# DISCUSSION OF SOME RECENT PAPERS ON ANCIENT CONTINENTAL CONFIGURATIONS RECONSTRUCTED FROM PALEOMAGNETIC EVIDENCE

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## SUMMARY

In theory it is possible now to reconstruct the ancient continental configurations, both in latitude and in longitude, from paleomagnetic data alone. The papers that have first applied this new method are discussed.

At present only the data from Africa and South America seem appropriate for practising the theory. Their configuration (Creer, 1964a) agrees with the well-known continental drift hypotheses. Creer's ideas on the Upper Paleozoic positions of the Laurasian continents are not shared by the present author.

## INTRODUCTION

Independently of each other Creer (1964a, 1964b), Graham et al. (1964) and Van Hilten (1964a) reached the conclusion on theoretical grounds that relative ancient continental configurations can be reconstructed from paleomagnetic data. Formerly we thought that only the continents' ancient latitudinal positions could be retraced; now we are able to reconstruct also the relative ancient longitudes when sufficient and reliable data are available, and provided that these data are suitable for such a reconstruction: it is shown by these authors that the characteristic item to look for is identical curvature of polar wandering paths over the same geological time interval. When such paths are found and brought to coincidence with one another, the continents show their ancient relative positions during that time. The identical curvatures develop when the continents have not performed relative movements with respect to one another during the period considered.

This notion makes paleomagnetism a most valuable tool for the unbiassed testing of continental drift hypotheses. This was also realized by the authors mentioned above, and they made attempts to put into practice the fruit of their thoughts: the results thereof should produce continental configurations free of geological speculations; they are based only on the usual assumptions regarding the character of the ancient magnetic field.

There is little to say about my paper (Van Hilten, 1964a) because I could not find the required similarities in the polar wandering paths; so I concluded that the method could not (yet) be applied in practice at that time. Considering now the practical parts of the other papers, we are happy to observe some points of agreement with well-known continental drift hypotheses. There remain places where the opinions seem to conflict, but this is mainly due to differences in the sources used rather than in the application of the method.

## ANCIENT GONDWANALAND

Graham et al. (1964) confine their attempts to a reconstruction of the Late Paleozoic Gondwanaland, and they find that only the paleomagnetic data of Africa and Australia come near to satisfying the criterion of equal curvature in a given period. In fig.2b, 2c and 2d they show the various positions which Africa and Australia might have occupied with respect to one another. They agree that the situation depicted in fig.2b may be ruled out as it fails to give the Permian pole for Australia, newly determined by Irving and Parry (1963), the weight it deserves. In fig.2c and 2d (Graham et al. 1964) two alternative configurations are presented, fig.2c with the respective Middle Paleozoic and Permian poles of both continents coincident, fig.2d with the Permian and Mesozoic ones brought to coincidence. Thus the polar wandering paths of Africa and Australia from the Silurian till the Mesozoic do not have identical shapes (determinable by at least three pole positions on each path), but only two pairs of equally separated poles, offering two different possibilities of reconstruction. If we have to choose between these I would prefer the configuration of Africa and Australia presented in fig.2d (given here in Fig.1A), as the "Silurian" pole of Africa appears to be based on rocks from one stratigraphic bed, from only one road-cut sampling site; furthermore, the age of these rocks is not known precisely, being "certainly not younger than the Middle Devonian and approximately equivalent to the Lower Devonian; it may, however, possibly range down into the top of the Silurian" (Du Toit, 1954, p.183).

Creer (1964a) has similar difficulties in arranging Africa and Australia in agreement with their paleomagnetic records. He finds that the well-known reconstruction by Du Toit (1937) gives the best solution to the problem, though only the Permian poles of Australia, Africa and South America are reasonably well together and their other coeval poles are not coinciding at all (see Creer, 1964, fig.7, shown in Fig.1B in this paper). In Du Toit's fit the Devonian-Silurian pole of Australia comes to lie close to the common polar wandering path of Africa and South America; however, it lies half-way between their Carboniferous and Devonian poles instead of between the Silurian and Devonian ones.

