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LOWER TRIASSIC STAGES AND AMMONOID ZONES OF ARCTIC CANADA

(Report and 2 figures)

E. T. Tozer

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ABSTRACT

Nine ammonoid zones are recognized in an unusually complete section of marine Lower Triassic rocks exposed on Ellesmere and Axel Heiberg Islands. These zones are grouped into four new stages, named, in ascending order, Griesbachian, Dienerian, Smithian and Spathian. The Spathian strata are followed conformably by beds with early Anisian (Middle Triassic) ammonoids. The Lower Triassic rocks of Western Canada are dated in terms of these stages. The stages may fill a need for named subdivisions within the Lower Triassic and provide a standard for rocks of this age throughout the world. Comparison with alternative classifications shows the need for the new subdivisions.

SERIES	STAGE	ZONE	SUBZONE
MIDDLE TRIASSIC (lower part)	ANISIAN		
LOWER TRIASSIC	SPATHIAN	*Keyserlingites subrobustus*	
		Nordophiceras pilatum	
	SMITHIAN	*Arctoceras blomstrandi*	*Wasatchites tardus*
			Meekoceras gracilitatis
	DIENERIAN	*Paranorites sverdrupi*	
		Proptychites candidus	
	GRIESBACHIAN Upper	*Pachyproptychites strigatus*	
		Ophiceras commune	
	GRIESBACHIAN Lower	*Otoceras boreale*	
		Otoceras n. sp.	

Underlying beds: **PERMIAN**

Table I. Lower Triassic stages, zones and subzones, Ellesmere Island and Axel Heiberg Island.

LOWER TRIASSIC STAGES AND AMMONOID ZONES OF ARCTIC CANADA

INTRODUCTION

An unusually complete section of marine Lower Triassic beds has been discovered on Ellesmere and Axel Heiberg Islands, in Arctic Canada. This sequence provides a basis on which to divide the Lower Triassic into four stages. The stages can be recognized in British Columbia and Alberta and are thus useful to express the age relations of Triassic rocks in Canada. They may also fill a need for named subdivisions in the Lower Triassic and provide a standard for rocks of this age throughout the world.

The sequence of stages and ammonoid zones on Ellesmere and Axel Heiberg Islands is shown by Table 1. Some of the sections and faunas have already been described (Tozer, 1961b, 1963a, 1963b, 1965), while recent field work, summarized in this paper, has added new data.

The Canadian Permanent Committee on Geographical Names has accepted a proposal to name features in Arctic Canada after contributors to the study of Lower Triassic stratigraphy and faunas. This affords a unique opportunity for, in effect, naming the stages after C.L. Griesbach (1847-1907), Carl Diener (1862-1928), James Perrin Smith (1864-1931) and L.F. Spath (1882-1957), through geographical features named for them.

STAGES

The type localities for the four stages are given below. The type sequences for the Griesbachian, Dienerian and Smithian Stages are in the Blind Fiord Formation (Tozer, 1961b); the type Spathian is in the Lower Shale Member of the Blaa Mountain Formation (Tozer, 1965). In some sections on Ellesmere Island Spathian beds occur in the Blind Fiord Formation (Tozer, 1963b, p. 3). The Griesbachian rocks disconformably overlie Permian formations. In places the sub-Triassic rocks are late Artinskian (R. Thorsteinsson, personal communication); elsewhere they are Guadalupian (Nassichuk *et al.*, in press).

Griesbachian Stage: Griesbach Creek, NW Axel Heiberg Island (lat. 80°31'N, long. 94°40'W), where the *Otoceras* n. sp., *Boreale*, *Commune* and *Strigatus* Zones are in sequence (*see* Fig. 1).

Dienerian Stage: South side Diener Creek, south of Otto Fiord, Ellesmere Island (lat. 80°57'N, long. 88°50'W) where the *Strigatus* Zone (Upper Griesbachian) is followed by the *Candidus* and *Sverdrupi* Zones (*see* Fig. 2).

