

# LUCIEN CAYEUX: A CHALLENGER OF THE PRINCIPLE OF UNIFORMITY IN GEOLOGY?

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Lucien Cayeux, the famous French sedimentary petrographer, published in 1941, a few years before his death, a book entitled *Causes anciennes et causes actuelles en géologie* which summarized his lifetime experience. This volume has been strongly criticized as being a refutation of the principle of uniformity in geology. Cayeux was supposed to be of the opinion that the formation of certain past marine sediments can only be explained by the operation of mysterious ancient causes and that the latter are totally non-existent today, having been replaced by an entirely different set of present causes.

A translation in English of Cayeux's volume has revealed that his statements are not so categorical. Actually Cayeux has shown that 'ancient' and 'past' causes were associated at all times forming a pool of *permanent causes*, but during given periods the effects of certain causes were largely predominant while the effects of others were barely noticeable or restricted to certain areas: at other periods the reverse would occur. For Cayeux 'ancient' and 'present' causes really mean ancient and present situations during which permanent causes led to different geological results, namely different sediments. In conclusion, Cayeux remains as uniformitarian as his critics.

Lucien Cayeux (1864–1944), at the end of an unusually productive career—almost 50 years—in the microscopic investigation of the entire spectrum of sedimentary rocks presented in a book entitled *Causes anciennes et causes actuelles en géologie* (1941, Paris, Masson & Cie) a viewpoint which has been generally considered until today as a refutation of the principle of uniformity.<sup>1, 2</sup>

According to his two critics, Laffitte<sup>3</sup> and Rutten,<sup>4</sup> Cayeux is supposed to be of the opinion that the formation of certain past marine sediments can only be explained by the operation of mysterious ancient causes, and that the latter are totally non-existent today, having been replaced by an entirely different set of present causes. Hooykaas,<sup>5</sup> after a long discussion of Cayeux's ideas where he essentially agreed with the criticism of Laffitte and Rutten, assumes that Cayeux's concept could be considered approximately as follows: 'The causes of some geological changes of the past *differ in kind from those now in operation but are not more violent.*' That is, in former periods of the earth's history forces of another kind ('ancient causes') were operating, but they were not of a more catastrophic character than those in action now.

This assumed doubt about the validity of uniformitarianism, an attitude in flagrant opposition to the permanency of the fundamental laws of physics, seems rather extreme to be adopted by such an experienced geologist as Cayeux. This position could not even be considered as hasty or senile taken near the end of his career, since the first expression of it may be found in his doctoral dissertation dated 1897. It will reappear as leitmotif in some of the conclusions of his voluminous monographs on the chalk, the iron ores, the siliceous rocks, the carbonates and the phosphates. Since there is still today no question about the validity of the fully documented observations that he presented, it seems to me that Cayeux's critics have misunderstood his message.

While undertaking the translation of this volume (to be published in 1971 by Hafner Publishing Company, New York), I had to take a very careful look at the wording of Cayeux's statements and it became apparent that they contain many nuances and are consequently not so categorical as they seem to be at first glance.

I shall quote here, in their order of presentation by Cayeux, some of his major statements and conclusions followed by a few appropriate comments :

'... present processes are not always capable of explaining past events...' (p. 8, original pagination). He says *not always* (French: *pas toujours*), therefore, present processes are able, in some cases, to explain past events. '... I am not going to challenge point by point the doctrine of present causes whose great effectiveness should not be disputed. Yet, I have been led... to the conclusion that many ancient causes do not have equivalents among present causes...' (p. 8). Here, the word *many* is used (French: *bien des*), consequently, not all ancient causes have no equivalents because they have disappeared. Logically, one can assume that some ancient causes must have present equivalents.

'... present processes are far from being the truthful image of past ones...' (p. 23). This again does not imply that present processes have replaced ancient ones, but that for certain reasons, some effects clearly displayed in ancient sediments have become almost imperceptible at present.

'... this is another instance showing that the environmental conditions of ancient seas are very often different from those of present seas...' (p. 35). Notice the use of *very often* (French: *très souvent*) and not *always* different. In other words, some ancient seas had environmental conditions similar to those of present ones.

'... some causes which play a fundamental role in the formation of ancient sediments do not participate at all in the generation of present-day deposits' (p. 73). Two words should be stressed in this statement, first, *some* ancient causes, not all of them, do not participate in the deposition of present sediments; second, *do not participate* (French: *n'interviennent pas*), in other

words, their effects are not detectable. These causes are essentially inactive, but have not disappeared having been replaced by entirely different ones.

'... the present epoch is characterized by the inactivity of a series of processes which played a great role in the formation of sediments during the geological past' (p. 75). Cayeux says *inactivity* (French: *repos*), not *absence* of a series of processes at present. In other words, these processes are potentially present, but their effects are difficult to detect or geographically restricted, but the processes themselves have not disappeared and been replaced by others.

