THE DISTRIBUTION OF LOWER CARBONIFEROUS GONIATITE FAUNAS IN RELATION TO SUGGESTED CONTINENTAL RECONSTRUCTIONS FOR THE PERIOD

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ABSTRACT. The geographic distribution of Lower Carboniferous goniatite faunas (referred to seven faunal assemblages) are shown located on a modern map and on a suggested repositioning of the continents in Lower Carboniferous times. Except at the top of the Viséan the faunas generally are cosmopolitan and the reconstruction provides satisfactory migration routes along shallow seaways bordering continental masses. The reconstruction narrows the latitudinal range of the faunas and places them more symmetrically with regard to the postulated equator except for certain sites in Siberia. These are sufficiently anomalous as to question the placing of the Siberian Shield.

FINALITY in our knowledge of the distribution of fossil faunas may never be achieved. Even when all suitable outcrops have been located and explored, unknown sub-surface data will remain as a background of uncertainty. That even a reasonable approach to a complete knowledge of the global distribution of Carboniferous goniatites has not yet been achieved is evident from recent reports of important faunas from hitherto barren places. Thus, recent spectacular finds from the Arctic Canadian Islands, Japan, Uruguay, and surprisingly, South West Africa continue to force us to revise previous tentative conclusions. New descriptions of Russian faunas, including those from east of the Urals keep not only distribution data but also taxonomy and biostratigraphy in a state of flux. It is therefore with some trepidation that students of Carboniferous goniatites judge whether the known distributions seem to plot more naturally on a particular continental reconstruction than on a modern geographic map.

The palaeobiologic distribution map is initially compiled by transferring the sites of known occurrences of selected taxons on to a suggested continental reconstruction which takes into account both continental drift and polar wandering. The compilation is rendered more useful if the inferred positions of the principal land masses, as deduced from all relevant factors of palaeogeographic significance, is similarly transferred.

In judging whether the newly displayed distribution is more meaningful than that from the raw data, we might consider it more satisfactory and so containing at least an element of reality if it: (i) provides suitable migration routes for cosmopolitan faunas; (ii) suggests barriers for the isolation of endemic faunas; (iii) relocates fossiliferous sites in latitudes which seem more appropriate than in the original plot; (iv) results in symmetrically disposed 'diversity gradients' in relation to the palaeoequator.

It is generally thought that cephalopods migrated along relatively shallow seaways bordering continental land masses rather than by crossing open oceans. Palaeogeographic changes of relatively local effect might be capable of isolating fragments

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of the gene pool or producing environments selecting specialized forms. The modern *Nautilus* lives between latitudes 20° N. and 35° S. of the equator and if this (the only surviving externally shelled cephalopod) is a sufficient guide to the water temperature requirements of fossil forms, an equatorial (not necessarily symmetric) distribution would appear more reasonable than a more random arrangement (Ramsbottom 1971).

In the present state of our knowledge the evaluation of the diversity of goniatite faunas will have to be subjective but in the future it is likely that it may be quantified with some degree of confidence and agreement. Perhaps the most difficult task in compiling a distribution map is to see through the synonomy, refusing to accept the apparent anticipation by fossil taxa of present-day political boundaries.

In what follows the discussion is confined to genera interpreted in the widest sense in the belief that conclusions so broadly based reduce their chance of being an artifact of taxonomy.