Smithian Stage: Smith Creek, Ellesmere Island, 4 miles NW of entrance to Hare Fiord (lat. 80°39'N, long. 87°30'W) where the *Gracilitatis* and *Tardus* Subzones are in sequence, and overlain by beds with *Posidonia aranea* Tozer, representing the *Subrobustus* Zone (Spathian) (Tozer, 1961b, p. 12; 1963b, p. 9) (*see* Fig. 2). A critical reference section is immediately west of Lindstroem Creek, on the north side of Otto Fiord (lat. 81°04'N, long. 88°52'W) where the *Blomstrandi* Zone (Smithian), represented by *Euflemingites*

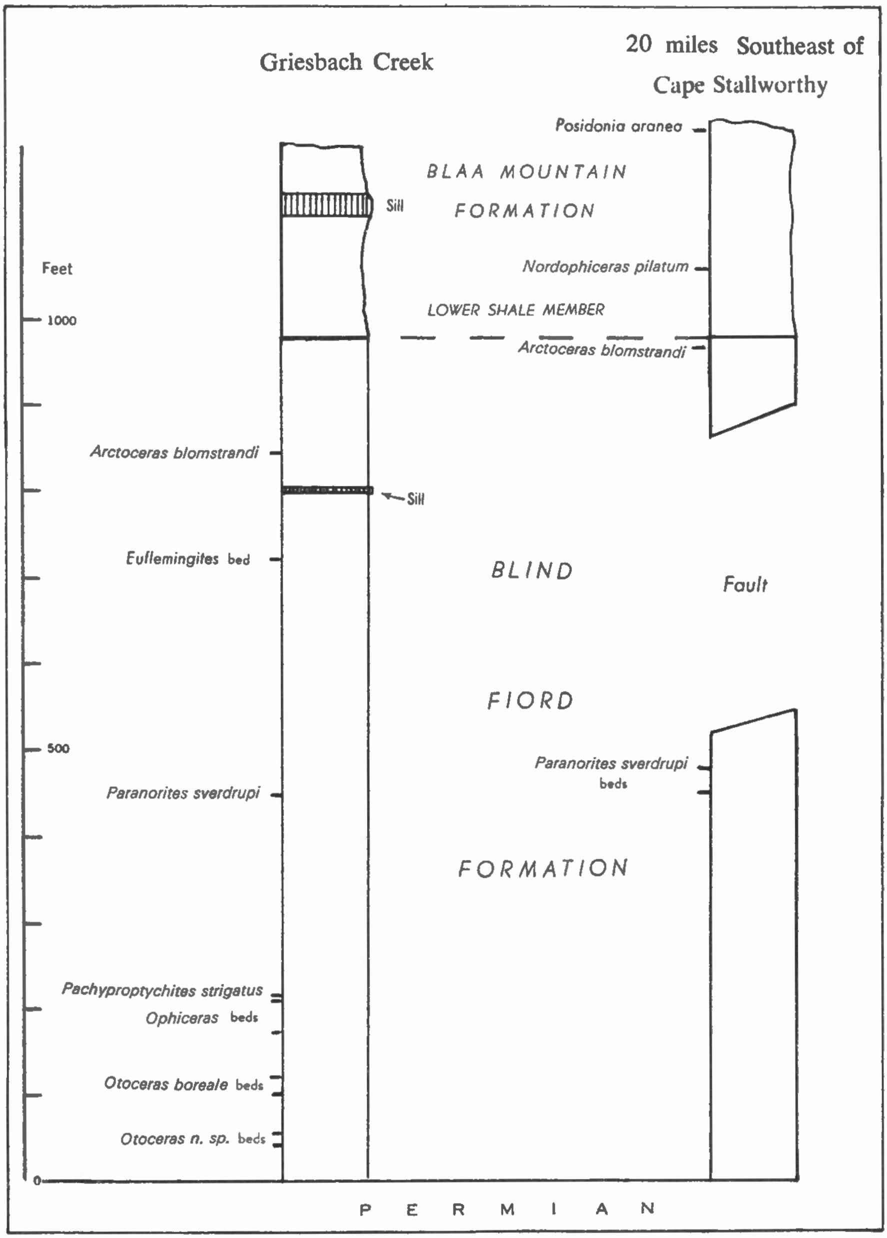

Figure 1. Columnar sections showing positions of fossiliferous beds with Lower Triassic faunas, in the Blind Fiord and Blaa Mountain formations, Axel Heiberg Island

