DISTRIBUTION AND SEQUENCE OF SILURIAN CORAL FAUNAS.

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ABSTRACT.

After a review of the Silurian coral faunas of the different continents, in which intra- and intercontinental correlations are made (with reference to the graptolite zonal sequence where possible), it is concluded that Silurian coral faunas were in general cosmopolitan as to genera; weak evidence of zoogeographical (generic) provinces is seen only in Asio-Australian and in North American seas. The fauna had its origins in the uppermost Ordovician, gradually increased in number of genera during the Lower Llandovery, then so rapidly increased as to give an evolutionary ‘burst’ during the Upper Llandovery and at the beginning of the Wenlock; thereafter this evolutionary vigour rapidly decreased into the basal Devonian, with gradual extinction of the characteristically Silurian families and genera. The development of rich coral-stromatoporoid-algal reefs in northern latitudes between 50° and 70° N. suggests to the author that at least the northern Silurian oceans were warmer than those of today. The rarity or absence of Silurian corals in S.W. Europe, S. America, Africa, Antarctica and New Zealand is remarked.

I. INTRODUCTION.

The beginning of the Silurian is taken in this review at that point in time represented by the base of the Glyptograptus persculptus zone of the Valentinian graptolite sequence, and the base of the brachiopod zone with Sowerbyella precursor, S. gracilis, S. tricostata and Whitfieldella angustifrons, which presumably lies at the base of the Lower Llandovery sediments of Wales (Evans and Stubblesfield, 1929). The best known sequence where corals are developed across the Ordovician–Silurian boundary is in Estonia, and here the Porkuni horizon (F₂=Borkholm Beds) is now correlated (Jaanusson, 1956; Martna, 1957) with the Dalmanitina beds of Sweden (and with 5b of Norway), the Dalmanitina beds (Jones, 1949) apparently being correlatable with Welsh Upper Ordovician beds (see also Magnusson, 1958). The view that 5b and its Scandinavian correlatives were to be equated with the basal Llandovery was however held by many, and I subscribed to it in my 1951 essay on the Ordovician coral faunas; the Porkuni horizon of Estonia (Borkholm Beds=F₂ and the nearly equivalent 5b) is indeed still regarded in Russia and in Estonia as basal Silurian, though here now considered Upper Ordovician. Its fauna, now being described (Kaljo, 1956, 1957, 1958; Sokolov, 1951, 1955), is predominantly Ordovician in type. The Rugosa are still dominated by non-dissepsimented streptelasmids, Brachyelasma, Streptelasma, “Lindstroemia”, “Sclerophyllum”, “Kodonophyllum” rhizobolon (Dybowski); but rare solitary tryplasmids (Neotryplasma Kaljo, 1957) continue from the Lyckholm beds and are joined by the first fasciculate species of Tryplasma, T. tubulus (Dybowski). The first dissepsiments known in the Columnarina are seen in the earliest Strombodes species (middendorfi Dybowski), and these are the large, lonsdaleoid type characteristic of the suborder. The earliest ‘normal’ type dissepsiments, characteristic of the Streptelasmatina, small and formed in the loculi between major and minor septa only, are seen in the probably streptelasmid species “Pilophyllum” porosum Kaljo (1958), but only sporadically. The aberrant Calostylis (with retiform septa), fairly common in and characteristic of the Silurian, enters herein. In 5b of Norway (Scheffen, 1933) the columnellate, non-dissepsimented streptelasmatinid Dalmanophyllum (“Lindstroemia” and “Tyria”) appears, with the insufficiently figured “Stegophyllum”. 
Of the Tabulata several characteristically Ordovician genera occur in, but not above, the Porkuni horizon. These include *Sarcinula* (the last of the syringophyllids), *Rhabdotetradium* Sokolov (1955), the last of the tetradiids, and *Proheliolites*, while *Palaeoporites* is known within it only. *Propora* and *Stelliporella* continue through it. *Paleofavosites* is joined by *Mesofavosites* Sokolov with pores appearing mid-wall as well as at angles, and by the first *Multisolena*; this represents the beginning of the great favositid development that becomes so characteristic of the Silurian. In Norway *Calapoecia* is found in 5b, but does not continue above it.

The Porkuni horizon thus contains a fauna that is in many respects a transition fauna between Ordovician and Silurian; many "Silurian" characteristics have already appeared in it, albeit rarely, while many Ordovician genera become extinct within it.

The end of the Silurian is taken herein as at the top of the Upper Ludlow and the base of the Ludlow Bone Bed in Britain, and at the base of the Gedinnian of N.W. Europe, though suggestions have been made (Schouppé, 1954a, 1954c) that the Gedinnian is but a facies of the uppermost Ludlow.

The Ordovician coral faunas (Hill, 1951) from which the Silurian fauna must have evolved, were characterised by non-dissepimented Rugosa, though all three suborders of Rugosa were present—*Streptelasma*, *Columnariina* and *Cystiphyllina*, and by the presence of all six superfamilies of Tabulata, the *Syringophyllidae*, *Tetradiinae* and *Palaeoporitinae* not continuing beyond the Ordovician.

Compared with the Ordovician corals, the Silurian corals are striking because of the overwhelming development of dissepimented genera in all three suborders of the Rugosa and in the appearance of important subfamilies of Favositidae like the *Alveolitinae*, the *Thamnoporininae*, and the *Theciinae*.

Four general works are indispensable in the study of Palaeozoic corals—Lang, Smith and Thomas (1940), Bassler (1950), Sokolov (1955) and Hill, and Hill and Stumm in Moore (1956). The systematic classification used herein is that of the last mentioned work, amended to profit by Russian and other work not available when it was being written.

The attempt will be made throughout this review to indicate the equivalence in time of the coral faunas with the successive graptolite zones.

Knowledge of corals is insufficient as yet to enable species to be used in palaeogeographic discussion or inter-continental correlation, and this review therefore concerns itself with genera or subgenera only.

II. CORAL FAUNAL SEQUENCES IN THE CONTINENTS.

**Europe**

The Silurian here is now commonly divided into the stages Llandoveryian (=Valentian), Wenlockian and Ludlovian, the first seemingly occupying a much longer period of time than the others.

Lower (and Middle) Llandoveryian strata contain the successive graptolite zones of *Cephalograptus acuminatus*, *Orthograptus vesiculosus*, *Monograptus cyphus*, *M. fimbriatus*, *M. triangulatus*, *M. argenteus* and *M. convolutus*. Graptolites of the lowest Valentian zone, *Glyplograptus persculptus*, appear not to have been recognised in early Llandovery strata in Wales.

In Great Britain the early Silurian was poorly coralliferous. The Mulloch Hill beds of Girvan, Scotland, which are possibly of the zone of *Cephalograptus acuminatus*, contain only small solitary non-dissepimented Rugosa, *Streptelasma* and the columnellate *Dalmanophyllum subduplicatum* (McCoy), with the tabulatans *Paleofavosites*, *Pinacopora* (=*Propora*) and *Heliolites*. At Llandovery in Wales *Calostylis* occurs also. No corals as old as these are known in Gotland, and in
Norway 7₁ and 7₂ are very poor in corals. In Estonia the Juuru horizon (=G₁-Jorden) is probably Lower Llandovery, and contains (Kaljo, 1956, 1958, Orvik, 1958 and Dybowski, 1873-4) Palaeohalsites and the small solitary non-dissepimented rugosa Brachyelasma, Pycnactis, Rhegmaphyllum and "Sclerophyllum", with the dissepimented Paliphyllum soshkince. This last genus, with a wide normal dissepimentarium, includes the species Cyathophyllum kjerulfi Kiaer (1932) from the Kalstad limestone of Norway, which is probably not younger than Middle Ordovician, and which has the oldest known dissepiments. Paliphyllum is common in the Upper Ordovician Upper Stolbo group of the Stony Tunguska in Siberia. The systematic position of the species at present included in the genus is doubtful.