This comparison between Creer's (1964a) reconstruction and that by Graham et al. (1964) demonstrates that it is still not possible to make an unprejudiced reconstruction on mere paleomagnetic observations of the relative positions of Africa and Australia during the Upper Paleozoic, simply because their polar wandering paths have not the required identical shapes over a sufficient period. The difference, however, between what these authors think the best solutions is small, and their Africa–Australia configuration is very near to what geologists have predicted on geological grounds.

Creer attains a more spectacular result with his African and South American data (see Fig.1B), the latter having not yet been available to

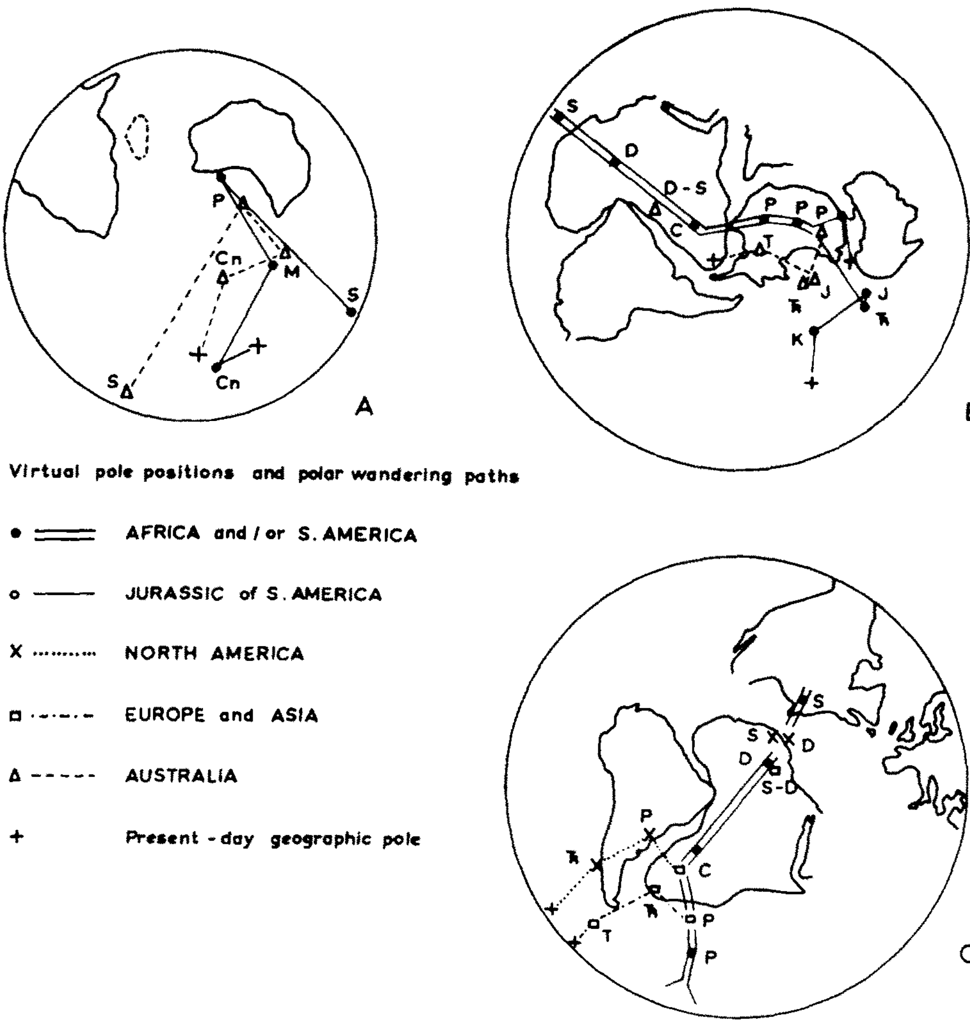


Fig.1. The discussed reconstructions of ancient configurations of continents as found by fitting together of their polar wandering paths: A. The Permian–Mesozoic configuration of Africa and Australia presented by Graham et al. (1964, fig.2d). B, C. The Upper paleozoic configurations, simplified after Creer (1964a, fig.4, 7; 1964b, fig.2). The centres of projection are without significance. S = Silurian; D = Devonian; C = Carboniferous; P = Permian; M = Mesozoic; T = Triassic; J = Jurassic; K = Cretaceous; Ŧ = Tertiary; Cn = Cenozoic.