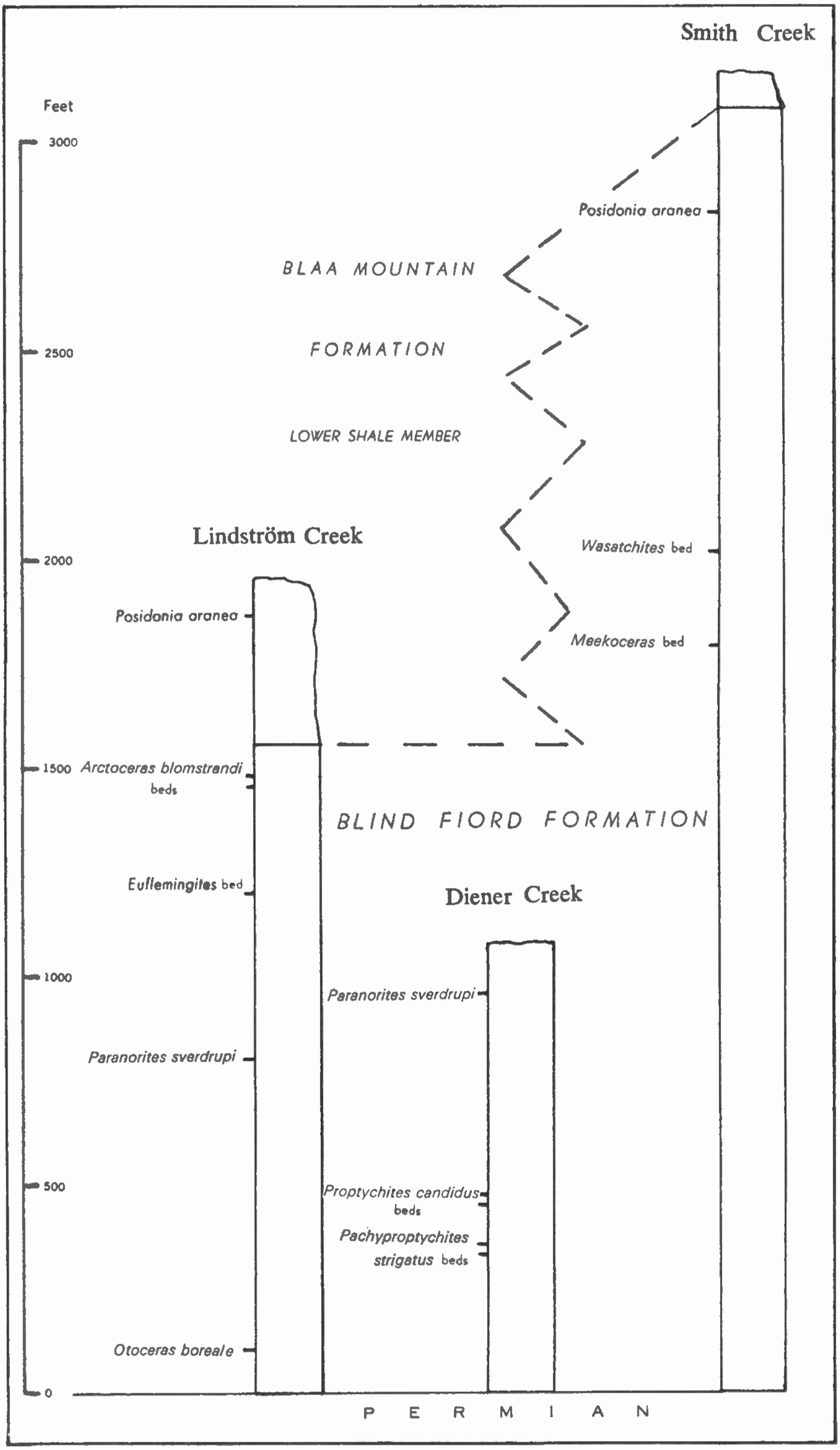

Figure 2. **Columnar sections showing positions of fossiliferous beds with Lower Triassic faunas, in the Blind Fiord and Blaa Mountain formations, Ellesmere Island**

romunderi Tozer and Juvenites crassus Tozer, overlies the late Dienerian Sverdrupi Zone (Tozer, 1963b, p. 7) (see Fig. 2).