The Upper Llandoveryan includes the graptolite zones Monograptus sedgwicki, M. turriculatus, M. crispus, M. griestonensis and M. crenulatus.

In Great Britain Upper Llandovery corals are found in the Pentamerus beds and Purple shales of Shropshire (Smith, 1930) and are possibly of the M. turriculatus zone. They include the small, solitary non-dissepimented Rhegmaphyllum whittardi (Smith) and Streptelasma aranea, and the non-dissepimented lykophyllinids Pycnactis crassiseptata (Smith) and Pycnactis (Onychophyllum), dissepimented and large Phaulactis, the phaceloid Petrozium, the cystiphyllinids Palaeocyclus, Rhabdocyclus, Cantrillia and Cystiphyllum and the aberrant Calostylis, with the tabulatans Paleofavosites, Favosites, Heliolites and Halysites. Probably none of the Gotland corals is as old as this, but the Estonian G₁ Tamsal horizon (=Pentamerus borealis or oblongus beds), which contains bioherms, may be equivalent or even a little older. It contains Brachyelasma, Rhegmaphyllum whittardi, "Sclerophyllum", the lykophyllinids Pycnactis crassiseptata and Phaulactis (Cyathactis), with Petrozium, Paliphyllum and a species like Paliphyllum but which Kaljo (1956, 1958) refers to Pliophyllum Wedekind, and Schlotheimophyllum, with the columnarine Cyathophyloides. Tabulata (Sokolov, 1955 and Orvik, 1958) include Protaraea, Propora, Paleofavosites, Mesofavosites and Halysites and doubtless others described in Sokolov (1951) which I have not seen. The G₁ (Zone 5) Raikull horizon of Estonia has a similar but less rich rugosan fauna, with "Sclerophyllum", Paliphyllum, Petrozium (ex. Donacophyllum), Strombodes and Cyathophyloides, with Favosites amongst others. It also has bioherms and would seem to be early Upper Llandovery.

The most striking feature of these early Upper Llandovery faunas is the richness in lykophyllinids, a feature that is continued in all later Silurian faunas.

In the later Upper Llandovery fauna we have a widely occurring rich and distinctive unit, whose upper and lower limits are still not precisely defined in relation to graptolite zones. This is the fauna of Arachnophyllum, Palaeocyclus, Dinophyllum, Dalmanophyllum and Schlotheimophyllum.

The H (Zone 6) or Pentamerus estonicus Adavere horizon of Estonia contains Arachnophyllum, Calostylis and Favosites; it has been correlated by some with Pentamerus oblongus or 7₁₃ beds of Norway. It may correlate with the Red or Arachnophyllum layer of Gotland that occurs below low water mark along the N.W. shoreline, and that has yielded according to Lindström the colonial rugosan Arachnophyllum, the solitary Dinophyllum with the vortical axial structure, and the prismatic Goniophyllum pyramidale, Favosites and a great richness in heliolitids of the genera Heliolites, Stelliporella, Cosmiolithus, Plasmopora and Propora. The lower Visby marls (Stricklandia marls=Horizon I of Hedström and b of Lindström) above the Red layer contain an even richer fauna, with in addition to the above genera Palaeocyclus,* the small button-shaped coral that seems particularly useful as an index fossil for the Upper Llandovery, Rhabdo-
and numerous small solitary Tryplasma, Cystiphyllum and the endemic and prismatic Arceopoma, numerous lykophyllinids and an early Kyphophyllum, Calostylis, and the additional tabulatans Paleofavosites, Alveolites, Syringolites, Halysites and the endemic heliolitid Pycnolithus. In the Upper Visby marls (about 20 metres thick) the Upper Llandovery graptolite M. spiralis occurs (Hede, 1942), indicating a horizon somewhere over the range M. crispus zone to M. crenulatus zone, possibly as late as the crenulatus zone (Waern, 1948); the fauna is very similar to that of the Lower Visby marl, but Palaeocyclus disappears and Schlotheimophyllum patellatum, Polyorophe, Holohyphrigma calcicoloïdes, "Zaphrentis" vortex, omphymoids (doubtfully Spongophyllinae, d), and Hedströmo-phylum are new rugosan entries that seem to indicate a late subfauna within this late Upper Llandovery fauna. New tabulatan entries are the branching favositids Striatopora and Pachypora, and the massive favositid Angopora with Planalveolites. Some small reefs occur in the Upper Visby marls.

Thus in Gotland this Upper Llandovery fauna appears on present evidence to be divisible into three: the oldest with Arachnophyllum, Ooniophyllum and Dinophyllum; the second with these, and Palaeocyclus and Arceopoma; the third with all these except Palaeocyclus, and with in addition Schlotheimophyllum, Polyorophe and Holohyphrigma.

We are unfortunately without any modern monographic treatment of the Gotland corals; interpretations of the stratigraphy have varied much in the past, and in the above lists I have taken all figured Gotland corals and tried to place them correctly in the stratigraphic sequence worked out by Hede (1942).

If the Upper Llandovery-Wenlock boundary lies between the Upper Visby marls and the Hogklint group, the early Wenlockian can be said to be distinguished by the entry of Acervularia and the (local) absence of Arceopoma, Goniophyllum, Schlotheimophyllum, Holohyphrigma and Dinophyllum.

In Great Britain the "Coralliferous Series" of Wooltack Park and Marloes Bay in Pembrokeshire contains a rich fauna (Hill MS.) that seems to correlate perfectly with the Lower Visby marls, containing as it does the brachiopod Stricklandia lirata and the corals Palaeocyclus, Dinophyllum, Dalmanophyllum, Rho-maphyllum, ? Brachyclasma, Calostylis, the lykophyllinids Pycnactis and Phaulactis, the cystiphyllines Rhabdocyclus, Tryplasma, Cystiphyllum, and the tabulatans Favosites, Alveolites, Multisolenia, Heliolites, Propora and Halysites. It also is therefore probably within the range M. crispus zone to M. crenulatus zone.

This Pembrokeshire fauna may thus be very slightly older than the Herefordshire fauna of the Petaloeverus Band and the 80 feet of beds overlying it in the Herefordshire area, which correlates well with the third Gotland subfauna, that of the Upper Visby marks. This Herefordshire fauna (Hill MS.) consists of Goniophyllum pyramidale, Dalmanophyllum, Schlotheimophyllum patellatum, Pycnactis, Phaulactis, Streptelasma (?Rhegphyllum) roemeri, Rhabdocyclus, Tryplasma, Cystiphyllum, ? Polyorophe, Calostylis, Syringaxon and the tabulatans Favosites, Paleofavosites, Alveolites, Angopora, Thecia, Heliolites, Propora, ? Paeckelmannopora and Halysites. If we accept the evidence of M. spiralis in the Upper Visby marls and the above correlation, these beds in Herefordshire should still be Upper Llandovery. Whether the Woolhope limestone is distinguishable by its coral fauna from these 80 feet of strata remains to be shown. It is traditionally regarded as basal Wenlockian and is now commonly correlated with the Hogklint group.

The full sequence of WENLOCKIAN graptolite zones in Wales is Cyrtograptus murchisoni, Monograptus riccartonensis, M. symmetricus, M. linnarssoni, C. rigidus and C. lundgreni, but some of these are missing in Shropshire (Whittard, 1952).
In Gotland the Hogklint reefal group may be basal Wenlockian; *Dalmanophyllum* and *Polyorophe* are prominent early, *Hedstromophyllum* becomes important and *Zelophyllum* is restricted to it. *Acervularia* appears nearly everywhere, and early solitary *Kodonophyllum* and *Pseudomphyma* enter. Notable absences, so far as illustrations in the literature show, are *Arceopoma*, *Goniophyllum* and *Schlotheimophyllum*, and probably also *Holophragma* and *Dinophyllum*, but lykophyllinids continue as does *Kyphophyllum*. ‘Zaphrentis’ vortex is replaced by *Rhegmaphyllum conulus* (Lm). Changes in the tabulatan fauna are the entry of *Nodulipora*, *Thecia* and *Diploepora*. *Xiphelasma*, the dissepimented and cerioid tryplasmid, must have been collected from one of the three Upper Llandovery formations or the Hogklint reefal group, since it is recorded as from Visby, and Ma (1956) records *Pseudolindstroemia* and *Stortophyllum* from Visby.

