Available online at www.sciencedirect.com
SCIENCE DIRECT®
C. R. Geoscience 335 (2003) 659–660
COMPTES RENDUS GEOSCIENCE

Perspective

Validity of some sedimentological tools used in palaeoclimatic reconstructions

Médard Thiry *, Régine Simon-Coinçon

École des mines de Paris, 35, rue Saint-Honoré, et CNRS-UMR 7619 Sisyphe, « Structure et fonctionnement des systèmes hydriques continentaux », 77305 Fontainebleau, France

1. Introduction

In their interesting paper, Murru et al. [5] deal with palaeoclimatic reconstructions from various marine and continental deposits. This is a difficult and critical topic, often debated since long. Their analysis is based on the interpretation of clay mineral series, pollen assemblages and pedological features in continental deposits, and foraminiferal assemblages in interbedded marine deposits. The use of different kinds of arguments, relative to different deposits is fruitful. Nevertheless, the increase of the number of arguments makes them not more precise and reliable. This does not reduce the uncertainty, and the danger of a cyclic reasoning is not excluded. The arguments classically forwarded, and sometimes used like a recipe, deserve to be assessed critically in order to state their domain of use and their limits. Here in, we will draw attention to a few arguments often used to reconstruct palaeoclimatic evolutions and which may be examined more critically.

2. Weathering, palaeoweathering and sedimentary deposits: what links them?

A critical review regarding palaeoclimatic interpretation of sedimentary clay minerals has been done recently by Thiry [8,10]. It should be pointed out that only reworking of thick, mature and mineralogically differentiated soils will leave their mark on sedimentary deposits and thus be useful for palaeoclimatic interpretations. In fact, mature soils develop only in landscapes of relatively low relief, where erosion is moderate. With stepper land morphology, strong erosion will not allow the maturation of the weathering profiles and will remove clay minerals belonging to the substratum that are irrelevant to their soil environment. Thus soil maturation and soil erosion appear somehow antinomic.

Recent dating of thick soils in the tropics have shown that the deep kaolinitic profiles identified over extensive palaeosurfaces from the Brazilian, African and Australian regoliths started to form during the Cretaceous and continued to develop throughout the Tertiary [6,7,11]. The persistence over geological times of huge amounts of ancient kaolinitic weathering materials in the landscapes may seriously alter the palaeoclimatic signal of kaolinite in the sedimentary record. Palaeoclimatic interpretations of sedimentary clay mineral assemblages have to be done with much care, because clays inherited in the basin formed most probably earlier in the soils.

3. Coal deposits, wetlands and palaeoclimate: what links them?

Palynofloral assemblages are often used as palaeoclimatic records. Moreover, occurrence of coal deposits, or lignite in Cainozoic deposits, are interpreted

* Corresponding author.
E-mail address: medard.thiry@ensmp.fr (M. Thiry).

1631-0713/$ – see front matter
doi:10.1016/j.crte.2003.08.001

as an indicator of tropical subhumid climatic conditions and widespread rainforests. However, interpretations of past vegetation from fossil palynofloras suffer from a number of problems, including uncertainties about affinities with modern species and the environmental tolerances of fossil taxa.

A palaeoclimatic misinterpretation of organic rich deposits is provided by the Lower Eocene 'Sparnacian' deposits in the Paris Basin. Lignitic deposits and the presence of numerous palynoflora taxa, such as nipa palms, myricaceae, tropical ferns, etc. lead to interprete 'Sparnacian' palaeoclimate as tropical subhumid. Recent $\delta^{13}C$ chemiostratigraphy and recognition of the Late Palaeocene Thermal Maximum (LPTM) in these deposits have allowed us to show that they are correlative with flood plain deposits with widespread pedogenic calcretes, pointing clearly to Mediterranean or tropical dry palaeoclimates [9]. This contradiction results from fluviatile and deltaic environments.

