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'Perestroika' in Stratigraphy

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Historical geology or stratigraphy is based upon the aspect or appearance of sedimentary rocks. From the observable evidence, it seemed reasonable to its founders to consider that strata were formed by layers of sediment being deposited upon each other intermittently or continuously. Intermittence is characterized by joints which separate the strata.

These joints appear to result from hardening of the upper surface of each layer during the period of time when the supply of sediment had been interrupted. From all outward appearances, it looked as if the layers had been deposited horizontally. Where sedimentary rocks had formed in an ocean basin or had covered a range of mountains, the strata, that were parallel to the slope of the basin or the mountain side, were attributed to basin subsidence due to the weight of sediments, in the one case, and to being lifted up by the mountain when it was formed, in the other.

In different places, moreover, the same successions of facies (sandstone, shale, marl, limestone, dolomite etc.), in whole or in part, could be observed. Each facies was composed of a series of superposed strata of the same lithological composition and contained characteristic fossil zones (biozones). It was therefore assumed that these facies, and identical facies in other areas, had all been deposited at the same geological time. The fossils they contained, and the species the fossils represented, were consequently considered to be of the same age.

THE STRATIGRAPHIC TIME SCALE/COLUMN

Stratigraphy, based on these premises, started to develop towards the end of the eighteenth century. In 1830, Charles Lyell produced the first stratigraphic time scale. The basic unit of the scale was the 'stage'. It was defined in terms of a reference cross-section of marine facies, and although bearing the name of its geographical origin, it was considered to be of universal application.

The age or duration of each 'stage' was estimated by application of the principle of 'uniformitarianism'. According to this principle, the speed of sedimentation in the past was the same as it is today. Consequently, the relative position of a stage in the time scale is considered to have an absolute age. For example, the 'Kimmeridgian' stage is estimated to have lasted five million years, from 151 million years BP (before the present) to 146 million years BP.

Divisions of a greater magnitude than the stage are: series, systems and era-themes. They correspond respectively to the chronological divisions of: epoch, period and era. The stratigraphic scale or geologic column is, therefore, presented as a succession through time of lithological and palaeontological facies. The genus 'Ammonite', for example, appears in the Permian period and disappears in the Cretaceous. The shells of the species seem to develop during the 'period'. To the palaeontologist this development constitutes the proof of evolution. More often the species succeed each other in the column and so palaeontologists consider this succession as a proof of transformation of species or evolution. The theories of Lamarck, Darwin and their successors are founded on such data.

During the twentieth century, an evolutionist cosmology was developed whereby, from an original primeval explosion or 'Big Bang', energy was converted into matter, and that matter eventually evolved into life. As Engels pointed out, such a scientific concept left no place for a Creator.

INTERPRETATIONS OF SUPERPOSITION

Since stratigraphy is the foundation upon which evolutionary theory has been built, it seems scientifically legitimate to put its tenets to the test. It is clear that there are a number of suppositions contained in the science of stratigraphy. This is inevitable because nobody was there to witness the formation of the sedimentary rocks.

What is known is that these rocks consist of ancient sediments carried and deposited by oceans during their transgressions and regressions.

The study of stratigraphy should, of course, have begun by an examination of present-day marine sediments in order to determine their formation according to their physical, chemical and geographical features. Much valuable information could have been obtained concerning the genesis of old basins.

Unfortunately, at the time of the pioneers of stratigraphy, little was known about sediments. It was not until 1875, with the sea-floor core samplings of the U. S. vessel 'Glomar Challenger', that sedimentology started to develop. It was the observations of Johannes Walther[1] of littoral sediments in the Gulf of Naples that provided the first lesson on the subject. In 1885 he reported:

'As with biotopes, it is a basic statement of far-

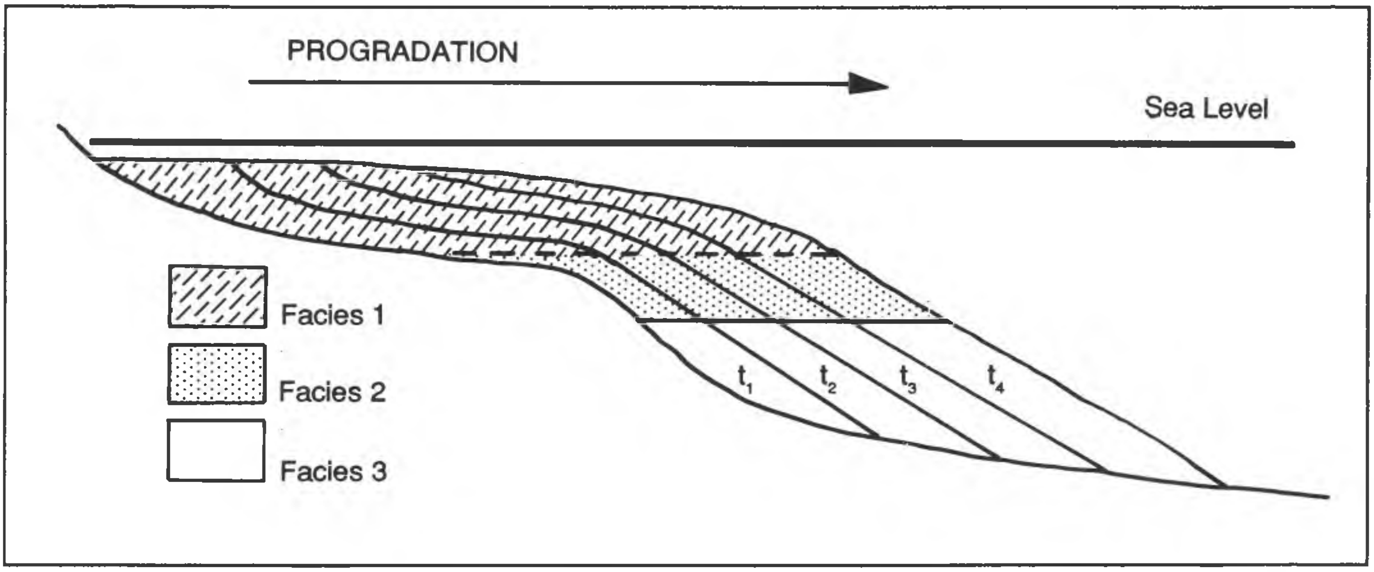

Figure 1. Superposition of facies during progradation. Note that each facies does not represent a horizontal bed of sediment deposited at a different time, but all facies were continuously deposited contemporaneously forming beds where facies grade into one another within each bed.

reaching significance that only those facies and facies areas can be superimposed primarily which can be observed beside each other at the present time'.

This explanation can be understood from Figure 1. The facies 1, 2, 3 prograde towards the open sea at t_1, t_2, t_3, t_4, (t = time) and are superposed. Little by little the marine basin becomes filled by fluviatile, marine, detrital, chemical and organic sediments. The sea floor, thus, spreads toward the open sea. This spreading movement is known as 'progradation'. Figure 1 shows how 'facies' 1, 2 and 3 prograde together and superpose each other.

The 'differentiation' of facies arises in two ways. First from the sedimentary particles undergoing a sorting process due to the action of the waves, tides, currents, whereby the larger particles are deposited near the shore and the smaller ones further away. Second, from the presence of benthic species living at specific depths, and migrating plankton giving rise to chemical deposits (evaporites), with the order of deposits depending upon their solubility.

Following Walther's observations, the sedimentologists of his school sought an explanation for the superposition of facies in ancient sedimentary basins. Being unable to observe large transgressions and regressions of the past, they adopted the following reasoning. Refer again to Figure 1. If the sea level falls abruptly at each of the times t_1, t_2, t_3 and t_4, then the sedimentary level will fall in the same proportion. The result is shown in Figure 2.

