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The quest for internationally recognized divisions of Cambrian time

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Although regional stadial schemes are available, and widely used, on all the major Cambrian continents, Armorica, Australia, Avalonia, Baltica, China, Kazakhstan, Laurentia, Siberia, the system currently has no formally agreed internationally recognized divisions. Since the IUGS Commission on Stratigraphy requires the definition of Global Boundary Stratotype Sections and Points (GSSPs), it has become the prime objective of the International Subcommittee on Cambrian Stratigraphy to commence to document suitable biostratigraphic horizons within the system which might assist in achieving this goal. In this paper we suggest the consideration of fourteen late Early Cambrian-terminal Cambrian levels, and document their stratigraphical and biogeographical distributions. Once agreement within the Subcommittee is reached on which are the most suitable, it will be necessary to search for appropriate stratotype sections, bearing in mind the necessity to calibrate the biostratigraphy by way of non-biological correlation techniques, such as chemostratigraphy and magnetostratigraphy.

Introduction

The Cambrian and Carboniferous Systems are the only major periods of the Phanerozoic which are presently without formal international stages and series. In the case of the Cambrian this remarkable situation is partly due to the strong regional aspects of studies over prolonged periods of time, and partly a result of subsequent changes in the stratigraphic position of the lower boundary of the Cambrian. Cambrian stratigraphical units primarily satisfied requirements regionally rather than globally and, as a result, often developed into parochial subdivisions. As emphasized by the *International Subcommittee on Cambrian Stratigraphy* (ISCS), the growing international interest during the last decade has led to an increasing number of projects, mainly focussing on the lower and upper boundaries of the system. Accordingly, regional correlation charts still suffer from the absence of a formally agreed left-hand scale. The recognition of formal international stages or series for the Cambrian has thus developed into the major task of Cambrian stratigraphers.

The last decades of research on Cambrian stratigraphy were characterized mainly by the long struggle for defining the lower and upper boundaries of the Cambrian. The first was finally decided in 1991 (Landing, 1991), and the last is presently close to a final decision (Cooper, 1998; Cooper and Nowlan, 1999). Internal Cambrian divisions, however, have been extensively discussed for some Cambrian continents but rarely in a global context. The most prominent

exceptions are articles by Robison and Rowell (1976), Robison et al. (1977) and Rowell et al. (1982) who examined possible stage boundaries in the light of the knowledge of two decades ago. This article reviews and examines the possibilities for Cambrian divisions on the basis of more recent information (Figure 1) and shows that the faunal horizons with potential for international correlation emphasized by Robison et al. (1977) are still among the most powerful levels with potential for defining the lower boundaries of international stages.

Traditional Cambrian series

The traditional subdivision of the Cambrian System is based on the comforting and archetypical tripartition which characterizes most of the other periods of earth's history. However, other than for the classical Triassic or Jurassic, the tripartition of the Cambrian is an awkward and largely artificial subdivision. The resulting Lower-Middle and Middle-Upper Cambrian series boundaries are located at stratigraphic levels that are difficult to define on a global scale by biostratigraphic or physical methods and/or bear major problems of correlation. Especially, the Lower-Middle Cambrian boundary has been the topic of intensive research in recent years and shown to be at different chronostratigraphic levels in the various regions (Geyer,

Figure 1 Generalized stratigraphic position of the reviewed horizons of possible Cambrian divisions with potential for international correlation.

1990, 1998; Geyer and Palmer, 1995; Zhuravlev, 1995). In addition, the lower boundary of the Cambrian System has been shifted downward so that the Early Cambrian now represents a period of time that is considerably longer than the Middle plus Upper Cambrian (Landing, 1996; Landing et al., 1998).

In the search for divisions of the Cambrian, the traditional series boundaries should not be regarded as holy shrines. Practical series primarily need internationally suitable boundaries that are somehow recognizable in the majority of the Cambrian regions rather than being recognizable in one or two areas. A tripartition of the revised Cambrian System would not only have consequences for possible confusion of traditional old and new Lower, Middle, and Upper Cambrian Series, but also lacks adequate positions for such revised stage boundaries. Thus, subdivision into four, five, or six series may be more appropriate. It could furnish established divisions as well as offering the possibility of establishing boundaries at well correlatable levels. Such possible levels are discussed in the following paragraphs in stratigraphically descending order.

Base of the *Cordylodus proavus* Zone (C.p.)

Cordylodus proavus has a cosmopolitan distribution (An, 1981; Miller, 1984), having been described from Argentina (Jujuy Province), Australia (Georgina and Bonaparte Basins), Canada (North West Territories, Alberta, New Brunswick, Newfoundland), China (Anhui, Hebei, Hubei, Hunan, Jilin, Liaoning, Shandong, Shanxi, Zhejiang), Greenland, Iran, Kazakhstan, Mexico, the Siberian Platform, the East European Platform (northern Estonia, St. Petersburg area) and Sweden, Turkey, USA (Arkansas, Idaho, Maryland, Missouri, Nevada, New Jersey, New York, Oklahoma, Pennsylvania, South Dakota, Texas, Utah, Vermont, Wisconsin), and Wales. In carbonate platform biofacies, it has been used biostratigraphically to define the base of the Ibxian Stage in Laurentia, the Datsonian Stage in Australia, the Xinchangian Stage in China and the Ungurian Stage in Kazakhstan. In Laurentia, the first appearance datum (FAD) of *C. proavus* marks the base of the Symphysurid biomere. *Cordylodus proavus*, however, has a long stratigraphic range, almost to the Cambrian-Ordovician boundary, as currently recognized by the International Cambrian-Ordovician Boundary Working Group, and its range is not necessarily homotaxial in all the regions listed above. Its FAD coincides with conodonts of the *Hirsutodontus hirsutus* Subzone immediately succeeding those of the *Cambroistodus minutus* Subzone of the *Eoconodontus* Zone, at a time of significant faunal turnover. On the trilobite biostratigraphic scale the base of the *Cordylodus proavus* Zone correlates with the *Eurekia aopsis* Subzone of the *Saukia* Zone in Laurentia.

Irvingella in association with Agnostotes (I.-A.)

These genera have overlapping ranges in the medial part of the Late Cambrian, and quite extensive palaeogeographic distributions. *Irvingella* occurs in Australia (western Queensland), Vietnam, China (Hunan, Liaoning, Anhui, Xinjiang), South Korea, Kazakhstan (Lesser Karatau), Russia (NE Siberian Platform, NW Siberian Platform, Novaya Zemlya), Sweden, UK, Canada (Alberta, British Columbia, North West Territories), and USA (Oklahoma, Missouri, Montana, Nevada, Texas, Utah, Wisconsin, Wyoming), Argentina, and possibly in Antarctica (Northern Victoria Land). Reported occurrences of *Irvingella* from Nei Monggol need confirmation. In Laurentia it ranges across the Steptoean-Sunwaptan Stage boundary; in Australia it defines the beginning of the Iverian Stage; in China it

occurs in the middle and late Changshanian; and in Kazakhstan and Siberia, the late Sakian. *Agnostotes* (embracing its synonyms *Pseudoglyptagnostus* Lu in Wang, 1964 and *Glyptagnostotes* Lazarenko, 1966) occurs in Australia (western Queensland, Tasmania?), Canada (British Columbia, North West Territories), China (Hunan, Liaoning, Nei Monggol, Qinghai, Xinjiang, Zhejiang), Kazakhstan (Lesser Karatau), Russia (NE Siberian Platform), South Korea, and possibly USA (Nevada?) according to Pratt (1992). The FAD of *Agnostotes* is apparently earliest in Canada and its youngest occurrence is in Nei Monggol. In a significant number of regions *Irvingella* and *Agnostotes* co-occur and have been used as zonal index fossils: *Irvingella tropica*-*Agnostotes inconstans* Zone in Australia; *I. angustilimbata*-*A. latilimbata* Zone in South China (Hunan); *I. tropica*-*A. clavata* in the *Irvingella-Sinoproceratopyge kiangshanensis* Zone in the Tarim Basin of NW China; *I. major*-*A. elegans* in the *Irvingella-Cedarellus felix* Zone of Yakutia; *I. tropica*-*A. elegans* in the *Pseudagnostus "curtare"* Zone of Kazakhstan; and *I. major*-*A. clavata* in the *I. major* Zone (marking the base of the Sunwaptan, following Chatterton and Ludvigsen, 1998) in Canada. The occurrence of the oldest species of the *Irvingella* clade (Palmer, 1965) with species of *Agnostotes* seems most useful biostratigraphically.

