Foreword

Stratigraphic scale of the geodynamic and climatic events in continental realm

Problematics

Contrary to popular belief, continents form much wider areas than the subsidizing marine areas where most sediments have accumulated. Despite this, geological records of the evolution of ancient continents are scarce, with some records totally missing, and often scrambled by successive superimposed evolutions. Often continents preserve only limited testimonies of their evolution and show only a patchwork of relict landforms and weathering products, discontinuous over time and space.

Nevertheless, study of paleoweatherings and paleolandscapes is not useless: as most of the basin deposits originate from the continents it is necessary to reconstruct the successive weatherings, landscapes and environments which have led to these deposits. From this point of view, paleoweatherings are of major significance: they feed the basins in soluble and detrital compounds, and allow grasping the paleoenvironments, the paleoclimates, the paleogeographies, etc. Integrated in the stratigraphic scale, they allow establishing global correlation and contributing to apprehend rates and timing of uplift and erosion. Lastly, paleoweatherings also act as an exchange interface with the atmosphere and thus contribute to global changes.

Progresses in dating paleoweatherings and azoic continental deposits as well as contribution of geochemical modeling have deeply renewed the interpretation of the paleoweatherings. In a near future, the datings will allow to build up a "continental stratigraphic scale" of the ancient climatic and geomorphological events and to establish mass balances between weathering/erosion/basin deposits.

Steps in the studies

Starts during the 19th century

The concept of "meteoric" alteration of rocks and its rule in the development of some sedimentary deposits appeared in the second half of the 19th century. The "superficial" hypothesis, based on the dissolution power of rainwater, has been developed through the impetus provided by chemists (Ebelmen, 1851; Delesse, 1853; Delanoue, 1854; Friedel, 1876). Then, these chemical processes have been applied to explain the genesis of particular geological formations. First of all, these concepts have been applied to paleokarst features, for these it was obvious that alteration and dissolution of the carbonate were promoted by descending solutions (van den Broeck, 1881; Dieulafait, 1885; Fleury, 1909). In the mean time, first descriptions of the landforms have been done and the concept of successive erosion/planation cycles related to uplifts and/or sea level falls was forwarded to explain the superposed benches often observed in landscapes (Davis, 1899).

During this early period, numerous papers are devoted to the study of paleoweathering features and materials and related continental deposits. This is due to the active mining of the Siderolithic formations during the industrial revolution, exploiting iron ore of course, but also the kaolinitic clays and the silcretes for refractory bricks, the white sand for smelting casts, the phosporites for soil enrichment, etc. Numerous descriptions of paleoweathering materials date back from this time and they have never been observed and described since. It is not possible to give here in an exhaustive bibliography, but a special attention has to be paid to papers giving good descriptions of occurrences around the French Massif Central (Gras, 1835; Boulanger,1844; Coquand, 1860; Fabre, 1875; de Grossouvre, 1886), in the Swiss and French Jura and Rhenish Graben in France (Gressly, 1838-1841; Muller, 1853; Fleury, 1909), in the Bavarian Jura and Rhenish Graben in Germany (Walchner, 1830; Fraas, 1852; Schnarrenberger, 1915; Schalch, 1922) and in the Ardenne-Eifel massifs (d'Halloy, 1841; Briart, 1888; Gosselet, 1888).

Investigation of the weathering processes during the 50's and 60's

With the development of new analytical techniques, like XR Diffraction, chemical analyses, micromorphological analyses, etc., soil studies have been renewed during the 50's and 60's. This brought a better knowledge and understanding of the weathering processes acting on Earth surface. Ahead comes the description of soil micromorphogies (Brewer, 1964) which has been a major input to paleoweathering studies by providing the tool for recognition specific soil environment structures in the geological record. Mapping of the main weathering types around the Earth (Pedro, 1966, 1968) has been another major step for interpreting paleoweatherings. Of special interest for paleoweathering studies have been the recognition and the characterization of the different kinds of soils, especially the different types of duricrusts, like laterites and bauxites (Millot et Bonifas, 1955; Valeton, 1972), ferricretes (Maignien, 1958; Delvigne, 1967; Eschenbrenner & Grandin, 1970; Leprun, 1972) and calcretes (Netterberg, 1969; Ruellan, 1970; Sehgal & Stoops, 1972; Goudie, 1973), due to their ability to be preserved in geological records. The recognition of catena and the rule of soils in shapping landforms were also a main achievement of these studies for helping interpretation of inherited weathering products in geological formations (Boulet, 1970; Bocquier, 1973; Nahon, 1976; Millot *et al*., 1979).

The importance of the soils in geology appeared as early as the 50's, with the interpretation of the clay mineral assemblages (Millot, 1949, 1964; Paquet, 1970) and the recognition of the major rule of climatic changes and soil erosions in the elaboration of the geological series (Erhart, 1956). In the mean time, geomorphologists questioned the landform evolution sequences in relation with development of soils, duricrusts (ferricretes, calcretes, silcretes …) and climate evolution (Baulig, 1956; King, 1962). These concepts have only been transferred to geological studies during the next decades.

