THE DEVONIAN OF WESTERN AUSTRALIA.

A PRELIMINARY REVIEW.

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PART II.

RELATIONSHIPS OF THE WESTERN AUSTRALIAN DEVONIAN.

THE Western Australian Devonian province is geographically rather isolated. The nearest occurrence of Devonian strata is possibly found in Central Celebes—1100 miles away—, if Rutten and Brouwer are correct in believing that the find of *Spirifer verneuili* in that region is authentic.[3]

Somewhat farther away, about 1350 miles distant, are the Central ranges of Dutch New Guinea with Devonian strata about which very little is known (Martin 1911, Feuilletau de Bruyn 1921, Stehn 1927, Teichert 1928). The following Devonian fossils have been reported in this general area[4]: *Orbiculoidea* cf. *media* Hall, *Schuchertella* cf. *umbraculum* Schlotheim, *Spirifer ziczac* Roemer, *Spirifer* cf. *bifidus* Roemer, *Spirifer undiferus* cf. var. *takwanensis* Kayser, *Spirifer* cf. *ibergensis* Scupin, *Atrypa desquamata* Schlotheim, *Retzia* sp., *Wilsonia* sp., *Chonetes* sp., *Sphenotus*? sp., *Goniophora* sp., *Ontaria concentrica* v. Buch., *Crenipecten*? sp., *Leptodesma* sp., *Gosseletia*? sp., *Dentalium* sp., *Cyrtolites*? sp., *Murchisonia* sp., *Phacops* sp.

There is no striking resemblance between this fauna and any of the faunas from Western Australia. The reason for this might lie in differences of facies rather than of age. The writer has pointed out that in a general way the New Guinea faunas must contain a strong early Upper Devonian element and no tyical brachiopods fauna of that age is as yet known from Western Australia.

Mostly still farther away from the Western Australian Devonian province are the disconnected areas in eastern Australia where Middle and Upper Devonian strata outcrop. The

[3] For detailed discussion of this occurrence and for further literature see Rutten, 1927, pp. 620-21.

[4] The occurrence of *Halysites*, first reported and discussed by me in 1928 (pp. 5-6), and since confirmed by Musper (1938), is now believed definitely to indicate Silurian, rather than Devonian, strata.

Devonian faunas have been very thoroughly summarized by Benson in 1922.[5]

Middle Devonian is well developed in the southeastern (Murrumbidgee-Buchan) province of New South Wales and Victoria, in the Tamworth province of New South Wales, and in Queensland. In the two latter regions a coral facies predominates and only when the Western Australian Middle Devonian corals are better known, will a closer comparison be possible. From the occurrence of *Calceola* and *Stringocephalus* in Queensland (see also Reid 1930) and of *Stringocephalus* in the Tamworth province one should expect no very close relationships between those two provinces and Western Australia where those forms are absent. The Murrumbidgee-Buchan province is the only one from which a major non-coral fauna of Middle Devonian age is known and there are undoubtedly some general resemblances to the *Atrypa* limestone fauna of Western Australia. In both provinces, forms similar to or identical with the following species have been observed: *Douvillina interstrialis*, *Atrypa desquamata*, *A. reticularis*, *Pugnax pugnus*; furthermore it might be expected that similarities will be shown to exist among the species of *Spirifer*; also, the following additional genera are represented by related species in both regions: *Conocardium*, *Paracyclas*, *Bellerophon*, *Murchisonia*. On the whole, however, it seems that the relationships are not particularly close. This can hardly be surprising, if it is remembered that the distance between the Devonian area of western Australia and that of the southeastern province is about 2500 miles in a straight line, and the actual line of communication between the two areas along the shores of the Australian continent which was already in existence in Devonian time must have been still longer.