The Slite group of marls and limestones is certainly Wenlockian, older than the zone of *Cyrtograptus lundgreni* on the graptolite evidence (Hede, 1942). It contains the same *Eugose* genera listed below for the British Wenlock shale, with additional records of *Pseudomphyma*, *Hedstromophyllum*, lykophyllinids, *Rhegmaphyllum*, *Helminthidium*, *Circophyllum*, *Stauria* and the endemic *Rhytidiophyllum*. Amongst the Tabulata *Thecia* and *Diploepora* are notable.

A Lower Wenlockian coral fauna in Great Britain is, if traditional correlations are correct, that of the Woolhope limestone of Herefordshire; but this requires restudy, to separate its species from those of the *Petalocorinusa* bed and the succeeding 80 feet of strata, as mentioned above. The Wenlock Shale coral fauna so far known from Great Britain is mainly that of the uppermost parts of the Shale, the Tickwood Beds of Shropshire and the beds immediately below the Wenlock Limestone in the Midlands. Perhaps the most important feature is the appearance of the phaceloid *Entelophyllum*, but *Acervularia*, *Spongophylloides*, 'Omphyma', *Pyenactis*, *Phaulactis* and *Plasmophyllum*, *Syringaxon*, *Strombodes*, *Calostylis*, *Tryplasma*, *Rhabdoecylus*, *Cystiphyllum* and many Tabulata occur.

The Lower Oesel (J) beds of Estonia, traditionally regarded as a Wenlock equivalent, contain no graptolites and their Rugosa have not been revised since their original descriptions by Dybowski (1873–1874), whose figures permit doubtful identifications of *Rhabdoecylus*, *Schlotheimophyllum*, *Cystiphyllum*, lykophyllinids and *Pseudomphyma* (or *Mucophyllum*). Twenhofel (1916) listed *Palaecycalus*, and if this is correct this fauna could well be Upper Llandovery rather than Wenlock. The beds are now divided into the Jaani horizon (J1) with the tabulatans (Sokolov, 1952 and 1955) *Paleofavosites*, *Subalveolites*, *Syringolites*, *Mastopora*, *Paeonealysites*, *Thecia*, *Heliolites* and *Propora* and the J2 Jaagarachu horizon with *Favosites* and *Jaaremolites*.

The Upper Wenlockian Wenlock Limestone of Shropshire and the Midlands is of the zone of *Cyrtograptus lundgreni*. It is reefal in Britain, and contains a rich fauna that requires modern monographic treatment. Genera I have studied from it are *Entelophyllum*, *Acervularia*, *Arachnophyllum*, *Kodonophyllum*, *Pyenactis*, *Phaulactis*, *Plasmophyllum*, *Strombodes* (rare), *Spongophylloides*, *Syringaxon*, 'Omphyma', *Calostylis*, *Helminthidium*, *Rhabdoecylus*, *Tryplasma*, *Cystiphyllum* and *Goniophyllum* with *Streptelasma pseudoceratites*. Tabulata are very rich, and include *Paleofavosites*, *Favosites*, *Alveolites*, *Cocinates*, *Angopora*, *Nodulipora*, *Thecia*, *Heliolites* (a dominant reef builder, Colter, 1957), *Stelliporella*, *Plasmopora*, *Propora*, *Diploepora*, *Striatopora*, ?*Pachypora*, ?*Cladopora*, *Halyites* and *Syringopora* being very common. This is the fauna usually called ‘Wenlock fauna’.

In Gotland the Mulde Marls may correlate with the Wenlock limestone. Of the fauna listed for the Slite group, *Pseudomphyma*, *Hedstromophyllum*,

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Rhegmaphyllum, Circophyllum and Stauria are apparently not recorded in the Mulde Marls, but Acervularia, Arachnophyllum, Entelophyllum and Thecia are common.

In Estland some part of the Oesel group may be equivalent to the Wenlock limestone, but present lists suggest that the Wenlock limestone fauna is not represented there.

In the Urals small Wenlock faunas occur (Soshkina, 1937; Sytova, 1952; Yanet, 1955) with ? Dinophyllum ("Stereophyllum" spirale Soshkina), ? Favistella ("Dokophyllum" sociale), "Tenuiphyllum", omphymoids, tryplasmids, Entelophyllum and Micula (with which some of the British and Gotland Entelophyllum species may be congeneric) and the tabulatan Thaumatolites Yanet.

In Bohemia corals are common in reefal masses in ex2 and ex2/ex2 at horizons possibly near the Wenlock–Ludlow boundary; Tryplasma, Cystiphyllum, Microplasma, Acervularia, Arachnophyllum, Entelophyllum, Spongophyllinae, Phaulactis, Favosites, Paleofavosites, Alveolites, Coenites, Heliolites, Propora, Halysites and Autopora from the America Quarry (Prantl, 1939) certainly suggest a Wenlock Limestone horizon. The classical Tachlowitz fauna is now regarded as a little younger than the America and possibly Ludlow.

In England in the Lower Ludlow shales, corals are not uncommon, but are mostly undescribed. No new genera are known; Syringaxon, Entelophyllum, Favosites, Heliolites and Halysites are amongst the few recorded. The graptolite zones of the Lower Ludlow are M. nilssoni and M. scanicus. The Aymestry Limestone (zones of M. tumescens and M. leintwardinensis) contains Phaulactis, Spongophyllinae, Rhabdocyclus, Tryplasma, and Hedstromophyllum with Favosites, Heliolites etc. Upper Ludlow corals are practically unknown; Syringaxon occurs in Westmoreland.

In Gotland Ludlow coral faunas are much richer. That of the Klinteberg reefal group is possibly basal Ludlow. It is not well figured, but Pilophyllum enters and is important and Gyalophyllum is endemic, making but a brief appearance. Spongophyllinae, Helminthidium, Kodonophyllum, Acervularia and Entelophyllum are recorded.

The Hemse marls (Petesvik, Hablingbo etc.) are to be correlated by their graptolites (Hede, 1942) with the M. nilssoni zone of the Lower Ludlow. They have the phaulactid Plasmophyllum (as Lampropyllum), phaceloid Tryplasma, Rhizophyllum gotlandicum, Arachnophyllum, Acervularia, omphymoids and some phaulactids, Weissmeridia lindstromi, "Fascicularia" dragmoides (these last two could possibly be the same species), Strombodes munthei (Wdkd.) and Prisciturbin. The Tabulata are significantly different from the Wenlockian generic assemblage only in the absence of Diplopora and Syringoldites.

The Eke marls at Lau Backar, overlying the Hemse marls, may be Lower or Middle Ludlow and have the endemic Stortophyllum and Holmophyllum holmi, Entelophyllum, Rhizophyllum (forming a Rhizophyllum limestone), Kodonophyllum and Spongophyllinae, while the overlying Burgsvik sandstone and oolite has Favosites clausus, F. hisingeri, Spongophyllinae and cf. Striatopora calyculata Lm. figured from it. The Hoburg reef at the top of the Gotlandian has Favosites gotlandica and F. hisingeri, cf. Striatopora calyculata, Heliolites, Plasmopora and Propora, but the full fauna remains to be described. Spjeldnaes (1950) has suggested that the Hoburg reef is possibly basal Devonian (Downtonian).

These Ludlow faunas are thus seen to be almost entirely of genera relict from the Wenlock.