Base of *Glyptagnostus reticulatus* Zone (G.r.)

The *Glyptagnostus reticulatus* Zone is one of the most widely recognizable trilobite horizons. To be precise, the base of the range of *G. reticulatus* is eminently suitable to mark a stage and series boundary on a global scale as first discussed by Kobayashi (1949) and subsequently by Palmer (1962), Öpik (1966), Rosova (1968), and Robinson et al. (1977). Its index fossil, *Glyptagnostus reticulatus*, has been identified from Antarctica (Ellsworth Mountains), Australia (western Queensland, Tasmania), Canada (British Columbia, North West Territories), China (S. Anhui, NW Gansu, E. Guizhou, W. Hunan, Xinjiang, W. Zhejiang), Denmark, Kazakhstan (Lesser Karatau), Norway, Russia (NW Siberian Platform, NE Siberian Platform), South Korea, Sweden, UK, USA (Alabama, Alaska, Nevada, Tennessee, Texas), and Argentina. It is used as a zonal index fossil in Siberia, Kazakhstan, the Yangtze Platform, Australia, and Laurentia. Co-occurrences with numerous other trilobites permit correlation into other regions such as Argentina and Baltica. The base of the zone marks the time of a significant faunal change that is expressed by the boundary between the Marjumiid and the Pteroccephaliid biomes in Laurentia (base of the *Aphelaspis* Assemblage-Zone), the base of the Idamean Stage in Australia, the base of the Sakian Stage in Kazakhstan (which is regarded there as the base of the Late Cambrian Series), the base of the Kugorian Stage in Siberia, and coincides with the base of the *Olenus* Stage and the base of the *Homagnostus obesus* Zone in Scandinavia (in the sense of Henningsmoen, 1957).

Base of *Glyptagnostus stolidotus* Zone (G.s.)

Glyptagnostus stolidotus has a similar but slightly less frequent occurrence to that of *Glyptagnostus reticulatus*. It is known from such regions as Antarctica (North Victoria Land), Australia (western Queensland, Northern Territory), China (E. Guizhou, W. Hunan, Xinjiang, W. Zhejiang), Kazakhstan (Lesser Karatau), Russia (NE Siberian Platform, Altay Sayan) and USA (Alabama). It is used as a formal index fossil in Siberia, Kazakhstan (late Ayusokkanian), the Yangtze Platform (late Kushanian), and Australia (late Mindyallan).

Table 1 Correlation chart for the Cambrian biostratigraphic units of important regions/paleocontinents. The South China column shows the newly introduced stratigraphic scheme by Peng Shanchi, Zhou Zhiyi, Lin Tianrui, and Yuan Jinliang, approved by the Chinese National Committee on Stratigraphy, May 2000. Horizontal lines show positions of potential subdivisions as discussed in the text. Abbreviations: FT, first occurrence of trilobites; HCST, *Hebediscus attleboensis*-*Calodiscus-Serrodiscus-Triangulaspis* band; PHCO, *Protolenus-Hamatolenus-Cobboldites-Ovatortocara* band; O.I., *Oryctocephalus indicus*; T.g., *Ptychagnostus gibbus*; A.a., *Acidus atavus*; P.p., *Ptychagnostus punctuosus*; L.L., *Lejopyge laevigata*; L.r., *Linguagnostus reconditus*; G.s., *Glyptagnostus stolidotus*; G.r., *Glyptagnostus reticulatus*; I.-A., *Irvingella* in association with *Agnostotes*; C.p., *Cordylodus proavus*. Generated for the International Subcommission of Cambrian Stratigraphy by G. Geyer, S. Peng, and J. H. Shergold (See pages 190-191).