[5] There has always been uncertainty regarding the occurrence of marine Lower Devonian in Australia. Benson did not recognise any. David (1932, p. 53) referred certain sedimentary series in Queensland to the Lower Devonian, but since those beds are unfossiliferous they cannot be discussed here. Allan (1935) in his thorough discussion of Lower Devonian facies could find no evidence for the occurrence of Lower Devonian, but somewhat later Shirley (1938) thought that the Australia Yeringian, usually classified in its entirety as Upper Silurian, might include strata of Lower Devonian age. This idea possibly finds support in the description by Hill (1939), and Hill and Jones (1940) of small coral faunas from localities in Victoria and New South Wales which they believe to be of Lower Devonian age. These faunules are apparently unrelated to the austral facies of the Lower Devonian (Bokkeveld beds of South Africa, Reefton and Baton River beds of New Zealand).

In regard to the correlation of the Western Australian Upper Devonian, only the brachiopod facies can of course be taken into account since no goniatite facies is known from eastern Australia.[6] An Upper Devonian brachiopod facies is well developed in the Lambian province of New South Wales, where we find a fauna mainly composed of brachiopods and lamellibranchs of European and American affinities. It is generally asserted (Gürich 1901; Benson 1922, 1923; Gregory 1930) that the Lambian fauna contains some Chemung (lower Upper Devonian) elements. However, the faunal assemblage of the Lambian reminds one most of that of the *Productella* limestone as may be seen from the following list of Lambian species which may be identical with or similar to species from Western Australia (after Benson, 1922; pp. 22-23); *Leptaena rhomboidalis*, *Stropheodonta* cf. *perplana*, *Camarotoechia* cf. *pleurodon*, *Hypothyridina cuboides*, *Spirifer* cf. *disjunctus*, *Spirifer* cf. *jaqueti*, *Athyris concentrica*?, *Bellerophon* sp., *Naticopsis* sp. The fairly rich lamellibranch fauna of the Lambian has no equivalent in Western Australia.

It must be borne in mind that according to recent investigations by Brown and Joplin (1938) this fauna occurs in strata near the base of the Lambian series. This series is now estimated to be only about 2500 feet thick as against 10,000 feet as previously supposed. Only the lowermost fossiliferous part of the Lambian can be discussed here, the greater part of the series being unfossiliferous.

[6] There are only two published records of goniatites in the Devonian of eastern Australia which were already listed by Benson (1922, p. 115). The one is by Dun (1898, p. 174) who listed "*Goniatites* sp. ind." from the Devonian boulders of White Cliffs, New South Wales, but since Dun states that no sutures were seen in the specimen on which this determination was based, the occurrence of goniatites at White Cliffs must be regarded as very doubtful, as already observed by Gürich (1901, p. 507). The second reference can be found in Stirling's paper on the Bindi limestone of Middle Devonian age (1886, p. 12) which lists a form "resembling *Goniatites Marcellensis* from the American Devonian strata." Peculiarly enough no goniatite has ever been described in America under that specific name. It seems likely that Stirling relied on unpublished information supplied by James Hall or some other New York geologist who changed the name of the species when he published it at a later date. However, it seems almost certain that the species with which the Bindi form was compared must have come out of the Marcellus shale of Middle Devonian age which, according to Miller (1938), contains species of *Bactrites*, *Agoniatites*, *Werneroceras*, and *Tornoceras*. The Bindi form might have belonged to one of the three last mentioned genera, but no additional information on any goniatites from that locality has ever been published.

If the lower part of the Lambian was an equivalent of the American Chemung, it would mean that, since the Chemung is known to contain *Manticoceras* the Lambian starts at the base of the Upper Devonian and that its fossiliferous part is an equivalent of the *Manticoceras* beds of the Kimberley. On the other hand, the similarites of the Lambian are closest with the *Productella* limestone which contains clymeniids and is considerably younger. Such differences in the time of appearance of related faunas in eastern and western Australia may of course be conditioned by facies, but on the other hand it is also possible that the significance of species with supposed Chemung affinities has been overestimated. Only by a much closer study of the Australian faunas will it be possible to elucidate the true relationships between the Australian and the North American faunas.