The difficulty lies in the fact that organic materials may not come from widespread rainforest covers, but may relay to restricted wetlands in subdued landscapes where sediments accumulate [1–3]. Wetlands may develop under dry climates. Three types of such wet environment can be distinguished in modern dry landscapes: (1) mangroves in dry or even arid climate like California, South Australia, Saoudi Arabia, and others; (2) riparian forests widespread in dry savannah country of Africa, like Kenya, Ivory-Coast and Chad; and (3) endorheic drainage basins feed from more humid climatic zones like Okawongo and Lake Chad. These deposits could be indicative of warm palaeotemperatures, but their interpretation in mean of palaeorainfall has to be used with caution.

4. Pedological features and soil maturity: what links them?

Illuviations and cutans are frequently described in clastic sediments and used as indicators of buried palaeosoils, but may not be exclusive of soils. Such structures result primary from successive dragging and sealing of the clay fraction by water seeping through unconsolidated sandy and loamy materials. It may be worth discussing the use of these structures in palaeoclimatic reconstructions. In riverbank deposits, illuviation structures may form by dewatering after flooding without true soil development, and, in soils, illuviations and cutans develop relatively quickly; thus, they do not indicate soil maturity and/or pedoclimatic equilibrium [4].

In this case, clay minerals content may just be inherited and are not at all indicative of palaeoclimatic conditions. To use palaeosoil clay minerals for palaeoclimatic interpretations, it is necessary to make sure that the palaeosols are mature and have developed a profile with differentiated horizons between depth and surface.

References

[1] N.F. Alley, J.D.A. Clarke, M. Macphail, E.M. Truswell, Sedimentary infillings and development of major Tertiary palaeodrainage systems of south–central Australia, Spec. Publ. Int. Ass. Sediment. 27 (1999) 337–366.

[2] J.-J. Chateauneuf, Palynostratigraphie et paléoclimatologie de l'Éocène supérieur et de l'Oligocène du bassin de Paris (France), Mém. BRGM 116 (1980) 1–424.

[3] W.L. Kovach, D.G. Batten, Association of palynomorphs and palynodebris with depositional environments: quantitative approaches, in: A. Traverse (Ed.), Sedimentation of Organic Particles, Cambridge University Press, 1994, pp. 391–407.

[4] P.J. McCarthy, I.P. Martini, D.A. Leckie, Use of micromorphology for palaeoenvironmental interpretation of complex alluvial palaeosols: an example from the Mill Creek Formation (Albian), southwestern Alberta, Canada, Palaeogeogr. Palaeoclimatol. Palaeoecol. 143 (1996) 87–110.

[5] M. Murru, C. Ferrera, S. Da Pelo, A. Ibba, The Palaeocene–Middle Eocene deposits of Sardania (Italy) and their palaeoclimatic significance, C. R. Geoscience 335 (2003) 227–238.

[6] G. Ruffet, C. Innocent, A. Michard, G. Féraud, A. Beauvais, D. Nahon, B. Hamelin, A geochronogical $^{40}Ar/^{39}Ar$ and $^{87}Rb/^{87}Sr$ study of K–Mn oxides from the weathering sequence of Azul, Brazil, Geochim. Cosmochim. Acta 60 (1996) 2219–2232.

[7] H. Théveniaut, P. Freyssinet, Timing of lateritization on the Guiana Shield: synthesis of palaeomagnetic results from French Guiana and Suriname, Palaeogeogr. Palaeoclimatol. Palaeocol. 178 (2002) 91–117.

[8] M. Thiry, Palaeoclimatic interpretation of clay minerals in marine deposits: an outlook from the continental origin, Earth Sci. Rev. 49 (2000) 201–221.

[9] M. Thiry, C. Dupuis, The Palaeocene/Eocene boundary in the Paris Basin: the Sparnacian deposits. Field trip guide, ENSMP, Mém. Sci. Terre 34 (1998) 1–91.

[10] M. Thiry, R. Simon-Coinçon, J.-M. Schmitt, Paléoaltérations kaoliniques : signification climatique et signature dans la colonne sédimentaire, C. R. Acad. Sci. Paris, Ser. IIa 329 (1999) 853–863.

[11] P.M. Vasconcelos, P.R. Renne, G.H. Brimhall, T.A. Becker, Direct dating of weathering phenomena by $^{40}Ar/^{39}Ar$ and K–Ar analysis of supergene K–Mn oxides, Geochim. Cosmochim. Acta 58 (1994) 1635–1665.