Use of the tools and concepts during the 70's and 80's

It is really during these decades that paleoweathering studies flourished out. First, there were a lot of works devoted to study paleoweathering occurrences in the sedimentary pile, mainly in mean to marking out paleoclimates. Secondly came studies of residual paleoweathering formation, onto basement as well as on sedimentary deposits, in order to back track the history of the continent, its paleoenvironments, paleolandscapes, paleodrainages, etc. It is not possible to give here in a complete review of the studies produced during this period; we may just illustrate how this was going on in France.

Among the numerous publications related to paleoweathering studies during this period, mention has to be made to those related to specific weathering features like silcretes, calcretes, and other duricrusts (Thiry, 1978, 1981; Parron, 1975; Freytet & Plaziat, 1978; Spy-Anderson, 1980; Meyer, 1981; Triat, 1982; Ménillet, 1987), to morphogenetic evolution of basement or basin areas (Freytet, 1971; Estéoule *et al*., 1972; Coinçon *et al*., 1976; Dejou & Chesworth, 1979; Valleron, 1981; Archanjo, 1982; Dewolf, 1982; Estéoule-Choux, 1983; Simon-Coinçon, 1989), to paleokarsts (Rousset, 1973; Guendon *et al*., 1983; Astruc, 1988; Ertus, 1990; Virol, 1987; Simon-Coinçon & Astruc, 1991) and also studies related to development of ore deposits (Lagny, 1974; Grandin, 1976; Schmitt, 1976, 1983; Barbier, 1976, 1978; Laville, 1981).

Several national and international programmes devoted to paleoweathering studies were running during these decades. In France, numerous studies started around a stratigraphic working group, the "Groupe d'Etude du Paléogène" (GEP) which organized several field trips on continental Palaeogene deposits. In 1982, the first trip of this series, "Surfaces d'aplanissements et paléosols ferrugineux" led by Régine Simon-Coinçon, acted as a cluster for forcoming programmes. Then came successive Conferences organized around paleoweathering and paleosurfaces theme. In 1982, a first Journée Spécialisée de la Société géologique de France, "Altérations et silicifications au Tertiaire en France. Implications stratigraphiques"; in 1983, an Int. Coll. CNRS, "Petrology of Weathering and Soils"; in 1984, a second Journée spécialisée de la Société géologique de France, "Paléoaltérations et paysages associés" and finally in 1989, two field trips dealing mostly with paleoweathering topics during the 9th Intern. Clay Conference AIPEA, Strasbourg, one trip "Paris Basin, Border of Massif Central, Pyrenees" and a second one "Paleoweatherings and related clay minerals in South-East France". In the mean time, two research programmes came out, a first one running from 1983 to 1987, was a cooperative research group (RCP 706) from CNRS, "Paléoaltérations superficielles et profondes"; then from 1990 to 1995 was set up an UNESCO programme (IGCP 317), "Paleoweathering Records and Paleosurfaces" which was the frame for two other international field trips in France, in 1990 "Surficial silicifications in Paris Basin" and in 1995 "From inland paleosurfaces towards sedimentary basins: the example of south western French Massif Central".

These two decades were very productive in paleoweathering and paleosurface research.

New twists for the millennium

Dating paleoweathering features

Dating paleoweathering features, especially the ones away from the basins, has since long been the major problem for studying the paleocontinents. Now datings remain one of the fundamentals of geology. Without datings, no correlations between continents and basins, nor between different continental areas, nor possibility to build up a sequence or a scale of the major continental events, etc.

Datings of paleoweathering minerals, especially alunite, have been worked out by classical radiochronologic methods since the 70's (Ashley & Silberman, 1976; Blanco *et al*., 1982) and were followed by numerous others mainly applied to alunite and manganese oxydes (Alpers & Brimhall, 1988; Bird *et al*., 1990; Vasconcelos *et al.*, 1994; Dammer, 1995; Ruffet *et al*., 1996). Variation of stable isotope can be used as an "indirect" method for dating based upon the changing composition of atmosphere in response to climatic variation, to latitudinal drift and has been applied to kaolinite (Bird & Chivas, 1989; Gilg, 2000) and calcite and organic matter contained in paleoprofiles or continental azoic deposits (Sinha *et al*., 1995; Thiry *et al*., 1998; Cerling, 1999; Cojan *et al*., 2000). Dating ferricretes, by mean of paleomagnetism, has been developed with success (Idnurm & Senior, 1978; Schmidt *et al.*, 1983; Schmidt & Ollier, 1988; Theveniaut & Freyssinet, 1999; Ruellan *et al.*, 2003) and appears very promising in the next future.

Dating the paleosurfaces is another way to constrain the continental geodynamics. Thermoluminescence and ESR datings applied to quartz and kaolinites have provided interesting results (Ambrosi & Chen, 1990; Muller & Calas, 1990; Laurent *et al*., 1999; Singhvi *et al*., 2001). Cosmogenic radionuclides promise an alternative solution to the problem of surface dating, by allowing estimates of the duration of exposure (Phillips *et al*., 1986; Bernat *et al*., 1990; Hancock *et al*., 1999; Heimsath *et al*., 1999).