In Estonia the upper Oesel (K) Beds (Zone 8) are usually regarded as Ludlow. Here again the Rugosa have not been revised since Dybowski (1873, 1874) originally described them; his figures may be interpreted doubtfully as of Tryplasma, Cystiphyllum, Entelophyllum, Phaulactis, Micula, Stauria and
Strombodes. Twenhofel’s list (1916) also includes Acervularia and Omphyma. This list could equally well imply a Wenlock age. Sokolov (1955) figures Thecia, Romingerella, Laceripora and Syringopora from the K2 Paadla horizon, Multisolenia and Favosites from the K3 Kaugatoma horizon with Lissatrypa (? Atrypella), and Favosites from K4.

In Bohemia the classical Tachlowitz (εx₂ according to Prantl and Pribyl 1944 quoted by Flügel, 1956a) and Kozel (εß, according to Zelizko 1904 quoted by Flügel, 1956a) are both a little younger than the America fauna regarded as probably Upper Wenlock above; they are possibly Lower Ludlow, and contain the genera listed above for the America Quarry, plus, in one or the other, Omphyma, Spongophyllum, Syringaxon, Pachyphora and Stelliporella (Pöcta, 1902; Prantl, 1952). This is the only European Silurian occurrence of Spongophyllum known to me. A smaller fauna from Graz in Austria is regarded as εx₂/εß₁ Lower Ludlow by Flügel (1956a); it has Syringaxon, Entelophyllum, Favosites, Thamnopora, Chetetes and Heliolites. Schouppé (1954c) has considered it uppermost Ludlow. From the Carnic Alps Schouppé (1954a) described a somewhat larger fauna and correlated it with εγ₁ of Bohemia, and regarded it as topmost Upper Silurian.

Weissermel (1943) described a small Ludlow fauna from west and central Germany mainly from calical moulds.

In Podolia Sokolov (1955) refers to faunas similar to the Bohemian Ludlow. Pachyfavosites occurs in the Borschchov horizon of the Ludlow, while in the Skala Stage of Aymesty—Ludlow equivalence, Rozkowska (1946) has described Mucophyllum eurycaulyx, Tryplasma, Microplasma, Rhizophyllum and Spongophylloides. Earlier descriptions were by Eichwald and by Semiradski.

In Asia Minor an important Silurian fauna has been described by Weissermel (1939) and Unsalaner—Kiraglı (1958). It contains Tryplasma, ? Polyorophe, Cystiphyllum, ? Dinophyllum, Spongophylloides, Entelophyllum, Phaulactis, Fletcheria, Alveolites (as Roseoporella), Asteroerium, Favosites, Paleofavosites, Halyites, Heliolites and Syringopora. It could well be either Upper Wenlock or Ludlow.

Ludlow faunas are thus almost entirely of genera relict from the Wenlockian. Coral vitality was surprisingly low after the great burst at the top of the Llandovery and in the early Wenlock.

S.W. European Silurian is graptolitic in facies, corals being extremely rare; ‘Cyathophyllum’ and ‘Zaphrentis’ are recorded (Sampelayo, 1942).

Asia

In Asiatic Russia rich faunas are now being made known. Russian work on Tabulata has been most active, and a number of generic names new to western research appear in the following review. They suggest a degree of isolation in Siberian faunas, but this may well be more apparent than real, since the Tabulata have been rather neglected in the European and English-speaking world and the new Russian genera may represent groups of species submerged in the west in genera perhaps too broadly defined. In the Sino-Japanese world Halyites has recently been subdivided into many subgenera. In India and Burma little Silurian research has been done recently, and in Indochina and Indonesia very little indeed is known of the Silurian.

Llandovery equivalents are widespread in Asiatic Russia, in Kazak A.S.S. (Sokolov, 1955) and on the western (Sokolov, 1946, 1950; Kraevskaya, 1955) and northern outskirts of the Siberian platform (Nikoläva, 1955), in the Tunguska River basin (Lindström, 1882; Sokolov, 1947, 1955; Soshkina in Ivanova et al., 1955), the Taimyr (Chernysh, 1941; Sokolov, 1955), Olenek (Lindström, 1882) and Verkhoyansk. A horizon near the boundary with the Wenlock is the richest with the Tabulata Paleofavosites, Favosites, Multisolenia,
Agetolites, Alveolites, Subalveolitella, Striatopora, Parastriatopora, Syringopora, Syringoporinvs, Palaeohalyites, Cystihalyites and Propora (Soshkina, 1955). The new generic names in these do not necessarily imply endemism, since Russian subdivision of the Tabulata has been carried further than any other. Rugosa are Dybowskia, Streptelasma (some like Rhegmaphyllum), Pycnactis and lykophyllinids (including Cyathactis).

In China, Japan, Indochina and Indonesia Llandovery coral faunas seem not to have been described, but from Spiti in the central Himalayas, Reed (1912) has figured from beds with Pentamerus oblongus halytisids now (Hamada, 1958) referred to Catenipora ? and Schedohalyites, plus Favosites. At a lower horizon Calostylis occurs.

Wenlockian faunas, first made known by Lindström (1882) from the Stony Tunguska, have there (Soshkina in Ivanova et al., 1955) Paterophyllum, Pycnactis and Holophragma in the lower parts, and Rhegmaphyllum whittardi (Smith), Pycnactis crassiseptata (Smith) Phaulactis (Cyathactis), Phaulactis, Kyphophyllum, Micula, Dokophyllum (“Omphyna”), Hedstromophyllum, Plasmophyllum (as Lamprophyllum), Erenkiella (ceroid ? Enteloophyllum), Enteloophyllum, Favosites and Paleofavosites, with (Sokolov, 1955) Syringopora in the upper part. In the Taimyr Favosites (Sapporipora) and the new genus of favositid Moyerolites are reported (Sokolov, 1955). To the south-west of the Siberian platform, in Kazak A.S.S., the multisolenid Antherolites and the compact halytisid Hexismia occur with Heliotites (Sokolov, 1955) while the Australian favositid genus Hattonia occurs in South Fergana (Sokolov, 1955).

Chinese Silurian corals are only broadly known as to horizon within the Silurian. Assemblages referred by Wang (1944, 1947, 1948 and 1950) to the Middle Silurian occur in Yunnan. Only the Rugosa have been fully treated by this author, who reports Amplexoides, Pycnactis, ? Dinophyllum, omphymoids, Enteloophyllum (as Stereoxylodes), Pilophyllum, Pseudocystiphyllum, Lindstroemophyllum, Kyphophyllum, Disphyllum (?=Weissermelia), Cystiphyllum, Rhizophyllum, Holmophyllum, Zelophyllum and Gyalophyllum. Of these Pseudocystiphyllum and Lindstroemophyllum are not recorded elsewhere, but the material on which they were founded does not seem very satisfactory. Another possibly Middle Silurian fauna is described (Yü, 1956) from West Kansu, with Ptychoophyllum (Nanshanophyllum), Paleofavosites, Favosites, Halytis and Heliotites.

A fauna from Szechuan was the first Silurian fauna described from China (Lindström, 1883) and it may be somewhat younger than the Yunnan fauna with which it has one species in common—Amplexoides appendiculatus (Lindström); for the rest, it has Synamplexus, ? Ptychoophyllum, Cystiphyllum, Rhizophyllum, Teratophyllum, Stauria, Phaulactis, Favosites, Somphopora, Halytis, Heliotites and Propora. A somewhat similar fauna from Hupei (Grabau, 1925; Yü, 1956; Hamada, 1958) is also possibly post-Wenlock, with Amplexus, Pselophyllum, Ehabdocyclyus, Cystiphyllum, Teratophyllum, Stauria, Favosites, Heliotites and Schedohalyites.

Amplexoid forms and Teratophyllum are the somewhat distinctive features of these Chinese faunas.

Some Manchurian species are referred to the Wenlockian, and to the genera Pseudomphyma, Spongophyllum and Favosites (Yabe and Hayasaka, 1920; Yabe and Eguchi, 1943, 1944, 1945).