'... therefore, the data obtained from the analysis of Past causes and of their effects should not be neglected—if it were only for the purpose of stating problems, and of contributing to establish a research program fulfilling the needs of geology—on the day when oceanographical exploration will start anew and on a much larger scale than in the past' (p. 78). If the data afforded by rocks formed through the action of 'past' causes should be taken into consideration for establishing some of the goals of modern oceanography, this implies that some present marine environments might well, upon extensive investigation, show these 'past' causes locally active. Indeed, recent investigations have confirmed the coexistence of 'past' and 'present' causes today, their difference being only a matter of geographic extent and nature of effects, as suggested by Rutten (1949). '... In the study of the sedimentary formations of the earth's crust, it is necessary to take into account ancient causes besides present causes, if one wishes to use all the factors capable of providing a complete understanding of such formations' (p. 79). Cayeux says that ancient causes should be considered *besides* (French: *à côté*) present causes, not *in the place of*. He does not mean that ancient sediments were produced under the influence of past causes which have ceased to exist at present having been replaced by a new set of present causes; he says that in order to understand ancient sediments we should combine ancient causes with present causes.

Before drawing any final conclusions on Cayeux's thinking, some data should be given on the rocks he so carefully investigated. The essentials of his observations pertain to the chalk and its cherts, the oölitic iron ores and the phosphates. In these deposits he repeatedly noticed the puzzling association of two conflicting sets of characters: one similar to those of recent pelagic sediments deposited in mid-ocean, the other indicating neritic conditions similar to recent near-shore coastal deposits. For such environmental interpretations he used extensively the results of the 'Challenger' expedition which in his time represented the basic background of oceanography. To understand such an association he assumed the effects of particular processes not active today. I should stress that he remained silent about the factors regulating the deposition of the other groups of ancient rocks, such as the

different types of shales, sandstones and even carbonates associated with the deposits he studied. He remained equally silent about the agents responsible for the deposition of the thick clastic series which alternate with the chalk, the iron ores and the phosphates throughout the geological column. I am therefore entitled to assume that he found nothing peculiar about them as compared to present sediments, hence not all ancient deposits are different from present ones, only some of them. In other words, the conclusion may be reached that the past geological record not only displays thick clastic series similar to present deposits, but also shows the *simultaneous occurrence* of rocks which might claim 'ancient' and 'recent' causes as their regulating factors.

This situation is perfectly understandable since the chalk, the oölitic iron ores and the phosphates, as widespread as they might have been in the past, were certainly not the only kind of sediments being deposited over the entire earth at a given time. Therefore, 'ancient' and 'present' causes were associated at all times forming a pool of *permanent causes*. In other words, throughout the geological column, the causes (or the physical forces, such as gravity) have really never changed, but during given periods the effects of certain causes were largely predominant while the effects of others were barely noticeable or restricted to certain areas; at other periods the reverse would occur. Since the causes are permanent, these differences in their effects can only be the consequences of two different circumstances under which these forces or causes acted. Therefore, the 'ancient' and 'present' causes really mean ancient and present situations during which permanent causes led to different geological results, in this particular case different sediments.

If Cayeux's contribution is understood along these lines, and I think it should be, he becomes as uniformitarian as his critics. He has not only preceded them in some of their conclusions, such as the periodical occurrence of these two sets of circumstances, but has also anticipated, as we shall see later, the discovery of many types of present sediments which in localized areas obey 'ancient' causes. Consequently his book is not a refutation of uniformitarianism, but an attempt to show the intriguing results of the variations of the effects of permanent causes. The question is now to understand the real nature of these two sets of circumstances and the intrinsic reasons for their periodical occurrence during geological time. This periodicity, long ago visualized by Hutton, was refuted by the rigid approach of Lyell but has recently been included by Laffitte and Rutten, among others, in the modern and enlarged definition of uniformitarianism (Hooykaas, *op. cit.*, pp. 56-64).

Concerning the real nature of these two sets of circumstances, Cayeux made a miscalculation of the order of magnitude of the processes he was observing, mainly because of his great emphasis on petrographic studies under the microscope. This error of appreciation, as pointed out by Laffitte and

Rutten, consisted in his tendency to exaggerate the importance of the disturbances or *ruptures of equilibrium* which he considered responsible for the puzzling and repeated alternations of 'pelagic' and 'neritic' sediments in the chalk, the oölitic iron ores and the phosphates. This association implied for him oscillations of the sea floor of an amplitude similar to the difference of depth existing today between oceanic bottoms covered with pelagic sediments and continental shelves overlain by neritic deposits. Cayeux, however, pointed out that he visualized these ruptures of equilibrium as nothing but regional disturbances, devoid of any influence on the areas located beyond their direct action: 'Is it necessary to add that these ruptures of equilibrium do not have the magnitude and the generality of Cuvier's catastrophes?' (p. 75). This geographical restriction of the action of the past causes represented by their ruptures of equilibrium reinforces the point made above that sediments claiming 'past' and 'present' causes as their regulating factors coexisted in the geological past.