Modeling paleosurfaces

Modeling paleosurfaces is an emerging discipline (Summerfield, 1991). Computers now allow new and rapid appraisal of spatial data obtained from remote sensing or GIS (McAlister & Smith, 1997; Ringrose & Migon, 1997; White *et al.*, 1997; Evans & Cox, 1999). Modeling erosion appears as a promising track by providing tools which for now allow reconstructing mainly the different steps in soil, valley, and scarp erosion (Perrin *et al*., 1993; El-Hames & Richards, 1994; Wainwright *et al.*, 1995; Torri *et al*., 1998). In the next future, more sophisticate models will allow modeling erosion on a larger scale, by successive steps, coupling erosion with geodynamics and sea level changes and thus allowing modeling evolution of the continents over the geological scale (Ivanov, 1996; Desmet & Govers, 1997; van der Beek *et al*., 1999; Braun, 2002). By modeling successive loading and unloading of the paleosurfaces, endogen phenomena like tectonics and crustal studies may be linked to exogen processes (Wyns, 1991; Kooi & Beaumont, 1994; Tucker & Slingerland, 1994; Quesnel, 1997; Gallagher *et al.*, 1998; Widdowson & Gunnell, 1999; Barbarand, 1999; Lageat, 2001; Wyns, 2002). These advances in understanding the relationships between geomorphological processes, the sedimentary record and tectonics will provide tools for evaluating models of landscape evolution.

Challenges

The increase of available datings of paleoweathering profiles and related paleosurfaces will allow to:

1) Draw complete paleogeographical maps, on which the white areas corresponding to the continental surfaces will be replaced by true maps, on which will appear not only the paleoweathering features, but also the paleolandforms with contours levels above the paleosealevel;

2) Build up an uplift story of the continents comparable to the subsidizing charts which are constructed in the basins. The target is to set up in the continental realm a "sequence stratigraphy of the geodynamic and climatic events" which can be put in parallel with the "sequence stratigraphy" in the marine realm.

3) Give constrains for the lithosphere geodynamics modeling.

Could the Belgian, Dutch, German, Luxembourgian and French people participating at the Preizerdaul's meeting "Paleoweatherings and Paleosurfaces in Ardenne-Eifel Region" be the cluster of a wide transdisciplinary network of geologists, geomorphologists, geochemists, palaeontologists, mineralogists, geophysicists, (geo)mapmakers, … working on this exciting paleocontinent challenge.

Médard THIRY

Ecole des Mines de Paris, 35 rue St Honoré, 77305 Fontainebleau, France, and CNRS-UMR 7619 Sisyphe "Structure et fonctionnement des systèmes hydriques continentaux"
medard.thiry@ensmp.fr

Bibliographie

Alpers C.N., Brimhall G.H. (1988) - Middle Miocene climatic change in Atacama Desert, northern Chile; Evidence from supergene mineralization at La Escondida. *Geol. Soc. Amer. Bull*., **100**, 1640-1656.

Ambrosi J.P., Chen Y. (1990) - ESR dating for lateritic weathering: a preliminary approach. Geochemistry of the Earth's Surface and of Mineral Formation. 2nd Internat. Symp., Aix en Provence 1990. *Chem. Geol*., **84**, 19-22.

Archanjo J.D. (1982) - Le sidérolithique du Quercy blanc (France). Altérations polyphasées paléogènes sur roches sédimentaires. Essai de datation. Thèse docteur-ingénieur, Univ. Louis Pasteur, Strasbourg, 148 p.

Ashley R.P., Silberman M.L. (1976) - Direct dating of mineralization at Goldfield, Nevada, by potassium-argon and fission track methods. *Econ. Geol*., **71**, 904-924.

Astruc J.G. (1988) - Le paléokarst quercynois au Paléogène ; altérations et sédimentations associées. *Doc. BRGM*, **133**, 135 p.

Barbarand J. (1999) - Cinétique de cicatrisation des traces de fission dans les cristaux d'apatite et histoire thermique de la bordure sud-est du Massif Central. Thèse Sciences de la Terre, Univ. Nancy I, 323 p.

Barbier J. (1976) - Sur la signification paléogéographique de certaines minéralisations filoniennes fluorine barytine. *Mém. hors-série Soc. géol. Fr.*, **7**, 85-94.

Barbier J. (1978) - A propos de calcrètes, d'érosion et de la répartition des gîtes d'uranium intragranitique français. *Bull. BRGM*, *Sect. II,* **1**, 31-38.

Baulig H. (1956) - Pénéplaines et pédiplaines. *Bull. Soc. belge Géogr*., **25**, 25-58.

Beek (van der) P.A., Braun J., Lambeck K. (1999) - Post-Palaeozoic uplift history of southeastern Australia revisited: results from a process-based model of landscape evolution. *Australian J. Earth Sciences*, **46**, 157-172.