Graham and his co-authors at the time of their writing. After thermal demagnetization of the Permian and older rocks, the polar wandering path of South America from the Silurian up till the Permian shows a curvature identical to that derived from African magnetizations during that period. When brought to coincidence Africa and South America occupy precisely the adjacent positions that are favoured by the classical theories on continental drift.

To dwell a little longer on ancient Gondwanaland: in a later paper Creer (1964b) envisages also the virtual poles of India and Antarctica, still on the basis of the Du Toit hypothetical reconstruction. Here speculation enters the story, for Creer begins to draw conclusions as to the possible position of the (not yet measured) Triassic virtual pole of Antarctica and the time of breaking open of Gondwanaland into the continental fragments. Such speculations are not based anymore on the sound arguments mentioned in the beginning of this paper, but are mere deductions starting from a hypothetical situation (Du Toit's fit); many similar papers might be written with even more startling deductions, depending on from which hypothetical configuration of Gondwanaland one starts.

## CREER'S RECONSTRUCTION OF LAURASIA

Creer (1964a) pays much attention to the question of the Devonian pole of Europe. In their thorough analysis by thermal treatment of the magnetization of Old Red Sandstones Chamalaun and Creer (1964) and Chamalaun (1964) point out that what was formerly considered to be the European Devonian pole is derived from rocks that were probably remagnetized during the Permo–Carboniferous. The stable direction of magnetization they found, after thermal demagnetization of their rocks, is quite divergent and produces a new virtual pole position that is far from the other European and Asian Devonian poles (see Fig.2). If this new Devonian pole position is accepted, the new European polar wandering path looks in some respects like that found for Africa and South America, in particular in the great separation between the Permian and Devonian poles. Furthermore, Creer distinguishes a similar traject in the polar wandering path of North America, enabling him to bring into coincidence in total four polar wandering paths in their Permo–Devonian trajects. The configuration of the four continents resulting from this manipulation is presented in Creer's fig.4 and 5, and their essentials are shown here in Fig.1C. This Upper Paleozoic reconstruction struck me as rather improbable when compared with other recent reconstructions on paleomagnetic data by Irving (1964, fig.10.17, p.270) and by me (Van Hilten, 1964b, pl.II); independently we are both forced to introduce an appreciable eastward displacement of Africa relative to Laurasia, because otherwise parts of these continents would have to be superimposed owing to lack of room in between them. Creer's reconstruction, on the contrary, shows a big gap between Africa and Laurasia.

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Fig.2. The Devonian virtual pole positions of Europe (dots) and Asia (crosses) plotted on the Northern Hemisphere (stereographic projection). These poles have been compiled from the lists published by Cox and Doell (1960) and by Irving (Geophys. J., 1960–1963). Pole V is the one given by Vlasov and Kovalenko (1963). The divergent pole at 10°N 40°W is the "revised" European pole after Chamalaun and Creer (1964).

## THE NORTH AMERICAN DATA

A survey of the data used by Creer showed me that the resemblance of the polar wandering path of North America to those of Africa and South America in the pre-Permian traject is less close than Creer suggests: the Devonian pole of North America is at least doubtful, because the magnetization of the rocks used must have been post-depositional (Cox and Doell, 1960, p.697). The directions of magnetization are derived from both flat lying and deformed beds, yet they lie close together in the diagram (Graham, 1956, fig.3, p.738); in other words, these magnetizations do not satisfy Graham's fold test for stability. As for the Ordovician of North America, Creer used only two of the three known poles, viz. C 37 and C 38 from Cox and Doell's (1960, p.699) list, leaving out of consideration pole C 40. Concerning pole C 37, its original author (Graham, 1956) admits that post-depositional magnetization is present in the rocks from which it was derived; these rocks are samples from a

