COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

RECORDS:

1966/6

C A M B R I A N

by

A. A. Öpik

15928/65

CAMBRIAN

by

A. A. Öpik

Records 1966/6

CAMBRIAN

by

A.A. Öpik

Records 1966/6

DEFINITION

The name Cambrian in modern usage designates (1) the earliest period of the Palaeozoic Era with the radiometric time interval of 560 - 480 millions of years; (2) the now fossil life of that period; and (3) the biological and (4) inorganic events of that period, such as deposition of sediments, emplacement of igneous rocks, metamorphism, tectonic deformation and erosion of Cambrian and older rocks, movements of the Earth's crust, changes of climate, hydrology, and of the geographic face of the Earth.

The name 'Cambrian System' designates the existing rocks which represent the preserved record of the events of the Period. Rocks of the Cambrian System rest on Precambrian rocks and below rocks of the Ordovician, or of any other of the Prozoic systems.

The stratigraphic nomenclature of the subdivisions of the Cambrian is deficient in internationally accepted names and different standards are used regarding the concepts of Lower and Middle Cambrian. Hence, tables correlating the nomenclature are included here to facilitate the reading of this article and of the literature in general.

HISTORY

Rev. A. Sedgwick in 1835 published the name 'Cambrian group', deriving it from the ancient Latin name of Cambria - the present North Wales - and thought of it as the lowermost division of his new and tripartite 'Cumbrian'. The 'Cumbrian' itself was defined as the strata of Cumberland and North Wales resting below the Silurian System of Murchison.

In 1836, that is only one year after his first contribution, Sedgwick modified his original nomenclature by replacing the name "Cumbrian" by "Cambrian" and the designation Cambrian group of 1835 became "Lower

Cambrian".

The definition, however (sedimentary strata below the Silurian), remained unchanged and implied the necessity of a definition of the Silurian System as well. Murchison regarded his Silurian System as a grand order of life with an appointed span and unfossiliferous strata below it were to him incapable of a scientific interpretation. Sedgwick, however, included in his Cambrian a larger part of Murchison's fossiliferous Lower Silurian - the Ordovician of modern usage. Subsequently the name Cambrian was transferred to a concept completely different from Sedgwick's; still, designations like 'Cambro-Silurian' and 'Cambro-Ordovician' of Scandinavian and German authors are in the spirit of Sedgwick's ideas.

The modern concepts of Cambrian and its subdivision were developed gradually by piecing together evidence from Scandinavia, North America, and Newfoundland, and served afterwards in the interpretation of the sequence of Wales and England.

Trilobites significant in the stratigraphic subdivision of the Cambrian were already known well before Sedgwick and Murchison announced, and named, their systems. In Sweden Wahlenberg (1821) described several species; Brogniart in 1822 established the genera Paradoxides and Agnostus and Dalman in 1827 the genus Olenus. The Olenellus fauna ("Olenus" thompsoni) was described by Hall in 1859 from the United States and placed in the Upper Cambrian, above Paradoxides. Only in 1886 did Brögger discover the true position of the Olenellus Zone below Paradoxides in Norway and suggested the same order for North America. This was confirmed by Walcott in 1888 after a study of the Cambrian sequence in eastern Newfoundland. Finally Walcott (1891) exhaustively summarized the knowledge accumulated in North America and Europe and thus inaugurated the modern conception of the Cambrian and its main subdivisions.

The nomenclature Lower, Middle, and Upper Cambrian was employed by Walcott (1891, p.49) when it was 'necessary to refer to a standard generally known'.

Cambrian epoch, and series nomenclature:

standard and palaeontological designations

General Standard, Walcott, 1891	Palaeontological nomenclature		
	Brogger, 1882-1886	Derived epoch and series names	Subsequent lax usage
Upper Cambrian	Olenus Zone	Olenian	Olenidian, Olenid -
Middle Cambrian	Paradoxides Zone	Paradoxidian	Paradoxididian, Paradoxidid -
Lower Cambrian	Olenellus Zone	Olenellian	Olenellidian, Olenellid -

Cambrian epoch and series nomenclature:

geographic names

Standard (as above)	Walcott, 1891 (modern French usage)	Walcott 1912 (U.S.G.S. usage)	Rejected homonyms and synonyms
Upper Cambrian	"Potsdamian"	St. Croixan	"Saratogan"
Middle Cambrian	Acadian, Dawson 1867	Acadian	"Albertan"
Lower Cambrian	Georgian	Waucoban	"Comleyan"

CAMBRIAN SERIES - EPOCH AND STAGE NAMES OF MODERN USAGE: SUCCESSION AND APPROXIMATE CORRELATION OF SUBDIVISIONS

1. SERIES - EPOCH NAMES	2. SWEDEN	3. BRITAIN	4. NEWFOUND LAND	5. NORTH AMERICA	6. AUSTRALIA	7. U. S. S. R. (SIBERIA)	8. S.-E. ASIA CHINA	9. SERIES - EPOCH NAMES
Upper Cambrian or St Croixan, or Potsdamian	Olenid Series *divided into zones and sub-zones.*	Dolgelly Ffestiniog Maentwrog	*As in Sweden*	Trempealeauan Franconian Dresbachian	*Unnamed stages* Idamean Mindyallan	*Unnamed stages*	Fenghshanian or Yenchouan Changshanian Daizanian Paishanian Kushanian	Upper Cambrian
Middle Cambrian or Acadian or "Alberton"	Paradoxides forchhammeri P. paradoxissimus P. oelandicus	Menevian Solvan	*Unnamed stages*	*Unnamed stages; divided into some six zones*	*Unnamed stages* *Swedish agnostid zones* Xystridura *and* Redlichia beds	Mayan Amgan	Changhsian or Taizuan Hsuchuanian or Tangshihian, or Mapanian	"Middle Cambrian
Pre - Paradoxides Middle Cambrian			Hanfordian (Catadoxides and Protolenus)			Lena stage	Mantuan	Post Olenellus Lower Cambrian and Lower Cambrian
Lower Cambrian or Olenellian or Waucoban or Georgian	Lower Cambrian	Lower Cambrian; 'Caerfai or 'Comleyan' *used only outside Britain*	Lower Cambrian	Upper Olenellus Lower Olenellus	Lower Cambrian	Aldanian (Olenellian)		

REMARKS

Column 2(Sweden): In Norway the Strenuella linnarssoni zone may belong to the Pre-Paradoxides Middle Cambrian.

Column 3 (Britain): Earliest Upper Cambrian is missing; 'Lingula Flags' is an old name of the Upper Cambrian.

Columns 2 and 3: Pre-Paradoxides Middle Cambrian is missing; it is, however, present in Poland (Holy Cross Mountains), Spain, Sardinia and Anti-Atlas, and placed in the Lower Cambrian.

Column 5 (North America): Appalachian, Central Interior and Rocky Mountains scale.

Column 7 (U.S.S.R., Siberia): The Amgan stage begins with Paradoxides pinus, of the upper zone of the Paradoxides oelandicus stage.

Column 8 (S.E. Asia, China): Upper Cambrian correlation is satisfactory; detail correlation of the "Middle Cambrian" is veiled by the indigenous character of the fauna. Only the early Mantuan may grade downward into the Olenellian; Olenellus and its concomitant fauna is absent in S.E. Asia and a break below the Mantuan therefore is postulated here.

NOMENCLATURE OF EPOCHS AND SERIES

The threefold subdivision (lower, middle, and upper) of the Cambrian was invented by Sedgwick; it was dictated by the shortcoming of language rather than scientific considerations. Geographic names were introduced later but the triparte cliché remained unchanged.

The geographic names of the series (epochs) are not accepted universally; even in the United States, as elsewhere, preference is given to Sedgwick's nomenclature: it has the merit of leaving open for inquiry or surmise the positions of the interseries 'boundaries'.

Dogmatic application of geographic nomenclature, however, may lead to typological considerations affecting the original concepts. Cambrian itself is a geographic name, but the concept of that Period cannot be tied to North Wales (and Cumberland); the whole globe is the 'type locality' of the Cambrian System.

'Potsdamian' is derived from Potsdam in the State of New York: St. Croixan from St. Croix River, tributary of the Upper Mississippi; Acadian refers to New Brunswick; Georgian to Georgia in Vermont; Waucoban to Waucoba Springs in northern California; Saratogan to Saratoga in New York; Albertan is derived from the Province of Alberta (Canada), and Comleyan from Comley in Shropshire.

The palaeontological nomenclature attained its modern meaning after the discovery of the superpositional order of the faunal entities - Brögger's Zones. These zones became epochs and series (Olenellian, Paradoxidian and Olenian) with names derived from generic names of the trilobites.

For reasons unknown names derived from families (Olenellid -, Paradoxidid -, and Olenid-series) gained in popularity and the families themselves became somewhat 'definitional' of the epochs. The generic-stratigraphic names are now symbolic only, but their retention is advisable in respect of the original concepts because families are even of a lesser stratigraphic meaning than the genera. So, according to Hupé (1960), in Morocco two species of Kjerulfia (Olenellidae) and several genera of presumed Lower Cambrian trilobites occur in association of early Middle Cambrian species of Paradoxides (Acadoparadoxides) and Öpik (1961) mentions that Protolenidae and Protolenus, disputable protolenids and Paradoxididae (family) are inadequate as criteria in series

(epoch) stratigraphy.

The generic-stratigraphic names were originally designed as 'definitional'; the advance in the knowledge of Cambrian faunas and the modern elaborate taxonomy of trilobites deprived these genera of their definitional power. The opinion, however, prevails, and should be accepted, that Olenellian refers to the genus Olenellus of the modern taxonomy and its extinction marks the end of the Lower Cambrian. Furthermore, Paradoxides does not replace Olenellus immediately in time: quite a long interval supervened, which is discussed below under the heading 'Post-Olenellian and pre-Paradoxidian (Lower? or Middle?) Cambrian'.