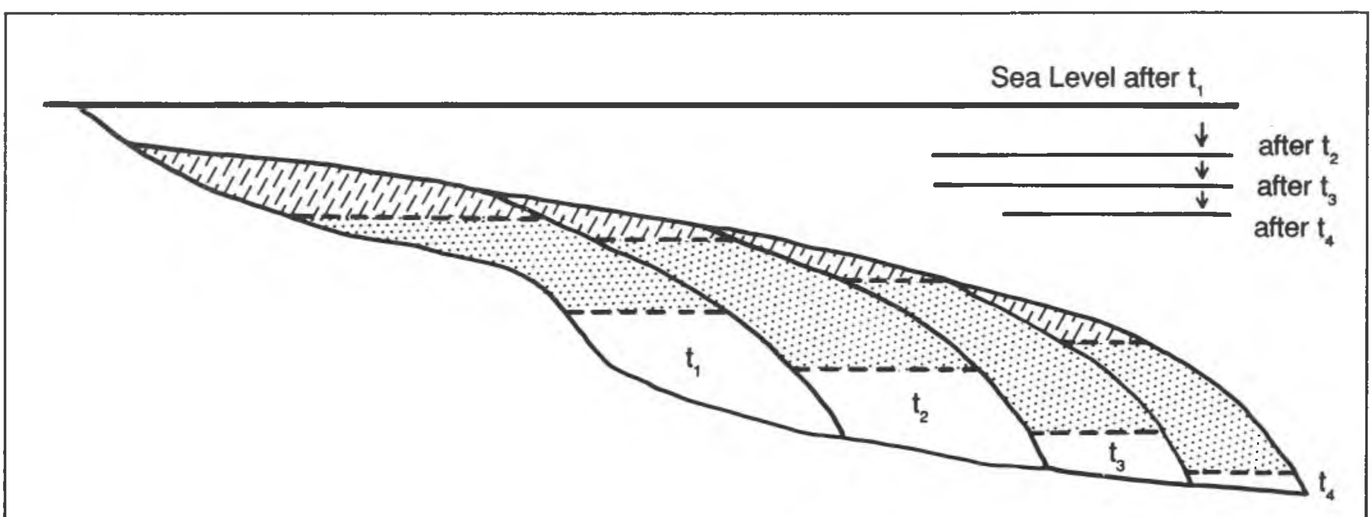

Figure 2. Superposition of facies due to abrupt falls in sea level. Note the horizontal discontinuities between the equivalent facies in each sloping bed because the abrupt falls in sea level rapidly changed the positions of depositional conditions.

