Reconstructing the Late Paleocene-Early Eocene continental paleosurface in and around the Paris and adjacent basins: new insights for paleogeographic, geodynamic and climatic studies

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INTRODUCTION, AIMS AND METHODS

The geological archive records "hyperthermal" crises, along with their consequences for the biotic and physical environment. Among these, the Paleocene–Eocene Thermal Maximum (PETM) is considered the closest analogue to the current climate crisis, due to its global character and speed at which the CO_2 rate and average temperatures increased (Higgins and Schrag 2006; Zachos *et al*. 2001, 2008). Some 55.8 Ma, it affected the Earth for a period of almost 200 k.y. (Röhl *et al.* 2000; Westerhold *et al.* 2007), and continental and marine paleoenvironments were marked by a negative $\delta^{13}C$ anomaly coinciding with a negative $\delta^{18}O$ anomaly indicative of a notable temperature rise (3–8°C).

We are developing a multi-disciplinary study in the coastal to continental paleoenvironment of the Sparnacian facies preserved within the Paris and adjacent basins, and also on the neighbouring basements that are sites of contemporary weathering. We aim to integrate the upstream to downstream sequence of diversified paleoenvironments, their landscapes and ecosystems, in order to assess the impact of the PETM climate crisis on each and the whole sequence.

The preliminary work described here has involved:

- compiling, reviewing and validating all available evidence;
- making new field observations in poorly investigated areas;
- studying occurrences of paleo-weathering and continental deposits, dating these using a variety of tools (e.g. litho, bio and chemo-stratigraphy, paleomagnetism, Ar/Ar geochronology), and relating them to the P–E continental paleosurface;
- organizing all the data in a GIS Database, using these to digitally reconstruct the current geometry of this paleosurface at 1:1 000 000 scale, then drawing the geological cross sections through the studied basins and their borders;
- reconstructing the continental paleogeography of the Paris and adjacent basins and their surroundings during this interval (Fig. 1).

FIRST RESULTS

Historically, the Paris and adjacent basins are the cradle of stratigraphy, where the notion of "Sparnacian" took shape (Dollfus 1880; see the detailed lithostratigraphy in Aubry *et al*. 2005). The Sparnacian facies, mainly continental to coastal, often display paleo-weathering features. Near the Mesozoic cover and older basement surrounding those basins, many fluviatile sands and conglomerate units seal or incise older thick kaolinitic weathering profiles. Sedimentological and stratigraphic studies and the mapping of those deposits show them associated with a major unconformity, spanning the uplifted areas to the lowlands of the shallow basins where they incise marine formations of Late Thanetian age. Almost all these paleo-weathering profiles and fluvial deposits are oxidized and/or leached and silicified in and around the studied