Paradoxides in its turn disappeared before the end of the Middle Cambrian, which is fixed by the agnostid Leiopyge laevigata or its contemporaries. Finally, all species of the genus Olenus (in its modern taxonomic meaning) lived in the early Upper Cambrian, but the Olenidae survived even the Lower Ordovician.

BASE OF THE CAMBRIAN

The Lower Cambrian is the earliest epoch of the Cambrian, of the Palaeozoic Era, and of the Prozoic Eon. The theoretical 'Base of the Cambrian' is its lowermost stratum. In the earliest Lower Cambrian began the continuous record of life, especially of animals, capable of being classified in terms of neozoology; these are Porifera, Brachiopoda, Mollusca, Annelida, Arthropoda, and Echinodermata. Species of these phyla existed already before the Cambrian, but, in the absence of shells and skeletal structures, escaped fossilization. At the onset of the Cambrian Period, however, hard parts, as a grade of evolution, became a rapidly developing feature of invertebrates. At the turn of the Eons geochemical changes in the sea inflicted similar physiological changes independently on selections of species of the diverse phyla of invertebrates; the response, of course, was not simultaneous in terms of geological time.

The known materials are silica, phosphate, and calcium-carbonate. Silica was already employed by sponges in the late Precambrian. In early Cambrian phosphate became the material of tests of brachiopods and calcium-carbonate in archaeocyathids and echinoderms. Platysolenites possessed the first known agglutinated test.

It stands to reason that no exactitude can be expected in locating the base of the Cambrian because the lowermost fossils found in a particular section may be not the 'very first' ones; an interval of uncertainty must be accepted, but its duration, undefinable by itself, can be taken as small when compared with the duration of the whole Lower Cambrian Epoch.

LIFE OF THE CAMBRIAN PERIOD

The Cambrian land was, apparently, lifeless; all known fossils are aquatic, marine.

PLANTS

Vascular plants are unknown; lime-secreting algae (Stromatolites, Collenia, etc.) are widespread and constitute occasional small reefs.

ANIMALS

All known Cambrian animals are marine invertebrates.

RADIOLARIA: passed from the Precambrian into the Cambrian.

FORAMINIFERA: are represented by two species of Platysolenites in the Baltic Lower Cambrian.

PORIFERA: sponges are abundant and diversified; their siliceous spicules may constitute siliceous sediments (chert).

PLEOSPONGIA (Archaeocyathida) flourished in the Lower Cambrian and expired during the Middle Cambrian; they represent an extinct phylum not quite interpretable in neobiological terms. They occur aggregated in limestone in biotopes which were occupied later by corals.

COELENTERATA are represented by jellyfishes and graptolite-like Hydroidea; rare and doubtful corals (Cambrotrypa) have been found in North America.

DENDROID GRAPTOLITES (including Dictyonema) are known from the late Upper Cambrian of North America.

BRACHIOPODA

Inarticulate phosphatic forms (Acrotreta, Acrothele, Paterina, Lingulella) are rather common; articulate brachiopods arose in the Lower Cambrian; better known are the Orthoidea Nisusia, Protorthis, Eoorthis and Billingsella, and the Syntrophiacea (Pentameroidea), which gained in significance in Late Cambrian.

MOLLUSCA:

Cephalopoda: (Nautiloidea) were certainly present in the late Cambrian; the Lower Cambrian Volborthella is still queried as a nautiloid.

Pelecypoda: the only published record refers to an occurrence in Spain. Gastropoda: undisputed gastropods are the late Cambrian genera Matherella, Scaevogyra, and related forms, and Bellerophontacea (for example Owenella). Disputable gastropods are Pelagiella and Helcionella and its relatives, whose record starts with the earliest Lower Cambrian. Monoplacophora are rare but appeared early.

Doubtful molluscs are the hyolithids.

ARTHROPODA

The Trilobita dominated the Cambrian faunas and the stratigraphy of the Cambrian is based on trilobites; important are Agnostida, Eodiscida, Olenellacea, Ellipsocephalacea, Ptychopariacea, Paradoxidacea, Redlichiacea, Ptychopariacea, Corynexochida, Dikelocephalacea, and several others.

Crustacea are known only as integuments and their classification is therefore vague; the bivalved Archaeostraca (Bradoriida) started early in the Lower Cambrian and are probably ancestors of Ostracoda. Other arthropods are very rare: Merostomata and Xiphosura (Aglaspida) are known from the Lower Cambrian onward and Walcott discovered in the Burgess shale of British Columbia a unique assemblage of some fifteen genera of several subclasses of the extinct Trilobitoidea; the best known genera are Marella, Sydneyia, Burgessia, and Naraoia. In the same assemblage, Aysheaia represents an extinct order of marine Onychophora.

ECHINODERMATA

Echinoderms are represented in the Cambrian by five classes of which one (Helicoplacoidea) is known only from the Lower Cambrian of California; the Edrioasteroidea arose in the Lower Cambrian and the Eocrinoidea and Carpoidea appeared in the Middle Cambrian. The fifth class - the Holothuroidea - is represented by imperfect material.

PHYLUM INCERTUM

Conodonts occur from the Middle Cambrian onward.

THE SUBDIVISIONS

Lower Cambrian (Olenellian; Georgian, Waucoban; Aldanian, N.P. Suvorova, 1950): Undisputed Lower Cambrian is recognized from the presence of species of the genus Olenellus; the following genera of Olenellidae, on the present state of knowledge, also are diagnostic: Holmia, Callavia, Nevadia, Fremontia, Paedeumias, Elliptocephala, Judomia, Sinskia, and some more; concomitant are, for example, Bonnia, Hebediscus, Pagetides, Weymouthia. The Olenellian fauna is known sufficiently well and may serve, in the absence of diagnostic olenellids, in correlation. It is possible, already, to distinguish an early and a late Olenellian.

Post-Olenellian, pre-Paradoxidian (Lower? or Middle?) Cambrian:
In the literature this division is usually designated as the Protolenus or protolenid zone, Protolenus and Catadoxides zones (in Newfoundland), Hanfordian (in Newfoundland), and Lena stage (N.P. Suvorova, 1950) in Siberia (Yakutia). The reference to Protolenus and Protolenidae as indicated above is of no stratigraphic meaning, and of Catadoxides only one species is known which occurs at a single locality. In Europe the fauna of this division is rather meagre or missing altogether. So, in Sweden a hiatus of undefinable duration separates the Paradoxides celandicus sequence from the Lower Cambrian and in Shropshire (at Comley) the Lower Cambrian was folded and truncated prior to the arrival of the initial Paradoxides - fauna. In North America in the Canadian Rocky Mountains the fauna of Mount White together with the Albertella Zone represent the pre-Paradoxides Middle Cambrian. In Siberia the same interval is represented by the Lena stage, preceded by the Olenellian (Aldanian) and followed by the Amga stage, whose initial fauna indicates a correlation with a later part of the Paradoxides celandicus stage. Nevertheless, the whole Lena stage is placed in the Lower Cambrian. In Northern Australia the Redlichia followed by the Xystridura-bearing beds are post-Olenellian and placed in the Middle Cambrian. It seems, therefore, that the Redlichia sequence of south-east Asia also needs revision as regards its current correlation with the whole of the Olenellian Lower Cambrian. The problem of post-Olenellian Lower Cambrian has been touched in the literature several times. Still, two standards as regards the scales of the Lower Cambrian and Middle Cambrian remain in use, and should be disentagled from the semantics of Sedgwick's tripartition of the Cambrian. It is, however, apparent that a fourth subdivision is in sight, represented by the Hanfordian, or the Lena stage, and by a substantial part of the Redlichia sequences. In his writings the present author adheres to a classic Lower Cambrian which terminates with Olenellus and regards the post-Olenellus, pre-Paradoxides Cambrian as the beginning of Middle Cambrian.

Middle (Paradoxidian) Cambrian:
Scandinavian authors (G. Linnarsson, W.C. Brogger) established in the past century the succession of Paradoxides species-zones which subsequently (with variants) were used in global correlation. Finally, Westergaard (1946) introduced the following stage nomenclature:

C. Paradoxides forchhammeri stage (above)
B. Paradoxides paradoxissimus stage
A. Paradoxides oelandicus stage (below)

These stages represent the Middle Cambrian of Sweden, but not the whole sequence of the epoch. An early part is missing, which in Norway is represented probably by the zone of Strenuella linnarssoni, above the Lower Cambrian (Olenellian) Holmia, and below the Paradoxides oelandicus faunas.

In Newfoundland P. bennetti substitutes for P. celandicus, and in Newfoundland and in Wales equivalents of the P.paradoxissimus stage are the zones of Paradoxides hicksi (below) and P. davidis.

Geographic stage names were formally introduced in Britain by Stubblefield (in Rodgers, 1956): Solvan for "all Middle Cambrian strata older than the P. hicksi Zone" (i.e. for the equivalents of the P. oelandicus stage) and Menevian for strata above it (stages B and C of Westergaard).

Westergaard (1946) also established a sequence of zones based on particular species of Agnostidae and assemblages of agnostids; stratigraphically the most important are the Ptychagnostinae. These zones are recognizable in eastern Canada, in Australia, and in Siberia.

In North America stages have not been introduced as yet, but a scale of zones has been set up. The zones refer to trilobite genera and combinations of genera. Important forms are Albertella, Zacanthoides, Glossopleura, Bathyuriscus, and several genera of Ptychopariidae. In Eastern Asia (China, Manchuria, Korea) diverse scales of stages and zones are in use, in different regions, and by different authors. The fauna is essentially endemic and correlations with the Scandinavian and North American scales are approximate.

