8) are well visible, and are the cause of the internal mold smoothing visible to the naked eye (Fig. 4.9).

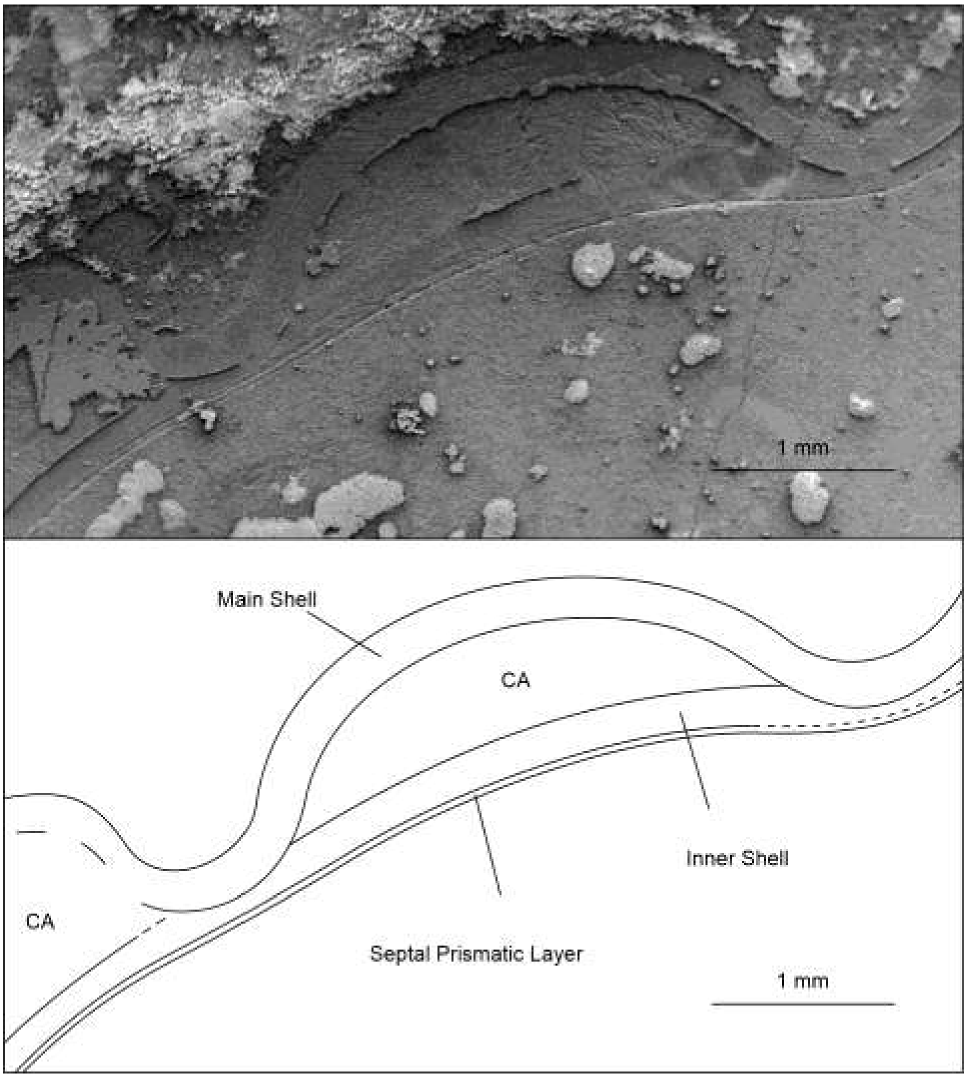


***Fig. 4.7** – Interpreted test structure of Genus B compressum (Johnston), based on a SEM image of specimen D10-93, sectioned in correspondence of the ventral ribs on the first part of the adult body chamber, at a whorl height of about 24mm. Section is parallel to the plane of coiling.*

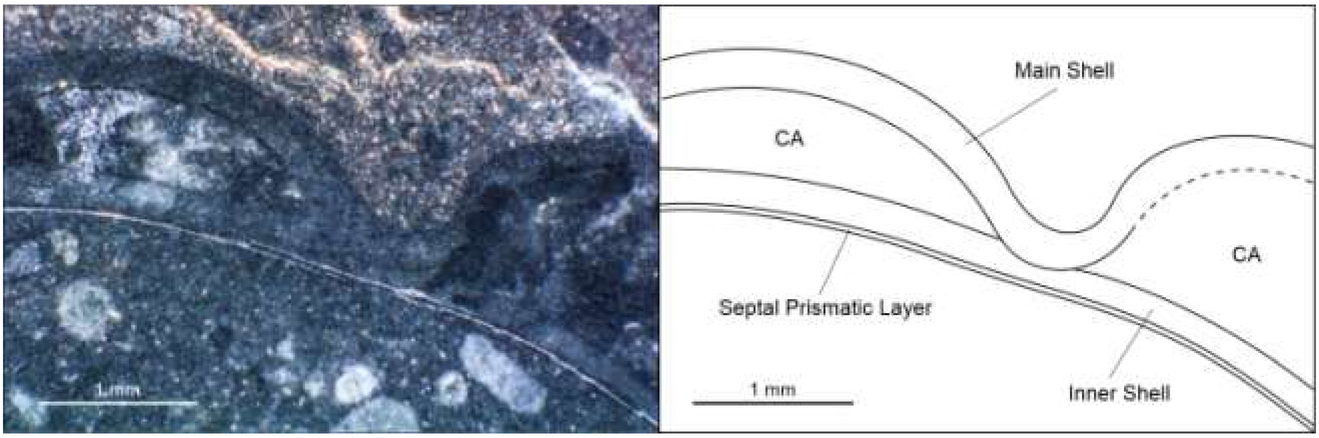


***Fig. 4.8** – Interpreted test structure of Genus B compressum (Johnston), based on a stereoscope image of the same specimen of Fig. 4.7.*

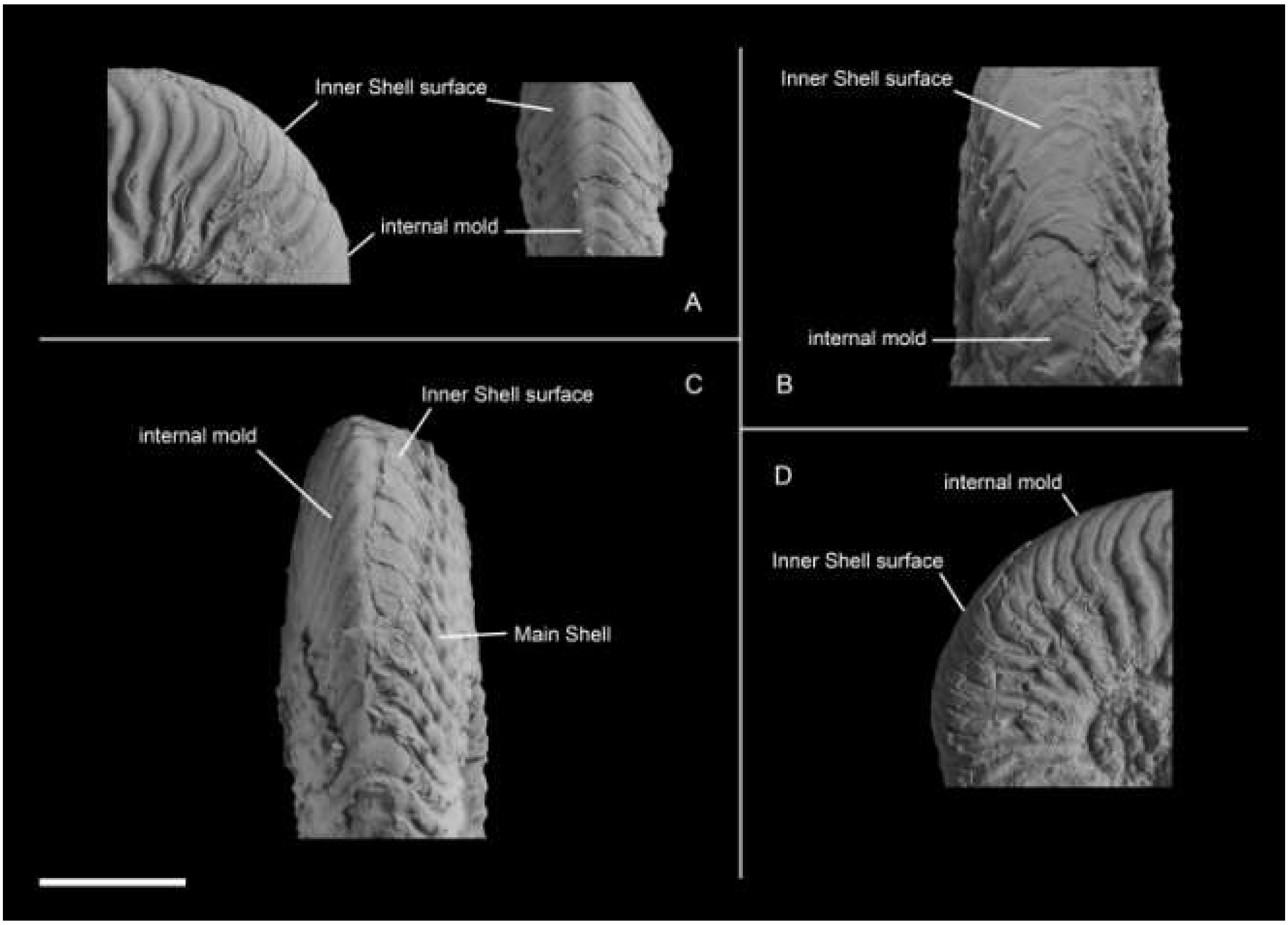


Fig. 4.9 – Examples of the smoothing caused by the complex test structure in Genus B compressum (Johnston). A – specimen D10-32 (Pl. 17, fig. 3); B – specimen JJ6-05-2 (Pl. 16, fig. 3); C – specimen JJ5-05-4 (Pl. 17, fig. 4); D – specimen D10bis-8 (Pl. 16, fig. 5). All specimens coated with ammonium chloride. For all specimens bar scale is 10mm.

In Genus B the Inner Shell is developed on the entire phragmocone and on the first 50°-60° of the body chamber, and then it abruptly ends (see chapter 4.3 - Systematic descriptions). On the last part of the body chamber only the Main Shell is present, and the ornamentation of internal mold closely follows that of the external test surface.
The septa are always secreted, together with the Septal Prismatic Layer, on the internal surface of the pre-existing Inner Shell. Septa are never in contact with the Main Shell. The observations made on tens of specimens show that this structural feature does not have a simplifying effect on the indentations of the suture lines, as already noted by Balini & Jenks (2007, p. 19). Wavy ceratitic suture lines (e.g. Textfig. 19.9) unlikely result from simplification of denticles. The wide variability of suture lines (e.g. Textfig. 21-22), drawn from the surface of the internal molds, is also proof of the primary character of the suture outline.

The other species belonging to the Subfamily Trachyceratinae that occur in South Canyon and China Mountain show a test structure similar to that of Genus B. The smoothing, however, is much less developed, and due to recrystallization it is more difficult to investigate the microstructure of the test. Cavities in correspondence of the most prominent ornamentation elements are observed in *Daxatina* *bispinosa* (Johnston) and *Trachyceras* sp. B. The cavities have not been recognized in other species. Probably in the less ornamented species the Inner Shell is more in contact with the Main Shell, and cavities are very limited or absent.

4.4.2 – Taxonomic significance of the "preseptal layer" in the Trachyceratinae from Nevada

The data obtained show that the "preseptal layer" is not related to pathology in the representatives of Subfamily Trachyceratinae from South Canyon and China Mountain. The development of this complex test structure is closely related to ontogenesis, and is widespread at the population level. For these reasons the "preseptal layer" can be considered of systematic significance.

In this thesis the morphological characteristics of the "preseptal layer" have been used for the classification at the genus level, as a populationistic and stratigraphic consistency has been identified. Genus B has been recognized also for his extremely developed "preseptal layer" (see chapter 4.3 and 4.4.1 for details), and the occurrence of this complex test structure has been identified in other *Daxatina* and *Trachyceras* species from Nevada.

The occurrence and taxonomic significance of the "preseptal layer" in the populations of *Daxatina* and early *Trachyceras* of the Tethys (e.g. Southern Alps and Tethys Himalaya) has still to be tested. From these areas, however, only few specimens are available. Most of them are preserved with test, therefore the comparison of the outer morphology with that of the internal mold is not yet possible.

4.5 - Evolutionary trends within the South Canyon Trachyceratinae

According to Tozer (1994), the Subfamily Trachyceratinae shows a wide composition. The genera attributed to this subfamily are *Anolcites* Mojsisovics, 1893, *Zestoceras* Tozer, 1994, *Maclearnoceras* Tozer, 1963, *Asklepioceras* Renz, 1911, *Muensterites* Mojsisovics, 1893, *Frankites* Tozer, 1971, *Daxatina* Strand, 1929, *Trachyceras* Laube, 1869, *Austrotrachyceras* Krystyn, 1978, *Trachysagenites* Mojsisovics, 1893. In this chapter only the genera recognized at South Canyon are considered in detail.

In my PhD thesis I have studied in detail the variability of the suture lines of the Trachyceratinae on the basis of a populationistic approach. The integration of my new data with literature, however, is complex because the available knowledge on the suture lines of Trachyceratinae is very scarce. There are few suture lines published (e.g. Tozer, 1994; Urlichs, 1994; Mietto et al., 2008), and most of them refer to single specimens, so the population variability is impossible to assess.

In literature, the complication of the suture line seems to be the main evolutionary trend within the Family Trachyceratidae. Between the Ladinian and the Early Carnian this trend probably affected two different lineages in chronologic succession.

The first evolutionary trend occurred in the Ladinian (Tozer, 1980), within the Subfamily Protrachyceratinae, with the Early Ladinian *Eoprotrachyceras* characterized by ceratitic sutures and the Late Ladinian *Protrachyceras*, showing ammonitic suture lines.

The second trend is documented in the earliest Carnian *Daxatina* and *Trachyceras*, but it has not yet been described in detail. According to literature (e.g. Tozer, 1994; Balini & Jenks, 2007; Mietto et al., 2008; 2012) the two genera can be distinguished only by their suture lines, that is ceratitic in the former and ammonitic in the latter. The two genera are recorded in stratigraphic succession, with limited overlap at Prati di Stuores (e.g. Mietto et al., 2008; 2012) and Spiti (Krystyn et al., 2004), and some authors have suggested the hypothesis that the two genera were part of a single lineage.

South Canyon is an important site to verify the supposed evolutionary relationships between *Daxatina* and *Trachyceras*, because this site yields the best fossiliferous succession documenting in great detail the late *Daxatina* and the early *Trachyceras*. The data obtained during the PhD work suggest an evolutionary relationship between *Daxatina* Strand and *Trachyceras* Laube, mainly supported by the suture line general shape (Fig. 4.10), the similar external morphology and the stratigraphic position.

The populationistic study of the suture lines shows that:

1) There is the lack of populations showing only ceratitic suture lines, corresponding to *Daxatina sensu strictu*.
2) There are populations showing sutures ranging from ceratitic to wavy ceratitic (Textfig. 3-11), and only the largest adult specimens show subammonitic sutures at large whorl height (e.g. Textfig. 5.1 and 8.4). These populations occur in section A (e.g. beds A21 and scan3) and in section B (e.g. beds scan16 and B11).
3) In sections D2, E, F and G there are populations characterized by ammonitic suture lines already at small whorl height (Textfig. 13-17). The populations of stratigraphically lower beds (e.g. bed E5) show relatively short saddles with a moderate spiral elongation. The stratigraphically higher populations (e.g. bed F26) shows more deeply indented and more spirally elongated suture lines.

From a taxonomic point of view, the ammonoids with the sutures referred to in point 2 are attributed to *Daxatina*, because Tozer (1994) includes in this genus ceratitic and also wavy ceratitic suture lines. The ammonoids with exclusively ammonitic sutures (referred to in point 3) are attributed to *Trachyceras*.

At South Canyon the evolutionary trend of complication of the suture line is documented for example by the lineage *Daxatina* sp. A > *Trachyceras desatoyense* > *Trachyceras* sp. A > *Trachyceras* sp. B (Fig. 4.10). The Canadian *Daxatina s.s.* generally show a simple ceratitic suture line, with well rounded saddles and simple short denticles on the lobes (Fig. 4.10A). At South Canyon *Daxatina* sp. A shows a relatively wide suture line intraspecific variability, ranging from ceratitic to subammonitic (Fig. 4.10C, D). On average the suture lines are wavy ceratitic. *Trachyceras desatoyense* is the first species of *Trachyceras* occurring at South Canyon. It shows an ammonitic suture line already at small whorl height, characterized by relatively short saddles and a moderate spiral elongation (Fig. 4.10E). In *Trachyceras* sp. A the suture shows a more evident spiral elongation, with deeper indentations (Fig. 4.10F). The stratigraphically higher *Trachyceras* sp. B shows the more complex ammonitic suture lines, with elongated and deeply indented triangular shaped saddles and very long denticles on lobes (Fig. 4.10G).

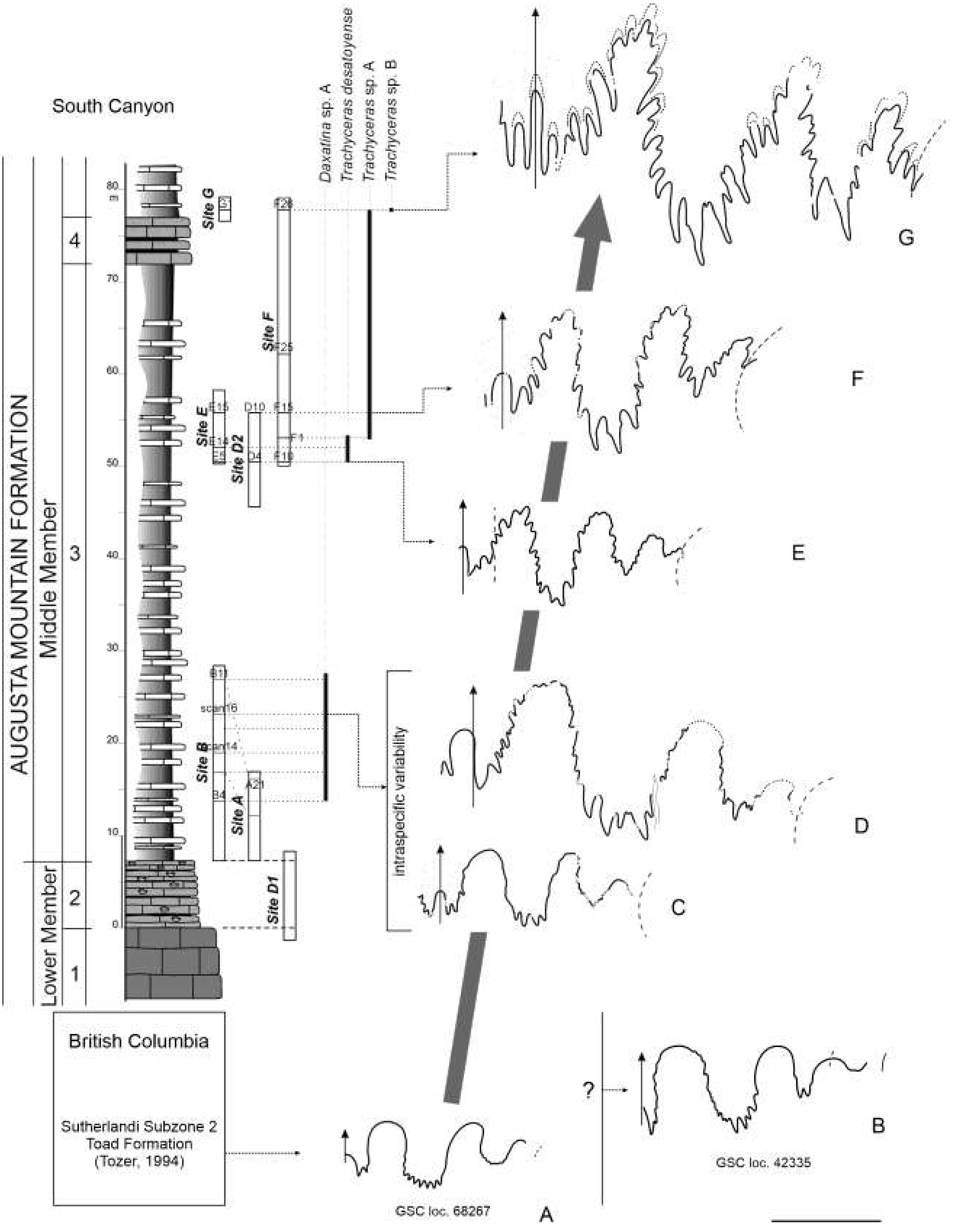


Fig. 4.10 – The main evolutionary trend of complication of suture line within the Subfamily Trachyceratinae recognized at South Canyon. Suture lines: **A** – Holotype GSC 28805, *Daxatina laubei* Tozer; **B** – GSC 28810, *Daxatina canadensis* (Whiteaves); **C** – scan16-1, *Daxatina* sp. A; **D** – scan16-581, *Daxatina* sp. A; **E** – E5-100, *Trachyceras desatoyense* Johnston; **F** – E3-33, *Trachyceras* sp. A; **G** – F26-6, *Trachyceras* sp. B. For all the sutures bar scale is 10mm.

Trachyceras silberlingi Balini et al., 2012 probably belongs to a different lineage, as its suture line is less deeply indented and less triangular shaped than for example *Trachyceras* sp. B in sample F26 (compare Textfig. 15.1 with Textfig. 16.1).

The South Canyon *Daxatina* are most probably stratigraphically higher than the Canadian *Daxatina*. The reasons for this hypothesis are explained below. At South Canyon the Maclearni Subzone 3 and the base of the Sutherlandi Zone is documented in the thin shaly intercalations of the lower member of the Augusta Mountain Formation (Waller & Stanley, 2005; Balini pers. comm.; personal determination of ammonoids from Balini's Section C), about 150m below the base of the middle member. The upper part of the lower member document a carbonate platform, and do not contains ammonoids.
In British Columbia the FO of *Daxatina* occurs in the lower part of the Sutherlandi Zone (Tozer, 1994), so it is highly probable that at South Canyon this bioevent is not visible because it falls in the lower member, probably in the lower part of the 150 m of platform limestones. Although the sedimentation rate of the carbonate platform is difficult to estimate, the rock succession between the hypothesized FO of *Daxatina* and the fossiliferous beds of Section A and B is relatively thick, and represents a discrete amount of time.

Chapter 5
Faunistic analysis

5.1 – South Canyon

During the PhD work a total of 3223 cephalopods have been collected from the locality of South Canyon. The material comes from six different stratigraphic sections and various out of section beds outcropping as isolated spots along the northern slope of South Canyon. Some of these isolated beds have been traced to the stratigraphic sections through the excavation of lateral trenches in the debris cover. During collection and subsequent preparation, no selection on specimens regarding their size or preservation was done. Therefore, the composition of the association obtained from a bed is regarded as documenting the original assemblage of cephalopod fauna.

The faunal composition at family/subfamily rank of the most important fossiliferous beds are reported in the following tables and in Fig. 5.1.

Section A

A11		
Family / Subfamily	n° of specimens	%
Trachyceratinae	24	85.7
Lobitidae	2	7.1
Noritidae	1	3.6
ind.	1	3.6
Total specimens	28	

A15		
Family / Subfamily	n° of specimens	%
Trachyceratinae	10	100.0
Total specimens	10	

A16		
Family / Subfamily	n° of specimens	%
Trachyceratinae	19	90.5
Lobitidae	1	4.8
Noritidae	1	4.8
Total specimens	21	

A17		
Family / Subfamily	n° of specimens	%
Trachyceratinae	12	100.0
Total specimens	12	

A21		
Family / Subfamily	n° of specimens	%
Trachyceratinae	39	34.2
Clionititidae	21	18.4
Joannitidae	16	14.0
Noritidae	10	8.8
Lobitidae	7	6.1
Arcestidae	2	1.8
Nautiloidea	17	14.9
ind.	2	1.8
Total specimens	114	

A22		
Family / Subfamily	n° of specimens	%
Trachyceratinae	8	61.5
Clionititidae	3	23.1
Noritidae	2	15.4
Total specimens	13	

Section B

scan15		
Family / Subfamily	n° of specimens	%
Trachyceratinae	66	91.7
Joannitidae	4	5.6
Noritidae	1	1.4
ind.	1	1.4
Total specimens	72	

scan16		
Family / Subfamily	n° of specimens	%
Trachyceratinae	372	87.3
Arcestidae	14	3.3
Clionititidae	13	3.1
Joannitidae	12	2.8
Noritidae	10	2.3
Nautiloidea	3	0.7
ind.	2	0.5
Total specimens	426	

B11		
Family / Subfamily	n° of specimens	%
Trachyceratinae	42	28.2
Joannitidae	43	28.9
Clionititidae	28	18.8
Lobitidae	15	10.1
Noritidae	11	7.4
Arcestidae	3	2.0
Cladiscitidae	1	0.7
Nautiloidea	5	3.4
ind.	1	0.7
Total specimens	149	

B13		
Family / Subfamily	n° of specimens	%
Trachyceratinae	9	69.2
Joannitidae	3	23.1
Noritidae	1	7.7
Total specimens	13	

Section D

D4		
Family / Subfamily	n° of specimens	%
Trachyceratinae	32	71.1
Arpaditinae	5	11.1
Badiotitidae	3	6.7
Clionititidae	2	4.4
Arcestidae	1	2.2
ind.	2	4.4
Total specimens	45	

D10 + D10bis		
Family / Subfamily	n° of specimens	%
Trachyceratinae	222	82.8
Badiotitidae	34	12.7
Clionititidae	2	0.7
Cladiscitidae	1	0.4
Nautiloidea	8	3.0
ind.	1	0.4
Total specimens	268	

Section E

E5		
Family / Subfamily	n° of specimens	%
Trachyceratinae	131	75.3
Arpaditinae	19	10.9
Clionititidae	10	5.7
Cladiscitidae	8	4.6
Arcestidae	1	0.6
Sageceratidae	1	0.6
Nautiloidea	4	2.3
Total specimens	174	

E3		
Family / Subfamily	n° of specimens	%
Trachyceratinae	102	98.1
Badiotitidae	2	1.9
Total specimens	104	

Section F

F1bis		
Family / Subfamily	n° of specimens	%
Trachyceratinae	68	47.9
Clionititidae	41	28.9
Arpaditinae	17	12.0
Sageceratidae	4	2.8
Cladiscitidae	4	2.8
Arcestidae	2	1.4
Nautiloidea	6	4.2
Total specimens	142	

F1		
Family / Subfamily	n° of specimens	%
Trachyceratinae	89	60.5
Clionititidae	47	32.0
Lobitidae	4	2.7
Hungaritidae	3	2.0
Arcestidae	1	0.7
Nautiloidea	3	2.0
Total specimens	147	

F15		
Family / Subfamily	n° of specimens	%
Trachyceratinae	9	19.6
Badiotitidae	36	78.3
Nautiloidea	1	2.2
Total specimens	46	

F26		
Family / Subfamily	n° of specimens	%
Trachyceratinae	144	56.3
Lobitidae	48	18.8
Clionititidae	38	14.8
Hungaritidae	20	7.8
Nautiloidea	6	2.3
Total specimens	256	

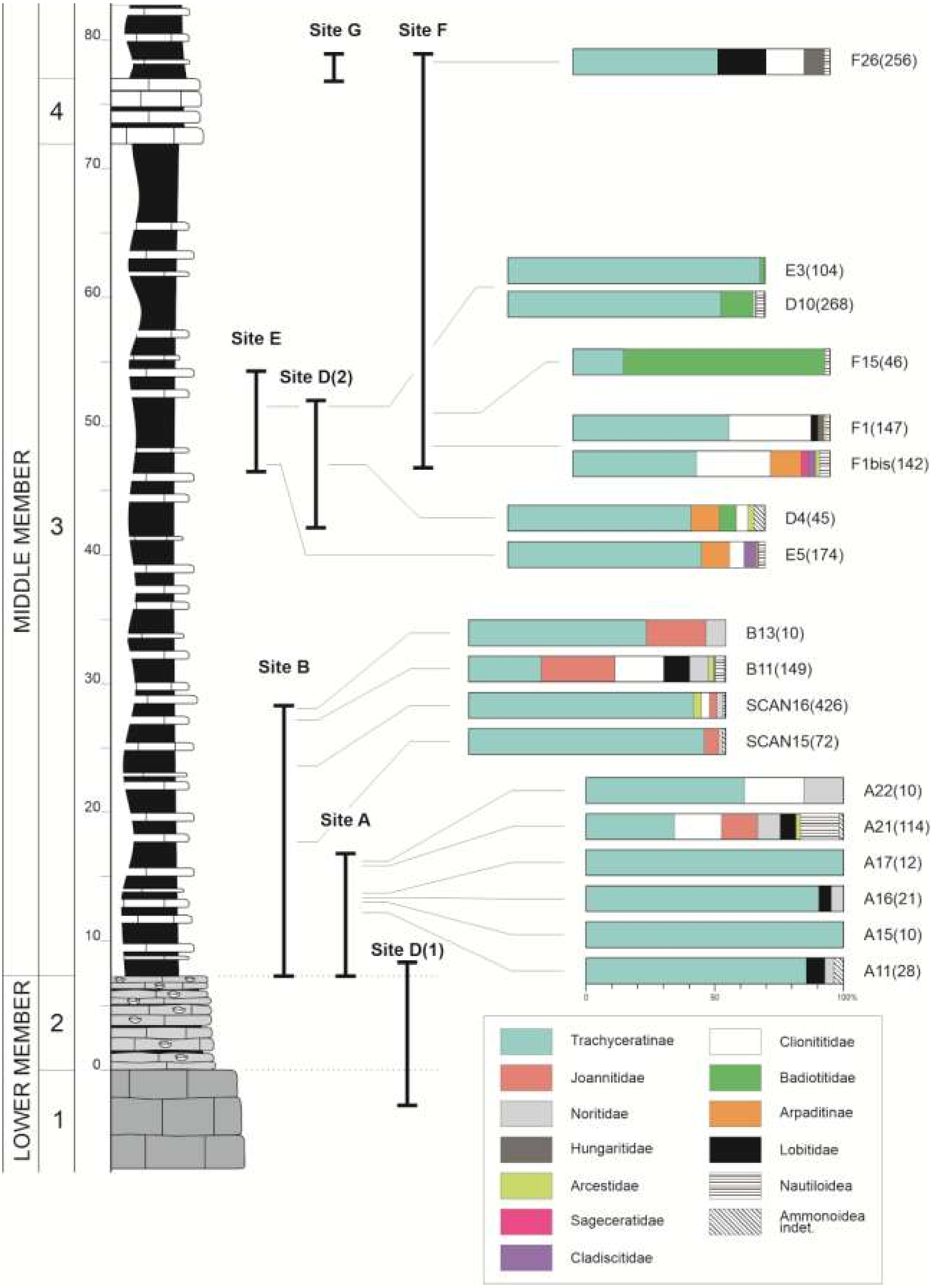


***Fig. 5.1** – Faunal composition of the most important cephalopod assemblages. Numbers at the right of the faunal bars show the designation number of the sample, numbers in brackets show the total number of specimens. Data are shown in the text (modified from Balini & Jenks, 2007, fig. 4).*

Ammonoids belong to the families/subfamilies Trachyceratinae, Arpaditinae, Joannitidae, Noritidae, Hungaritidae, Clionititidae, Badiotitidae, Lobitidae, Arcestidae, Sageceratidae and Cladiscitidae.

Trachyceratinae are the most frequent group of ammonoids. Their dominance normally ranges between 50% to 80%, and only rarely it is lower than 40%. Faunal diversity at the family/subfamily rank may change from bed to bed, and does not seem to be much influenced by sample size. In Section A and B the faunas with the highest diversity are A21 and B11, with six to seven families present. In these two samples Trachyceratinae constitute less than 40% and Joannitidae, Clionititidae, Noritidae and Lobitidae are relatively abundant.

In samples E5, D4, F1 and F1bis Trachyceratinae constitute between 50% to 75% and other relatively abundant groups are Arpaditinae and Clionititidae. In sample F15 Badiotitidae are the dominant family (about 80%) while Trachyceratinae, represented by Genus B, are only about 20%. In sample D10 and the correlative E3 Trachyceratinae (largely represented by Genus B) are between 82% to 98%, while Badiotitidae are between 2% and 13%.

In sample F26 Trachyceratinae are about 56%, while other abundant families are Lobitidae, Clionititidae and Hungaritidae.

Discussion. South Canyon is the only known locality where the Trachyceratinae are the most abundant group of ammonoids in the majority of the faunas. In the literature (e.g. Mojsisovics, 1882; Urlichs, 1994) they are reported to be generally subordinated to other groups. For example in the San Cassiano Formation the Trachyceratinae are usually no more than 15%, and only rarely they reach 50% (see Urlichs, 1974, fig. 6).

At South Canyon the dominance of Trachyceratinae is usually high, but in some beds it abruptly decrease. For example in Scan16 fauna the Trachyceratinae are 87% while in sample B11, which is less than 2.5 m above, their dominance is only 28%. It is worth noting that the lithofacies of these beds does not change notably, and consists of bioclastic mudstones/wakestones. In these cases the decrease of Trachyceratinae dominance is accompanied by an increase of diversity at the family/subfamily rank. The interpretation of this record is currently difficult, because the paleoecology of this group of ammonoids, as for many Triassic ammonoids, is not yet known (see Balini et al., 2010). A possible explanation implies a change in paleoecologic and/or paleoenvironmental conditions, such as position of the redox boundary in respect of the seafloor, or of the structure of the food chain. Additional evidence in support of changes in paleoecological and/or paleoenvironmental conditions comes from the conodont faunal analysis of the South Canyon succession performed by Orchard & Balini (2007), that emphasizes the strong variation of composition of conodont faunas in sections A and B, with the transition to oligotypic associations dominated by *Mosherella newpassensis* (Mosher).

Sample D10 and correlatives show a very low diversity both at the family/subfamily rank and at the genus rank. Trachyceratinae are largely dominated by Genus B, with subordinate *Trachyceras*. In these beds the specimens are often fragmentary, with high packing. On the bed surfaces are visible isooriented orthocones nautiloids. These features might be explained as evidences of transport and resedimentation. Faunas of these beds may have been transported from a shallower environment to the deeper basinal environment documented at South Canyon. This interpretation is supported also by the finding of similar faunal compositions in the upper part of the Smelser Pass Member at China Mountain, which should be more proximal than South Canyon (see the following Chapter 5.2).

In order to better precise the paleoenvironmental conditions of the South Canyon fossiliferous succession it will be necessary an in-depth sedimentological study, and the study of other fossil groups such as bivalves and brachiopods.

5.2 - China Mountain

A total of 685 cephalopods have been collected from China Mountain during the PhD work.
Bed CHM42 is the most important *in situ* fossiliferous level. Other samples are considered part of the CHM42 fauna, as they come from lateral correlative beds (e.g. CHM37) outcropping very close to CHM42, or from blocks which are certainly part of the same bed, found exactly in correspondence of bed CHM42.

The faunal composition of sample CHM42 is reported in the following table and in Fig. 5.2.

CHM42 (+CHM31, 37, 39, 40, 41, 44, 45, 46, 47)		
Family / Subfamily	n° of specimens	%
Trachyceratinae	174	98.3
Badiotitidae	1	0.6
Nautiloidea	2	1.1
Total specimens	177	

CHM42 (+CHM31, 37, 39, 40, 41, 44, 45, 46, 47)		
Genus	n° of specimens	%
Genus B	173	97.7
?Trachyceras	1	0.6
Badiotites	1	0.6
Nautiloidea	2	1.1
Total specimens	177	

The CHM42 fauna is characterized by an extremely low diversity, both ath the family/subfamily rank and at the genus rank. Trachyceratinae are about 98%, and within this subfamily Genus B is 97.7%. Also the other fossiliferous beds show this low faunal diversity.

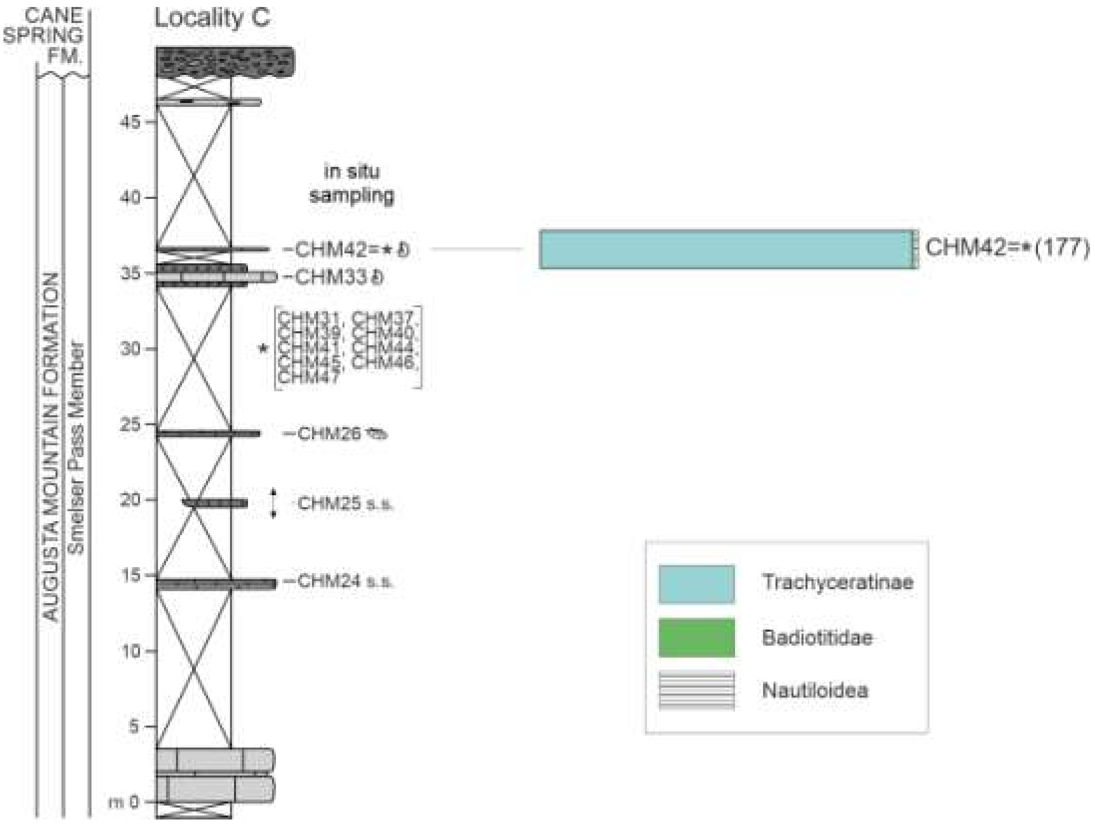


***Fig. 5.2** – Faunal composition at family/subfamily rank of sample CHM42. Correlative samples are shown by the asterisk.*

Discussion. The upper part of the Smelser Pass Member shows features consistent with a drowning trend, whose general setting is difficult to assess. Taking into account the regional reconstructions (e.g. Nichols & Silberling, 1977; see also Fig. 2.4) the succession of China Mountain was located in a more proximal setting than that of South Canyon, so the drowning should not be as marked as in South Canyon.

The faunal composition of sample CHM42 is very similar to that of bed D10 and correlatives of South Canyon, which show resedimentation evidences. In all of these samples Genus B largely dominates in the faunas. This similarity suggest a correlation of the fossiliferous succession of China Mountain with beds D10 and correlatives of South Canyon. It might be possible that CHM42 is within or close to the source area from which the fauna of D10 was displaced.

An explanation of the extremely low faunal diversity is difficult. The lack of leiostraca ammonoids could been due to a shallower paleoenvironment, but the low diversity at genus level might result from restricted environment. In order to better precise the paleoenvironmental setting of this ammonoid bearing interval, it should necessary to study microfacies, bivalves and brachiopods.

Chapter 6
Biochronostratigraphy

6.1 - Results

6.1.1 - South Canyon

The stratigraphic sections, including out of section beds for sites A, B, D, E and F with the distribution of taxa recognized are reported in Figures 6.1 - 6.5. In all figures the numbers in brakets show the number of specimens attributed to each taxon. The synthetic section reported in Fig. 6.6 summarize the distribution of taxa recognized in the stratigraphic sections A, B, D, E, F, G.