W. AVALONIA			E. AVALONIA			MOROCCO			SPAIN			BALTICA			SIBERIA			
ORD.	TRD.	<i>Rhabdinopora flabelliforme</i>	TRD.		<i>Rhabdinopora flabelliforme</i>	ORD.		<i>Rhabdinopora flabelliforme sociale</i>	ORD.		<i>Oryctoconus interval</i>	ORD.		<i>Rhabd. f. norvegicum</i> <i>Rhabd. f. flabelliforme</i> <i>Rhabdinop. f. sociale</i>	ORD.	TREMADOCIAN	<i>Rhabdinopora flabelliforme</i>	
UPPER CAMBRIAN	MERIONETHIAN SERIES	<i>Acerocare</i>	MERIONETH SERIES		<i>Acerocare</i>	UPPER CAMBRIAN		no zones and stages established	UPPER CAMBRIAN		no zones and stages established	UPPER CAMBRIAN		<i>Acerocare ecome</i>	UPPER CAMBRIAN	MANSIAN	<i>Dolgeuloma - Kaninia</i>	<i>Dolgeuloma</i>
								<i>Westergaardia</i>										
		<i>Peltura</i>			<i>Peltura</i>		<i>Peltura scarabaeoides</i> <i>Peltura minor</i> <i>Protopeltura praecursor</i>				<i>Peltura</i>		<i>Peltura costata</i> <i>Peltura transiens</i> <i>Peltura scarabaeoides</i> <i>Peltura minor</i> <i>Protopeltura praecursor</i>	KETYAN		Kujandaspis	Kaninia	
		<i>Leptoplastus</i>			<i>Leptoplastus</i>			<i>Leptoplastus</i>										
		<i>Parabolina spinulosa</i>			<i>Parabolina spinulosa</i> <i>Parabolina brevispina</i>					<i>Parabolina spinulosa</i> <i>Parabolina brevispina</i>	YURAKIAN		Amorphella - Yurakia					
		<i>Homagnostus obesus</i>	<i>Olenus and Hom. obesus</i>	<i>Olenus cataractes</i> <i>Olenus wahlenbergi</i> <i>Olenus truncatus</i> <i>Olenus gibbosus</i>		<i>Olenella interval</i>		<i>Olenus scanicus</i> <i>Homagnostus obesus</i> <i>Agnostus pisiformis</i>	ENSYAN	Faciura - Garbiella								
		<i>Agnostus pisiformis</i>		<i>Agnostus pisiformis</i>						MADUAN	Maspakites - "Idahoella" - Raashellina							
		<i>Paradoxides forchhammeri</i>		<i>Lejopyge laevigata</i>		<i>Bailella cf. lewyi interval</i>		<i>"Solenopleuropsis-free"</i>		<i>P. forchhammeri</i>	<i>Lejopyge laevigata</i> <i>Erratopora brachymetopa</i> <i>Tr. lundgr. - G. nathorstii</i>	MAYAN	<i>Lejopyge laevigata</i> <i>Oidaia</i> - <i>trispinosa</i> <i>Anomocanoides limbataeformis</i> <i>Anopolenus henrici</i> - <i>Corynexochus perforatus</i>					
		<i>Paradoxides davidis</i>		<i>Paradoxides davidis</i>		no zone established		<i>Solenopleuropsis</i>	<i>Paradoxides paradoxissimus</i>	<i>Ptychagnostus punctuosus</i> <i>Hypagnostus parvifrons</i> <i>Tomagnostus fissus</i>								
MIDDLE CAMBRIAN	ACADIAN SERIES	<i>Hydrocephalus hicksi</i>	ST. DAVID'S SERIES	<i>Hydrocephalus hicksi</i>	MIDDLE CAMBRIAN		<i>Pardailhania</i>		<i>Pardailhania</i>	MIDDLE CAMBRIAN	<i>Badulesia</i>	MIDDLE CAMBRIAN	<i>Badulesia</i>	MIDDLE CAMBRIAN	<i>Ptychagnostus gibbus</i>	MIDDLE CAMBRIAN	AMGAN	<i>Kounamkites</i>
		<i>Eccaparadoxides eteminiensis</i>				"Paradoxides" aurora		<i>Badulesia tenera</i>			<i>Eccaparadoxides asturianus</i>		<i>Eccaparadoxides pinus - Pentagnostus praecurrens</i>					
						"Paradoxides" harknessi		<i>Kymataspis arenosa</i>			<i>Eccaparadoxides szduyi</i>		<i>Eccaparadoxides insularis</i>					
		<i>Eccaparadoxides benetti</i>				no zone establ.					<i>Acadoparadoxides oelandicus</i>							
						<i>Acadoparadoxides harlani interval</i>												
		<i>Pagetides n. sp. interval</i>															<i>Oryctocara Schistocephalus antiquus</i>	
LOWER CAMBRIAN	BRANCHIAN SERIES	<i>Oryctocara (Ovator) granulata - Myoposstrenua sabulosa interval</i>	COMLEY SERIES	<i>Protolenid-strenuella</i>	LOWER CAMBRIAN		<i>Hupectenus</i>		<i>Hamatolenus (H.) ibericus</i>	LOWER CAMBRIAN	<i>Acadoparadoxides mureoensis</i>	LOWER CAMBRIAN	<i>"Protolenus" interval</i>	LOWER CAMBRIAN	TOYONIAN	<i>Lermontovia grandis</i> <i>Bergeroniellus ketemensis</i> <i>B. ornata</i> <i>B. asiaticus</i> <i>B. gurali</i> <i>Bergeroniellus micmaccliformis/ Erbiella</i>		
		<i>Protolenus interval</i>				<i>Sectigena</i>		no zone established			<i>"Ornamentaspis" linnarssoni</i>							
		<i>Callavia broeggeni Zone</i>		<i>Olenellid</i>		<i>Callavia Zone</i>		<i>Antattasia gutta-pluviae</i>			<i>L. ribotanus interval</i>		<i>Archaeocyathan zones VIII-X</i>					
							<i>Antattasia hollardi</i>		no trilobite zone established		<i>Archaeocyathan zones I-VII</i>							
		<i>Camenella baltica Zone</i>				no zone established		<i>Daguinaspis</i>			no trilobite zone established							
		<i>Sunnaginina imbricata Zone</i>					<i>Choubertella</i>						<i>Holmia kjerfuffi</i>	BOTOMAN	<i>B. gurali</i> <i>Bergeroniellus micmaccliformis/ Erbiella</i>			
							<i>Fallotaspis tazemmourensis</i> <i>Eofallotaspis</i>					<i>Schmidtellus mickwitzii</i>						
								no zones and stages established					<i>Platysolenites</i>	TOMMOTIAN	<i>D. lenaicus - Turm. primigenius</i> <i>Dokidocyathus regularis</i> <i>Nochorocyathus sunnaginicus</i>			
		<i>Watsonella crosbyi</i>																
		"Ladatheca" cylindrica																
		no faunas known																
		<i>Sabellidites cambriensis/ Trichophycus pedum</i>																