The wide geographical distribution and uniformity of certain Devonian faunas is well known. One of the long-established facts is the wide extension of a Middle Devonian fauna of European type across Central Asia to southeastern Asia where it is well developed in Burma, Indochina and southeastern China. The further extension of this fauna to Australia was recognised by Reed as early as 1910. Among the most important members of this fauna which reached Australia are *Calceola* and *Stringocephalus*. Their absence from Western Australia has already been commented on and is rather remarkable in view of the very marked European affinities of the Western Australian Middle Devonian fauna in other respects. Among the European forms which are represented in Western Australia and which are not found elsewhere in southeastern Asia and Australasia are *Sphaerospongia* cf. *tessellata* and *Paracyclas antiqua*. Both species are elsewhere only known from the Rhineland and from Manitoba. Also, a large *Myalina*, close to *M. bilsteinensis* from the *Stringocephalus* limestone of the Rhineland is rather unique for this part of the world. Other genera which have not been previously reported from the Devonian of Australia are the lamellibranchs *Macrodus*, *Mecynodon*, and *Eumegalodon* and the gastropods *Euphemites*, *Ectomaria*, *Euryzone*, *Straparollus*, and *Macrocheilina*.

It will be difficult at the present state of the investigation to propose a satisfactory explanation for the differences between the Kimberley and eastern Australia. Benson (1923, p. 27) suggested that "the great Tethyan migration of European forms [in the Devonian] through Asia was divided by the northern end of an ancient Cambodia-Malayan continental mass—perhaps the Aequinoctia of Abendanon (1919)—through Burma to Western Australia, while the other, receiving in China an influx of American forms arriving by the circum-pacific channel, passed southeastwards towards the then Tasman Sea." The best known Middle Devonian fauna in Burma is that of Padaukpin (Reed 1908, 1929). The composition of this fauna resembles that of the Western Australian Middle Devonian, but hardly more so than do those of any other contemporaneous Asiatic fauna. *Calceola* which does not occur in Western Australia is present at Padaukpin. On the other hand, as will be shown, the Upper Devonian fauna of Western Australia almost certainly arrived by way of southeastern China.

In this connexion the main interest centres around the occurrence of the Upper Devonian goniatite facies in Western Australia. It has been demonstrated in a previous section of this paper, how closely the succession of goniatite genera in Western Australia corresponds to the succession in Europe. A thorough search of the literature has revealed the existence of a number of additional localities in Asia which connect the Western Australian with the European occurrences and which were formerly overlooked (Teichert 1941) (see Fig. 4). In 1935, Sun described an occurrence of *Manticoceras* from Central Hunan province in China, stating that this was the first true Devonian goniatite so far known from China. However, *Manticoceras* ("*Gephyroceras intumescens*") had already been reported from Szechwan Province in southern China by Patte in 1932, as already observed by Miller (1938). Furthermore, it has been generally overlooked that as early as 1912 Mansuy (p. 10) stated that in 1903 the "mission Lantenois" had found "*Paradoceras* [sic!] *globosum* Munst." in eastern Yunnan. This determination apparently refers to *Goniatites globosus* Münster, a species of *Cheiloceras*, and, if correct, indicates the presence of Oberdevonstufe II in Yunnan. Scanty as these references are they indicate the possibility of a rather wide distribution of goniatite faunas at least of early Upper Devonian age in southern and southeastern China.

Further occurrences of Upper Devonian goniatite faunas are known from widely separated localities in Siberia. Miller (1938, p. 3-4) has already assembled what little information is