Bernat M., Bokilo J.E., Yiou F., Raisbeck G.M., Muller J.P. (1990) - ^{10}Be and natural isotopes of U and Th in a laterite cover from Cameroon. 2nd Intern. Symp. "Geochemistry of the Earth's Surface and of Mineral Formation". Aix-en-Provence. *Chem. Geol*., **84**, 347-348.

Bird M.I., Chivas A.R. (1989) - Stable-isotope geochronology of the Australian regolith. *Geochimica et Cosmochimica Acta*, **53**, 3239-3256.

Bird M.I., Chivas A.R., Mc Douglas I. (1990) - An isotopic study of surficial alunite in Australia. 2. Potassium-argon geochronology. *Chemical Geology (Isotope Geoscience Section),* **80**, 133-145.

Blanco J.A., Corrochano A., Montigny R., Thuizat R. (1982) - Sur l'âge du début de la sédimentation dans le bassin tertiaire du Duero (Espagne). Attribution au Paléocène par datation isotopique des alunites de l'unité inférieure. *C.R. Acad. Sci. Fr.*, **295**, 259-262.

Bocquier G. (1973) - Génèse et évolution de deux toposéquences de sols tropicaux du Tchad. Interprétation biogéodynamique. *Mém. ORSTOM*, Paris, **62**, 350 p.

Boulanger M.C. (1844) - Statistique géologique et minéralurgique du département de l'Allier. Imp. P.A. Desrosiers, Moulins, 482 p.

Boulet R. (1970) - La géomorphologie et les principaux types de sols en Haute-Volta septentrionale. *Cah. ORSTOM, Sér. Pedol*, **VIII**, 3, 245-272.

Braun J. (2002) - Quantifying the effect of recent relief changes on age-elevation relationships. *Earth Planetary Science Letters*, **200/3-4**, 331-343.

Brewer R. (1964) - Fabric and mineral analysis in soils. Wiley, New-york, 470 p.

Briart A. (1888) - Notice descriptive des terrains tertiaires et crétacés de l'Entre-Sambre-et-Meuse. *Ann. Soc. géol. Belgique*, **15**, 3-58.

Broeck E. (Van den) (1881) - Mémoire sur les phénomènes d'altération des eaux météoriques étudiés dans leurs rapports avec la géologie stratigraphique. *Mém. Acad. Sci. Lett. Beaux-Arts de Belgique*, **44**, 180 p.

Cerling T.E. (1999) - Stable carbon isotopes in palaeosol carbonates. *In*: Palaeoweathering, palaeosurfaces and related continental deposits, (Eds. Thiry M. & Simon-Coinçon R.). *Spec. Publ. Int. Ass. Sediment.*, **27**, 43-60.

Coinçon R., Tardy Y., Godard A. (1976) - Les enseignements d'ordre morphogénique et paléoclimatique apportés par l'étude des bassins de l'ouest de la Margeride. *Géomorphologie dynamique*, **3**, 81-91.

Cojan I., Moreau M.G., Stott L.E. (2000) - Stable carbon isotope stratigraphy of the Palaeogene pedogenic series of southern France as a basis for continental-marine correlation. *Geology*, **28/3**, 259-262.

Coquand H. (1860) - Description physique, géologique, paléontologique et minéralogique du département de la Charente. III - Description minéralogique et géologique. Barlatier-Feissat et Demonchy, Marseille, vol. 2, 5-56.

Dammer D. (1995) - Geochronology of chemical weathering processes in the northern and western Australian regolith. Thèse Doctorat, Australian National University, 214 p.

Davis W.M. (1899) - The geographical cycle. *Geogr. J*., **14**, 481-504.

Dejou J., Chesworth W. (1979) - Nouvelles observations concernant l'évolution géochimique superficielle des basaltes miocènes du bassin d'Aurillac (Cantal). Nature fersiallitique de cette évolution et conséquences paléoclimatiques. *C.R. Acad. Sci. Fr.*, **288**, 295-298.

Delanoue J. (1854) - Des sources sulfurées et des eaux ordinaires. *Bull. Soc. géol. Fr.*, **11** (2), 569-574.

Delesse (1853) - Sur la transformation du granite en arène et en kaolin. *Bull. Soc. géol. Fr.*, **10** (2), 256-266.

Delvigne J. (1967) - Bilans géochimiques de l'altération des roches basiques en Côte d'Ivoire ferralitique. *Revue Géogr. Phys. Géol. Dyn*., **IX**, n°4, 311-320.

Desmet P.J.J., Govers G. (1997) - Two-dimensional modelling of the within-field variation in rill and gully geometry and location related to topography. *Catena*, **29/3-4**, 283-306.

Dewolf Y. (1982) - Le contact Ile de France - Basse Normandie - Evolution géodynamique. *Mém. et doc. de géographie*, CNRS, 253 p.

