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Review of the Lower Triassic Ammonoid Succession and its Bearing on Chronostratigraphic Nomenclature

By E. T. Tozer

2 Tables

Abstract

The relationship between proposed schemes for subdividing the Lower Triassic with events in the ammonoid history is reviewed. Several schemes based on sequences in Asia are compared with one in North America where four Stages (Griesbachian, Dienerian, Smithian, Spathian, in ascending order) are recognized. None appears to be wholly satisfactory for International use. For this purpose a division of the Lower Triassic (Scythian) Series into three Stages is suggested. For the earliest stage Griesbachian is appropriate, for the latest, Spathian. The middle Stage, for which no name is available, is equivalent to the Dienerian and Smithian combined. No name is proposed at present. Definition of the Permian-Triassic boundary at the base of the Griesbachian is recommended. Proposals to place the boundary at higher levels are also mentioned.

Introduction

This review of Lower Triassic chronostratigraphy was prepared at the invitation of Professor H. Zapfe for presentation, under his chairmanship, at the meeting of the Subcommission on Triassic Stratigraphy, held in Vienna, October 2, 3, 1975. It is restricted to the marine Triassic, notable events in the succession of ammonoid faunas and their bearing on questions of chronostratigraphic nomenclature. The subject of the continental Triassic and the problems of its correlation with the marine sequence are beyond the scope of this paper.

Marine Lower Triassic rocks with ammonoid faunas are widely distributed in the lands surrounding the Arctic and Pacific Oceans and in the Tethys. Many faunas

Address: Dr. E. T. Tozer, Geological Survey of Canada, Department of Energy, Mines and Resources, 601 Booth Street, Ottawa, Ontario, K1A OE8, Canada.

occur in the central and eastern parts of the Tethys but in the west, Lower Triassic ammonoids, except those of the *Tirolites* fauna, are rare and poorly preserved. The faunas of western Tethys thus fail to provide anything approaching a complete representation of Lower Triassic ammonoids and for this part of Triassic time it is necessary to look elsewhere in order to find sections where the sequential arrangement of the faunas is demonstrable. Most Lower Triassic ammonoid faunas known from other parts of the world are represented in North America where, for the purpose of reviewing the ammonoid history, the sequence (Table 1) provides a chronology at least as satisfactory as any other. The zones, defined at type localities and thus Standard Zones in the sense of CALLOMON (1965, p. 82), are arranged in sequence from observed stratigraphic data. Details of the individual stratigraphic sequences which form the foundation of this scheme were provided by KUMMEL (1954), TOZER (1965, 1967), SILBERLING and TOZER (1968) and SILBERLING and WALLACE (1969). When first proposed, the zones of the Canadian sequence were grouped into four stages with new names: Griesbachian, Dienerian, Smithian and Spathian (TOZER, 1965). The proposal was made, not only to provide a terminology for expressing unambiguously the age of rocks in North America but also with the expectation that at least some of the stages would prove useful for expressing world-wide correlations.

Schemes for dividing the Lower Triassic into stages and substages have also been made by WAAGEN and DIENER (1895), ICHIKAWA (1950, 1956), KIPARISOVA and POPOV (1956, 1961, 1964), MUTCH and WATERHOUSE (1965), VAVILOV and LOZOVSKIY (1970), ZACHAROV (1973, 1974) and KOZUR (1973, 1975). In all about 20 chronostratigraphic names have been proposed (Appendix, p. 32). A comparative table (Table 2) shows the relationship, in some instances only approximate, of most of the names. This table also shows that several names have been used in more than one sense. The Appendix (page 10) provides definitions and explanations. Some names which do not appear to have been used extensively (e. g. those based on occurrences in Japan and New Zealand), are not on the table.

Other schemes for subdividing the Lower Triassic involve the recognition of "Ages" or "Major Zones" as opposed to conventionally defined stages and substages, e. g. those of SPATH (1934) and KUMMEL (1973). The scheme proposed by SMITH (1932) is also partly of this nature. All three are shown on the table. The scheme that has been used most extensively is that of SPATH, who recognized 6 divisions, which appear to be comparable in concept with the "Ages" of BUCKMAN (1922, p. 14). KUMMEL (1973, p. 226) recognizes 4 "Major Zones" which, like Spath's divisions, appear to be comparable with Buckman's Ages. A major weakness of divisions of this kind is that they lack explicit stratotypes and their sequential arrangement is not in all cases based on observed stratigraphic relationships. For example, the oldest beds regarded as representative of the Owenitan by SPATH (1934, p. 27) (*Pseudosageceras multilobatum* Subzone of SMITH, 1932, p. 7) are not demonstrably younger than the Ceratite Sandstone (SPATH's youngest Flemingitan bed.) SMITH believed that they are the same age. There is now almost universal agreement that units comparable with BUCKMAN's Ages do not satisfy the requirements of a chronostratigraphic hierarchy (TOZER, 1971a, p. 992), for which purpose divisions with