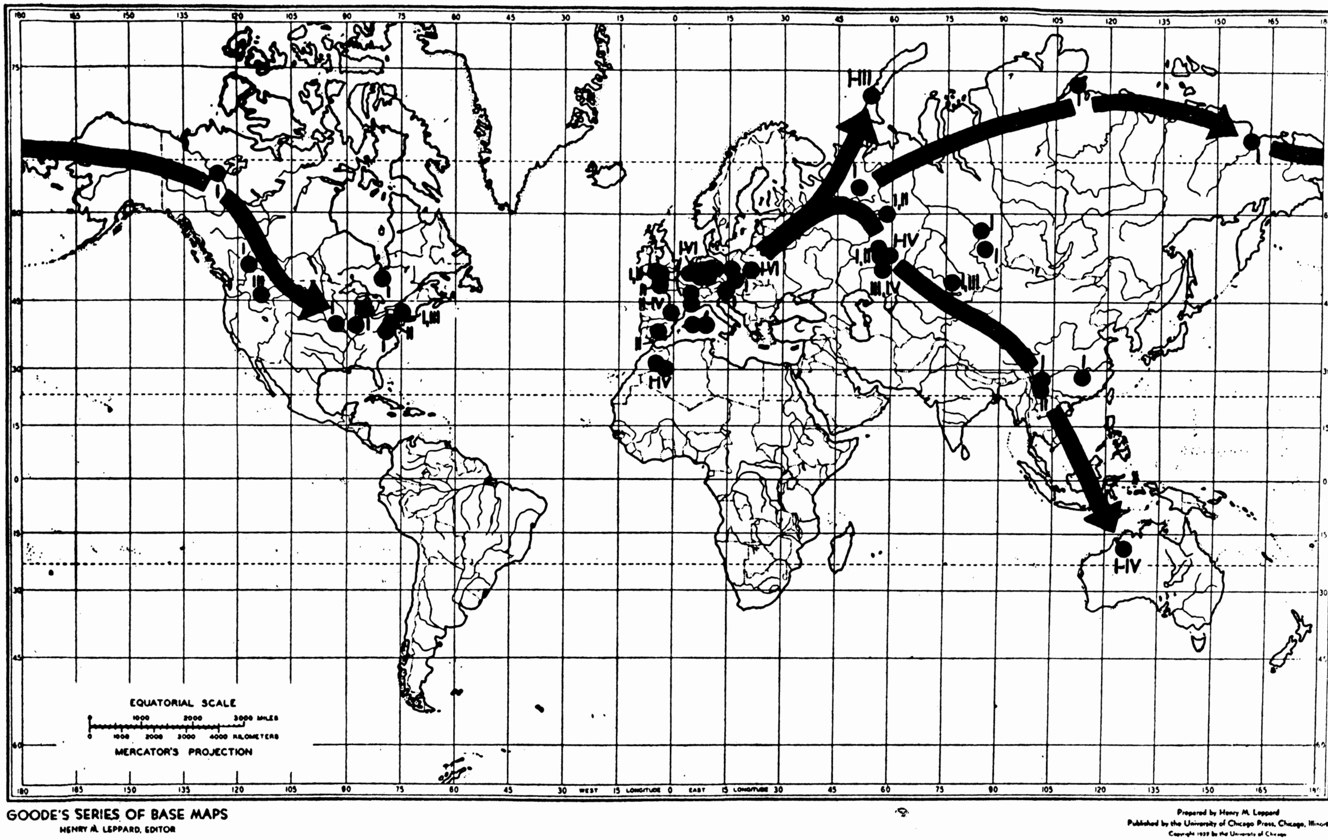

Fig. 4. Distribution and probable routes of migration of Upper Devonian goniatite faunas. The numbers I to VI indicate the occurrence of goniatites characteristic of the respective stages ("Oberdevonstufen").

available regarding most of these occurrences. He quotes various authors from whose writings it appears that the *Manticoceras* fauna is distributed at a few points along the Arctic coast of Siberia as far east as the Kolyma River, and that *Beloceras*, a member of that same fauna, has also been recorded from the Kuznetsk coal basin; furthermore, that *Sporadoceras* cf. *biferum* has been reported from the Kirghiz Steppe. We might add that according to information furnished by Muchketov and communicated by Kayser (1923, p. 228), *Beloceras* has also been found near Tomsk and *Pharciceras* and *Prolobites*—indicating presence of Oberdevonstufen I and III—in the Kirghiz Steppe, and that the occurrence of Frasnian goniatite beds in the Kuznetsk basin has been confirmed by more recent investigations (Yavorsky 1937, p. 42; Fomitchev 1937, p. 125).