The sampled sedimentary succession is about 70m thick, and is subdivided into three parts. Ammonoids are documented in the lower part (Section A and B, total thickness of about 20m) and in the upper part (Section D, E, F, G, total thickness of about 35m), while in the barren middle part the marly lithology is not suitable to a good ammonoid preservation. The few specimens found are extremely deformed and flattened by compaction.

Species belonging to the Subfamily Trachyceratinae are the most important taxa for biostratigraphy. *Daxatina* sp. A, *Daxatina bispinosa* (Johnston) and *Daxatina* sp. B occur in the lower part of the fossiliferous succession, in Sections A and B. Other taxa confined to this stratigraphic interval are *Neoclypites desertorum* (Johnston), *Hannaoceras newpassense* Johnston, *Sympolycyclus antiquus* Tozer and *Clionitites barwicki* (Johnston).

Trachyceras desatoyense Johnston occurs just above the barren stratigraphic interval, in the lower part of Section D, E and F. Here ?*Daxatina* sp. A, also occurs, and shows characteristics of both *Daxatina* and *Trachyceras*. Other taxa that appear in this part of the succession are *Perrinoceras novaditum* Johnston, *Clionitites* aff. *wheeleri*, *Clionitites reesidei* (Johnston), *Badiotites trauthi* (Johnston) and *Silenticeras schencki* (Johnston).

An abrupt increase of diversity is documented in level F1, where *Trachyceras silberlingi* Balini et al. and *Trachyceras* sp. A appear. These two species co-occur with *Trachyceras desatoyense*, ?*Daxatina* sp. A and Genus A sp. A, a discoidal form that is confined to a very narrow stratigraphic interval. Level F1 is a lens that was exposed few tens of meters east of the main Section F. Lateral tracing based on strike and dip of F1 suggests a correlation with the lowermost part of the section (Balini et al., 2012).

In a higher stratigraphic position the diversity decrease, and in bed D10 and correlatives the faunas are largely dominated by Genus B *compressum*, in association with the much less abundant *Trachyceras* sp. A.

In the highest sampled stratigraphic interval another important faunal change is recorded. Bed F26 document the FO of discoidal *Trachyceras* sp. B, *Clionitites* sp. A and *Coroceras zephyrum* Johnston. *Trachyceras silberlingi* co-occurs with these taxa.

The zonation proposed here consists of three zones (Fig. 6.1-.6), from base to top:

- *Daxatina* sp. A range zone (lower boundary: FO of *Daxatina* sp. A; upper boundary: LO of *Daxatina* sp. A); Section B is the best outcrop where this zone is documented, with a thickness of about 14m.

Interval without zonal assignment, about 15m thick.

- *Trachyceras desatoyense* interval zone (lower boundary: FO of *Trachyceras desatoyense*; upper boundary: FO of *Trachyceras* sp. B); Section F document the lower and upper boundary, for a total thickness of about 27m.
- *Trachyceras* sp. B range zone (lower boundary: FO of *Trachyceras* sp. B; upper boundary: LO of *Trachyceras* sp. B); Section F is the best outcrop, here this zone is documented in bed F26.

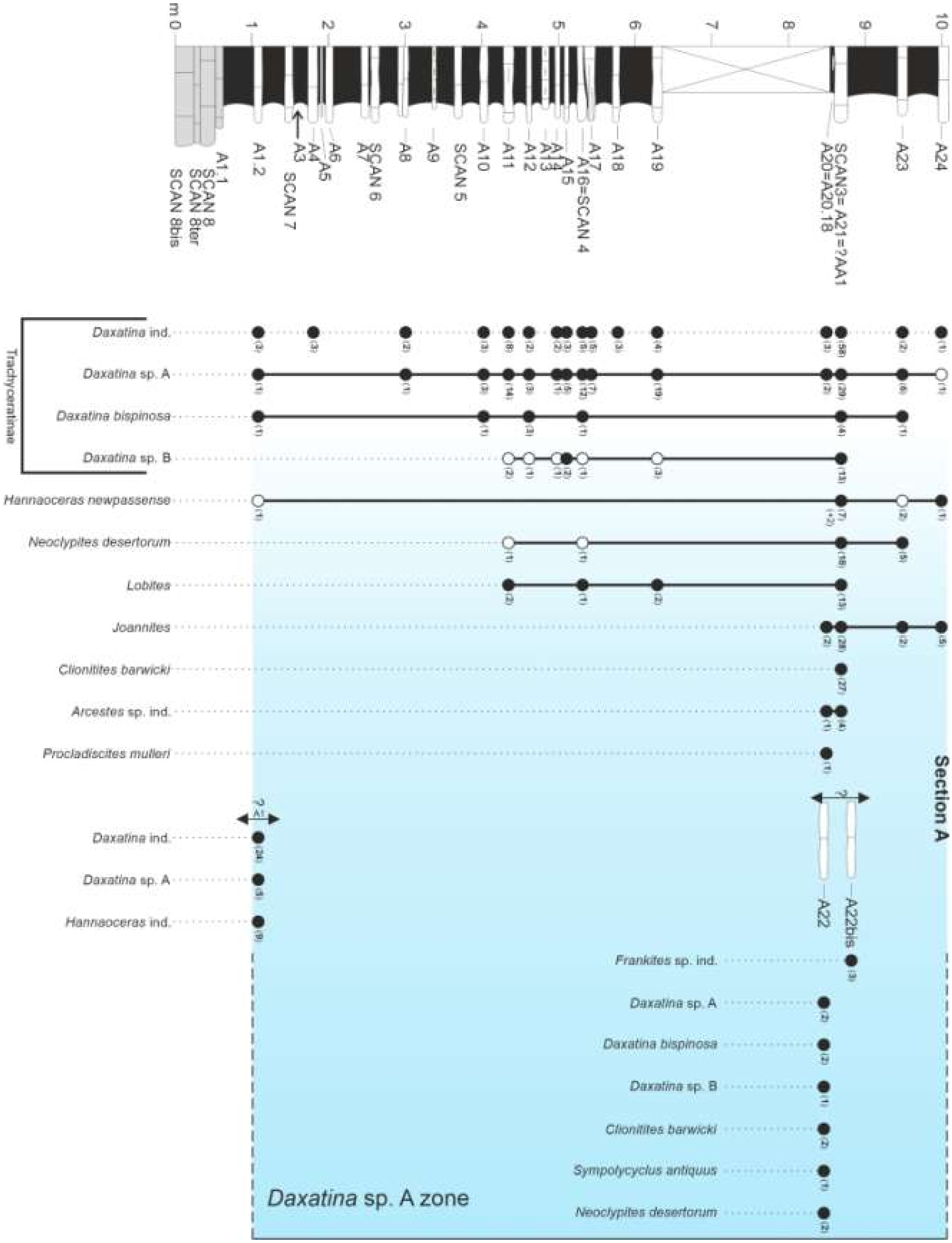


***Fig. 6.1** – Range chart of Section A.*

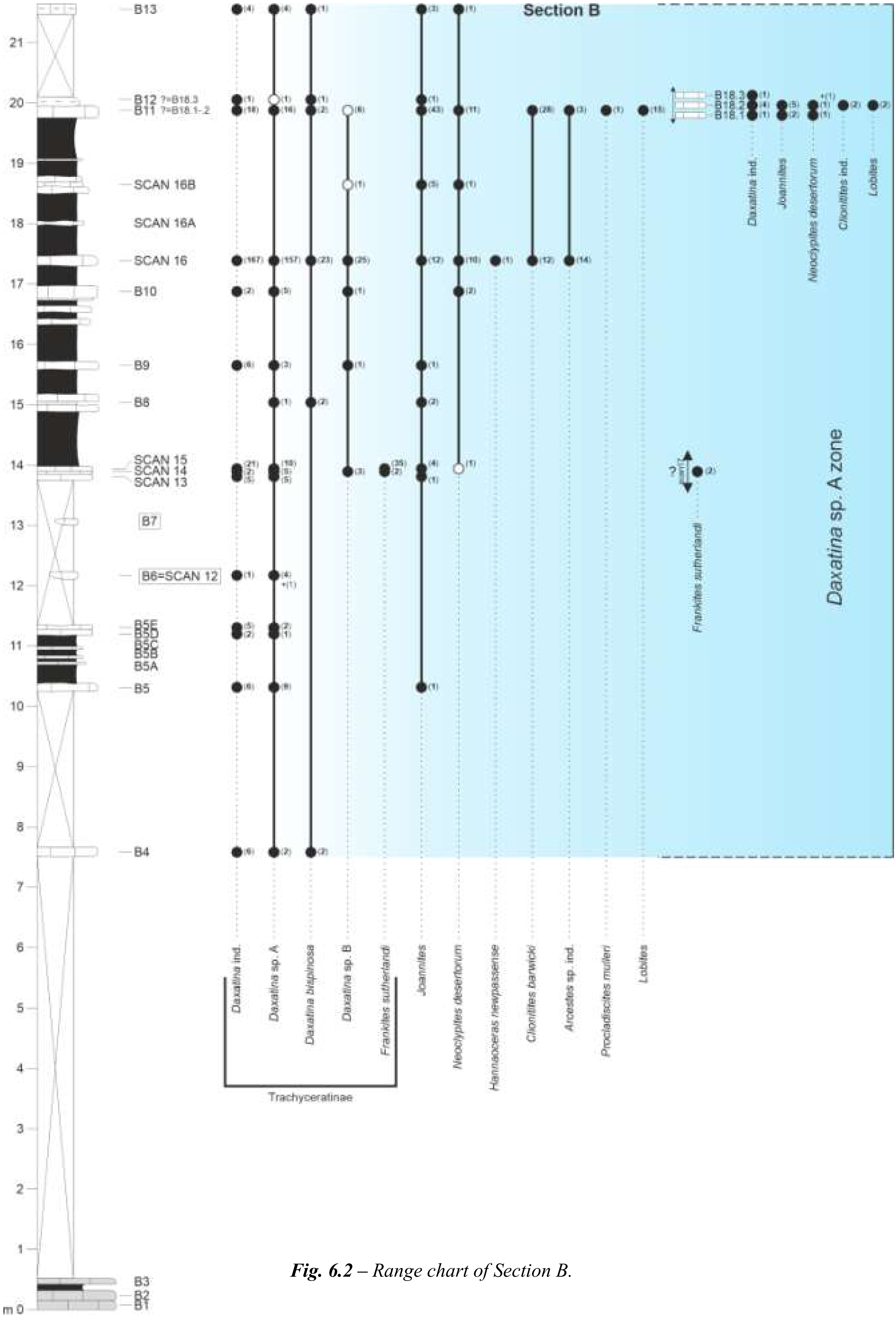


Fig. 6.2 – Range chart of Section B.

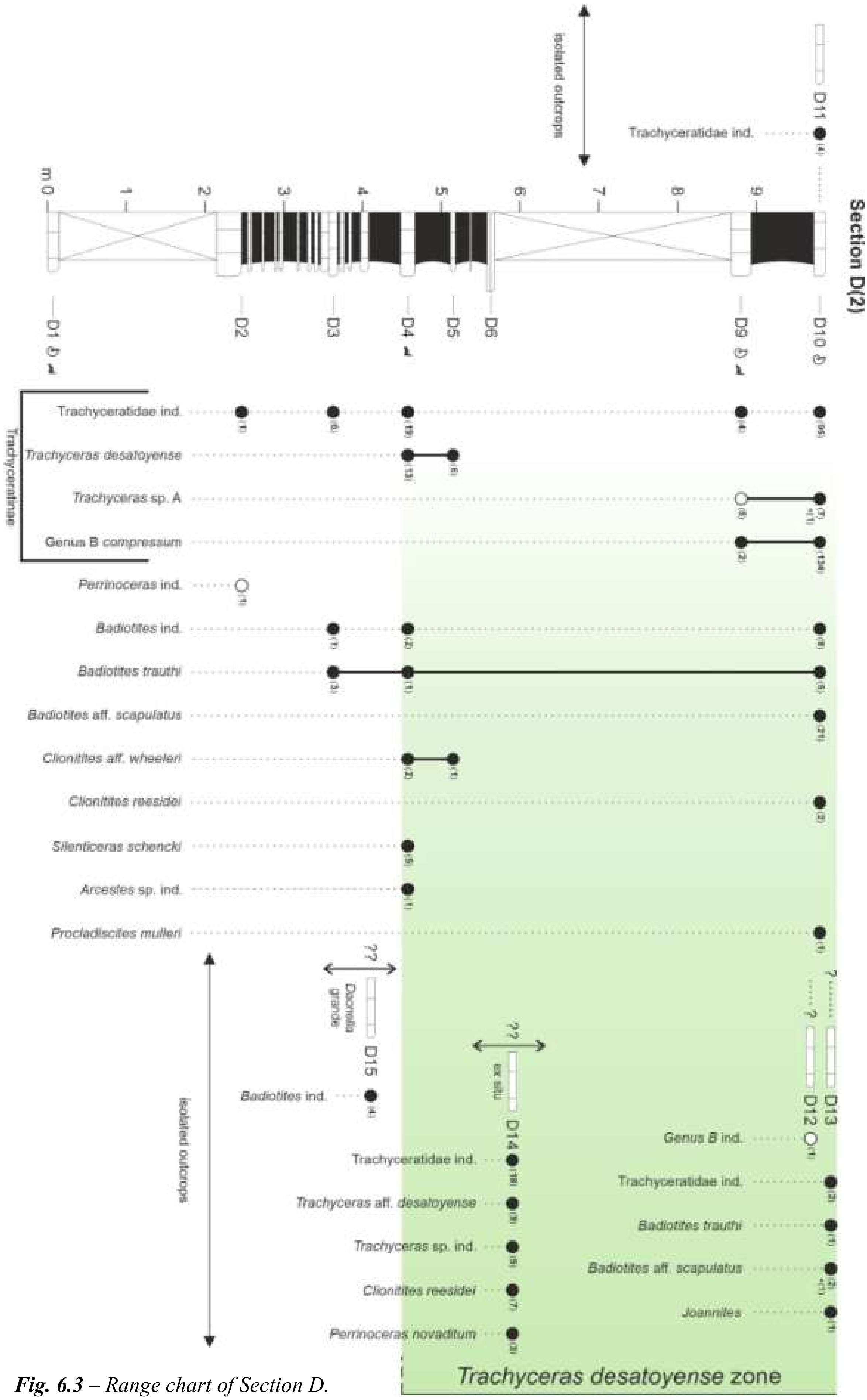


***Fig. 6.3** – Range chart of Section D.*

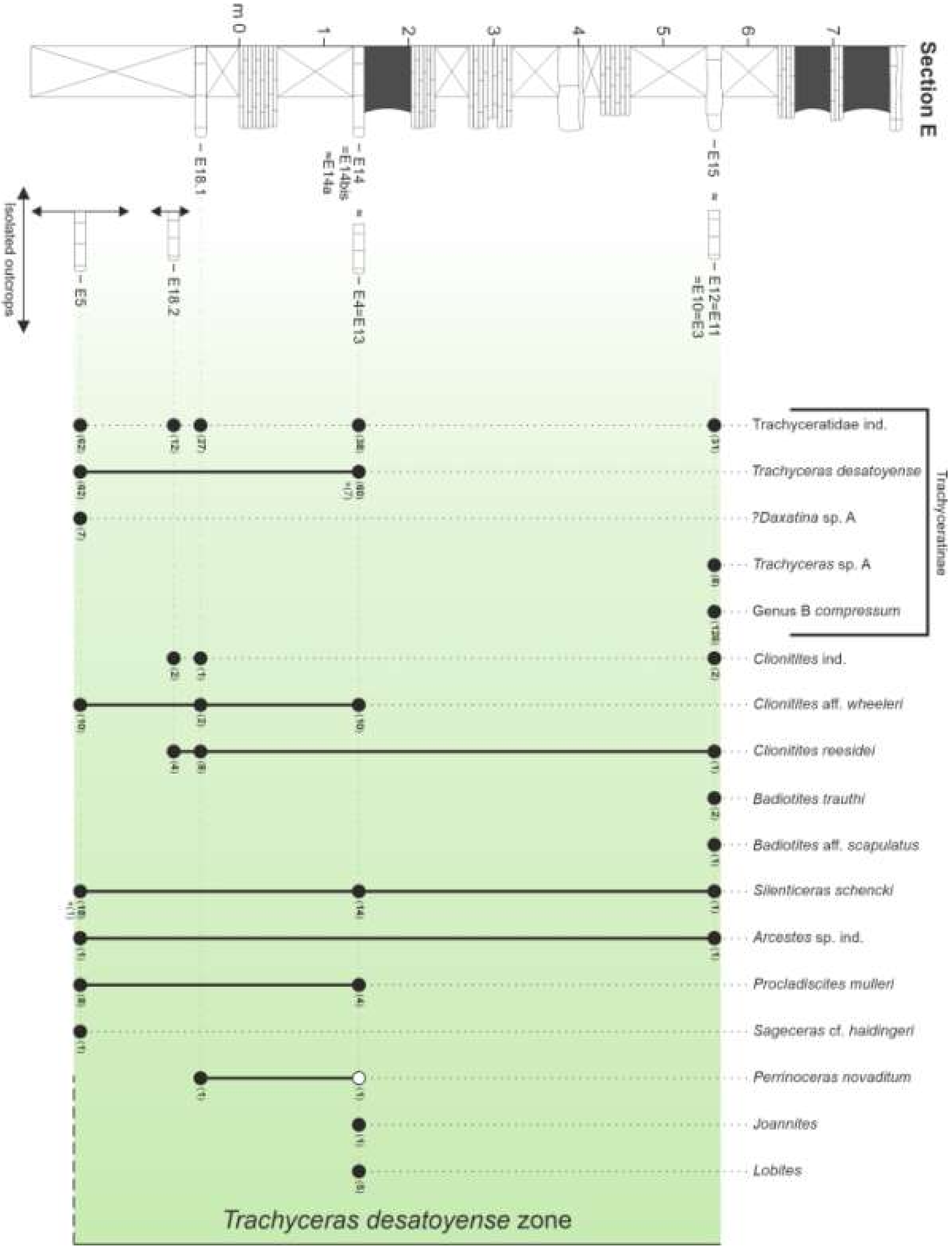


***Fig. 6.4** – Range chart of Section E.*

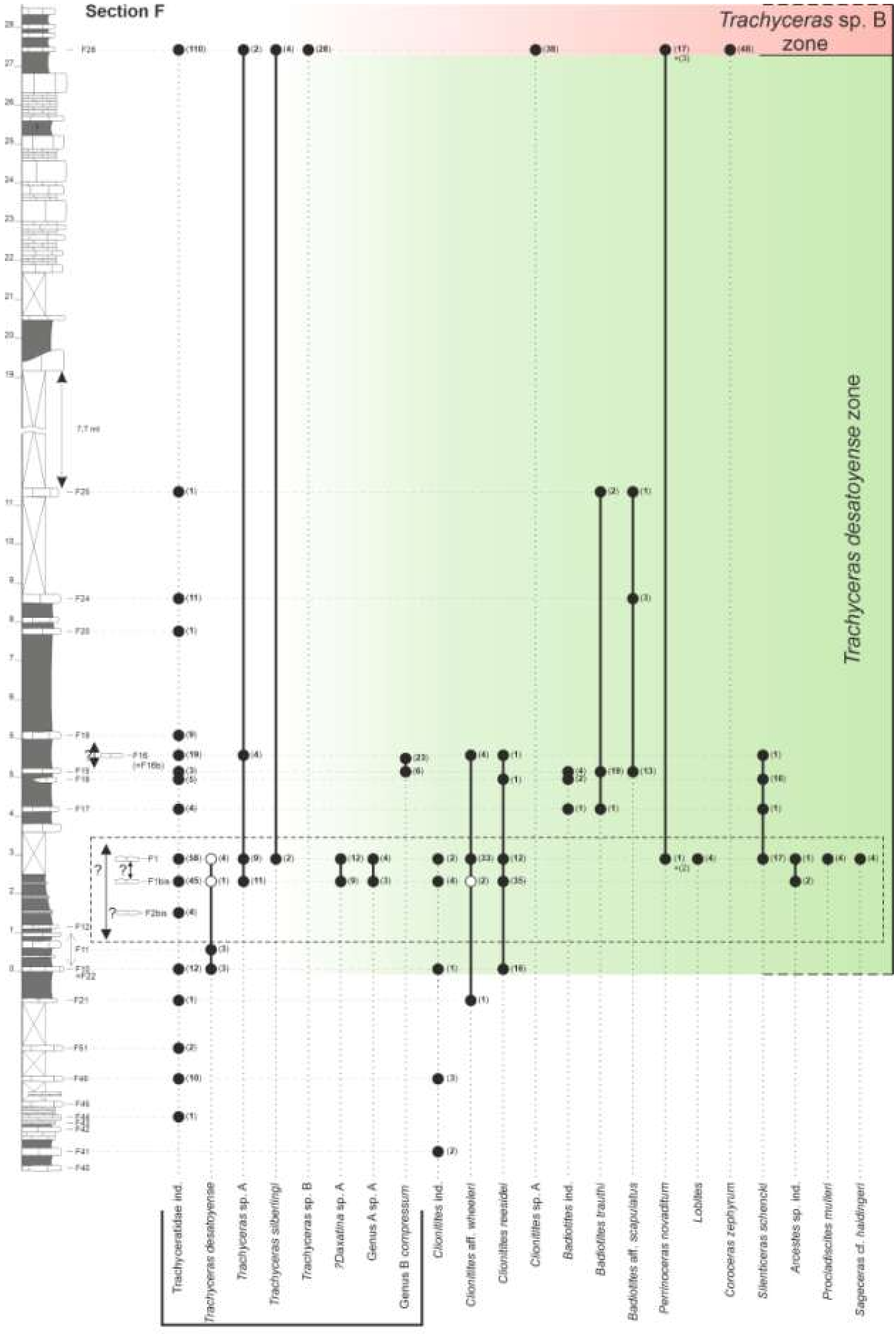


Fig. 6.5 – Range chart of Section F.

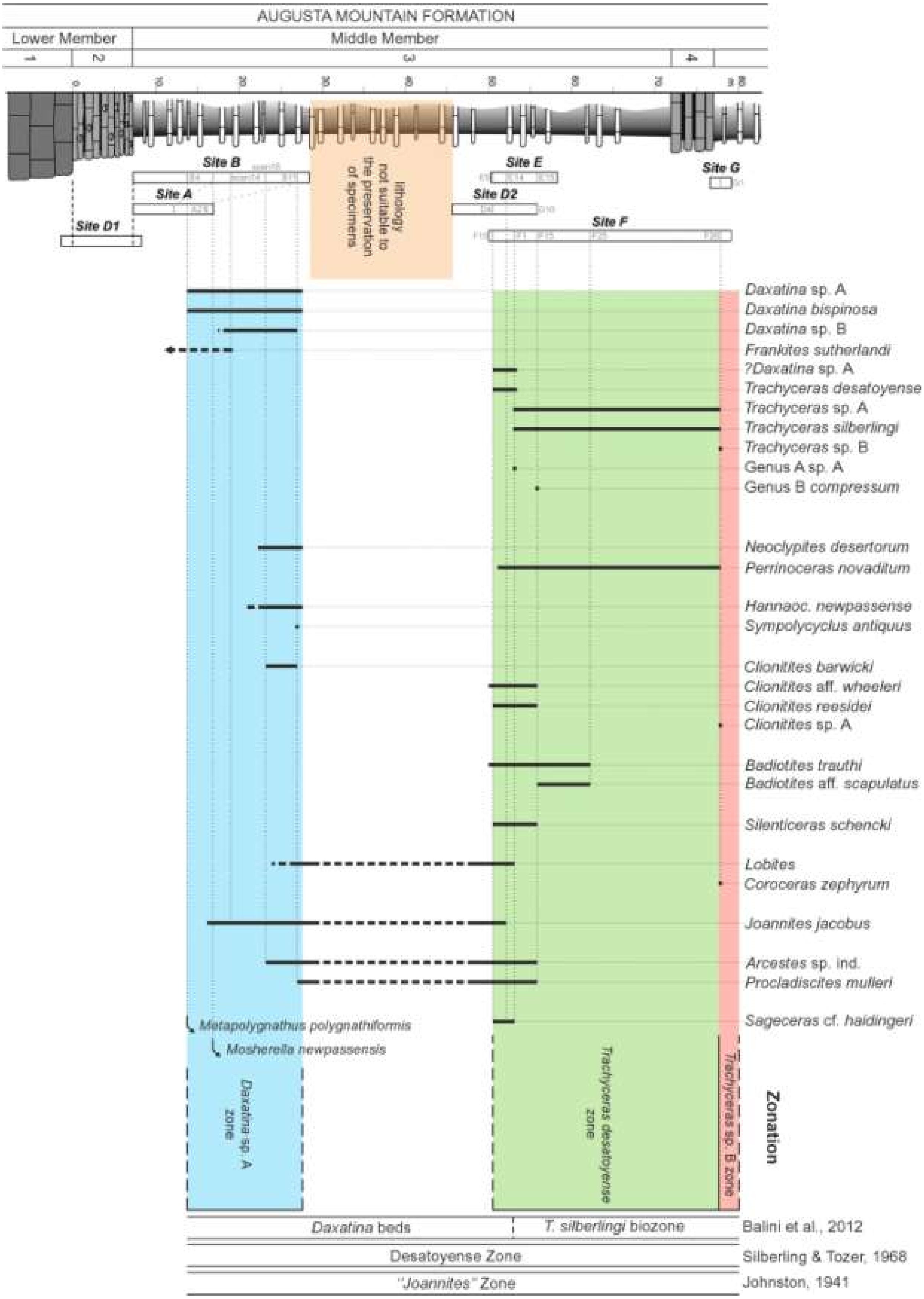


Fig. 6.6 *– Synthetic section of the upper part of the lower member and the lower part of the middle member of the Augusta Mountain Formation, showing the distribution of taxa recognized and the proposed zonation (stratigraphic section modified from Balini et al, 2012).*

6.1.2 - China Mountain

The distribution of taxa in the China Mountain stratigraphic sections are shown in Fig. 6.7.

The fossiliferous interval documented at China Mountain is characterized by the nearly total dominance of Genus B in all the ammonoid faunas. The most abundant species is Genus B sp. A, with subordinate Genus B sp. B. One single specimen of ?*Trachyceras* sp. ind. has been found in the main fossiliferous bed (CHM42). Rare specimens of *Perrinoceras novaditum* Johnston have been found in debris samples above bed CHM42. Extremely rare occurrences of other taxa are represented by one specimen of *Clionitites reesidei* (Johnston), one specimen of *Silenticeras schencki* Johnston and two specimens of *Badiotites* aff. *scapulatus*.

The fossiliferous interval of China mountain is correlated with the lower part of the *Trachyceras desatoyense* interval zone recognized at South Canyon (Fig. 6.8), in particular with bed D10 occurring in Section D and the correlative beds E3 (Section E) and F16 (Section F). Correlation is based mostly on account of the widespread abundance of Genus B, which occur at South Canyon in bed D10 and correlatives with a different species, Genus B *compressum* (Johnston). The rare occurrence of ?*Trachyceras*, *Badiotites*, *Clionitites reesidei*, *Silenticeras* and *Perrinoceras* are consistent with this correlation.

These results confirm and improve the chronological correlation between the upper part of the Smelser Pass Member and the lower part of the middle member of the Augusta Mountain Formation of South Canyon.

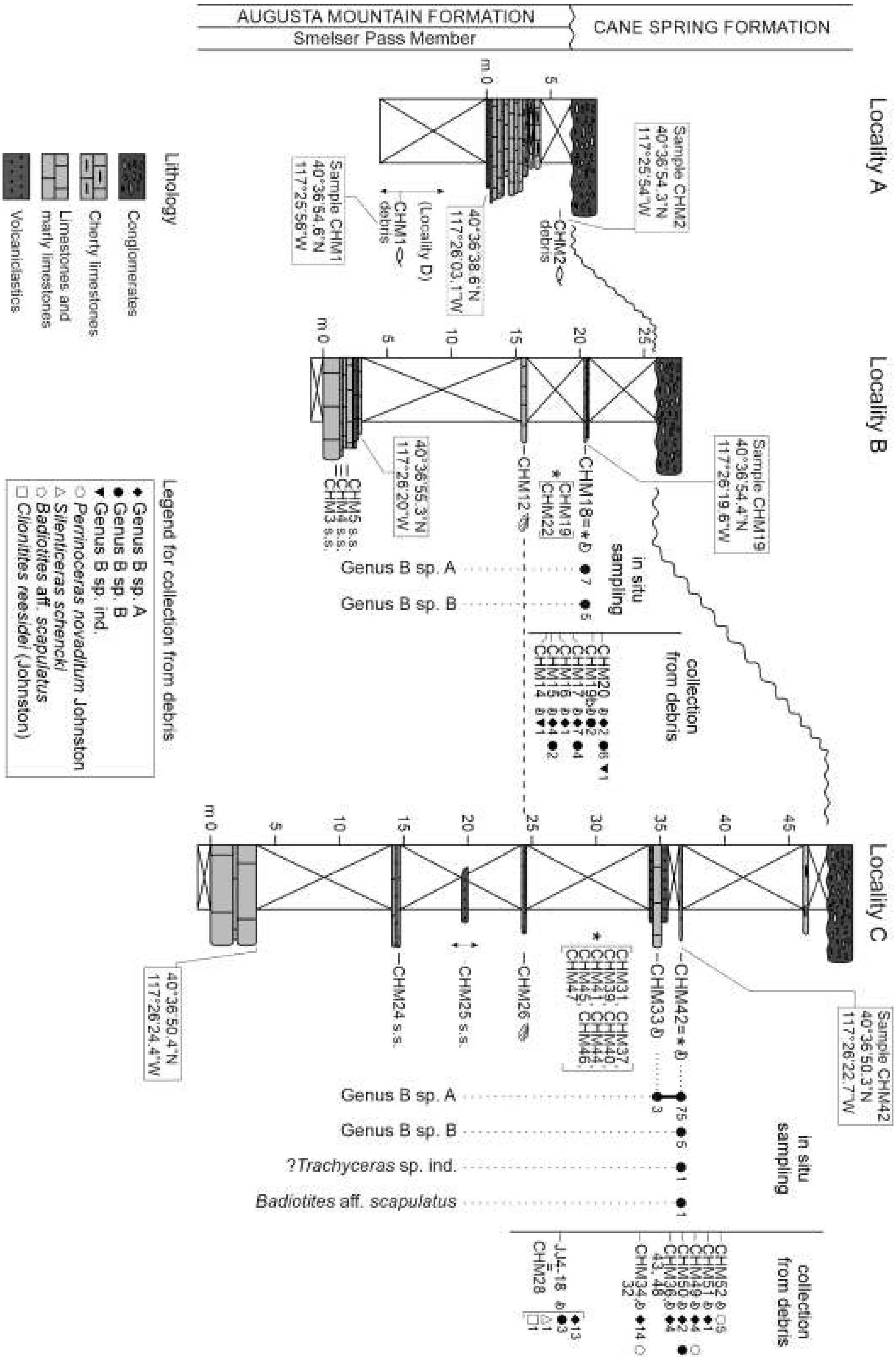


Fig. 6.7 – Stratigraphic sections of the fossiliferous interval of China Mountain, showing the distribution of ammonoid taxa. Ammonoids collected from debris are reported separately, with the indication of the ex-situ stratigraphic position. The numbers near the symbols indicate the amount of specimens attributed.

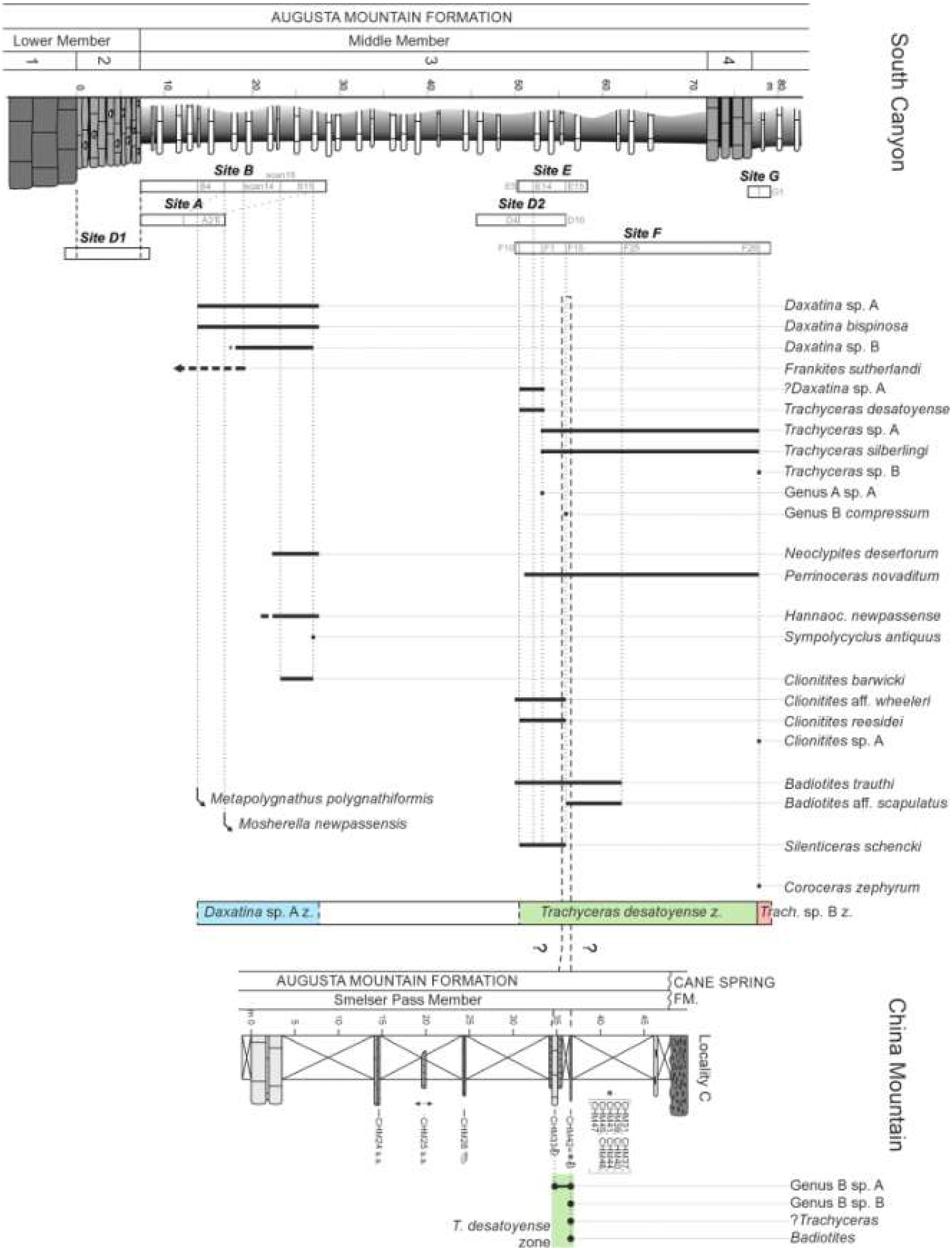


Fig. 6.8 – Correlation between South Canyon and China Mountain. The fossiliferous interval of China Mountain is correlated with part of the Trachyceras desatoyense zone of South Canyon.

6.2 - Correlation between South Canyon and British Columbia

The correlation between South Canyon and British Columbia (Fig. 6.9) is tentative, as the zonation proposed by Tozer (1967; 1994) for the Canadian successions is not based on range charts, but on a biochronologic approach. The ammonoid record of the Canadian Desatoyense Zone is rather poor, especially with regard to the ammonoids of the Subfamily Trachyceratinae (see Tozer, 1994, pl. 88-90).

The *Daxatina* sp. A zone of South Canyon show faunal similarities with the Canadian Sutherlandi Subzone 2. *Frankites sutherlandi*, which is the zonal index of the Sutherlandi Zone, occur in the *Daxatina* sp. A zone in Section A and B, although it is a very rare species. The South Canyon *Daxatina* show a relatively wide variability of suture line, which range from ceratitic to subammonitic, while in the Canadian *Daxatina* sutures are generally more simple, and the variability range from ceratitic to wavy ceratitic (e.g. Tozer, 1994, fig. 68a-e). The *Daxatina* sp. A zone of South Canyon could document the uppermost part of the Sutherlandi Subzone 2, as hypothesized in Chapter 4.5.

Conodont data (Orchard & Balini, 2007) are consistent with this correlation. Conodonts occurring in the *Daxatina* sp. A zone document in part the *intermedius* Zone of Orchard (2007), correlated with the Canadian Sutherlandi Subzone 2 (Orchard, 2007). At South Canyon the FO of *Metapolygnathus polygnathiformis* (Budurov & Stefanov, 1965) occurs in the uppermost part of the lower member in Section A and in bed B4 (=MJO-4) in Section B (Fig. 6.9). The appearance of *Mosherella newpassensis* (Mosher, 1968) and *Metapolygnathus tadpole* (Hayashi, 1968) occurs in Section A and B about 6 m above the base of the middle member, within the *Daxatina* sp. A zone (Fig. 6.9). This conodont association is typical of the younger *Daxatina* faunas in British Columbia, and is referred to the *tadpole* Zone (Orchard, 2007; Orchard & Balini, 2007). The ranges of *M. newpassensis* and of *Frankites sutherlandi* partially overlaps both in British Columbia and in South Canyon.

The biochronologically useful pelagic bivalves occurring in the *Daxatina* sp. A zone are referred by Balini et al. (2007) to *Daonella*? cf. *D. elegans* McLearn, and they are most closely related to *Daonella elegans* McLearn. Although the precise Canadian locality and age of the types of *D. elegans* are not well constrained, this species is reported by Tozer (1967) at several levels within the type locality of the Sutherlandi Zone.

The *Trachyceras desatoyense* zone and the *Trachyceras* sp. B zone of South Canyon are correlated with the Canadian Desatoyense Zone. Although the Canadian specimens are poorly preserved, the suture line and the external morphology of some specimens (e.g. Tozer, 1994, pl. 89, fig. 4; pl. 90, fig. 1; fig. 72c) are similar to *Trachyceras desatoyense* (Johnston) occurring in the *Trachyceras desatoyense* interval zone of South Canyon.

Conodont faunas of Section D(2), occurring in the *Trachyceras desatoyense* interval zone, are dominated by *Mosherella newpassensis*, while metapolygnathids are absent. These faunas document the *tadpole* Zone, known to embrace the Canadian Desatoyense Zone (Orchard & Balini, 2007).