Dieulafait L. (1885) - Origine et mode de formation des phosphates de chaux en amas dans les terrains sédimentaires. Leur liaison avec les minerais de fer et les argiles des terrains sidérolithiques. *Ann. Chim. Phys*., (**6**), 5, 204-240.

Ebelmen (1851) - Altération des roches stratifiées sous l'influence des agents atmosphériques et des eaux d'infiltration. *C.R. Acad. Sci. Fr.*, **33**, 678-682.

El-Hames A.S., Richards K.S. (1994) - Progress in arid-lands rainfall-runoff modelling. *Progress in physical geography*, **18(3)**, p. 343-365.

Erhart H. (1956) - La genèse des sols en tant que phénomène géologique. Masson et Cie, Paris, 90 p.

Ertus R. (1990) - Les néoformations d'halloysite dans les cryptokarsts oligo-miocènes de l'Entre-Sambre-et-Meuse (Belgique). Approche sédimentologique, pétrographique et minéralogique. Thèse doctorat, Fac. Polytechnique de Mons, Univ. Paris-Sud Orsay, 177 p.

Eschenbrenner V., Grandin G. (1970) - La séquence de cuirasses et ses différenciations entre Aquibilékrou (Côte d'Ivoire) et Diebougou (Haute Volta). *Cah. ORSTOM, sér. Géol.,* II, **2**, 205-246.

Estéoule-Choux J. (1983) - Altérations et silicifications au Tertiaire dans le Massif armoricain. *géologie de la Fr.*, **4**, 345-352.

Estéoule J., Estéoule-Choux J., Perret P. (1972) - Etude des formations superficielles du Massif armoricain : caractères distinctifs et passage des altérites et des dépôts tertiaires aux formations quaternaires. *Bull. Soc. Géol. Minér., Bretagne*, (C), IV**, 2**, 97-106.

Evans I.S., Cox N.J. (1999) - Relations between land surface properties: altitude, slope and curvature. *In*: Process Modelling and landform Evolution (Eds., Hergarten S & Neugebauer H.J.), Springer, Berlin, 13-45.

Fabre G. (1875) - Sur les terrains sidérolithiques dans le département de la Lozère. *Bull. Soc. géol. Fr.*, (**3**), 3, 583-591.

Fleury E. (1909) - Le Sidérolithique Suisse. Contribution à la connaissance des phénomènes d'altération superficielle des sédiments. *Mém. Soc. Fribourgeoise Sci. nat*., **6,** 260 p.

Fraas O. (1852) - Découverte de fer oolithique à ossement du gypse au sommet de l'Alb de Souabe. *Bull. Soc. géol. Fr.*, **9** (2), 266-267.

Freytet P. (1971) - Les dépôts continentaux et marins du Crétacé supérieur et des couches de passage de l'Eocène en Languedoc. *Bull. Bur. Rech. Géol. Minières*, Paris, (2), sect. I, **4**, 1-54.

Freytet P., Plaziat J.C. (1978) - Les redistributions carbonatées pédogénétiques (nodules, croûtes, "calcrètes") : les deux types principaux d'environnements favorables à leur développement. *C.R. Acad. Sci. Fr.*, **286**, 1775-1778.

Friedel C. (1876) - Sur l'altération des agates et des silex. *Ann. Chim. Phys*., (**5**), 7, 540-546.

Gallagher K., Brown R., Johnson C. (1998) - Fission track analysis and its applications to geological problems. *Annu. Rev. Earth Planet. Sci.,* **26**, 519-572.

Gilg H.A. (2000) - D-H evidence for the timing of kaolinization in Northeast Bavaria, Germany. *Chemical Geology*, **170**, 5-18.

Gosselet J. (1888) - L'Ardenne. Mém. service explic. Carte géol. dét. France, 881 p.

Goudie A. (1973) - Duricrust in Tropical and Subtropical Landscapes. Oxf. Research Studies in Geogr. Clarendon Press, 174 p.

Grandin G. (1976) - Aplanissements cuirassés et enrichissement des gisements de manganèse dans quelques régions d'Afrique de l'Ouest. *Mém. ORSTOM*, **82**, 275 p.

Gras S. (1835) - Statistiques minéralogiques du département de la Drôme. Imprimerie Prudhomme, Grenoble, 296 p.

Gressly A. (1838-1841) - Observations géologiques sur le Jura Soleurois. *Mém. Soc. Helv.,* **II, IV, V,** 549 p.

Grossouvre (de) A. (1886) - Etude sur les gisements de minerais de fer du centre de la France. *Ann. Mines* (**8**), X, 211-315, pl. V, VI.

Guendon J.L., Parron C., Triat J.M. (1983) - Incidences des altérations crétacées sur la notion de Sidérolithique dans le Sud-Est de la France. *Bull. Soc. géol. Fr.*, **7**, 1, 41-50.

Halloy (d') J.B. (1841) - Notice sur le gisement et l'origine des dépôts de minerais, d'argile, de sable et de phtanite du Condroz (Belgique). *Bull. Soc. géol. Fr.*, **12** (1), 242-251.