In Siberia the Pardoxidian Middle Cambrian is divided into the Amga stage (below) and the Maya stage (above) by F.G. Gurari, 1950; the fauna is partly endemic, and partly Scandinavian; even index species of Westergaard's agnostid zones are present. The Amgan consists of the Paradoxides oelandicus, and the lower half of the P. paradoxissimus stages; the Mayan covers the upper half of the Middle Cambrian.

The Middle Cambrian terminates with the agnostid zone of Leiopyge laevigata; this species occurs in Scandinavia, Siberia, and Australia. In North America Middle Cambrian terminates with the Bolaspidella genus - zone.

Upper Cambrian (St. Croixan):

In Sweden according to Westergaard the Olenid series is a sequence of six zones; the lowermost zone of Agnostus pisiformis is not divisible further. The other five zones are named after genera or combinations of genera of Olenidae and are composite, consisting each of several subzones named after particular genera, or species. Stage names have not been established yet. The Scandinavian scale of zones in a simplified form has been applied also in Britain and Newfoundland.

In Britain three geographically named stages are recognized: Maentwrog Stage, Ffestiniog Stage, and Dolgelly Stage (by Watts, 1929; vide Stubblefield in Rodgers, 1956). The sequence in Britain is less fossiliferous than in Scandinavia.

In Scandinavia the olenid Acerocare ecorne (Angelin) is regarded as marking the end of the Upper Cambrian (and the Cambrian) and is followed immediately by Dictyonema flabelliforme and the Tremadocian - the earliest division of the Ordovician. In America, in Eastern Asia, and in Australia the end of the Upper Cambrian and of the Cambrian in general coincides with the extinction of the trilobites of the families Dikelocephalidae and Saukiidae.

In North America the Croixan is divided into three stages: Dresbachian (below) Franconian, and Trempealeauan (above) as formalized in Howell et al., 1944. The names refer to geographic places in the Upper Mississippi Valley. Olenid trilobites are absent. The lower part of the Dresbachian is characterized by the trilobites Cedaria, Crepicephalus, Tricrepicephalus, and Meteoraspis, and the upper by Aphelaspis, Dunderbergia, and related genera. In the Franconian significant are the trilobites Elvinia, Wilbernia, Idahoia, Irvingella, Conaspis, Taenicephalus, and related forms, and higher up Prosaukia and Ptychaspis. In the Trempealeauan significant are Dikelocephalus, Tellerina, and Calvinella.

The Croixan stages are characterized rather well and are favoured in international correlation.

In China the commonly used stages are Kushanian (below), Changshanian (divisible into a lower Paishanian and an upper Daizanian) and Fengshanian (or Yenchouan) above. The Kushanian is characterized by the Damesellidae (Damesella, Blackwelderia, Stephanocare, Drepanura) and till lately was regarded as the top of the Middle Cambrian. It is, however,

a temporal equivalent of the lower Dresbachian and of the Agnostus pisiformis zone. The Changshanian fauna is quite endemic, the agnostids Homagnostus and Pseudagnostus excepted. In the Fengshanian, Saukiidae are predominant, indicating its correlation with the Trempealeauan and uppermost Franconian.

In U.S.S.R. (Siberia) preference is given to zones, especially where Olenidae are present.

In Australia geographically named stages for the lower part of the Upper Cambrian are Mindyallan (below) and Idamean (above). The Mindyallan corresponds to the Kushanian, the Agnostus pisiformis zone, and the early Dresbachian; the Idamean correlates with the late Dresbachian.

In the Upper Cambrian some trilobites are important in global correlation. These are Glyptagnostus stolidotus (Mindyallan) known in Australia, North America, and Siberia; Glyptagnostus reticulatus (early Idamean, early Aphelaspis zone, early Olenus zone of Scandinavia) - universal; Irvingella - universal; Lotagnostus (late Olenian) - in Europe, Asia, North and South America. Universal also is the genus Pseudagnostus, whose many species range throughout the Upper Cambrian.

CLIMATE

No geological record exists regarding the Cambrian climate and its changes. Terrestrial vegetation is unknown; the bare surface of the land unprotected from erosion by vegetation was a desert in arid as well as in humid regions. The climatic meaning of sediments derived from such land cannot be interpreted unambiguously. Upland icecaps presumably existed, but no general glaciation is evident. Some clues regarding the climate of the globe are evident in the geographic distribution of marine life. For instance, archaeocyathids occur in the Antarctica and in the Arctic, but also in to-days warmer latitudes of all continents (Morocco, Mediterranean Europe, central China, northern and South Australia and Mexico). Hence, reasonably warm water should be assumed in the seas of the Lower Cambrian.

Trilobite species of global distribution indicate also that no prohibitive thermal barriers existed in the oceans. It can be generally concluded that the Cambrian seas were as habitable as the modern seas, and so was the climate of the land. The absence of terrestrial life is a biological rather than a climatic problem.

Places with an arid climate also existed, as testified by saline sequences, as for example in Australia, and rock salt deposits in Western Pakistan (Salt Range), Iran (the Hormuz series), and eastern Siberia.

GEOTECTONIC SETTING

Fossiliferous Cambrian is known from all continents, and occurs in two geotectonic environments: geosynclines and platforms. Cambrian is commonly present in early Palaeozoic geosynclines, which subsequently were folded by the Caledonian and Variscian and even later orogenies. The Cambrian rocks of the platforms are undeformed, or weakly folded and unaffected by metamorphism. The known platform regions are: (1) the mantle of the Baltic Shield east of the Caledonian front with the famous Alum shale sequence of Scandinavia and the Estonian Lower Cambrian plastic Blue Clay, which extends east in the subsurface of the Moscow syneclise; (2) the interior platform of North America, especially the Upper Cambrian of friable sandstone of the Upper Mississippi Valley; (3) the East Siberian Platform with the northern mantle of the Aldan Shield and the periphery of the Anabar Shield; (4) the western mantle of the Arabian Shield at the Dead Sea; and (5) Northern Australia.

TECTONIC AND IGNEOUS ACTIVITY

The known record of orogenetic diastrophisms of the Cambrian Period is a modest one. In Sardinia and in the Iberian Peninsula the tectonic activity culminated in the Upper Cambrian as the Sardic, in Poland (Holy Cross Mountains) as the Sandomir, and in the Altaid chains (southern Siberia) as the Salair diastrophism. In Australia movements are evident in the Lower Cambrian of Queensland and South Australia, in the Upper Cambrian of Tasmania, and in New South Wales north of Broken Hill, where an angular unconformity was recently discovered between early Middle Cambrian and late Upper Cambrian.

Vulcanicity was active in the geosynclines but almost absent on the platforms. In north-west Australia, however, plateau basalts and their remnants, of Lower Cambrian age, occur in a region of some 100,000 square miles.

PALAEOZOOGEOGRAPHY

Walcott (1891) introduced for the North American continent "four principal geographic areas or geologic provinces": (1) the Atlantic Coast, (2) the Appalachian Chain, (3) the Rocky Mountain, and (4) the Interior Continental or Central Province. With the advance of palaeontological knowledge concepts were developed regarding the palaeozoogeography

of the Cambrian of the World. The Pacific faunal realm is represented by the Appalachian, Rocky Mountains, and Interior provinces of North America, and the Atlantic Coast province is a part of the Acado-Baltic realm, which includes also the Paradoxides and Olenid sequences of Europe.

The separation of the Pacific and Acado-Baltic realms around the North Atlantic is rather abrupt and a dividing barrier or ridge (the Caledonian Barrier) has been advocated by C. Schuchert's school as an explanation of the diversity of faunas of these realms. A somewhat similar meridional divide in the early Middle Cambrian has been suggested for Australia. A Cambrian land (whose main mass is Tibet) isolated the Redlichia faunal realm of Iran, Himalaya, and China from the Tien Shan and Siberian seaways, and acted in a similar manner even in the Upper Cambrian. Another explanation based on environmental diversification of faunas on a geotectonic background is favoured by Lochman & Wilson (1958). The multiprovincial Middle and Upper Cambrian faunas of Australia and Siberia, however, are evidence of open seaways and commingling of faunas; the Caledonian Barrier impenetrable in the Atlantic region was not a global, absolute, obstacle: the Acado-Baltic elements are spread in the Siberian province, Olenus reached Korea and Australia, and Paradoxides reached Colombia in South America. The cosmopolitan distribution of the archaeocyathids in the Lower Cambrian and of the agnostids in the Middle and Upper Cambrian is ample evidence against regional confinement of faunas.

Faunal realms, nevertheless, are recognizable in general terms, but no geographic region maintained its 'realm' throughout the whole Period and each realm should be referred to a particular time interval. Furthermore, the geographic meaning of the realms depends on the rank of the characteristic taxa of trilobites.

Some major realms and their temporal succession are outlined below.

LOWER CAMBRIAN

1. Olenellus - North America; Olenellidae - North America, Europe, Siberia, and passing into the Paradoxidian Middle Cambrian in Morocco.

2. Redlichia - pre-Paradoxides Middle Cambrian of Iran, India, south-eastern Asia, and Australia. Representatives of the family Redlichiidae

occur also in the Mediterranean and Siberia.