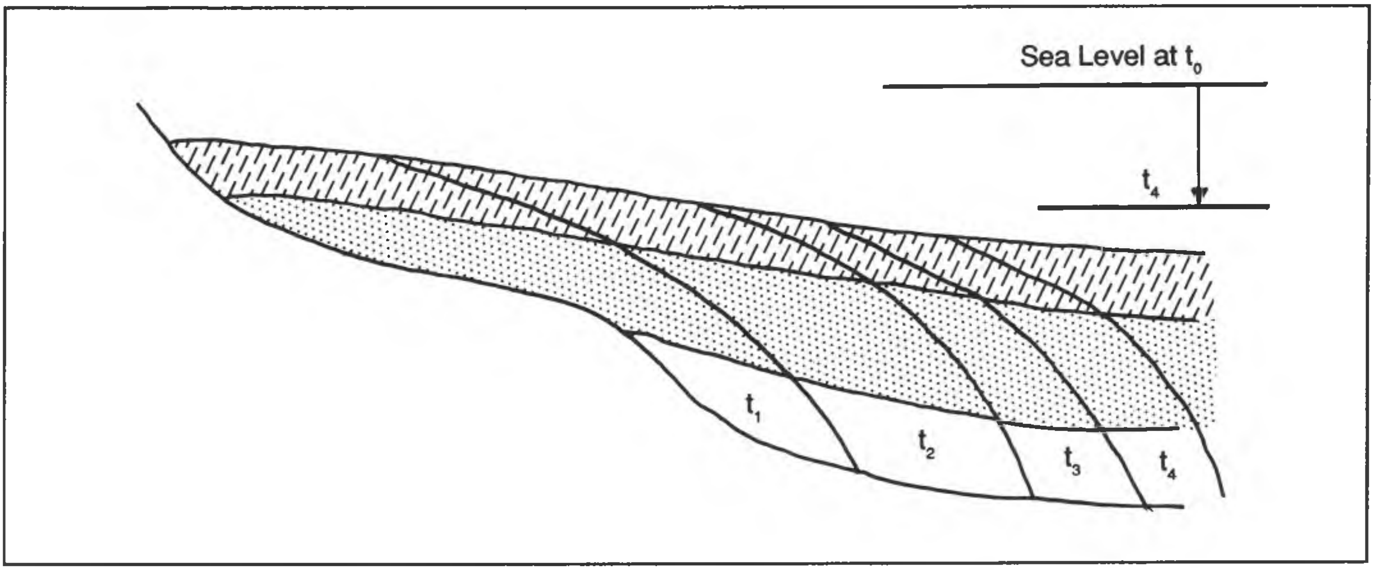

Figure 3. Superposition of facies due to a continuously falling sea level. Note that the horizontal discontinuities between equivalent facies in each sloping bed of Figure 2 are now gone so that the result is similar to Figure 1, that is, each facies appears to be a separate near horizontal bed when in fact each facies grades into one another within the steeper sloping beds of each time 'step'.

So if the sea level falls continuously from t_1 to t_4, then the situation will be as shown in Figure 3.

If, however, the sea level rises, then the order of superposition of facies will be reversed. The facies represented in Figures 1, 2 and 3 constitute sequences of progradation, transgression and regression. These facies are not in chronological succession because their superposition results both from 'differentiation', as explained above, and lateral spreading of the deposits. In sedimentology, this is known as mobility of deposits.

The foregoing reasoning, based on the fact of progradation, corresponds to the configuration of superposed facies found in sedimentary basins. The latter resemble the facies in Figure 3. This explains why those geologists who took Walther's teaching into account have studied the genesis of sedimentary basins in this manner. This approach is known as sequential analysis and it tries to identify from successions of facies, sequences resembling those in Figure 3, to determine the corresponding marine transgressions and regressions.

It should be noted that superposed facies in a sequence, which are being deposited at the same time (as in Figure 3), are themselves composed of superposed strata. These strata, according to classical stratigraphy, are identified as successive layers. The facies, therefore, according to this reasoning should also be successive and should not be deposited at the same time. There is, therefore, a contradiction here between the concept and the observed facts, and it is the identification of 'stratum' as 'layer' that is responsible. Present-day sedimentology provides a number of other observed facts which call into question the concept of stratigraphy.

First, as regards the assertion made by geologists in times past that layers were deposited horizontally, seismic profiles of marine sediments near the surface provide clear evidence of stratification being parallel to the slope of the basin, and only horizontal where there is no slope, as in the abyssal plains. Consequently, there is no *a priori* reason to assume that where strata are roughly parallel to the slope of a basin or mountain-side, either the basin has subsided under the weight of sediments or the mountain has lifted them up. Such assumed movements have been thought to be the cause of transgressions and regressions.

Second, regarding the joints of stratification separating strata (there are other types of bounding surfaces), which are thought to indicate an interruption in sedimentation and an induration, in the water, of the upper surface of the previously deposited strata, examination of cores of marine sediments, particularly those produced by the 'Glomar Challenger', have shown that apart from certain exceptions, sediments up to a depth of 300 metres are unconsolidated or unindurated. This means that the cores show no evidence of indurated or hardened joints of stratification. The assumed formation of these joints by induration is not, therefore, generally consistent with the observations of marine sediments. The question still remains, therefore, to establish the conditions responsible for forming the joints.

STUDIES IN SEDIMENTATION

Not having a marine transgression to examine, reference to an example of a fluvial flood is of value. The Bijou Creek Flood in Colorado in 1965[2] after forty-eight hours of rain produced a layer of sediment reaching twelve feet in thickness in some places. After the water had receded, sedimentologists McKee, Crosby and Berryhill studied the site. They dug trenches in the sediments in order to