GONIATITE DISTRIBUTION

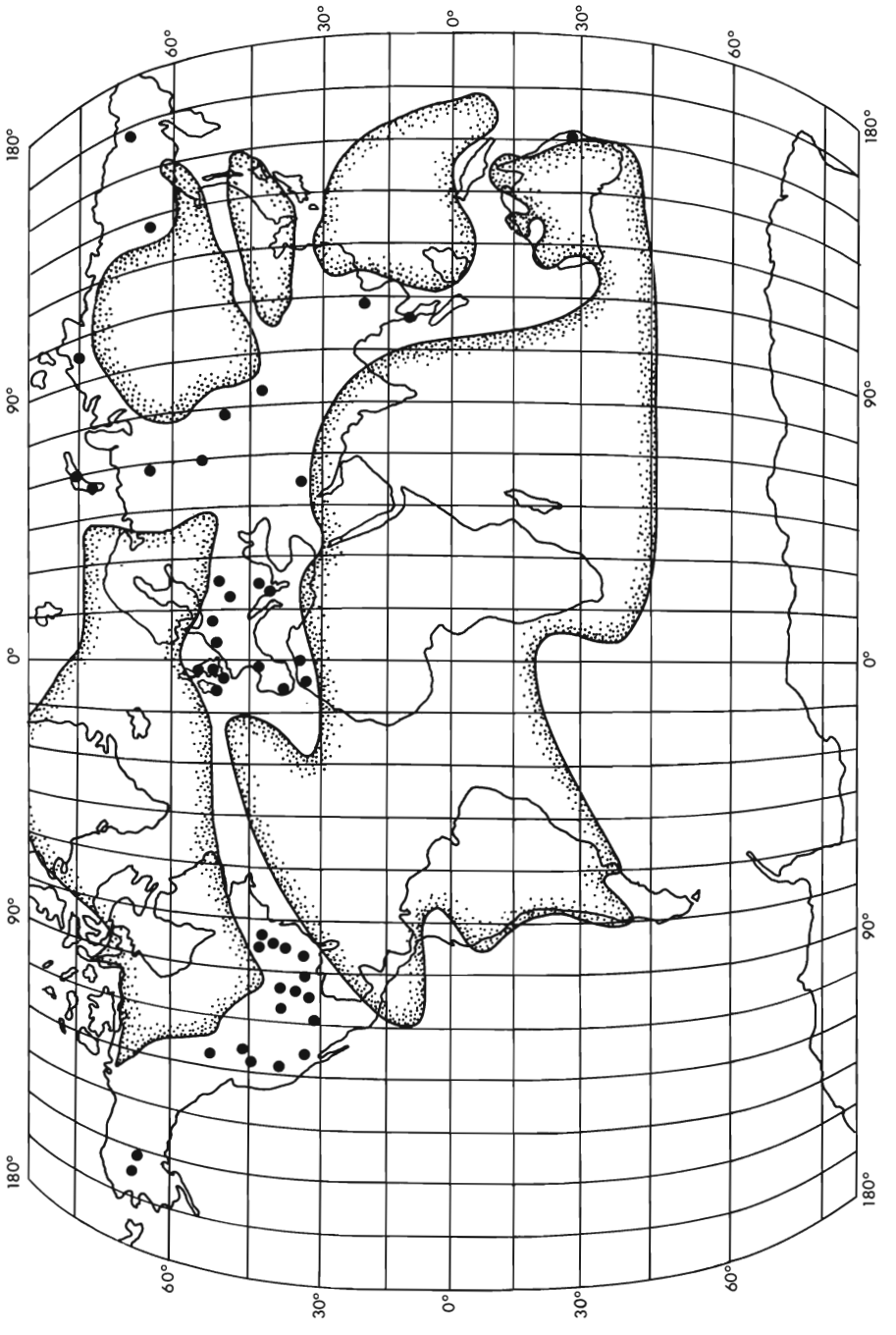
Lower Carboniferous goniatite faunas have been recovered from fossiliferous sites between latitudes 76° N. and 30° S. and from virtually circumglobal longitudes. But their distribution is very unequally apportioned between the two hemispheres. Thus, all Carboniferous goniatites are extremely uncommon in the Southern Hemisphere.

In Australia they are few and confined to the east being found in New South Wales and possibly in Queensland although the records of Jack and Etheridge (1892) from Queensland require revision. David (1950), however, records *Protocanites* and *Pseudarietites* from the Rockhampton district of Queensland.

In New South Wales there is an association of *Protocanites*, *Imitoceras*, and *Pericyclus* (?) (Delepine 1941, Campbell and Engel 1963). *Beyrichoceras* from younger beds in New South Wales (Cvancara 1958, Brown *et al.* 1965) indicates a higher level in the Lower Carboniferous. In addition, the genus *Cravenoceras*, indicative of the early Upper Carboniferous (Namurian), is also recorded from New South Wales (Campbell 1962). No Carboniferous goniatites are recorded from Western Australia (Perth, Caernarvon Basins) nor from the north-west (Bonaparte Basin) although Devonian and Permian goniatite faunas are well known in Western Australia.