KAZAKHSTAN				NORTH CHINA				SOUTH CHINA				AUSTRALIA				LAURENTIA										
ORDOV.	UNGUERIAN	Cordylodus caseyi Cordylodus prion C. oklahomensis Cordylodus proavus	Dikelocephalina Euloma limitaris - Taoyuania	ORD.	XINCHANGIAN	Wanliangtingia Yosimuraspis Richardsonella/ Platypeltoides Missisquoiia perpetis	ORD.			Apatokcephalus latilimb. Taoyuania affinis Hysterolenus Onchopyge Leiostracina constrictum - Shenjiawania brevis	ORD.	WAREN DIAN	Chosondina herfurthi/ Cordylodus angulatus Cordylodus lindstromi Cordylodus prolindstromi Hirsotodontus simplex Cordylodus proavus	ORDOVICIAN	CANADIAN	IBEXIAN/ SKULLROCKIAN	Symphysurina bulbosa Symphysurina brevispicata Missisquoiia typicalis Miss. depressa Eurekia apopsis Saukiella serotina									
UPPER CAMBRIAN	BATYR- BAIAN	Proconod. muelleri - Eoconodontis notchpeakensis	Lotagnostus hedini Harpidioides Lophosaukia	UPPER CAMBRIAN	FENGSHANIAN	Mictosaukia Sinoeremoceras Quadricephalus Proconodontus postero- costatus Ptychaspis- Tsinania Proconod. tenuiserratus	UPPER CAMBRIAN	HUNANIAN	TAOYUANIAN	Mictosaukia striata - Falccephalus Archaeuloma taoyuanense - Leioagnotus cf. beveli Lotagnostus punctatus - Hedinaspis regalis Probinacunaspis nasalis - Peichiashania humanensis Eolotagnostus decorus - Kaolishaniella Rhaptagnostus ciliensis - Onchonotellus cf. kuruktagensis Agnostotes clavata- Irvingella angustilimbata	UPPER CAMBRIAN	PAYNT- ONIAN	Mictosaukia perplexa Neoagnotus quasibilibus/ Shergoldia nomas Sinosaukia impages Rhaptagnostus clarki maximus/R. papilio Rhaptagnostus bilaxi/ Neoagnotus denticulatus Rhaptagnostus clarki prolatus/ Caznia sectatrix Rhaptagnostus clarki patulus/ Caznia squamosa Hapsidocare lilyensis Peichiashania tertia/ Peichiashania quarta Peichiashania secunda/ Prochuanguia glabella Wentsuia rotata/ Rhaptagnostus apsis Irvingella tropica	UPPER CAMBRIAN	MILLARDAN	SUNWAPTAN	Saukia Saukiella junia Saukiella pyrene- Rasettia maga Ellipsocephaloides Idahoia Taenicephalus									
	AKSAYAN	Westergaardodina- Fumshia Oncagnostus ovaliformis Oncagnostus kazachstanicus Pseudagnostus pseudangustilobus Changshania conica- Irvingella taizuhensis Pseudagnostus "curtare" Oncagnostus longifrons Glyptagnostus reticulatus Glyptagnostus stolidotus Kormagnostus simplex	Tsulsicagnostus trisulcus Eolotagn. scrobicularis Neogn. quadratiformis		CHANGSHANIAN	Kaolishania pustulosa Shirakiella xiaoshiensis Maladioidella splendens Chuanguia subquadrangulata Prochuanguia mansuyi				IVERIAN		Rhaptagnostus clarki patulus/ Caznia squamosa Hapsidocare lilyensis Peichiashania quarta Peichiashania secunda/ Prochuanguia glabella Wentsuia rotata/ Rhaptagnostus apsis Irvingella tropica	Saukia Saukiella pyrene- Rasettia maga Ellipsocephaloides Idahoia Taenicephalus													
	SAKIAN				KUSH- ANIAN	Drepanura premesnili Blackwelderia paronai Damesella/Yabeia Leioipaishania Taitzia/Poshania Amphoton				IDAMEAN		Stigmatocella dilloma Erixanum sentum Proceratopyge cryptica Glyptagnostus reticulatus Glyptagnostus stolidotus Acmahachis quasivespa Erediaspis eretes	Saukia Saukiella pyrene- Rasettia maga Ellipsocephaloides Idahoia Taenicephalus													
	ARYUSOK- KANIAN									MIND- YALLAN		Lejopyge laevigata	Saukia Saukiella pyrene- Rasettia maga Ellipsocephaloides Idahoia Taenicephalus													
	ZHANA- RYKIAN									BOOM- ERAN- GIAN		Lejopyge laevigata	Saukia Saukiella pyrene- Rasettia maga Ellipsocephaloides Idahoia Taenicephalus													
	MIDDLE CAMBRIAN	TYESAIA	Acidus atavus			MIDDLE CAMBRIAN				CHANGHSIAN			MIDDLE CAMBRIAN				WULINGIAN	TAJIANGIAN	Acidus atavus (Ptychagnostus gibbus)	MIDDLE CAMBRIAN	LATE TEMPLETONIAN/ FLORAN	Euagnostus opimus Acidus atavus Ptychagnostus gibbus	MIDDLE CAMBRIAN	LINCOLNIAN		
			Ptychagnostus intermedius																							
			Peronopsis ultimus																							
"LENAN"		Probowmania asiatica		MIDDLE CAMBRIAN	HSUCHUANGIAN	Bailiella - Lioparia Poriagraulos Inouyops Metagraulos Sunaspis-Sunaspidella P. jinnanensis Ruichengaspis Kochaspis ? Shantungaspis Yaojiayuella	MIDDLE CAMBRIAN	WULINGIAN	TAJIANGIAN	Oryctocephalus indicus	MIDDLE CAMBRIAN	ORDIAN/ EARLY TEMPLETONIAN	Xystridura templetonensis/ Redlichia chinensis	MIDDLE CAMBRIAN	LINCOLNIAN											
LOWER CAMBRIAN	"LENGAN"	Redlichia chinensis - Kootenia gimmerfari		LOWER CAMBRIAN	MAOCHUANGIAN	Qiaotouaspis Redlichia nobilis Redlichia chinensis Megapalaeolenus ? no zones established	LOWER CAMBRIAN	WULINGIAN	TAJIANGIAN	Bathynotus Protoryctocephalus Arthrocephalites- Changaspis Arthrocephalus ? Sichuanolenus- Chengkouia Hupediscus- Sinodiscus Sinosachites- Lapworthella ? Paragloborillus- Siphonochites ? Anabarites- Circotheca	LOWER CAMBRIAN	MIDDLE CAMBRIAN														
		Ushbaspis limbata																								
		Hebediscus orientalis																								
		Ushbaspis sp.1 - Microcomus - Burithes																								
	"MEISHUCUNIAN"	Uniformitheca		LOWER CAMBRIAN	TSANGLANG- PUAN		LOWER CAMBRIAN	WULINGIAN	TAJIANGIAN		LOWER CAMBRIAN	MIDDLE CAMBRIAN														
LOWER CAMBRIAN	"LENGAN"	Hyalithellus rectus - Pseudorthiscosta costata		LOWER CAMBRIAN	CHUNG- CHUSSUAN		LOWER CAMBRIAN	WULINGIAN	TAJIANGIAN		LOWER CAMBRIAN	MIDDLE CAMBRIAN														
	"MEISHUCUNIAN"			LOWER CAMBRIAN	TSANGLANG- PUAN		LOWER CAMBRIAN	WULINGIAN	TAJIANGIAN		LOWER CAMBRIAN	MIDDLE CAMBRIAN														
LOWER CAMBRIAN	"LENGAN"			LOWER CAMBRIAN	CHUNG- CHUSSUAN		LOWER CAMBRIAN	WULINGIAN	TAJIANGIAN		LOWER CAMBRIAN	MIDDLE CAMBRIAN														
	"MEISHUCUNIAN"			LOWER CAMBRIAN	CHUNG- CHUSSUAN		LOWER CAMBRIAN	WULINGIAN	TAJIANGIAN		LOWER CAMBRIAN	MIDDLE CAMBRIAN														
LOWER CAMBRIAN	"LENGAN"			LOWER CAMBRIAN	CHUNG- CHUSSUAN		LOWER CAMBRIAN	WULINGIAN	TAJIANGIAN		LOWER CAMBRIAN	MIDDLE CAMBRIAN														
	"MEISHUCUNIAN"			LOWER CAMBRIAN	CHUNG- CHUSSUAN		LOWER CAMBRIAN	WULINGIAN	TAJIANGIAN		LOWER CAMBRIAN	MIDDLE CAMBRIAN														
LOWER CAMBRIAN	"LENGAN"			LOWER CAMBRIAN	CHUNG- CHUSSUAN		LOWER CAMBRIAN	WULINGIAN	TAJIANGIAN		LOWER CAMBRIAN	MIDDLE CAMBRIAN														
	"MEISHUCUNIAN"			LOWER CAMBRIAN	CHUNG- CHUSSUAN		LOWER CAMBRIAN	WULINGIAN	TAJIANGIAN		LOWER CAMBRIAN	MIDDLE CAMBRIAN														
LOWER CAMBRIAN	"LENGAN"			LOWER CAMBRIAN	CHUNG- CHUSSUAN		LOWER CAMBRIAN	WULINGIAN	TAJIANGIAN		LOWER CAMBRIAN	MIDDLE CAMBRIAN														
	"MEISHUCUNIAN"			LOWER CAMBRIAN	CHUNG- CHUSSUAN		LOWER CAMBRIAN	WULINGIAN	TAJIANGIAN		LOWER CAMBRIAN	MIDDLE CAMBRIAN														
LOWER CAMBRIAN	"LENGAN"			LOWER CAMBRIAN	CHUNG- CHUSSUAN		LOWER CAMBRIAN	WULINGIAN	TAJIANGIAN		LOWER CAMBRIAN	MIDDLE CAMBRIAN														
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	"MEISHUCUNIAN"			LOWER CAMBRIAN	CHUNG- CHUSSUAN		LOWER CAMBRIAN	WULINGIAN	TAJIANGIAN		LOWER CAMBRIAN	MIDDLE CAMBRIAN														
LOWER CAMBRIAN	"LENGAN"			LOWER CAMBRIAN	CHUNG- CHUSSUAN		LOWER CAMBRIAN																			

It directly underlies the zone of *Glyptagnostus reticulatus* and thus has a slightly less advantageous potential position for a stage or series boundary in traditionally Upper Cambrian strata.

Base of the *Linguagnostus reconditus* Zone (L.r.)

The traditional index fossil of the base of the Upper Cambrian is *Agnostus pisiformis*, which, in contrast to earlier reports, appears to be restricted to Sweden, Norway, Poland, England, Novaya Zemlya, and southeastern Newfoundland (e.g., Henningsmoen, 1958; Rushton, 1978). In addition, the *Agnostus pisiformis* Zone is seemingly based on local abundance, and *A. pisiformis* is present in the subjacent *Lejopyge laevigata* Zone (see Westergård, 1946, figs. 10-14; Peng and Robison, 2000). To overcome this problem, Peng and Robison (2000) suggest to use the lowest appearance of *Linguagnostus reconditus* to replace the *Agnostus pisiformis* level.

Linguagnostus reconditus, as emended by Peng and Robison (in press), is a distinctive and widespread species, known from South China, Australia, the Altay-Sayan region, England, and Scandinavia (e.g., Poletaeva and Romanenko, 1970; Taylor and Rushton, 1972; Rushton, 1978; Shergold et al., 1990; Ahlberg and Ahlgren, 1996; see synonymy in Peng and Robison, 2000). It can be used to define a brief zone with a number of species (*Ammagnostus sinensis*, *Clavagnostus spinosus*, and *Pseudagnostus koerferi*) restricted to this zone and a large number of additional species ranging into the zone (such as *Acmahachis typicalis*, *Kormagnostus minutus*, *Proagnostus bulbosus*, *Glyptagnostus stolidotus*, *Hypagnostus brevifrons*, and *Tomagnostella sulcifera*) (data from Peng and Robison, 2000).