Hancock G.S., Anderson R.S., Chadwick O.A., Finkel R.C. (1999) - Dating fluvial terraces with ^{10}Be and ^{26}Al profiles: application to the Wind River, Wyoming. *Geomorphology*, **27/1-2**, 41-60.

Heimsath A.M., Dietrich W.E., Nihiizum K., Finkel R.C. (1999) - Cosmogenic nuclides, topography, and the spatial variation of soil depth. *Geomorphology*, **27/1-2**, 151-172.

Idnurm M., Senior B.R. (1978) - Paleomagnetic ages of late Cretaceous and Tertiary weathered profiles in the Eromanga Basin, Queensland. *Palaeogeogr. Palaeoclim. Palaeoecology*, **24**, 263-277.

Ivanov S. (1996) - Variability of sedimentary sequence: numerical modeling of the deposition-erosion process. *Geol. Rundsch*., **85/1**, 12-18.

King L.C. (1962) - Morphology of the Earth. Oliver and Boyd Ed., Edinburgh, 725 p.

Kooi H., Beaumont C. (1994) - Escarpment evolution on high-elevation rifted margins: Insights derived from a surface processes model that combines diffusion, advection, and reaction. *J. Geophys. Res.,* **99/B6**, 12 191-12 209.

Lageat Y. (2001) - Mégaformes et grandes articulations de la lithosphère continentale. *Sud-Ouest Européen*, Toulouse, **10**, 23-38.

Lagny P. (1974) - Emersions successives, karstification, la sédimentation continentale au Trias moyen dans la région de Sappada. *Sciences de la Terre*, Nancy, **19**, 195-233.

Laurent M., Falguères C., Bahain J.J., Rousseau L., Van Vliet Lanoé B. (1999) - ESR dating of quartz extracted from Quaternary and Neogene sediments: method, potential and actual limits. *Quaternary Science Reviews*, **17/11**, 1057-1062.

Laville P. (1981) - La formation bauxitique provençale (France). Séquence des faciès chimiques et paléomorphologie crétacée. *Chron. Rech. minière*, **461**, 51-68.

Leprun J.C. (1972) - Cuirasses ferrugineuses autochtones et modelés de bas-reliefs des pays cristallins de Haute-Volta orientale. *C.R. Acad. Sci. Fr.*, **275** (D), 1207-1210.

Maignien R. (1958) - Le cuirassement des sols en Guinée. Afrique Occidentale. *Mém. Serv. Carte Géol. Als.-Lorr.*, Strasbourg, 239 p.

McAlister J.J., Smith B.J. (1997) - Geochemical trends in Early Tertiary palaeosols from northeast Ireland: a statistical approach to assess element behaviour during weathering. *In*: Palaeosurfaces: recognition, reconstruction and palaeoenvironmental interpretation (Ed. Widdowson M.), *Geol. Soc. Spec. Publication*, **120**, 57-65.

Ménillet F. (1987) - Les meulières du Bassin de Paris (France) et les faciès associés. Rôle des altérations supergènes néogènes à quaternaire ancien dans leur génèse. Thèse Sciences, Univ. Louis Pasteur, Strasbourg, 536 p.

Meyer R. (1981) - Rôle de la paléoaltération, de la paléopédogenèse et de la diagenèse précoce au cours de l'élaboration des séries continentales. Présentation d'exemples choisis dans quelques formations sédimentaires françaises. Thèse Sci. Univ. Nancy 1, 229 p.

Millot G. (1949) - Relations entre la constitution et la genèse des roches sédimentaires argileuses. *Géol. Appl. Prospec. Min.*, Nancy, **2/2-3-4**, 1-352.

Millot G. (1964) - Géologie des argiles. Masson, Paris, 499 p.

Millot G., Bonifas M. (1955) - Transformations isovolumétriques dans les phénomènes de latéritisation et de bauxitisation. *Bull. Serv. Carte géol. Als.-Lorr.*, Strasbourg, **8**, 3-10.

Millot G., Chauvel A., Leprun J.C., Nahon D., Paquet H., Pédro G., Rognon P., Ruellan A., Tardy Y. (1979) - Géochimie de la surface, pédogenèse, aplanissements et formes de relief dans les pays méditerranéens et tropicaux. *Sci. Géol. Bull.*, **53**, 39-43.

Muller A. (1853) - Über der Entstehung der Eisen und Manganerz in Jura. *Verh. Basel*, **1**, p. 98.

Muller J.P., Calas G. (1990) - Paramagnetic centers in kaolinite and the history of weathering crust, Geochemistry of the Earth's Surface and of Mineral Formation, 2nd Internat. Symp., Aix en Provence 1990. *Chem. Geol.*, **84**, 105-107.

Nahon D. (1976) - Cuirasses ferrugineuses et encroûtements calcaires au Sénégal occidental et en Mauritanie. Systèmes évolutifs: géochimie, structures, relais et coexistence. *Sci. Géol. Mém.,* **44**, 232 p.

Netterberg F. (1969) - The interpretation of some basic calcrete types. *South African Archaeol. Bull.*, **21**, 3/4, 117-122.