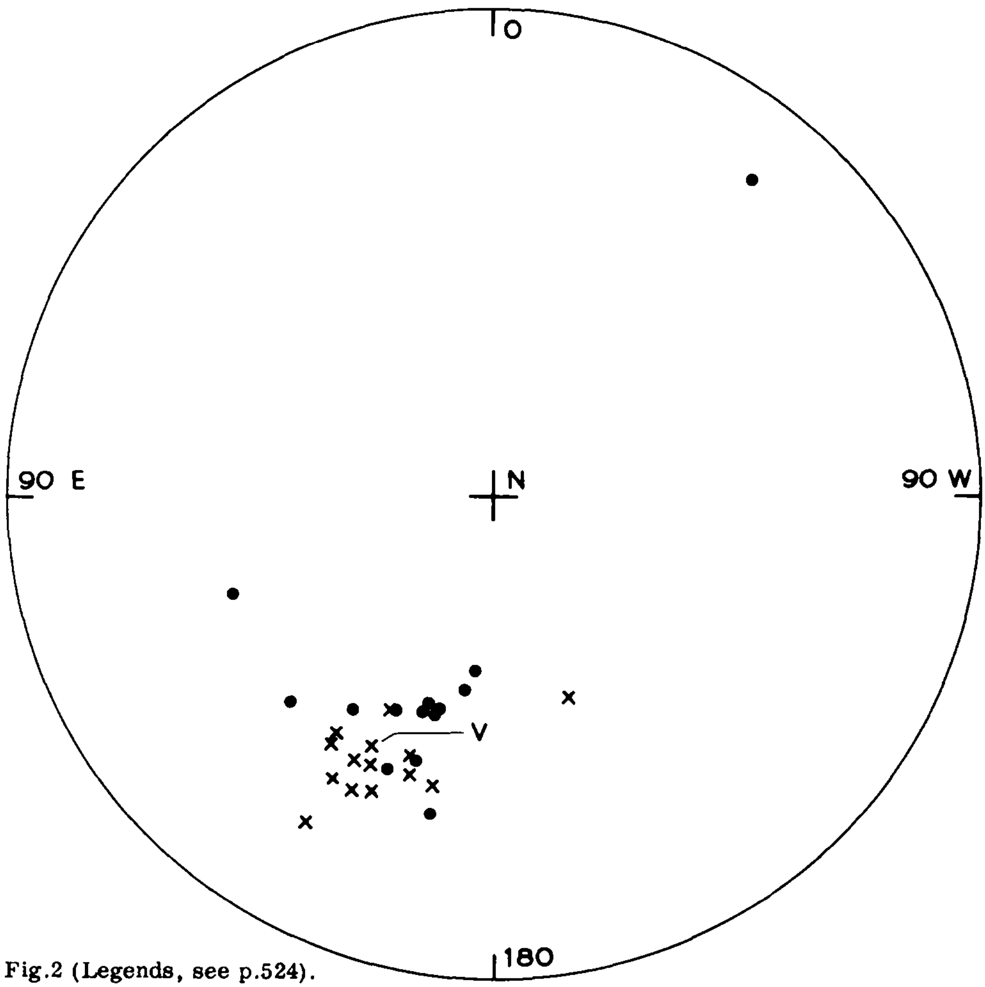



Fig.2 (Legends, see p.524).

limestone conglomerate, of which the directions of individual pebbles show a fairly close cluster (Graham, 1956, p.738 and fig.2); generally this (the "conglomerate test") is taken as a strong indication that much of the magnetization entered the rocks after deposition. The fold test has been applied to the magnetizations responsible for pole C 38; its original author produces a diagram (Graham, 1954, fig.5, p.219) from which it can be seen that the magnetizations of distorted strata are less scattered than might be expected from the deformation. These magnetizations are considered post-depositional both by Cox and Doell (1960, p.699) and by Irving (1961, p.79, footnote 23). The Ordovician pole C 40 that is left out of account by Creer, is situated far from C 37 and C 38. Finally, there is yet another pole left out of consideration by Creer, the Silurian pole C 21 in Cox and Doell's list. Stability of its magnetization is indicated by the fold test. It lies quite close to C 40, and therefore also rather away from the North American polar wandering path as devised by Creer.