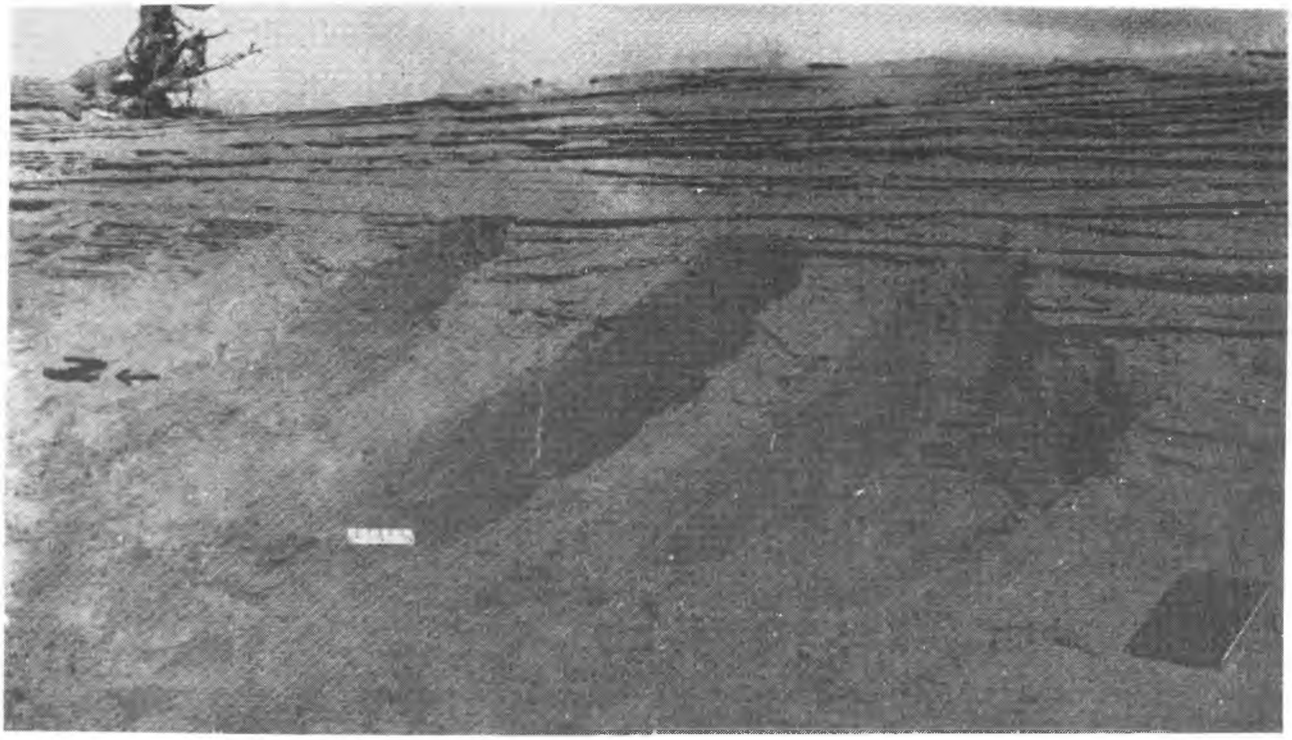

Figure 4. Sedimentary structures in the east bank of the main channel of Bijou Creek, Colarado (after McKee, Crosby and Berryhill[3]). Note the low angle cross-bedding in the upper part of the bank.

examine their structure and texture. 90% to 95% of the sediment consisted of horizontal strata.

The external vertical face of the sediment deposited on the original bank, perpendicular to the river bed, shows strata separated by nearly horizontal fissures resembling joints of stratification in rocks (see Figure 4).

As the flood only lasted forty-eight hours, clearly the joints cannot be explained by under-water induration. The only explanation seems to be that the joints were caused by the desiccation of the sediments after the water had receded.

My objective then was to test this hypothesis experimentally. If it is correct, then it provides an explanation for joints of stratification in rocks without reference to an interruption in sedimentation.

An examination of the texture of the sediments in Bijou Creek shows a vertical and sometimes horizontal variation in the size of the particles. Fair sorting of particles, on a large scale, does not arise here, as in the case of successive and intermittent layers by the differentiation of speed of fall of the particles according to their size, but is related, according to McKee, Crosby and Berryhill, to the speed of the current. The deposit of coarse particles results from a rapid current and the finer particles from a decelerating current.