Paquet H. (1970) - Evolution géochimique des minéraux argileux dans les altérations et les sols des climats méditerranéens et tropicaux à saisons contrastées. *Mém. Serv. Carte géol. Als. Lorr.*, Strasbourg, **30**, 212 p.

Parron C. (1975) - Contribution à l'étude des paléoaltérations des grès du Crétacé supérieur du Gard (de Pont-Saint-Esprit à Uzès). Conséquences stratigraphiques et paléogéographiques. Thèse 3ème cycle Aix-Marseille, 103 p.

Pedro G. (1966) - Essai sur la caractérisation géochimique des différents processus zonaux résultant de l'altération des roches superficielles (cycle alumino-silicique). *C.R. Acad. Sci. Fr.*, **262-D**, 1828-1831.

Pedro G. (1968) - Distribution des principaux types d'altération chimique à la surface du globe. Présentation d'une esquisse géographique. *Rev. Géogr. Phys. Géol. Dyn.*, **10**, 457-470.

Perrin M., Roudier P., Peroche B. (1993) - Computer aided 3D erosional modeling operated on geologically diversified folded and faulted terrains. *Geoinformatics*, **4** (n°3), 161-166.

Phillips F.M., Leavy B.D., Jannik N.O., Elmore D., Kubik P.W. (1986) - The accumulation of cosmogenic chlorine-36 in rocks: a method for surface exposure dating. *Science*, **231**, 41-42.

Quesnel F. (1997) - Cartographie numérique en géologie de surface. Application aux altérites à silex de l'Ouest du Bassin de Paris. Thèse, Univ. Rouen, *Documents du BRGM*, **263**, 268 p.

Ringrose P.S., Migon P. (1997) - Analysis of digital elevation data for the Scottish Highlands and recognition of pre-Quaternary elevated surfaces. *In*: Palaeosurfaces: recognition, reconstruction and palaeoenvironmental interpretation (Ed. Widdowson M.), *Geol. Soc. Spec. Publication*, **120**, 25-35.

Rousset C. (1973) - Rôle de la karstologie dans l'élaboration des reconstitutions paléogéographiques: les cycles karstiques en Provence. *Revue Geogr. Phys. Geol. Dyn.,* (**2**), 15, 273-294.

Ruellan A. (1970) - Les sols à profil calcaire différencié des plaines de la Basse Moulouya (Maroc oriental). *Mém. ORSTOM*, **54**, 302 p.

Ruellan P.-Y., Thiry M., Moreau M.-G. (2003) - Datation des paléoaltérations et des évènements géodynamiques continentaux. I – Premières datations par paléomagnétisme des formations "sidérolithiques" du Lembron. Rapport Armines/Ecole des Mines, LHM/RD/03/01, 23 p.

Ruffet G., Innocent C., Michard A., Féraud G., Beauvais A., Nahon D., Hamelin B. (1996) - A geochronological $^{40}Ar/^{39}Ar$ and $^{87}Rb/^{87}Sr$ study of K-Mn oxides from the weathering sequence of Azul, Brazil. *Geochimica et Cosmochimica Acta*, **60/12**, 2219-2232.

Schalch F. (1922) - Erläuterungen zu Blatt Griessen (Nr 157). Geologische spezialkarte von Baden, Heidelberg, 117 p.

Schmidt P.W., Ollier C.D. (1988) - Palaeomagnetic dating of late Cretaceous to Early Tertiary weathering in New England, N.S.W. *Australian Earth Sci. Rev.*, **25**, 363-371.

Schmidt P.W., Prasad V., Raman P.K. (1983) - Magnetic ages of some indian laterites. *Paleogeography, Palaeoclimatology, Palaeoecology*, **44**, 185-202.

Schmitt J.M. (1976) - Sédimentation, paléoaltération, géochimie et minéralisation en plomb de la série triasique de Zéïda (Haute-Moulouya, Maroc). Thèse Doct.-Ing., Ecole des Mines de Paris, 97 p.

Schmitt J.M. (1983) - Albitization in relation to the formation of uranium deposits in the Rouergue area (Massif Central). *In*: Petrology of weathering and soils, (Nahon D., Noack Y., edits), *Sci. Géol. Mém.*, **73**, 185-194.

Schnarrenberger C. (1915) - Erläuterungen zu Blatt Kandern (N° 139). Geologischen spezialkarte von Baden, Heidelberg, 131 p.

Sehgal J.L., Stoops G. (1972) - Pedogenic calcite accumulation in arid and semi-arid regions of the Indo-Gangetic alluvial plain of erstwhile Punjab (India), their morphology and origin. *Geoderma*, **8**, 59-72.

Simon-Coinçon R. (1989) - Le rôle des paléoaltérations et des paléoformes dans les socles: l'exemple du Rouergue (Massif central français). *ENSMP, Mém. Sci. de la Terre*, **9**, 290 p.