Series	Stage	Sub-Stage	CANADA	WESTERN UNITED STATES	
Middle Triassic (Part)	Anisian (Part)	Aegean	Lenotropites CAURUS	Lenotropites CAURUS	
					← EVENT 5
LOWER TRIASSIC (SCYTHIAN)	SPATHIAN		Keyserlingites SUBROBUSTUS	Neopopanoceras HAUGI	
				Prohungarites & Subcolumbites beds	
			Kazakhstanites PILATICUS	Columbites & Tirolites beds	
					← EVENT 4
	SMITHIAN		Wasatchites TARDUS	Anasibirites beds	
				(Owenites beds)	← MID-SCYTHIAN EVENTS
			Euflemingites ROMUNDERI	Meekoceras GRACILITATIS	
	DIENERIAN		Vavilovites SVERDRUPI		← MID-SCYTHIAN EVENTS
			Proptychites CANDIDUS		
					← EVENT 3
	GRIESBACHIAN		Proptychites STRIGATUS		
			Ophiceras COMMUNE		
					← EVENT 2
			Otoceras BOREALE		
			Otoceras CONCAVUM		
					← EVENT 1
PERMIAN					

Table 1. Lower Triassic Time Scale based on North American sequence (SILBERLING and TOZER, 1968) indicating age of events referred to in text. Names of Standard Zones are in UPPER CASE. Units designated "beds" do not, at present, satisfy all requirements for Standard Zones. The exact position and chronostratigraphic significance of the *Owenites* beds has not been determined. The Permian-Triassic boundary is placed at Event 1, as recommended in the text. Alternatives discussed are at Events 2, 3 and at the time of the Mid-Scythian Events.

<table>
<tr><th colspan="3">1</th><th>2</th><th colspan="2">3</th><th colspan="2">4</th><th>5</th><th>6</th><th colspan="2">7</th><th>8</th><th>9</th><th colspan="3">10</th><th colspan="2">11</th><th colspan="3">12</th></tr>
<tr><th>Series</th><th>Stage</th><th>Sub Stage</th><th>Stage</th><th>Series</th><th>Zone</th><th>Stage</th><th>Division</th><th>Stage</th><th>Stage</th><th>Stage</th><th>Sub Stage</th><th>Stage</th><th>Stage</th><th>Series</th><th>Stage</th><th>Sub Stage</th><th>Stage</th><th>Major Zone</th><th>Series</th><th>Stage</th><th>Sub Stage</th></tr>
<tr><td rowspan="4">Dinarian (Part)</td><td rowspan="3"></td><td rowspan="6"></td><td rowspan="11">Scythian</td><td rowspan="11">Lower Triassic</td><td rowspan="2">V Columbites</td><td rowspan="5">Upper Eo-Trias</td><td>Prohungaritan</td><td rowspan="5">Olenekian</td><td rowspan="6">Olenekian</td><td rowspan="3">Spathian</td><td rowspan="8"></td><td rowspan="3">Olenekian</td><td rowspan="3">Russian</td><td rowspan="10">Scythian</td><td rowspan="3">Olenekian</td><td rowspan="5"></td><td rowspan="11">Scythian</td><td rowspan="3">Prohungarites-Subcolumbites</td><td rowspan="11">Scythian</td><td rowspan="5">Jakutian</td><td rowspan="3">Spathian</td></tr>
<tr><td rowspan="2">Columbitan</td></tr>
<tr><td>IV Tirolites</td></tr>
<tr><td>Hydaspian</td><td rowspan="2">III Meekoceras
IIIc Anasibirites Subzone
IIIb Owenites Subzone
IIIa Pseudosageceras multilobatum Subzone</td><td rowspan="2">Owenitan</td><td rowspan="2">Smithian</td><td rowspan="3">Verkhoyanian</td><td rowspan="3">Ussurian</td><td rowspan="2">Jakutian</td><td rowspan="2">Owenites - Anasibirites</td><td rowspan="8"></td></tr>
<tr><td rowspan="7">Scythian</td><td rowspan="2">Jakutian</td></tr>
<tr><td rowspan="3">II Genodiscus (Nomen nudum)</td><td rowspan="6">Lower Eo-Trias</td><td rowspan="2">Flemingitan</td><td rowspan="6">Induan</td><td rowspan="3">Dienerian</td><td rowspan="5">Brahmanian</td><td rowspan="3">Gandarian</td><td rowspan="3">Gyronites - Prionolobus</td><td rowspan="6"></td></tr>
<tr><td rowspan="5">Brahmanian</td><td rowspan="2">Gandarian</td><td rowspan="5">Induan</td><td rowspan="5">Induan</td><td rowspan="5">Induan</td></tr>
<tr><td rowspan="2">Gyronitan</td></tr>
<tr><td rowspan="2"></td><td rowspan="3">I Otoceras</td><td rowspan="3">Griesbachian</td><td rowspan="2">Upper</td><td rowspan="2">Ellesmerian</td><td rowspan="3">Otoceras - Ophiceras</td></tr>
<tr><td rowspan="2">Otoceratan</td></tr>
<tr><td>Gangetian</td><td>Lower</td><td></td><td>Dzhulfian (Part)</td><td>Gangetian</td></tr>
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Table 2. Comparative table of subdivision schemes for the Lower Triassic. Column 1, WAAGEN and DIENER (1895); 2, ARTHABER (1905); 3, SMITH (1932); 4, SPATH (1934); 5, KIPARISOVA and POPOV (1956, 1961); 6, KIPARISOVA and POPOV (1964); SAKS *et al.* (1972); ARKHIPOV (1974); 7, TOZER (1965, 1967), SILBERLING and TOZER (1968); 8, VAVILOV and LOZOVSKIY (1970); 9, ZACHAROV (1973, 1974); 10, KOZUR (1973, 1975); 11, KUMMEL (1973); 12, KRYSTYN (1974).