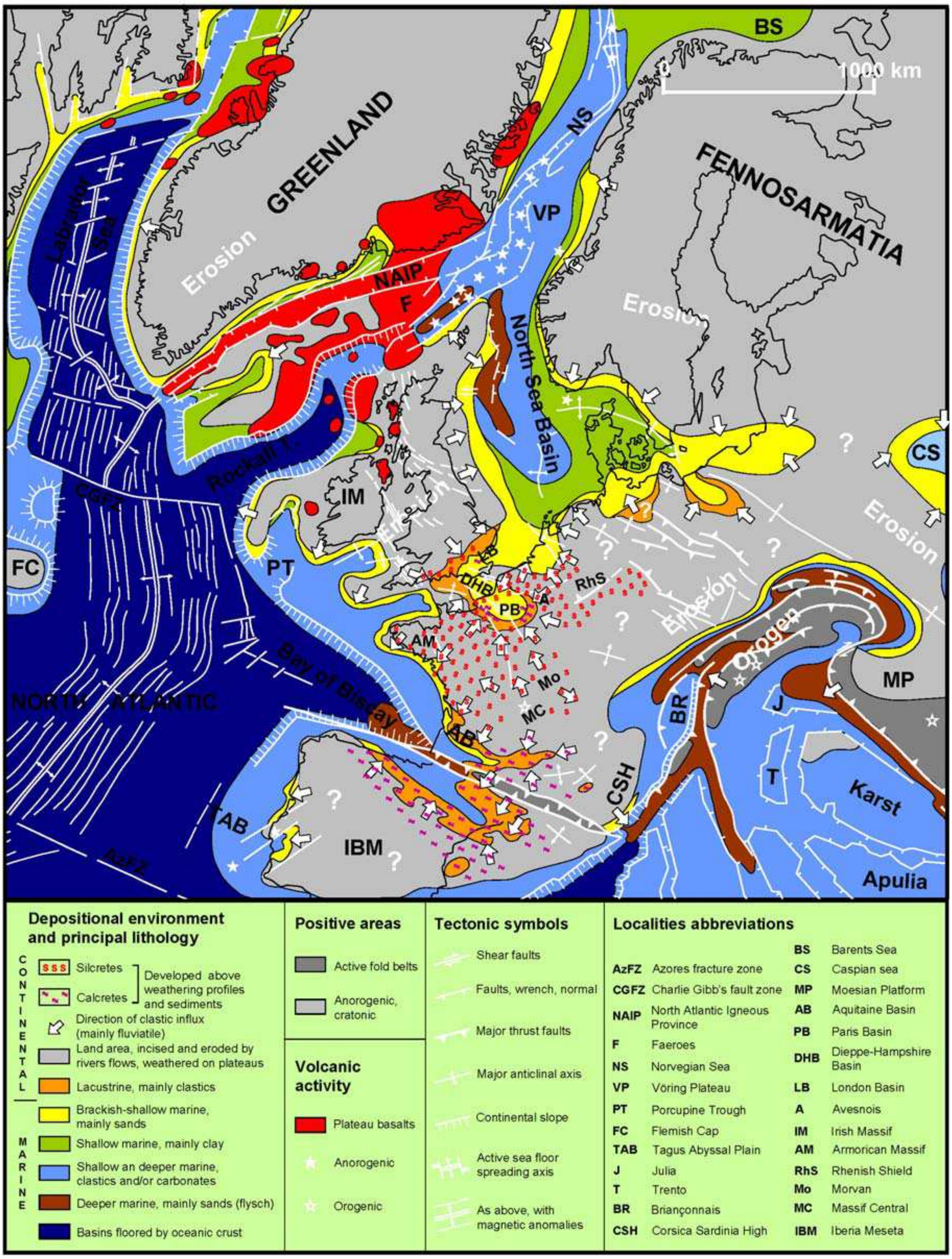

Figure 1 Paleogeographic map of NW Europe and North Atlantic around the Paleocene–Eocene boundary, modified after Ziegler (1988), and showing the continental facies and paleo-weathering types on emerged lands

basins, with pedogenic silcretes upstream andquartzitic silcretes on the leached fluviatile deposits of the lowlands, originally rich in lignite and pyrite. These silcretes are probably the most striking geological markers of the P–E paleo-weathering, and were long known to geologists and geomorphologists who tried to map the "Eocene continental paleosurface". They are often ascribed to Late "Landenian" to the north of the Paris-Belgian Basins and correlated to Sparnacian continental deposits to the south, west and east of the Paris Basin

(Dupuis 1979; Thiry 1981; Quesnel 1997). The silcretes also crop out in England — the pedogenic facies close to the Devon, and the quartzitic facies, termed Sarsenstone, which is more widespread around the London and Hampshire Basins, and locally found *in situ* in the Reading Beds. Some silcretes are more oxidized, giving ochreous and red sandstones (e.g. "Pays d'Ouche" in Normandy and Grandglise Sandstones in Belgium).