Spathian Stage: North side of Spath Creek, flowing into Nansen Sound, 1 mile south of Otto Fiord, Ellesmere Island (lat. 80°56'N, long. 89°25'W) where the Subrobustus Zone overlies Smithian beds, and is followed by strata with Anisian ammonoids (Tozer, 1965, p. 3). The cliffs 20 miles SE of Cape Stallworthy, Axel Heiberg Island, expose an important reference section. Here the Blomstrandi Zone is overlain first by the Pilatum Zone, then by beds with Posidonia aranea Tozer (=Subrobustus Zone) (see Fig. 1).

AMMONOID ZONES

The ammonoid faunas of the successive zones are given below. The faunal lists for the Dienerian and younger stages have been amplified by including fossils obtained from equivalent rocks in British Columbia. Correlative formations in Alberta and British Columbia are also listed.

GRIESBACHIAN

Otoceras n. sp. Zone. Axel Heiberg Island (Blind Fiord Formation): characterized by a species of Otoceras with the suture line of Otoceras boreale Spath and a whorl section resembling that of the Permian Araxoceras tectum Ruzhencev.

Boreale Zone. Ellesmere and Axel Heiberg Islands (Blind Fiord Formation): Otoceras boreale Spath, Metophiceras cf. nielseni (Spath), Ophiceras sp. indet.

Commune Zone. Ellesmere and Axel Heiberg Islands (Blind Fiord Formation): abundant ophiceratids, including Ophiceras commune Spath, Discophiceras wordiei (Spath), "Glyptophiceras" n. sp. cf. extremum Spath. Ophiceras (formerly Vishnuites) decipiens (Spath) occurs in the upper part of the zone. Otoceras is unknown.

Strigatus Zone. Ellesmere and Axel Heiberg Islands (Blind Fiord Formation): Ophiceras decipiens Spath, Proptychites cf. rosenkrantzi Spath (rare), Pachyproptychites strigatus (Tozer).

Claraia stachei Bittner occurs in the Commune and Strigatus Zones. Occurrences of this species in the Grayling Formation of British Columbia (McLearn, 1945; Tozer, 1963a) and the Sulphur Mountain Formation of Alberta (Warren, 1945) are thus Griesbachian, probably Upper Griesbachian.

DIENERIAN

Candidus Zone. Axel Heiberg and Ellesmere Islands (Blind Fiord Formation): Discophiceras cf. columbianum (Tozer), Prionolobus cf. lilangense (Krafft), Proptychites candidus Tozer. British Columbia ("Toad-Grayling" Formation): Prionolobus cf. plicatus Waagen, Prionolobus cf. lilangense (Krafft), Proptychites cf. candidus Tozer; Prionolobus cf. indoaustralicus (Wanner) has been collected from talus, probably from this zone. The fauna with Discophiceras columbianum (Tozer), from the

Grayling Formation of Dunedin River, B.C., is Dienerian and probably about the same age as the Candidus Zone (Tozer, 1963a).

Sverdrupi Zone. Axel Heiberg and Ellesmere Islands (Blind Fiord Formation): Pseudosageceras multilobatum Noetling, Paranorites sverdrupi Tozer, Paranorites cf. kingianus (Waagen), Paranorites heibergensis (Tozer) (= Prionolobus plicatus Tozer, non Waagen), Clypeoceras n. sp. British Columbia ("Toad-Grayling" Formation): Paranorites sverdrupi Tozer, Hedenstroemia sp. indet., "Dinarites" cf. minutus Waagen.