Divisions aligned with Griesbachian and Spathian are correlative. Correlations at level of broken line (e. g. Dienerian-Smithian boundary) are imprecise. For definitions of chronostratigraphic divisions see Appendix.

components based on stratotypes are necessary. Such divisions are the Series, Stage, Substage and Standard Zone. The recognition of more than one division is necessary to express unambiguously what is known regarding the correlation of marine Lower Triassic rocks, as shown by number the of proposals made in the last 20 years suggesting division of the Lower Triassic into two or more stages. Admittedly agreement is not complete on this question. KUMMEL (1973, p. 225), who has been engaged in the study of Lower Triassic ammonoids for many years, still maintains that the recognition of no more than one Stage — the Scythian — is necessary. As shown by Table 2, Scythian Series, as originally proposed, comprised two Stages (Brahmanian and Jakutian), believed to be older than the Hydaspian Stage. In this sense Scythian does not correspond with the whole of the Lower Triassic. Nevertheless, for nearly the whole of this century, following ARTHABER (1905), it has been used as synonymous with Lower Triassic. KRYSTYN (1974, p. 43) has presented a case for including the youngest Lower Triassic beds in the Jakutian (See Appendix). For these reasons Scythian is probably best accepted as the Series name for the Lower Triassic, and not abandoned, as previously suggested (TOZER, 1971 b, p. 452). An alternative, to use Werfenian, as by DE LAPPARENT (1900), HAUG (1908) and GIGNOUX (1960), does not appear to have met with much favour. ROSENBERG (1959) treated Werfenian as a junior synonym of Scythian.

Major Events in Lower Triassic Ammonoid History and their Bearing on Chronostratigraphic Nomenclature

Lower Triassic ammonoids include some genera of highly distinctive morphology, the identification of which is easy and not a matter of dispute. Examples are *Otoceras*, *Owenites*, *Anasibirites*, *Tirolites* and *Subcolumbites*. Also in the Lower Triassic faunas are genera with less distinctive characters, for which different authors have offered different interpretations. Examples are the smooth or simply-ribbed serpenticones with 5-lobed ceratitic suture lines. These are much like *Xenodiscus*, the type species of which (*X. plicatus* WAAGEN) is Permian. Forms at least superficially similar to *Xenodiscus* occur in the lowest Triassic beds. Another group of the less distinctive forms is the Meekoceratinae — more or less smooth, tabulate ventered genera — which occur at many levels in the Lower Triassic, although apparently not in the lowest beds. In reviewing the Lower Triassic ammonoid history and its bearing on Lower Triassic correlations, several events seem particularly significant. Most refer to the appearance and disappearance of distinctive forms, the identification of which is not disputed; some of these may be used in making world-wide correlations which form the basis for the establishment of clearly defined and easily recognized chronostratigraphic units.

The age of these events, in relation to the chronostratigraphic scheme based on the North American sequence, is indicated on Table 1. The nature of the individual events is now given, drawing attention to their relationship to the chronostratigraphic divisions (Table 2).