A fauna described from boulders in the Mesozoic Kenniho conglomerate in Korea by Ozaki in Shimizu, Ozaki and Obata (1933–5) and by Ma (1956) and regarded as Wenlockian, consists of tryplasmids and cystiphyllids with Favosites including Sapporipora, Paleofavosites, Heliotites, Propora including Koreanopora, Plasmopora, Syringopora and Quepora. The age of the derived fauna is doubted by Hamada (1958), who suggests Ordovician.
The very small faunas described from Indochina by Mansuy (1908, 1913, 1915) are not informative as to horizon or province.

No certainly Wenlockian corals are known from India or Indonesia.

Ludlovian faunas are possibly represented in the Kitakami Mountainland and other parts of Japan (Hamada, 1958), though Hamada continues to refer a lower Favositae limestone there to the Wenlockian. The Halysites limestone of the Kawauti series, remarkably rich in the characteristic Australian-Asiatic slender halysitid Schedohalysites, is, he considers, not Wenlockian, as Sugiyama (1940) thought, but Lower Ludlovian; it contains some elements not yet known in Europe, such as Kitakamiphylum and Nipponophyllum (though Entelophyllum fasciulatum Wedekind 1927 may be congeneric with the latter). Other Rugosa are Spongophyllum, Helminthidium, Tryplasma, Cystiphylum and Rhizophyllum, while the Tabulata are Favositae, Paleofavositae, Thamnopora, Alveolites, Coenites, Heliolites, Propora, Spongoporella, Syringopora and the halysitids Halysites, Falsicatenipora and Schedohalysites.

In China the Spirifer tingi beds of Kueichou were considered by Grabau (1930) to be Upper Silurian, with Amplexus, "Omphyma", Cystiphylum and Favositae; possibly, as noted above, the faunas from Szechuan and Hupei may be post-Wenlockian. Regnell (1941) refers to the Ludlovian a fauna rather like the S. tingi fauna from Tien-Shan, with Angopora and Plasmopora additional, and considers a small fauna of Tabulata from the same region to be possibly transitional from Silurian into Devonian.

From Asiatic Russia my Ludlovian records are all of Tabulata. In Fergana Chernychev (1951) and Sokolov (1955) record Favositae and Squameofavositae with the Australian Hattonia; and in the Salair Sokolov (1955) figures Hattonia and the favositid Salairia. In Turkestan the new tabulatan genera Cylindrostylus (Edwardsiella) and Syringoporella are figured by Sokolov (1955), and in Central Asia Helioplasmolites. Chechovich (1955) considers four complexes can be discerned in central Asiatic Ludlow faunas; two, a Propora-Multisolenia and a Favositae fortesi complex in the Pentamerus zone of the Lower Ludlow, and two, a Heliolites-Squameofavositae complex and a Favositae complex in the Upper Ludlow.

Australia, New Guinea and New Zealand

In the southwest Pacific region Silurian corals are known only in eastern Australia and western New Guinea; from the latter Teichert (1928) records the halysitid Catenipora wallichi (Reed), a species originally described from the Llandoverian of Spiti, central Himalayas. None is known from New Zealand.

In eastern Australia Llandovery coral faunas are recorded, but require description. From the Orange district of N.S.W., Stevens and Packham (1953) list Cystiphylum, "Mucophyllum liliiforme", Desmidopora, Heliolites and halysitids in the Bridge Creek Limestone Member, which lies 50 feet below shales bearing graptolites they regard as of the M. gregarius zone at the top of the Lower Llandovery. Of these only Desmidopora has been described (Fitzgerald, 1955). The Quarry Creek Limestone Member, which according to Packham and Stevens (1955) is younger (Upper Llandovery), is, they state, immediately overlain by beds with Monograptus cf. pragensis pragensis while 20 feet above it M. marri occurs. Some of its corals have been described by Etheridge (1904, 1907, 1908, 1909) and these include the large colonial rugosan ? Arachnophyllum, the endemic Miictocyctis, with "Tryplasma liliiformis" and Halysites, Schedohalysites and Acanthohalysites (Hamada, 1958).

Wenlockian corals have long been known from the Yass district of N.S.W. Here, in the Yass beds, which are possibly early Wenlockian, ? Herco-

phylum, Tryplasma, Rhizophyllum, Holmophyllum, Coenites, Alveolites, Aulopora
and Syringopora are known (Etheridge, 1921; Hill, 1940; Brown, 1941). The younger Bowspring Limestone, Barrandella Shale and Hume Limestone possess a rich coral fauna. Endemic genera are the colonial Rugosa, Zenophila and Yassia, and the phaulactid Hercophyllum. Microporhyllum is very like some Gotland Pseudomphyma; Bacophyllum Hill is probably a junior synonym of the Japanese Nipponophyllum Sugiyama; the otherwise Devonian Disphyllum is recorded in the Silurian elsewhere only in China. Entelophyllum, Tryplasma, Pycnostylus, Rhizophyllum, Cystiphyllum and Streptelasma occur as in many European countries and North America, and Spongophyllum as in Bohemia and Japan. These Rugosa, many of which were first described in short papers by Etheridge or by Jones, were revised by Hill (1940). The endemic Mazaphyllum occurs in the Bathurst district of N.S.W. (Crook, 1955). The accompanying Tabulata are cosmopolitan as to genera, with Favosites (Jones, 1937), Hattoria (a favositid, not a chaetetid as reported Jones, 1927), Coenites, Alveolites (Etheridge, 1921), Aulopora and Syringopora, and the heliolitids (revised by Jones and Hill, 1939) Heliolites, Plasmopora and Propora. Very remarkably, no halysitids are known.

This classical Yass fauna may in its younger parts be early Ludlovian, but is probably mainly Upper Wenlockian. Beds with graptolites of the M. nilssonii zone overlie it (Brown and Sherrard, 1952). From Quedong Hill (1943) has recorded a similar, smaller fauna that, however, contains Calostylis, the only known occurrence for Australia.

A fauna from Yarrangobilly, further south in N.S.W. and somewhat like the Yass fauna, but rich in the halysitids Hexismia, Schedohalyssites, Falsicatenipora and Acanthohalysites (Hamada, 1958), contains also Heliolites, ? Propora, Diploepora, Favosites, Striatopora, Parastriatopora, Alveolites and Coenites, with rare Rugosa Tryplasma and ? Neomphyma. It also is probably Wenlockian, though possibly Ludlovian (Hill, 1954).

An endemic tabulatan genus Fosspora Etheridge (1903) possibly related to the northern hemisphere Thecia has been described from rocks doubtfully Silurian in the Wellington district of N.S.W.

In Tasmania a few Silurian (? Wenlockian) corals are known. Hercophyllum and Entelophyllum occur in the Gordon River Limestone (Hill, 1942), and Falsicatenipora is recorded (Hamada, 1958).

In North Queensland rich Silurian coral faunas have been collected from the Broken River, Clarke River, Chillagoe and Mungana districts and are at present being worked by the writer.

The oldest fossiliferous limestones here contain Tryplasma, ? Streptelasma and ? Paliphyllum (with disseipments), Favosites, Heliolites, Plasmoporella, Plasmopora, Propora and Catenipora. Plasmoporella in Europe is confined to the Borkholm Beds, now regarded as uppermost Ordovician, and this fauna could possibly be uppermost Ordovician rather than Lower Silurian.

A younger Silurian fauna is much richer, with Entelophyllum, Pseudomphyla, omphymoids, Tryplasma solitary and fasciculare, ? Pseudamplexus, Cystiphyllum, Rhizophyllum, Favosites, Multisolenia, Alveolites, Heliolites, Plasmopora, Propora, Diploepora, halysitids (numerous) and a new syringoporoid genus. This is either Upper Wenlockian or Lower Ludlovian.

North America

In North and Arctic America Silurian strata were deposited in three distinct geosynclinal regions, Appalachian, Innuitian and Cordilleran, and on the craton by shallow seas spreading from these geosynclines.