The *Linguagnostus reconditus* Zone apparently correlates with much, or all, of Westergård's (1922, 1946) *Agnostus pisiformis* Zone of Scandinavia, and a global stage or series boundary at the base of this zone therefore would have the advantage of being as close as possible to the traditional Middle-Upper Cambrian boundary. However, *Linguagnostus reconditus* was previously widely neglected, or attributed to other species (see Peng and Robison, in press), and its FAD is not currently in use for any widely recognized stage.

Base of *Lejopyge laevigata* Zone (L.l.)

Although the areal occurrence of *Lejopyge laevigata* is a little more limited compared to some other late Middle Cambrian agnostoids, other trilobites and conodonts of the *Lejopyge laevigata* biota (e.g., the trilobites *Opsidiscus bilobatus*, *Oidagnostus trispinifer*, *Diplagnostus planicauda*, *Hypagnostus brevifrons*, *Megagnostus glandiformis*, *Peronopsis insignis*, and the conodonts *Gapparodus bisulcatus*, *Hertzina carinata*, *Prosagittodontus dahlmani*), permit a relatively precise correlation into a number of other deeper water successions. *Lejopyge laevigata* occurs in Australia (western Queensland, Tasmania), China (Anhui, Guizhou, Hunan, Sichuan, Xinjiang, Zhejiang), Denmark, Germany (in erratics), Greenland, India (Ladakh), Kazakhstan (Lesser Karatau), Turkmenistan, Russia (southern Siberian Platform, NE Siberian Platform), Sweden, Norway, northern Poland, and USA (Alaska, Nevada). In Scandinavia, Siberia, Australia, Kazakhstan and China it is in use as a formal index fossil (*Lejopyge laevigata* and *Lejopyge laevigata-Aldanaspis truncata* Zones), and it defines the base of the Boomerangian Stage in Australia and the Ayusokkanian Stage in Kazakhstan. It should be emphasized that *Agnostus pisiformis*, the traditional index fossil for the base of the Upper Cambrian in Baltica, has been reported from the *Lejopyge laevigata-Aldanaspis truncata* Zone in Siberia (although convincing species have not been illustrated). Furthermore, it should be noted that *L. laevigata* is commonly reported to co-occur with *L. armata*. However, careful studies of sections indicate that *L. armata* appears to occur earlier in Kazakhstan and China, whereas *L. laevigata* predates *L. armata* in Laurentia.

Base of *Ptychagnostus punctuosus* Zone (P.p.)

Ptychagnostus punctuosus is a frequent and widely distributed agnostoid. Representatives have been described from such areas as

Australia, New Zealand, South China (Hunan), NW China (Xinjiang), Kazakhstan, Siberian Platform, Sweden, Denmark, Norway, England, Wales, Greenland, Canada (western Newfoundland, New Brunswick) and the USA (New York, Utah, Nevada). In most areas of its occurrence the species is used as an index fossil and defines an interval-zone. It defines the base of the Undillan Stage in Australia, the base of the Zhanarykian Stage in Kazakhstan, and the base of the newly proposed Wangcunian of China (Peng et al., 1998). *Ptychagnostus punctuosus sensu stricto* has a FAD which appears to define a useful time-marker.

Base of *Acidusus atavus* Zone (A.a.)

Acidusus atavus is a widespread species known from Australia (western Queensland, South Australia), Vietnam, China (Hunan, Guizhou, Xinjiang, Zhejiang), North Korea, Russia (Siberian Platform), Sweden, Denmark, Norway, UK, Greenland, Canada (western Newfoundland) and USA (Nevada, Utah). The base of the zone marks a significant faunal change, defining the base of the Marjuman Stage boundary in Laurentia (Ludvigsen et al., 1985). The base of the *Acidusus atavus* Zone corresponds with the base of the Floran Stage in Australia (Öpik, 1967). The faunal change documented at the base of the *A. atavus* Zone is correlated in Laurentia with that at the base of the *Bolaspidella* Zone, but this is not a biore boundary in the definition of Palmer (1981, 1998) and Sundberg (1994).

Base of *Ptychagnostus gibbus* Zone (T.g.)

Ptychagnostus (or *Triplagnostus*) *gibbus* is even more widespread than *Acidusus atavus*. It is known from Antarctica (in erratics), Australia (western Queensland), Kazakhstan, Russia (Siberian Platform), Poland, Sweden, Norway, UK, Greenland, Canada (Newfoundland), and USA (Nevada, New York, Utah), and it is widely used as an index fossil (Baltica, Siberian Platform, Yangtze Platform, Australia). The *Ptychagnostus gibbus* Zone is the basal zone of the *Paradoxides paradoxissimus* Stage in Scandinavia (Westergård, 1946).

Base of the *Eliasum-Cristallinum* Assemblage Zone

Studies of acritarch assemblages revealed a pronounced change from the *Volkovia-Liepaina* assemblage to the *Eliasum-Cristallinum* assemblage (Moczydlowska, 1999). Both are used to define formal acritarch assemblage zones regarded as Lower and Middle Cambrian in age, respectively. The base of the *Eliasum-Cristallinum* Assemblage Zone has recently been suggested to define the base of the Middle Cambrian on a global scale (Moczydlowska, 1999). The *Eliasum-Cristallinum* assemblage is represented by a wide array of such species as *Eliasum llaniscum*, *Cristallinum cambriense*, *Timofeevia lancarae*, *T. phosphorica*, and *Lophosphaeridium latviense*. It can be traced between shelf areas of various Cambrian continents and is known from such areas as Poland, Sweden, Spain, Morocco, Wales and southeastern Newfoundland (Vanguestaine and Van Looy, 1983; Martin & Dean, 1988; Palacios, 1993; Young et al., 1994; Moczydlowska, 1999). It appears to correlate into the uppermost "Protolenus Zone" of Baltica, the upper Bilbilian of Spain and the upper Protolenid-Strenuelliid Zone of Wales, but appears to be fairly unaffected by the faunal provincialism which is seen in the trilobite assemblages.

Base of the *Oryctocephalus indicus* Zone (O.i.)

Recent investigations suggest that the FAD of *Oryctocephalus indicus* may be suitable for the base of a GSSP. This species, first described from the Spiti area of Kashmir (Reed, 1910; revised by Jell and Hughes, 1997), has been found in the Great Basin area just above the top of the *Bomia-Olenellus* Zone (Sundberg and McCollum, 1997) and in the lower part of the Kaili Formation, attributed to the *Oryctocephalus-Xingrenaspis* Assemblage-zone, in Guizhou province, Yangtze Platform, South China (Zhao et al., 1996; Yuan et

al., 1997; Sundberg et al., 2000). A recent article discusses the potential of this latter occurrence as a GSSP, particularly because *Oryctocephalus indicus* is associated with a number of other oryctocephalids in South China and Laurentia as well as apparently *Pagetia prolata* (Sundberg et al., 2000).

Bathynotus occurs at the top of the subjacent zones in both regions, which marks the top of the Lower Cambrian. In the *Bathynotus-Nangaops* Assemblage-zone of South China, *Bathynotus* occurs together with *Redlichia*, a “traditional” Lower Cambrian faunal element. If the species of *Bathynotus* turn out to be coeval, the occurrence of this genus would tentatively permit a correlation into Siberia and Australia. Further correlation of the Siberian Platform with southeastern Newfoundland and from there to Great Britain would provide the base for a broad international correlation.