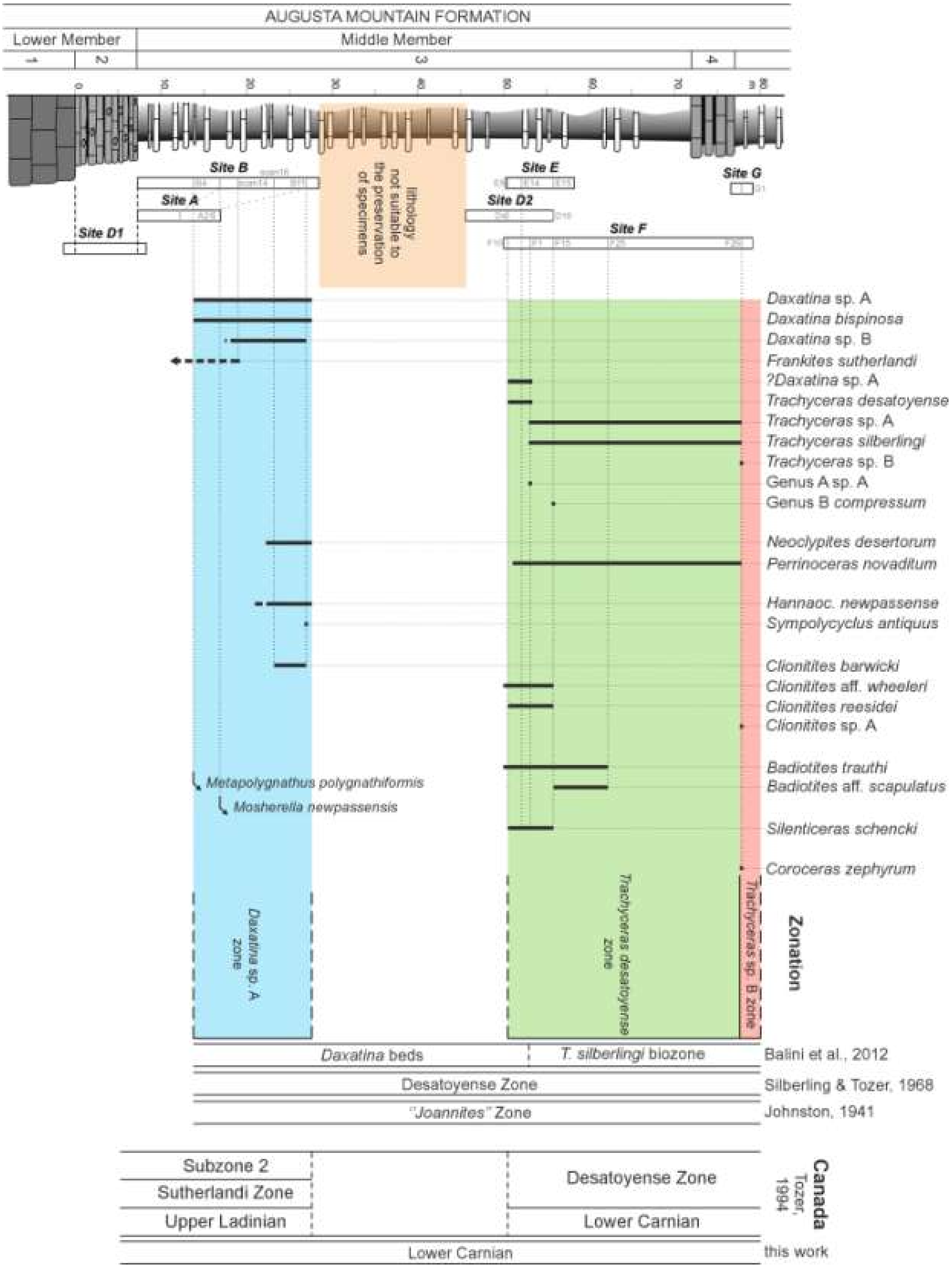


***Fig. 6.9** – Correlation between South Canyon and the Canadian successions. The Daxatina sp. A zone is correlated with the uppermost part of the Sutherlandi Subzone 2; the Trachyceras desatoyense zone and the Trachyceras sp. B zone are correlated with the Canadian Desatoyense Zone.*

6.3 - Correlation between South Canyon and the Tethys

6.3.1 – The Carnian GSSP at Prati di Stuores (Dolomites, Italy)

The GSSP of the base of the Carnian Stage is defined in the Prati di Stuores section (Dolomites, Italy) (Fig.6.10-.11). Here Mietto et al. (2008; 2012) recognize the Protrachyceras Zone, with the Regoledanus Subzone, and the Trachyceras Zone, with the Canadensis and Aon subzones.

The selected marker bioevent is the FO (First Occurrence) of the ammonoid *Daxatina canadensis* in bed SW4 (Mietto et al., 2008; 2012), which marks the lower boundary of the Trachyceras Zone and of the Canadensis Subzone. Conodont faunas are sparse and composed by the genera *Budrovignatus*, *Gladigondolella* and *Paragondolella*. The FO of *Paragondoloella polygnathiformis* is the GSSP secondary marker bioevent. It occurs in bed SW4c (Mietto et al., 2012), 70 cm above the FO of *Daxatina canadensis*.

The FO of *Trachyceras muensteri*, documenting the FO of *Trachyceras*, is reported (Mietto et al., 2008; 2012) less than 34 meters above the FO of *Daxatina canadensis*. These two species co-occurs for about 80 meters of the succession. *Trachyceras muensteri* from the Canadensis Subzone show a subammonitic suture line (Mietto et al., 2008, fig. 9g). *T. muensteri* from the Aon Subzone show a suture line similar to that of *T. aon* (see Urlichs, 1994, fig. 5h and 5a), and the ammonitic suture line figured by Mojsisovics (1882, pl. 21, fig. 20) is attributed by Urlichs (1994, p. 23) to *T. muensteri*.

From the analysis of the literature we have observed that the ammonoid faunas from the Canadensis Zone of Prati di Stuores are relatively meagre (Fig. 6.12), and the productivity of a single bed is very low. Moreover the preservation of the material is not very good. In particular the suture line, the best feature for the distinction of *Trachyceras* from *Daxatina*, is hardly visible. Mietto et al. (2008) report nine sutures (Mietto et al., 2008, fig. 9), of which only two for *Daxatina canadensis* and only one for *Trachyceras muensteri*.

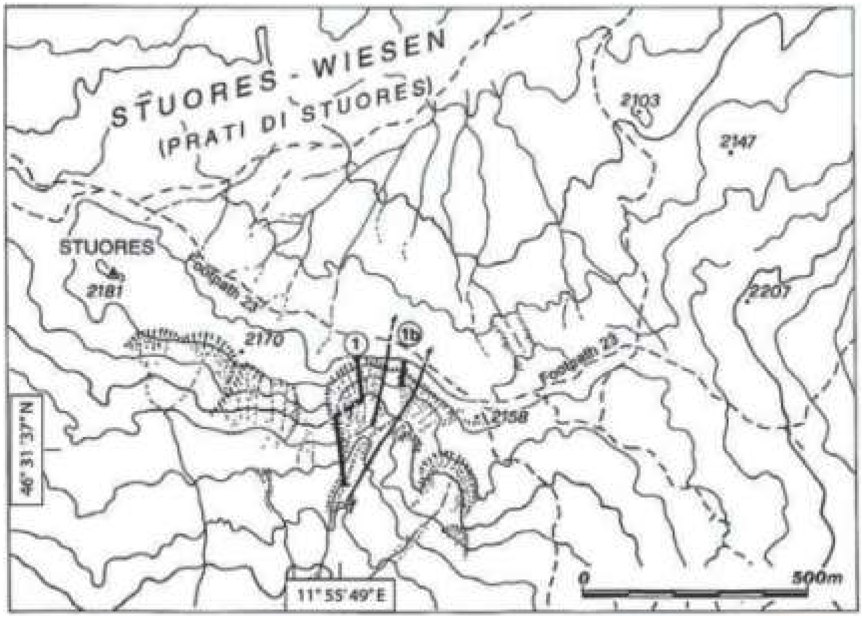


Fig. 6.10 – Location map of the Prati di Stuores section, Dolomites, Italy (from Mietto et al., 2012).

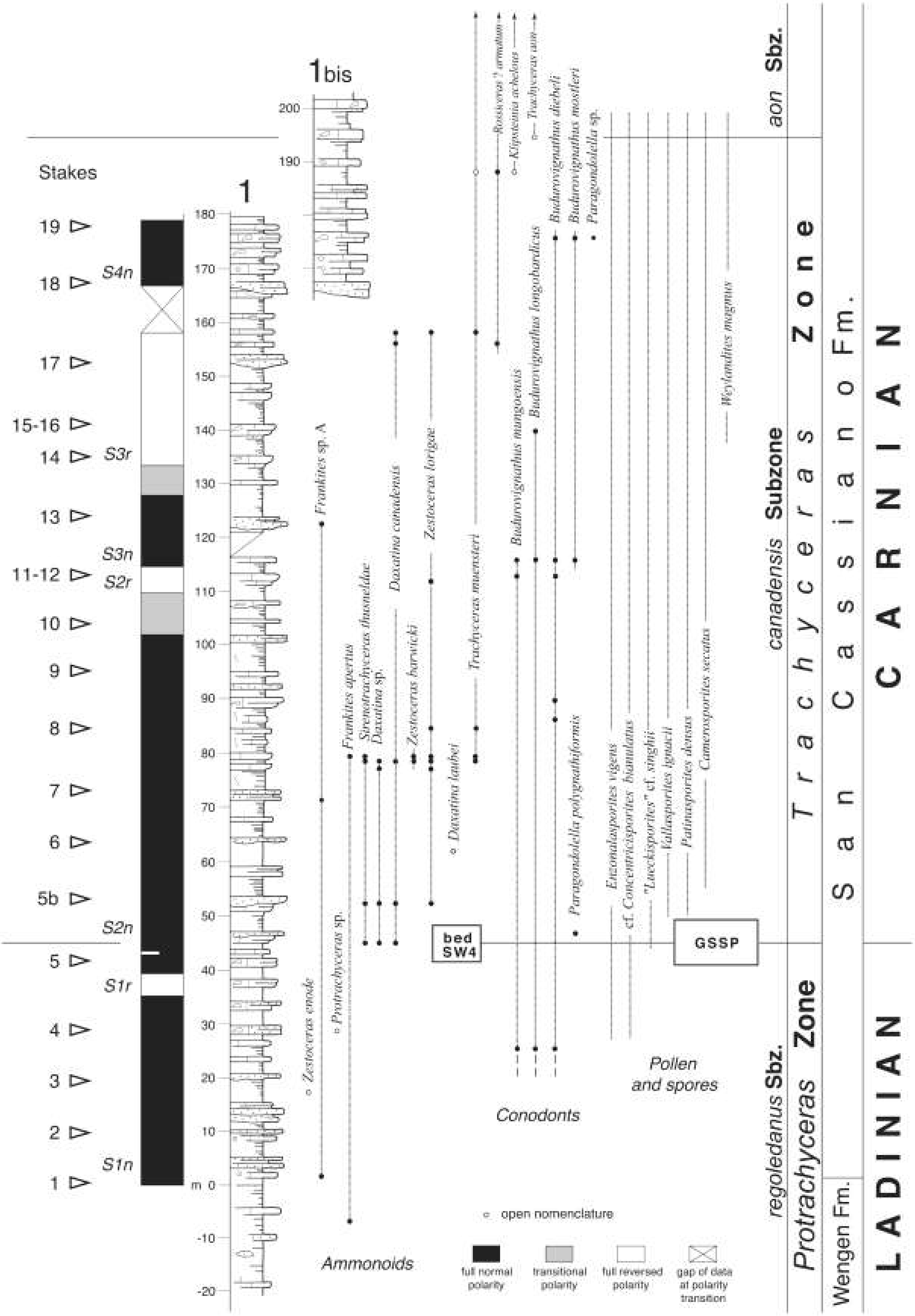


Fig. 6.11 – The GSSP section of Prati di Stuores (Dolomites, Italy). (from Mietto et al., 2012).

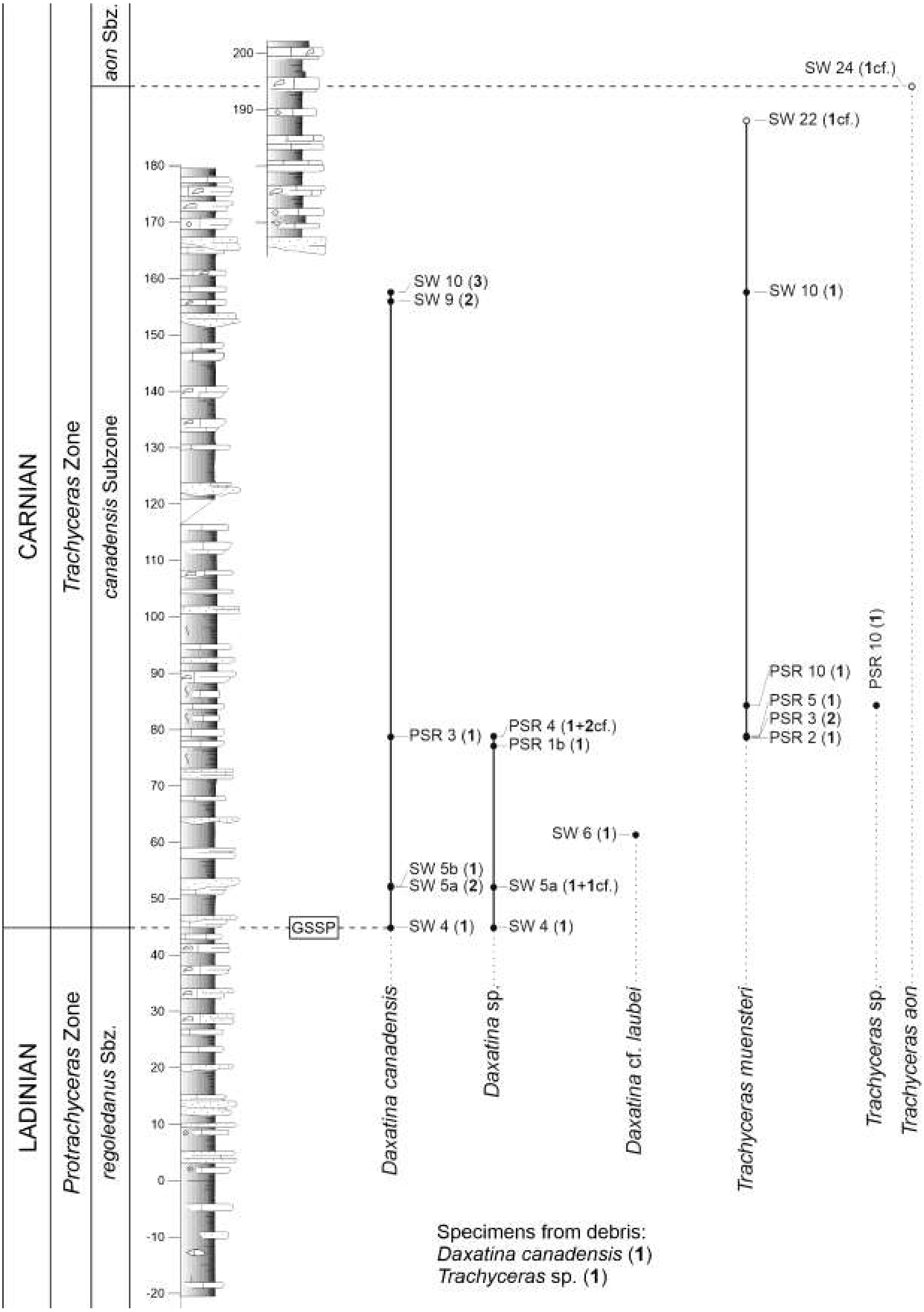


***Fig. 6.12** – Stratigraphic section of Prati di Stuores with range chart showing the distribution of species attributed to Trachyceras and Daxatina. Numbers in brackets refer to the number of specimens. Data are taken from Mietto et al., 2008.*

Bivalves of the Canadensis Subzone of Prati di Stuores are mainly represented by posidonioids, referred by Broglio Loriga et al. (1999) and Mietto et al. (2012) to "*Posidonia*" *wengensis* (Wissmann), "*Posidonia*" cf. *wengensis* and ?*Halobia* sp. Data on foraminifers, microcrinoids and holoturian sclerites are reported in Broglio Loriga et al. (1999). Foraminifera are reported to be of Carnian affinity, microcrinoids and holoturian sclerites are common to the Canadensis Subzone and extends into the Aon Subzone. Palynomorph data point out the presence of typical upper Ladinian – Lower Carnian sporomorphs (Mietto et al., 2012). The Prati di Stuores Section has been investigated for carbon and oxygen stable isotope variations and for magnetostratigraphy (Broglio Loriga et al., 1999; Mietto et al., 2012).

6.3.2 – The Aon Subzone of the Dolomites

The ammonoid record of the Aon Subzone of the Dolomites has been investigated with a bed-by-bed approach by Urlichs (e.g. 1974; 1977; 1994; 2004; 2012; 2017). The successions studied by Urlichs (Fig. 6.13-.14) are stratigraphically higher than the GSSP section of Prati di Stuores, and constitute part of the historical localities attributed to the Aon Zone in literature (e.g. Mojsisovics, 1882). Some of the most important genera occurring in these successions are *Trachyceras* Laube, *Brotheotrachyceras* Urlichs, *Sirenotrachyceras* Krystyn, *Muensterites* Mojsisovics and *Klipsteinia* Mojsisovics (Fig. 6.14).

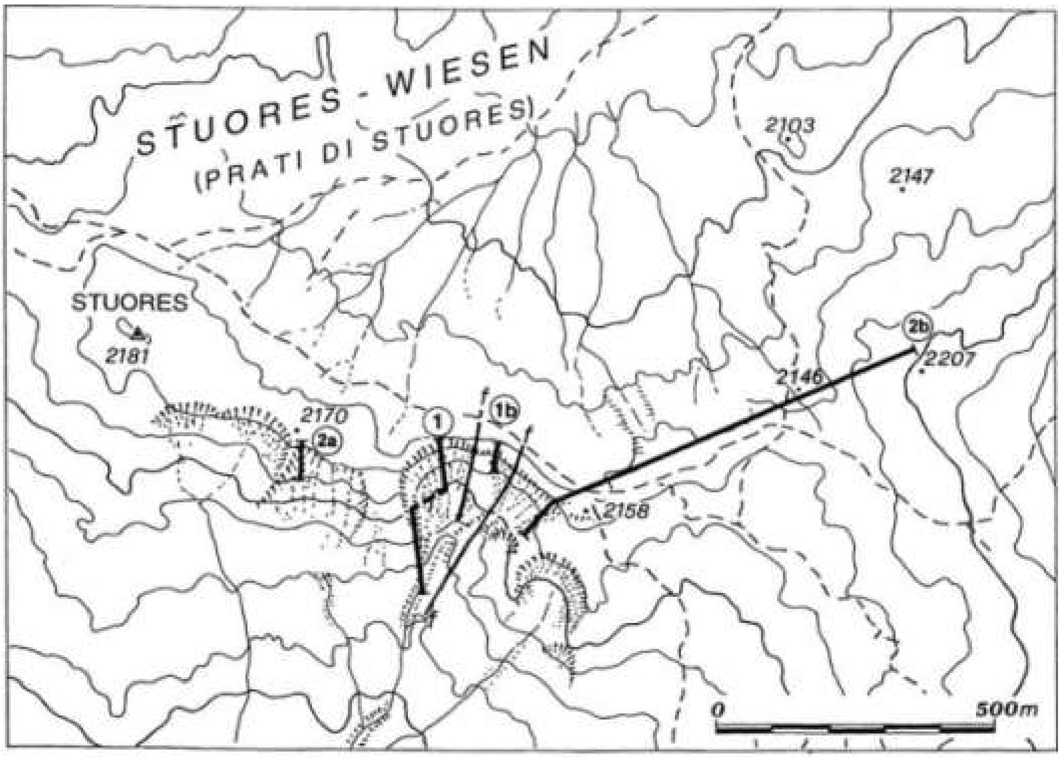


Fig. 6.13 *– Location map of the Prati di Stuores area and the sections studied in literature. Section 1 and 1b: GSSP Ladinian/Carnian of Mietto et al., 2008. Section 2a: Prati di Stuores faunas 1a-b of Urlichs, 1994. Section 2b: Prati di Stuores faunas 2-20 of Urlichs, 1994 (from Urlichs, 2012).*

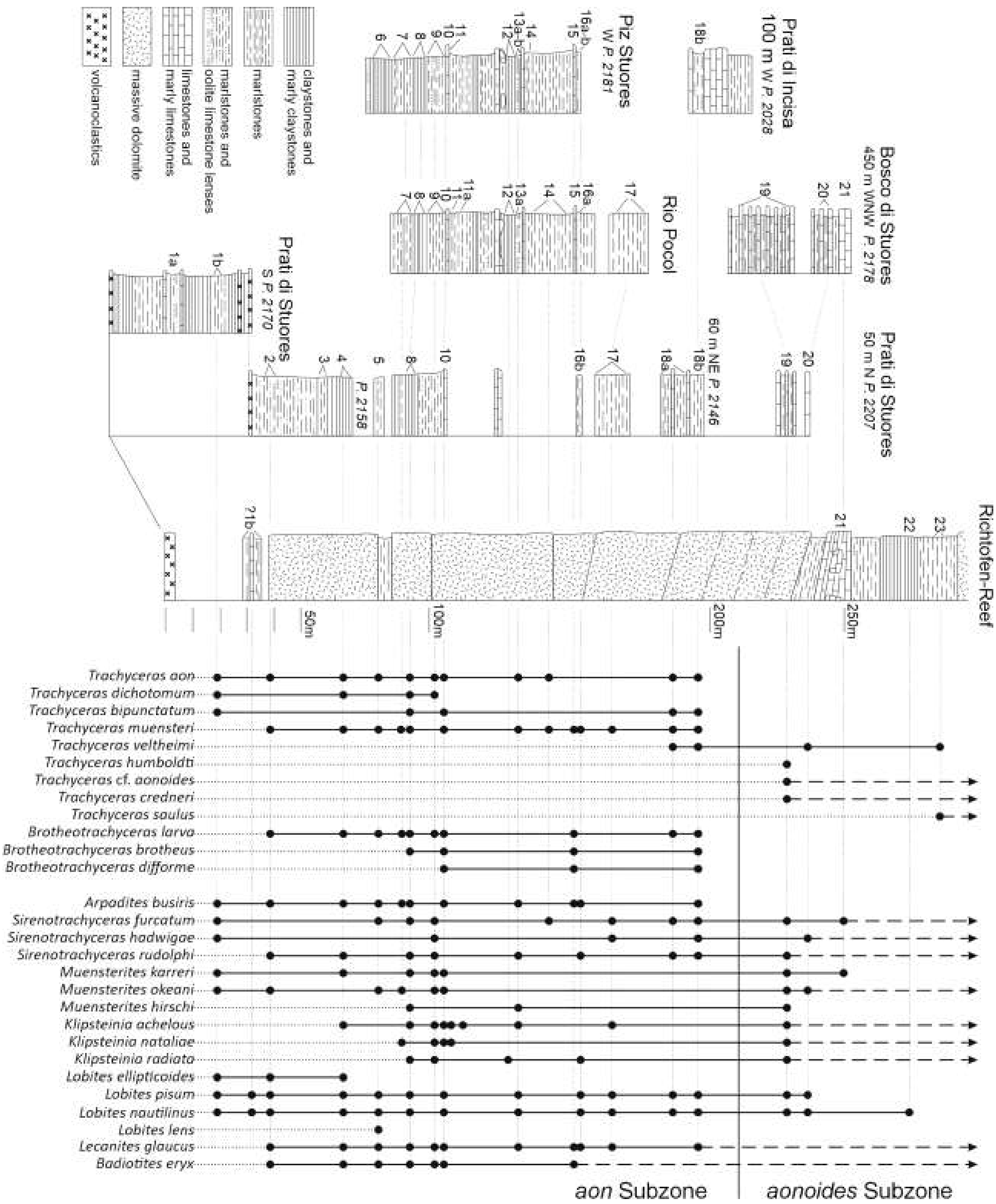


***Fig. 6.14** – Ranges of some of the most important ammonoid taxa in the Aon and early Aonoides Subzones from the surroundings of St. Cassian/Dolomites, arrows at the stratigraphic occurrence indicate survival into late Aonoides Subzone (modified after Urlichs, 1994; 2004; 2017).*

6.3.3 – Correlation

The *Daxatina* sp. A zone of South Canyon shows an overall faunal similarity with the Tethyan Canadensis Subzone (Fig. 6.15-.16). The suture line and the external morphology of specimens attributed to *Trachyceras muensteri* by Mietto et al. (2008) could fall within the variability of the South Canyon *Daxatina*. *Frankites* occurs both in the *Daxatina* sp. A zone and in the Tethyan Canadensis Subzone. At South Canyon the FO of *Daxatina*, and probably also the FO of *Metapolygnathus polygnathiformis*, are influenced by the lithologic change between Lower and middle member.

The ammonoid faunas of the *Trachyceras desatoyense* and *Trachyceras* sp. B zones of South Canyon show similarities with the Tethyan Aon Subzone (e.g. Krystyn, 1978; Urlichs, 1994) (Fig. 6.15,-.16). The South Canyon *Trachyceras* show ribs with a symmetric cross section, a typical feature of the Tethyan *Trachyceras* gr. *aon* (Krystyn, pers. comm. 2019). Genus A and Genus B occurring at South Canyon are not present in the Tethyan sections. *Brotheotrachyceras*, *Sirenotrachyceras*, *Muensterites* and *Klipsteinia* are some important genera occurring in the Tethyan sections, but are absent in South Canyon. The occurrence of *Coroceras* in the Dolomites is documented in the late Aonoides Zone by Urlichs (1994, fig. 6). In other Tethyan sections *Coroceras* is documented also from the base of the Aon Subzone (Krystyn, 1978, fig. 13), therefore the FO of *Coroceras* at South Canyon is a late occurrence.

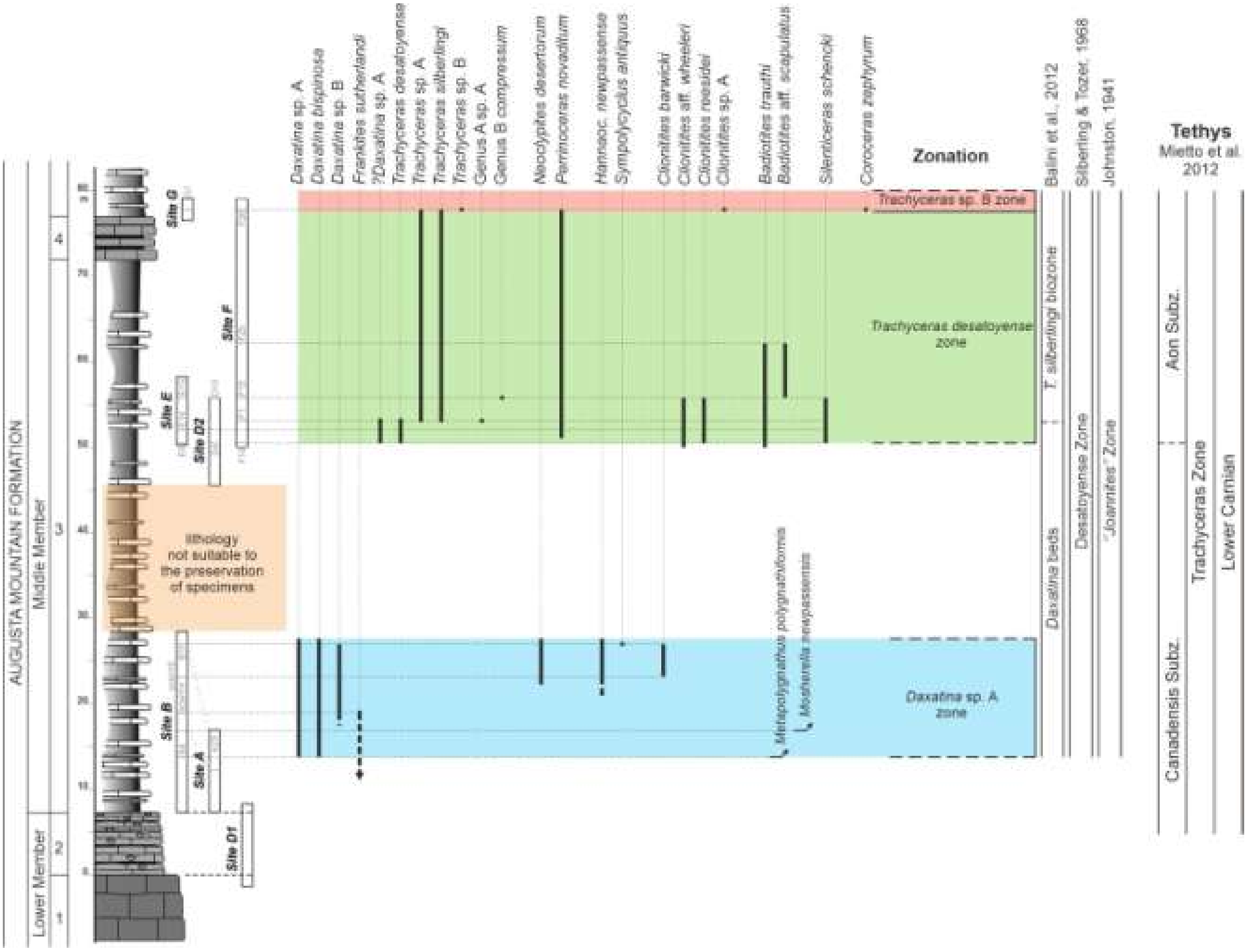


Fig. 6.15 – Correlation between South Canyon and the Tethys. The Daxatina sp. A zone is correlated with the Canadensis Subzone; the Trachyceras desatoyense zone and the Trachyceras sp. B zone are correlated with the Tethyan Aon Zone.

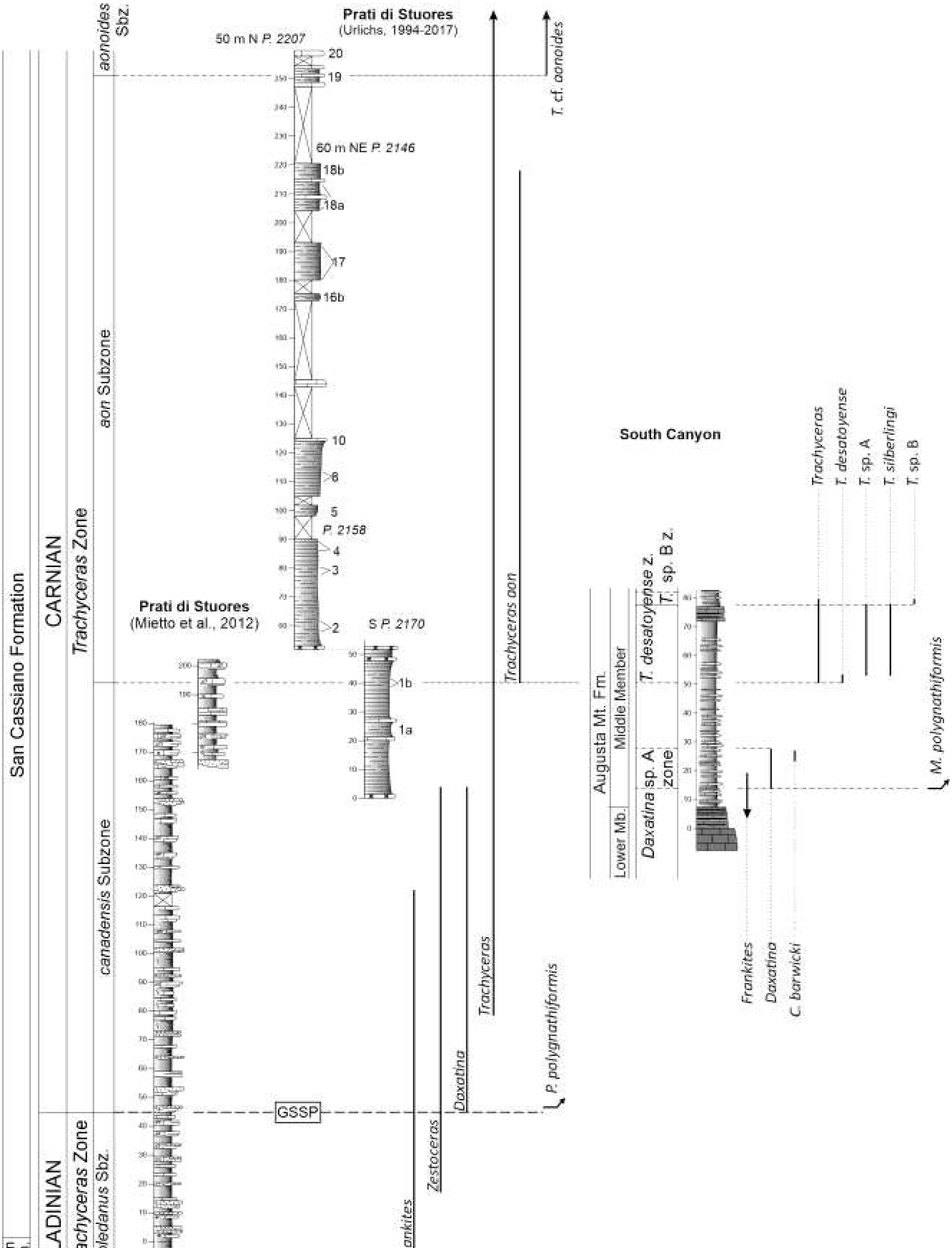


***Fig. 6.16** – Correlation between the Tethyan successions of Prati di Stuores and the North American succession of South Canyon (stratigraphic logs of the Tethyan successions modified after Mietto et al., 2008 and Urlichs, 2017).*

Chapter 7

Conclusions

The results achieved with this thesis are the following:

- A collection of 3130 Early Carnian ammonoids from the locality of South Canyon has been studied. These specimens have been bed-by-bed collected from 103 fossiliferous beds in six stratigraphic sections.
- The systematic study led to the recognition of 29 taxa, 10 of which are new. These taxa belong to 18 genera, two of which are new: *Neoclypites*, *Sageceras*, *Perrinoceras*, *Badiotites*, *Procladiscites*, *Arcestes*, *Joannites*, *Silenticeras*, *Frankites*, *Daxatina*, *Trachyceras*, Genus A, Genus B, *Clionitites*, *Sympolycyclus*, *Hannaoceras*, *Lobites* and *Coroceras*. Ammonoids of the Subfamily Trachyceratinae are the most abundant.
- The variability of the suture lines has been studied in detail. This study leads to identify a main evolutionary trend of complication of the suture line, recognized within the Subfamily Trachyceratinae.
- The Desatoyense Zone sensu Silberling & Tozer (1968), an Oppel Zone, has been revised and divided into three zones, based on range charts. These zones are in stratigraphic order: the *Daxatina* sp. A range zone, the *Trachyceras desatoyense* interval zone and the *Trachyceras* sp. B range zone. Correlations of these three zones are discussed at the North American and global level.
- The *Daxatina* sp. A zone, characterized by the occurrence of *Frankites sutherlandi* and three species of *Daxatina*, is correlated with the upper part of the Sutherlandi Subzone 2 of British Columbia, and with the Tethyan Canadensis Subzone.
- The *Trachyceras desatoyense* zone is characterized by the occurrence of three species of *Trachyceras* and two new genera belonging to the Subfamily Trachyceratinae. This zone is correlated with the Desatoyense Zone of British Columbia and the Tethyan Aon Subzone.
- In the *Trachyceras* sp. B zone occur *Trachyceras* with highly indented suture lines and *Coroceras*. Also this zone is correlated with the Desatoyense Zone of British Columbia and the Tethyan Aon Subzone.
- A collection of 681 Early Carnian ammonoids, from two new fossiliferous localities in the area of China Mountain has been studied. These localities provide further data to constrain the earliest Carnian North American ammonoid scale.
- The systematic study of this collection led to the recognition of 8 taxa, 3 of which are new: Genus B sp. A, Genus B sp. B, Genus B sp. ind., ?*Trachyceras* sp. ind., *Perrinoceras novaditum*, *Badiotites* aff. *scapulatus*, *Silenticeras schencki*, *Clionitites reesidei*.
- The China Mountain faunas are largely dominated by two new species of Genus B, that are not documented at South Canyon.
- The widespread occurrence of Genus B, with very rare *Perrinoceras*, *Silenticeras*, *Clionitites* and ?*Trachyceras*, suggest a correlation of the China Mountain fossiliferous interval with the lower part of the *Trachyceras desatoyense* zone recognized at South Canyon. This datum is crucial for the age constraining of the China Mountain succession and, in turn, for the time

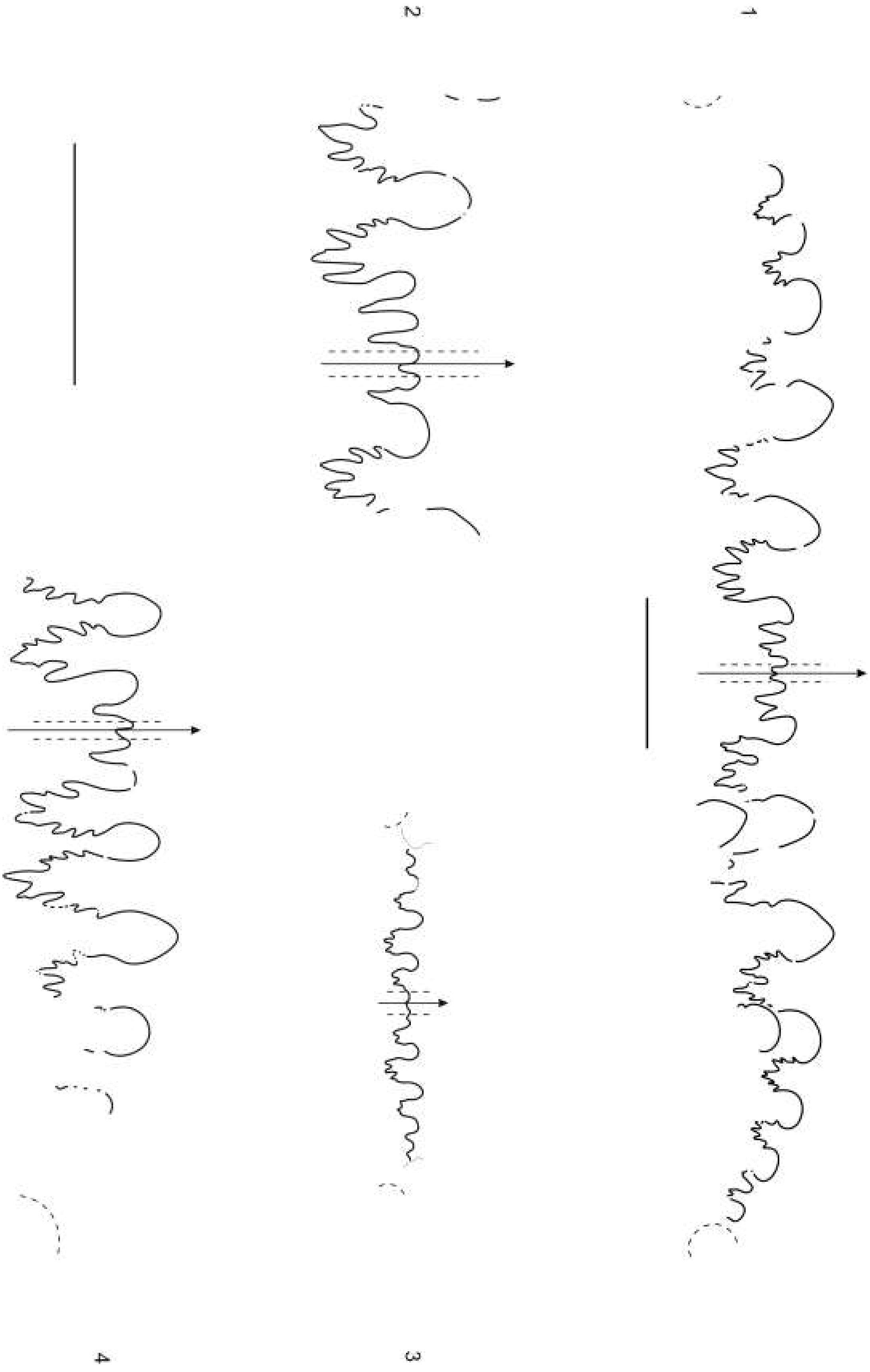
calibration of the sedimentary evolution of the western active margin of North America during the Early Carnian time.

- All the taxa belonging to the Subfamily Trachyceratinae occurring at South Canyon and China Mountain show a complex test structure, called “preseptal layer” in the literature. The morphological study of this test structure has proved useful for the classification at the genus level.
- The ammonoid faunal composition in the South Canyon succession is characterized by a great abundance of Trachyceratinae and the occurrence of abrupt variations in the relative abundance of taxa at the family/subfamily rank. A possible explanation of this record implies a change in paleoecologic and/or paleoenvironmental condition, such as position of the redox boundary in respect of the seafloor, or of the structure of the food chain. Further sedimentologic and paleontologic studies are needed for a better characterization of the paleoenvironmental and paleoecologic conditions.