Elsewhere in the Southern Hemisphere, records indicate Upper Carboniferous probably Moscovian. Thus *Pseudoparalegoceras* occurs in Peru (Berry 1928, Thomas 1928, Miller 1934, Newell *et al.* 1949), *Eoasianites* (*Glaphyrites*) is recorded from Uruguay (Closs 1967), South West Africa (Martin *et al.* 1970), and from the Argentine (Miller and Garner 1955). From the last country, the same authors also record *Anthracoceras*. All these finds in the Southern Hemisphere are based on only a few specimens in contrast to the huge collections which have been made at many localities north of the equator. Text-fig. 1 shows the distribution of the Lower Carboniferous goniatites. Since the time interval is estimated to span some 20 million years, it cannot be assumed that such a distribution was ever synchronous.

For the purposes of a more detailed survey the distribution is reviewed at seven successive time intervals during the Lower Carboniferous which can be biostrati-



TEXT-FIG. 1. Map showing distribution of Lower Carboniferous goniatites.

graphically defined as follows, and whose average duration would thus be something over 3 million years each:

vii	*Prolecanites* with Neoglyphioceratids	
vi	*Prolecanites* with *Goniatites* of *striatus* group	without
v	*Prolecanites* with *Goniatites* of *crenistria* group	Neoglyphioceratids
iv	*Merocanites* with Beyrichoceratids	
iii	*Merocanites* with *Muensteroceras*	
ii	*Protocanites* with *Muensteroceras*	
i	*Protocanites* without *Muensteroceras*.	

The basis of the scheme is the succession of three genus-biozones *Protocanites*→ *Merocanites*→*Prolecanites* which forms a continuously evolving lineage in the family *Prolecanitidae*. The ranges of accessory short-lived genera enables further subdivision as shown above.

(i). The first Carboniferous fauna is characterized by the occurrence of *Protocanites* unaccompanied by *Muensteroceras*. The main associated genera belong to the Imitoceratidae, namely *Imitoceras*, *Gattendorfia*, and *Kazakhstania* which are usually much commoner than *Protocanites* itself.

The fauna, on the basis of present knowledge is known from western Europe (U.K. and Germany), U.S.S.R. (Kazakhstan), North Africa (Gourara), and possibly Iran and Portugal. In some places it conformably succeeds Upper Devonian ammonoid-bearing beds and the region above delineated may represent the 'cradle' of its origin. Although *Protocanites* is recorded outside this region, indeed as far away as Australia and North America, the association there with *Muensteroceras* dates such beds as younger than those mentioned above.

Current European stratigraphic practice would name these beds Lower Tournaisian. Ruzhencev suggested the name Gattendorfian but the genus biozone of *Gattendorfia* has an appreciable range and some evidence is presented later which might indicate that the regional teilzones are diachronous.

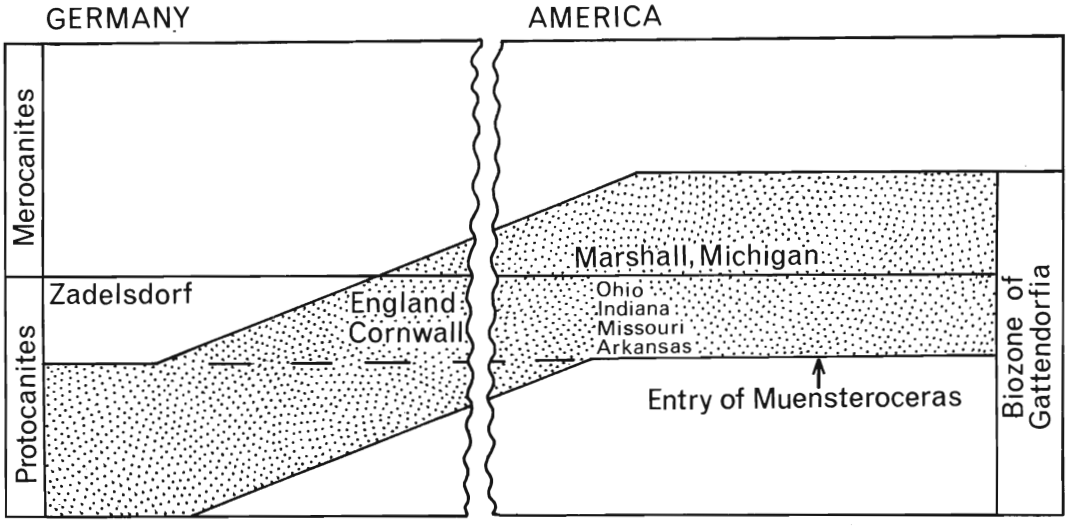
(ii). The second Carboniferous fauna contains an association of *Protocanites* and *Muensteroceras*. In contrast to the first fauna, it is cosmopolitan, known from Australia probably to Alaska. *Muensteroceras* (which persists at least into the third fauna) is the earliest unambiguous member of the Goniatitidae, the family particularly characteristic of the Carboniferous. It is widely distributed from Australia to Alaska and from Spain to the Taymir Peninsula. *Imitoceras*, *Gattendorfia*, and *Kazakhstania*, amongst the Cheiloceratids persist, and the heavily ribbed *Pericyclus* s.l. is a distinctive associate of *Muensteroceras* in some regions. However, *Pericyclus* s.l. also persists into the third fauna and may exhibit some provincialism for although it is relatively common in Europe, North Africa, Kazakhstan, and central Asia, it is very scarce in North America where only very few specimens have been found.