Event 1

This is the appearance of *Otoceras* at the base of the Griesbachian Stage and the Gangetian Substage (Tables 1, 2) a chronostratigraphic datum recognizable in the Arctic and the eastern Tethys. Commonly associated with *Otoceras* are smooth or variocostate serpenticones with 5-lobed suture lines which in most contemporary publications are named *Glyptophiceras* or *Metophiceras*. Earlier workers (e. g. DIENER, 1915) referred these ammonoids to *Xenodiscus* of which, as already mentioned, the type species is Permian. On the mature conch there seem to be no morphological characters to justify generic separation of Permian *Xenodiscus* from Griesbachian species such as "*Glyptophiceras*" *nielseni* SPATH*). SPINOSA, FURNISH and GLENISTER (1975) assert that the suture ontogeny of Permian Xenodiscidae is different from that of the Griesbachian serpenticones. As far as the writer can determine, the full ontogeny has been determined for only one genus, the Permian *Paraceltites*. It has not been established that the ontogeny of a Permian *Xenodiscus* differs from that of the Griesbachian serpenticones. *Xenodiscus* is interpreted by the writer, following DIENER (1915), as a genus ranging from the Permian into beds at least as young as Lower Griesbachian. Also present in the *Otoceras* beds of the Himalayas is *Episageceras dalailamae*, a medlicottid obviously related to Permian forebears. *Otoceras* itself also has obvious Permian ancestors. The lowest beds with *Otoceras* in Canada and Siberia (ZACHAROV, 1971, p, 56), probably also in Greenland (SPATH, 1935; TRÜMPY, 1969) are devoid of typical Triassic Ceratitida but the records from the Himalayas seem to indicate that *Ophiceras* and *Proptychites* occur at this level (DIENER, 1912, p. 22). These two genera are distinguished from Permian Ceratitida (e. g. *Xenodiscus*) by having 6-lobed suture lines. Apart from the Himalayan records, which might be questioned, in view of the extraordinarily thin, possibly condensed nature of the sequence, the ammonoid fauna of Event 1 is essentially of Permian character.

Event 1 was taken to mark the base of the Triassic by WAAGEN and DIENER (1895) and this convention was followed by most later workers (e. g. SMITH, 1932; SPATH, 1934; KUMMEL, 1957; KIPARISOVA and POPOV, 1956 etc.; SILBERLING and TOZER, 1968). As mentioned below, some contemporary workers recommend placing it at a higher level, but because WAAGEN and DIENER's procedure has been so widely followed definition of the Permian Triassic-boundary at the base of the Griesbachian is still advocated by the writer in preference to the alternatives. Admittedly much of the Griesbachian ammonoid fauna has an essentially Palaeozoic character but it marks a level that can be correlated, with virtually unanimous agreement, in many parts of the world. Also, according to ASSERETO *et al.* (1973), this boundary more or less corresponds to the base of the Werfen Beds, traditionally the base of the Alpine Triassic. In many places, possibly everywhere, Griesbachian beds rest on older rocks paraconformably (TOZER, 1972a, p. 648).

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*) True *Glyptophiceras* is evidently a Smithian genus, morphologically distinct from the Permian and Griesbachian forms (TOZER, 1969, p. 354).

Event 2

This event, which occurred at the base of the Upper Griesbachian, is the appearance of abundant Ophiceratidae**). In Canada *Otoceras* has disappeared at this level. In Greenland (SPATH, 1935; TRÜMPY, 1969), Siberia (ZACHAROV, 1971, p. 65), at Spiti in the Himalayas (DIENER, 1912, p. 16) and in Kashmir (NAKAZAWA *et al.*, 1970, fig. 2) beds with *Ophiceras* overlie strata with *Otoceras*. These beds are probably all Upper Griesbachian. As already mentioned, it is possible that Ophiceratidae occur in the Lower Griesbachian and for this reason KUMMEL (1972, 1973) used the term *Otoceras-Ophiceras* Zone for the equivalent of the whole Griesbachian. This terminology seems undesirable, not only because the zone has no stratotype, but also because it masks the fact that in many sections *Ophiceras* ranges higher than *Otoceras*. KOZUR (1973) takes a very different view of the significance of base of the Upper Griesbachian (which he has named Ellesmerian) (Table 2), and chooses to place the Permian-Triassic boundary at this level.

Event 3

This event, at the base of the Dienerian, is the appearance of Meekoceratinae, the first tabulate-ventered Ceratitida, in beds whose stratigraphic position in relation to Griesbachian strata is clearly displayed on Ellesmere Island (TOZER, 1967, p. 51), apparently also in the Himalayas (base of *Meekoceras* beds of Spiti, DIENER, 1912, p. 16) and in the Salt Range (base of Lower Ceratite Limestone = base of Mittiwali Member of Mianwali Formation). The Salt Range boundary is the stratotype for the base of the Gandarian Substage (WAAGEN and DIENER, 1895). The base of the *Gyronites-Prionolobus* Zone of KUMMEL (1973) is presumably to be equated with this level. SPATH's Gyronitan Age includes older strata (*Proptychites* beds of East Greenland), which are Upper Griesbachian. As mentioned elsewhere in this paper (p. 7), identification of Meekoceratinae presents problems and members of this subfamily are consequently of limited stratigraphic use in Dienerian and younger beds, though their appearance seems to represent a significant, readily recognized chronostratigraphic datum. KUMMEL (1972, p. 382), using the old Himalayan records, accepts the presence of Meekoceratinae in the Griesbachian, but because these occurrences have never been confirmed by subsequent discoveries it seems reasonable to regard them as questionable (TOZER, 1972 a, p. 647).

To NEWELL (1973, p. 9) this event marks the Permian-Triassic boundary, a view also adopted by NOETLING (1905, p. 129).