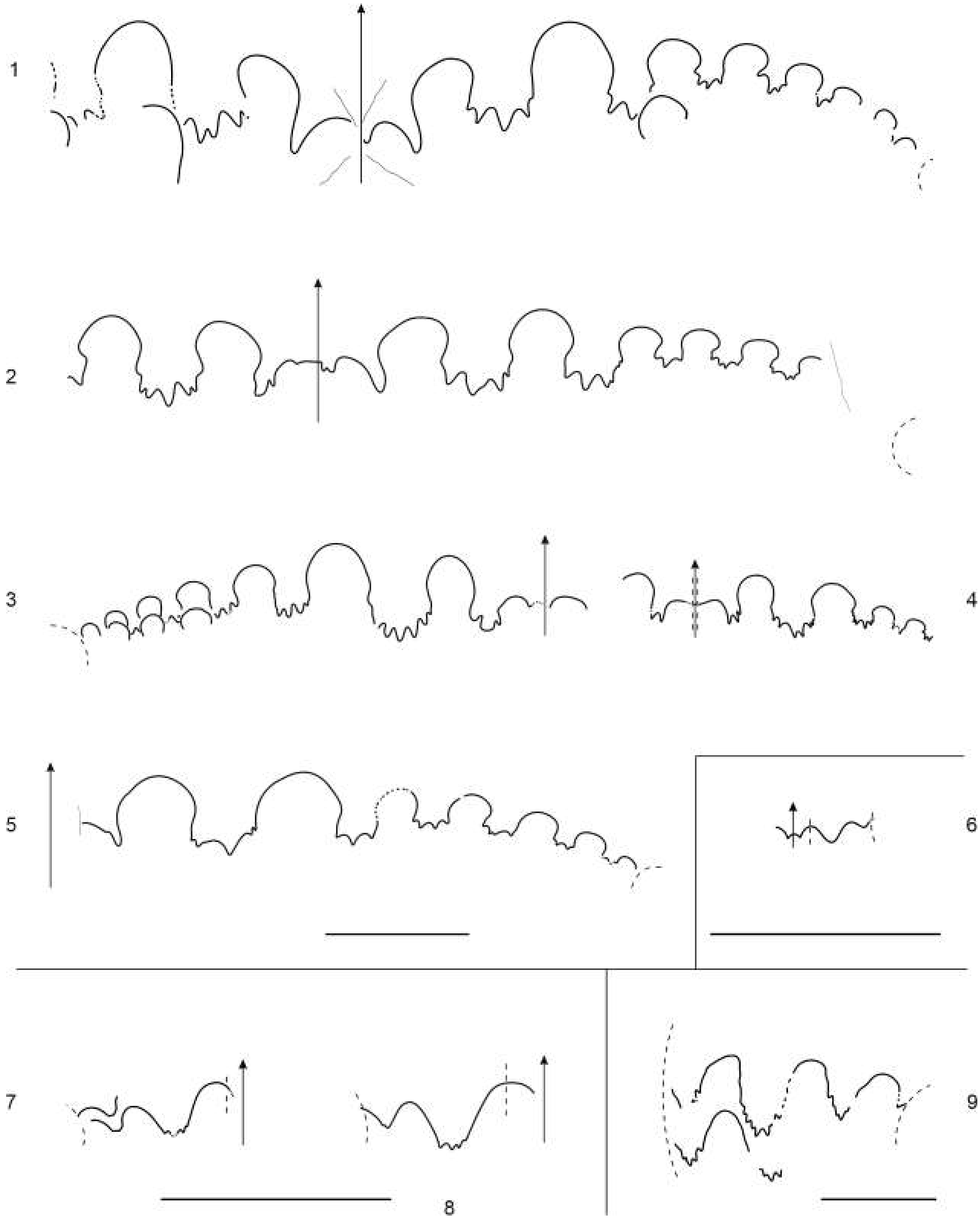
Chapter 8

Appendix and References

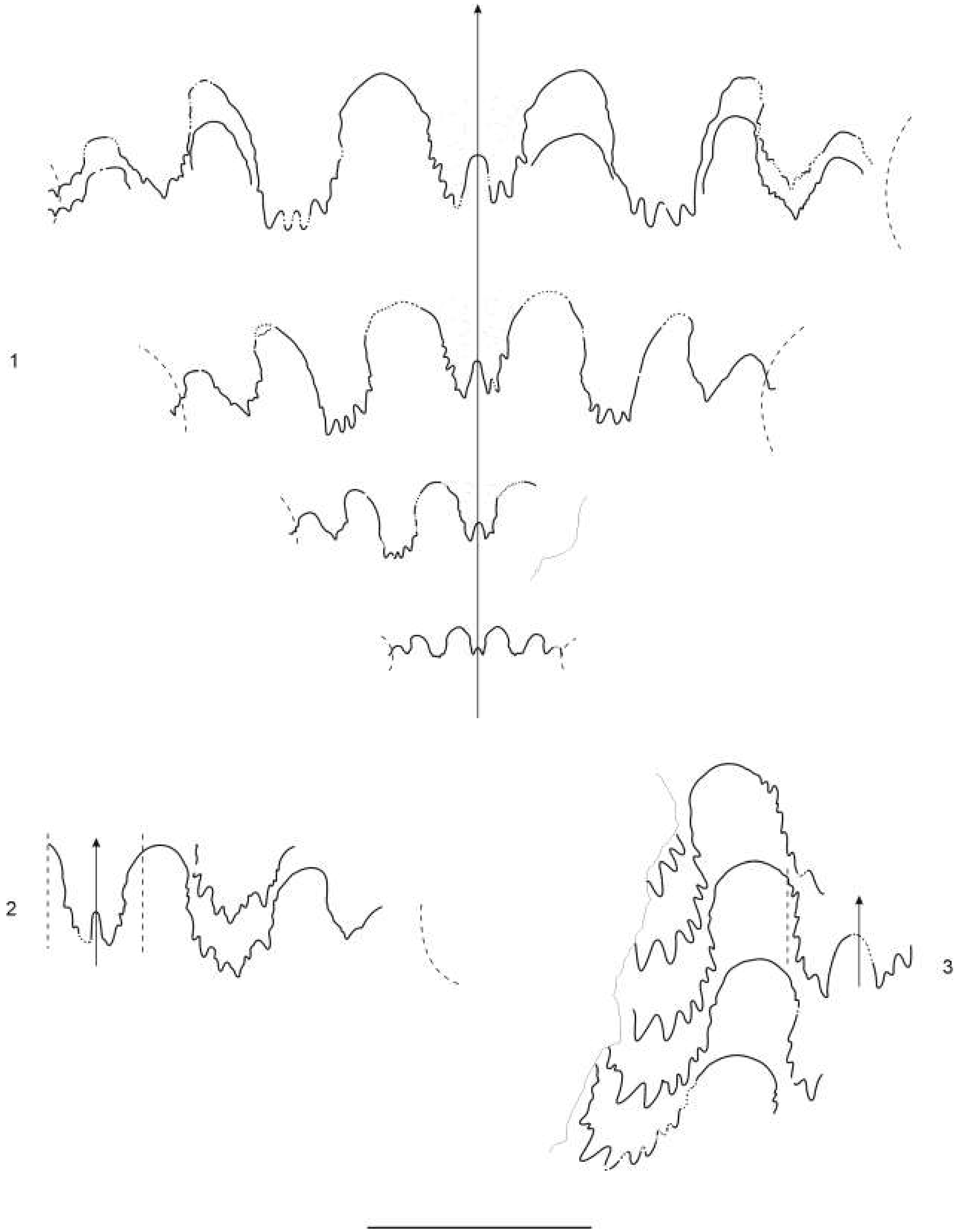
8.1 - Text Figures



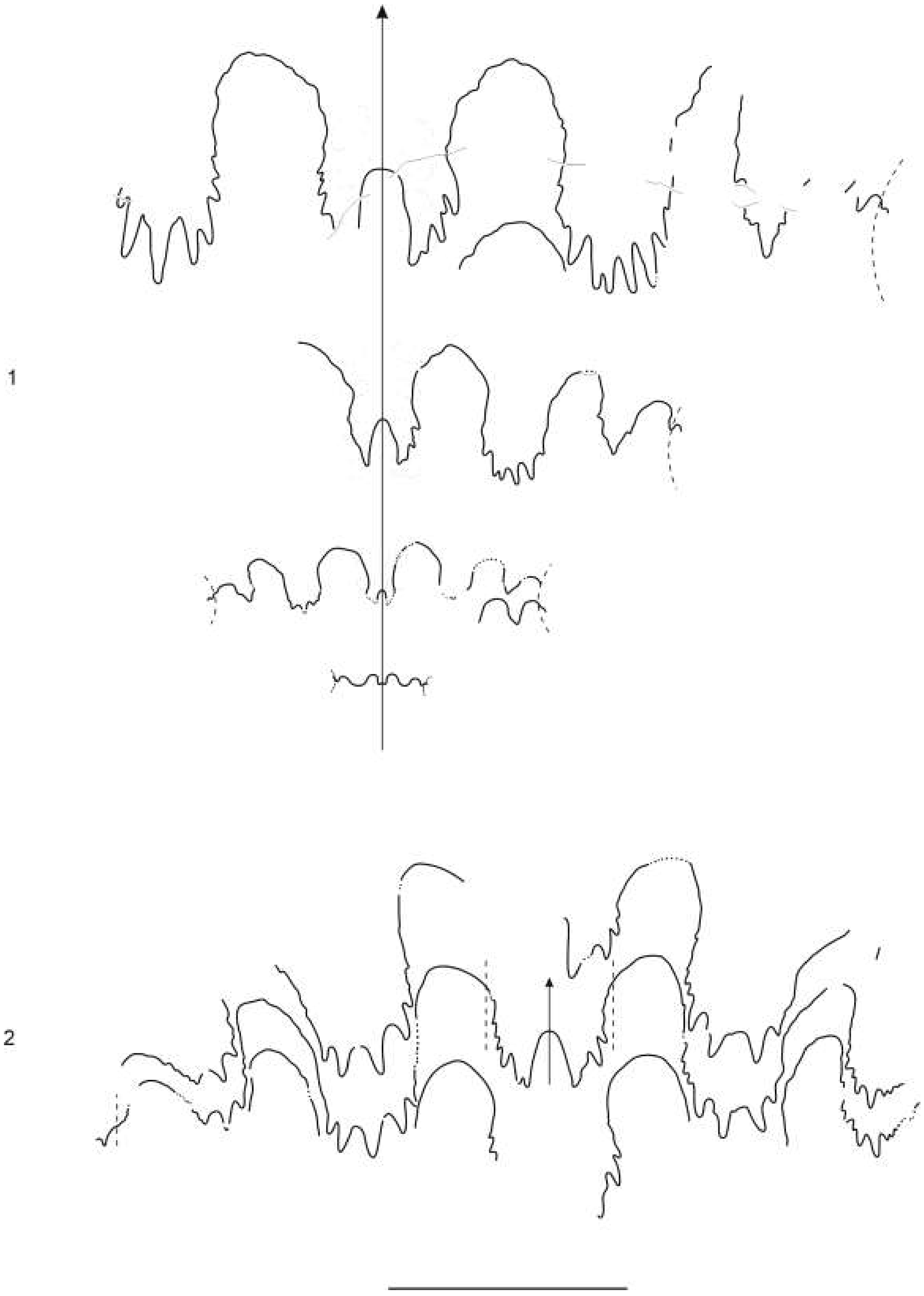
Textfig. 1. 1-3 – Suture lines of *Neoclypites desertorum* (Johnston, 1941) from South Canyon. **1** – USNM 77518c, H=35mm. **2** – A21-3, H=26mm. **3** – scan16-197, H=7mm. **4** – A22-10, H=19mm. Bar scales are 10mm.



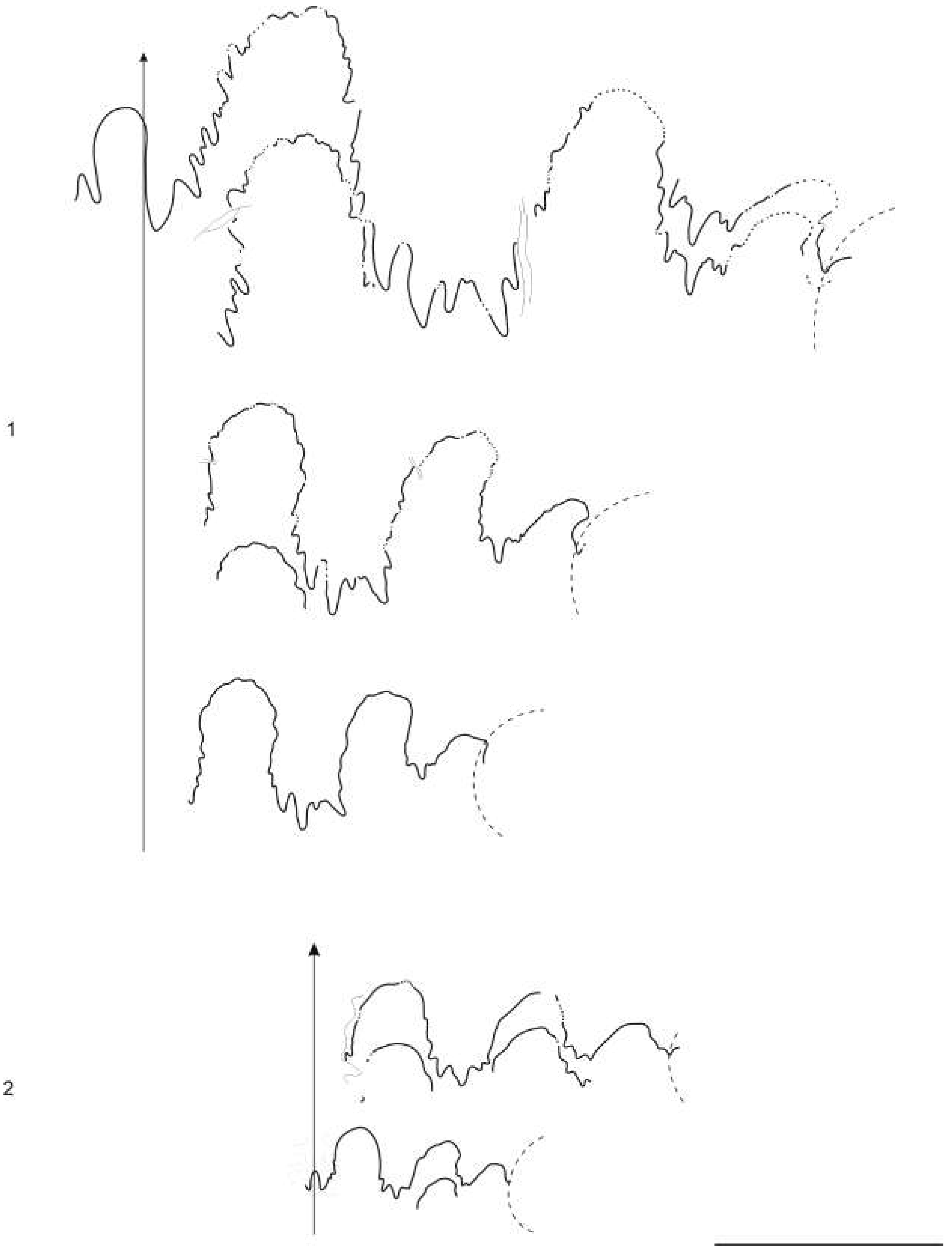
Textfig. 2. 1-5 – Suture lines of *Perrinoceras novaditum* Johnston, 1941, 1-4 from South Canyon, 5 from China Mountain. **1** – Holotype USNM 77516a, H=36.5mm. **2** – F26-74, H= 40mm. **3** – F1-46, H=32mm. **4** – E18.1-59, H=24mm. **5** – CHM49-14, H=42mm. **6** – *Badiotites trauthi* (Johnston, 1941) from South Canyon, Holotype USNM 77515c, H=3mm. 7-8 – Suture lines of *Silenticeras schencki* (Johnston, 1941) from South Canyon. **7** – Holotype USNM 77517, H=6.3mm. **8** – D4-40, H=7mm. **9** – *Frankites sutherlandi* (McLearn, 1947), from South Canyon, MPUM 9278(scan15-3) (from Balini, 2008, fig. 6). Bar scales are 10mm.



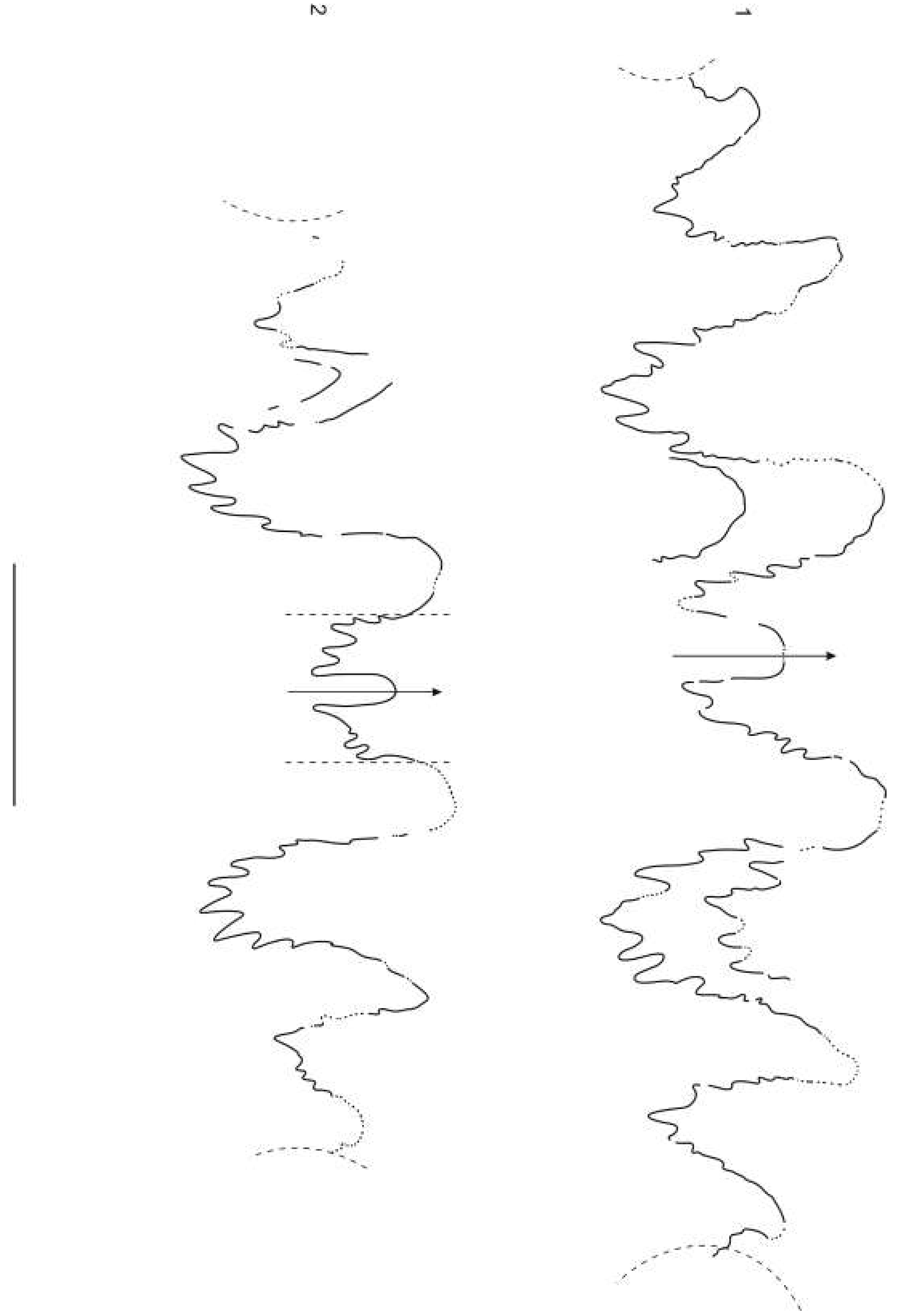
Textfig. 3. Suture lines of *Daxatina* sp. A from South Canyon. **1** – scan16-1, four sutures of the same specimen respectively at H=3.2mm, H=7mm, H=11.7mm; H=16.7mm. **2** – scan16-233, H=11.7mm. **3** – scan16-483, H=19mm. Bar scale is 10mm.



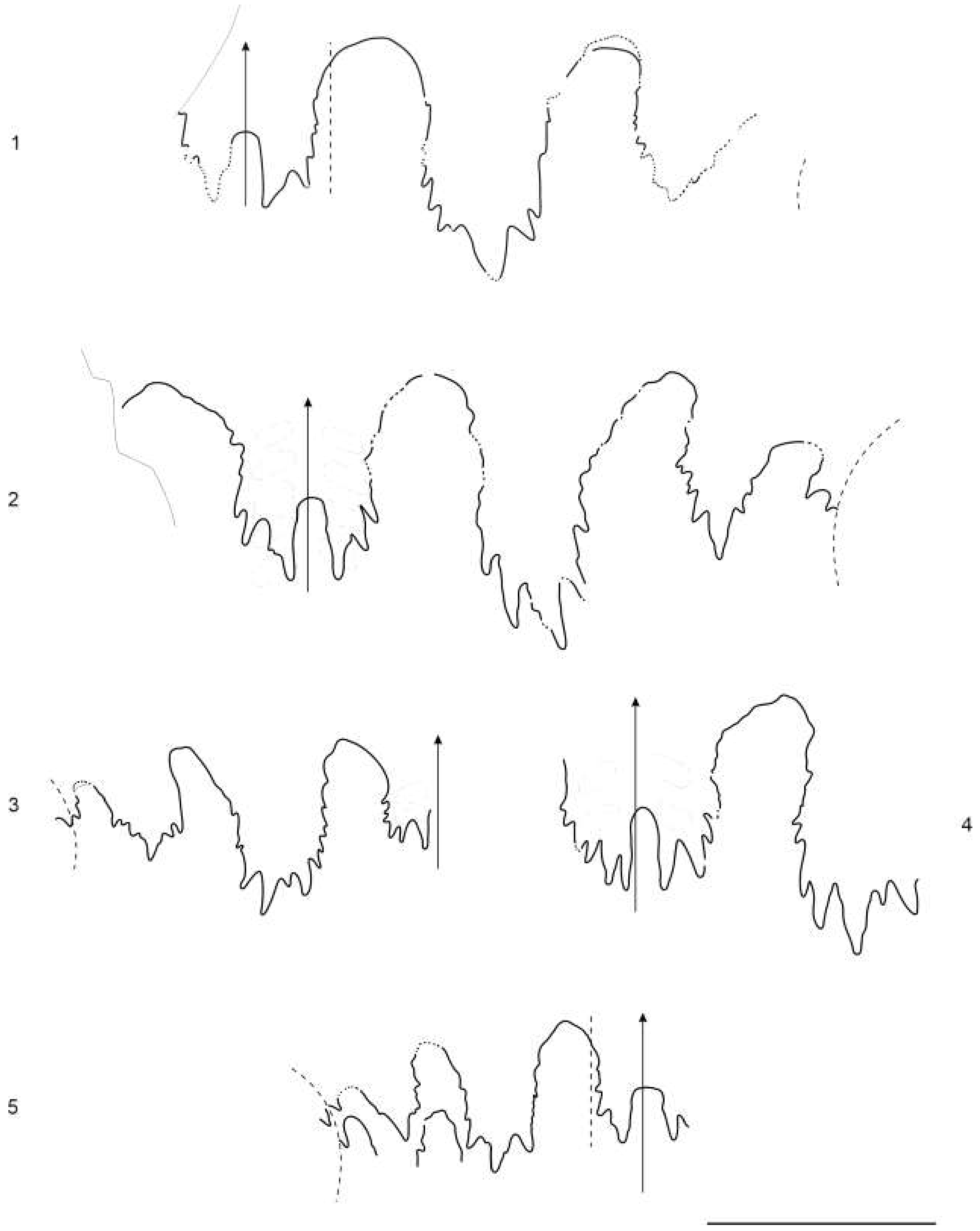
Textfig. 4. Suture lines of *Daxatina* sp. A from South Canyon. **1** – scan16-586, four sutures of the same specimen respectively at H=1.6mm, H=5.8mm, H=10.4mm, H=18.3mm. **2** – scan16-11, H=16.8mm. Bar scale is 10mm.



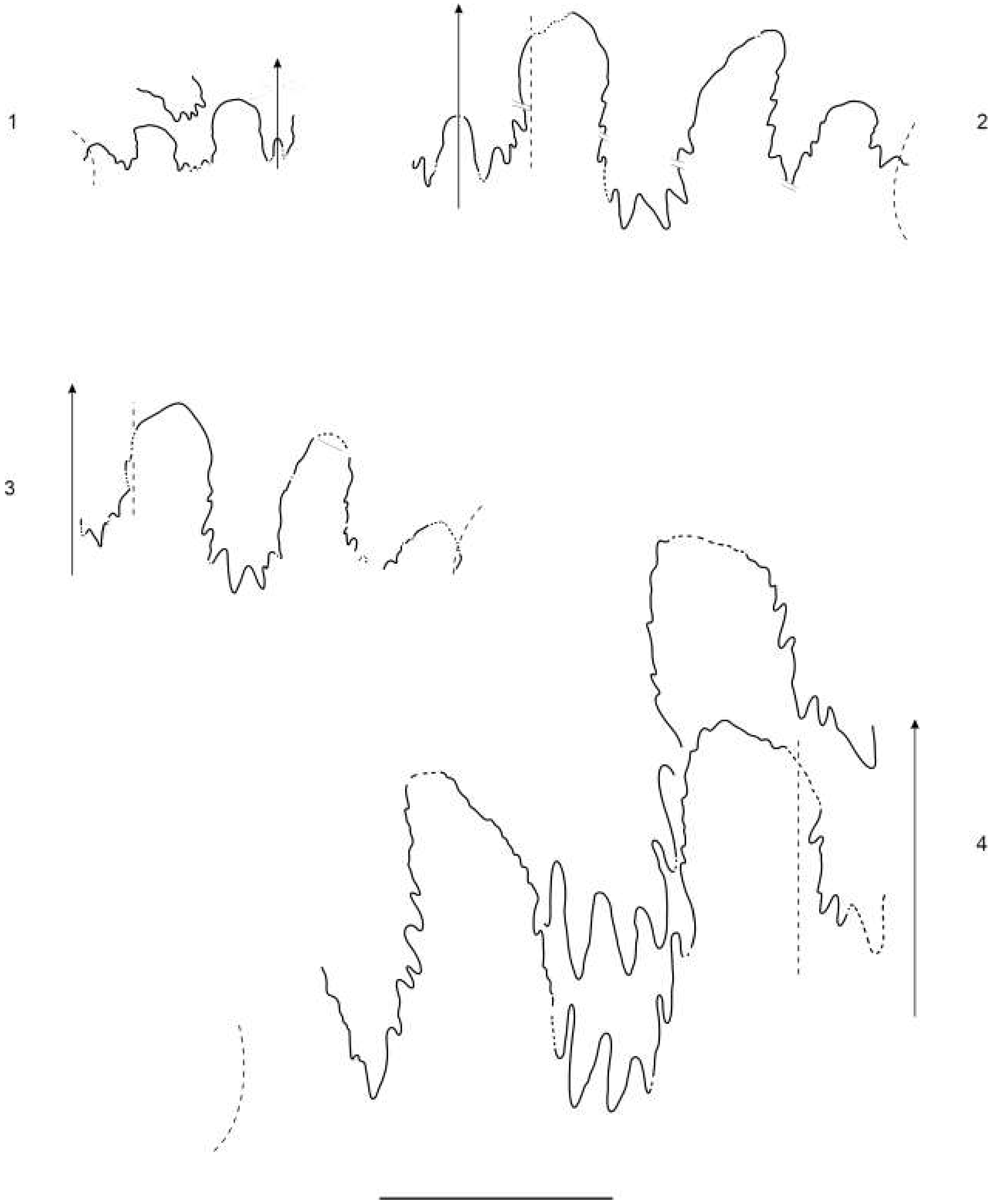
Textfig. 5. Suture lines of *Daxatina* sp. A from South Canyon. **1** – scan16-581, three sutures of the same specimen respectively at H=13mm, H=17.8mm, H=27mm. **2** – scan16-582, two sutures of the same specimen respectively at H=8mm and H=17.7mm. Bar scale is 10mm.



Textfig. 6. Suture lines of *Daxatina* sp. A from South Canyon. **1** – scan16-578, H=21.6mm. **2** – scan16-10, H=17.3mm. Bar scale is 10mm.

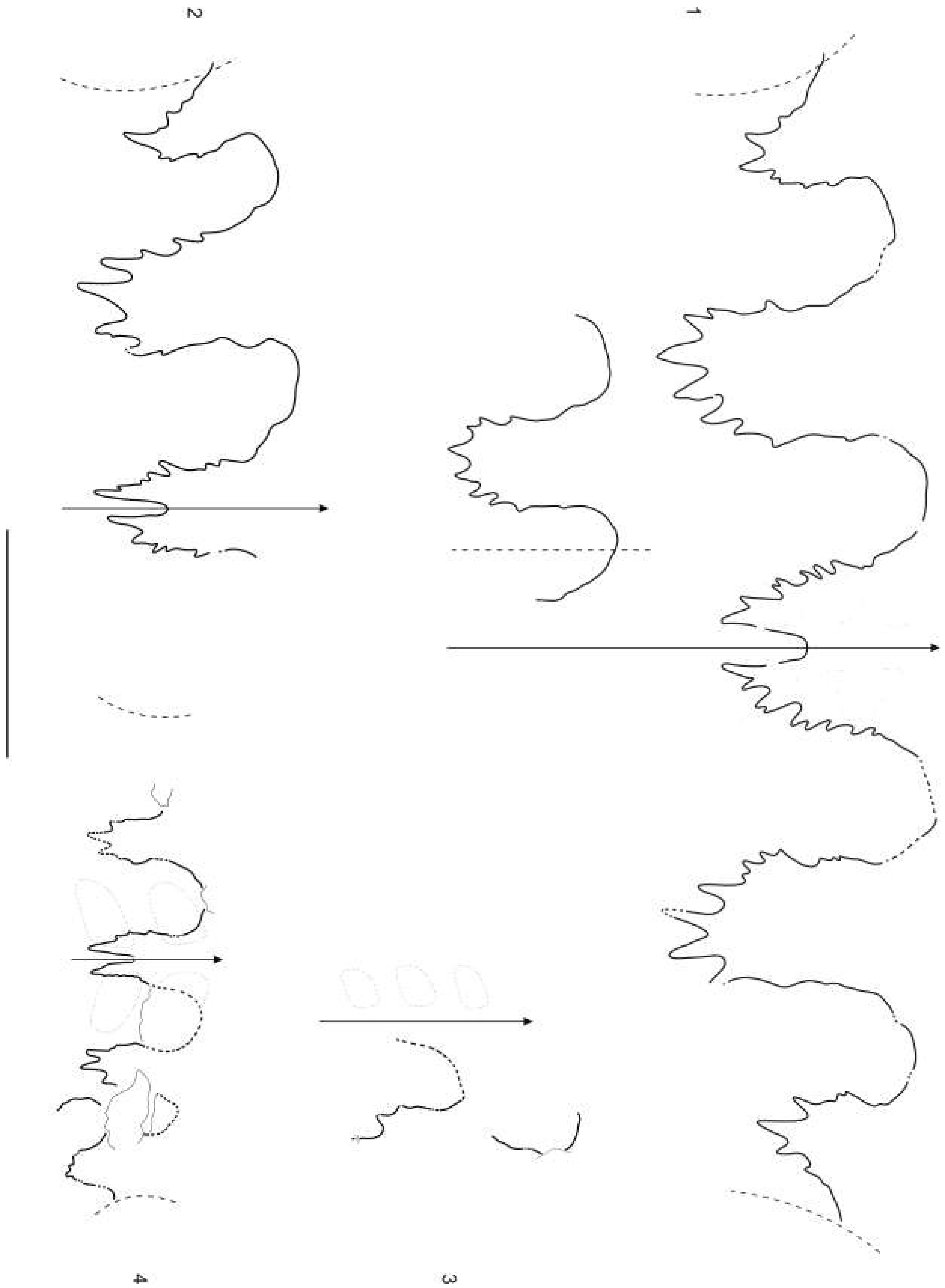


Textfig. 7. Suture lines of *Daxatina* sp. A from South Canyon. **1** – scan16-537, H=20.4mm. **2** – B11-81, H=21mm. **3** – B11-36, H=15mm. **4** – A21-76, H=19.4mm. **5** – A21-38, H=12mm. Bar scale is 10mm.

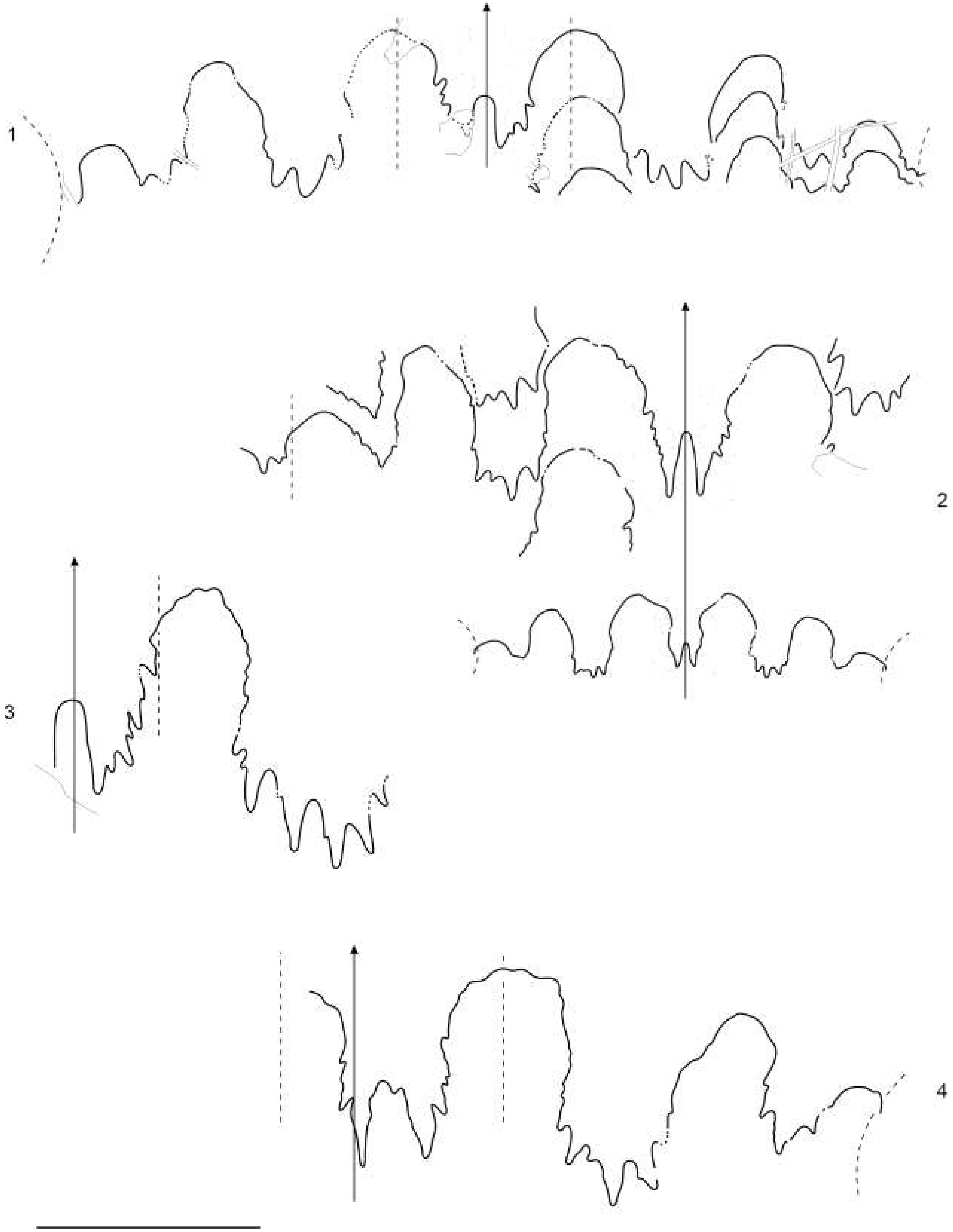


Textfig. 8. Suture lines of *Daxatina* sp. A from South Canyon. **1** – A21-82, H=8mm. **2** – scan3-1, H=18mm. **3** – A21-5, H=15mm. **4** – JJ1-97-8, H=27mm. Bar scale is 10mm.

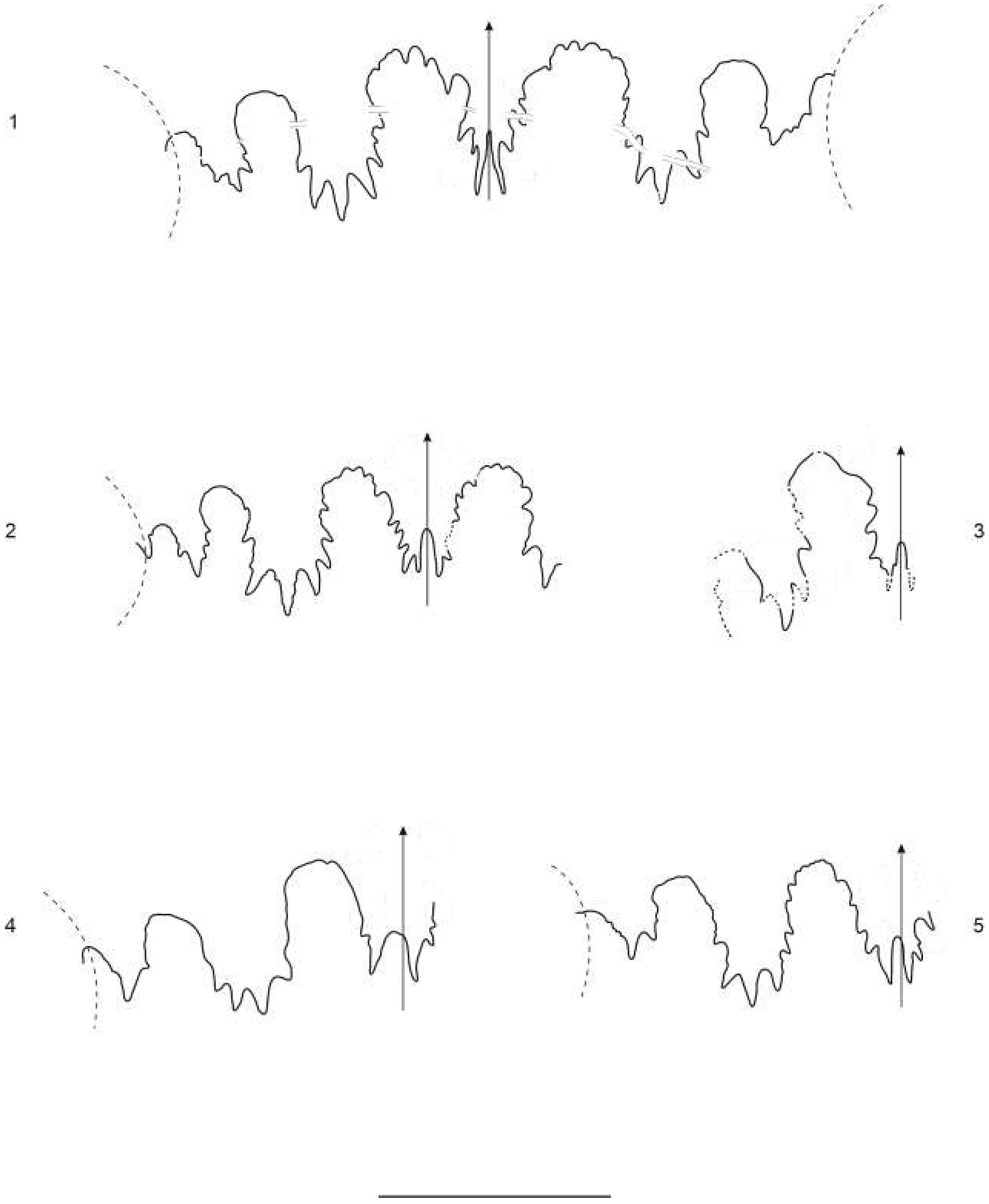
Textfig. 9. Suture lines of *Daxatina* sp. A from South Canyon. **1** – B11-66 (from Balini & Jenks, 2007, fig. 8c). **2** – A22-8 (from Balini & Jenks, 2007, fig. 8a). **3** – USNM 77532b, H=12mm. **4** – USNM 77532a, H=19.5mm. **5** – USNM 128316, H=23mm (=Silberling, 1956, textfig. 2a). Bar scale is 10mm.