The best known coral-bearing strata are those of the eastern epicontinental seas in Ontario and Michigan, but the corals collected from these are largely
silicified or have had their internal structure obscured by dolomitization, so that it is difficult to draw comparisons between them and the beautifully preserved specimens from Europe. The Canadian corals were revised or described by Lambe (1899-1901) but many of his specimens are now missing (Twenhofel, 1928) and there is doubt about the horizon of others. A further difficulty experienced by the non-American palaeontologist in assessing these faunas is the variable stratigraphic connotation, so that a term, e.g. Clinton, has different significance for almost every author. In this review I have taken the stratigraphic definitions given by the latest Canadian Memoir on Ontario (Bolton, 1957) since they are clear and since the stratigraphic equivalencies set out in the memoir seem to be broadly based and acceptable to workers in different groups, e.g. brachiopods, corals, ostracods and nautiloids.

Possibly the oldest Silurian coral fauna of the eastern seas is that of the Manitoulin dolomite of Ontario (Bolton, 1957) and Michigan (Ehlers and Kesling, 1957). Williams (1919) figures *Palceophyllum* and a cerioid rugosan that he refers to *Acercularia*, together with solitary streptelasmoids and *Paleofavosites*, and lists *Syringopora*, *Halysites* and *Chonophyllum belli*. Bolton (1957) lists the small solitary streptelasmoids *Enterolasma*, *Neozaphrentis* and *Kionelasma* (with axial structure), and the Tabulata *Paleofavosites* and *Propora* (as *Lyellia*). A much smaller fauna occurs in the overlying Cabot Head Formation. These two together are equivalent to part of the Medinan of New York, and possibly part of the lower Beecie of Anticosti and the Edgewood and Brassfield of Illinois and Missouri. They are almost certainly Lower Llandovery in equivalence.

The lower Clinton in the sense of Bolton (1957) begins with beds with the brachiopod *Virgiana*, which are widely distributed in eastern Canada and north eastern U.S.A. and are all probably nearly coeval. In Ontario and Michigan these are poor in corals, but in Anticosti the upper Beecie and lower Gun River (Twenhofel, 1928) contain small solitary streptelasmoids (? *Brachyelasma*), two insufficiently illustrated phaceloid rugosans, one possibly allied to *Stauria favosa*, *Syringopora*, *Favosites*, *Paleofavosites*, 'Halysites' and *Propora* (as *Lyellia*). In Manitoba the Fisher Branch Dolomite at the base of the Interlake group also has small solitary streptelasmoids with *Paleofavosites*, *Favosites* and *Propora*, but with *Multisolenia* and the compact halyositid *Hexismia* making their first appearance.

The upper part of Bolton's (1957) lower Clinton contains the Reynales Formation and its equivalents with bioherms, the coral-rich Fossil Hill of Manitoulin, the Manistique of Michigan, the Thornloe limestone (with *Multisolenia* and *Hexismia*) of the Lake Timiskaming area, the Jupiter of Anticosti, the Attawapiskat of Hudson Bay and the East Arm formation of the Interlake group of Manitoba. The Michigan and Manitoulin fauna was figured by Rominger (1876) but his collection-localities mostly covered more than this formation. From Ehlers and Kesling (1957) and Bolton (1957) this fauna is taken to consist of *Palaeocyclus*, *Dinophysillum*, *Arachnophysillum*, *Goniophysillum pyramidale*, *Tryplasma*, *Diplophysillum*, small solitary streptelasmoids and *Kionelasma*, *Amplexus shumardi*, *Psychophysillum* and "*Opympha*", together with the tabulatans *Favosites*, *Striatopora*, *Alveolites*, *Coenites*, *Cladopora*, *Halysites*, *Catenipora*, *Heliolites*, *Propora*, *Plasmapora*, *Syringopora*, *Romingerella*, *Thecia* and in the lower beds *Hexismia compacta*. The first four genera suggest correlation with the Upper Llandovery Lower Visby marls of Gotland. The Jupiter formation of Anticosti I. (which has *Pentamerus oblongus* and *Stricklandia*), also has *Monograptus clintonensis*, (like an early *M. priodon*), *Palaeocyclus*, *Arachnophysillum*, *Cystiphyllum*, lykophyllinids (solitary "*Cyathophysillum*" with normal dissepimentaria), small solitary streptelasmoids and most of the tabulatan genera of the Fossil Hill-Manistique. The La Veille formation of Chaleur Bay seems to
correlate herewith (Alcock, 1935; Northrop, 1939), and the Pike Arm formation of Notre Dame Bay, Newfoundland (Shrock and Twenhofel, 1939) also.

Thus Bolton's upper part of his lower Clinton correlates very well with the Lower Visby marls and the Coralliferous Series of Pembrokeshire, both of which are Upper Llandovery, probably pre-crenulatus zone. Iowan corals listed by Rominger (1876) and the small fauna with Goniophyllum pyramidale, Petalocrinus and Stricklandia described by Weller and Davidson (1896) from dolomite surely correlate with the topmost Llandovery.

The Chicotte formation (Twenhofel, 1928) at the top of the Anticosti sequence also may represent topmost Llandovery since it contains ? Schlotheimomophyllum (as Chonophyllum canadense) and Arachnophyllum, but if Entelophyllum is present it may possibly represent very early Wenlock.

In Manitoba the East Arm Formation of the Interlake group (with Striatopora, Favosites, Paleofavosites, Corrugopora, Multisolenia, Alveolites, Propora) is thought to correlate with the Manistique (Stearn, 1956), and above it, from the two topmost members of the group (Chemahawu Member and Cedar Lake Dolomite), Stearn figures two phaceloid Rugosa, Pycnostylus and Synamplexoides, with the solitary Dinophyllum and Cystiphyllum, and the tabulates Alveolites, Corrugopora and Striatopora joining Paleofavosites, Favosites and Propora. The presence of Dinophyllum suggests that this is still within the Upper Llandovery, so that the Interlake group might well be wholly within the Llandovery.

The sequence above the Reynales and Manistique in New York, Michigan and Ontario is poor in corals, and in his Upper Clinton (including Irondequoit, Rochester and Decew) Bolton (1957) lists only small solitary streptelasmoids with Aulopora, Favosites, Striatopora and Coenites. On the corals it is thus not possible to say whether his Upper Clinton is Llandovery or Wenlock.

In Ohio the small fauna of the West Union formation is said by Foerste (1917) to contain Holophragma calceoloides, ' Zaphrentis ', ' Cyathophyllum ', and Acurcularia, while the possibly equivalent Laurel limestone has Calostylis. This may be uppermost Llandovery. Grabanphyllum (? a cerioid Spongophyllum) occurs in ' Niagara ' dolomite in Illinois.

The Silurian of Alaska (Buddington and Chapin, 1929) and of the Cordillera of Western Canada (including the Ronning Formation, Hume, 1954) is poorly known, but lists without illustrations indicate Palaeocyclus, Arachnophyllum, ' Zaphrentis ', ' Cyathophyllum ', ' Disphyllum ', Favosites, Alveolites, Syringopora and Halysites. Horizons within the Silurian are not clear, but from the first two genera lower Clinton and Upper Llandovery strata appear to be represented. This north-western fauna has been compared with the Silurian coral fauna of the western U.S.A., which (Duncan, 1956) includes Tryplasma (solitary and fasciculate species), Palaeocyclus, Cystiphyllum, Pycnactis, solitary ' Cyathophyllum ', phaceloid Entelophyllum and Cicrophylum, Cystihalyssites, Halysites, Catenipora, Alveolites, Favosites including squamulate types, Cladopora, Syringopora and Heliolites, all of which remain to be investigated by modern techniques. Entelophyllum, Cicrophylum and squamulate Favosites suggest that faunas younger than Upper Llandovery are also represented, and descriptions will be awaited with interest.