As soon as we arrive at a line connecting the southern Urals with Novaya Zemlya we approach a region from which many occurrences of the Upper Devonian goniatite facies are known. Among these the sections at Verchne Uralsk and of Novaya Zemlya may be specially mentioned on account of their greater completeness. However, for these as well as for all other European and North African occurrences of the Upper Devonian goniatite fauna the reader must be referred to the summaries given by Schindewolf in 1921 and by Miller in 1938.

A map showing the world-wide distribution of the Upper Devonian goniatite faunas has been compiled (Fig. 4). It will be seen that, notwithstanding the scattered occurrences throughout Asia, the Western Australian goniatite sequence is more complete—and also, much richer in species—than any other goniatite locality anywhere east of the Ural Mountains. Also, the associated fauna, mainly of lamellibranchs and trilobites, is richer and more typical than any known outside Europe and North America. In particular the association of *Buchiola*, *Ontaria* and the trilobites *Cyrtosymbole*, *Pteroparia*, *Drevermannia*, *Chaunoproetus*, *Harpes*, and *Scutellum* with the goniatites of the *Manticoceras* fauna should be remembered. However, none of the Western Australian goniatite faunas approaches the contemporaneous faunas of central Europe as regards variety of genera and species.

If it is thus possible to trace the origin of the goniatite and associated fauna of Western Australia back to Central Europe, there seems to be little reason to assume another source for the fauna of the brachiopod and reef facies, and as a matter of fact I cannot see any element of that fauna in Western Australia which could not be derived from central and western European origins. It is true that certain genera, e.g. *Productella*, are much more prolific in Western Australia than in Europe; in this respect the Western Australia fauna is more like that of North America, but to explain this it seems unnecessary to assume migration of American species to Western Australia.

The best known Upper Devonian fauna of southeastern Asia is the Wetwin fauna in Burma (Reed, 1908, pp. 157-183), but this fauna has probably only one species in common with Western Australia, viz. *Athyris* cf. *spiriferoides*. Fenestrellinidae, *Chonetes*, *Lingula*, *Janeia*, *Phthonia* are prominent in the Wetwin fauna and absent from Western Australia. Reed states that the Wetwin fauna is allied to the Naples fauna of New York, but here again, as in the case of our comparison with New Guinea, we are obviously concerned with differences due to facies. Both the Wetwin fauna and the contemporaneous Western Australian *Manticoceras* fauna show relationships to the Naples fauna, but it must be remembered that the Naples fauna itself, or rather the various faunas found in the Naples facies which were included by J. M. Clarke under this name, is a derivative of Central European faunas, and a general resemblance with southeastern Asiatic and Western Australian faunas is, therefore, not surprising. It will appear from all these facts that at no stage during the time which the Western Australian Middle and Upper Devonian deposits represent can the Australian sea have been separated from the Chinese sea by a continuous land bar. In other words, Gregory's "Malaysia" did not exist (Gregory, 1930, p. lxxxii). Nor is it necessary to assume that the Upper Devonian fauna of eastern Australia arrived there from North America. All the known facts are best explained, if we assume a European origin of the Australian Devonian faunas.

It should be mentioned that Grabau (1931 and elsewhere) has advocated a Pacific origin of the greater part of the European Middle and Upper Devonian faunas, and that Clarke (1904, 1915) suggested that the *Manticoceras* fauna might have originated in northern Siberia, but a discussion of the interrelationships of Devonian faunas in general is outside the scope of the present paper.

Faunal Migration and Facies.