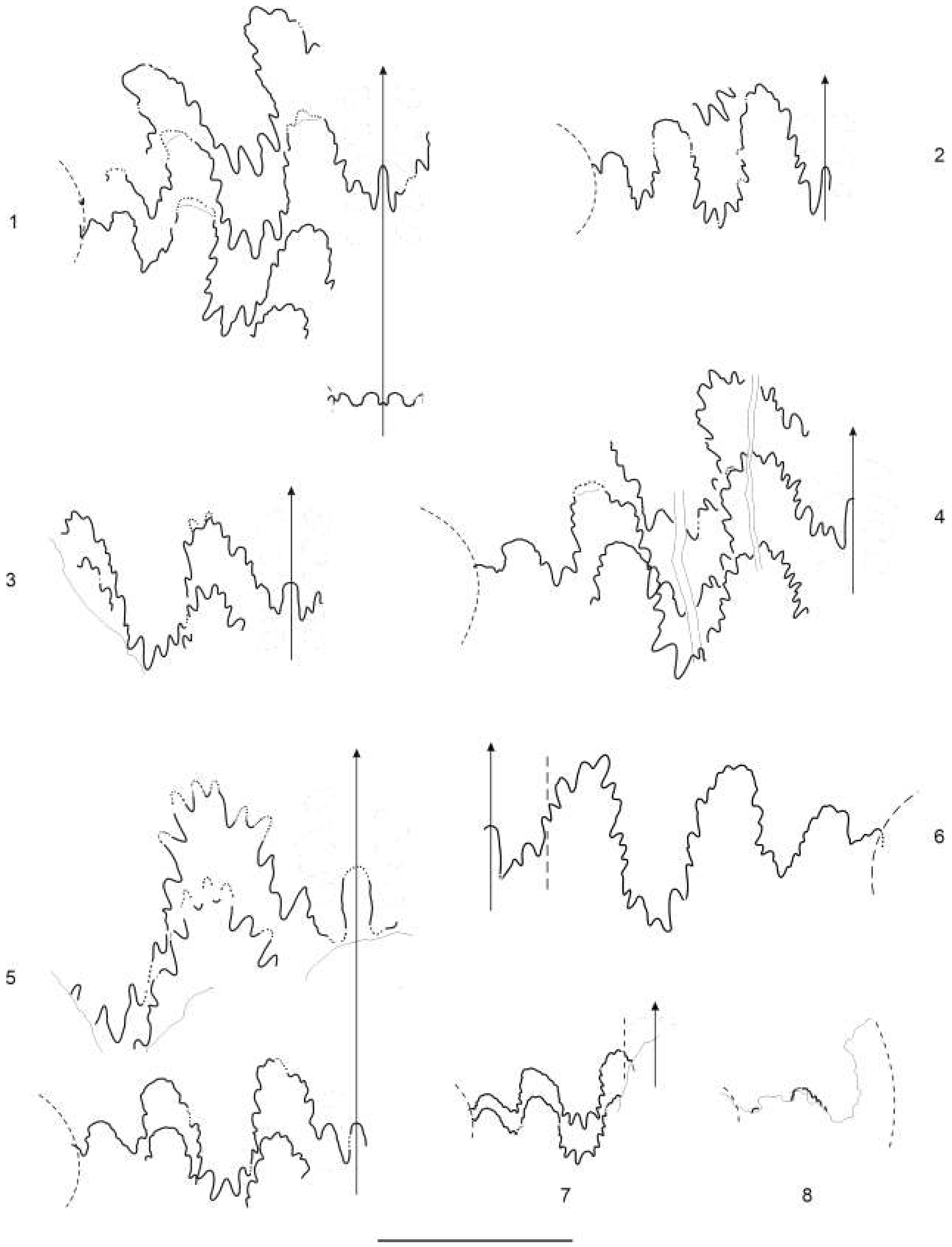
Textfig. 10. Suture lines of *Daxatina bispinosa* (Johnston, 1941) from South Canyon. **1** – B11-95, two sutures of the same specimen respectively at H=11.5mm (from Balini & Jenks, 2007, fig. 8b) and H=20mm. **2** – JJ1-97-6, H=14mm. **3** – USNM 77538, H=8.8mm. **4** – Holotype USNM 77537, H=9mm. Bar scale is 10mm.



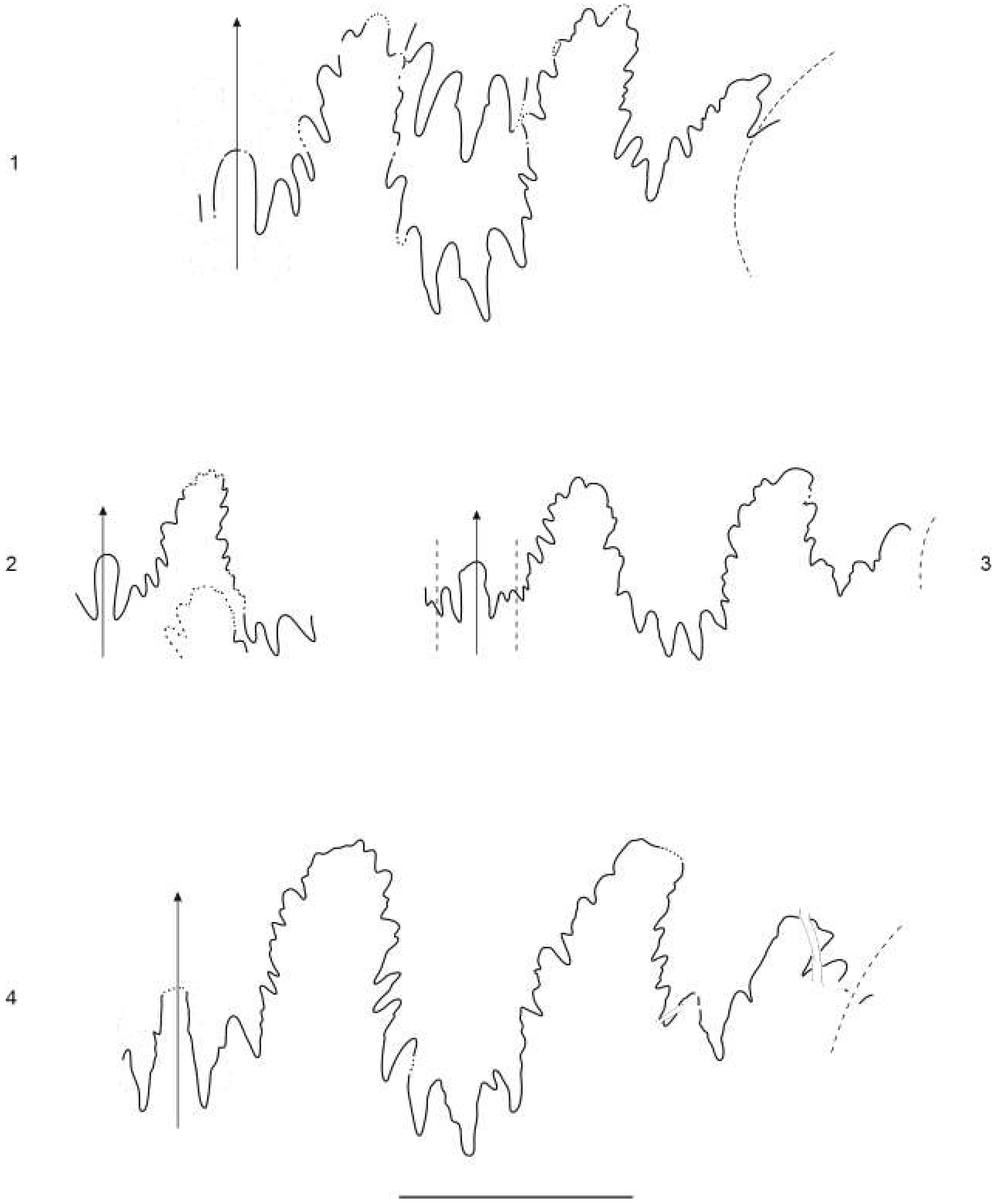
Textfig. 11. Suture lines of *Daxatina* sp. B from South Canyon. **1** – scan16-253, H=16.7mm, last septum. **2** – scan16-361, two sutures of the same specimen respectively at H=8.8mm and H=15.3mm. **3** – scan3-12, H=20mm. **4** – JJ1-97-3, H=17.5mm. Bar scale is 10mm.



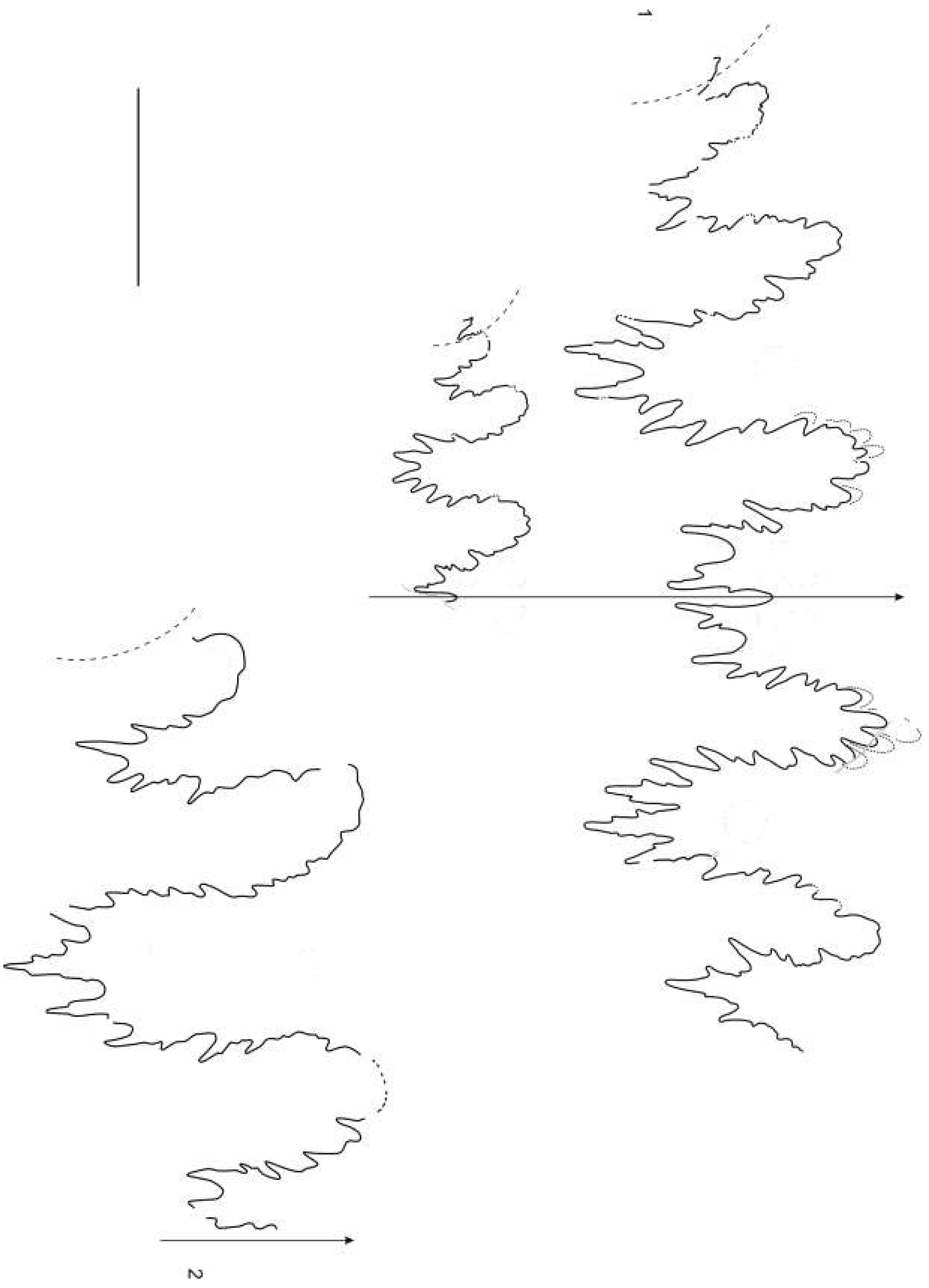
Textfig. 12. Suture lines of ?*Daxatina* sp. A from South Canyon. **1** – F1-145, H=12.5mm. **2** – F1-67, H=10mm. **3** – E5-23, H=12mm. **4** – F1-68, H= 12.5mm. **5** – F1-89, H=11.7mm. Bar scale is 10mm.



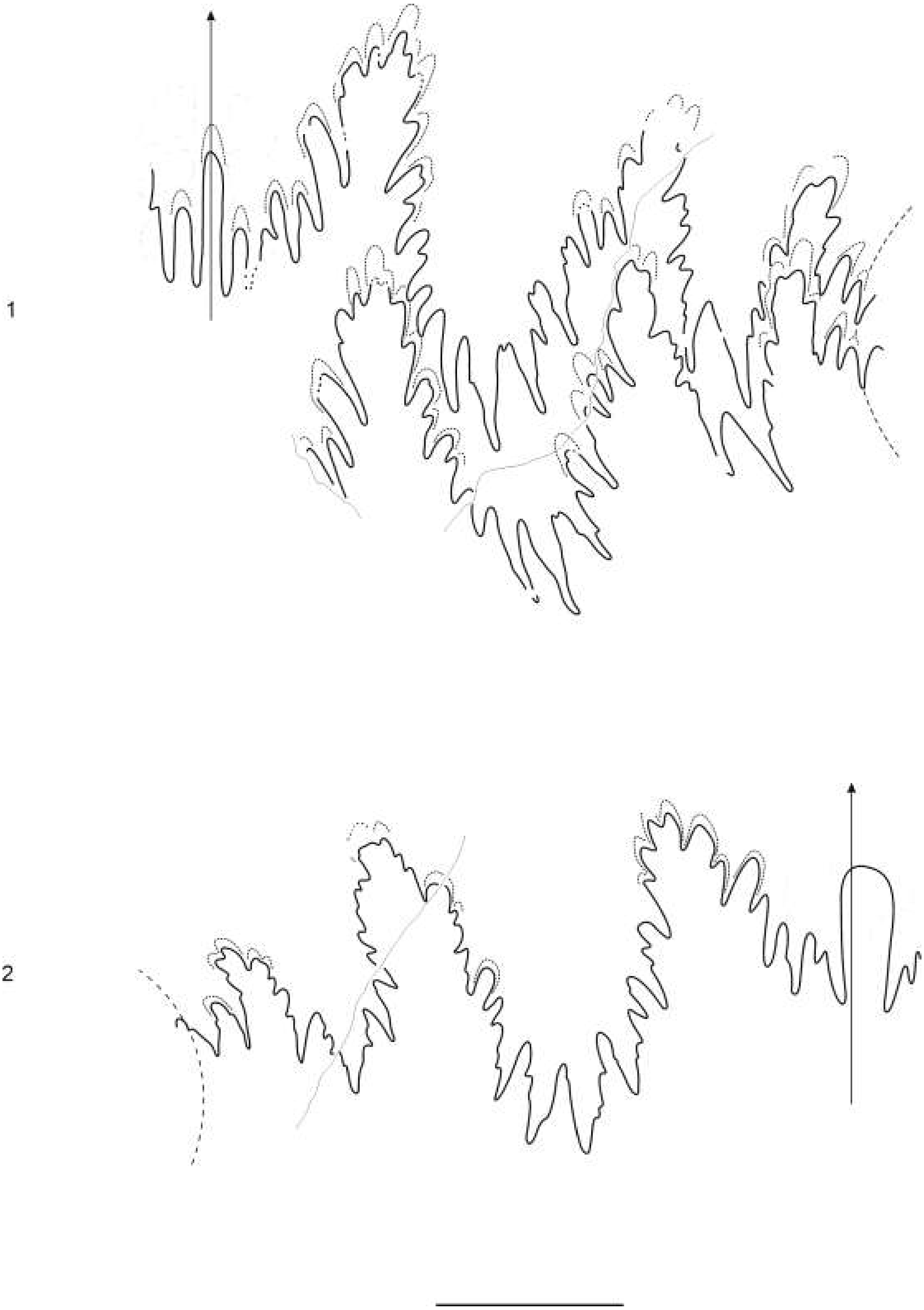
Textfig. 13. Suture lines of *Trachyceras desatoyense* Johnston from South Canyon. **1** – E5-72, two sutures of the same specimen respectively at H=2mm and H=13mm. **2** – E5-73, H=10mm. **3** – E5-82, H=?. **4** – E5-75, H= 18mm. **5** – E5-85, two sutures of the same specimen respectively at H=12.8mm and H=26.8mm. **6** – E5-100, H=18mm, last septum. **7** – USNM 77534, H=9mm. **8** – Holotype USNM 77535c, H=9mm. Bar scale is 10mm.



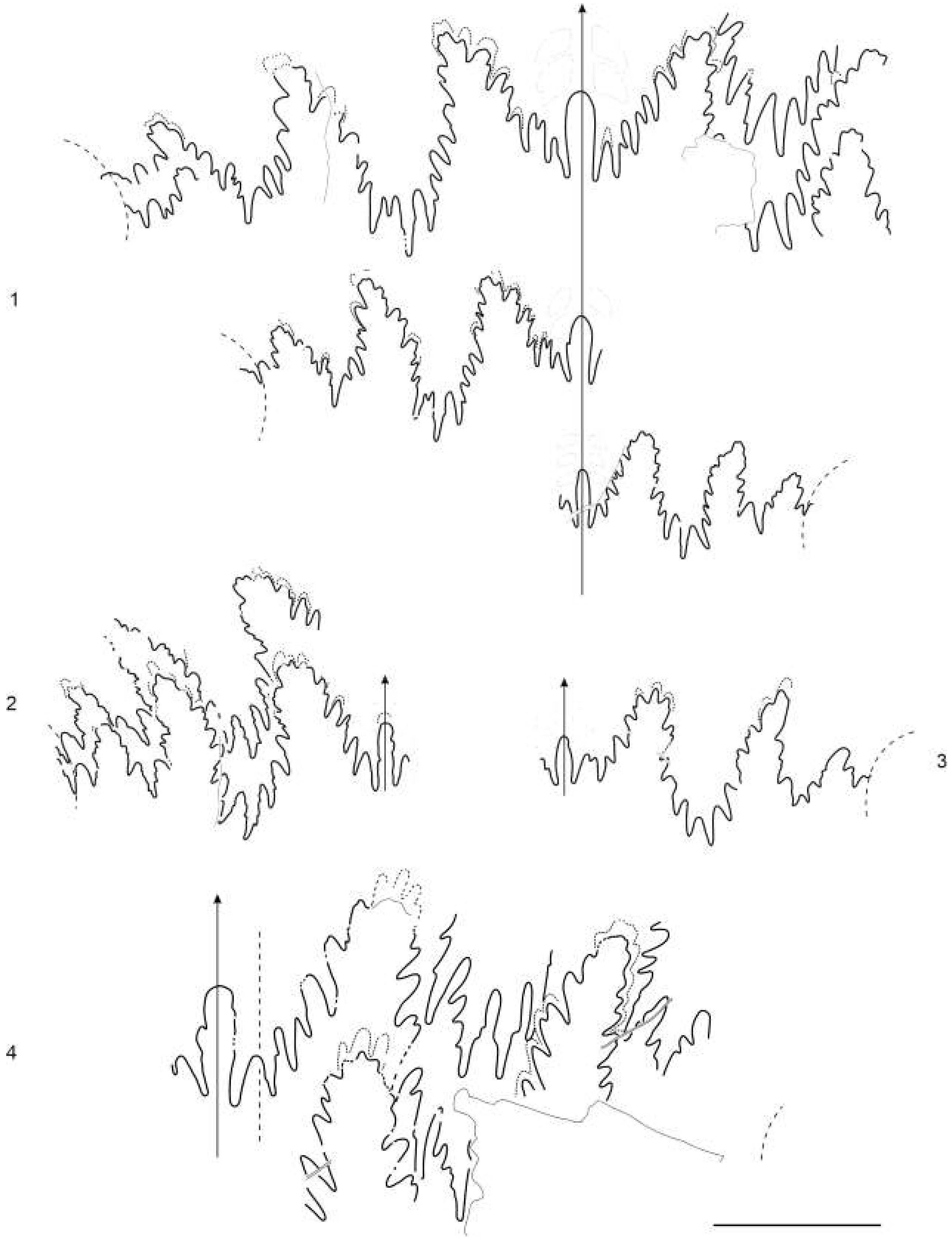
Textfig. 14. Suture lines of *Trachyceras* sp. A from South Canyon. **1** – E3-33, H=18.7mm. **2** – D10bis-42, H=?. **3** – F1-54 (from Balini & Jenks, 2007, fig. 10a). **4** – F1-44, H=27mm. Bar scale is 10mm.



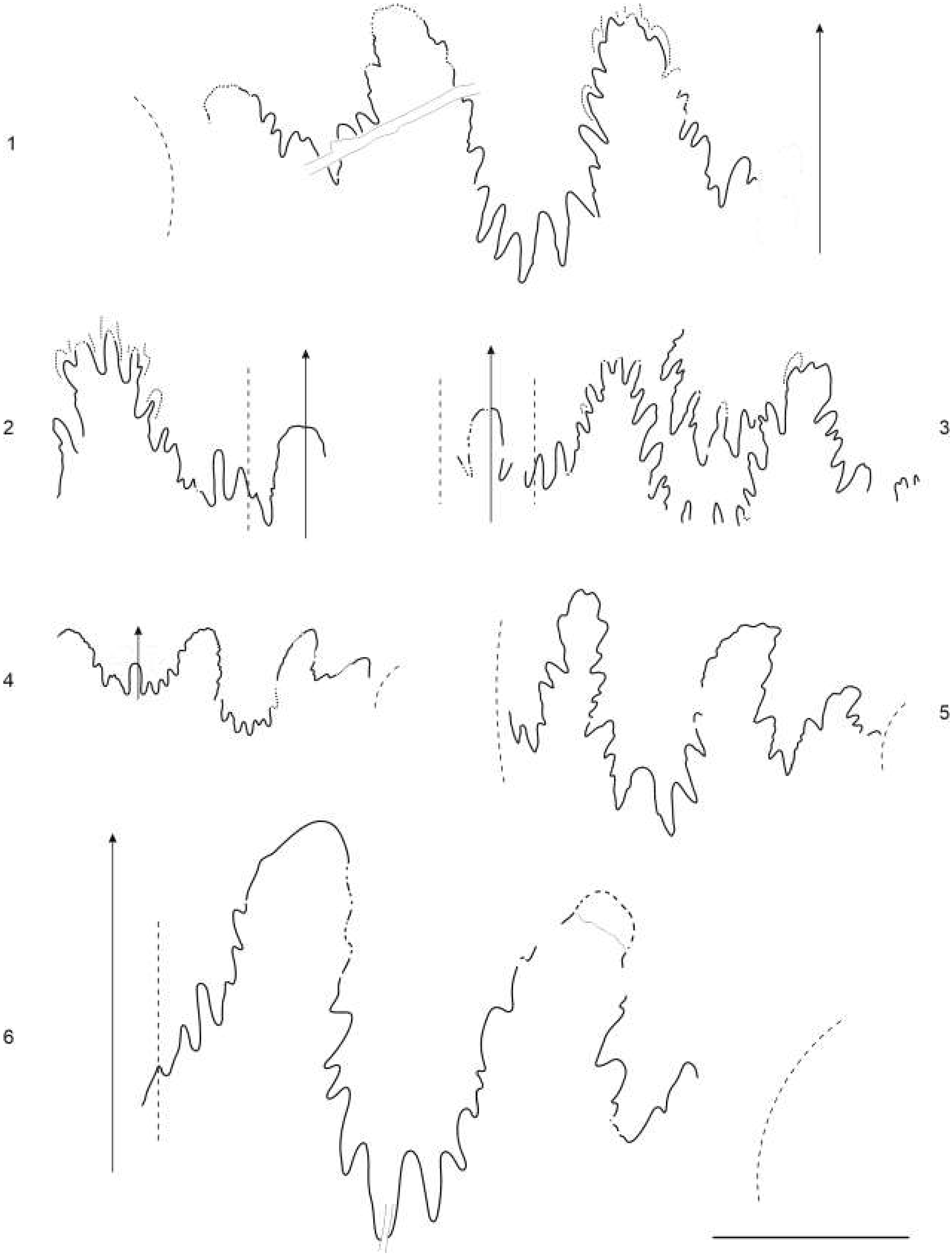
Textfig. 15. Suture lines of *Trachyceras silberlingi* Balini et al., 2012 from South Canyon. **1** – Specimen F26-281, two sutures of the same specimen respectively at H=11mm and H=23mm. **2** – MPUM 11063 (F1-91), H=26mm (from Balini et al., 2012, fig. 4). Bar scale is 10mm.



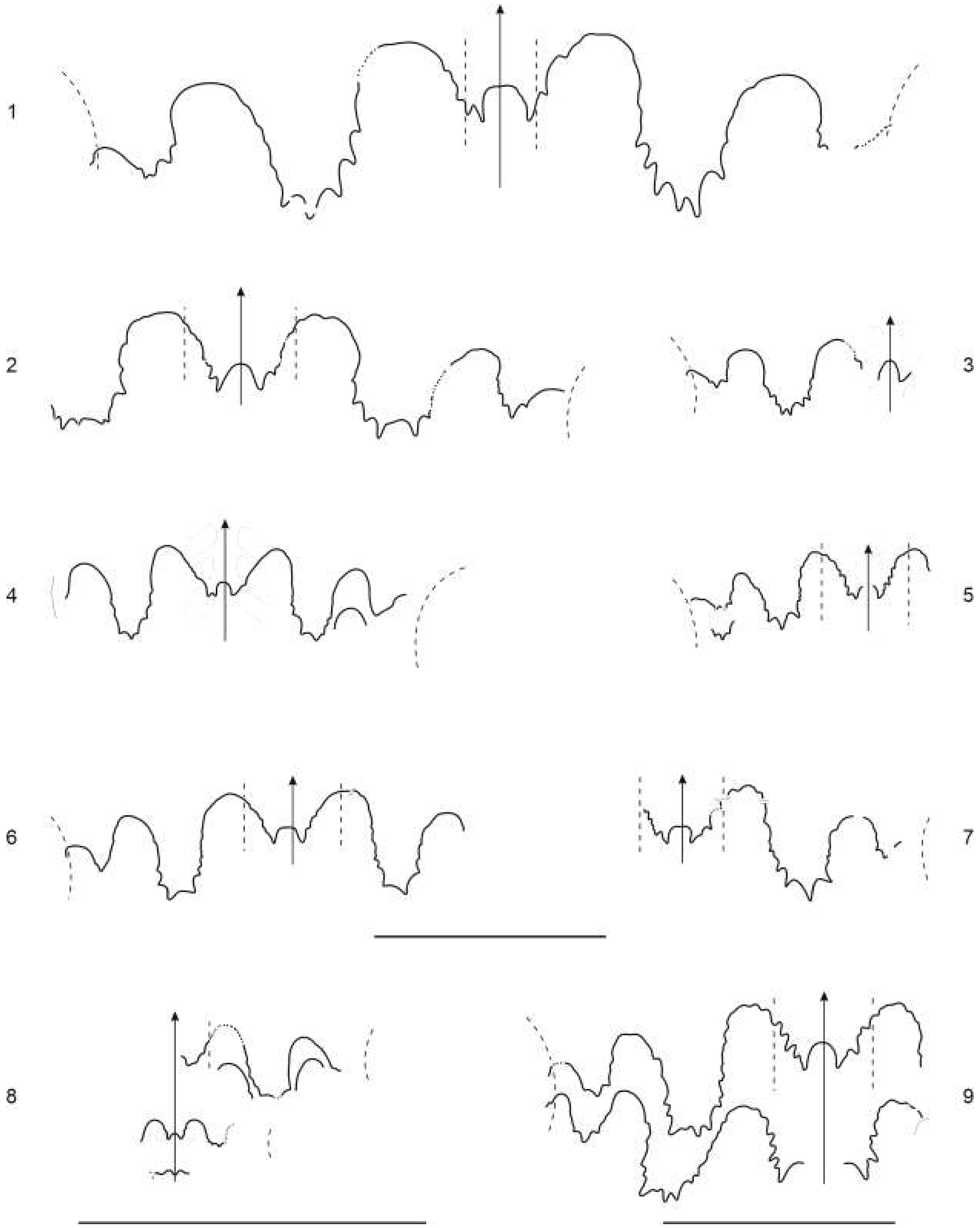
Textfig. 16. Suture lines of *Trachyceras* sp. B from South Canyon. **1** – F26-6, H=31mm. **2** – F26-291, H=32mm. Bar scale is 10mm.



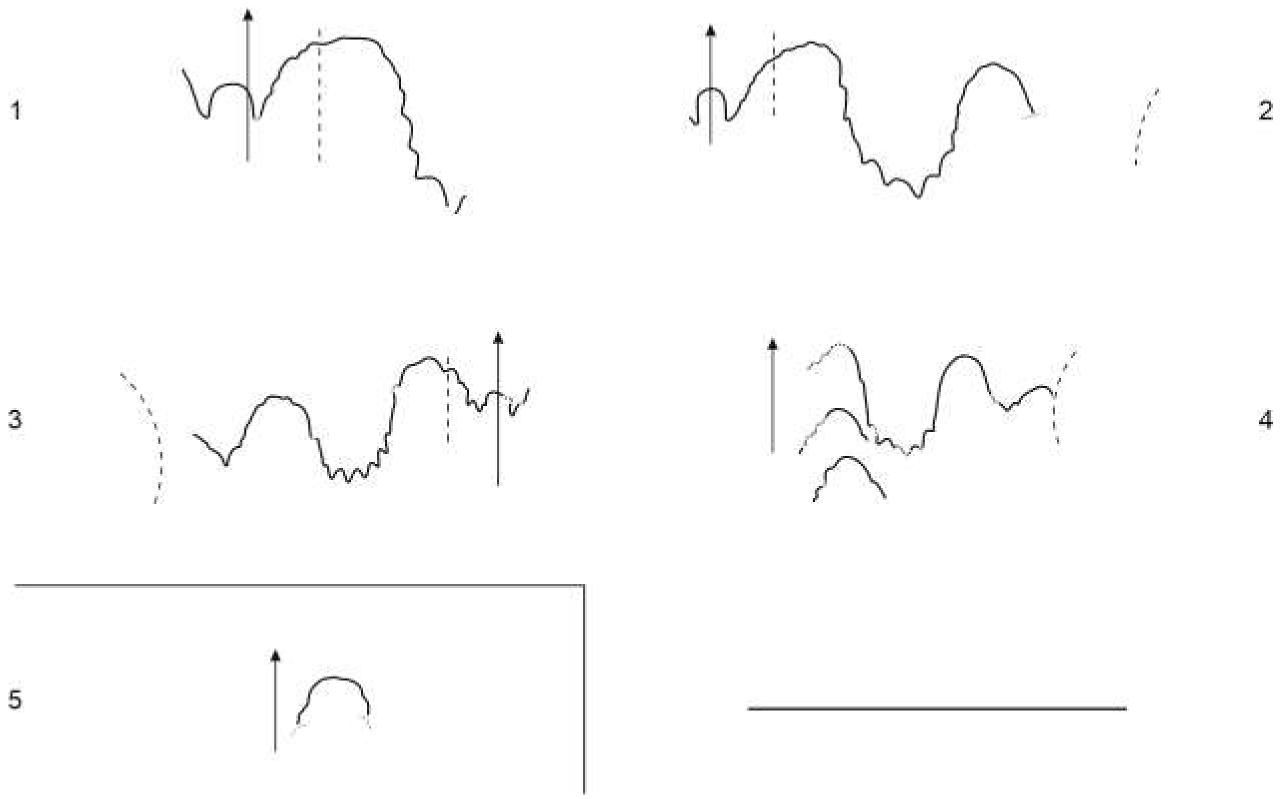
Textfig. 17. Suture lines of *Trachyceras* sp. B from South Canyon. **1** – F26-282, three sutures of the same specimen respectively at H=13mm, H=18mm and H=26mm. **2** – F26-8, H=17mm. **3** – F26-283, H=17.4mm. **4** – USNM 128317, H=31.5mm (=Silberling, 1956, textfig. 2b). Bar scale is 10mm.



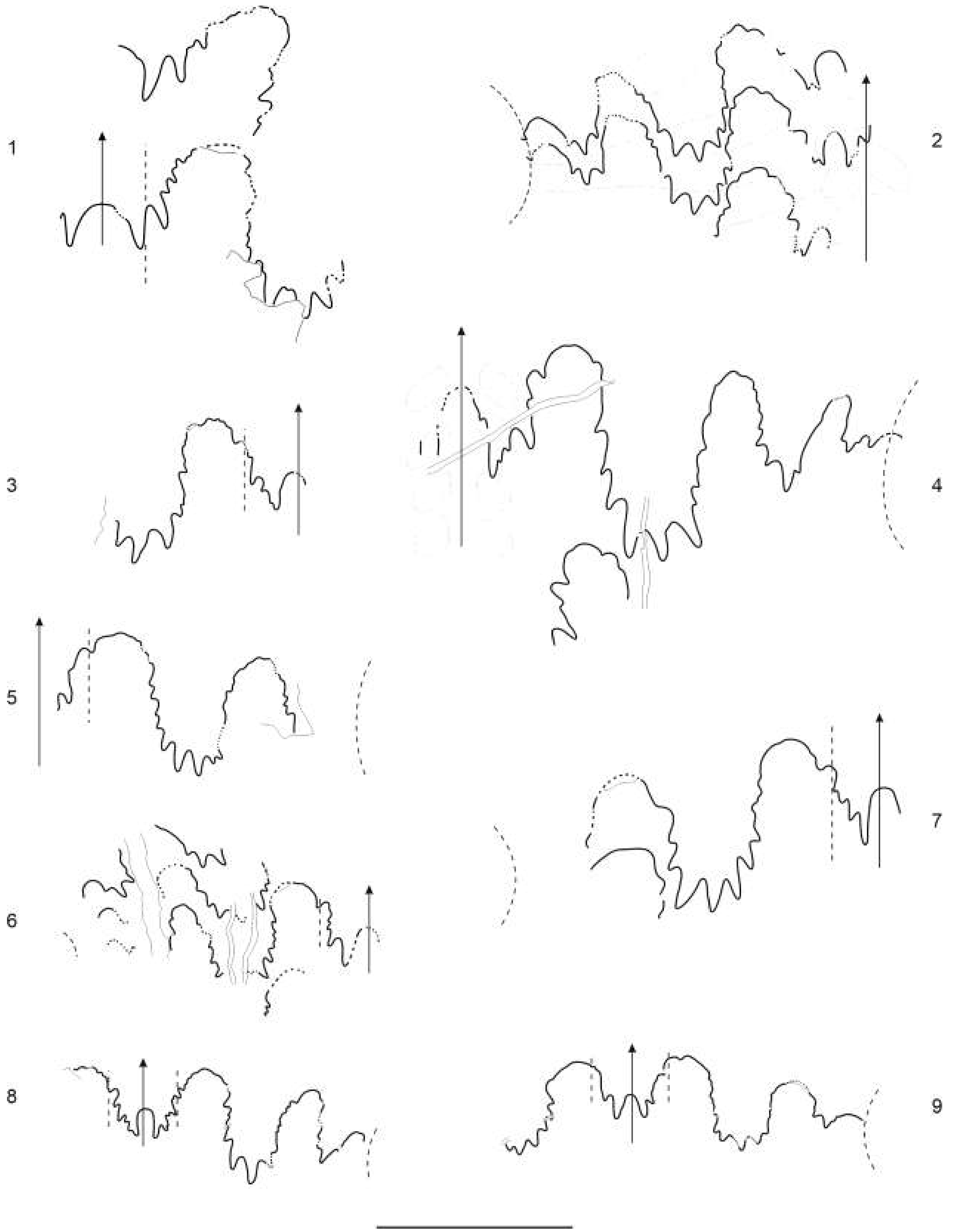
Textfig. 18. Suture lines of Genus A sp. A from South Canyon. **1** – F1-2, H=30.5mm. **2** – F1-119, H=?. **3** – F1-116, H=24mm. **4** – F1bis-48, H=10.5mm. **5** – F1-1 (from Balini & Jenks, 2007, fig. 10b). **6** – F1bis-34, H=30mm. Bar scale is 10mm.



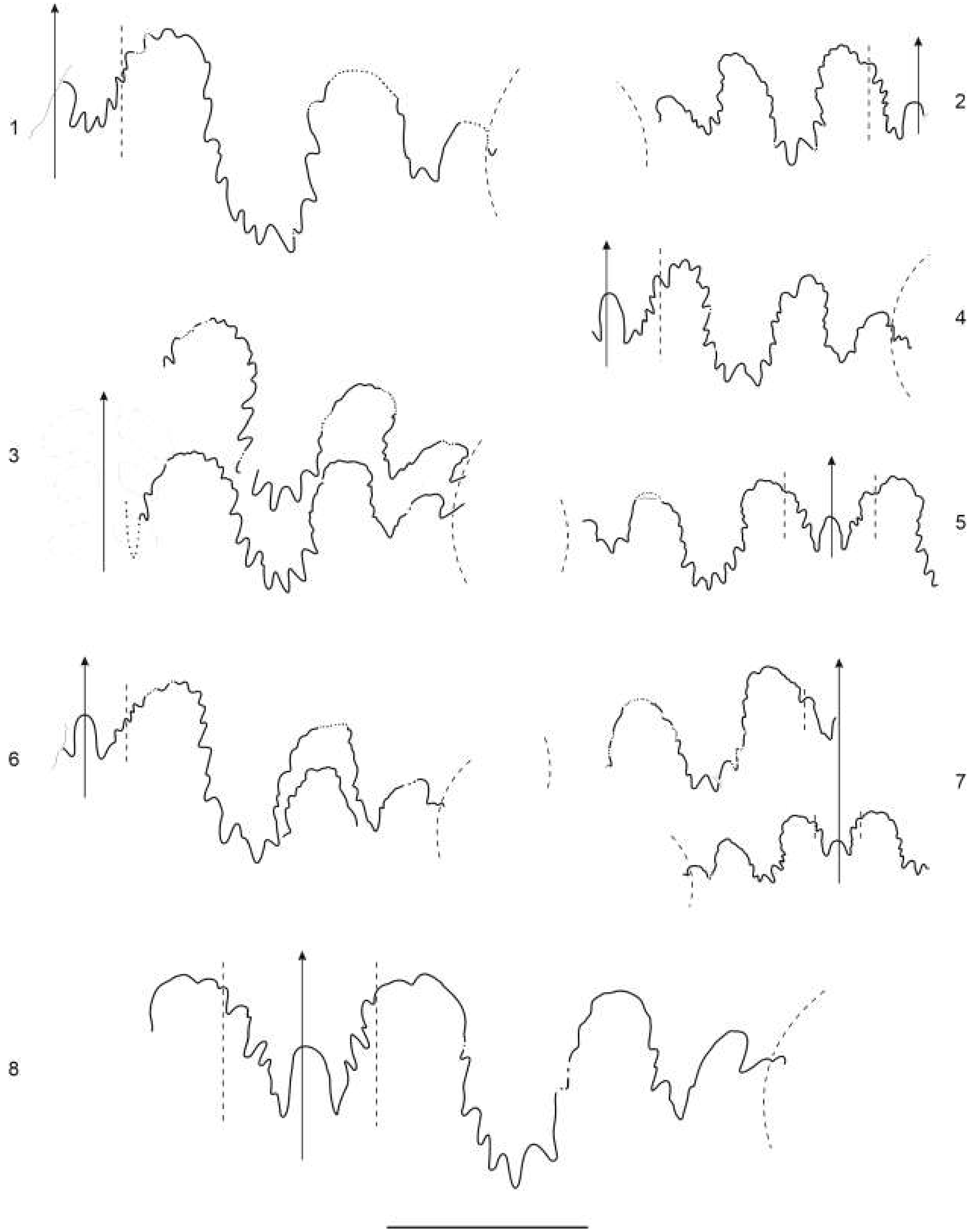
Textfig. 19. Suture lines of Genus B sp. A from China Mountain. **1** – CHM19-8, H=16.7mm, last septum. **2** – CHM34-1, H=12.5mm. **3** – CHM44-1, H=7mm, last septum. **4** – CHM42-2, H=8mm, last septum. **5** – CHM45-10, H=6.6mm, last septum. **6** – CHM44-7, H=8mm, last septum. **7** – CHM47-1, H=9mm, last septum. **8** – CHM34-21, three sutures of the same specimen respectively at H=0.5mm, H=2mm and H=5mm. **9** – CHM42-24, H=10mm, last septum. Bar scale is 10mm.