## THE EUROPEAN DEVONIAN POLE

The aberrant position of the newly determined Devonian pole for Europe with respect to the other Devonian poles derived from European and Asian rocks (see Fig.2) is explained by Chamalaun (1964) by the assumption that all Eurasian rocks of that age might have been remagnetized during the Permo–Carboniferous. Such a dramatic, continentwide phenomenon looks hardly probable to me in view of the diversity of rocks and their tectonic histories, and the occurrence of both normal and reversed directions of magnetization in a number of cases. On the other hand, the convincing results obtained by Chamalaun and Creer by thermal demagnetization cannot be reasoned away, and I will not try to do so.

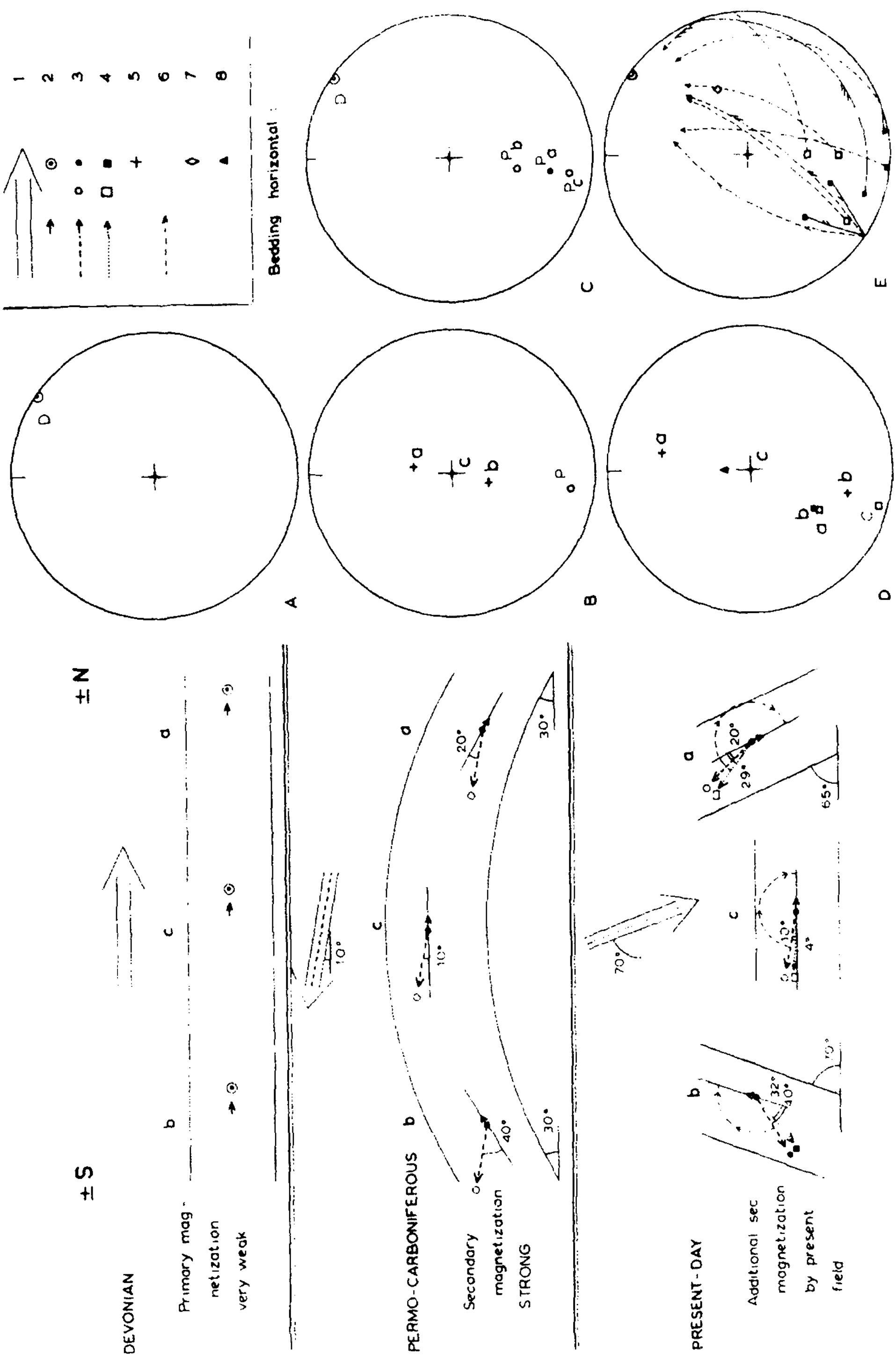
A careful study of their observations, especially the stereographic plots of the change in direction of magnetization during the various stages of demagnetization, convinced me that most of the samples had probably not been completely cleaned. This certainly goes for the samples from Nant Du and Portishead (In: Chamalaun and Creer, 1964, fig.7, 8) and for some of the specimens from Cwmbran (fig.6 of the same article). Even one of their best examples (specimen BR 26 D 1; see Chamalaun, 1964, fig.9, 10) shows that a small secondary component, possibly parallel to the ancient Permo-Carboniferous geomagnetic field, might well be still present in the final direction of magnetization after treatment at a temperature of 650°C: the vector diagram presenting the change in direction of the specimen (Chamalaun, 1964, fig.10, unfortunately the only vector diagram of the whole paper) fails to prove that the secondary magnetization has been removed totally. This might be so if the vector stopped changing its direction between the final two stages (600° and 650°) of the demagnetization procedure.