MIDDLE CAMBRIAN (Paradoxidian)

3. Paradoxides - Europe, Morocco, Asia Minor, Siberia, Atlantic North America; the concomitant agnostids are universal.

4. Oryctocephalidae - North America (Atlantic coast excluded), Argentina, Asia, Australia.

5. Bathyuriscus, Zacanthoides, Glossopleura, Bolaspidella: North America (Atlantic coast excluded).

UPPER CAMBRIAN

6. Damesellidae: eastern Asia, Australia, Sweden, and Siberia; coeval agnostids are universal.

7. Aphelaspididae: N. America, Australia, Korea.

8. Pagodiidae (partly coeval with 7) - South eastern Asia and Australia.

9. Saukiidae: North America (Atlantic coast excluded), south-eastern Asia, Iran, Australia.

This pattern of biogeographic realms, however, is rather incomplete; it can be amplified greatly; for example the early Middle Cambrian ptychopariacean Pardailhania occurs in Eastern Newfoundland ("Andrarina" tenera (Hartt)), Morocco, Portugal, Spain, France, Germany, and Asia Minor.

GEOGRAPHIC DISTRIBUTION

North America: Walcott in 1891 published maps showing the distribution of Cambrian formations in North America and elcuidated it by a "theoretical section close of Cambrian time" across the continent. Subsequent authors continued and amplified these findings. The deposition began in Lower Cambrian in the western (Rocky Mountains), eastern (Appalachian), and Canadian Atlantic maritime provinces, and persisted throughout the whole Period. In the west the Middle Cambrian advanced towards the interior, where land prevailed till the beginning of the Upper Cambrian. In the Upper Cambrian the interior platform itself was inundated and became a sea with islands; the Canadian Shield, however, remained above the water. The thickness of the Cambrian sediments in the western geosyncline is about three miles, and in the Appalachians somewhat less. The upper Cambrian epicontinental deposits in Minnesota and Wisconsin are less than 1000 feet and in Missouri some 2000 feet. The

known southern extension of Lower and Middle Cambrian of the western geosyncline lies in Sonora (north-west Mexico). In Greenland fossiliferous Lower Cambrian is known from the north-east and north (Peary Land) and Lower and Middle Cambrian from the north-west (Inglefield Land and Ellesmere Land). Lower Cambrian is also established in Spitzbergen. The fauna indicates Appalachian - Rocky Mountains affinities.

South America: Cambrian fossils are found in Colombia (Middle Cambrian; even a Paradoxides is present) and in Bolivia. Middle and Upper Cambrian are well represented in the foothills of the Andes in the Province of Mendoza, Argentina. In spite of the Colombian Paradoxides, and agnostids in Mendoza, these faunas have the aspect of the Rocky Mountains province.

Antarctica: Lower Cambrian limestone with archaeocyathids became known in erratics first; recently outcrops were discovered in the Holyoake Range. Craddock and Webers (1964) discovered early Upper Cambrian fossils in the Heritage Range, Ellsworth Mountains. The relatively thin fossiliferous limestone bed occurs near the top of a sequence of some 24,000 feet thick.

EUROPE: The Scandinavian (Norwegian) part of the Caledonian Geosyncline contains an unfossiliferous Cambrian sequence. East of the Caledonian front in Sweden, in the Oslo area, on the islands of Bornholm and Gotland fringing the Baltic Shield, sandstone and shale of Lower Cambrian and the black (Alum-) shales of the Middle and Upper Cambrian were deposited in platform conditions. The thickness of the Cambrian part of the Alum shale in Sania is somewhat less than 100 meters and the Cambrian of the Oslo region is estimated as 120m. thick. The most northern occurrence of Paradoxides is Tana Fiord. East of Gotland only Lower Cambrian - the Blue Clay and almost unconsolidated arenites - was deposited. In Estonia its thickness is about 150 m., increasing to the east toward the Moscow synelise to some 500 m.

In Wales and England some 4000 meters of shale and sandstone were deposited in the British part of the Caledonian geosyncline, whose fauna is essentially the Scandinavian platform fauna of agnostids, olenids, and Paradoxides. In northern Scotland, however, only Lower Cambrian is present, of some 2000 feet of quartzite and dolomite. Unique in Europe, the Scottish Olenellidae have an Appalachian affinity.

In Central Europe Cambrian occurs in numerous disconnected areas; the setting is geosynclinal. The Cambrian of the Ardenne Mountains (essentially in Belgium), is recognized as such from the position of the

sequence below Tremadocian. In Germany fossiliferous Middle Cambrian (with Paradoxides) occurs in Fankenwald and at Doberlug, and fossiliferous Lower Cambrian at Görlitz; in the Holy Cross Mountains in central Poland a relatively complete Cambrian sequence is documented by trilobites of Acado-Baltic character.

In Bohemia the incomplete Middle Cambrian of the isolated syncline of Prague is considered as classic. It is a sequence of shale with Paradoxides and other trilobites. Scandinavian species are, however, absent: the specific composition indicates Mediterranean affinities. The age of the fauna corresponds to late Paradoxides oelandicus and P. paradoxidimus stages in Scandinavian terms.

The Mediterranean geosynclinal Cambrian region in Europe comprises France, Sardinia, and the Iberian Peninsula (Spain).

In Southern France, in the Central Massive (Montagne Noire, Cevennes) the Cambrian sequence comprises some 3,000 meters of sediments. Archaeocyathids are present in the late Lower and early Middle Cambrian; the Middle Cambrian carries a sparse Paradoxides and Pardailhania fauna; Upper Cambrian is not evident. In Normandy and Brittany archaeocyathid-bearing marbles are known.

The Mediterranean Middle Cambrian faunas reached Asia Minor: Pardailhania the Amanos Mountains, and Paradoxides Mardin in Turkey.

In Sardinia Lower Cambrian with archaeocyathids and trilobites (Dolerolenidae) is followed by Paradoxides-bearing beds; this sequence was folded and truncated in the Upper Cambrian.

In Spain (Lotze, 1961) and Portugal Cambrian was deposited in two separate geosynclinal troughs, filled with 4000 - 5000 meters of sediments. The northern trough extends from Galicia, Asturia, and Leon to Sierra de la Demanda and Sierra Moncayo and is complete with the Upper Cambrian. The southern trough, from Elvas in Portugal to the Sierra Morena in Andalusia, was folded in the Upper Cambrian by the Sardic orogeny. The troughs were separated by a platform in central Spain, whose thin sediments were also deformed by the same diastrophism.

In the Lower Cambrian (including the post-Olenellian) archaeocyathids, Dolerolenidae (as in Sardinia), Redlichiacea (as in Morocco), Ellipsocephalidae and Protolenidae, and in the Middle Cambrian the Paradoxides fauna of Mediterranean aspect populated the seaways. The Upper Cambrian of northern Spain has been compared with the 'Lingula Flags' of Britain.

In the Timan Mountains Middle Cambrian trilobites and algal dolomite have been found.

ASIA

Platforms:

Jordan and Arabia: The relatively thin and incomplete sequence of the Dead Sea platform consists of sandstone with some limestone interbeds. It extends south at least to Petra. Its fossils (Kingaspis campbelli and Redlichops (the senior synonym of Wutingaspis of Yunnan and China) indicate a post-Olenellian, pre-Paradoxides age. The Saq sandstone of Saudi Arabia may be the eastern extension of the Dead Sea sequence.

Siberia: East Siberia (Yakutia) displays the largest known area of platform Cambrian; it rests unconformably on Precambrian (Sinian and older) rocks. Its main outcrops are seen on the northern slope of the Aldan, and in the mantle of the Anabar Shields. Best known is the Cambrian of the upper Lena and its tributaries Aldan, Amga, and Maya. The Olenellian (Aldanian) begins with archaeocyathid-bearing limestone and dolomites (which may contain gypsum) in sequence with oil-bearing sandstones; upper Aldanian trilobites indicate a late Olenellian age. Above follows the Lena stage with a prolific fauna of endemic trilobites. It is the post-Olenellian Lower Cambrian; the aspect of the fauna is 'endemic' because in Europe faunas of the same age are rather poor or corresponding strata are missing altogether.

Strata resting on the Lena stage are attributed to the Middle Cambrian, in two stages: Amgan (below), and Mayan. The Amgan begins with a fauna of Oryctocephalidae, Dinesidae, agnostids, and species of Paradoxides, and in the Mayan, Acado-Baltic species of agnostids, Anomocaridae, and Centropleura are conspicuous. The early Upper Cambrian bears an Acado-Baltic and universal fauna and is developed along the southern and eastern fringes of the Anabar region. The rest of the Upper Cambrian is missing, or represented by continental deposits (for example, in the Amphitheatre of Irkutsk, and on the Olenk) with salt and gypsum.

Geosynclines:

Bennett Island in the Arctic Ocean is known by its classic Acado-Baltic Middle Cambrian fauna; the sequence (shale, siltstone, limestone) is some 550 meters thick.

On the Taimyr Peninsula the Cambrian is about 5000 - 5000 m. thick; algal dolomites are rather common. Trilobites of the Lower Cambrian include eodiscids and Olenellidae, and of the Middle a meagre Paradoxides fauna is known.

In Novaya Zemlya fossiliferous Middle Cambrian (with Paradoxides) and Upper Cambrian are present; the Upper Cambrian fauna is largely indigeneous, except for the cosmopolitan Irvingella and agnostids.
In the Ural Cambrian occurs along the whole extent of its ranges. Prominent are limestone and dolomite with algae and archaeocyathids.
In the Caucasus marbles with archaeocyathids and metamorphics with Middle Cambrian trilobites have been recorded.
In Iran Cambrian deposits are widespread. In the foothills along the Persian Gulf effluent Cambrian salt in numerous domes carries to the surface fossiliferous Middle and Upper Cambrian material; on the plateau of Eastern Iran beds with Redlichia occur in the Kuh-i-dinar and Kuh-banan ranges, and Upper Cambrian in Ozbak-kuh. A thick sequence was discovered recently in the Elburz Mountains; its Middle and Upper Cambrian trilobites recall the fauna of the salt domes.
The Altaid Geosyncline (From Kasakhstan to the trans-Baikal region):
In Kasakhstan breaks occur on several levels, indicating a tectonic activity referable to the Salair diastrophism.
In the Salair range (and east of it, in the Kuznetsk-Alatau) the Lower and Middle Cambrian are complete, but most of the Upper Cambrian is missing owing to the Salair diastrophism, which is apparent also in the Western Sayan.
In the Altai Mountains post-Dresbachian Upper Cambrian is unfossiliferous, or even absent. In the Eastern Sayan the sequence is related to that of the Platform; redbeds with salt are common. In Tuva Lower and early Upper Cambrian are well developed; but only a middle part of the Upper Cambrian is fossiliferous.
In the trans-Baikal region, on the Vitim Plateau, Lower Cambrian and early Middle Cambrian are fossiliferous; the rest of the sequence is apparently missing.

