

Stratigraphy, palaeogeography: a fruitful permanent dialogue

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Summary

The 70's were a real turning point for the palaeogeography. The plate-tectonics theory was verified. Many believe that it was a geophysics success. It is not fully correct. Most of hypotheses have been achieved by geologists dealing with stratigraphy and the plate-tectonics theory can be regarded as the geometrical expression of the continental drift proposed by Wegener. Nevertheless the kinematics, daughter of the plate-tectonics theory, is a beautiful tool to reconstruct the successive geographies of our planet. But as soon as we say "successive", "evolution", "event", "correlation", "movement", "speed", we need a time scale and reference is made to stratigraphy. Thus a palaeogeographic map being a synthesis of the geological events last in a time slice, it needs kinematics and stratigraphy. The combination of these two geosciences is a fruitful permanent dialogue. It reveals the stronger points and the weakness of the two partners. It leads to reduce the uncertainties.

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The FAMOUS survey (French American Mid Ocean Undersea Survey) carried out at the beginning of the 70's was the first study *in situ* of the oceanic seafloor. The most important observation was the volcanic nature of the oceanic ridge. This conclusion supported Hess (1962) hypothesis which assumed that convection currents exist in the lithosphere. They arise at the mid oceanic ridge and sink at the oceanic borders. This hypothesis had been imagined earlier by Holmes (1931) the famous geochronologist; the first one who dated rocks with the radioactivity and published the first geochronological time scale (Holmes, 1937). And also by Vine & Matthews (1962) who observed the magnetic anomalies stratigraphy on each part of the ridge and concluded that the ridge must be volcanic. At least this FAMOUS result was the proof that Wegener's reconstructions (1912, 1929) were reasonable even if Wegener and his geologist and palaeontologist collaborators were not able at that time to explain physically the horizontal movement of the continents: the sea-floor spreading. Actually it appears that most of the significant hypotheses were written by teams seriously involved in stratigraphic researches.

The second FAMOUS result was the verification of the plate tectonics theory published separately by Morgan (1968) and Le Pichon (1968). This theory can be resumed as follow: The lithosphere is divided in rigid plates of which the movements may be described using the eulerian geometry concepts. It is a pertinent theory but it is a theory so it has to be verified. Thus which are the parameters of these geometrical concepts? A plate moves, related to another one considered as fixed, around a pole defined by its latitude and longitude, and the movement amplitude is given by an angle. Therefore the questions are: where is the pole and which is the rotation angle? The theory says that the answer is along the transform faults cutting the oceanic floor. A good bathymetry map is required to locate the transform faults, but we have to observe sites of the same age on

several faults. Obviously the data we need are given by magnetostratigraphers and the biostratigraphers. However, even if we have an acute correlation in age, the position of the considered rotation pole will be inside an uncertainty circle due to statistical analysis. Here too it is obvious that stratigraphy plays an important role in the palaeogeographical reconstructions.

In the middle of the 70's, the first palaeogeographical reconstructions applying the plate tectonics are published. If you close present-day oceans at the width they had some millions of years ago, you open area from which the present-day mountains belts issued. That is why the very first reconstructions concern Alps issued from Tethys Ocean and particularly the Mediterranean regions which were better known (Biju-Duval *et al.*, 1977). Then the considered area has been enlarged to the Middle East up to Pamir (Dercourt *et al.*, 1985). These maps showed the different continental blocs in their palaeolocation, three colours were used to distinguish the thickness of the continental lithosphere and few patterns indicate the sediment types observed. Stratigraphers boosted the reconstruction at the middle of 80's. Led by E. Fourcade they put on the previous maps the fossiliferous sites in their paleolocation (i.e. Bassoulet *et al.*, 1985). The fruitful discussions emphasized the significance of fossils as stratigraphic and also palaeogeographical markers. Biostratigraphy and its daughter biogeography could be tools to precise kinematics parameters.

At the end of 80's several palaeogeographical atlases were published: one concerns the craton of Western and Central Europe (Ziegler, 1990), another is at global scale and deals with large time slices (Scotese & Golonka, 1993). Let us also not forget the palaeo-geographic atlas of the North Atlantic Ocean (Tucholke & McCoy, 1986). But with the Tethys scientific programme (Dercourt *et al.*, 1993) a further step is taken. The complete Alpine Belt, from Caribbean to Indonesia, was being considered. The resulting maps were developed in two steps. The first one carried out kinematic maps similar to previous published maps; we named them initial maps. The second step drew sedimentary palaeoenvironment maps. Stratigraphers and palaeontologist as well tectonicians informed the maps with the data they mastered. All information given by the facies were taken into account. Here the stratigraphy reigns supreme. The coherency of the final map depends on the correlation of the facies. We have to be accurate on the time slice concerned with the map. Thus the choice of time slices is decisive. The time slice may not be a stage but a part of it; except if this is a very short time one. But even by taking these precautions, correlations remain crucial questions. Nevertheless such syntheses were very fruitful. They stimulated thoughtful discussions and passionate debates. But the maps were yet published! For example look at the palaeoposition of the radiolaritic Timor Basin on the Tethys Kimmeridgian map. Why have we such a basin at 50°S latitude? Nobody agrees with this location. Actually the age given by radiolarians is accurate and the computed location is geometrically exact. However magnetic paleopole is never a point but an uncertainty circle. If we compute the Timor Basin palaeolocation with a paleopole distinct from the centre of the circle but judiciously choose within the circle, the Timor Basin lays at 30°S. Kinematicians, palaeomagneticians and palaeontologists are now confident with the corrected map. This is a new proof of the fruitful exchange between palaeogeography and stratigraphy.

Following the Tethys programme, the Peri-Tethys one (Dercourt *et al.*, 2000) restricted the study area to the European and African-Arabian regions. The objective was to understand how Pangean cratonic blocs behaved during the Tethys Ocean evolution. But even if the question was a tectonics one, the choice of periods of maps exclusively followed stratigraphic criteria. The time-slices generally correspond to well define biostratigraphic intervals. They range between 1 and 4.5 Ma. These periods are short compared to the duration of the major tectonic events which may last for several tens of millions years but the effect of tectonics can be depicted on the maps. During the Tethys programme we have mainly paid attention to marine series; in the Peri-Tethys regions we deal with ocean margins, epicontinental seas and continental areas. Thus to reduce the correlation discrepancy between the continental and marine time scales, we have preferred the maximum flooding periods. Each map explanatory note begins by a discussion on the correlations and time slice definition. It clearly appears that in all the maps the correlations are difficult to establish. They depend not only on the regional stratigraphy knowledge, but also on the stratigraphic fossil group occurrence which differs from sedimentary environment to sedimentary environment. These facts constrain the choice of the time slice; i.e. Early Tithonian allows better correlations than Late Tithonian. Obviously the paleogeography wants the moon; it is the enfant terrible of stratigraphy.

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