Apart from the patchiness in the distribution of *Pericyclus*, the fauna as a whole evidently occurs in Australia (New South Wales), north-west Europe (England, Belgium, and Germany), the Urals, Kazakhstan, and in North India (Gourara). It is widespread in the U.S.A. (typical at Rockford, Indiana) and probably occurs in Alaska and Alberta (Canada).

Chronostratigraphically in Europe the rocks enclosing the fauna are referred to the Upper Tournaisian which is the Tournaisian in the restricted sense of Ruzhencev.

(iii). The third Carboniferous fauna is marked by the entry of *Merocanites*. Both *Muensteroceras* and *Pericyclus* s.l. persist although the latter is rare in North America. *Gattendorfia* and *Kazakhstania* occur as relict genera directly associated with *Merocanites* in the Marshall Sandstone of Michigan (Miller and Garner 1955). Elsewhere *Gattendorfia* and *Kazakhstania* seem confined to the *Protocanites* biozone. If such is the case, then *Gattendorfia* is unreliable as a biostratigraphic index genus being diachronous (text-fig. 2). The typical *Merocanites*/*Muensteroceras* association, characteristic of the third fauna, occurs over a wide area. In north-west Europe it is found in Britain and Ireland, and Germany. It occurs in southern France and northern Spain and is well known from North Africa. (G4 fauna of Gourara and the S $_{1a-b}$ faunas of the Sud Oranais; Pareyn 1961.) It occurs in Iran (Stepanov 1971). In the U.S.S.R. it is recorded from the Urals (Librovitch 1947), central Asia, Tien Shan (Popov 1968), and possibly from Kazakhstan. It occurs also widely in the U.S.A. and probably in Alaska.

The fauna would be referred to the Late Tournaisian and earliest Viséan of European usage. Ruzhencev characterizes it as the Saourian.



TEXT-FIG. 2. Diagram of diachronous occurrence of the genus *Gattendorfia*.

(iv). The fourth Carboniferous fauna is marked by the incoming of the Beyrichoceratids which include the genera *Beyrichoceras* and *Bollandoceras*. This fauna is known in Britain and Ireland, Belgium, Germany, and Poland. It is found in Spain and is particularly well known from North Africa (Morocco and Sud Oranais). It possibly occurs in Iran whilst in the U.S.S.R. it is recorded from Kazakhstan and Tien Shan. In North America it is found in the U.S.A. and Alaska and is represented by a record of *Beyrichoceras* in New South Wales, Australia.

Chronostratigraphically it is sometimes referred to the Middle Viséan by European stratigraphers whilst Ruzhencev does not separately distinguish it and includes it in the Saourian.

(v) and (vi). The fifth and sixth Carboniferous faunas can be considered together since they have very similar distributions. The replacement of *Merocanites* by *Prolecanites* marks the base of the fifth fauna which contains *Goniatites* of the *crenistria* group including *G. hudsoni* Bisat. The sixth fauna contains *Goniatites* of the *striatus* group.

Neither is known from the Southern Hemisphere but they are widely known from numerous localities from Alaska to Malaysia where records of *Prolecanites* indicate one or other of these faunas. It is particularly well developed in north-west Europe from Ireland to Poland. In north-west Europe, twenty-six of the thirty-five species of *Goniatites* occur of which twenty-one species are currently considered exclusive to that region. Elsewhere six species are recorded from North Africa, three in the U.S.A., and five in various parts of the U.S.S.R. including Novaya Zemlya, the Urals, Kazakhstan, the Taymir Peninsula, and central Asia. These faunas are found in Spain and Portugal, Yugoslavia and Bulgaria.