Arctic American corals are on the whole, poorly known. Reefs are reported (Fortier in Stockwell, 1957) in the Read Bay Formation of Cornwallis Island, now in part dolomitic. Possibly the oldest Silurian fauna is in the Offley Island Formation (Poulsen, 1941) and of the M. sedgwicki zone at the base of the Upper Llandovery, and here Palaeophyllum, ? Cystiphyllum and small solitary Rugosa occur with Paleofavosites, Favosites, ? Proheliolites, Propora, ? Nyctopora and halysitids. On Brodeur Peninsula at the northwest end of Baffin Island, and at
Kuk at the north tip of Southampton Island on the northwest of Hudson Bay, Teichert (1937) has described a few corals including small solitary Rugosa, Favosites and Halysites that are probably Llandoverian. From King William Land he has described Paleofavosites and halysitids referable to Quepora, ? Cateni-pora and ? Eocatenipora. From unknown horizons in the Arctic Silurian are the rugosan Naos (= ? Oraterophyllum) pagoda from Melville Island (Lang, 1926) and the tabulatans Boreaster from Beechy Island in Lancaster Sound (Sokolov, 1955).

Where one should draw the base of the Wenlockian in the Ontario-Michigan-New York sequences it is difficult to say, but probably the Wenlockian includes Bolton’s (1957) Lockport there, and the Amabel which he regards as equivalent to the Lockport. In the Wiarton member of the Amabel he lists, but does not figure Cystostylus, small solitary streptelasroids (Enterolasma and ‘Zaphrentis’) ‘Omphyma’, Pycnostylus, Favosites, Striataopora, Coenites, Thecia, Heliolites, Syringopora and Halysites. From the Lockport (shale) of New York (restricted) Hall (1852) figured Striatoporta and Astrocristum.

In Britain the Wenlockian is called Middle Silurian, but in North America the Niagaran is commonly called Middle Silurian. As seen above, in Bolton’s usage the Niagaran includes the Upper Llandovery Clinton group as well as his Albemarle, which includes both Lockport and overlying Guelph dolomites. According to some the Guelph is equivalent to part of the Lower Ludlow. Thus Niagaran fully corresponds neither to the Wenlockian nor to the British Middle Silurian, a fact that must be borne in mind in reading coral faunal papers.


In Tennessee the coral fauna of the Brownsport formation has been investigated by modern thin section methods (Amsden, 1949). It is quite rich, and contains several solitary non-dissepimented Rugosa showing a peculiar rejuvenescence, the corallites expanding and contracting in diameter rhythmically, giving angular projections and concave surfaces between; other forms are Anisophyllum, Ditoecholasma and non-dissepimented ? Spongophyloites waynensis (Safford), Tryplasma, Rhizophyllum, Cystiphyllum, lykophyllins with wide, normal dissepimentaria, solitary entelophyllids such as ‘Naos’ sewellensis Amsden, and the compound Entelophyllum rugosum and Arachnophyllum, with the tabulatans Favosites, squamulante Favosites, ? Pleurodictyum, Striatoporta, Alveolites, Planalveolites and Coenites, ? Dendropora, ? Cladopora, Romingerella and Thecia, Heliolites, Stelliporella (as Cosmiolithus), ? Propora, ? Plasmopora and Cystihalytes. This fauna has little in common with the Llandovery Clinton faunas, and it resembles European Wenlockian and early Ludlovian faunas. Amsden correlates it with the Louisville of Kentucky, the Bainbridge of Missouri (from which Syringaxon (Laccophyllum) is known) and the Henryhouse of Oklahoma. But Freeman (1950) shows the Louisville as lying immediately below the Brownsport. Berry (1958) reports Lower Ludlovian M. nilssoni zone graptolites in the Henryhouse of Oklahoma, and suggests the Brownsport therefore is Lower Ludlovian.

In the Arctic the Atrypella beds with the Atrypella scheei fauna (formerly the Lissatrypa phoca fauna) are now considered to be Middle and Upper Silurian and possibly later, and contain a long list of corals (Foerste, 1929) nearly all of which require elucidation. The fauna is widespread in the Arctic (including
Vaigach I.). It is found on King William Island, in Boothia Peninsula and in Victoria Strait Basin to at least Scoresby Bay near the eastern margin of the central Ellesmere belt.

The Lower Ludlovian may possibly be represented by the Guelph dolomite of the Niagaran escarpment, from which Bolton (1957) lists *Amplexus shumardi*, *Arachnophyllum*, "Cyathophyllum", "Omphyma", *Ptychophyllum, Pycnostylus elegans* and *guelphensis*, *Coenites, Favosites* and *Halysites*. The New York Guelph also contains *Diplophyllum* Hall (1876). The two *Pycnostylus* species are recorded from the Silurian of Great Slave Lake (Hume, 1926). As mentioned above, the Brownsport fauna of Tennessee may be Lower Ludlovian.

Higher Silurian strata contain extremely few corals.

**South America, Africa and Antarctica**

Records of Silurian corals are remarkably rare in South America. A doubtfully Silurian collection from Bom Jesus de Lapa in the Amazon Valley of Brazil contains *Favosites niagarensis* (Rendemann in Maury, 1929). In Cerro del Fuerte, San Juan, in the Argentine, *Favosites argentinus* occurs in probably Clinton (Upper Llandovery) strata (Clarke, 1913).

In Africa graptolitic Silurian beds are known from Morocco and Algeria, but corals are extremely rare; Termier and Termier (1950) figure *Favosites tachlowitzensis*, *Columnopora* sp., *Streptelasma* cf. *aggregatum* Nich. and Eth., and *Spongophyllum fritschii* Novak from Morocco from ? Ludlovian horizons, and Barbier, Termier and Termier (1948) mention *Favosites gothlandicus* from Ludlovian limestones of western Algeria, in Grande Kabylie. As in Spain and France, in N.W. Africa and French Guinea the Silurian facies is graptolitic except in the Ludlovian, where calcareous beds with *Cardiola interrupta* appear.

No Silurian corals are recorded from Antarctica.

**III. Coral Reefs.**

Small coral-stromatoporoid-algal reefs are characteristic of epicontinental shelf regions in the Silurian from late Upper Llandovery to early Ludlow times. They are most beautifully displayed in the Islands of Gotland and Oesel in the Baltic sea (58° N), on Wenlock Edge in Great Britain (52° N) and less well on Vaigach I. south of Novaya Zemblya (70° N). Excellent descriptions in English are available for the Gotland reefs (Hadding 1956, 1950, 1941). In North America similar reefs are well known in the Great Lakes area (Lowenstamm, 1950) and Hudson Bay. Others occur in Alaska, on Cornwallis I. (75° N, Fortier in Stockwell, 1957) and further south in Nevada (*B.A.A.P.G.*, 1959). In Japan (Ma, 1956; Hamada, 1958) no bioherms appear to have been described, but in Siberia on the Stony Tunguska R. (Soshkina in Ivanova et al., 1955) (63° N) small masses occur. In southern Europe and North Africa graptolitic facies predominate, possibly reflecting depths of water too great for reef growth. In South America, Africa and Antarctica no reefs (and very few corals) are known, but in Australia reefs occur in north Queensland (19° S) and in N.S.W. at Yass (35° S) and Yarrangobilly (35° 40' S). Talent and Philip (1957) consider topmost Silurian or early Devonian reefs occur in Victoria at 37° S.

Ma (1956) to explain this distribution invoked sudden total displacements of the solid earth shell and accompanying drift of continents. But it seems to me that a rise in sea temperatures is a more likely explanation.

**IV. World Faunal Sequence and Distribution.**

Generalising from these sequences in the various continents, we may obtain a working understanding of the world sequence and distribution.