SMITHIAN

Blomstrandi Zone. This zone is divisible into two subzones, known in sequence only in the Blind Fiord Formation at Smith Creek, Ellesmere Island (Tozer, 1963a, p. 9). The lower subzone, characterized by Meekoceras gracilitatis White, also carries Pseudosageceras multilobatum Noetling, Euflemingites romunderi Tozer, Flemingites ? sp., Juvenites canadensis Tozer, Juvenites crassus Tozer, Prosphingites spathi Frebold, Anakashmirites borealis Tozer, Arctoceras blomstrandi (Lindstroem) (Tozer, 1961b, p. 29). The upper subzone has Xenoceltites subevolutus Spath, and Wasatchites tardus McLearn (Tozer, 1961b, p. 31; 1963a, p. 9). Representatives of both subzones occur in the Toad Formation of British Columbia (McLearn, 1945; Tozer, 1963a, p. 9); here the Tardus Subzone has rare Anasibirites sp. in addition to Wasatchites and Xenoceltites. In Alberta the Euflemingites beds of the Sulphur Mountain Formation are Smithian (Tozer, 1961a, p. 7).

SPATHIAN

Pilatum Zone. Axel Heiberg Island (Lower Shale Member, Blaa Mountain Formation): Nordophiceras pilatum (Hyatt and Smith), associated with small ammonoids, probably Columbites sp.

Subrobustus Zone (Tozer, 1965). Ellesmere Island (Blind Fiord Formation and Lower Shale Member, Blaa Mountain Formation): Popovites borealis Tozer, Zenoites arcticus Tozer, Keyserlingites subrobustus (Mojsisovics), Olenikites canadensis Tozer, Svalbardiceras freboldi Tozer. British Columbia (Toad Formation): Pseudosageceras bicarinatum Tozer, Preflorianites intermedius Tozer, Prosphingites cf. czekanowskii Mojsisovics, Isculitoides minor Tozer, Popovites occidentalis Tozer, Monacanthites monoceros Tozer, Metadagnoceras pulcher Tozer, Keyserlingites subrobustus (Mojsisovics), Svalbardiceras chowadei Tozer, Procarnites modestus Tozer, Leiophyllites sp. indet. Posidonia aranea Tozer also characterizes this zone and is very widespread.

On Ellesmere Island, and also in British Columbia, the Subrobustus Zone is overlain by beds with early Anisian ammonoids (Tozer, 1965, p. 9).

DISCUSSION

The decision to group the Lower Triassic zones of Canada into four new stages may be justified by reviewing alternative schemes of

1		2	3	4		5	
Series	Stage	Stage	Stage	Divisions		Stage	Zone
LOWER TRIASSIC	SPATHIAN	OLENEKIAN	OLENEKIAN	Upper Eo-trias	Prohungaritan	SCYTHIAN	*Prohungarites similis*
					Columbitan		*Columbites parisianus* *Tirolites cassianus*
	SMITHIAN				Owenitan		*Anasibirites multiformis* *Meekoceras gracilitatis*
	DIENERIAN	INDUAN		Lower Eo-trias	Flemingitan		*Flemingites flemingianus*
			INDUAN				*Koninckites volutus*
					Gyronitan		*Xenodiscoides fallax* *Prionolobus rotundatus*
	GRIESBACHIAN						*Proptychites rosenkrantzi* *Vishnuites decipiens*
					Otoceratan		*Ophiceras commune* *Otoceras woodwardi*

1. Canada
2. Kiparisova and Popow (1956, 1961)
3. Kiparisova and Popow (1964)
4. Spath (1934)
5. Kummel (1957)

Table II. Comparative classification, Lower Triassic Series.

classification that have been based on ammonoid faunas. The discussion that follows also shows what is known regarding the relationship of the proposed stages to previously proposed subdivisions and in this way indicates the principal world-wide correlatives of the four stages.

The first attempt to subdivide the Lower Triassic was made by Waagen and Diener (1895). They introduced the Scythian Series and a number of stages and substages. Arthaber (1905) adopted Scythian as the term for the Lower Triassic, in the marine facies, but an examination of Waagen and Diener's table shows that strictly speaking Scythian is not correctly applied to this time interval. This is probably why Spath (1934) preferred the term "Eo-Trias". Waagen and Diener's stages and substages have not been used by most subsequent workers. Diener himself made no use of them in his later work (Diener, 1912, 1925). One of their stages, the Hydaspian, was used by Pia (1930), but he did so incorrectly (Spath, 1934). This stage, named for the Upper Ceratite Limestone of the Salt Range, West Pakistan, is equivalent to part, at least, of the Smithian. The Gangetic substage, equivalent to the *Otoceras woodwardi* Zone of the Himalayas, is equivalent to the Lower Griesbachian.