McKee, Crosby and Berryhill also suggested that horizontal laminae result from a rapid current and cross laminae from a decelerating current, and that a switch from one form to another entails no interruption of sedimentation. From this example, it appears that a variable but continuous supply of sediment produces deposits with stratification having the essential characteristics of stratification in rocks, that is, fair sorting, horizontal and cross lamination, and joints of stratification (probably resulting from desiccation).

As McKee, Crosby and Berryhill's observations were only made after the flood, I decided to attempt to reproduce these phenomena in the laboratory. My first series of experiments was undertaken fourteen years ago and a second series more recently at the Institute of Mechanics of Fluids in Marseilles (l'Institut de Mecanique des Fluids de Marseille) by hydraulic engineers.

The object of the experiments was to study lamination and internal structure of strata in continuous sedimentation, in still water and in water subject to a current.

A segregation of particles of comparable size was shown to take place in dry heterogranular powders when in movement.[4] This phenomenon was reproduced in aqueous sedimentation giving rise to laminations both in still water, provided a slight agitation existed, and in water subject to a current. The lamination was horizontal or parallel to the slope. The results of these experiments are contained in two published reports.[5]

The next stage was to construct an experimental model of the Bijou Creek Flood in a flume in order to study the variations of structures and textures of deposits in continuous sedimentation, arising from differences in currents, depth of water and sizes of particles. The flume in

Marseilles was too small to undertake such work.

That work has been undertaken between December 1988 and April 1990, in the larger flume of the Engineering Research Center of the University of Colorado, in which, during the years 1956–61, were performed the experiments of Guy, Simons and Richardson.[6] The results of these experiments are that deposits, prograding in the way of the current, under steady flow conditions are stratified, reproducing Bijou Creek's conditions, the graded-bedding resulting from variations of the flow velocity, and joints, from dessication.

A 'PERESTROIKA' NEEDED

The conclusions that can already be drawn from the sedimentological observations and experimental data to hand, are the following. Continuous sedimentation produces a deposit in which particles are segregated into two essential forms. The first is a large-scale sorting of particles where there is a current, and the second is the formation of horizontal or cross laminations whether or not there is a current, but provided there is a slight agitation of the water.

Moreover, it has been observed that joints of stratification did not appear in the sediments covered by water. There is, therefore, no good reason to identify the joints with periods of interruption in sedimentation.

Generally, stratification, characterised by lamination, sorting, joints and other types of separation between the strata, can just as easily result from continuous sedimentation in progradation associated with transgression and regression, as from intermittent deposition, layer by layer, as traditionally postulated. This latter concept is therefore just one hypothesis amongst others.

It follows that the identification of a 'stratum' with a 'layer' can no longer be accepted and, in consequence, that chronostratigraphy is in need of a restructuration or 'perestroika'! Only an outline of the way that this can be achieved can be given at this stage. Certainly, it involves sequential analysis, as mentioned above, but analysis free from that erroneous identification and from the limitation of sequences to joints of stratification.

The principal result of such an analysis is the explanation it provides of the superposition of facies. It gives palaeoecology its rightful place, especially as regards fossils, which similar to marine ecology associates marine species living in the same medium at distinct depths. It also takes into account the lateral displacement of the species under the effect of progradations, transgressions and regressions which might perhaps resolve the enigma of the 'missing links' and help to understand that what has been taken for evolution is probably no more than the superposition of fossil zones resulting from progradations, transgressions and regressions.

The analysis also helps to determine the transgressions and regressions of oceans, which were responsible for submerging entire continents, in terms other than supposed subsidences or uplifts as previously deduced from the slope of strata.

The cause of these transgressions and regressions must have been of major physical proportions. It is usually postulated that the poles have changed position in the past and that continents have moved apart. Such movements on an ellipsoidal Earth may certainly have had an effect upon the ocean sufficient to account for submerged continents.

It is my conviction that this 'perestroika' in stratigraphy will eliminate all contradictions that have been thought to exist with the first chapters of Genesis in the Bible. It will, I believe, demonstrate the illusory nature of geologic time and evolution of the species, and provide scientific credibility for the reality of the Great Flood, still so alive in the legendary tradition of so many peoples.

Sedimentologists, it is hoped, will co-operate in this restructuring of stratigraphy, and thus contribute towards a better understanding of the crustal formation of our planet.

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