Contribution of sedimentology, organic geochemistry and clay mineralogy to reconstruct the palaeoenvironments of late Carboniferous to Permian of the northeastern Massif central, France.

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Late Carboniferous to Permian French intracontinental basins have been studied during the 20th century, mainly for industrial applications due to their carbonaceous resources. This period is also of great interest for its palaeogeographical, palaeoenvironmental and palaeoclimatic evolution associated with large geodynamic modifications, such as the transition from the Variscan orogeny to the breakup of Pangaea, and with the change from an icehouse to a greenhouse climate.

The end-Carboniferous (i.e. late Pennsylvanian) to Permian Autun and Lucenay-lès-Aix basins, studied here, are located south of the Paris Basin (France). The Autun Basin crops out in the Morvan area and lies on a Devonian and Carboniferous magmatic substratum. The Lucenay-lès-Aix area is a subsurface basin, under a ca. 250 m-thick Meso-Cenozoic cover, located in the southern termination of the outcropping Decize-La Machine Basin.

The study is based on subsurface data, using cored boreholes, well-log and seismic profiles. Our investigations have been achieved through a sedimentological approach including facies associations analysis and sequence stratigraphy, mineralogy and petrography, supplemented by a geochemistry approach to characterise the deposition and preservation mechanisms of organic matter (OM).

In the Autun Basin, three cores encompass a part of the lower Autunian, near the Gzelian/Asselian boundary. Sedimentological observations indicate lacustrine-dominated environments, with black shales and intercalated turbidites, interrupted by more proximal facies (microbial deposits and coarse river-mouth sediments). Palynofacies and Rock-Eval analyses show a dominant Type I OM, i.e. lacustrine algae, in the laminated fine-grained deposits. The geochemical results indicate periods of both high primary productivity and sedimentary OM storage, reflected in high total organic carbon and total nitrogen contents in sediments (TOC and TN, up to 21.5 wt.% and 0.76...
wt.%, respectively), and very low $\delta^{13}C_{\text{org}}$ values (down to -29.1‰, $\sigma = 0.07‰$).

In the Lucenay-lès-Aix Basin, the sedimentation dated from the late Gzhelian to the late Sakmarian is mostly characterised by alluvial, deltaic, lacustrine and floodplain deposits (coal), with a great volcaniclastic component. The geochemical proxies in coal deposits show high TOC and TN contents (up to 71 wt.% and 1.6 wt.%, respectively), with $\delta^{13}C_{\text{org}}$ values averaging -23.7‰ ($\sigma = 0.03‰$), indicating a Type III OM, as already reported for these deposits at that time.

In both basins, the main clay assemblage, slightly affected by burial diagenesis and mostly detrital, is dominated by kaolinite, illite, R1 type illite/smectite and chlorite/vermiculite mixed-layers. Kaolinite/illite ratio (K/I) is used as a proxy of the continental runoff, considering that kaolinite was formed in soils under more humid climate, although reworked kaolinite from previous deposits under high runoff conditions is possible. Moderate K/I values in black shales indicate low continental runoff conditions, while a substantial runoff indicated by high K/I ratio is associated with the more proximal coarse detrital sediments (river-mouth/delta). These interpretations are consistent with the mixture of both lacustrine and terrestrial OM (i.e. C3 vascular plants, Type III).