Mid-Scythian Events

After the Candidus Zone and before the Spathian (Table 1), an interval that may be described as the Mid-Scythian, the ammonoid faunas become increasingly

**) *Durvilleoceras*, from the Permian of New Zealand, assigned to the Ophiceratidae by its author (WATERHOUSE, 1973), differs from true representatives of the family in having deeply denticulate lateral lobes and an umbilical lobe not bisected by the umbilical seam. *Durvilleoceras* is accordingly excluded from Ophiceratidae by the writer.

diversified. Distinctive newcomers include *Flemingites*, *Euflemingites*, *Arctoceras*, Melagathiceratidae, Paranannitidae, *Inyoites*, Ussuriidae, *Lanceolites* and *Hedenstroemia*. *Owenites*, a notable representative of some of the Mid-Scythian faunas, is interpreted by the writer (TOZER, 1971a, p. 1024) as a laterally compressed member of the Paranannitidae, related to *Paranannites* in the same way as is, for example, *Discotropites* to *Paratropites*. The distinctive and easily identified Prionitidae (*Anasibirites*, *Wasatchites* etc., i. e. sensu TOZER, 1971a, p. 999, 1024) also appear in the Mid-Scythian but there is now agreement that they do so later than most or all of the taxa mentioned above. Referring to the time scale (Table 1), Prionitidae characterize the Tardus Zone and correlative beds which are widely distributed around the Arctic and Pacific Oceans and in eastern Tethys. For these beds there are stage names available — the Hydaspian (WAAGEN and DIENER, 1895), based on the Upper Ceratite Limestone of the Salt Range and the Uonashian (ICHIKAWA, 1950, 1956), defined in Japan. Segregation of these beds as a discrete stage seems unjustified because in California, and possibly also Nevada, *Owenites* and Prionitidae occur in association (SMITH, 1932; SILBERLING and TOZER, 1968, p. 30). The Prionitidae of California evidently include both *Anasibirites* (*A. noetlingi* HYATT and SMITH) and *Wasatchites*, represented by "*Anasibirites*" *lindgreni* SMITH.

Mid-Scythian faunas are known from many parts of the world. Some of the more important, excluding those correlative with the Tardus Zone, are from the *Pseudosageceras multilobatum* and *Owenites* Subzones of the *Meekoceras* Zone, of the Western United States (SMITH, 1932, p. 15), the Romunderi Zone of Arctic Canada, the *Arctoceras* beds of Spitsbergen, the *Hedenstroemia bosphorense* Subzone of Primor'ye, the *Paranorites* Zone (now called *Meekoceras gracilitatis* Zone) of Siberia, the *Owenites costatus* Zone of Kwangsi, China; the *Hedenstroemia* beds of the Himalayas; the *Flemingites flemingianus* Zone in the Ceratite Sandstone of the Salt Range; and the *Flemingites* fauna of Barabanja, Madagascar. The literature on these faunas is large and no summary can be attempted within the scope of this paper. A useful summary of these, and some additional occurrences, as known until about 1960, has been provided by KUMMEL and STEELE (1962, p. 641—659). Later contributions on these faunas, unpublished when KUMMEL and STEELE's paper was prepared, deal with faunas from Primor'ye (KIPARISOVA, 1961, ZACHAROV, 1968), northeast Siberia (POPOV, 1961; VAVILOV, 1967; VAVILOV and LOZOVSKIY, 1970; ARKHIPOV, 1974), Canada (TOZER, 1961, 1963), Afghanistan (KUMMEL and ERBEN, 1968; KUMMEL, 1968) and Australia (RUNNEGAR, 1969).

According to some authors (notably KIPARISOVA and POPOV, 1964, p. 97) the faunas listed above are essentially correlative. If this conclusion is accepted and a census made of all the ammonoid genera represented, the conclusion may be drawn that they characterize a level at which the Triassic ammonoid fauna suddenly increases greatly in diversity. Those who accept these correlations take this to justify recognizing a major boundary within the Lower Triassic, namely that between the Induan and Olenekian as interpreted by many Russian workers (Column 6, Table 2). Examination of the evidence gives grounds for questioning the significance of this boundary as a synchronous event, in terms of either extinctions or new appearances. In the Mid-Scythian there is by no means unanimous agreement regarding the correlations. KIPARISOVA and POPOV (1964, p. 97) regard the *Flemingites flemingianus* Zone of the Salt Range as correlative with the *Meekoceras gracilitatis* Zone of North America. KUMMEL and STEELE (1962, p. 653) take a different view, in agreement with that of SPATH (1934, p. 27), that the beds in the Salt Range are older than those in North America. The writer considers that there are insufficient data to resolve this problem, which has a crucial bearing on the recognition of the Induan-Olenekian boundary. The correlation problems for this part of the Lower Triassic stem from the fact that there are apparently no sections that serve to show the sequential arrangement of a number of faunas which appear to be approximately, but not exactly, the same age. This problem has been discussed elsewhere (TOZER, 1971a, p. 1005, 1015), with the conclusion that it will not be resolved until more is known of the actual faunal succession. A recent note by ISHII, FISCHER and BANDO (1971, p. 5) suggests that the *Owenites* limestone of Kotel-e-Tera, Afghanistan, may contribute important data. In this limestone KUMMEL (1968, p. 487) reported that the *Anasibirites* and *Owenites* faunas appeared to be mixed in the upper part but that anasibiritid elements were not found in the lower. ISHII *et al.* (1971) suggest that there may be 3 zones, in ascending order: *Pseudosageceras multilobatum* Zone; *Dieneroceras, Owenites* & *Meekoceras* Zone; *Anasibirites kingianus* Zone; but as yet details have not been provided. This zonal scheme resembles that proposed by SMITH (1932) for the subdivision of the *Meekoceras* Zone of the Western United States (Table 2). SMITH did not give complete stratigraphic documentation for his scheme but may nevertheless have recognized the correct sequence. SMITH's scheme has been discussed by KUMMEL and STEELE (1962) and SILBERLING and TOZER (1968, p. 28—30); if nothing else, it serves as a reminder that *Owenites* has not been recorded from the typical beds of the *Meekoceras gracilitatis* Zone (= *Pseudosageceras multilobatum* Subzone of SMITH) in Idaho.