Above the upstream paleo-weathering profiles, the silcretes and oxidized sandstones are almost never overlain by other formations, preventing any precise dating. Yet they are sealed by lacustrine limestones of Lutetian to Bartonian age in a few small grabens in Normandy, Perche, and on the Beauce margins. In the best preserved successions downstream, these weathering profiles lie above, or are developed upon, marine or continental upper Thanetian formations and are overlain by lower Ypresian marine formations, in England, northern France-Belgium and Upper Normandy. Locally they are the stratigraphic equivalents to fluvial sands containing lignitic units where the PETM has been recorded (e.g. Belgium (Steurbaut *et al.* 2003) and Northern France (Magioncalda unpublished data; Quesnel 2006; Storme *et al.* unpublished data)). The paleomagnetic ages obtained from the silcretes and oxidized sandstones from the "Pays d'Ouche" and Grandglise Sandstones indicate a paleo-weathering episode around the P–E boundary (Ricordel-Prognon *et al.* unpublished data). The ^{39}Ar-^{40}Ar dating of the supergene Mn oxides from the Morialmé weathering profile formed on the Ardenne basement also gives an age around the P–E boundary (Barbier *et al.* unpublished data). Finally, the quartzitic and oxidized silcretes (Sarsenstones and Landenian Sandstones) are reworked in a few small very well rounded pebbles that accompany flint pebbles within the coastal Blackheath and Oldhaven Formations (Early Ypresian) in England (Stamp 1921) and the "Conglomérat à galets avellanaires", their stratigraphic equivalent in Upper Normandy and Avesnois (Quesnel 2006 unpublished data). All this data implies that the paleo-weathering that produced the silcretes and oxidized sandstones occured after the Late Thanetian and prior to the lower Ypresian transgression. Additionally, the kaolinitic weathering profiles were clearly formed earlier, and probably under wetter conditions, than the silcretes, mainly during the Early Cretaceous on the old basement and Jurassic formations (Yans *et al.* 2003; Thiry *et al.* 2006; Ricordel, 2007; Théveniaut *et al.* 2007) and during the Paleocene on the Chalk (Quesnel *et al.* 2007).

DISCUSSION

The widespread occurrence of a peculiar paleo-weathering in and around the Paris and adjacent basins is present around the P–E boundary. We have recognised pedogenic, quartzitic and oxidized silcretes in Limbourg, Thiérache, Upper Lorraine, Luxembourg, Brittany, Touraine, northern Aquitaine Basin, around the Morvan and the Massif Central, on the Bresse edge and they are also described in Germany in the Saale-Elbe Basin (Eissmann 2002), Eifel (Löhnertz 2003 pers. comm.) and in Hesse (Thiry 2003 pers. comm.). The processes involved in generating these types of silcretes are relatively well known in the Paris and adjacent basins and their borders (Dupuis and Steurbaut 1987; Thiry 1999) and some appear to be closely linked to effects in relation with a climate crisis such as the PETM (i.e. marked alternations of flooding, inducing clay deposition in pores and soil cracks, followed by dry phases saturating the ground solutions; acid drainage of highly organic and pyrite-rich sediments, destabilization of kaolinite). The silica may have been provided by the weathering of the quartz sands and of the flints of the Clay-with-flints (Cwf) profiles formed during the Paleocene at the expense of the Chalk, which largely covered the area at the end of the Cretaceous (Quesnel *et al.* 2007).

Other types of paleo-weathering, such as variegated clay, oxide nodules, gley and pseudogley features formed in the lacustrine and fluviatile formations along the P–E continental paleosurface on the borders of the Sparnacian basin (Buurman 1980; Thiry 1981; Laurain and Meyer 1986). These probably formed in a less well drained paleoenvironment in the clayey lowlands. Sparse calcretes also occur in similar P–E formations south and east of the Paris Basin. These are much more common in the Languedoc, Provence and Pyrenees Garumnian facies (i.e. the Upper Paleocene and Lower Eocene continental formations; Plaziat *et al.*

1987; Cojan *et al.* 2000; Schmitz and Pujalte 2003, 2007). Here, they also probably formed in alternating, strongly seasonal, wet and dry conditions, but in a less acidic paleoenvironment due to carbonate input from the surrounding landscape.

We use the silcretes and all other contemporaneous geological markers to reconstruct the P–E continental paleosurface and to draw its features on the paleogeographic map presented in Figure 1. Added to appropriate climatic conditions, the shaping of this continental paleosurface was probably triggered at the end of the Paleocene by lithospheric deformation related to the first steps of the Pyreneo-alpine orogeny and to the rifting and volcanic activity of the NAIP, and also accompanied by significant sea level variations.

Once the continental paleogeography of the P–E transition in the Paris and adjacent basins has been established, we aim to:

- refine the litho-, bio- and chemo-stratigraphic record of the sedimentary units from coastal to continental paleoenvironments;
- study and date other weathering profiles along the paleotoposequence from the uplands to the lowlands; and
- study the evolution of several proxies to determine the impact of the PETM climatic crisis on the processes (and their intensities) affecting the various compartments of the P–E continental paleosurface.

Furthermore, this regional study may be directly used in improving the tools for simulating the landscape evolution and the Earth's climate in paleoenvironmental modeling.

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