The wide distribution and uniformity of Devonian faunas is usually explained by trying to establish routes of migration by which faunas could have arrived at localities distant from their place of origin. Recently, however, Allan (1935) has attempted to replace this explanation by one which he applied in detail to the study of the distribution of Lower Devonian faunas. In his study of the Lower Devonian Reefton beds of New Zealand, Allan found that it seemed to be impossible to demonstrate the existence of any routes of migration, either by way of the Tethys or by a circum-Pacific route, along which that Lower Devonian fauna could have arrived in New Zealand. He then suggested (p. 35) "that facies has been the dominant element in the distribution of marine faunas at this period. The evidence points to a cosmopolitan fauna, which, as today, would vary with such factors as temperature, light, salinity, food conditions, and so on." He goes on to state that "the Reefton fauna is most closely related to that of the same age in Western Europe not because of geographical station, but because in both areas the physical conditions were identical, and that those parts of the cosmopolitan fauna inhabiting those areas being subjected to, or stimulated by, a similar set of environmental controls, are therefore closely related in their characteristic fossils." This idea has already been disputed by Shirley in 1938 who was able to present some, if slender, evidence for the existence of a Lower Devonian Tethys along which western European faunas could have reached New Zealand. Allan's thesis also seems to be disputable on general considerations. It implies, in fact, the polyphyletic origin of all Lower Devonian faunas, and should be equally applicable to faunas of other than Lower Devonian age. In the case of Middle and Upper Devonian faunas, however, we are in the much more fortunate position of being able to demonstrate the existence of migration routes which practically eliminate the necessity of assuming independent centres of origin for faunas of that age. Furthermore, if it is considered that the origin of new species seems to be conditioned by an accumulation of undirected gene mutations and a complicated repatterning of chromosomes, the chances for an independent origin of identical species in distant parts of the world will probably be rated low by the geneticist.

We must, however, be grateful to Allan for having emphasized with force the importance of facies as a dominant element in the distribution of Devonian faunas. The existence of routes of migration is a *conditio sine qua non* for the dispersal of any fauna, but its distribution along the route of migration and at points which can be reached via such routes will be entirely dependent on facies conditions.

Recently, Gayle Scott (1940) has presented convincing evidence that the ammonites of the Cretaceous of Texas are distributed according to bathymetric and facies zones, so that it can be concluded that the ammonites in that region were benthonic and necto-benthonic. As early as 1912 (p. 84) Diener had stated his opinion, mainly in opposition to views held by J. Walther and others, that "der Lebensbezirk der Tiere [ammonites] mit der Stelle zusammenfällt, an der wir die fossilen Schalen antreffen. Der passiven Verfrachtung der leeren Schalen . . . kann ich nur eine sehr untergeordnete Bedeutung für die Verbreitung der Ammoniten zuerkennen." But Diener still attempted to divide the ammonoids into nektonic and benthonic forms, as many authors before and after him. In 1930, Schmidt opposed such a division of cephalopods and concluded that the majority of shell-bearing cephalopods must be regarded as "epibenthonisch," a term which was proposed for the same mode of life for which Scott later used the word "necto-benthonic." However, it is not intended to enter into a general discussion of the palaeoecology of ammonoids. As far as Devonian ammonoids are concerned, their dependence on certain facies had already been suspected before. Thus, Wedekind had stated in 1926 (p. 201) that in the Devonian seas of Central Europe ammonoids were most prominent in a zone just outside the reef belt. Also, Miller and Furnish (1937) had proposed to explain the absence of late Upper Devonian ammonoid faunas in North America by the fact that "over much of our continent the uppermost Devonian is represented by a black shale facies."

Considering the conditions in Europe it becomes clear that the Devonian ammonoids preferred habitats at a moderate distance from, though not in the immediate vicinity of the shore. As can be seen from maps published by Schindewolf (1921), Von Bubnoff (1926, p. 24) and Wedekind (1926, p. 206) the Upper Devonian ammonoids flourished in great profusion and throughout the greatest length of time in the seas surrounding