The Lower (and Middle) Llandoveryian faunas are so far known only in the Northern Hemisphere, and are still very similar to the Upper
Ordovician faunas. They are perhaps richest in Estonia, where the first normally dissepimented genus *Paliphyllum* (that arose in the Upper Ordovician) is accompanied by solitary, non-dissepimented streptelasmids and by the tabulatan *Paleohaly* sites. In Great Britain *Calostylis* (earlier found in the Upper Ordovician of Estonia) and small columnellate *Dalmanophyllum* accompany the streptelasmids, with *Paleofavosites*, *Pinacopora* (= Propora) and *Heliolites*. In eastern North America the Manitoulin dolomite contains *Paleophyllum*, small solitary non-dissepimented streptelasmids and a doubtful *Acrervularia*, *Chonophyllum belii*, *Paleofavosites*, *Propora* (as *Lyellia*), *Syringopora* and halysitids. These faunas are too small to establish whether they are divisible into geographic provinces or not.

It was in the Upper Llandovery that the great burst of Silurian coral vigour occurred, numerous new families, genera and species entering, the number increasing rapidly from a quite vigorous first appearance in the *M. turriculatus* zone of Shropshire. Small coral reefs were present in Northern Europe at the time, especially in Gotland and Estonia.

In Europe, amongst the Streptelasmatina, small non-dissepimented Streptelasmatinae (*Streptelasma*, *Rhegmaphyllum*, *Brachyelasma*, *Dalmanophyllum*) are joined by *Dinophyllum* and the characteristically Silurian large and wide-bordered solitary chonophyllinid *Schlotheimophyllum*, by a wealth of solitary Lykophyllinae, both non-dissepimented (*Pycnactis*, *Onychophyllum*, *Holophragma*) and dissepimented (*Phaulactis*) and by the colonial *Arachnophyllum* and *Petrozium*, while the aberrant *Calostylis* continues. Amongst the Columnariina, *Strombodes* and *Cystophylloides* continue; of the Cystiphyllina, *Tryplasma* continues and is joined by *Cystiphylum*, *Hedströmophyllum*, *Polyorophe*, *Paleocyclus*, *Centriilla* (these last two disappearing below the top), *Rhabdocyclus* and *Goniophyllum*. The tabulatans *Paleofarosites*, *Protarcea*, Propora, Heliolites and halysitids are joined by *Mesofavosites*, *Favosites*, *Alveolites* and *Syringolites*, *Striatopora* and *Parastriatopora*, *Syringopora*, *Syringoporinus*, *Paleohaly* sites, *Gystihaly* sites and Propora. This includes newly described genera that may yet be recognised within genera as presently known from Northern Europe. It is too soon, therefore, to know whether the Siberian fauna is of a zoogeographical province distinct from that of northern Europe.

The Australian Upper Llandovery fauna is small, but contains at least one endemic Rugosan, *Mictocystis*; its halysitids however are *Halysites*, *Acanthohaly* and *Schedohaly* sites, and according to Hamada (1958) indicate that the ‘Gotlandian’ sea of Asia and Australia constituted a distinct faunal province.

In North America the “lower Clinton” in the sense of Bolton (1957) probably correlates with the Upper Llandovery. It includes the famous Manistique fauna of Michigan made known by Rominger, and its generic list seems to indicate that eastern North America was co-provincial with northern Europe at this time. Some elements, the streptelasmid ‘*Kionelasma*’ with spongy axial structure and ‘*Amplexus*’ *shumardi*, appear endemic, and the compact halysitid *Hexismia* seems to have entered here earlier than elsewhere. Western and Arctic North American faunas are smaller but similar.
Though in Britain Wenlockian faunas are richer than the British Llandoverian in general, elsewhere in Europe they simply represent a weakened further development from the Upper Llandovery burst. Some Llandovery genera die out before or early in the Wenlockian, e.g. the Rugosa *Paleocyclus*, *Cantrillia*, *Dinophyllum*, *Arvopoma*, *Schlotheimophyllum* and *Holophragma*, and some new Rugosa enter early (*Acervularia*, *Kyphophyllum*, ‘*Omphyma*’ (= *Ketophyllum*), *Kodonophyllum* and *Pseudomphyma*); *Zelophyllum* is restricted to the early Wenlockian, *Heiminitidium*, *Cirrophylum*, *Slaviria* and *Rhizidiophyllum* (the latter endemic to Gotland) enter later in the Wenlockian, as does *Entelophyllum* and *Micula*; *Lykophyllinae* proliferate. Of the Tabulata *Coenites*, *Nodulipora* and *Diplolopora* appear within the Wenlockian and in Estonia *Subalveolites*, *Mastopora* and *Jaaremolites* have recently been split off from broader genera. *Heliolites* is a dominant reef builder. The Asiatic (Stony Tunguska) Wenlockian fauna is smaller than that of northern Europe, but it does not contain many endemic genera and there is little reason for thinking it of a separate province from that of Europe, though some new favositid genera and subgenera have recently been distinguished—*Sapporipora*, *Moyeroites* and *Antherolites*, with *Hexismia* (earlier known in the Clinton of North America) and the otherwise Australian favositid *Hattonia*. Hamada (1958) considers the Halystitidae indicate an Asio-Australian province separable from the European in ‘Gotlandian’ times. Chinese Wenlockian lists contain some generic names not found elsewhere, but on the whole they are like the European.

The Australian Wenlockian fauna has a few endemic elements (*Zenophila*, *Crinophyllum*), shares a few genera only with Asia (*Beophyllum* (= *Nipponophyllum*), *Hattonia*, *Schedohalysites*), but otherwise is very similar to the northern European fauna. *Rhizophyllum* may have made its earliest appearance herein. The North American Wenlockian faunas are mostly poorly known, except for that of the Brownsport formation of Tennessee, though this indeed might be early Ludlovian; mostly its genera are as in Europe, but a few may prove endemic.

One must, I think, be more impressed by the cosmopolitan nature of the Wenlockian coral genera than by the few evidences of geographical differentiation, such as the weakly defined Asio-Australian subprovince and the even more weakly defined North American subprovince.

Ludlovian faunas are cosmopolitan, show few new genera (*Gyalophyllum*, *Weissermilia* and *Rhizophyllum* in Gotland, *Squameofavosites*, *Salairia*, *Syringoporella* and *Helioplasmolites* in Asia) and are on the whole poorer than the Wenlockian; everywhere they can only be regarded as a weakening development from the Wenlockian. The number of genera is radically reduced in the Gedinnian, and it is not until the Coblenzian that the Devonian fauna proliferates.

Of the Silurian genera mentioned above only *Rhizophyllum*, *Cystiphyllum*, *Pseudamplexus*, *Entelophyllum*, *Spongophyloides* and *Spongophyllum* amongst the Rugosa, and *Favosites*, *Hattonia*, *Squameofavosites*, *Alveolites*, *Coenites*, *Striatopora*, *Thamnoporites*, *Heliolites*, *Plasmopora* and *Syringopora* amongst the Tabulata, commonly proceed into the Gedinnian. The subsequent development of the coral faunas in the Devonian and Upper Palaeozoic has already been reviewed by Hill (1957).

V. Conclusion.

We conclude therefore, that the ‘Silurian’ coral fauna began cautiously in the uppermost Upper Ordovician, gained evolutionary speed a little during the Lower Llandovery, then very rapidly increased its rate of development from early until late Upper Llandovery, and, though it did develop some new genera in the Wenlockian and fewer in the Ludlovian, began to weaken from early Wenlockian times, so that by latest Silurian and earliest Devonian times it
was reduced to but a fraction of its former self. Also, though there are suggestions of Asio-Australian and North American subprovinces, on the whole the Silurian fauna of the world is cosmopolitan, with its richest and best known development in the Upper Llandovery and early Wenlockian of northern Europe (Gotland). Further, the richest developments are always associated with coral-stromatoporoid-algal reef growth, especially in northern Europe and North America, as far north as 70° N. To me this suggests that at least the northern oceanic temperatures were higher in the Silurian than now.

Southern Europe, Africa, South America, Antarctica and New Zealand are extremely poor or lacking in Silurian corals; for southern Europe and northern Africa the widespread graptolitic facies may indicate a deeper-water environment not suitable for coral growth.

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Australia
DOROTHY HILL.

North America


**South America, Africa, Antarctica**


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