Another problem concerning the Mid-Scythian faunas is related to the taxonomy of the tabulate-ventered Ceratitida (Meekoceratinae of TOZER, 1971a, p. 1022). The type species of *Meekoceras* (*M. gracilitatis* WHITE) is from the Mid-Scythian of Idaho. Identical or closely similar species occur in the *Hedenstroemia bosphorense* Subzone of Primor'ye, the Romunderi Zone of Ellesmere Island and in several other of the Mid-Scythian faunas listed above. *Meekoceras gracilitatis* does not seem to be generically separable from some of the earliest known Meekoceratinae, e.g. *M. lilangense* KRAFFT, described from the *Meekoceras* Beds of Spiti and apparently also represented in the Dienerian Candidus Zone of North America (Table 1). Following SPATH (1934), the older discoidal Meekoceratinae have been assigned to *Prionolobus*, the younger to *Meekoceras* by many authors, including the writer (TOZER, 1967, p. 18), but DIENER (1915) made no such separation and I now find myself in agreement with his conclusion. *Gyronites*, an evolute version of *Meekoceras*, has commonly been regarded as characteristic of beds appreciably older than the Mid-Scythian faunas, but the fauna of the Romunderi Zone of British Columbia includes ammonoids which do not seem to be generically separable from *Gyronites frequens* WAAGEN, type species of the genus, from the Lower Ceratite Limestone, already mentioned as a Dienerian correlative. The range of both *Gyronites* and *Meekoceras* thus appears to be appreciably longer than supposed by many authors. These seem to be examples of prejudice regarding age difference controlling the taxonomy, as with the Permian and Triassic Xenodiscidae, mentioned earlier. It follows that the Dienerian and its correlatives (most of which are listed in TOZER, 1971a, p. 1015) have few truly distinctive ammonoid genera that are not also present in the Mid-Scythian faunas listed above. The Dienerian ammonoid fauna, although provided with newcomers that differentiate it from that of the Griesbachian, has essentially negative characteristics compared with the later Mid-Scythian faunas. The Dienerian-Smithian boundary, although useful for expressing relationships in North America, does not appear to be endowed with characteristics that permit its world-wide recognition. The same seems to be true of the criteria used to define the base of the Jakutian, Olenekian (s. l.), Verkhoyanian und Ussurian Stages (Table 2). The exact correlation of the bases of these divisions is not well established. As mentioned in the conclusions to this paper some or all should probably be regarded as substages, perhaps for no more than local use.

Between the base of the Dienerian (Event 3) and the base of the Spathian (Event 4) the ammonoid history does not seem to provide an obviously synchronous, readily recognized, easily correlated event suitable for defining and recognizing a major chronostratigraphic division within the Lower Triassic (Scythian) Series. WATERHOUSE (1973, p. 318) has tentatively suggested placing the Permian-Triassic boundary at the base of the Smithian, but in view of the correlation problems mentioned above, his proposal is not recommended.