The classification of the Lower Triassic proposed by J.P. Smith (1932) has been discussed by Spath (1934, p. 26), and also by Kummel and Steele (1962, p. 640). They have drawn attention to its shortcomings and this scheme will not be considered further.

More recent classifications of the Lower Triassic are those of Spath (1934), Kummel (1957) and Kiparisova and Popow (1956, 1961, 1964). Spath was the first to appreciate the degree of subdivision that might be possible, using ammonoid faunas. He was convinced that many faunas, previously considered contemporary, were heterochronous and that no single section contained representatives of all known faunas. To express his conception of Lower Triassic time he proposed six divisions, named after fossils (Table II). These divisions have much to recommend them but are not entirely satisfactory, for the following reasons.

1. A substantial faunal break occurs within the Gyronitan division, as defined in 1935 (Spath, 1935, p. 104). The earliest Gyronitan deposits, the "*Vishnuites*" Beds of East Greenland (Spath, 1935; Trümpy, 1961), contain abundant ophiceratids but lack true gyronitids, with tabulate venters on the outer whorls, although Spath showed that these beds contain the probable ancestors of the Gyronitidae. Gyronitids are also missing from the *Proptychites rosenkrantzi* Beds, above the "*Vishnuites*" Beds. The "*Vishnuites*" and *Proptychites* Beds correlate with the Upper Griesbachian of Canada. Later Gyronitan beds, typified by the Lower Ceratite Limestone of the Salt Range, have abundant gyronitids. In terms of Spath's divisions the gyronitids appear within the Gyronitan, not at the base. In Canada they appear in the *Candidus* Zone, and their appearance marks the Griesbachian-Dienerian boundary.

2. The boundary between the Gyronitan and Flemingitan divisions, placed within the Ceratite marls of the Salt Range, does not seem to mark a readily recognized faunal break. In the proposed classification most of the late Gyronitan and Flemingitan beds are Dienerian, for the fauna of the *Candidus* Zone is related to that of the Lower Ceratite Limestone and

Ceratite Marls, and the Sverdrupi Zone has ammonoids resembling those in the Stachella Beds (middle part of Ceratite Sandstone).

3. Discrimination of the Flemingitan-Owenitan boundary, in areas remote from the Salt Range, is a matter of controversy, owing to the uncertain correlation of the youngest Flemingitan beds, namely the upper part of the Ceratite Sandstone. This problem is discussed in more detail below.

4. Separation of the Columbitan and Prohungaritan divisions seems impractical. The faunas characterized by Tirolites (Columbitan, Spath), have important elements in common with the Subcolumbites faunas (Columbitan ?, Spath), as indicated by the faunas listed by Silberling (1959) and Astachova (1960). The Subcolumbites faunas, in turn, are related to the Prohungarites and Keyserlingites assemblages (Prohungaritan, Spath), as shown by Kummel (1954, p. 187) and the writer (Tozer, 1965, p. 14). The Arctoceras fauna of Spitsbergen (Columbitan or Prohungaritan, Spath), is now known to be Owenitan (Smithian) (Kummel, 1961; Tozer, 1961b, p. 30). Misgivings about separation of the Columbitan and Prohungaritan have already been expressed by Kiparisova and Popow (1956), Chao (1959, p. 168) and Popow (1962a, p. 177). In the proposed scheme these divisions are Spáthian, for the Pilatum Zone correlates with the Columbites parisianus Zone and the Subrobustus Zone with the youngest Lower Triassic beds.

Kummel (1957, p. 124) recognized 13 standard zones in the Scythian Stage. These zones, their relationship to Spath's divisions (Kummel, 1959, p. 433), and to the stages defined in Arctic Canada, are shown on Table II. As mentioned below, problems arise regarding the exact position of the Dienerian-Smithian boundary in relation to the alternative schemes of classification.