In Europe these two faunas are included in the Viséan. Ruzhencev regards the stratigraphic range of the faunas as constituting the entire Viséan.

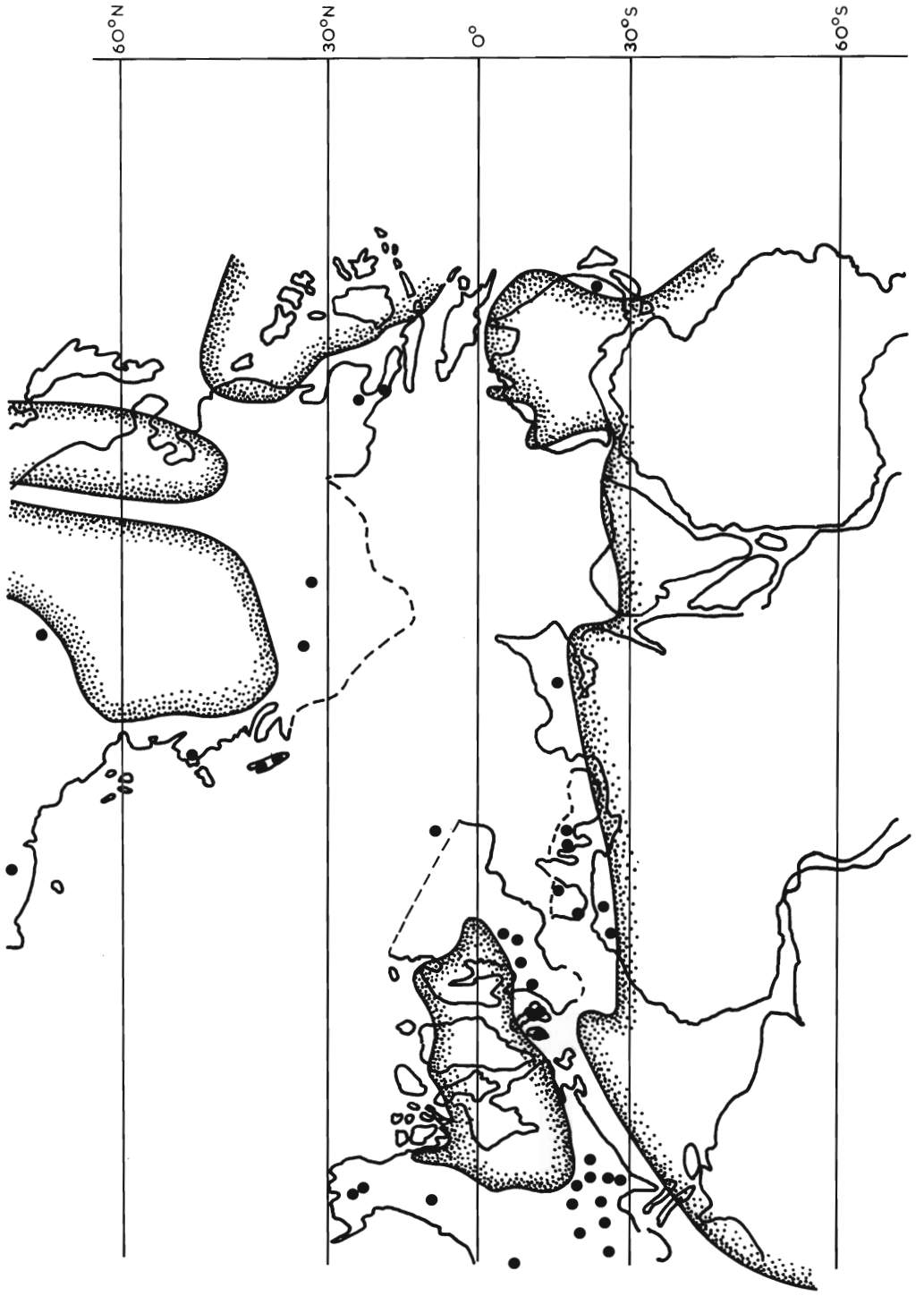
(vii). The seventh Carboniferous fauna is characterized by the appearance of the Neoglyphioceratids with *Prolecanites* as an associate in typical assemblages and which, with the related *Dombarocanites* makes up about 15% of the fauna (Ruzhencev and Bogoslovskaya 1971).