Schindewolf's "Alemannische Insel," particularly, as described in more detail by Wedekind, in the narrow waters of the Rhenish Basin ("Rheinisches Becken") and the Straits of Dinant, where all the famous localities such as Givet, Famenne, Adorf, Enkeberg, the Dill Basin, the Lahn Basin, the Harz, Saalfeld, Hof (with Gattendorf) are situated. The eastern, southern, and western shores of the Alemannische Insel are marked by well known and prolific goniatite localities such as Ebersdorf, Brno, the Karnic Alps, Cabrières, Bourbon-Lancy. In the northwestern continuation of the Straits of Dinant we find the Devonshire localities at a moderate distance from the Northern Continent. In the east we find the complete and rich sections of southern Poland (Kielce and Lagow) not far from the northwestern shores of the Podolian Island. All these localities are situated at a distance of between 10 and 70 miles from the nearest land. It is true that localities such as Guadalmez in southern Spain, Minorca and southern Sardinia are much farther away from any known coast, but their goniatite faunas are poor and the sections less complete. The more complete goniatite sections of Tafilet and Bénis-Abbès in northwestern Africa are possibly not far removed from the north edge of the African continent.

As a rule the Devonian ammonoids must have avoided the wide open shelf seas, or else we would expect some trace of ammonoid faunas in central and northwestern Russia which was then covered by a shallow continuous sea. That we do not know of more ammonoid faunas around the old shore lines of the Podolian Island might be due to the fact that the Devonian deposits surrounding it must be mostly buried by younger sediments. It remains still unexplained why the ammonoids did not establish colonies along the shores of the Northern Continent in northwestern Russia, for it is probably by this route that the Central European goniatites and clymeniids migrated eastwards into the region of the Ural Mountains and Novaya Zemlya. In the Urals the geographical conditions in Upper Devonian time must have been somewhat similar to those in Central Europe. From the large amount of terrigenous material in Upper Devonian sediments it is concluded that a long and narrow N-S running barrier, or an archipelago, divided the Ural sea from the central Russian sea and it is mainly along the eastern side of this bar or archipelago that we find the good ammonoid localities such as Ai River, Mursakajewa, Verchne-Uralsk. The famous *Manticoceras* fauna of the southern Timan Ranges (Domanik) lived somewhere near the northern extension of this western Uralian bar and perhaps not very far from the shores of the Northern Continent. Proximity of a coast line (eastern shore of the great Northern Continent?) can also be assumed for the Upper Devonian goniatite deposits of the south island of Novaya Zemlya where Alferov (1937, p. 17) reports a thickness of 1200 meters for the Frasnian alone.

From the Urals the ammonoid fauna spread eastwards and seems to have moved around the southern as well as the northern shores of Angaraland. The occurrences of the *Manticoceras* fauna at Tomsk, Kuznetsk, and at the Katangha River are all close to the coasts of this continent, whereas the occurrences of the Kirghiz Steppe may have been farther out to sea. Along the northern route the ammonoids penetrated via the Kolyma River and the Mackenzie River Basin as far as central and eastern North America where they then developed in great variety in the State of New York. In North America also some indigenous genera developed, such as *Probeloceras*, *Raymondiceras*, *Schindewolfoceras*, and *Acanthoclymenia*. North America is the only Upper Devonian province which has produced ammonoid genera which are not known from Central Europe. It is interesting to notice that in North America Upper Devonian ammonoids develop in greatest abundance in the vicinity of the great Catskill delta of the northern Appalachians in a belt which keeps a moderate distance from Laurentia in the north and from Appalachia in the east. This appears clearly from the facts as presented originally by Clarke (1904) and from the more modern interpretation of palaeogeographical conditions published by Chadwick (1935a and 1935b) and by Moore (1941, p. 200).

To return to the Ural region we notice that from there the ammonoids also radiated in a southeastern direction towards the sea to the south of Cathaysia, the land mass which occupied the region that is now eastern China, Manchuria and Korea. How they managed to bridge the gap between southern China and Western Australia remains at present unexplained, because nothing is known about the palaeogeography of the East Indies in Devonian time. From what we know of their ecology it would, however, appear unlikely that the ammonoids would have been able to cross more than 3000 miles of open sea; on the contrary, such a sea would probably have formed an effective barrier to prevent most of the littoral and neritic life from reaching Australia. The presence in Australia of rich faunas which are closely related to Devonian faunas of southeastern Asia necessitates the assumption of the existence of land somewhere in the East Indian region during that period. Abéndanon (1919) and Benson (1922, p. 27) have already arrived at similar tentative conclusions, and although Rutten (1927, p. 607) has pointed out that Abéndanon's original arguments which he put forward in favour of the existence of some land in the East Indian region ("Aequinoctia") in Palaeozoic times were not convincing, we must say that, in order to explain the distribution of Devonian faunas in this part of the world, such an assumption is found very helpful.