In the Altaid geosyncline a northern miogeosynclinal and a predominantly volcanic southern eugeosynclinal belt existed in the Lower Cambrian. In places volcanic activity continued into the Upper Cambrian.
Flora and fauna: In the Altaid geosyncline limestones and dolomites with calcareous algae and archaeocyathids occur in the Lower Cambrian over its whole extent; the abundant and diversified Lower Cambrian trilobites are predominantly Siberian. In the Middle Cambrian the character of the fauna is the same as that of the Siberian Platform, as seen from the agnostids, Paradoxides, Solenopleura, Corynexochus, and the Oryctocephalidae in the earlier part of the sequence. The same is evident in the early Upper Cambrian. In the late Upper Cambrian in Salair an apparently endemic

fauna occurs sprinkled with species of the universal Pseudagnostus and Apatokephalus.

Tien Shan: In the Tien Shan, (unnumbered sites, west of 61, Fig.E, Karatau, and Samarkand region) the sequence is more or less complete. From the eastern Tien Shan (Quruq Tagh Mountains) an Upper Cambrian fauna has been described; some of the trilobite genera (Irvingella, Lotagnostus) are universal. Recently Chinese geologists established the presence of a complete Cambrian sequence in Eastern Tien Shan.

Himalaya: In the Himalayan region well documented Cambrian is known in the Salt Range, north-west Kashmir and Spiti. In the Salt Range Redlichia noetlingi is followed upward by ptychopariid trilobites, in the upper half of a sequence about 1000' thick. Opinions regarding the age of the Redlichia fauna are divided: Lower Cambrian is the popular choice, but early Middle Cambrian has its adherents. The sequence rests on an acid volcanic flow whose age is determined as 530 my., favouring a pre-Paradoxides Middle Cambrian age for the Redlichia noetlingi sequence.

In Spiti, north of the metamorphic core of Himalaya, the sequence starts with Redlichia-bearing beds and ranges into the Upper Cambrian.

In Kashmir only Middle Cambrian is known; there and in Spiti Oryctocephalidae are conspicuous.

South Eastern Asia:

'South-eastern Asia' refers here to the region from Sikhota-Alin (USSR) in the north to the Tarutao Island in Siam; the Cambrian is geosynclinal (Palaeocathaysian geosyncline of Chinese geologists).

Sikhota-Alin: On the west slope of Sikhota-Alin an abundant archaeocyathid fauna is known.

Korea: In North Korea the sequence starts with protolenids followed by Redlichia and Oryctocephalidae, and is topped by limestone with Blackwelderia (early Upper Cambrian, Kushanian). In South Korea the fossiliferous sequence is less complete; notable is the occurrence of Olenus, Glyptagnostus reticulatus, and Irvingella in the early Upper Cambrian.

China: Northern China is a classic Cambrian region. Ch.D. Walcott in 1913 described a multitude of fossils, and was soon followed by Sun Yun-Chu; C.E. Resser and R. Endo took stock of the Cambrian of Manchuria; T. Kobayashi examined critically the trilobites and problems of palaeogeography. A scale of series and stages was also established for the region, based essentially on sections in Shantung and in Chili, east of Peking. The Lower Cambrian (Mantuan; post Olenellus) is distinct by its/ Redlichia fauna;

the Middle Cambrian (Changhsian or Fuchouan) bears a quite endemic fauna of trilobites (Amphoton, Anomocarella, Lisania, Proasaphiscus, Solenoparia, etc.); the Upper Cambrian (Chaumitian) has a more generally recognized stage nomenclature; the stages are (in ascending order) Kushanian, Changshanian and Fengshanian.

In the Kushanian Blackwelderia, Stephanocare, Drepanura, Liostracina are significant; in the Changhashanian Chuangia, Kaolishania; the Fenghshanian, finally, is the domain of Saukiidae and compares well with the Trempealeauan of North America.

Modern Chinese geologists (Lu, 1963) extended research beyond the classic region. Important discoveries have been made in the Khingan Mountains, in Ordos, and in Central China (e.g. Ichang); notable is an Upper Cambrian association of Acado-Baltic Olenidae with Pacific Saukiidae in Anhuei. On the island of Hainan the Middle Cambrian yielded Xystridura - hitherto known only from Australia.

In eastern Yunnan, and at the border with Tonkin, the lower part of the Cambrian sequence with Redlichia, Palaeolenus and Protolenidae deserves special attention - it is assumed to represent the whole of the Lower Cambrian.

In Thailand at the Malaysian border on the Tarutao Island fossiliferous late Upper Cambrian became known recently. The fauna contains trilobites (Saukiidae, Pagodia) of Fenghshanian aspect, but is also strongly reminiscent of Australian faunas.

Australia and New Zealand.

In New Zealand late Middle Cambrian occurs in the north-west of the South Island. The fauna is of an Acado-Baltic and Australian aspect.

In Australia geosynclinal fossiliferous Cambrian deposits occur in South Australia, Tasmania, Victoria, and New South Wales, and platform deposits in Northern Australia. In South Australia some 7 - 8,000 feet belongs to the Lower Cambrian (Olenellian), whose lower calcareous part contains archaeocyathis; it is overlain by about 9000 feet of shale, arenites, dolomite, and limestone attributable to Middle Cambrian; at the base of the sequence a limestone contains Redlichia and Archaeocyathus, but the rest is barren. In the far north of South Australia late Middle Cambrian and early Upper Cambrian sediments and volcanics were penetrated by the Gidgealpa No.1 well some two miles below the surface.

In Tasmania and Victoria thick sequences of Middle and early Upper Cambrian sediments and basic volcanics constitute a geosynclinal unit.

In western New South Wales, in the Mootwingee Range north of Broken Hill, a sequence of all three Cambrian series was discovered recently.

In Northern Australia, in the Cambridge Gulf area, in the MacDonnell Ranges, on the Georgina and the Burke River, deposits of the three series are present but the sequence is interrupted by breaks. In north-west Queensland (Georgina area) and the northern part of Northern Territory (Daly River, Barkly Tableland) Middle Cambrian occupies large areas.

The trilobite fauna is generally interprovincial but with a strong endemic slant. Redlichia is already present in the Lower Cambrian (Olenellian) / South Australia and its diverse species are widespread in the early Middle Cambrian of the North, where species of the Oryctocephalidae and Xystridura follow above it.

In the Middle Cambrian species of Acado-Baltic agnostids occur in the same zonal sequence as in Sweden, and even Centropleura is present in Queensland and Tasmania. The early Upper Cambrian contains also a number of species already known from other continents. The late Upper Cambrian contains a diversified fauna of Saukiidae of North American and Chinese affinities.

Africa:

In Africa a well documented geosynclinal Cambrian sequence estimated at 5,000 meters thick is present in the Moroccan Anti-Atlas. Lower Cambrian, 'post-Olenellus, pre-Paradoxides Cambrian' and Acadian Middle Cambrian are recorded. The fauna is close to that of Spain and Sardinia, and the Paradoxides fauna even to Bohemia. The occurrence of Kingaspis campbelli manifests connexions with the Dead Sea sequence. In western Sahara (Zemmour) phosphatic brachiopods and trilobite fragments (Redlichia?) have been interpreted in terms of a possible connexion with the Salt Range of Pakistan. Cambrian on the available evidence is absent in the rest of the African continent.

Palaeogeographic synopsis

The geographic face of the Earth during the Period was changing continuously within the areas of the present continents. Large parts of South America and Africa, India, and parts of Australia remained land during

the period and North America and Eurasia were covered by fluctuating platform seas and crossed by geosynclinal troughs. In many parts of the world (e.g., East Greenland, Rocky Mountains, Morocco, South Australia) Lower Cambrian is conformable with the late Proterozoic and there is no reason to speak of Lower Cambrian transgressions. In the absence of Lower Cambrian, Middle Cambrian seas transgressed at the Dead Sea, Himalaya, Salt Range, in Tasmania and Victoria, and, apparently, in western South America, but receded in the Baltic and eastern Europe. In the Upper Cambrian a large transgression flooded the central interior of North America, but the sea receded in Greenland, in the Mediterranean, and in north-eastern Asia. It is apparent that compared with the present Cambrian was in general a thalassocratic time, and especially so in the Northern Hemisphere. Oceans acted as seaways facilitating the spreading of Archaeocyathida, agnostids, hyolithids, etc., over the globe.

The relief of the lands is a matter of conjecture: mountains and uplands of basement rocks existed, of course; mountain ranges arose during the Cambrian in the Mediterranean and in Central Asia but were eroded before the Ordovician. In Central Asia, in the Rocky Mountains, in Tasmania and Victoria, and in the Caledonian Europe garlands of volcanic islands delivered sediments into the geosynclinal troughs. Carbonates were precipitated in warm water and salt and gypsum deposited in arid regions in confined basins in Iran, in Salt Range, in Siberia and to a lesser degree in Australia.

BIBLIOGRAPHY

CRADDOCK, C., and WEBERS, G.F., 1964 - Fossils from the Ellsworth Mountains, Antarctica. Nature, 201, 4915, p.174.