However, precise correlation into the western and central sectors of Gondwana remain problematic, and additional data are needed to corroborate the reliability of the data from Laurentia and South China, and the occurrence of *Oryctocephalus indicus* in chronic low diverse faunas poses an additional problem.

Base of the *Protolenus-Hamatolenus-Cobboldites-Oryctocara* band (PHCO)

Variable assemblages with both eodiscoid and polymerid trilobite genera around what is traditionally considered the Lower-Middle Cambrian transitional beds are known particularly from Avalonia and Western Gondwana. They have some potential for long distance correlation, although a precise chronocorrelation remains difficult for a number of regions because a deficiency of detailed studies in this interval. Those trilobite taxa include *Cobboldites* spp., *Bathydisculus* spp., *Protolenus* (*Protolenus*) spp., *Latoucheia* (*Latoucheia*) spp., *Hamatolenus* spp., *Acadoparadoxides/Eoparadoxides* spp., *Ovatoryctocara granulata*, and *Clavigellus* spp., known from such regions as Canada (southeastern Newfoundland, New Brunswick), UK (northern Wales and the Welsh Borderlands), Poland (Holy Cross Mountains), Spain (lower Leonian Stage of the Cantabrian Mountains and the Iberian Chains), Morocco (*Cephalopyge notabilis* Zone of the Moroccan Atlas ranges), Turkey, and Siberia. Correlation of these assemblages has been dealt with in a number of recent publications (Geyer, 1990, 1998; Geyer and Palmer, 1995), and the (relatively minor) differences in fine-scale correlation indicate problems related to taxonomic concepts as recently discussed by Geyer (1998).

Assemblages of the *Protolenus-Hamatolenus-Cobboldites-Oryctocara* band occur in both Lower and Middle Cambrian beds, indicating problems with the traditional assignment of the Lower-Middle Cambrian boundary in different regions (Geyer, 1990; Geyer and Palmer, 1995). The traditional concepts of the Lower-Middle Cambrian boundary, separately developed for Baltica (Brögger, 1886) and Laurentia (Walcott, 1891), are not coeval. The first occurrences of *Paradoxides s. l.* and the extinction of olenelloids are each on different stratigraphic levels and differ from region to region (Geyer, 1990, 1993; Geyer and Palmer, 1995).

Base of the *Hebediscus attleborensis-Calodiscus-Serrodiscus-Triangulaspis* band (HCST)

Relatively widespread eodiscoid trilobites mark a band in the upper part of the traditional Early Cambrian. Characteristic species of this assemblage include *Hebediscus attleborensis*, *Calodiscus schucherti*, *Calodiscus helena*, *Calodiscus lobatus* (in strict sense), *Serrodiscus bellimarginatus*, *Triangulaspis vigilans*, and *Triangulaspis annio* (Fletcher, 1972; Robison et al., 1977; Geyer, 1990; Geyer and Palmer, 1995). Most of the species have relatively limited occurrences, but their ranges show some regional overlap and associated taxa permit a subglobal recognition, such as in Baltica (Sweden), Avalonia (southeastern Newfoundland, New Brunswick, Welsh Borderlands), Western Gondwana (Spain, Morocco), Siberia, the Altay-Sayan Mountains, and Kazakhstan. Such assemblages

occur at the top of the *Callavia broeggeri* Zone in southeastern Newfoundland and the *Callavia* Zone in England, the *Sectigena* Zone in Morocco, the top of the *Judomia* and *B. micmaciformis-Erbiella* Zone in Siberia. The relatively limited occurrences reduce the possibility of a sharply defined lower boundary of this assemblage, and additional evaluation is required to allow a precise definition needed for an appropriate stage or series boundary.

At the first occurrence of trilobites (FT)

The first occurrence of trilobites certainly marks an important step in biotic development. However, correlation of this level is a priori difficult for two reasons. First, and logically, the first appearance of trilobites must be diachronous because trilobites originated in a certain region and progressive migration into other regions led not only to differences in the first appearance data (FAD) of trilobites but also to marked provincialism. The few genera and species which have some intercontinental distribution usually have such limited local stratigraphic ranges that their true biozones are poorly recognized (Palmer, 1998). Paleomagnetic investigations as well as chemostratigraphic investigations such as oxygen and carbon isotope studies (e.g., Brasier, 1993; Brasier et al., 1992, 1994) of the Early Cambrian offer data to explain this enigmatic pattern of semi-endemic faunas. Recent paleomagnetic data (Kirschvink et al., 1997) may explain such a pronounced provincialism in the light of unusual rapid plate movements during the early Cambrian.

In addition, the first trilobites appear in many regions in strata that immediately overlie unconformities, which supposedly represent extensive hiatus. Most of these trilobite assemblages are found in facies that suggest nearshore deposition or deposition in an inner detritic belt, and those biofacies are again characterized by endemic polymerid trilobites. Other fossils associated with these assemblages, such as archaeocyaths, molluscs, hyoliths, hyolithelminths, and other small shelly fossils, also have limited occurrences or show strong limitations to certain biofacies types, and thus have limited potential for intercontinental correlation. These facts suggest that a series boundary at the first occurrence of trilobites will be inappropriate because it generally lacks the possibility of global biostratigraphic identification and correlation. Identification by means of physical methods is promising, but cannot yet be taken into consideration.

Subtrilobitic Small Shelly Fossils

Small Shelly Fossils from supposedly earliest Cambrian strata have been extensively studied during the last two decades in such regions as Siberia, South China, Australia, India, Iran, Spain, the Canadian Cordillera, western U.S.A., and Mexico. However, no agreement has been achieved about the possibilities of intercontinental correlation by means of such Small Shelly Fossils. Preliminary examination of mollusk faunas from the Lower-Middle boundary interval suggests some potential for correlation (Geyer, 1986) but careful investigation and additional data are needed to quantify these results. The same is valid for Small Shelly Fossil assemblages from sub-trilobitic Early Cambrian levels. Uncertainties and misconceptions as well as generic oversplitting of SSFs obscure their potential for interregional, and possibly intercontinental, correlation. Especially the diverse SSF assemblages from Siberia and the Yangtze Platform may be used to calibrate paucispecific occurrences from other regions. However, major taxonomic revisions and investigations on the dependency from facies are needed before their value for correlation can be estimated.

The way ahead

The *International Subcommission of Cambrian Stratigraphy* recognizes good potential for global chronocorrelation at certain stratigraphic levels within the Cambrian, whereas other parts of the Cam-

brian (particularly in the Early Cambrian) are, for the moment, devoid of fossil assemblages or physical markers that readily permit a precise and more-or-less equidimensional subdivision of the Cambrian. In our opinion, the best levels for international correlation for the definition of international Middle and Late Cambrian stages and/or series are the FADs of *Triplagnostus gibbus*, *Ptychagnostus punctuosus*, *Lejopyge laevigata*, *Glyptagnostus reticulatus*, *Irvingella-Agnostotes* and *Cordylodus proavus*. The trilobite zones are selected because they belong in well documented biostratigraphic sequences, e.g., *Triplagnostus gibbus* is predated by *Pentagnostus praecurrens* and postdated by *Acidusus atavus*; *Lejopyge laevigata* is predated by *Goniagnostus nathorsti* and succeeded by *Lejopyge sinensis* and in the *Glyptagnostus* lineage; *Glyptagnostus reticulatus* is predated by *G. stolidotus*. In addition, *Ptychagnostus punctuosus* is predated by *P. affinis*, and the occurrence of *Goniagnostus nathorsti* correlates with the upper part of the *Ptychagnostus punctuosus* Zone. The co-occurrence of the early species of *Irvingella*, such as *I. tropica*, with species of *Agnostotes* in a number of regions emphasizes the potential for correlation and also indicates that the index species are postdated by younger species of *Irvingella* such as *I. major* and *I. perfecta*. In contrast, the conodont horizon of *Cordylodus proavus* suggested is at a major faunal turnover although *C. proavus* is part of the *Proconodontus* lineage (Miller, 1984). These suggestions are made in the search for practical solutions for the meaningful subdivision of the Cambrian System.