Kummel's zonation scheme represents the superimposition of local faunal sequences, with the 13 different zones derived from several different places, as widely separated as Greenland and the Himalayas. This has led to difficulties which render the scheme unsatisfactory as a standard for the Lower Triassic. The three main difficulties are as follows.

1. The Gyronites frequens Zone of Waagen and Diener (1895, p. 1279) (= Celtites radiosus Zone of Noetling (1905, p. 164) is not included in Kummel's table. The Frequens Zone, based on the Lower Ceratite Limestone, underlies the Rotundatus Zone, of the Ceratite Marls. Kummel places the Rosenkrantzi Zone, of East Greenland, immediately beneath the Rotundatus Zone. Spath (1935, p. 103) believed that the Rosenkrantzi Zone is older than the Frequens Zone. Placing the Rotundatus Zone adjacent to the Rosenkrantzi Zone probably fails to provide adequate zonal representation for this part of Lower Triassic time.

2. The correlation of the Flemingianus Zone, used by Kummel in the sense of Noetling (1905, p. 165), is uncertain, as stressed by Kummel and Steele (1962, p. 650). The Flemingianus Zone, in Noetling's sense, represents the whole of the Ceratite Sandstone. Kiparisova and Popow (1964) evidently consider that the Flemingianus Zone is essentially contemporary with the Gracilitatis Zone or Subzone of North America, unlike Spath (1934)

who thought that the Flemingianus Zone was the older of the two. Owing to the wide geographic separation of these two zones in their typical development the exact relationship is uncertain. In the proposed terminology the Gracilitatis Subzone is Smithian. It is possible that the Flemingianus Zone of Noetling, contains more than one fauna. Waagen and Diener (1895, p. 1279) recognized three zones in the Ceratite Sandstone. In ascending order they are the zones of "Ceratites" normalis, Flemingites radiatus (Stachella Beds) and Flemingites flemingianus (in the restricted sense). As already noted, there are grounds for correlating the Sverdrupi Zone with the Stachella Beds, so part, at least, of the Ceratite Sandstone appears to be Dienerian.

3. It has not been established that the Cassianus Zone, defined in the Alps, is older than the Parisianus Zone, of Idaho, as indicated by Silberling (1959, p. 2189).

Apart from these difficulties, some zones appear to be too precise to serve as standard subdivisions of the Lower Triassic, for use throughout the world. They may be useful in Greenland or the Salt Range but they are not suitable units for expressing intercontinental correlations. The same is true of the zones recognized in Canada. In the Lower Triassic there is a need for named stages to express long range correlations, for, as noted by Arkell (1956, p. 7) "it is convenient to group like zones together ...to have a grouping which enables several zones to be correlated in a general way over long distances when the zones individually are too precise. Such groupings are stages. They transcend zones horizontally as well as vertically and provide a stratigraphical unit of wider use, adapted to intercontinental comparisons and correlations."

Kiparisova and Popow (1956, 1961) have recognized the need for Lower Triassic stages by proposing two: a lower, Induan Stage; and an upper, Olenekian Stage. Typical Induan is in the Salt Range and typical Olenekian in Siberia. Initially they aligned the Induan-Olenekian boundary with the contact between the Ceratite Sandstone and the overlying Upper Ceratite Limestone in the Salt Range. This boundary corresponds with that between the Lower and Upper Eo-Trias of Spath. It marks an important change in the Lower Triassic ammonoid faunas and more or less corresponds with the Dienerian-Smithian boundary. Recently Kiparisova and Popow (1964) changed their original definition and now, in terms of the Salt Range section, place the Induan-Olenekian boundary at a lower level than before, between the Ceratite Marls and the Ceratite Sandstone. Judging from the faunas described by Waagen (1895), Noetling (1905) and Spath (1934), this boundary does not mark an appreciable faunal break. Kiparisova and Popow have made this change because they now believe that the Ceratite Sandstone (Flemingites flemingianus Zone) is the same age as beds classed as Owenitan by Spath. They state (1964) that "the composition of the genera and species of ammonoids change essentially when reaching the Owenites Zone (more than forty new genera appear), on which basis the boundary between the stages may be drawn". Owenitan genera (e.g. Anasibirites and other Prionitidae, Arctoceras, Prosphingites, Owenites, Inyoites and Metussuria) may occur with Flemingites in the Western United States (Smith, 1932; Kummel and Steele, 1962), Timor (Welter, 1922), China (Chao, 1959) and the Caucasus (Popow, 1962b), but with the exception of Prionites trapezoidalis Waagen, from the "topmost beds" (Waagen, 1895, pl. V), and a doubtful Prionites lower down (Kummel and Steele, 1962, p. 651), they have not been described from the Ceratite Sandstone. In other words, the rocks regarded as basal Olenekian in the Salt Range do not contain the characteristic early Olenekian fauna.