GLAESSNER, M.F., 1963 - The dating of the base of the Cambrian. J. geol. Soc. India, 4, 1-11.

GLAESSNER, M.F., 1963 - The base of the Cambrian. J. geol. Soc. Aust. 10 (1), 223-242.

HOWELL, B.F., et al., 1944 - Correlation of the Cambrian formations of North America. Bull. geol. Soc. Amer., vol.55, 993.

HUPE, P., 1960 - See: Report on the Twenty-first Session, International Geological Congress, Norden.

LAIRD, M., and WATERHOUSE, J.B., 1962 - Archaeocyathine limestones of Antarctica. Nature, 194 (4831), 861.

LOCHMAN-BALK, Christina, and WILSON, J.L., 1958 - Cambrian biostratigraphy of North America. J. Paleont., 32 (2), 312-350.

LOTZE, F., 1961 - Das Kambrium Spaniens, Teil 1: Stratigraphie. Akad. Wiss. Liter. Abh. Math. - Naturw. Kl. NR 6.

LU, YEN-HAO, 1960 - Cambrian deposits of China. Acad. sinica, Science Record, N.S., 4 (4), 199-216.

MARKOVSKI, A.P., (Ed.) et al., 1958 - Geological structure of USSR (Russian) 1, 2 & 3. V.S.E.G.E.I., Moscow.

"NORDEN", 1960 - Report of the Twenty-First Session, Norden, 1960 - int. geol. Cong., Copenhagen.

ÖPIK, A.A., 1961 - The geology and palaeontology of the headwaters of the Burke River, Queensland. Bur. Min. Resour. Aust. Bull., 53.

ÖPIK, A.A., 1963 - Early Upper Cambrian fossils from Queensland. Bur. Min. Resour. Aust. Bull., 64.

RASETTI, F., 1951 - Middle Cambrian stratigraphy and faunas of the Canadian Rocky Mountains. Smith., misc. coll., 116 (5).

REPINA, L.N., KHOMENTOVSKI, V.V., SHURAVLEVA, I.T., ROSANOV, A.U., 1964 - Stratigraphy of the Lower Cambrian of the Sayan - Altai region. Acad. sci. U.S.S.R., Siberian branch.

RODGERS, J. et al., 1956 - El Sistema Cambrico, su paleogeographia y el problema de su base, symposium, 1, 2. 20th int. geol. Cong. Mexico - 1961 - Part III (Russian).

VARDABASSO, S., 1956 - La fasa Sarda dell orogenese Caledonica in Sardegna. Geotectonisches Symposium zu Ehren von Hans Stille (Ed. F. Lotze) p.120-129. Stuttgart.

WALCOTT, C.D., 1891 - Correlation papers: Cambrian. U.S.G.S., Bull. 81.

WESTERGAARD, A.H., 1922 - Sveriges olenidskiffer. Avh. sver. geol. Unders. ser. Ca, 1, No.18.

WESTERGAARD, A.H., 1946 - Agnostidea of the Middle Cambrian of Sweden, Avh. sver. geol. Unders. Ser. C, No.477.

WILMARTH, Grace M., 1925 - The geologic time classification of the United States Geological Survey compared with other classifications. U.S.G.S., Bull. 769.

C. J. STUBBLEFIELD

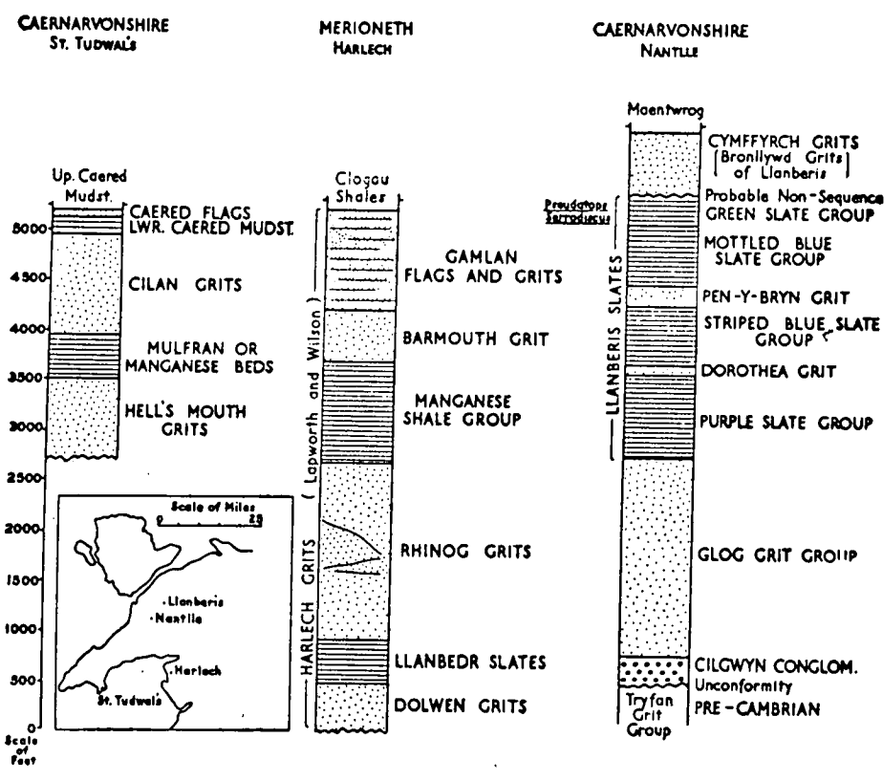

Fig. A. - Sections of earliest Cambrian of North Wales, according to C.J. Stubblefield in Rodgers et al., 1956, p.14, fig.4. The trilobites Pseudatops and Serrodiscus, Nantlle column, Green Slate group, are of a late Lower Cambrian (Olenellian) age. The Gilgwyn conglomerate is the presumed beginning of Cambrian deposition.

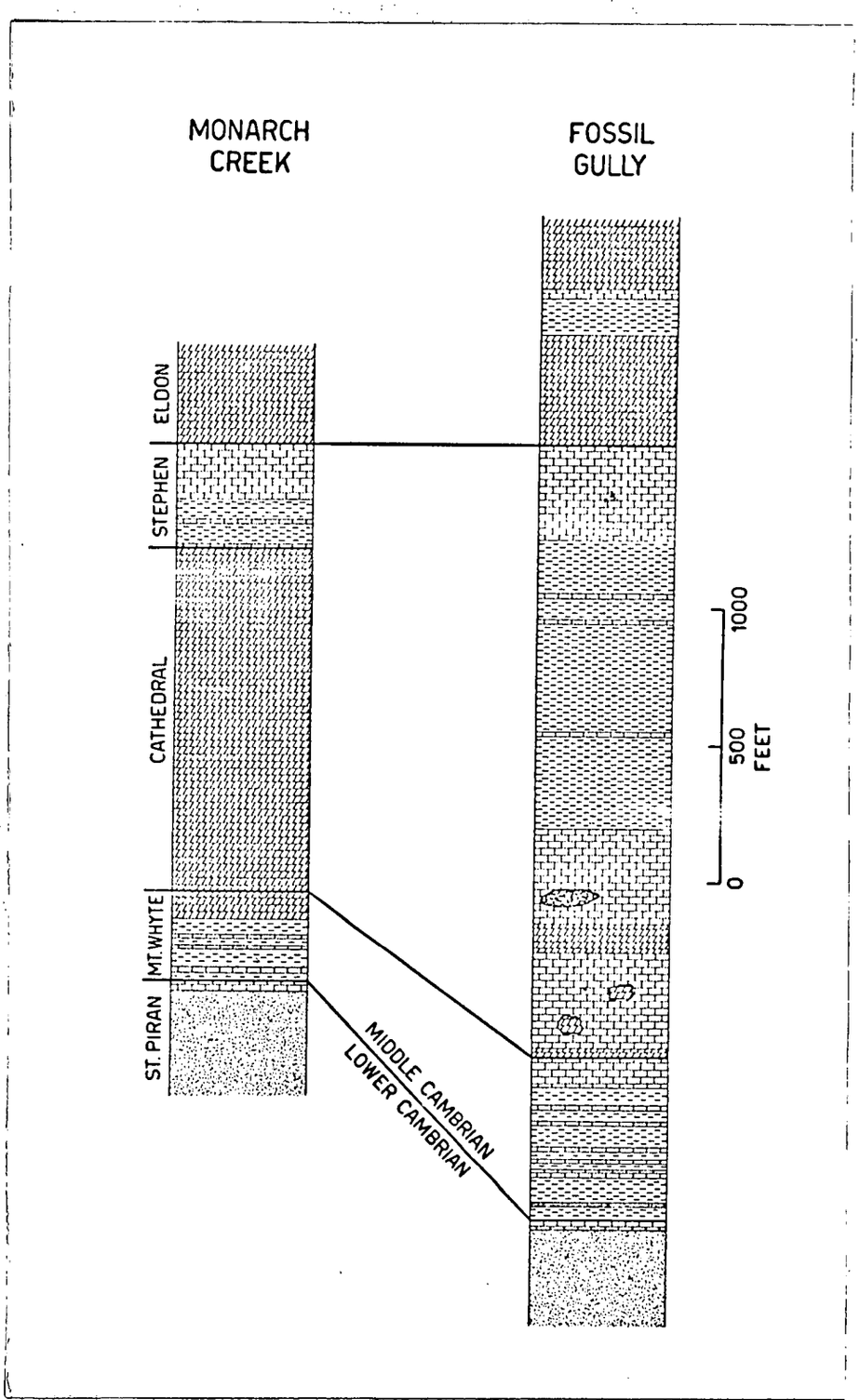

Fig. B. - Lower Cambrian/Middle Cambrian junction in Rocky Mountains, British Columbia. From Rasetti, 1951, p.44., fig.4 (section in the eastern and western parts of Mount Stephen). Last fragments of Olenellus marking the top of Lower Cambrian occur in the limestone bed just above St. Piran sandstone; the Mt. White formation contains the earliest Middle Cambrian fauna and the Cathedral formation of limestone and dolomite contains the Albertella fauna; these two together represent the 'pre-Paradoxides Middle Cambrian'. The Stephen formation and its famous Burgess Shale are approximately contemporaneous with the Paradoxides oelandicus stage.