Event 4

The youngest beds of the Lower Triassic are characterized by the appearance of many new genera. Dinaritinae, Tirolitinae und Columbitidae are particularly distinctive newcomers and occur in faunas devoid of the distinctive Mid-Scythian ammonoids (*Arctoceras*, *Owenites*, Prionitidae, etc.). In North America this level is expressed, in the chronostratigraphic hierarchy, as the Smithian-Spathian boundary (Table 1). KUMMEL (1969) has provided a world-wide survey of the Spathian faunas known to about 1968. Additions to our stratigraphic and morphological knowledge concerning the faunas of the latest Lower Triassic, unpublished at the time of the preparation of KUMMEL's monograph, have been provided by SHEVYREV (1968) on Mangyshlak (southern U.S.S.R.); ZACHAROV (1968) on Primor'ye; TOZER (1972b) on Iran; SILBERLING and WALLACE (1969) on Nevada; and KRYSTYN (1974) on the *Tirolites* beds of Yugoslavia. For present purposes it is unnecessary to provide a summary of all these data in that the significance of Event 4 seems to be universally accepted, having been discriminated as the base of a Stage, Substage, Age or Major Zone in virtually every stratigraphic scheme. In SMITH's scheme it was the base of the *Tirolites* Zone (SMITH, 1932); to SPATH (1934), the start of the Columbitan Age; to VAVILOV and LOZOVSKIY (1970), also KOZUR (1973, 1975), the base of the Olenekian, in a restricted sense; to ZACHAROV (1973), the base of the Russian Stage; and to KUMMEL (1973), the start of the *Prohungarites-Subcolumbites* Zone. KRYSTYN (1974), like SILBERLING and TOZER (1968), uses the name Spathian, but as a Substage, not a Stage. Event 4 thus seems to define the base of a chronostratigraphic unit that all agree to be necessary in the Triassic hierarchy. Spathian, which has priority, is advocated as a Stage of the Scythian.

Event 5

This, marked like Event 4 by both extinctions and new appearances, is at the level of the Spathian-Anisian (= Lower-Middle Triassic) boundary (Table 1). Almost no ammonoid genera, except the earliest Phylloceratida (*Leiophyllites* and *Ussurites*) are common to both the latest Lower Triassic and earliest Middle Triassic faunas. *Paracrochordiceras*, *Japonites*, *Gymnites*, Sturiidae, Isculitidae, Danubitidae, Longobarditidae and Cladiscitidae make their appearance in the earliest Middle Triassic (Caurus Zone and correlatives). The stratigraphic relations at the Spathian-Anisian boundary are well displayed in Arctic Canada (Caurus Zone over Subrobustus Zone, TOZER 1967, p. 47) and Nevada (Caurus Zone over Haugi Zone, SILBERLING and WALLACE, 1969, p. 17). The base of the Caurus Zone is correlated with the base of the Aegean Substage, recently proposed by ASSERETO (1974) as the earliest chronostratigraphic division of the Anisian and thus of the Middle Triassic. This definition for the base of the Middle Triassic necessitates treating the *Neopopanoceras haugi* Zone of the Western United States as latest Lower Triassic (SILBERLING and TOZER, 1968, p. 39), not basal Middle Triassic, as by SMITH (1914, p. 5), SPATH (1934, p. 35), KUMMEL (1957, p. L 124), and SKWARKO and KUMMEL (1974, p. 113). This treatment of the *Neopopanoceras haugi* Zone seems wholly justified in that it is evidently more or less correlative with the Subrobustus Zone, which all authorities have regarded as latest Lower Triassic (SILBERLING and TOZER, 1968, p. 12).

Summary and Conclusions

Established usage is taken to justify accepting Scythian as a synonym for Lower Triassic Series, despite the fact that its scope, as originally defined, was somewhat ambiguous.

Some of the more notable events in the history of Scythian ammonoids appear to be particularly significant for the purpose of defining and recognizing chronostratigraphic divisions. These are: Event 1, the appearance of *Otoceras*; Event 2, the appearance of abundant Ophiceratidae in the absence of *Otoceras;* Event 3, the appearance of Meekoceratinae; Event 4, the appearance of Dinaritinae, Tirolitinae and Columbitidae; and Event 5, the appearance of taxa (*Paracrochordiceras*, *Japonites*, etc.) characteristic of the lowest Middle Triassic (Caurus Zone = Aegean Substage of Anisian).

Following Event 3 many distinctive new ammonoid genera appear. Most disappear before Event 4. This interval, best described as a period of Mid-Scythian events, evidently represents a gradual build-up in diversity followed by contraction and many extinctions.

Event 1 marks the base of the Griesbachian Stage and Gangetian Substage; Event 2, that of the Upper Griesbachian (= Ellesmerian) Substage; Event 3, of the Dienerian Stage and Gandarian Substage; Event 4, of the Spathian Stage (= Russian and Olenekian s. s. Stages); Event 5, the base of the Middle Triassic Series (*see* Tables 1, 2).

The significance of Event 2 has been questioned. It does not merit recognition as more than a substage boundary. Events 1, 3, 4 and 5 permit clear correlations and are particularly suitable for the definition and recognition of stage boundaries. The Mid-Scythian events have been claimed by some authors to be more or less synchronous, forming the grounds for dividing the Lower Triassic (Scythian) Series into two stages (Induan and Olenekian, s. l.). Others (including the writer) are of the opinion that the events were not synchronous. Unanimity regarding the correlations is far from complete and a two-fold division of the Scythian into Induan and Olenekian Stages is therefore not recommended. Instead, a division into three Stages would appear to have the widest application. In terms of the four Stages proposed on the basis of the North American zonal sequence (Table 1) the three Stages would be:

Spathian (Upper)
Dienerian + Smithian (Middle)
Griesbachian (Lower)

For the time being, pending full description of the Salt Range succession and more data from the Himalayas and Afghanistan, it is considered premature to make a definite proposal for naming a middle Stage, as defined above. Dienerian and Smithian are useful in North America where they are currently treated as Stages. If the suggestion made above proves acceptable they could be treated as Substages. The Verkhoyanian and Ussurian Stages, which are approximate synonyms of the Smithian, should probably be treated similarly. Gandarian is an approximate synonym of Dienerian; Russian of Spathian (Table 2). For Griesbachian there is no exact synonym. Spathian has priority over Russian. Griesbachian and Spathian are accordingly reccommended for international use as Stages.