In order to make progress on the definition of GSSPs for Cambrian stages and series, it is now necessary to arrange a formal ballot of Voting Members of *International Subcommission on Cambrian Stratigraphy* to agree on which of the Middle and Late Cambrian data suggested above are mostly acceptable internationally. The accompanying Chart (Table 1) indicates levels of correlation, which can be achieved at each datum. International Early Cambrian stage nomenclature is likely to remain in abeyance for some time yet, but a start can certainly be made on the later half of the Cambrian. Having agreed, or otherwise, the appropriate biostratigraphic levels, it will then be the task of the *ISCS* to identify suitable sections in which to define GSSPs for stages. It is envisaged that a suite of sections at each selected datum will be submitted to the Voting Members for elimination by formal ballot. Following this, the choice of naming the stages internationally must be addressed. For example, should existing regional names be adopted internationally, or should they be renamed for this important exercise?

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References

- Ahlberg, P., and Ahlgren, J., 1996, Agnostids from the Upper Cambrian of Västergötland, Sweden: *Geologiska Föreningens i Stockholm Förhandlingar* 118, no. 3, pp. 129-140.
- An Tai-xiang 1981. Recent progress in Cambrian and Ordovician conodont biostratigraphy of China: *Geological Society of America Special Paper*, v. 187, pp. 209-225.
- Brasier, M. D., 1993, Towards a carbon isotope stratigraphy of the Cambrian System: potential of the Great Basin succession: in Hallwood, E.A., and Kidd, R. B., eds., *High Resolution Stratigraphy*, Geological Society Special publication, no. 70, pp. 341-350.
- Brasier, M. D., Anderson, M. M., and Corfield, R. M., 1992, Oxygen and carbon isotope stratigraphy of early Cambrian carbonates in southeastern Newfoundland and England: *Geological Magazine*, v.129, pt. 3, pp. 265-279.
- Brasier, M. D., Rozanov, A. Yu., Zhuravlev, A. Yu., Corfield, R. M., and Derry, L. A., 1994, A carbon isotope reference scale for the Lower Cambrian succession in Siberia: report of IGCP Project 303: *Geological Magazine*, v. 131, pt. 6, pp. 767-783.
- Brögger, W. C., 1886, Om alderen af Olenellus-zonen i Nordamerika [On the age of the Olenellus Zone in North America]: *Geologiska Föreningens i Stockholm Förhandlingar*, 101, v. VIII, no. 3, pp. 182-213.
- Chatterton, B. D. E., and Ludvigsen, R., 1998, Upper Steptoean (Upper Cambrian) trilobites from the McKay Group of Southeastern British Columbia, Canada: *Journal of Paleontology*, Memoir 49, 43 pp.
- Cooper, R. A., 1998, Cambrian-Ordovician boundary chosen. *Ordovician News*, no. 15, pp. 9-10.
- Cooper, R. A., and Nowlan, G., 1999, Proposed global stratotype section and point for base of the Ordovician System: Cambrian-Ordovician Boundary Working Group Report, March 1999, 28 pp.
- Fletcher, T. P., 1972, Geology and Lower to Middle Cambrian trilobite faunas of southwest Avalon, Newfoundland. Part Two. Unpubl. Ph. D. thesis, University of Cambridge, 295 pp.
- Geyer, G., 1986, Mittelkambrische Mollusken aus Marokko und Spanien: *Senckenbergiana lethaea*, v. 67, nos. 1/4, pp. 55-118.
- Geyer, G., 1990, Correlation along the Lower/Middle Cambrian boundary—a puzzling story with an elusory end?, in Repina, L. N. and Zhuravlev, A. Yu., eds., *Tretij mezhdunarodnyj simpozium po kembrijskoj sisteme*. Tezisy dokladov, pp. 100-102.
- Geyer, G., 1993, The giant Cambrian trilobites of Morocco: *Beringeria*, no. 8, pp. 71-107.
- Geyer, G., 1998, Intercontinental, trilobite-based correlation of the Moroccan early Middle Cambrian: *Canadian Journal of Earth Sciences*, v. 35, no. 4, pp. 374-401.
- Geyer, G., and Palmer, A. R., 1995, Neltneriidae and Holmiidae (Trilobita) from Morocco and the problem of Early Cambrian intercontinental correlation: *Journal of Paleontology*, v. 69, no. 3, pp. 459-474.
- Henningsmoen, G., 1957, The trilobite family Olenidae, with description of Norwegian material and remarks on the Olenid and Tremadocian Series: *Norske Videnskaps-Akademi i Oslo, Mat.-Naturv. Klasse*, 1957, no. 1, 303 pp.
- Henningsmoen, G., 1958, The Upper Cambrian faunas of Norway; with description of non-olenid invertebrate fossils: *Norsk geologisk Tidsskrift*, v. 38, pp. 179-196.
- Jell, P. A., and Hughes, N. C., 1997, Himalayan Cambrian trilobites: *Special Papers in Palaeontology*, no. 58, 113 pp.
- Kirschvink, J. L., Ripperdan, R. L., and Evans, D. A., 1997, Evidence for a large-scale reorganization of Early Cambrian continental masses by inertial interchange true polar wander: *Science*, v. 277, 25 July 1997, pp. 541-545.
- Kobayashi, T., 1949, The *Glyptagnostus hemera*, the oldest world-instant: *Japanese Journal of Geology and Geography*, v. 21, pp. 1-6.
- Landing, E., 1991, Upper Precambrian through Lower Cambrian of Cape Breton Island: Faunas, paleoenvironments, and stratigraphic revision: *Journal of Paleontology*, v. 65, no. 4, pp. 570-595.
- Landing, E., 1996, Avalon: Insular continent by the latest Precambrian, in Nance, R. D. and Thompson, M. D., eds., *Avalon and Related Peri-Gondwanan Terranes of the Circum-North Atlantic*: Geological Society of America Special Paper 304, pp. 29-63.
- Landing, E. L., Bowring, S. A., Davidek, K. L., Westrop, S. R., Geyer, G., and Heldmaier, W., 1998, Duration of the Early Cambrian: U-Pb ages of volcanic ashes from Avalon and Gondwana: *Canadian Journal of Earth Sciences*, v. 35, no. 4, pp. 329-338.
- Lazarenko, N. P., 1966, Biostratigrafiya i nekotorye novye trilobity verkhnego kembriya Olenekskogo podnyatiya i Kharaulakskikh gor: *Uchenye Zapiski Paleontologiya i Biostratigrafiya*, no. 11, pp. 33-78.
- Ludvigsen, R., and Westrop, S. R., 1985, Three new Upper Cambrian stages for North America: *Geology*, v. 13, pp. 139-143.
- Martin, F., and Dean, W. T., 1988, Middle Cambrian acritarch and trilobite zonation at Manuels River and Random Island, eastern Newfoundland: *Geological Survey of Canada, Bulletin* 381, 91pp.
- Miller, J. F., 1984, Cambrian and earliest Ordovician conodont evolution, biofacies, and provincialism: *Geological Society of America Special Paper*, no. 196, pp. 43-68.