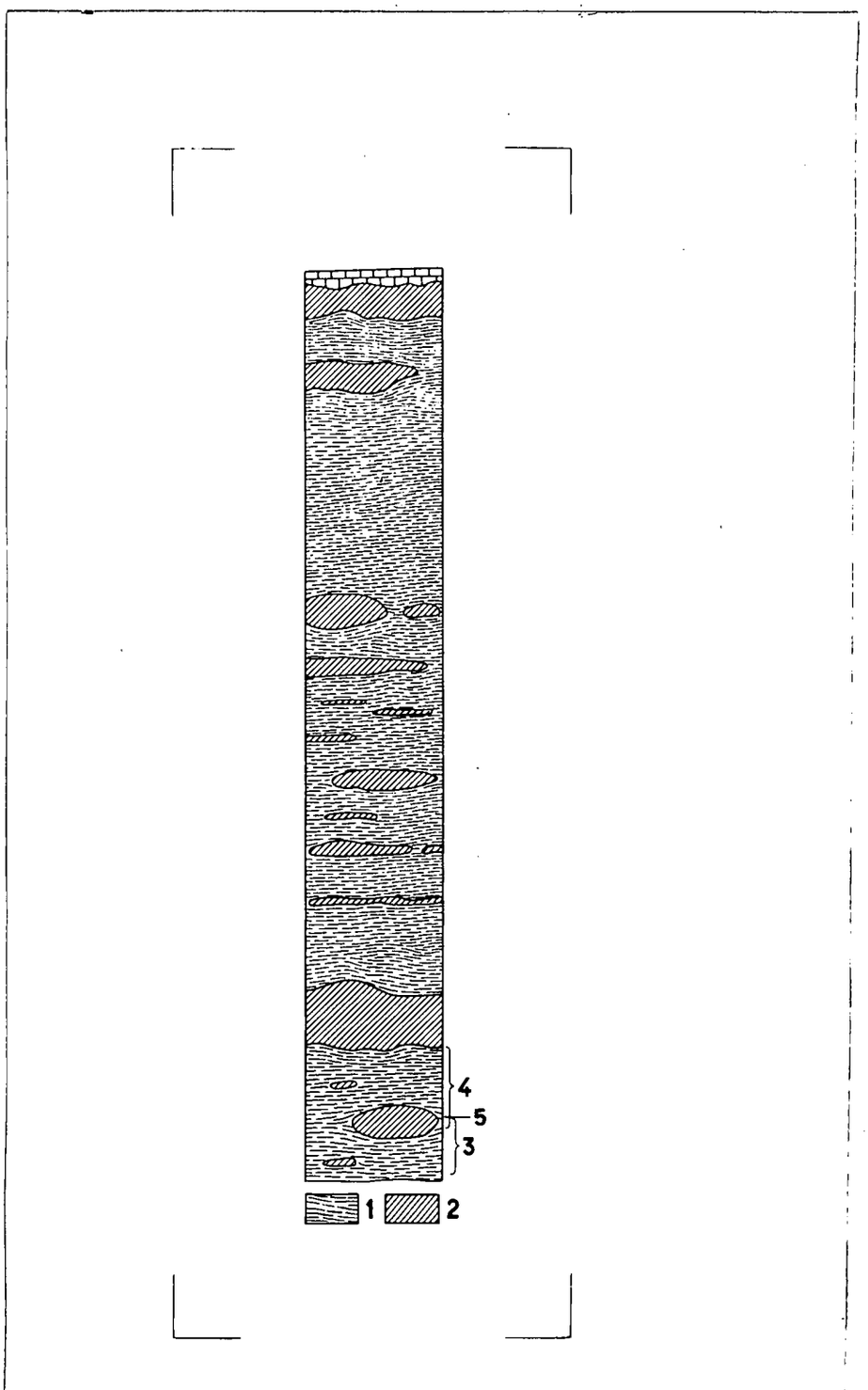

Fig. C. - Upper Cambrian sequence and its junction (below) with Middle Cambrian. Quarry at Odegaarden, Falbygden, Västergötland, Sweden. Westergaard 1922, p.68, fig.33 (simplified). Total thickness 12 meters; top-Ordovician limestone. 1. - Alum shale, bituminous; 2.- Ellipsoids of stinkstone (bituminous limestone); 3.- Top of Middle Cambrian with Leiopyge laevigata; 4.- Initial Upper Cambrian with Agnostus pisiformis; 5. - Overlap of the ranges of L. laevigata and A. pisiformis and inferred position of the series boundary.

Upper Mississippi Valley

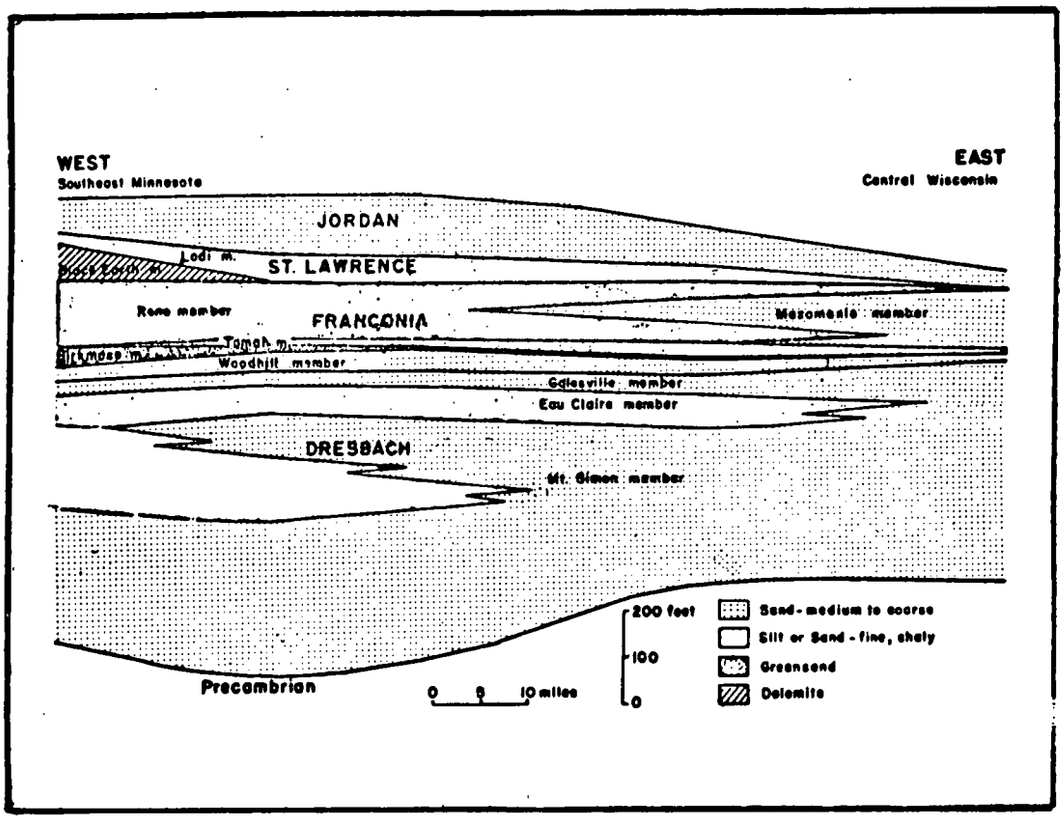

Fig. D. - Section across the Upper Cambrian (St. Croixan), Upper Mississippi Valley; after Bell, Berg and Nelson in Rodgers (1956, p.421). Jordan and St. Lawrence are the strata of the Trempealeauan stage.