It is possible now to get a fairly good idea of what might have been the direction of magnetization of these rocks by extrapolating the demagnetization process beyond the last measurement (after treatment with the highest temperature) shown in the stereographic plots of Chamalaun and Creer (1964). The path in the projection along which the demagnetization process tends to displace the vector from the NRM direction towards the direction measured on the more or less cleaned specimen, is well shown in the diagrams; we have therefore only to extend these paths - most of them are great circles or approximations thereof - beyond the last measurement and we can observe then that these great circles appear to intersect near the border of the north-eastern part of the projection (see Fig.3, diagram E). This intersecting of the great circles means, in fact, that the scatter of directions is there at a minimum. (This method could be regarded as an extension of Graham's fold test: the point of minimum scatter, i.e., the direction of the primary magnetization, is reconstructed for various samples taken from differently dipping strata; this reconstruction can be carried out when it is known what secondary direction of magnetization, in this case the Permo–Carboniferous one, has influenced the NRM. (A more extensive paper on this matter is in preparation).

I would not have bothered the reader with this tedious reconstruction if its results were not surprising: the direction thus obtained with a declination of some 35° east of north and an almost horizontal inclination, is very near to that usually taken as the direction of the Devonian geomagnetic field in Europe! Other examples of this "normal" direction are known, though the majority of Devonian directions of magnetization show "reversed" polarity. In Fig.3 a sketch is presented which depicts the paleomagnetic history of the Devonian rocks of the Anglo-Welsh Cuvette (Old Red Sandstones), after data from Chamalaun and Creer (1964) and Chamalaun (1964), according to my views. My interpretation gives full credit to the work of Chamalaun and Creer. However, where they calculated a mean direction of magnetization from specimens that are possibly not yet completely cleaned, I propose to extend a bit further their demagnetization trends, finding thus a direction where the scatter is at a minimum; this direction has the great advantage that it appears to coincide with the classical direction of the ancient Devonian field in England, solving thus at the same time what might develop into the "problem of the Devonian pole for Europe".

Additional evidence in favour of their newly found direction is brought forward by Chamalaun and Creer in the direction of magnetization obtained by Stubbs (1958) on Lower Old Red Sandstone lavas from Scotland, which comes very near to the directions found by them ($D$ = N 60°E, $I$ = - 38° and $D$ = N 66°E, $I$ = - 37°). However, Nairn (1960) has also made a paleomagnetic survey of the Scottish lavas, finding a well clustered group of magnetizations with a mean direction of $D$ = N 35°E and $I$ = + 5° (the classical Devonian direction of magnetization in Europe).

The suggestion of Chamalaun and Creer (1964, p.1616) that most of the other Eurasian magnetizations of Devonian rocks were not representative, and Creer's (1964a, p.1118) statement that there exist no reliable Middle Paleozoic observations in Siberia, is sufficiently contradicted by the paleomagnetic survey of Lower Devonian rocks by Vlasov and Kovalenko (1963): they made a scrupulous analysis of some reversals of the Devonian geomagnetic field registered in a sedimentary column. Using laboratory techniques like AC-demagnetization and thermal treatment of the specimens collected, they found, besides the wandering path of the pole over the globe during the reversals, two neat clusters of magnetizations, almost a 180° apart, representing the normal and reversed directions. Such a reversal test is just as good as the fold and conglomerate tests. The pole calculated from these magnetizations by Vlasov and Kovalenko lies in the middle of the cluster of the other European and Asian poles of the Devonian (see Fig.2).