- Moczydlowska, M., 1999, The Lower-Middle Cambrian boundary recognized by acritarchs in Baltica and at the margin of Gondwana: *Bollettino della Società Paleontologica Italiana*, v. 38.
- Öpik, A. A., 1966, The early Upper Cambrian crisis and its correlation: *Journal and Proceedings of the Royal Society of New South Wales*, v. 100, pp. 9-14.
- Öpik, A. A., 1967, The Ordian Stage of the Cambrian and its Australian Metadoxidae: Bureau of Mineral Resources of Australia, Bulletin, no. 92, pp. 133-170.
- Palacios, T., 1993, Acritarchs from the volcanosedimentary group Playon Beds. Lower-Upper Cambrian, Sierra Morena, southern Spain: *Terra Abstracts 5, Abstracts Suppl.*, v. 6: pp. 3.
- Palmer, A. R., 1962, *Glyptagnostus* and associated trilobites in the United States: United States Geological Survey, Professional Paper 374-F, 49 pp.
- Palmer, A. R., 1965, Trilobites of the Late Cambrian Pteroccephaliid Biome in the Great Basin, United States: Geological Survey, Professional Paper 493, 105 pp.
- Palmer, A. R., 1981, On the correlatability of the Grand Cycle Tops, in Taylor, M. E., ed., *Short Papers of the Second International Symposium on the Cambrian System*, Golden 1981, United States Geological Survey, Open-File Report 81-743, pp. 156-159.
- Palmer, A. R., 1998a, A proposed nomenclature for stages and series for the Cambrian of Laurentia: *Canadian Journal of Earth Sciences*, v. 35, no. 4, pp. 323-328.
- Palmer, A. R., 1998b, Why is intercontinental correlation within the Lower Cambrian so difficult? *Revista Española de Paleontología*, No. extr. Homenaje al Prof. Gonzalo Vidal, pp. 17-21.
- Peng Shanchi, and Robison, R. A., 2000, Agnostoid biostratigraphy across the Middle-Upper Cambrian boundary in China: *Journal of Paleontology*, Memoir, v.38, pp.103-107.
- Peng Shanchi, Zhou Zhiyi, and Lin Tianrui, 1998, Late Middle-Late Upper Cambrian chronostratigraphy of China: Fourth Field Conference of the Cambrian Stage Subdivision Working Group, International Subcommission on Cambrian Stratigraphy, Abstracts, p. 20.
- Poletaeva, O. K., and Romanenko, E. V., 1970, Nekotorye trilobity srednego i pozdnego kembriya Altaya: *Paleontologicheskij Zhurnal*, v. 1970, no. 2: pp. 72-83.
- Pratt, B. R., 1992, Trilobites of the Marjuman and Steptoean stages (Upper Cambrian), Rabbitkettle Formation, southern Mackenzie Mountains, northwest Canada: *Palaeontographica Canadiana*, no. 9, 179 pp.
- Reed, F. R. C., 1910, The Cambrian fossils of Spiti: *Memoirs of the geological Survey of India, Palaeontologia Indica*, ser. 15, v. VII, Memoir 1, pp. 1-76.
- Robison, R. A., 1976, Middle Cambrian trilobite biostratigraphy of the Great Basin, in Robison, R. A. and Rowell, A. J., eds., *Brigham Young University Geological Studies*, no. 23, pp. 93-109.
- Robison, R. A., Rosova, A. V., Rowell, A. J., and Fletcher, T. P., 1977, Cambrian boundaries and divisions: *Lethaia*, v. 10, no. 3, pp. 257-262.
- Robison, R. A., and Rowell, A. J., 1976, Subdivisions of the Cambrian System - are traditional boundaries appropriate?: 25th International Geological Congress, Abstracts no. 1, pp. 279-280.
- Rosova, A. V. 1968, Biostratigrafiya i trilobity verkhnego kembriya i nizhnij ordovika severo-vostoka Sibirskoj platformy [Biostratigraphy and trilobites of the Upper Cambrian and Lower Ordovician of the northwestern Siberian Platform]: *Akademiya Nauk SSSR, Sibirsk. otделение, Trudy Institut Geologii i Geofiziki*, no. 36, 196 pp.
- Rowell, A. J., Robison, R. A., and Strickland, D. K., 1982, Aspects of Cambrian agnostoid phylogeny and chronocorrelation: *Journal of Paleontology*, v. 56, no. 1, pp. 161-182.
- Rushton, A. W. A., 1978, Fossils from the Middle-Upper Cambrian transition in the Nuneaton district: *Palaeontology*, v. 21, no. 2, pp. 245-283.
- Shergold, J. H., Laurie, J. R., and Sun Xiaowen, 1990, Classification and review of the trilobite order Agnostida Salter, 1864: an Australian perspective: Bureau Mineral Resources, Geology and Geophysics, Report 296, 92 pp.
- Sundberg, F. A., 1994, *Corynexochida* and *Ptychopariida* (Trilobita, Arthropoda) of the *Ehmaniella* Biozone (Middle Cambrian), Utah and Nevada: *Contributions in Science*, Los Angeles County Museum of Natural History, no. 466, 137 pp.
- Sundberg, F. A., and McCollum, L. B., 1997, *Oryctocephalids* (Corynexochida: Trilobita) of the Lower-Middle Cambrian boundary interval from California and Nevada: *Journal of Paleontology*, v. 71, no. 6, pp. 1065-1090.
- Sundberg, F. A., Yuan Jin-liang, McCollum, L. B., and Zhao Yuan-long, 2000, Correlation of the Lower-Middle Cambrian boundary of South China and Laurentia: *Acta Palaeontologica Sinica*, v. 38, pp.103-107.
- Taylor, K., and Rushton, A. W. A. (with contributions by D. E. Butler, R. Dearnley, J. R. Hawkes, P. M. Howell, and W. H. C. Ramsbottom) 1971, The pre-Westphalian geology of the Warwickshire Coalfield with a description of three boreholes in the Merevale area: *Bulletin of the Geological Survey of Great Britain*, v. 35, VII+152 pp.
- Vanguetaine, M., and Van Looy, J., 1983, Acritarches du Cambrian Moyen de la Vallée de Tacheddirt (Haut-Atlas, maroc) dans le cadre d'une nouvelle zonation du Cambrian: *Annales de la Société géologique de Belgique*, v. 106, 69-85.
- Walcott, Ch. D., 1891, The Fauna of the Lower Cambrian or *Olenellus* Zone: Tenth Annual Report of the United States Geological Survey, Part 1, pp. 509-774.
- Wang Y., 1964, Handbook of index fossils of China, Hunan (South China) Region: Beijing, Science Press, 173 pp.
- Westergård, A. H., 1922, *Sveriges Olenidskiffer: Sveriges Geologiska Undersökning*, ser. Ca, no. 18, 205 pp. (in Swedish with English summary).
- Westergård, A. H., 1946, *Agnostidea of the Middle Cambrian of Sweden: Sveriges Geologiska Undersökning, Årsbok*, v. 40, 140 pp.
- Young, T., Martin, F., Dean, W. T., and Rushton, A. W. A., 1994, Cambrian stratigraphy of St Tudwal's Peninsula, Gwynedd, Northwest Wales: *Geological Magazine*, v. 131, 335-360.
- Yuan Jin-liang, Zhao Yuan-long, Wang Zong-zhe, Zhou Zhen, and Chen Xiao-yuan, 1997, A preliminary study on Lower-Middle Cambrian boundary and trilobite fauna at Balang, Taijian, Guizhou, South China: *Acta Palaeontologica Sinica*, v. 36, no. 4, pp. 494-524 (in Chinese and English).
- Zhao Yuan-long, Yuan Jin-liang, Zhu, Chen Xiao-yuan, Zhou Zhen, and Zhou, 1996, The division of the Lower-Middle Cambrian boundary in China: *Journal of the Guizhou Institute of Technology*, v. 25, no. 4, pp. 15-20.
- Zhuravlev, A. Yu., 1995, Preliminary suggestions on the global Early Cambrian zonation, in Geyer, G. and Landing, E., eds., *MOROCCO '95 - the Lower-Middle Cambrian standard of western Gondwana: Beringeria Special Issue*, no. 2, pp. 147-160.

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