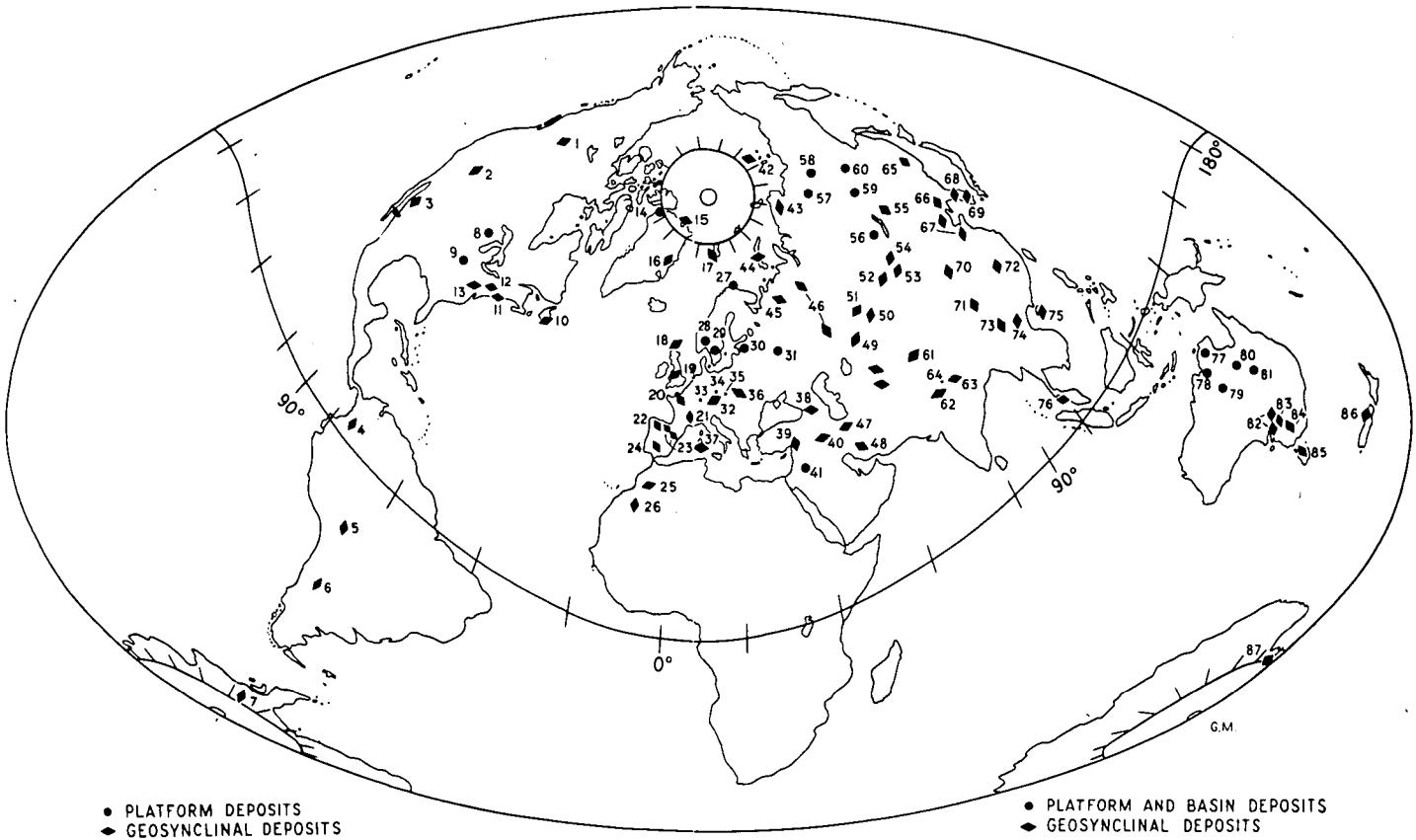
90°
0°
90°
180°
G.M.
• PLATFORM DEPOSITS
◆ GEOSYNCLINAL DEPOSITS
• PLATFORM AND BASIN DEPOSITS
◆ GEOSYNCLINAL DEPOSITS

Fig. E.

Principal occurrences of fossiliferous Cambrian rocks - a selection.

1. Burgess Pass, British Columbia
2. Waucoba Springs, North California
3. Sonora
4. Colombia
5. Bolivia
6. Mendoza
7. Heritage Range, Antarctica
8. St. Croix Valley, Minnesota, Wisconsin
9. Missouri
10. Eastern Newfoundland
11. Massachusetts
12. Georgia in Vermont
13. Appalachian Mountains
14. North-West Greenland, Ellesmere Land
15. Northern Greenland
16. East Greenland
17. Svalbard (Spitzbergen)
18. North Scotland
19. Wales and other British areas
20. Brittany and Normandy
21. Montague Noire, Southern France
22. Asturia, Galicia, Leon
23. Sierra de la Demanda and Sierra Moncayo
24. Andalusia (Sierra Morena) and Elvas in Portugal
25. Anti-Atlas
26. Zemmour, north-western Sahara
27. Tana Fjord, Norway
28. Oslo region
29. Scania in Sweden
30. Estonia
31. Moscow syneclise
32. Bohemia
33. Frankenwald
34. Doberlug
35. Görlitz
36. Holy Cross Mountains, Poland
37. Sardinia
38. Caucasus
39. Ammanos Mountains
40. Mersin in Turkey
41. Dead Sea
42. Bennett Island (Arctic Sea)
43. Taimyr Peninsula
44. Nova Zemlya
45. Timan Mountains
46. Northern and southern Ural
47. Elburz Mountains
48. Iran, foothills at Persian Gulf, and Eastern Iran
49. Kasakhstan
50. Altai Mountains
51. Salair
52. Western Sayan
53. Tuva
54. Eastern Sayan
55. Trans-Baikal, Vitim Plateau
56. Amphitheater of Irkutsk
57. and 58. Flanks of the Anabar shield
59. Olekma River, and
60. Upper Lena, north slope of Aldan shield
61. Eastern Tien Shan
62. Salt Range in Pakistan
63. Spiti, India
64. Kashmir
65. Sikhota-Alin
66. Manchuria
67. Shantung
68. Northern Korea
69. South Korea
70. Ordos
71. Ichang
72. Anhuei
73. Eastern Yunnan
74. Tonkin/China border
75. Hainan Island
76. Tarutac Island
77. Daly River area
78. Cambridge Gulf Area
79. MacDonnell Ranges
80. Barkly Tableland; Georgina River area
81. Burke River Area
82. South Australia (Adelaide Geosyncline)
83. Mootwingee Range in New South Wales
84. Victoria
85. Tasmania
86. New Zealand
87. Holyoake Range, Antarctica

To note, basins are developed in the Siberian, and Australian platform areas of the Cambrian.

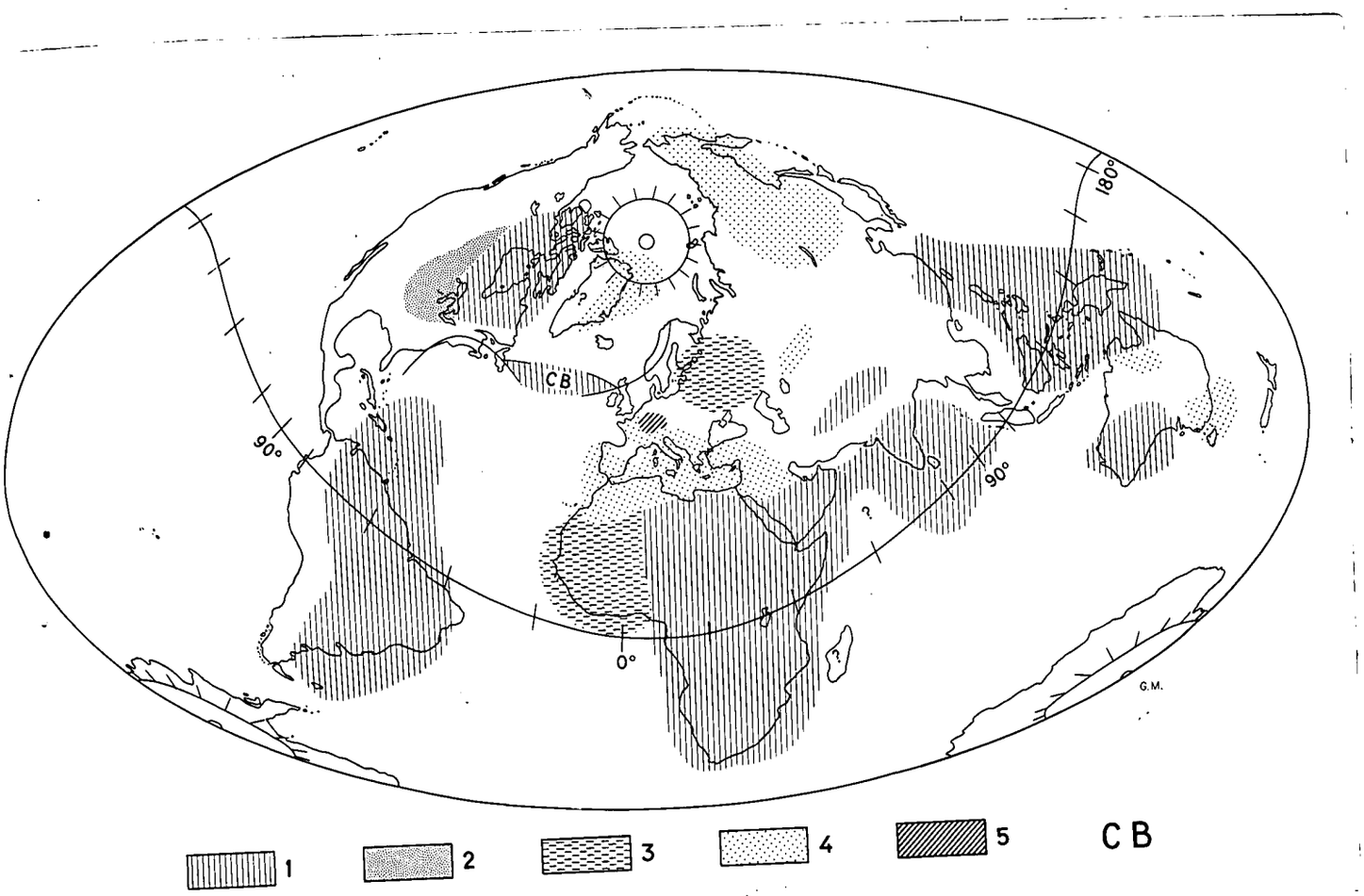

Fig. F. - Cambrian palaeogeography. 1.- Land during the whole of the Period; 2.- Land during Lower and Middle Cambrian; innundation in Upper Cambrian; 3.- Land in Middle and Upper Cambrian; In Spain, Sardinia, Central Asia and Australia - orogenic movements. 5.- Land in Lower and Upper Cambrian; transient innundation in Middle Cambrian; C.B. - Caledonian Barrier. Within the ocean (white) lands and large islands may have existed of which, however, no evidence yet is available. The reference to epochs is approximate: for example, in eastern Siberia and Australia the Upper Cambrian lands developed after the early part of that epoch. Outlines of the lands are indefinite because in most cases the positions of shores are unknown; and where known - the shore lines changed their positions rapidly as compared with the duration of an epoch.