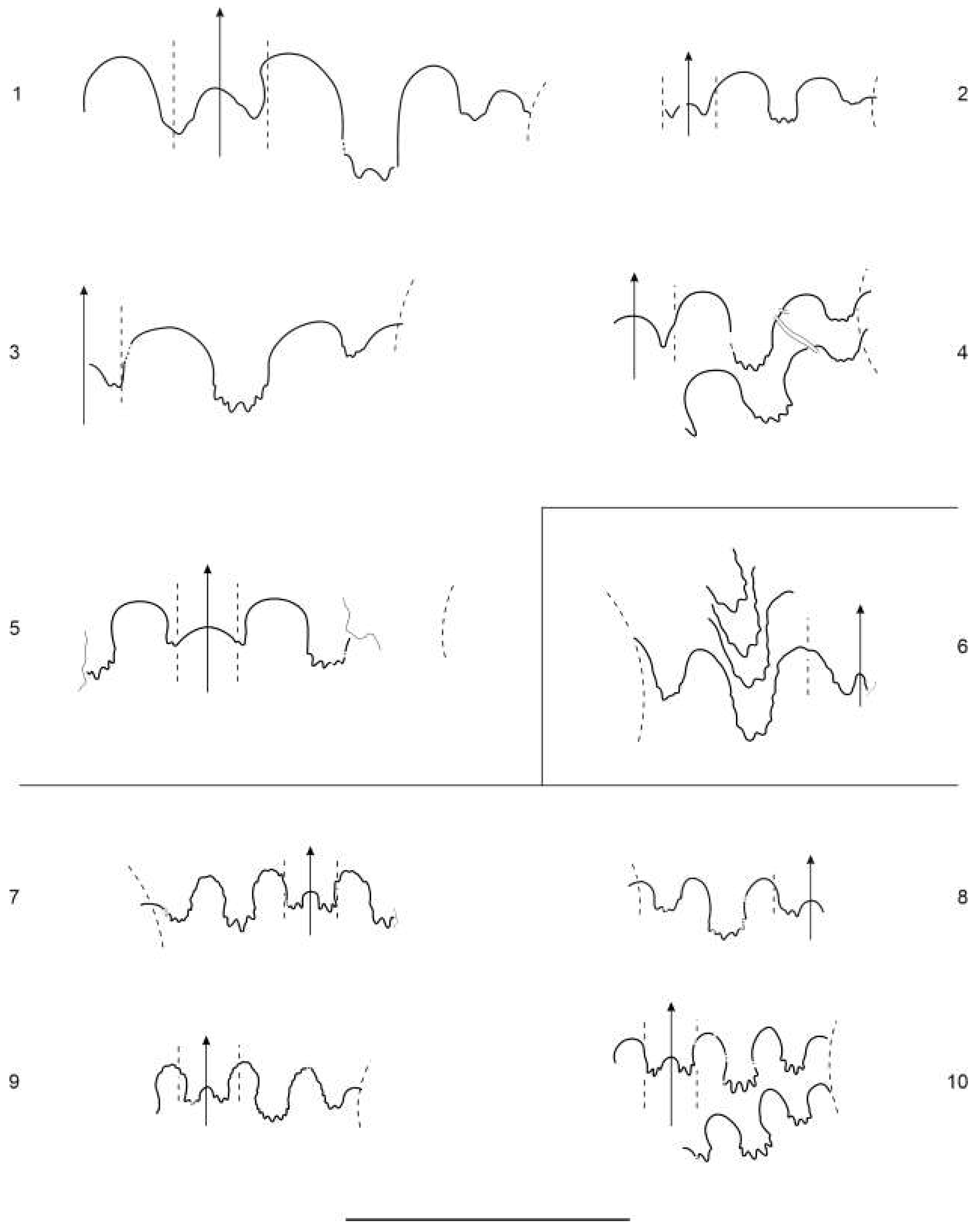
Textfig. 20. 1-4 Suture lines of Genus B sp. B from China Mountain. **1** – CHM15-A1, H=11.3mm, last septum. **2** – CHM20-1, H=10mm. **3** – CHM19-3, H=8mm, last septum. **4** – CHM41-2, H=7mm, last septum. **5** – Suture line of Genus B sp. ind. from China MountainCHM20-11, H=4.5mm, last septum. Bar scale is 10mm.



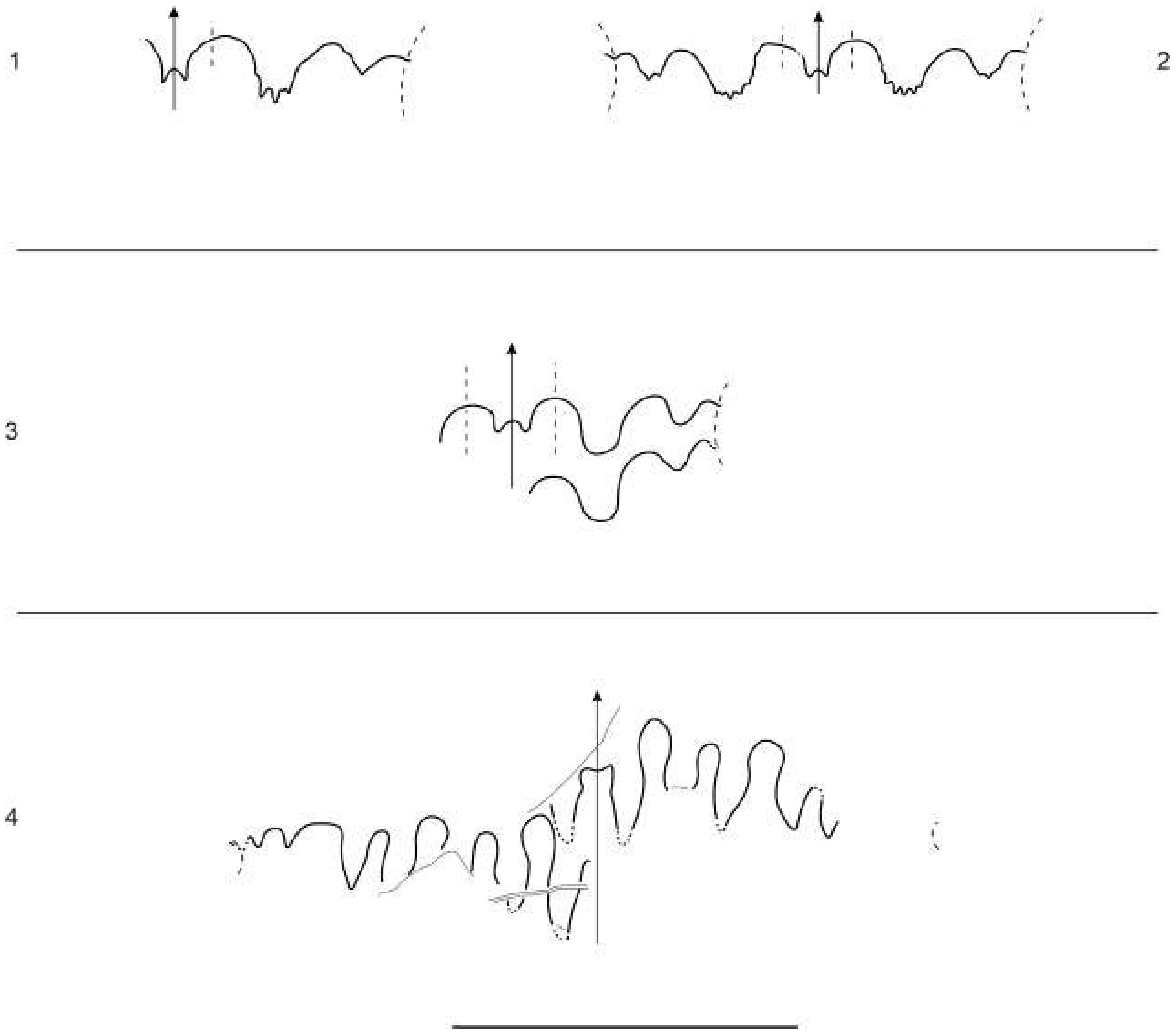
Textfig. 21. Suture lines of Genus B *compressum* (Johnston, 1941) from South Canyon. **1** – Holotype USNM 77536, H=24mm. **2** – D10bis-79, H=15mm. **3** – JJ6-05-1, H=15.5mm. **4** – D10bis-49, H=18mm. **5** – E3-65, H=15mm. **6** – D10bis-16, H=14.5mm . **7** – JJ5-05-2, H=15mm. **8** – D10bis-92, H=11.4mm, last septum. **9** – JJ5-05-5, H=10mm. Bar scale is 10mm.



Textfig. 22. Suture lines of Genus B *compressum* (Johnston, 1941) from South Canyon. **1** – D10-27, H=20.5mm, last septum. **2** – E3-5, H=12.4mm. **3** – D10-70, H=15mm, last septum. **4** – D10-118, H=13.3mm. **5** – D10-3, H=12mm. **6** – D10-95, H=16mm. **7** – D10-32, two sutures of the same specimen respectively at H=6.3mm and H=14mm. **8** – F15-1, H=20mm. Bar scale is 10mm.



Textfig. 23. 1-5 Suture lines of *Clionitites barwicki* (Johnston, 1941) from South Canyon. **1** – A21-87, H=9.7mm. **2** – A21-90, H=6.3mm. **3** – B11-66, H=10mm. **4** – USNM 77512c, H=7.7mm. **5** – USNM 77512b, H=8.2mm. **6** – Suture line of *Clionitites* aff. *wheeleri* (Johnston) from South Canyon, F1-99, H=6.8mm. 7-10 Suture lines of *Clionitites reesidei* (Johnston, 1941), 7, 9-10 from South Canyon, 8 from China Mountain. **7** – F1bis-98, H=6mm. **8** – JJ4-18-26, H=5.5mm. **9** – Holotype USNM 77513d, H=4.8mm. **10** – USNM 77513f, H=5mm. Bar scale is 10mm.



Textfig. 24. 1-2 Suture lines of *Clionitites* sp. A from South Canyon. **1** – F26-295, H=6mm. **2** – F26-299, H=5.3mm. **3** – *Hannaoceras newpassense* Johnston, 1941 from South Canyon, USNM 77514b, H=5.8mm. **4** – *Coroceras zephyrum* Johnston, 1941 from South Canyon, Holotype USNM 77522b, H=7.3mm. Bar scale is 10mm.

8.2 - Plates

Plate 1

Neoclypites desertorum (Johnston, 1941)
Fig. 1 – A21-37; 1a) lateral view; 1b) ventral view.
Fig. 2 – B11-97; 2a) lateral view; 2b) ventral view.
Fig. 3 – scan16-591; 3a) lateral view; 3b) ventral view.

Perrinoceras novaditum Johnston, 1941
Fig. 4 – CHM49-15; 4a) lateral view; 4b) ventral view. From China Mountain.
Fig. 5 – F26-74, phragmocone; 5a) lateral view; 5b) ventral view.
Fig. 6 – E18.1-59; 6a) lateral view; 6b) ventral view.
Fig. 7 – F1-46; 7a) lateral view; 7b) ventral view.

All specimens are from South Canyon, unless otherwise stated.

All specimens are coated with ammonium chloride. Bar scales are 10mm.

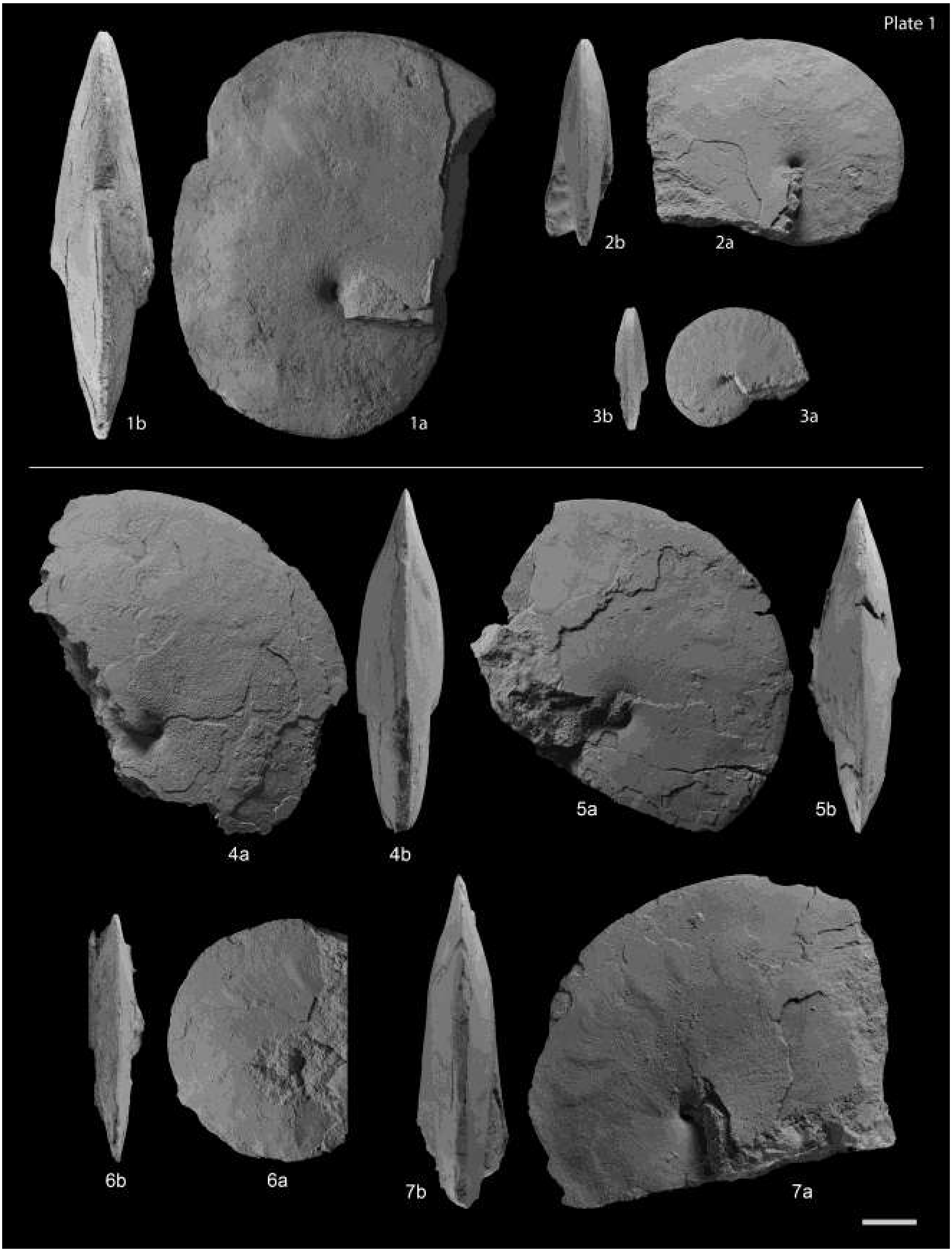


Plate 1
1b
1a
2b
2a
3b
3a
4a
4b
5a
5b
6b
6a
7b
7a

Plate 2

Sageceras cf. *haidingeri* Hauer
Fig. 1 – F1bis-135; lateral view.
Fig. 2 – F1bis-133; 2a) lateral view; 2b) ventral view.

Badiotites trauthi (Johnston, 1941)
Fig. 3 – D10-80; 3a) lateral view; 3b) ventral view.
Fig. 4 – D10-112; 4a) lateral view; 4b) ventral view.
Fig. 5 – F15-28; 5a) lateral view; 5b) ventral view.

Badiotites aff. *scapulatus* Tozer
Fig. 6 – D10-76; 6a) lateral view; 6b) ventral view.
Fig. 7 – D10-14; 7a) lateral view; 7b) ventral view.
Fig. 8 – D10-77; 8a) lateral view; 8b) ventral view.
Fig. 9 – CHM47-16; 9a) lateral view; 9b) ventral view. From China Mountain.

Procladiscites mulleri Johnston, 1941
Fig. 10 – E5-120; 10a) lateral view; 10b) ventral view.
Fig. 11 – B11-79; 11a) lateral view; 11b) ventral view.

All specimens are from South Canyon, unless otherwise stated.

The white arrows on lateral views indicate the direction of the corresponding ventral view. All specimens are coated with ammonium chloride. Bar scales are 10mm.

Plate 2

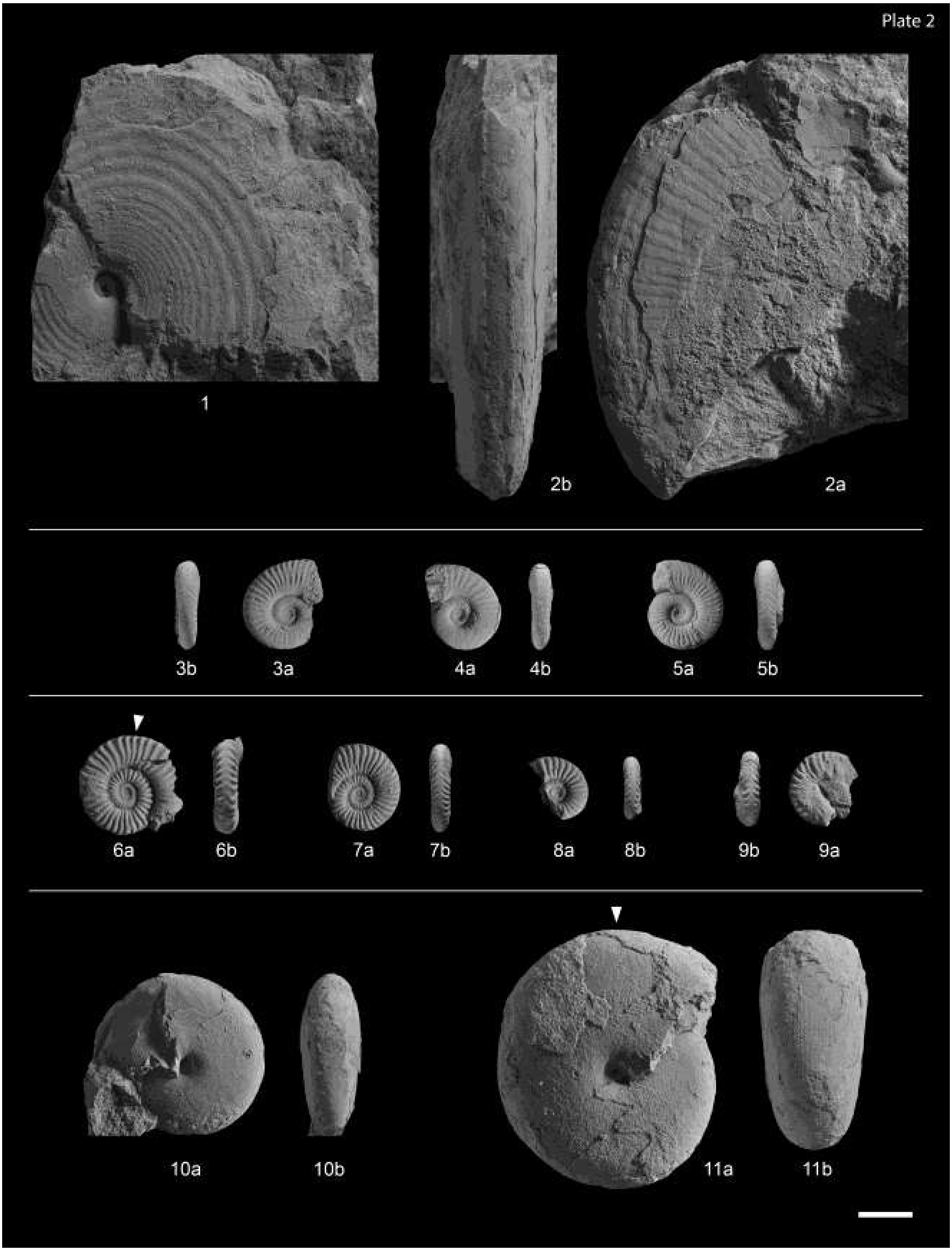


Plate 3

Arcestes sp. ind.
Fig. 1 – scan16-489; 1a) lateral view; 1b) ventral view.
Fig. 2 – B11-102; 2a) lateral view; 2b) ventral view.

Joannites jacobus Johnston, 1941
Fig. 3 – B11-75; 3a) lateral view; 3b) ventral view.

Silenticeras schencki (Johnston, 1941)
Fig. 4 – F18-8; 4a) lateral view; 4b) ventral view.
Fig. 5 – F18-3; 5a) lateral view; 5b) ventral view.
Fig. 6 – E13bis-14; 6a) lateral view; 6b) ventral view.
Fig. 7 – JJ4-18-25; ventral view. From China Mountain.

Frankites sutherlandi (McLearn, 1947)
Fig. 8 – MPUM 9278 (scan15-3), internal mold of phragmocone, lateral view (image taken from Balini, 2008).
Fig. 9 – MPUM 9277 (scan15-16), specimen with test, ventral view (image taken from Balini, 2008).

All specimens are from South Canyon, unless otherwise stated.

The white arrows on lateral views indicate the direction of the corresponding ventral view. All specimens are coated with ammonium chloride. Bar scales are 10mm.

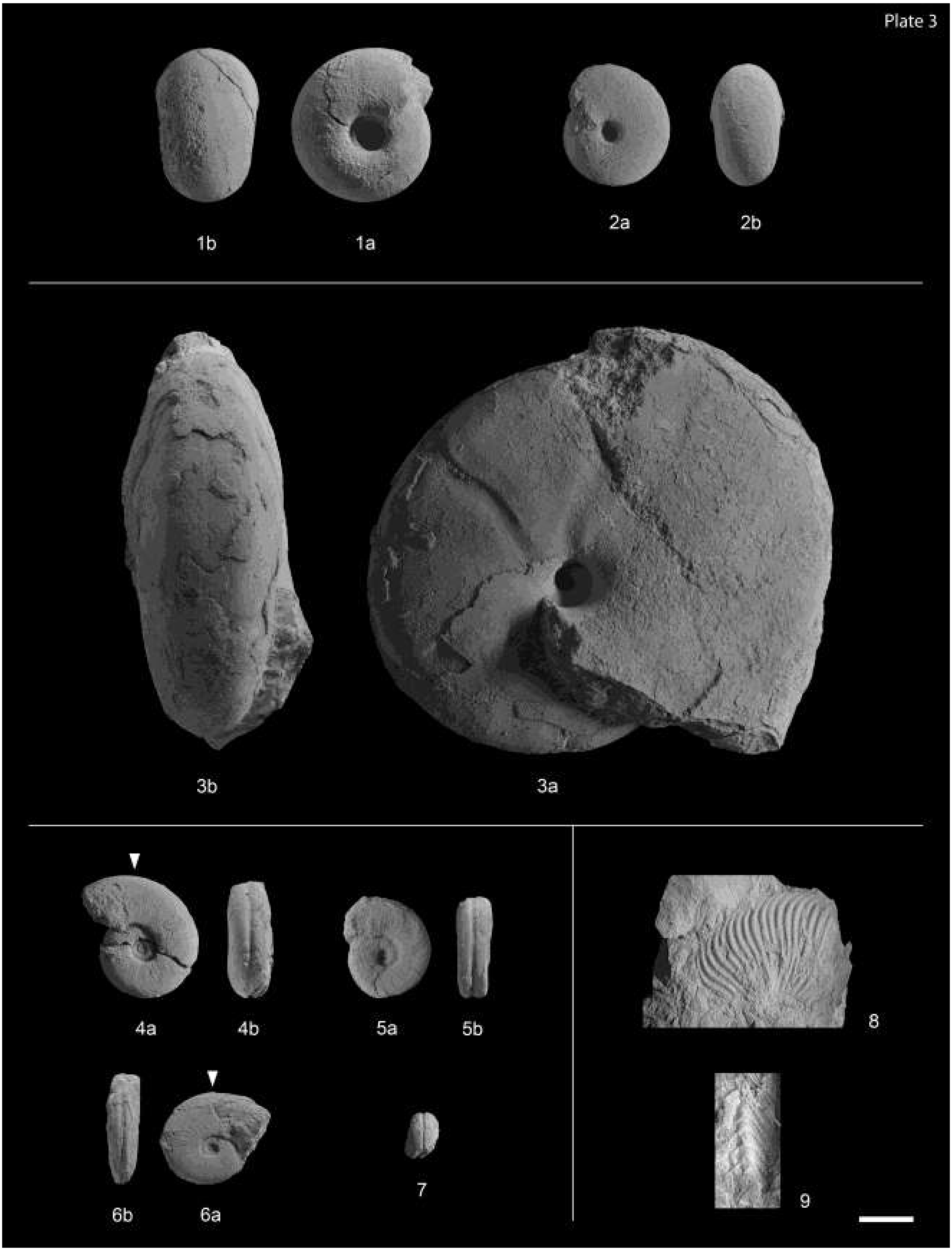


Plate 3

Plate 4

Daxatina sp. A

Fig. 1 – scan16-1; 1a) lateral view; 1b) ventral view; 1c) enlarged ventral view showing inner whorls; 1d) enlarged lateral view showing inner whorls.

Fig. 2 – scan16-232; 2a) lateral view; 2b) ventral view.

Fig. 3 – scan16-483; enlarged lateral view.

Fig. 4 – scan16-10; 4a) ventral view; 4b) lateral view.

Fig. 5 – scan16-537; lateral view.

Fig. 6 – scan16-233; 4a) ventral view; 4b) lateral view.

Fig. 7 – 7a) scan16-582, lateral view; 7b) scan16-581, lateral view.

Fig. 8 – scan16-297; 4a) ventral view; 4b) lateral view.

All specimens are from South Canyon.

The white arrows on lateral views indicate the direction of the corresponding ventral view. The white dots indicate the position of the last septum. All specimens are coated with ammonium chloride. Bar scales are 10mm.

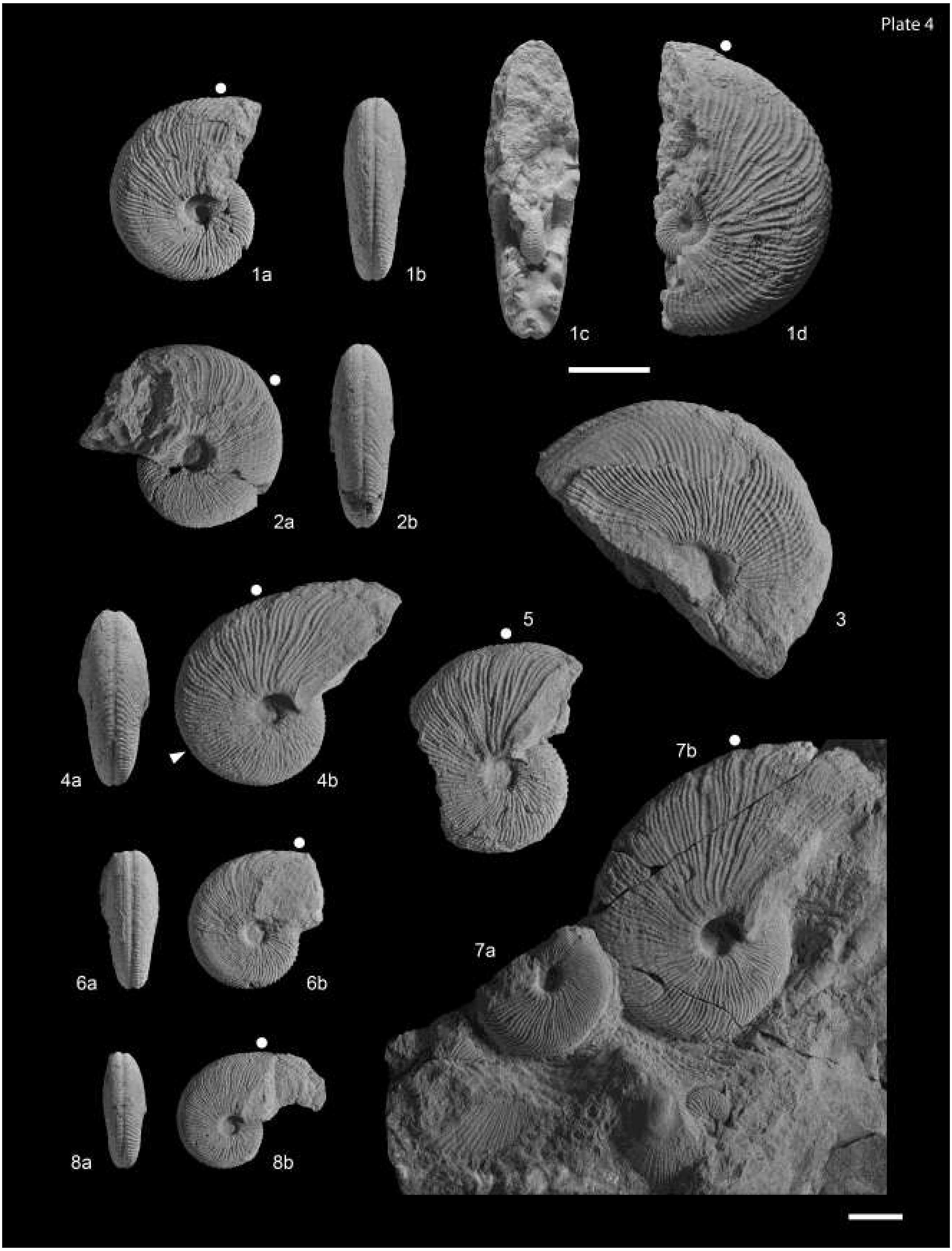


Plate 4
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Plate 5

Daxatina sp. A
Fig. 1 – A21-76; 1a) lateral view; 1b) ventral view; 1c) enlarged ventral view.
Fig. 2 – JJ1-97-1; 2a) ventral view; 2b) lateral view.
Fig. 3 – JJ1-97-7; lateral view.
Fig. 4 – JJ1-97-8; 4a) lateral view; 4b) ventral view.
Fig. 5 – scan3-1; 5a) ventral view; 5b) lateral view.

All specimens are from South Canyon.

The white arrows on lateral views indicate the direction of the corresponding ventral view. The white dots indicate the position of the last septum. All specimens are coated with ammonium chloride. Bar scales are 10mm.

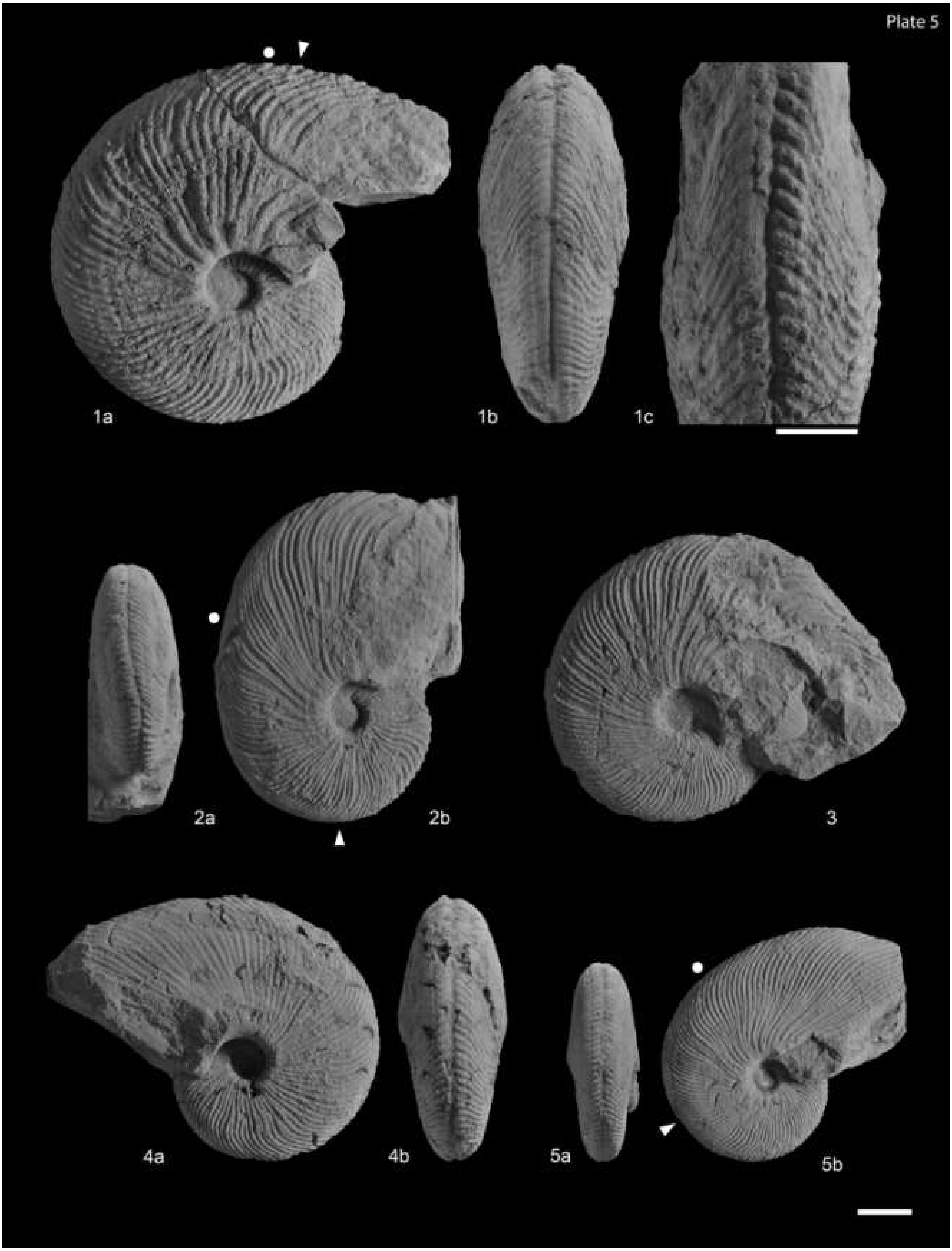
Plate 5
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Plate 6

Daxatina bispinosa (Johnston, 1941)
Fig. 1 – B11-95; 1a) oral view; 1b) lateral view; 1c) ventral view; 1d) enlarged lateral view.
Fig. 2 – JJ1-97-6; 2a) lateral view; 2b) ventral view.
Fig. 3 – Holotype USNM 77537; 3a) lateral view; 3b) ventral view.
Fig. 4 – USNM 77538; 4a) lateral view; 4b) ventral view; 4c) enlarged ventral view;
Fig. 5 – JJ1-97-2; 5a) lateral view; 5b) ventral view.

All specimens are from South Canyon.

The white arrows on lateral views indicate the direction of the corresponding ventral view. The white dots indicate the position of the last septum. All specimens are coated with ammonium chloride. Bar scales are 10mm.

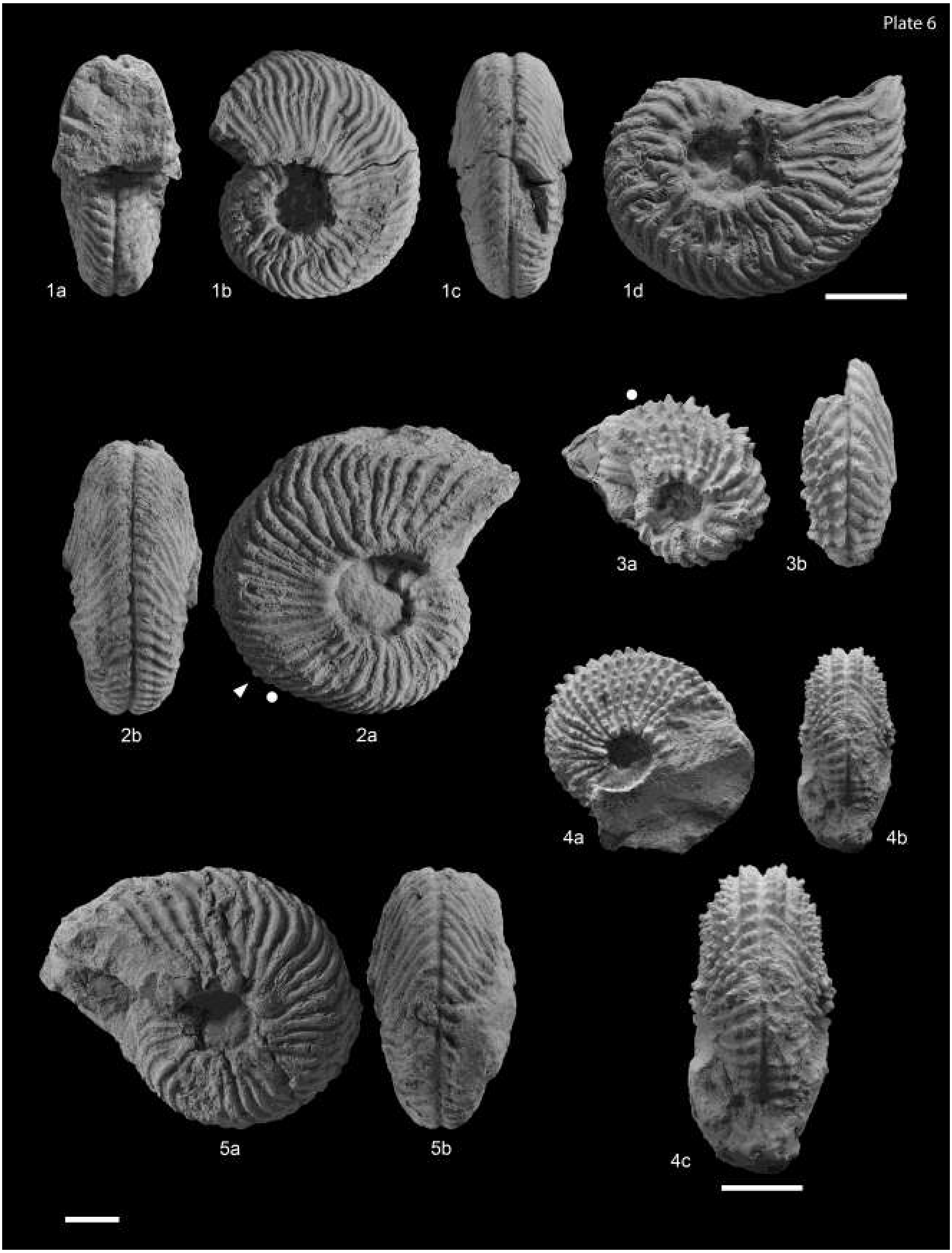
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Plate 7

Daxatina sp. B
Fig. 1 – scan3-12; 1a) left lateral view; 1b) ventral view; 1c) right lateral view.
Fig. 2 – JJ1-97-3; 2a) ventral view; 2b) lateral view.
Fig. 3 – scan16-253; 3a) lateral view; 3b) ventral view.
Fig. 4 – scan16-129; lateral view.
Fig. 5 – scan16-361; 5a) left lateral view; 5b) ventral view; 5c) right lateral view; 5d) enlarged detail of right lateral view.

All specimens are from South Canyon.

The white arrows on lateral views indicate the direction of the corresponding ventral view. The white dots indicate the position of the last septum. All specimens are coated with ammonium chloride. Bar scales are 10mm.