Rocks and fossils now classed as early Olenekian in Siberia have been described by Popow (1958, 1960, 1961, 1962a) and by Vozin and Tikhomirova (1964). The fauna of the Paranorites Zone, described as Induan by Popow (1961, p. 6), is now regarded as early Olenekian by Vozin and Tikhomirova (1964, p. 6). In this latter report there are inconsistencies, however, for Hedenstroemia hedenstroemi (Keyserling), of the Paranorites Zone, is listed as Olenekian on the table (p. 6) and in the text (p. 52), but as Induan on the plate description (p. 148). The more recent accounts (Popow, 1962a; Vozin and Tikhomirova, 1964) record Anasibirites and Wasatchites from the western Verkhoyan area but as yet the stratigraphic position of these fossils, in relation to those of the Paranorites Zone, has apparently not been described. Until this information is available, and until an accurate correlation is provided between the type Olenekian and the Salt Range section, it is not possible to determine where the Induan-Olenekian boundary should be placed in the ammonoid sequence of Arctic Canada.

In recent reports (Tozer, 1963a, 1963b, 1965), prepared before the publication of Kiparisova and Popow's recent proposal, the terms Induan and Olenekian were used, and interpreted as essentially synonymous with the Lower and Upper Eo-Trias of Spath (1934). Now, in view of the problems involved in defining and recognizing the Induan-Olenekian boundary, it is proposed to use the four new stages established in Arctic Canada. Eventually, if a correlation of the Olenekian-Induan and Dienerian-Smithian boundaries is demonstrated, it may prove appropriate to regard the Griesbachian and Dienerian as substages within the Induan, and the Smithian and Spathian as subdivisions of the Olenekian. However a four-fold division has advantages, for it draws attention, not to one, but to three important boundaries within the Lower Triassic. Of these the Griesbachian-Dienerian boundary and the Smithian-Spathian boundary are readily recognized in sections that preserve fossiliferous rocks of this interval. In terms of ease of recognition, they are not inferior to the boundary that separates the Dienerian from the Smithian. In the Salt Range, the Griesbachian-Dienerian boundary lies between the Ophiceras connectens bed, discovered by Schindewolf (1954) and the overlying Lower Ceratite Limestone (Kummel and Teichert, 1954). In the Himalayas this boundary is between the Otoceras Beds and the "Meekoceras" Beds (Diener, 1912). The Smithian-Spathian boundary is clearly displayed in Idaho, between the Anasibirites and Tirolites beds of the Thaynes Formation (Kummel, 1954). This boundary is also shown in the Naliling Section of Kwangsi, China (Chao, 1959, p. 158); between the Prosphingites and Subcolumbites beds of Primor'ye, Soviet Far East (Kiparisova, 1961, p. 193); and between the Arctoceras and Keyserlingites beds of Spitsbergen (Frebold, 1931, p. 32; Tozer, 1961b, p. 32).

The four stages proposed in Arctic Canada also possess a unique characteristic which may recommend them for wider use. These stages, unlike all the divisions discussed above, are based wholly on ammonoid zones observed in sequence in a single sedimentary basin. The definitions, in consequence, are free from the ambiguities that are hard to avoid when a standard is constructed by correlating partial sections scattered around the world.

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