Typical genera are *Neoglyphioceras*, *Lusitanites* (= *Paragoniatites* auctt.), *Mesoglyphioceras*, and *Lyrogoniatites*. A noteworthy feature is the recognition of the same *species* in widely separated localities. Thus *Mesoglyphioceras granosum* is found in the U.S.A., north-west Europe, Spain, North Africa, and Kazakhstan. *Neoglyphioceras spirale*, *N. caneyanum*, and *Lusitanites subcircularis* also have widespread geographic ranges.

The seventh fauna is found in Britain and Ireland, Belgium, Germany, southern France, northern Spain, Portugal, Algeria, and Morocco. It is widespread in the U.S.A. from Utah to Georgia and is recorded from Alaska. In the U.S.S.R., it is found in the regions of Aktubinsk, Orenburg Karaganda, and Kazakhstan as also from the Taymir Peninsular and the southern Verhoyansk region.

Yet notwithstanding the wide range of the fauna and of species characteristic of it, it is at this level that provincialism become evident. The composition of the north-west European fauna differs widely from those elsewhere. Thus in the Urals the Prolecanitidae (16%), the Agathiaratidea (21%), the Pronoritidae (3%), the Delepinoceratidae (6%), and the Ferganoceratidae (5%) make up half the fauna and all these are completely absent in north-west Europe. This provincialism is much more marked in the Upper Carboniferous (Ramsbottom 1971).

Evidently the palaeogeographic changes which almost isolated the Upper Carboniferous of north-west Europe were initiated about the time that the seventh fauna evolved. These changes involved the elevation of a Sudetic ridge stretching from Ireland to Czechoslovakia (at least) and separating the 'pro-Tethyan' seas from a north-west European trough whose northern edge was the southern side of the Acadia/Baltica shield. Ramsbottom (1971) has indicated that this trough was particularly narrow at its eastern edge in south-east Poland and possibly subject to periodic closure. It would also seem to have been closed to the west of Ireland so



TEXT-FIG. 3. Lower Carboniferous goniatite occurrences plotted on a symposium map for the Lower Carboniferous.

that direct faunal migration from North America to north-west Europe was at times inhibited.

The seventh fauna is included by Ruzhencev in the Namurian, though this is contrary to international agreements about the base of that series.

DISCUSSION

The distribution of the Lower Carboniferous goniatite faunas shown in text-fig. 1 differs little from that of the Upper Devonian goniatites plotted by House (1964, fig. 2) or from the Middle Devonian Stringocephalid brachiopods (Boucot *et al.* 1966, fig. 2).

When the continents are reassembled according to the symposium arrangement of Smith, Briden, and Drewry (text-fig. 3), the Lower Carboniferous goniatite-yielding regions are, with exceptions to be noted, brought within a much narrower latitudinal range. Thus apart from the most easterly Russian sites they come to lie within a belt bounded by limits about 30° north and south of the postulated equator. Amongst those sites not brought within this belt, those of Kazakhstan and Tien Shan are near the northern limit and the lack of precision causes sufficient uncertainty as to doubt whether they lie significantly outside the limits. The localities in Novaya Zemlya would not be anomalous if that region had not been (possibly arbitrarily) associated with the Siberian rather than the Baltic plate.

However, the Taymir Peninsula, relocated about 50° N., remains anomalous and, even more so, the sites east of the 'Angaraland' block. Thus the South Verhoyansk region comes to lie at least 65° N. and a locality plotted by Librovitch (1947, fig. 2) as yielding Viséan goniatites (now 64° N., 162° E.) would occupy an even more northerly latitude.

These anomalies, which could also be shown by the Devonian faunas mentioned above, might suggest a further consideration of the placing and orientation of the Siberian plate. In this connection it is to be noted that the distribution of Carboniferous evaporites has been claimed to support a different continental reassembly for that period due to Creer and Runcorn (Lotze 1964, fig. 8; Green 1961, fig. 4). Replotting of these sites also displays an equatorial distribution except for anomalous records east of the Urals.

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