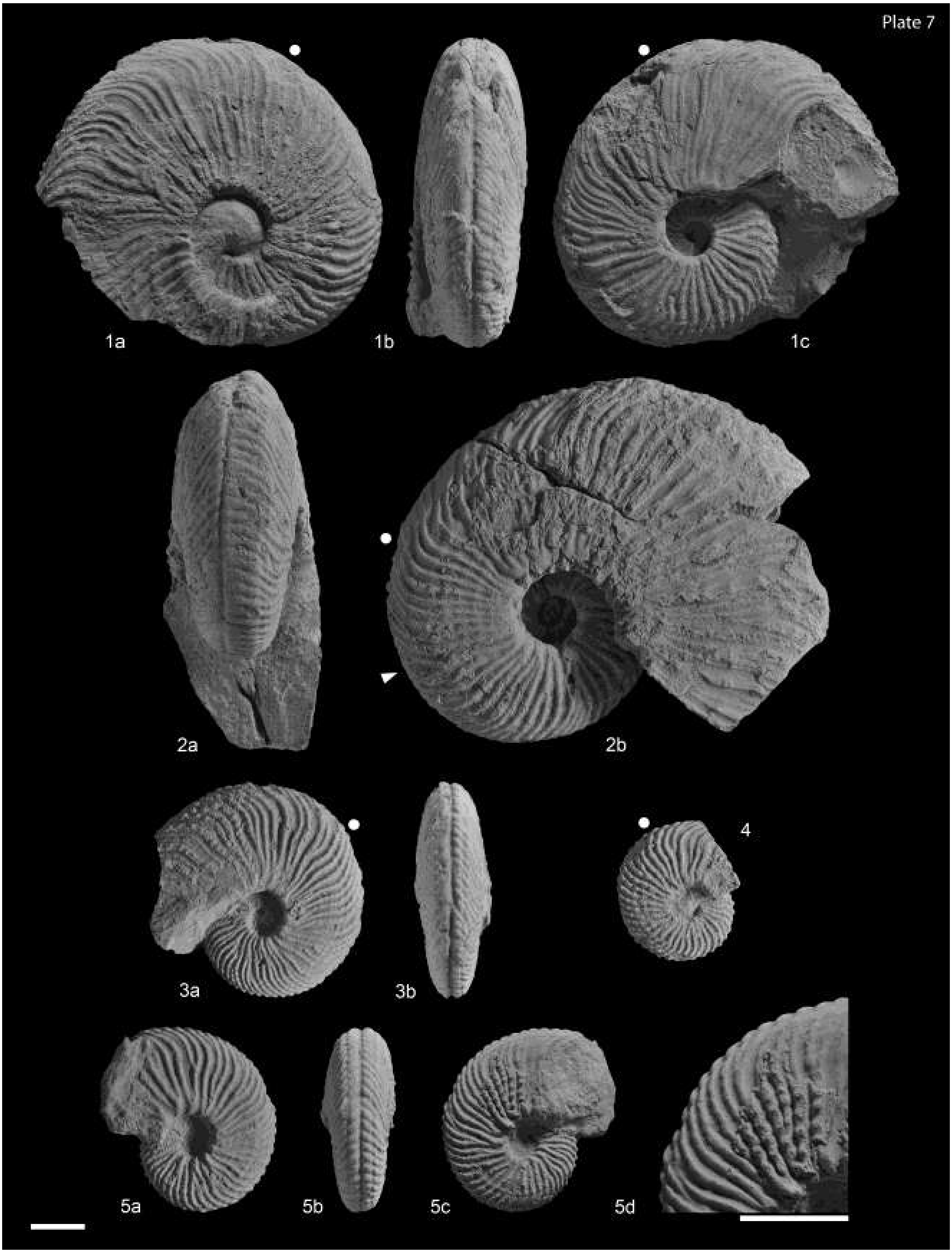
Plate 7
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Plate 8

?*Daxatina* sp. A
Fig. 1 – F1-68, phragmocone; 1a) lateral view; 1b) ventral view.
Fig. 2 – F1-145, phragmocone; 2a) lateral view; 2b) ventral view.
Fig. 3 – E5-65, phragmocone; 3a) lateral view; 3b) ventral view.
Fig. 4 – F1-89, phragmocone; 4a) lateral view; 4b) ventral view.

Trachyceras desatoyense Johnston, 1941
Fig. 5 – E5-100; 5a) lateral view; 5b) ventral view; 5c) enlargement of Fig. 5b.
Fig. 6 – E5-73, lateral view.
Fig. 7 – E5-72, phragmocone; 7a) lateral view; 7b) ventral view; 7c) enlarged lateral view showing the inner whorls; 7d) enlarged ventral view showing the inner whorls.

All specimens are from South Canyon.

The white arrows on lateral views indicate the direction of the corresponding ventral view. The white dots indicate the position of the last septum. All specimens are coated with ammonium chloride. Bar scales are 10mm.

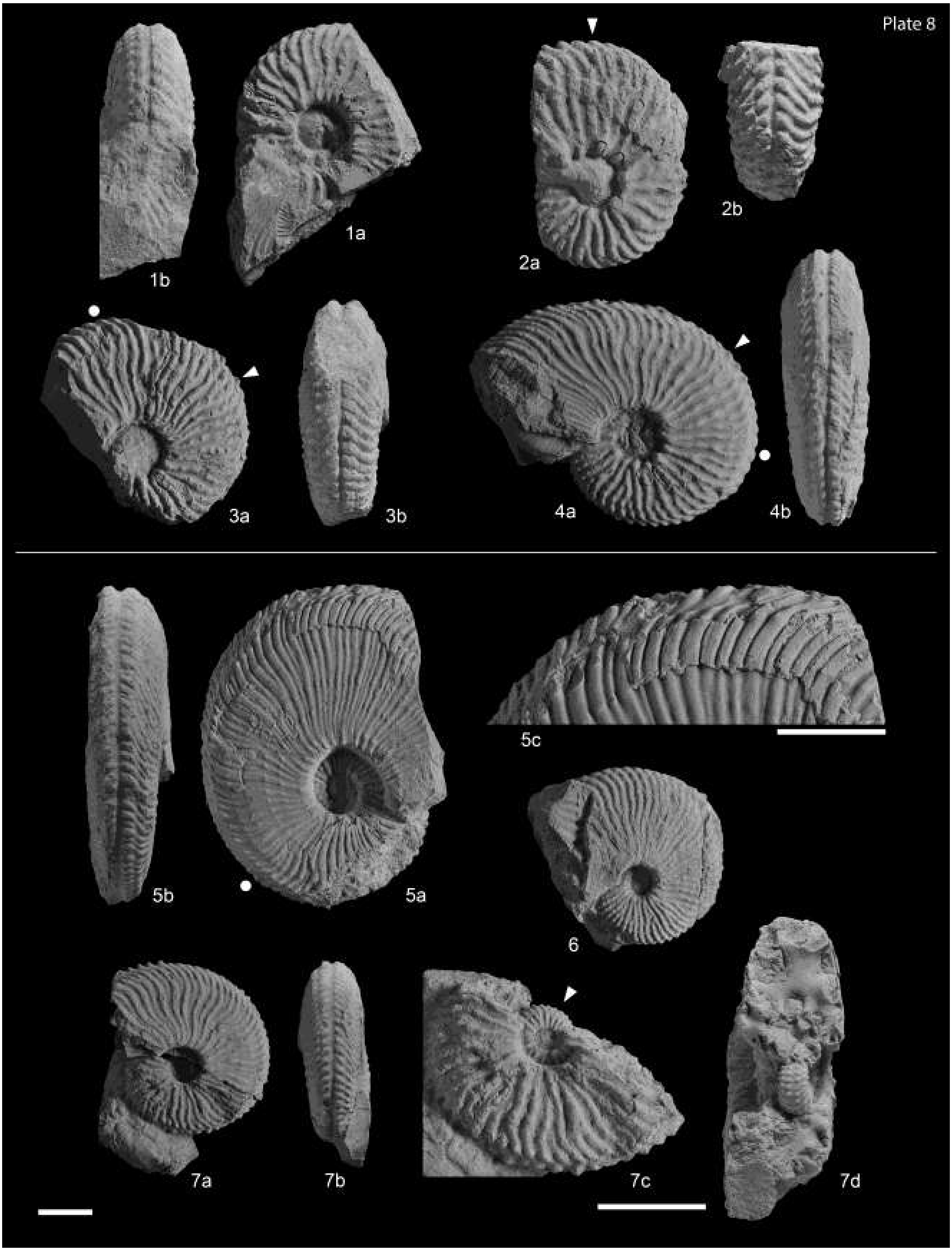
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Plate 9

Trachyceras desatoyense Johnston, 1941
Fig. 1 – Holotype USNM 77535c; 1a) left lateral view; 1b) ventral view; 1c) right lateral view.
Fig. 2 – Paratype USNM 77535d; 2a) lateral view; 2b) ventral view.
Fig. 3 – Paratype USNM 77535b; 3a) lateral view; 3b) ventral view.
Fig. 4 – Paratype USNM 77535a; 4a) lateral view; 4b) ventral view.
Fig. 5 – USNM 77534; 5a) left lateral view; 5b) ventral view; 5c) right lateral view.
Fig. 6 – USNM 77533; 6a) lateral view; 6b) ventral view.
Fig. 7 – E5-90, lateral view.
Fig. 8 – E5-75; 8a) lateral view; 8b) ventral view.
Fig. 9 – E5-18; 9a) lateral view; 9b) ventral view.

All specimens are from South Canyon.

The white dots indicate the position of the last septum. All specimens are coated with ammonium chloride. Bar scales are 10mm.


Plate 9
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5a
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6a
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8b
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9b

Plate 10

Trachyceras sp. A
Fig. 1 – E3-9, phragmocone; 1a) lateral view; 1b) ventral view.
Fig. 2 – F1-44, phragmocone; 2a) lateral view; 2b) ventral view.
Fig. 3 – E3-33, phragmocone; 3a) lateral view; 3b) ventral view.
Fig. 4 – F26-11, phragmocone; 4a) lateral view; 4b) ventral view.
Fig. 5 – USNM 77531; 5a) left lateral view; 5b) ventral view; 5c) right lateral view.

All specimens are from South Canyon.

The white arrows on lateral views indicate the direction of the corresponding ventral view. The white dots indicate the position of the last septum. All specimens are coated with ammonium chloride. Bar scales are 10mm.

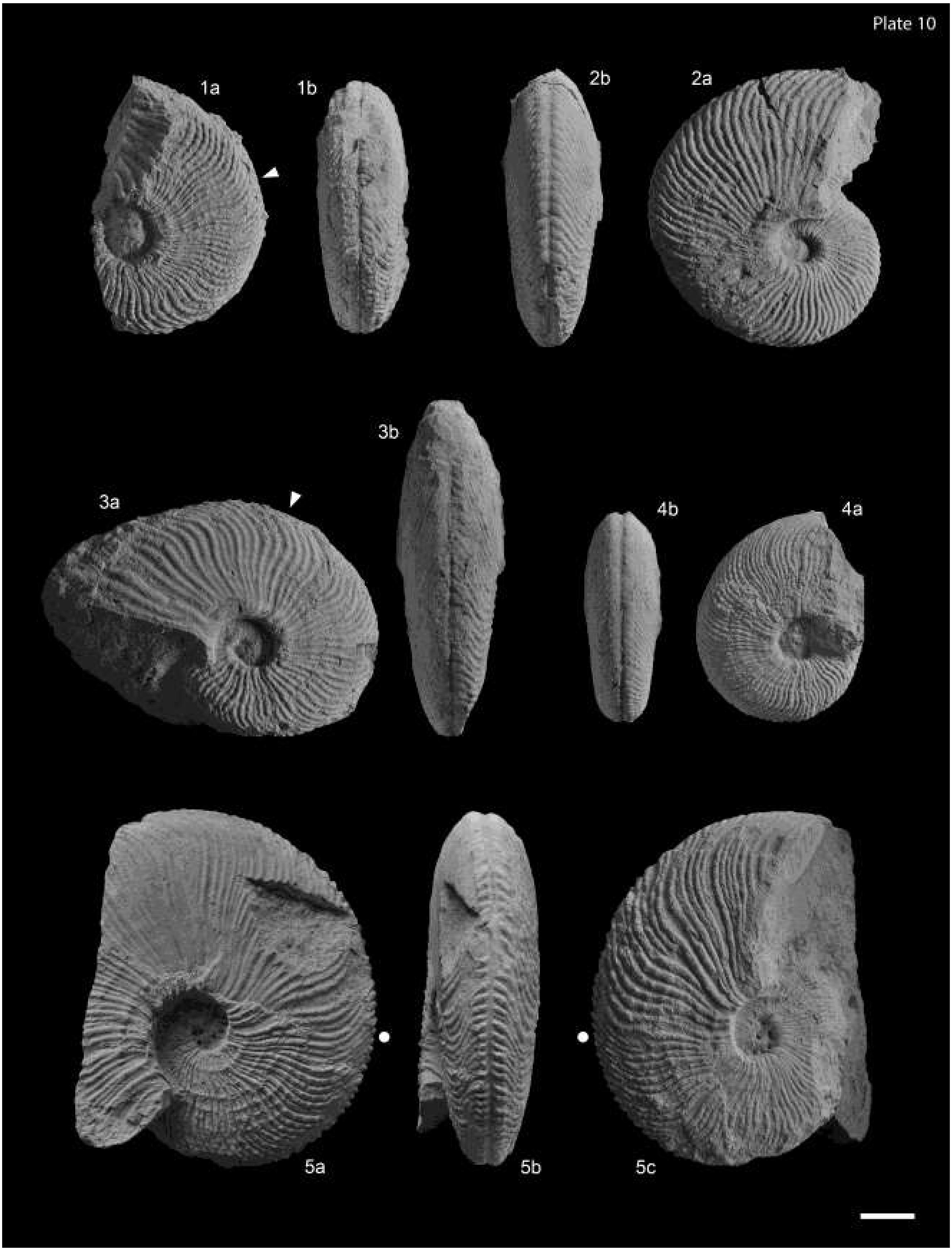
Plate 10
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Plate 11

Trachyceras sp. B
Fig. 1 – F26-6, phragmocone; 1a) lateral view; 1b) ventral view.
Fig. 2 – F26-9, phragmocone, lateral view.
Fig. 3 – F26-283, phragmocone; 3a) lateral view; 3b) ventral view; 3c) oral view.
Fig. 4 – F26-282, phragmocone; 4a) lateral view; 4b) ventral view; 4c) oral view.
Fig. 5 – F26-291, phragmocone; 5a) lateral view; 5b) ventral view; 5c) enlarged detail of the venter.

All specimens are from South Canyon.

The white arrows on lateral views indicate the direction of the corresponding ventral view. All specimens are coated with ammonium chloride. Bar scales are 10mm.

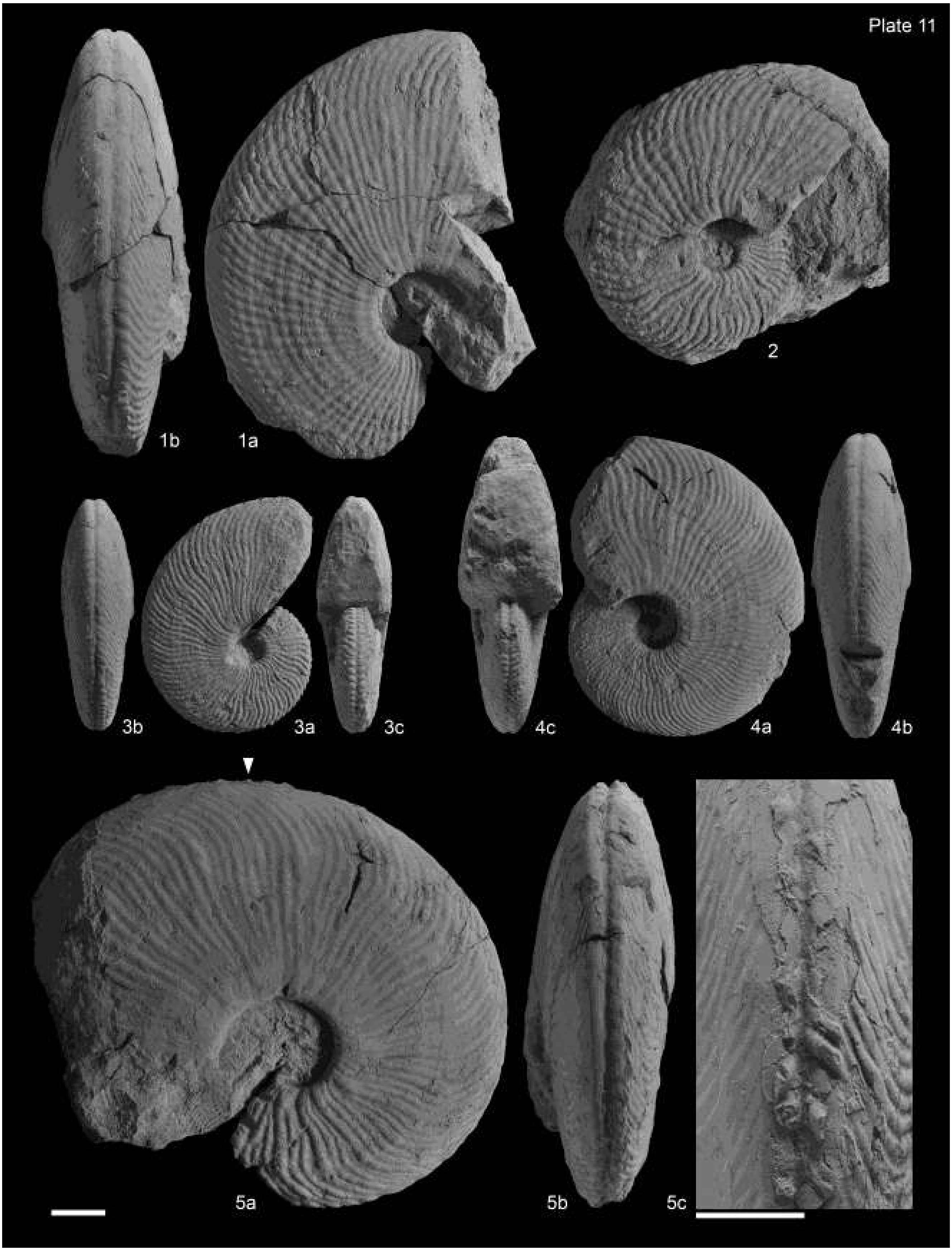

Plate 11

Plate 12

Trachyceras silberlingi Balini et al., 2012
Fig. 1 – F26-281, phragmocone; 1a) lateral view; 1b) ventral view.
Fig. 2 – Holotype MPUM 11061 (F26-14), lateral view; asterisk marks the last septum, white circle marks the ribs looped at the bulla (image taken from Balini et al., 2012).

?*Trachyceras* sp. ind.
From China Mountain, locality C.
Fig. 3 – CHM42-7, body chamber; 3a) lateral view; 3b) ventral view. From China Mountain.

Genus A sp. A
Fig. 4 – F1-1, phragmocone, lateral view.
Fig. 5 – F1-2, phragmocone; 5a) lateral view; 5b) ventral view; 5c) enlarged detail of the venter.
Fig. 6 – F1bis-48; 6a) lateral view; 6b) ventral view; 6c) enlarged detail of the venter.
Fig. 7 – F1bis-37; 7a) lateral view; 7b) enlarged detail of the flank with part of test preserved.

All specimens are from South Canyon, unless otherwise stated.

The white arrows on lateral views indicate the direction of the corresponding ventral view. The white dots indicate the position of the last septum. All specimens are coated with ammonium chloride. Bar scales are 10mm.

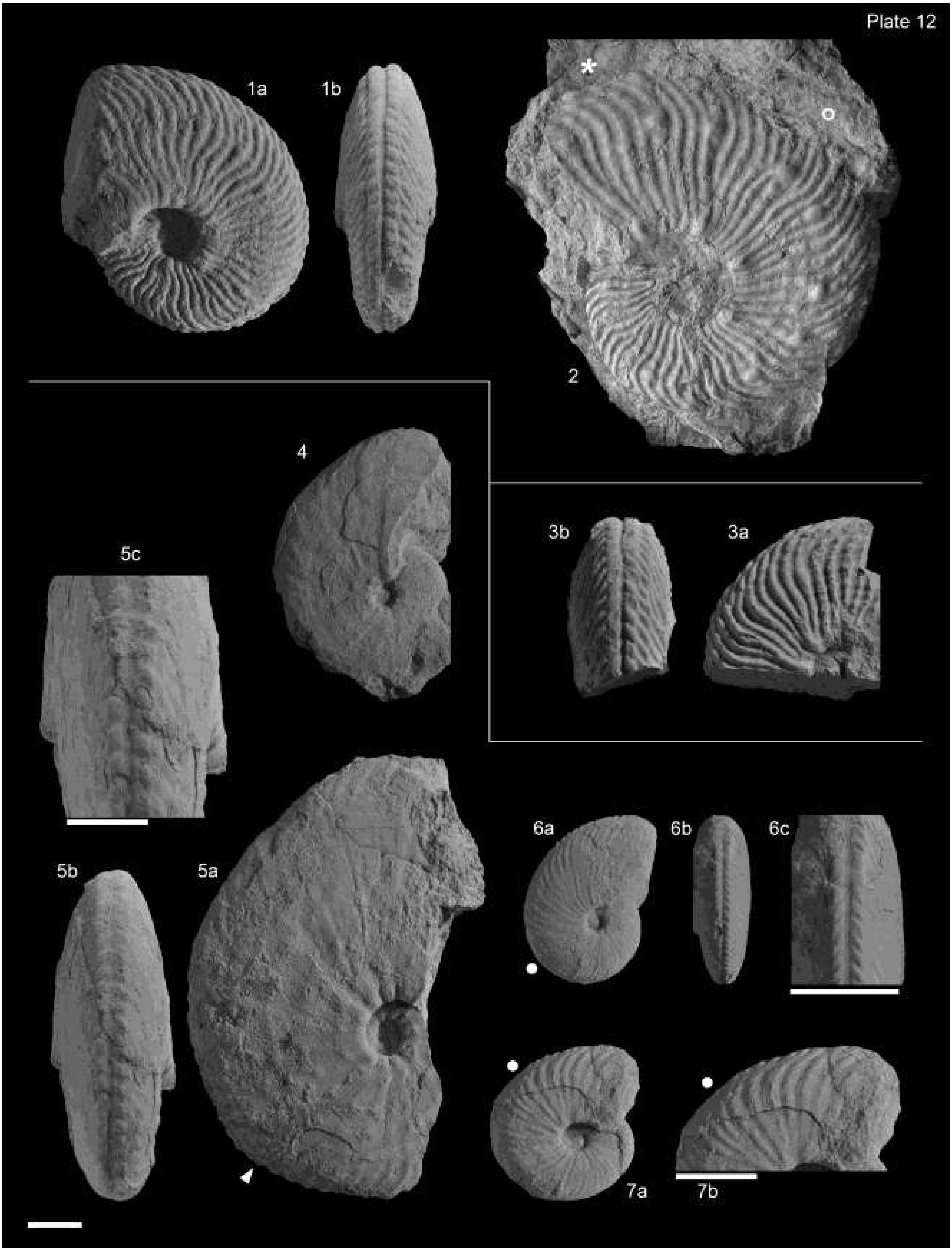
Plate 12
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Plate 13

Genus B sp. A

Fig. 1 – CHM37-1, internal mold with small parts of test; 1a) lateral view; 1b) ventral view; 1c) enlarged detail of the venter.

Fig. 2 – CHM34-1, internal mold with parts of test. 2a) lateral view; 2b) ventral view.

Fig. 3 – CHM19-8, internal mold with small parts of test. 3a) lateral view; 3b) ventral view.

Fig. 4 – CHM19-2, internal mold with parts of test. 4a) lateral view; 4b) ventral view.

Fig. 5 – CHM45-1, internal mold. 5a) lateral view; 5b) ventral view.

Fig. 6 – CHM17-1, internal mold. 6a) oral view; 6b) lateral view; 6c) ventral view.

Fig. 7 – CHM42-2, internal mold. 7a) oral view; 7b) lateral view; 7c) ventral view.

Fig. 8 – CHM33-10, internal mold with parts of test. 8a) ventral view; 8b) lateral view; 8c) detail of the flank with part of test preserved.

Fig. 9 – CHM45-10, internal mold. 9a) lateral view; 9b) ventral view.

Fig. 10 – CHM42-1, internal mold. 10a) left lateral view; 10b) ventral view; 10c) right lateral view.

Fig. 11 – CHM45-17, internal mold. 11a) lateral view; 11b) ventral view.

All specimens are from China Mountain.

The white arrows on lateral views indicate the direction of the corresponding ventral view. The white dots indicate the position of the last septum. All specimens are coated with ammonium chloride. Bar scales are 10mm.

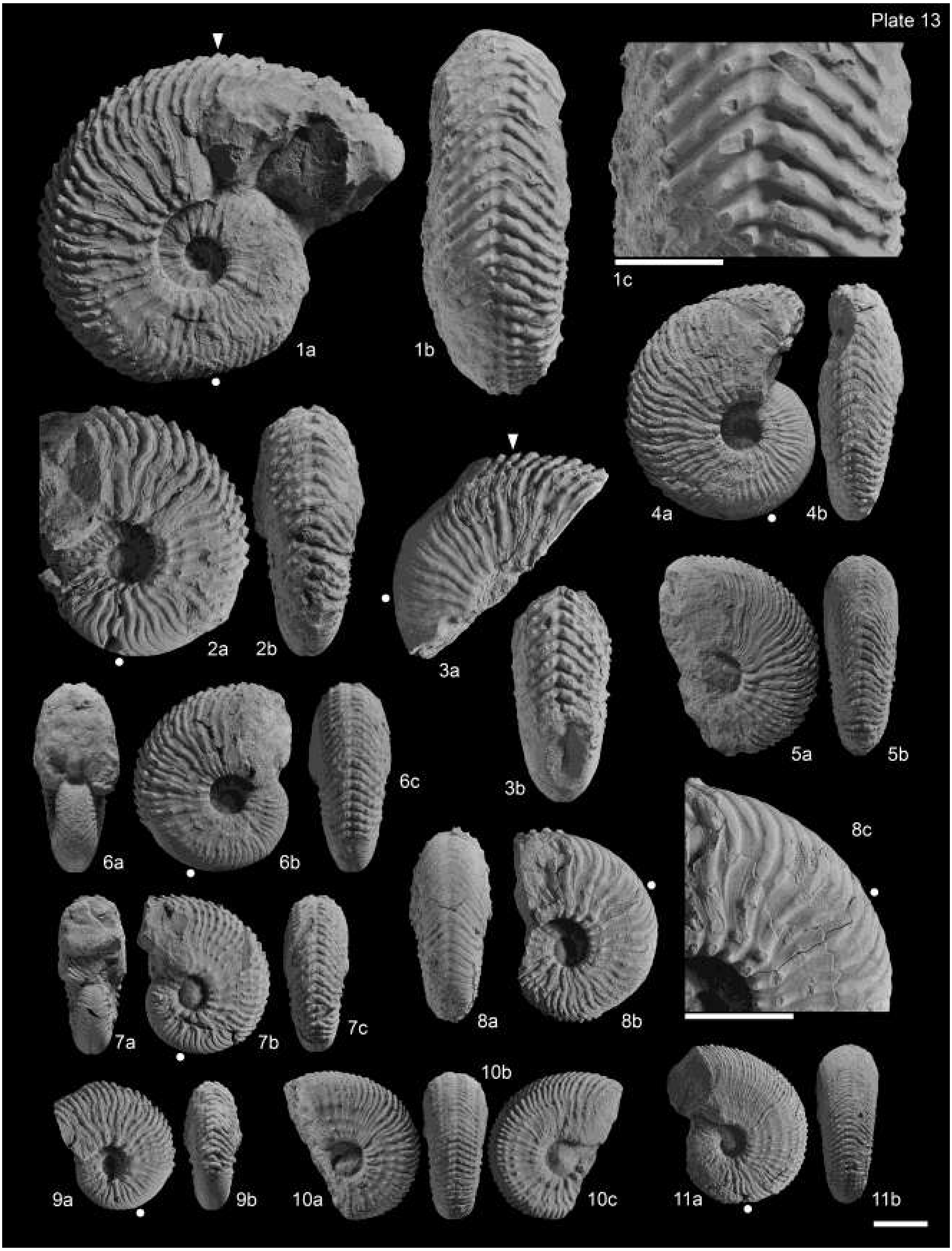
Plate 13
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8c
7a
7b
7c
8a
8b
10b
9a
9b
10a
10c
11a
11b

Plate 14

Genus B sp. B
Fig. 1 – CHM15A-1, internal mold. 1a) lateral view; 1b) oral view; 1c) ventral view; 1d) enlarged detail of the venter.
Fig. 2 – CHM41-4, internal mold with small parts of test, lateral view.
Fig. 3 – CHM20-2, internal mold with small parts of test. 3a) lateral view; 3b) ventral view.
Fig. 4 – CHM15A-2, internal mold with small parts of test. 4a) ventral view; 4b) lateral view; 4c) oral view.
Fig. 5 – CHM20-1, internal mold with small parts of test, lateral view.
Fig. 6 – CHM19-3, internal mold. 6a) lateral view; 6b) ventral view.
Fig. 7 – JJ4-18-2, internal mold. 7a) lateral view; 7b) ventral view.
Fig. 8 – CHM41-1, -2, internal molds, lateral view.

Genus B sp. ind.
Fig. 9 – CHM20-11, internal mold. 19: ventral view; 20: lateral view; 21: oral view.

Genus B *compressum* (Johnston, 1941)
Fig. 10 – Holotype USNM 77536, internal mold and big parts of test. 10a) lateral view; 10b) ventral view; 10c) oral view. From South Canyon.

All specimens are from China Mountain, unless otherwise stated.

The white arrows on lateral views indicate the direction of the corresponding ventral view. The white dots indicate the position of the last septum. All specimens are coated with ammonium chloride. Bar scales are 10mm.

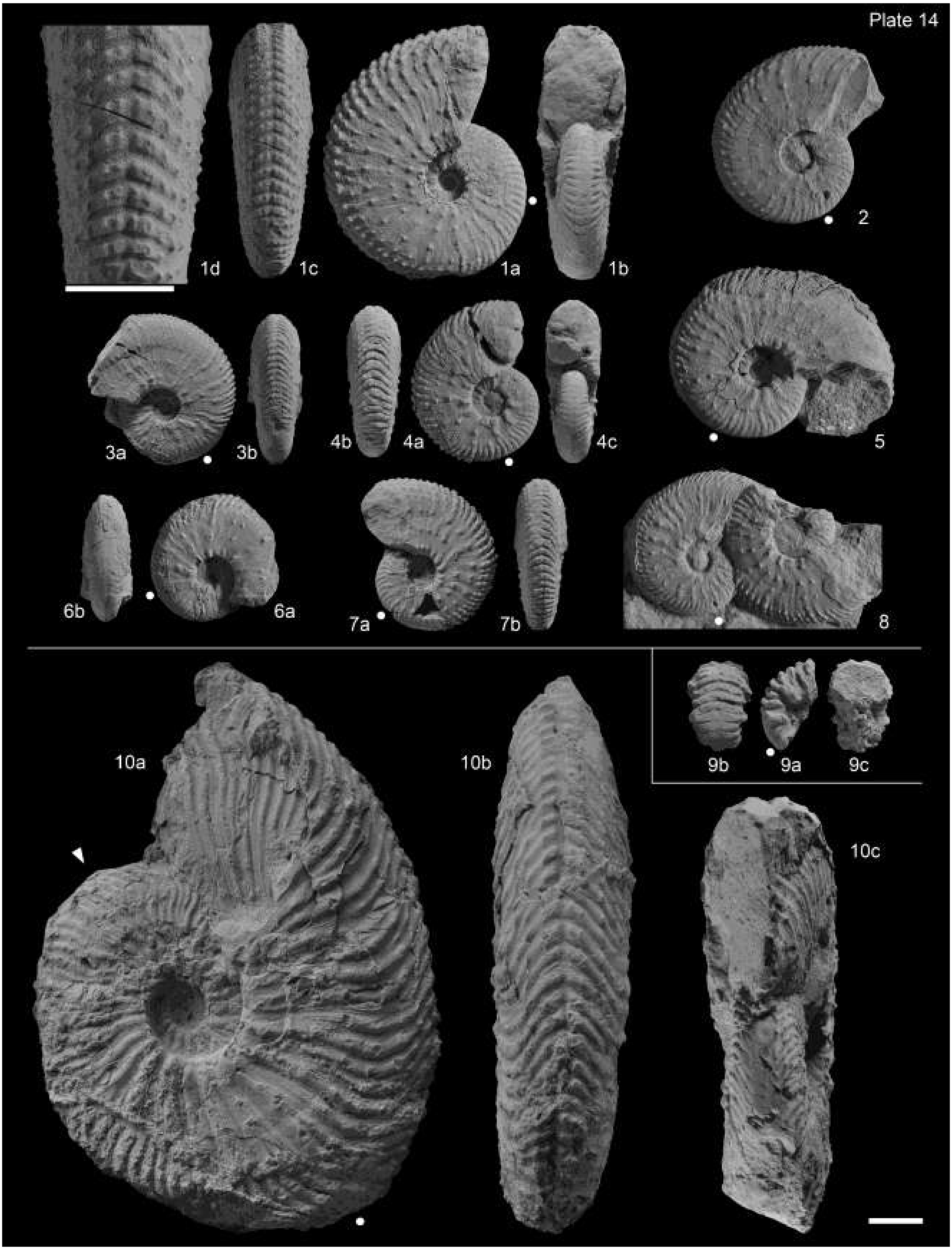
Plate 14
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Plate 15

Genus B *compressum* (Johnston, 1941)
Fig. 1 – JJ6-05-7; 1a) right lateral view, test; 1b) ventral view; 1c) left lateral view, internal mold.
Fig. 2 – JJ5-05-3; 2a) right lateral view, mostly test; 2b) ventral view, mostly test; 2c) left lateral view, test and internal mold; 2d) enlarged detail of the venter.
Fig. 3 – E3-74; 3a) right lateral view, mostly test; 3b) ventral view, mostly internal mold; 3c) left lateral view, mostly internal mold.

All specimens are from South Canyon.

The white arrows on lateral views indicate the direction of the corresponding ventral view. The white dots indicate the position of the last septum. All specimens are coated with ammonium chloride. Bar scales are 10mm.

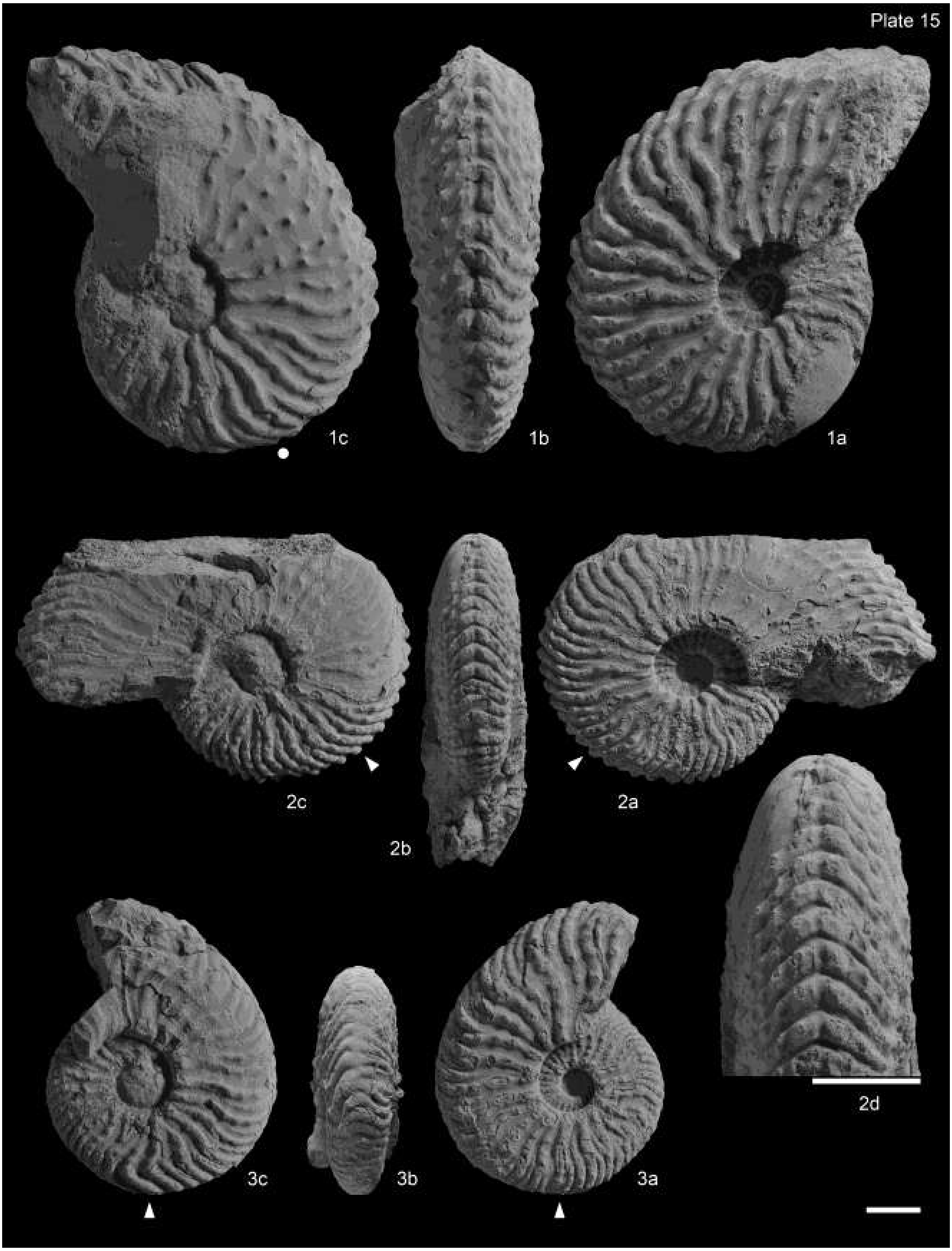
Plate 15
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3c
3b
3a

Plate 16

Genus B *compressum* (Johnston, 1941)
Fig. 1 – D10-70; 1a) left lateral view, test; 1b) ventral view; 1c) right lateral view, internal mold; 1d) ventral view.
Fig. 2 – JJ5-05-5; 2a) right lateral view, internal mold; 2b) oral view; 2c) left lateral view, mostly test; 2d) ventral view.
Fig. 3 – JJ6-05-2; 3a) lateral view, mostly test; 3b) ventral view.
Fig. 4 – D10bis-5, internal mold, lateral view.
Fig. 5 – D10bis-8, mostly internal mold, lateral view.
Fig. 6 – JJ5-05-2; 6a) right lateral view, mostly test; 6b) left lateral view, mostly internal mold.

All specimens are from South Canyon.

The white arrows on lateral views indicate the direction of the corresponding ventral view. The white dots indicate the position of the last septum. All specimens are coated with ammonium chloride. Bar scales are 10mm.