Regarding the Permian-Triassic boundary, it is recommended that the base of the Triassic be defined by Event 1 (base of *Otoceras woodwardi* Zone, correlative with the base of the Griesbachian), rather than by Events 2 or 3, or at the base of the Smithian, alternatives which have been proposed recently.

Appendix

Definitions of Lower Triassic Series, Stages and Substages based on Marine Sequences

Brahmanian Stage (Waagen and Diener, 1895) = Gangetian Substage + Gandarian Substage *(q. v.)*.

Dienerian Stage (Tozer, 1965) = Candidus + Sverdrupi Zones, Arctic Canada.

Ellesmerian Substage (Kozur, 1972) = Upper Griesbachian Substage (Tozer, 1967) *(q. v.)*.

Gandarian Substage (WAAGEN & DIENER, 1895) = Lower Ceratite Limestone + Ceratite Marls, Salt Range. Base at *Gyronites frequens* Zone.

Gangetian Substage (WAAGEN and DIENER, 1895) = *Otoceras woodwardi* Zone s. l., Himalayas.

Griesbachian Substage (TOZER, 1965, 1967) = Concavum, Boreale, Commune, Strigatus Zones, Arctic Canada.

Hydaspian Stage (WAAGEN and DIENER, 1895) = Upper Ceratite Limestone (*Stephanites superbus* Zone), Salt Range.

Induan Stage (KIPARISOVA and POPOV, 1956). *Otoceras woodwardi* Zone at base, Ceratite Sandstone (*Flemingites flemingianus* Zone, s. l.) at top. The *Flemingites flemingianus* Zone was later excluded (KIPARISOVA and POPOV, 1964).

Jakutian Stage (WAAGEN and DIENER, 1895). Lower boundary that of Ceratite Sandstone (*Flemingites flemingianus* Zone, s. l.), Salt Range. Followed by Hydaspian Stage *(q. v.)*. Conceived to include also *Tirolites cassianus* Zone of Mediterranean area and *Keyserlingites*-bearing beds of Himalayas and Siberia (= Jakutian *sensu* KRYSTYN, 1974).

Lower Griesbachian Substage (TOZER, 1967) = Concavum + Boreale Zones, Arctic Canada.

Malakovian Stage (MUTCH and WATERHOUSE, 1965). Beds with *Owenites* etc. in New Zealand.

Olenekian Stage (KIPARISOVA and POPOV, 1956). Stratotype = Olenek Beds, Siberia. Conceived to include all Lower Triassic later than Ceratite Sandstone (*Flemingites flemingianus* Zone s. l.). This Zone was later included (KIPARISOVA and POPOV, 1964).

Russian Stage (ZACHAROV, 1973) = *Neocolumbites insignis* + *Subcolumbites multiformis* Zones, Primor'ye.

Scythian Series (WAAGEN and DIENER, 1895) = Brahmanian + Jakutian Stages *(q. v.)*.

Smithian Stage (TOZER, 1965) = *Arctoceras blomstrandi* Zone, Arctic Canada = Romunderi + Tardus Zones (TOZER, 1967).

Spathian Stage (TOZER, 1965, 1967) = Pilaticus + Subrobustus Zones, Arctic Canada.

Tatean Stage (ICHIKAWA, 1950) = Hiraiso Formation, Japan. ? Medial Late Eo-Trias (ICHIKAWA, 1956).

Tsuyan Stage (ICHIKAWA, 1950) = Oosawa Formation, Japan. Latest Late Eo-Trias (ICHIKAWA, 1956).

Uonashian Stage (ICHIKAWA, 1950) = Taho Formation (with *Anasibirites*), Japan Early Late Eo-Trias (ICHIKAWA, 1956).

Upper Griesbachian Substage (TOZER, 1967) = Commune + Strigatus Zones, Arctic Canada.

Ussurian Stage (ZACHAROV, 1973) = *Hedenstroemia bosphorense* + *Anasibirites nevolini* Zones, Primor'ye.

Verkhoyanian Stage (VAVILOV and LOZOVSKIY, 1970) = *Meekoceras gracilitatis* + *Anasibirites multiformis* Zones as recognized in Verkhoyanie (VAVILOV, 1967).

Werfenian Stage (DE LAPPARENT, 1900) = Werfen Formation.

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