±S
±N
DEVONIAN
Primary magnetization very weak
PERMO-CARBONIFEROUS
Secondary magnetization STRONG
PRESENT-DAY
Additional sec magnetization by present field
Bedding horizontal :
A
B
C
D
E

To summarize, I do not see enough arguments to revise the European Devonian pole position in the way put forward by Chamalaun and Creer. For his reconstruction of the Upper Paleozoic configuration of Laurasia (Fig.1B, 1C) Creer bases himself completely on this revised Devonian pole and on a personal selection of Middle Paleozoic data from North America, which leads to a marked dispersion (see Fig.1) of the truly Upper Paleozoic (Permian) poles, of which the reliability is far less questionable. As a result, it is not surprising that Creer's reconstruction differs on some essential points from those obtained by other paleomagnetic reconstructors (Irving, 1964; Van Hilten, 1964b).

## CONCLUSIONS

(1) At present the only paleomagnetic data adequate for application of the newly discovered method of reconstructing the ancient relative positions of continents are those of Africa and South America for the Paleozoic. Their side by side position thus found (Creer, 1964a) is in excellent agreement with that predicted by geologists on the well-known paleontological, structural and morphological arguments.

(2) For the relative positions of Australia and Africa during the Upper Paleozoic two different solutions seem possible (Fig.1A, B, borrowed from Graham et al., 1964, and from Creer, 1964a respectively). Both configurations suggest that these continents once formed part of Gondwanaland.

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Fig.3. Schematic sketches and stereographic projections of the magnetic history of the Devonian Old Red Sandstones of the Anglo - Welsh Cuvette. (After data of Chamalaun and Creer, 1964, and Chamalaun, 1964, interpreted by the present author.) Examples are shown of the three different attitudes of strata, presently dipping North (example a), South (b), and flat laying (c). The weak primary magnetization of Devonian age (D in the projections) is far outweighted by the strong secondary component that entered the rocks during an early stage of the Permo-Carboniferous deformation (P in the projections). Possibly a minor viscous magnetization was added under the influence of the present-day magnetic field.

Diagram E is a compilation from Chamalaun and Creer's figures which shows some representative paths of the magnetization vectors during thermal demagnetization. These paths seem to converge near the northeastern border of the projection (i.e., the direction of the Devonian geomagnetic field in England, in agreement thus with a great number of palaeomagnetic investigations in Europe and Asia), rather than near the direction favoured by Chamalaun and Creer (also indicated) on which they based their aberrant "revised" pole position. 1 = Direction of the geomagnetic field at times of (re)magnetization; 2, 3, 4 = resultant direction of magnetization after entering of the Devonian (2) component, the Permo-Carboniferous (3) component, and the present-day (4) component (full symbols in lower hemisphere); 5 = bedding normal in upper hemisphere; 6 = demagnetization trends compiled from diagrams of Chamalaun and Creer (1964) (full lines in lower hemisphere); 7 = devonian direction of magnetization according to Chamalaun and Creer (1964); 8 = direction of present geomagnetic field in southern England.

(3) Creer's (1964a) paleomagnetic reconstruction of the northern continents is open to serious doubt since (a) he selected for his reconstruction data which are generally regarded as unrepresentative of the geomagnetic field of that period (Devonian and Ordovician of North America); (b) he left out of consideration data that do not fit his ideas (Ordovician and Silurian of North America), and (c) he prefers to determine the Upper Paleozoic position of Laurasia solely by his "revised" Devonian pole rather than by the many and reliable Permian poles. As I have shown here the observations on which this revision of the European pole for the Devonian was proposed by Chamalaun and Creer (1964) and Chamalaun (1964), can just as well be interpreted so as to fit in with the majority of the other 27 determinations of Devonian pole positions for Europe and Asia.

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