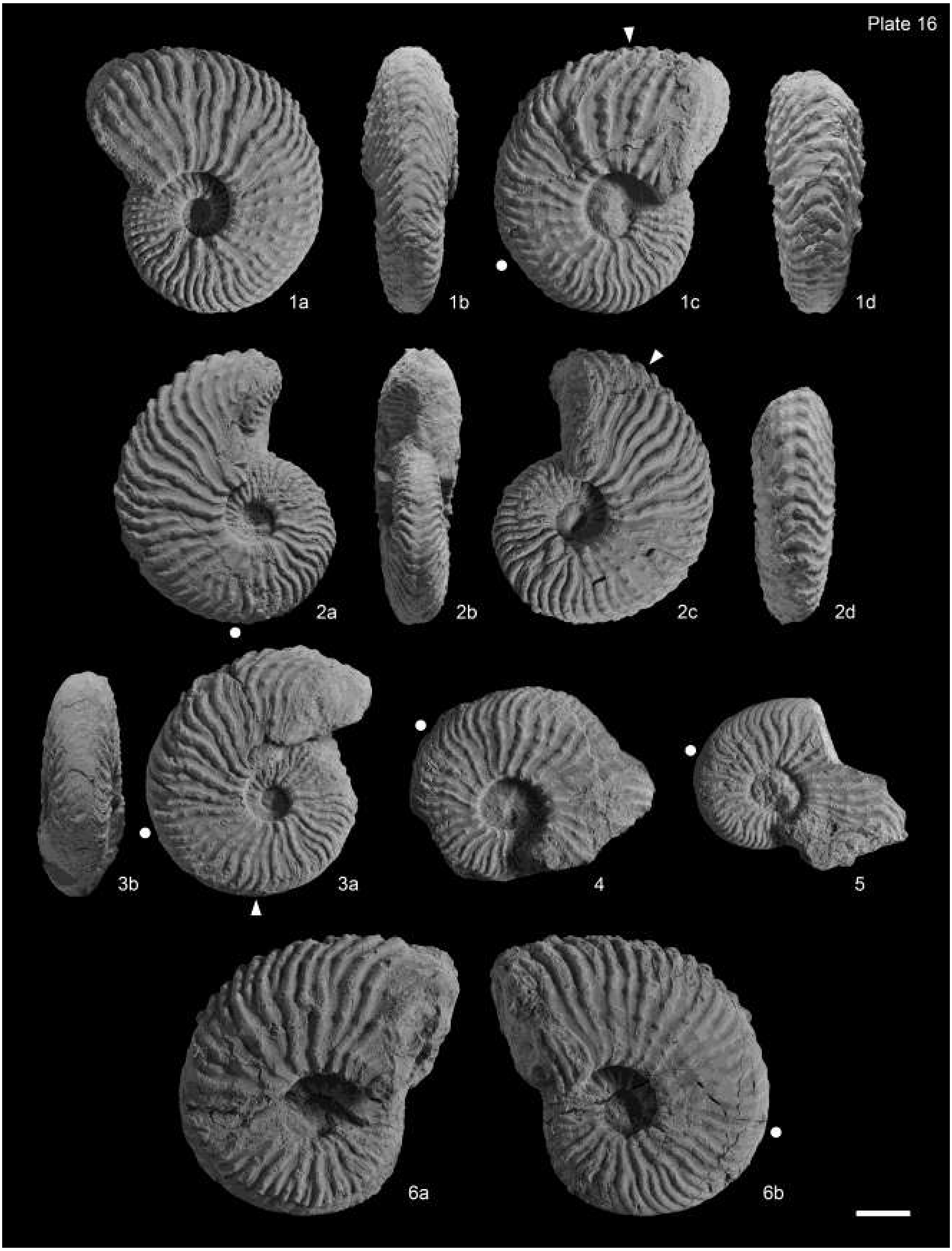
Plate 16
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Plate 17

Genus B *compressum* (Johnston, 1941)
Fig. 1 – JJ6-05-1; 1a) left lateral view, test and internal mold; 1b) ventral view; 1c) right lateral view, mostly test.
Fig. 2 – D10-69; 2a) left lateral view, mostly test; 2b) ventral view, mostly test; 2c) enlarged detail of the venter; 2d) right lateral view, test and internal mold.
Fig. 3 – D10-32; 3a) lateral view, mostly internal mold; 3b) ventral view; 3c) enlarged detail of the venter.
Fig. 4 – JJ5-05-4; 4a) ventral view; 4b) lateral view, mostly test.
Fig. 5 – E3-65; 5a) lateral view, mostly test; 5b) ventral view.
Fig. 6 – E3-5; 6a) lateral view, mostly test; 6b) ventral view, mostly internal mold.

All specimens are from South Canyon.

The white dots indicate the position of the last septum. All specimens are coated with ammonium chloride. Bar scales are 10mm.

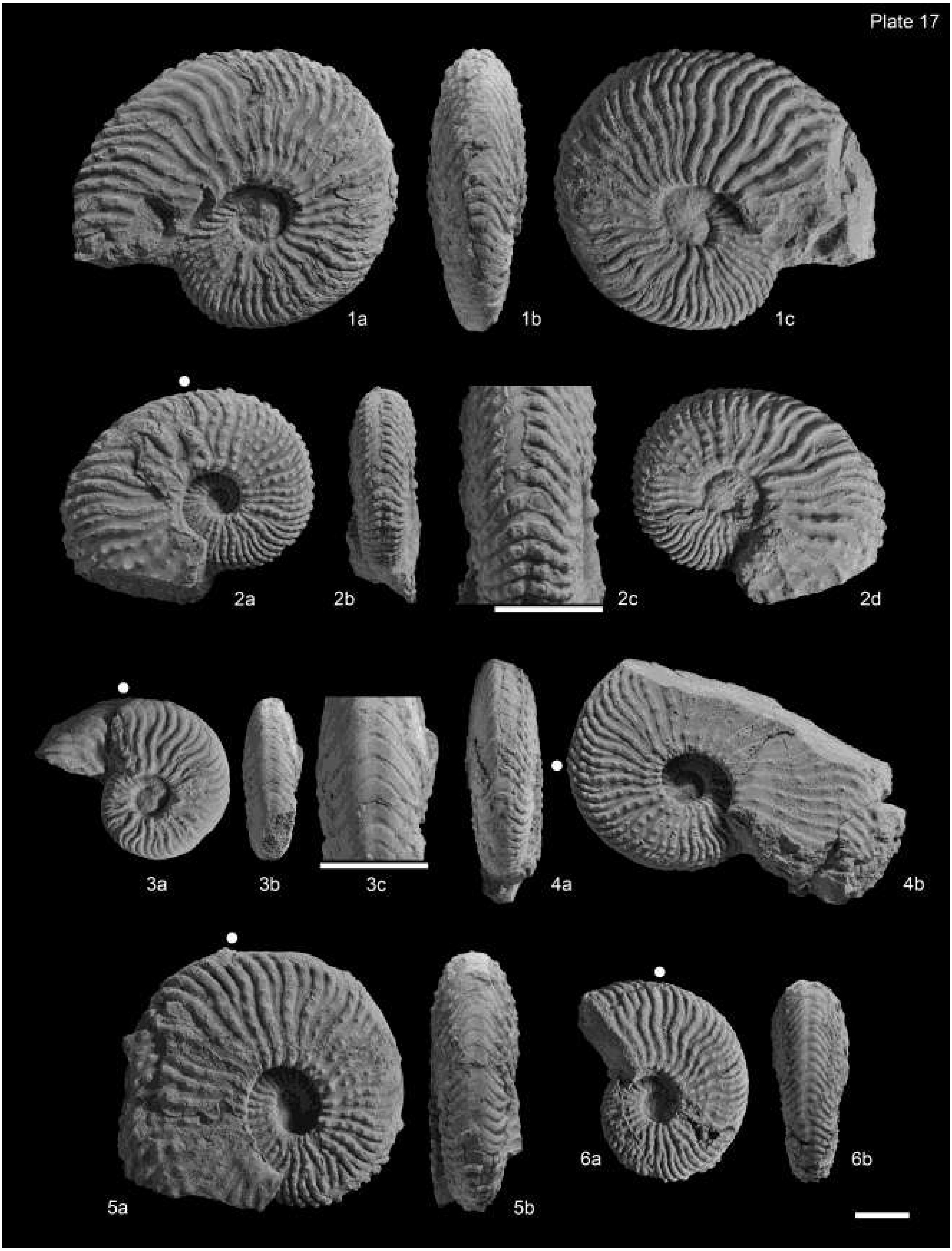
Plate 17
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Plate 18

Clionitites barwicki (Johnston, 1941)
Fig. 1 – A21-85; 1a) lateral view; 1b) ventral view.
Fig. 2 – scan16-15; 2a) lateral view; 2b) ventral view.
Fig. 3 – A21-86; 3a) lateral view; 3b) ventral view.
Fig. 4 – A21-87; 4a) lateral view; 4b) ventral view.

Clionitites aff. *wheeleri* (Johnston)
Fig. 5 – E5-160; 5a) lateral view; 5b) ventral view.
Fig. 6 – F1-99; 6a) lateral view; 6b) ventral view.
Fig. 7 – F1-11; 7a) lateral view; 7b) ventral view.
Fig. 8 – F1-97; 8a) lateral view; 8b) ventral view.

Clionitites reesidei (Johnston, 1941)
Fig. 9 – F1bis-95; 9a) lateral view; 9b) ventral view.
Fig. 10 – E18.2-19; 10a) lateral view; 10b) ventral view.
Fig. 11 – E18.1-14; 11a) lateral view; 11b) ventral view.
Fig. 12 – JJ4-18-26; 12a) lateral view; 12b) ventral view. From China Mountain.
Fig. 13 – F1bis-49; 13a) lateral view; 13b) ventral view.

Clionitites sp. A
Fig. 14 – F26-225; 14a) lateral view; 14b) ventral view.
Fig. 15 – F26-295; 15a) lateral view; 15b) ventral view.
Fig. 16 – F26-224; 16a) lateral view; 16b) ventral view.
Fig. 17 – F26-299; 17a) lateral view; 17b) ventral view.

Hannaoceras newpassense Johnston, 1941
Fig. 18 – A24-4; 18a) lateral view; 18b) ventral view.
Fig. 19 – scan3-; 19a) lateral view; 19b) ventral view.

Sympolycyclus antiquus Tozer, 1994
Fig. 20 – A22-2; 20a) lateral view; 20) ventral view.

All specimens are from South Canyon, unless otherwise stated.

The white arrows on lateral views indicate the direction of the corresponding ventral view. All specimens are coated with ammonium chloride. Bar scales are 10mm.

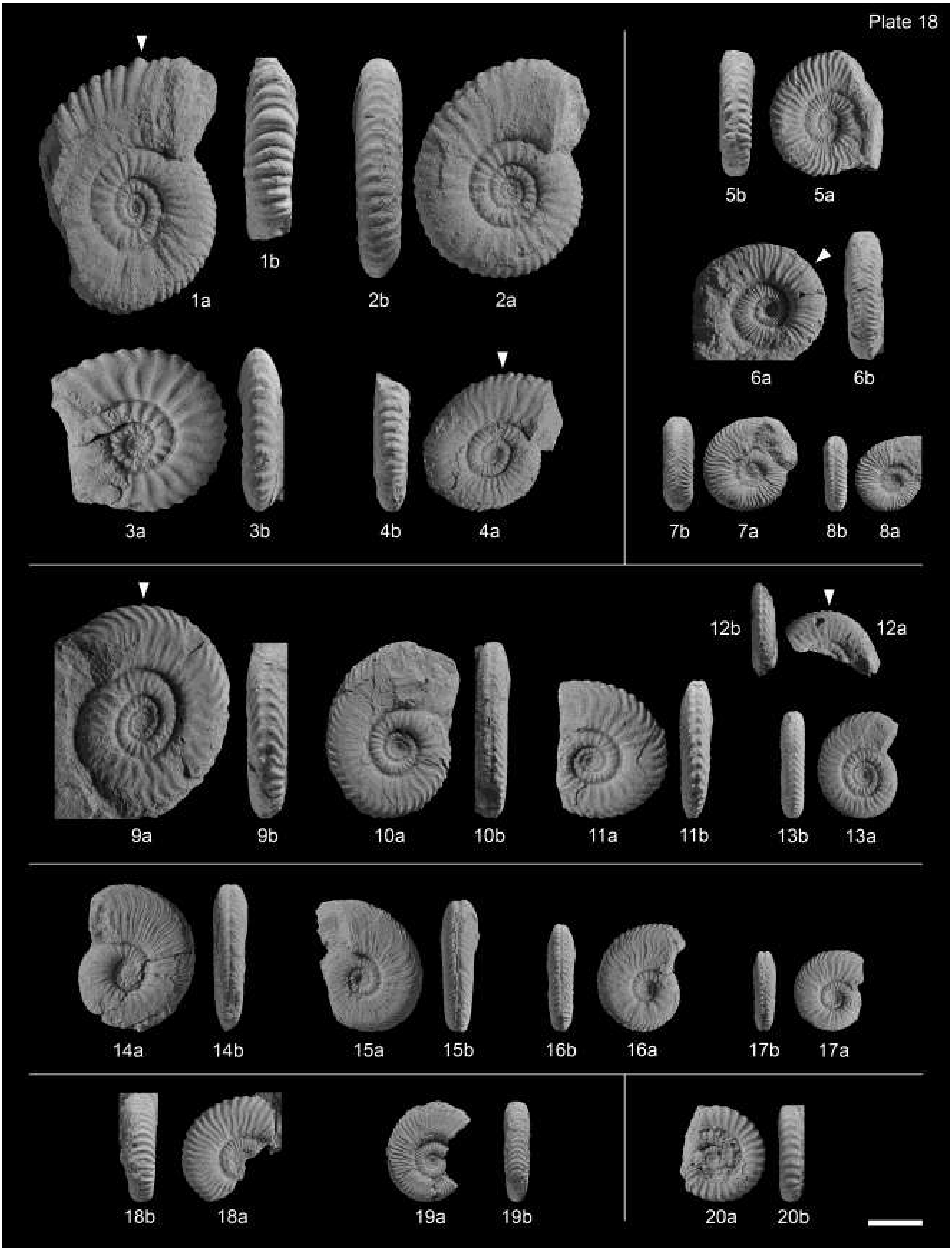
Plate 18
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Plate 19

Lobites gargantua Johnston, 1941
Fig. 1 – A11-28; 1a) lateral view; 1b) oral view.

Lobites carinatus Johnston, 1941
Fig. 2 – scan3-33; 2a) lateral view; 2b) ventral view.
Fig. 3 – B11-9; 3a) lateral view; 3b) oral view.
Fig. 4 – B11-134; lateral view.
Fig. 5 – scan3-42; 5a) lateral view; 5b) ventral view.

Coroceras zephyrum (Johnston, 1941)
Fig. 6 – F26-104; 6a) lateral view; 6b) ventral view.
Fig. 7 – F26-17; 7a) lateral view; 7b) ventral view.
Fig. 8 – F26-19; 8a) lateral view; 8b) ventral view.
Fig. 9 – F26-207; 9a) lateral view; 9b) ventral view; 9c) oral view.

All specimens are from South Canyon.

All specimens are coated with ammonium chloride. Bar scales are 10mm.

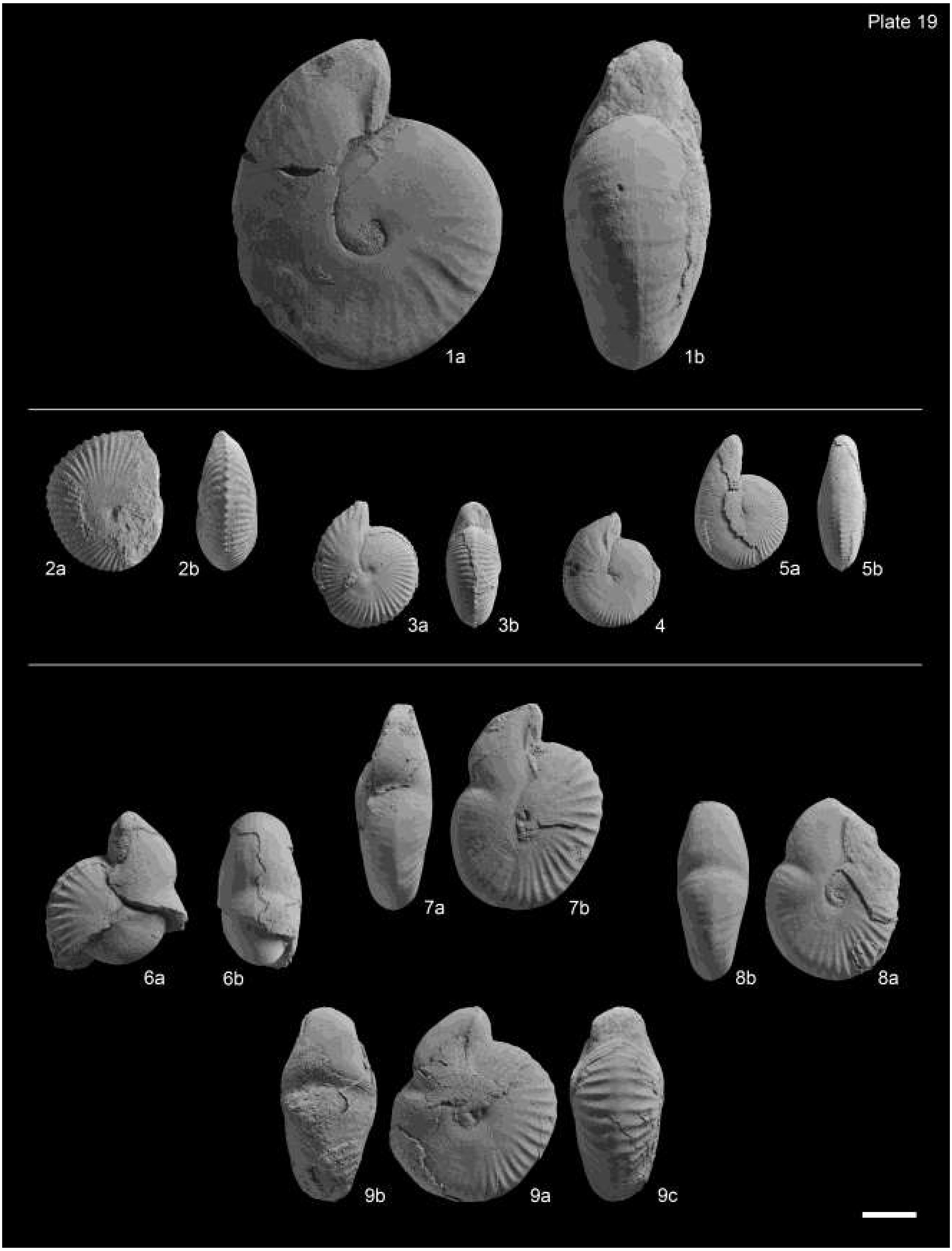
Plate 19
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8.3 - Tables

Table 1 – Measurements of specimens

Species	Specimen	D [mm]	H [mm]	h [mm]	U [mm]	W [mm]	U/D [-]	H/W [-]
Neoclypites desertorum (Johnston)	B11-97	44.50	27.00	15.50	2.00	9.70	0.04	2.78
	scan16-591	23.40	13.30	8.30	1.80	5.70	0.08	2.33
	A21-37	76.30	*46.50*	*27.00*	*2.80*	*17.00*	0.04	2.74
	A22-10	71.00	41.90	26.00	3.10	16.60	0.04	2.52
	USNM 77518b	24.00	14.00	8.50	1.50	5.50	0.06	2.55
	USNM 77518c	63.00	37.80	23.00	2.20	14.00	0.03	2.70
	USNM 77518d	37.00	22.50	13.00	1.50	—	0.04	—
	USNM 77518f	48.00	29.00	17.00	2.00	11.00	0.04	2.64
Perrinoceras novaditum Johnston	E18.1-59	45.00	28.00	15.00	2.00	8.30	0.04	3.37
	F1-46	—	46.70	—	—	*13.70*	—	3.41
	F26-74	—	40.00	—	—	14.00	—	2.86
		—	26.00	—	—	*9.80*	—	2.65
Silenticeras schencki (Johnston)	F18-8	*22.30*	*8.70*	*6.90*	*6.70*	8.10	0.30	1.07
	D4-42	13.40	5.90	4.00	3.50	5.00	0.26	1.18
	E13bis-14	17.00	7.30	5.00	4.70	5.80	0.28	1.26
	F18-3	18.40	6.70	6.00	5.70	—	0.31	—
Daxatina sp. A	scan16-537	39.60	21.50	12.00	6.10	—	0.15	—
		35.30	19.00	10.90	5.40	12.70	0.15	1.50
	scan16-11	—	19.60	—	—	11.20	—	1.75
	scan16-233	22.80	11.70	6.90	4.20	9.50	0.18	1.23
	scan16-226	30.80	15.80	9.20	5.80	10.70	0.19	1.48
	scan16-232	34.00	16.50	10.70	6.80	11.20	0.20	1.47
	scan16-266	28.20	14.40	7.80	6.00	10.30	0.21	1.40
	scan16-1	33.70	18.00	10.60	5.10	11.30	0.15	1.59
	scan16-81	22.20	11.40	6.70	4.10	8.70	0.18	1.31
	scan16-297	22.40	12.40	6.70	3.30	8.00	0.15	1.55
	scan16-492	34.00	16.00	12.20	5.80	—	0.17	—
	scan16-234	26.50	13.70	7.70	5.10	9.50	0.19	1.44
	scan16-2	52.90	28.40	13.80	10.70	—	0.20	—
	scan16-13	34.00	17.90	10.20	5.90	11.00	0.17	1.63
	scan16-270	24.70	12.80	7.00	4.90	8.50	0.20	1.51
	scan16-294	—	12.40	—	—	10.30	—	1.20
	scan16-10	35.00	18.30	11.20	5.50	13.00	0.16	1.41
		42.80	24.00	12.40	6.40	—	0.15	—
	scan16-271	29.80	15.40	8.60	5.80	10.50	0.19	1.47
	scan16-111	19.70	10.20	5.90	3.60	6.60	0.18	1.55
	B11-18	24.90	12.70	7.50	4.70	8.70	0.19	1.46
	B11-43	30.60	9.00	16.00	5.60	—	0.18	—
		40.00	22.10	12.10	5.80	—	0.15	—
	B11-44	33.30	16.00	10.40	6.90	13.60	0.21	1.18
	B11-105	21.40	11.00	6.40	4.00	8.00	0.19	1.38
	A21-38	43.40	23.40	13.10	6.90	—	0.16	—
	A21-20	53.90	30.00	16.60	7.30	21.90	0.14	1.37
	A21-78	40.80	21.90	11.80	7.10	17.50	0.17	1.25
	A21-82	25.90	13.00	7.90	5.00	9.00	0.19	1.44
	A21-81	23.00	13.00	6.20	3.80	8.50	0.17	1.53
	A21-83	17.10	9.00	4.90	3.20	6.10	0.19	1.48
	JJ1-97-1	60.90	35.00	16.90	9.00	—	0.15	—
	JJ1-97-8	55.00	30.00	16.90	8.10	20.50	0.15	1.46

	JJ1-97-7	53.20	28.00	16.80	8.40	—	0.16	—
	JJ1-97-4	47.00	26.20	14.00	6.80	—	0.14	—
	scan3-1	32.40	17.60	9.70	5.10	12.10	0.16	1.45
		47.10	27.20	13.70	6.20	—	0.13	—
	A21-76	66.80	35.10	21.30	10.40	28.50	0.16	1.23
		55.50	29.60	17.00	8.90	23.00	0.16	1.29
	USNM 77532b	44.00	23.00	13.90	7.10	16.00	0.16	1.44
Daxatina bispinosa (Johnston)	B11-95	45.90	21.10	12.80	12.00	22.00	0.26	0.96
	JJ1-97-2	50.70	23.30	15.30	12.10	—	0.24	—
	JJ1-97-6	48.00	22.70	13.20	12.10	21.60	0.25	1.05
	USNM 77537	33.20	15.40	9.40	8.40	17.30	0.25	0.89
	USNM 77538	33.70	16.50	10.20	7.00	16.20	0.21	1.02
Daxatina sp. B	scan16-129	25.30	11.40	8.00	5.90	10.70	0.23	1.07
	scan16-361	34.80	16.80	10.70	7.30	13.00	0.21	1.29
	scan16-253	37.00	19.00	10.80	7.20	11.90	0.19	1.60
	scan16-264	36.60	17.30	11.40	7.90	13.20	0.22	1.31
	scan3-12	60.00	30.50	17.70	11.80	21.00	0.20	1.45
		42.90	21.00	13.80	8.10	18.20	0.19	1.15
	scan3-58	21.00	10.90	5.80	4.30	—	0.20	—
	scan3-57	22.00	10.90	6.90	4.20	—	0.19	—
	JJ1-97-3	82.00	43.50	23.50	15.00	27.80	0.18	1.56
		55.50	27.70	16.10	11.70	24.90	0.21	1.11
	A21-79	31.20	15.20	10.00	6.00	—	0.19	—
	A21-53	38.90	20.00	12.20	6.70	—	0.17	—
?Daxatina sp. A	F1-89	45.00	22.00	13.30	9.70	16.30	0.22	1.35
	F1-145	41.30	19.00	11.80	10.50	15.90	0.25	1.19
Trachyceras desatoyense Johnston	E5-75	38.80	19.00	11.60	8.20	12.00	0.21	1.58
	E5-76	49.00	25.00	14.30	9.70	—	0.20	—
	E5-73	33.70	18.90	9.70	5.10	—	0.15	—
	E5-20	35.00	19.00	11.40	4.60	12.00	0.13	1.58
	E5-18	38.00	19.00	12.00	7.00	12.80	0.18	1.48
	E5-79	34.20	17.00	11.00	6.20	—	0.18	—
	E5-90	53.00	25.50	17.30	10.20	—	0.19	—
	E5-100	60.00	30.00	18.30	11.70	—	0.20	—
	USNM 77535a	41.60	21.30	12.60	7.70	—	0.19	—
	USNM77535b	56.70	27.50	17.00	12.20	19.00	0.22	1.45
	USNM 77535c	30.90	15.80	9.10	6.00	9.20	0.19	1.72
	USNM 77535d	42.00	22.00	13.00	7.00	13.40	0.17	1.64
	USNM 77533	20.20	9.60	6.10	4.50	—	0.22	—
Trachyceras sp. A	E3-33	50.70	25.30	15.40	10.00	17.50	0.20	1.45
	E3-9	45.00	23.00	13.80	8.20	16.00	0.18	1.44
	E3-59	40.00	20.50	11.00	8.50	—	0.21	—
	D10bis-42	30.00	15.40	9.00	5.60	10.10	0.19	1.52
	F26-11	38.40	19.40	11.20	7.80	14.30	0.20	1.36
	USNM 77531	63.20	33.40	18.90	10.90	19.60	0.17	1.70
Trachyceras silberlingi Balini et al.	F26-281	45.00	24.00	12.00	9.00	18.00	0.20	1.33
	F26-284	42.00	20.00	12.00	10.00	—	0.24	—
Trachyceras sp. B	F26-291	87.00	44.40	25.00	17.60	27.50	0.20	1.61
	F26-282	55.70	29.50	16.00	10.20	18.00	0.18	1.64

	F26-283	43.80	24.00	13.00	6.80	13.00	0.16	1.85
	F26-6	—	44.00	—	—	25.60	—	1.72
	F26-8	37.60	19.00	11.00	7.60	—	0.20	—
Genus A sp. A	F1bis-48	29.60	16.00	9.00	4.60	—	0.16	—
	F1-2	80.60	44.60	25.60	10.40	—	0.13	—
Genus B sp. A	CHM37-1	53.00	22.80	16.50	13.70	22.00	0.26	1.04
	CHM42-1	28.00	12.80	8.00	7.20	11.30	0.26	1.13
	CHM44-1	24.00	11.30	6.30	6.40	9.70	0.27	1.16
		—	5.10	—	—	6.30	—	0.81
		—	8.00	—	—	7.70	—	1.04
	CHM17-1	34.00	16.50	10.20	7.30	14.50	0.21	1.14
	CHM42-2	28.40	14.00	7.50	6.90	11.80	0.24	1.19
	CHM37-2	22.00	10.50	5.50	6.00	8.90	0.27	1.18
		14.40	6.90	3.40	4.10	6.80	0.28	1.01
	CHM45-10	23.50	11.80	6.00	5.70	9.50	0.24	1.24
		—	5.00	—	—	6.00	—	0.83
	CHM33-10	32.00	15.00	9.50	7.50	13.30	0.23	1.13
	CHM34-1	45.00	20.30	13.60	11.10	18.40	0.25	1.10
	JJ4-18-1	24.80	11.40	6.60	6.80	9.60	0.27	1.19
	CHM19-2	40.40	20.00	11.80	8.60	—	0.21	—
		27.00	12.80	8.00	6.20	10.00	0.23	1.28
	CHM34-11	23.50	11.00	6.70	5.80	9.50	0.25	1.16
	JJ4-18-4	17.00	7.30	4.30	5.40	7.20	0.32	1.01
Genus B sp. A (extreme variants)	CHM34-5	25.00	11.90	7.00	6.10	9.60	0.24	1.24
	CHM45-17	29.00	14.00	9.00	6.00	11.50	0.21	1.22
	CHM45-1	—	16.70	—	—	13.00	—	1.28
	CHM34-2	—	11.60	—	—	9.00	—	1.29
	CHM44-9	—	8.70	—	—	7.40	—	1.18
	CHM44-3	25.50	12.40	7.30	5.80	9.40	0.23	1.32
	CHM42-13	—	10.40	—	—	8.40	—	1.24
Genus B sp. B	CHM15A-1	44.40	21.80	13.90	8.70	14.00	0.20	1.56
		—	18.00	—	—	11.80	—	1.53
	CHM15A-2	25.00	12.00	6.40	6.60	8.50	0.26	1.41
		—	5.00	—	—	5.40	—	0.93
		—	7.30	—	—	6.20	—	1.18
		—	9.70	—	—	7.30	—	1.33
	CHM41-4	35.00	17.00	10.50	7.50	—	0.21	—
	JJ4-18-2	28.20	14.00	7.90	6.30	9.40	0.22	1.49
		22.40	11.20	6.30	4.90	—	0.22	—
		—	6.30	—	—	5.30	—	1.19
	CHM20-1	30.00	15.00	8.00	7.00	10.30	0.23	1.46
	CHM19-3	24.00	11.40	7.00	5.60	8.30	0.23	1.37
	CHM20-2	28.50	14.30	8.10	6.10	—	0.21	—
	CHM34-3	27.20	13.80	7.00	6.40	—	0.24	—
		20.00	9.60	5.00	5.40	7.60	0.27	1.26
Genus B *compressum* (Johnston)	D10bis-79	45.50	20.30	14.50	10.70	—	0.24	—
	D10bis-5	37.00	17.30	10.20	9.50	—	0.26	—
	JJ6-05-7	69.00	33.50	20.70	14.80	23.30	0.21	1.44
	D10-70	51.00	24.00	14.80	12.20	16.60	0.24	1.45
	D10bis-8	29.20	13.20	8.00	8.00	9.80	0.27	1.35
	JJ5-05-3	47.30	22.30	14.20	10.80	16.30	0.23	1.37
	JJ5-05-5	47.00	22.50	13.20	11.30	15.20	0.24	1.48
	JJ6-05-2	42.90	20.20	12.50	10.20	15.00	0.24	1.35

	D10-32	27.00	12.80	7.00	7.20	9.50	0.27	1.35
	D10-3	37.60	17.00	11.20	9.40	12.00	0.25	1.42
	E3-5	37.00	18.00	10.00	9.00	13.00	0.24	1.38
	JJ5-05-2	55.00	26.50	16.00	12.50	18.80	0.23	1.41
	D10-118	36.00	16.50	10.60	8.90	12.00	0.25	1.38
	D10-69	33.50	15.50	10.00	8.00	11.00	0.24	1.41
Clionitites barwicki (Johnston)	USNM 77512b	26.20	8.70	6.70	10.80	6.30	0.41	1.38
	USNM 77512c	24.00	7.60	5.90	10.50	—	0.44	—
	USNM 77512e	47.70	14.00	11.10	22.60	8.10	0.47	1.73
Clionitites reesidei (Johnston)	USNM 77513b	11.00	3.50	2.50	5.00	3.20	0.45	1.09
	USNM 77513c	15.40	5.00	3.00	7.40	3.70	0.48	1.35
	USNM 77513d	17.40	5.40	3.80	8.20	4.30	0.47	1.26
	USNM 77513e	16.90	5.20	3.90	7.80	4.20	0.46	1.24
	USNM 77513f	17.20	5.90	3.90	7.40	4.60	0.43	1.28
	USNM 77513g	22.40	7.80	5.30	9.30	5.30	0.42	1.47
	USNM 77513h	19.70	6.20	4.50	9.00	4.70	0.46	1.32
	USNM 77513j	29.70	10.20	6.70	12.80	—	0.43	—
Clionitites sp. A	F26-224	20.10	8.50	5.50	6.10	5.10	0.30	1.67
	F26-225	26.80	10.80	6.90	9.10	6.10	0.34	1.77
	F26-295	24.80	10.00	6.50	8.30	6.40	0.33	1.56
	F26-299	15.70	5.70	4.20	5.80	4.30	0.37	1.33
Hannaoceras newpassense Johnston	USNM 77514c	25.00	8.00	6.10	10.90	7.00	0.44	1.14
	USNM 77514a	20.00	6.90	4.50	8.60	5.80	0.43	1.19
	USNM 77514b	23.90	7.50	5.60	10.80	6.00	0.45	1.25

Table 2 – TDE/TDL ratio in Trachyceratinae specimens

Species	Specimen	H [mm]	TDE [mm]	TDL [mm]	TDE/TDL [-]
Daxatina sp. A	JJ1-97-8	27	10.00	16.78	0.60
	A21-38	12	5.30	6.59	0.80
	A21-76	19.4	8.49	11.31	0.75
	A21-5	15	6.16	8.15	0.76
	scan3-1	18	7.22	9.28	0.78
	B11-36	15	4.80	7.65	0.63
	B11-81	21	8.97	12.00	0.75
	scan16-1	16.7	5.98	6.97	0.86
		11.7	4.27	5.92	0.72
		7	2.62	3.40	0.77
		3.2	1.20	1.34	0.90
	scan16-586	18.3	8.60	9.77	0.88
		10.4	4.98	5.83	0.85
		1.6	0.42	0.49	0.86
	scan16-233	11.7	4.45	5.86	0.76
	scan16-483	19	6.07	8.01	0.76
	scan16-537	20.4	7.39	10.58	0.70
	scan16-11	16.8	5.49	7.61	0.72
	scan16-581	27	9.83	14.46	0.68
	scan16-582	8	2.73	3.12	0.87
	scan16-578	21.6	8.43	11.59	0.73
	scan16-10	17.3	5.33	10.70	0.50
	USNM 77532a	19.5	7.52	10.84	0.69
	USNM 128316	23	7.70	11.84	0.65
	USNM 77532b	12	4.68	6.76	0.69
Daxatina bispinosa (Johnston)	B11-95(-70)	20	9.00	11.82	0.76
	JJ1-97-6	14	8.95	9.68	0.92
	USNM 77537	9	4.83	5.29	0.91
Daxatina sp. B	scan16-253	16.7	5.24	7.07	0.74
	scan16-361	15.3	7.09	7.22	0.98
		8.8	3.24	3.69	0.88
	JJ1-97-3	17.5	8.44	10.55	0.80
	scan3-12	20	9.16	12.47	0.73
?Daxatina sp. A	F1-145	12.5	6.40	7.51	0.85
	F1-67	10	4.57	6.40	0.71
	F1-89	11.7	5.34	6.31	0.85
	F1-68	12.5	4.91	6.63	0.74
	E5-23	12	5.96	7.68	0.78
Trachyceras desatoyense Johnston	E5-72	13	5.07	7.60	0.67
		2	0.63	0.71	0.88
	E5-73	10	6.66	7.37	0.90
	E5-82	—	5.22	8.07	0.65
	E5-75	18	4.98	8.47	0.59
	E5-85	12.8	5.37	7.26	0.74
	E5-100	18	6.35	9.07	0.70
Trachyceras sp. A	D10bis-42	—	6.42	7.95	0.81
	E3-33	18.7	9.44	13.13	0.72
	F1-44	27	11.47	13.51	0.85

Trachyceras silberlingi Balini et al.	F26-281	23	10.15	15.36	0.66
		11	5.81	6.90	0.84
Trachyceras sp. B	F26-6	31	14.10	22.36	0.63
	F26-8	17	7.77	10.68	0.73
	F26-283	17.4	5.63	9.35	0.60
	F26-291	32	10.20	18.15	0.56
	F26-282	26	8.87	13.06	0.68
		18	6.26	9.83	0.64
		13	5.71	7.55	0.76
Genus B sp. A	CHM19-8	16.7	4.68	9.87	0.47
	CHM34-1	12.5	4.05	6.66	0.61
	CHM42-2	8	2.72	5.01	0.54
	CHM44-7	8	2.67	5.70	0.47
	CHM45-10	6.6	2.50	4.17	0.60
	CHM47-1	9	3.08	6.23	0.49
	CHM34-21	5	1.16	2.11	0.55
		2	0.54	0.76	0.71
		0.5	0.12	0.09	1.38
	CHM42-24	10	1.41	2.85	0.50
Genus B sp. B	CHM19-3	8	1.77	4.11	0.43
	CHM20-1	10	2.06	4.11	0.50
Genus B sp. C	D10bis-79	15	4.06	6.50	0.62
	D10bis-49	18	6.77	11.04	0.61
	JJ5-05	15	5.40	8.83	0.61
	D10-27	20.5	5.14	11.16	0.46
	D10-95	16	3.88	9.07	0.43
	D10-118	13.3	4.18	6.29	0.66
	D10bis-92	11.4	3.53	5.87	0.60
	D10-3	12	3.58	5.49	0.65
	D10-32	6.3	2.02	3.33	0.60
		14	3.66	6.26	0.58
	E3-5	12.4	4.70	6.00	0.78
	E3-65	15	3.94	7.32	0.54
	JJ6-05-1	15.5	4.66	7.40	0.63
	JJ5-05-5	10	2.89	4.73	0.61
	F15-1	20	7.02	10.70	0.66
Data from literature					
Daxatina canadensis (Whiteaves)	GSC 4718 (Tozer, 1994)	17.00	7.19	7.37	0.97
	GSSC 28810 (Tozer, 1994)	16.00	8.05	7.91	1.02
Daxatina laubei Tozer	GSC 28805 (Tozer, 1994)	16.00	4.96	6.09	0.81
Daxatina megabrotheus Tozer	GSC 28821 (Tozer, 1994)	15.00	6.34	6.42	0.99

Daxatina limpida Tozer	GSC 28817 (Tozer, 1994)	5.00	1.26	1.54	0.82
	GSC 28819 (Tozer, 1994)	—	3.28	4.51	0.73
Trachyceras aon (Münster)	SMNS 75003/12 (Urlichs, 1994)	15.00	15.63	25.17	0.62
Trachyceras bipunctatum (Münster)	SMNS 75007/10 (Urlichs, 1994)	10.00	30.50	34.72	0.88
Trachyceras credneri (Klipstein)	MSNV 10237/2 (Urlichs, 1994)	5.50	14.96	20.04	0.75
Trachyceras humboldti (Klipstein)	MSNV 10243 (Urlichs, 1994)	20.00	32.78	43.22	0.76
Trachyceras infundibuliforme (Klipstein)	SMNS 75025 (Urlichs, 1994)	6.50	19.69	15.40	1.28
	BMNH 35976 (Urlichs, 1994)	5.00	13.83	12.68	1.09
Trachyceras muensteri (Wissmann)	BSP AS VII 416 (Urlichs, 1994)	3.50	6.09	7.72	0.79
	SMNS 13470/7 (Urlichs, 1994)	15.00	17.17	20.75	0.83
	BSP -? (Mojsisovics, 1882)	18.00	10.07	15.04	0.67
Trachyceras pontius Laube	IGPT 1614/6 (Urlichs, 1994)	4.50	7.72	7.56	1.02
Trachyceras saulus Laube	MSNV 10235/1 (Urlichs, 1994)	4.00	11.35	11.45	0.99
Trachyceras veltheimi (Klipstein)	BMNH 35959a (Urlichs, 1994)	5.50	9.06	11.39	0.80

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Aknowledgements

Firstly, I would like to express my sincere gratitude to my tutor, Prof. Marco Balini for giving me the opportunity to study such an interesting subject and for much more. I thank him for his guidance and teachings, that have been extremely helpful during the PhD work.

My sincere thanks also goes to Jim Jenks and his wife Ruby for all the scientific and logistic support given to me and my tutor. I warmly thank them for their kindness, enthusiasm and welcome shown to us during these years.

I would like to thank Prof. Leopold Krystyn for the enlightening conversation with me on the South Canyon ammonoid collection and on the classification of the Tethyan Trachyceratinae during the congress Strati2019.

I thank Dr. Kevin C. McKinney and Dr. Mark S. Florence for the warm welcome and help during the visit respectively to the USGS Core Research Center (Denver) in October 2017, and to the Smithsonian National Museum of Natural History (Washington D.C.) in September 2019.

I warmly thank Prof. Lucia Angiolini (University of Milano), Dr. Arnaud Brayard (University of Burgundy, Dijon) and Dr. Spencer G. Lucas (New Mexico Museum of Natural History, Albuquerque) for their careful reviews of the thesis.

Many thanks also to Curzio Malinverno (University of Milano) for the technical advice and moral support. I also thank Andrea Ravasio (CRM Utensili Speciali S.r.l.) for his availability and patience.

I would like to express my gratitude to my work colleagues, who during these three years have never stopped encouraging me and showing me their esteem.

A special thank goes to Elena, who has always been by my side throughout this PhD, living every single minute of it. I thank her also for being the most unmerciful proofreader I’ve ever seen.

Last but not least, I would like to thank my parents, my brother and all my family for their unwavering support throughout this thesis and my life.