In Western Australia the ammonoids settled and flourished in the northeast corner of a large embayment in geographical surroundings not unlike those existing at the same time in New York State: There was land to the east and to the north, and from the east an enormous delta was being built during the time of the Upper Devonian goniatite stages I to III which corresponds to the time represented in New York by the goniatite bearing strata from the Genesee to and including the Conneaut. In Western Australia the goniatites as a rule kept away from the coast, although occasionally goniatites have been found in layers between coarse conglomerates. On the whole, however, they preferred the outer reaches of the lagoon between the coast and the barrier reef and are found anywhere from 10 to 50 miles off the coast. Sometimes they inhabited smaller reefs inside the barrier reef, but they avoided the main barrier reef itself.

This brief review of the distribution of Upper Devonian ammonoid faunas seems to provide a very good demonstration of the influence of facies on faunal migration. It is obvious that goniatites and clymenoids found the outer neritic zone the most congenial environment, and that, where possible, they settled in the vicinity of reefs, though as a rule not on them, except in the case of reefs in a particularly sheltered position. It is also obvious that the Upper Devonian ammonoids required a specially well balanced set of environmental conditions, if they were to flourish in numbers. Routes of migration were open to them which enabled them to spread across the Globe from their European centre, but it is only in certain selected places along these routes that they succeeded in establishing a foothold. Next to the existence of sea communications facies is, therefore, the all-important factor which determines the distribution of Upper Devonian goniatite faunas.

Conclusions.

In these pages I have attempted to present a preliminary picture of the Devonian stratigraphy, palaeontology, and palaeography of the Kimberley District in Western Australia, as far as it has been possible to do so without a detailed study of the fossils. Rich Middle and Upper Devonian faunas are present among which a rich Upper Devonian goniatite fauna is of particular interest. In general it was found that all faunas are of European origin, although the Western Australian faunas differ in many respects from those of eastern Australia which are likewise derived from Europe. It is suggested that the American ("Chemung") element in the Australian Upper Devonian fauna might have been overestimated and that there may not be any necessity to assume any migratory routes across or around the Pacific by way of which North American forms could have arrived in Australia, as has been done by Gürich (1901), by Benson (1923) and by Gregory (1930). Also, there are some points to suggest that the eastern Australian faunas with supposed Chemung affinities are actually considerably younger, corresponding approximately to Stage IV, not to Stage I, of the Upper Devonian.

The main interest centres around the Upper Devonian goniatite fauna whose evolution in Western Australia agrees remarkably well—in some cases step by step—with the evolution of that group in Europe. Numerous genera of the goniatite and associated fauna are found in Western Australia which are not known to occur elsewhere outside Europe.

These observations should further strengthen the belief of American geologists in the soundness of correlation of Devonian strata by means of goniatites. This has of course long been recognised for the *Manticoceras* fauna of the United States, but also the various isolated occurrences of goniatites of younger age in North America should be correlated with their European equivalents with a great degree of confidence.

Some attention was given to the question of goniatite migration in relation to facies. Goniatites and clymenoids must have been adapted to rather specialized, delicately balanced, environmental conditions. They were epibenthonic animals, mostly of the outer neritic belt, and preferred environments at distances of more than 10 miles, but as a rule less than 60 or 70 miles from the coast. They certainly were not planktonic and did not swim about widely. One is even led to assume that their empty shells did not float about much and that postmortal transport was of little importance, for otherwise one would expect more frequent finds of ammonoid shells in deposits formed outside their own habitat.

It is interesting to find that these conclusions are in remarkable agreement with those reached by Scott for Cretaceous ammonoids.

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