Whenever Cayeux observed the repeated alternations of 'pelagic' and 'neritic' conditions he assumed that the deposits he investigated represented *epochs of great instability of the sea floor*. On the contrary, the other periods would represent *times of stability*. In that respect Cayeux says, '... the present is in essence a period of great stability of the sea level and of the sea floor. Therefore, we are dealing with an exception in comparison with the geological periods taken as a whole...' (p. 75). As pointed out below, the present is certainly exceptional but because of its postorogenic instability. Cayeux's incorrect assumption of stability resulted from his above-described miscalculation of the order of magnitude of the processes involved. 'Consequently it is only by means of the analysis of ancient sediments, and only through it, that we can reach an understanding of the ancient processes of the marine environment' (p. 77).

The two critics of Cayeux, Laffitte and Rutten have presented new and essentially identical interpretations of these two sets of circumstances which summarize the present state of our knowledge and stressed that Cayeux's concept of stability and instability was erroneous. At the same time they explained the reasons for the periodical occurrence of such circumstances through geological time.

It is known today that all the deposits investigated by Cayeux, the chalk, the oölitic iron ores and the phosphates, belong to long periods of orogenic quietness, in other words to the so-called *periods of epeirogenic movements* which consist of gentle and slow oscillations. These periods are characterized by very extensive and shallow seas, bordered by low-elevation continental masses, often almost peneplained and therefore releasing very little clastic materials. Hence, the marine sedimentation was essentially pelagic and the slightest epeirogenic uplifting would have far-reaching consequences

on the sedimentation, such as widespread ruptures of equilibrium and related reworking which generates detrital (pseudo-littoral) deposits, extensive supratidal dolomites, large-scale conditions of seepage refluxion through well-developed reef barriers and broad evaporitic lagoons in the middle of pelagic deposits. Naturally, in other areas which had escaped erosion and which must have been geographically restricted, other types of sediments similar to the present ones were deposited. But these types of sediments would represent an exception hardly affecting the general picture, which is essentially dominated by the great development of the effects related to the existence of extensive shallow seas surrounded by low lands.

At other times, during the relatively short *periods of orogenic activity*, including the postorogenic times immediately following them—like the present—the earth was characterized by high continental reliefs undergoing active erosion, deep oceanic basins, narrow continental shelves receiving abundant clastic sedimentation, uplifted and drowned coastlines, almost no shallow seas, effects of glaciations. The resulting sedimentation is characterized at present by a strong contrast between pelagic deep-sea deposits and shallow clastic sediments, in the past by deep-sea siliceous or carbonate rocks and by thick clastics of flysch and molasse type. Naturally, in other areas which have escaped the rugged modern conditions and show a topography similar to the general physiography which prevailed during epeirogenic periods, one finds on a small scale sediments similar to those of these periods. Such is the case of the flat and almost invisible coast near the mouth of the Senegal (Laffitte 1949), the restricted lagoons where supratidal dolomitization occurs in the Persian Gulf, in Florida, in the Bahamas and elsewhere, of the small-scale conditions of seepage refluxion through modern reefs and of the limited shoals where oölitization takes place in the Bahamas and along the southern coasts of the Mediterranean.

Additional types of such deposits recalling closely those of the epeirogenic periods seem to be influenced more by local environmental similarities than by the general physiography. This is the case of the ferruginous pellets (goethite and chamosite) reported along the coasts of the Ivory Coast and Gabon, in the Malacca Strait, on the Sarawak and Guinea shelves, in the Niger and Orinoco-Paria deltas and in the Loch Etive in Scotland. Similar considerations apply to the phosphatic nodules scattered off the coasts of California and Baja California, and along many other coastlines around the world, and finally to the incipient cherts forming today in the alkaline lakes of East Africa.

However, all these deposits, in spite of their great intrinsic interest, remain exceptions hardly affecting the present picture which is essentially dominated by the great development of the effects related to the existence of deep ocean basins surrounded by high reliefs.

In essence, the two sets of circumstances just described express two general and distinct physiographic states of the earth corresponding respectively to long epeirogenic periods and to relatively short orogenic episodes, both being the direct manifestation of the periodical nature of the internal forces of the globe.

In conclusion, the observation of the present pattern of sedimentation in a world undergoing orogeny, or perhaps just emerging from an orogenic phase, demonstrates clearly that 'present' and 'ancient' causes are associated in a pool of permanent causes which give rise to a set of sediments typical of the present-day rugged face of the earth. Therefore, there is no opposition, at any time, between 'ancient' and 'present' causes. This is precisely the manner in which Cayeux's contribution should be interpreted and the reason why, in my opinion, it retains its outstanding value. Cayeux only stressed examples in which the permanent causes, acting on a different or 'ancient' world, produced sediments spectacularly different from those of today.

#### REFERENCES

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