Simon-Coinçon R., Astruc J.G. (1991) - Les pièges karstiques en Quercy: rôle et signification dans l'évolution des paysages. *Bull. Soc. géol. Fr.*, **162**, 595-605.

Singhvi A.K., Bluszcz A., Bateman M.D., Rao M.S. (2001) - Luminescence dating of loess-palaeosol sequences and coversands: methodological aspects and palaeoclimatic implications. *Earth-Science Reviews*, **54/1-3**, 193-211.

Sinha A., Aubry M.P., Stott L.D., Thiry M., Berggren W.A. (1995) - Chemostratigraphy of the "lower" Sparnacian deposits (Argiles Plastiques bariolées) of the Paris Basin. *Israel Journal of Earth Sciences*, **44/4**, 223-237.

Spy-Anderson F.L. (1980) - Dolocrètes et nodules dolomitiques. Résultats de la dolomitisation directe, en milieu continental de sédiments terrigènes de la « formation bariolée supérieure » (Keuper) de la région de Vans (Ardèche, Sud-Est de la France). *Bull. BRGM*, (2), **I,** 3, 195-205.

Summerfield M.A. (1991) - Global Geomorphology. An introduction to the study of landforms. Longman Scientific and Technical Publications, 537 p.

Théveniaut H., Freyssinet P. (1999) - Paleomagnetism applied to lateritic profiles to assess saprolite and duricrust formation processes: the example of Mont Baduel profile (French Guiana). *Palaeogeogr., Palaeoclim., Palaeoecol*., **148/4**, 209-231.

Thiry M. (1978) - Silicification des sédiments sablo-argileux de l'Yprésien du sud-est du bassin de Paris. Genèse et évolution des dalles quartzitiques et silcrètes. *Bull. BRGM,* (III), **I**, 19-46.

Thiry M. (1981) - Sédimentation continentale et altérations associées : calcitisations, ferruginisations et silicifications. Les argiles plastiques du Sparnacien du Bassin de Paris. *Sci. Géol., Mém*., **64**, 173 p.

Thiry M., Dupuis C., Sinha A., Aubry M.-P., Stott L.D., Berggren W.A. (1998) - Carbon isotopic signature of Sparnacian deposits. *In*: Thiry M. & Dupuis C. (eds.), The Palaeocene/Eocene boundary in Paris Basin: The Sparnacian deposits, Field Trip Guide, *ENSMP Mém. Sci. de la Terre*, **34**, 28-38.

Torri D., Poesen J., Borselli L.(1998) - Predictability and uncertainty of the soil erodibility factor using a global dataset. *Catena*, **31**, 1-22.

Triat J.M. (1982) - Paléoaltérations dans le Crétacé supérieur de Provence Rhodanienne. *Sci. Géol., Mém.*, **63**, 202 p.

Tucker G.E., Slingerland R.L. (1994) - Erosional dynamics, flexural isostasy, and long-lived escarpments: A numerical modeling study. *J. Geophys. Res.*, **99/B6**, 12 224-12 243.

Valleron M.M. (1981) - Les faciès calcaires du Lutétien à *Planorbis pseudoammonius* dans le Bas-Languedoc. Argilogenèse et silifications associées aux encroûtements calcaires. Thèse 3ème cycle, Univ. Louis Pasteur, Strasbourg, 108 p.

Vasconcelos P.M., Renne P.R., Brimhall G.H., Becker T.A. (1994) - Direct dating of weathering phenomena by $^{40}Ar/^{39}Ar$ and K-Ar analysis of supergene Mn-oxides. *Geochimica et Cosmochimica Acta*, **58**, 1635-1665.

Vateton I. (1972) - Bauxites. Develop. in Soil Sci., Elsevier Publ. Comp., Amsterdam, 226 p.

Virol F. (1987) - Le contact Massif central/Bassin Aquitain au niveau du Lot moyen et du Celé : enseignements fournis par les formations superficielles d'âge Secondaire et Tertiaire en matière d'évolution géomorphologique. Thèse doct., Univ. Paris I, 300 p.

Wainwright J., Parsons A.J., Abrahams A.D. (1995) - A simulation study of the role of raindrop erosion in the formation of desert pavements. *Earth surface processes and Landforms*, **20**, 277-291.

Walchner F.A. (1830) - Notice sur les minerais de fer pisiformes et réniformes des environs de Candern en Brisgau (Grand-Duché de Bade). *Mém. Soc. Histoire nat. Strasbourg*, **1**, 7-11.

White K., Drake N., Walden J. (1997) - Remote sensing for mapping palaeosurfaces on the basis of surficial chemistry: a mixed pixel approach. *In*: Palaeosurfaces: recognition, reconstruction and palaeoenvironmental interpretation (Ed. Widdowson M.). *Geol. Soc. Spec. Publication*, **120**, 283-293.

Widdowson M., Gunnell Y. (1999) - Lateritization, geomorphology and geodynamics of a passive continental margin: the Konkan and Kanara coastal lowlands of western peninsular India. *In*: Palaeoweathering, palaeosurfaces and related continental deposits (Eds. Thiry M. & Simon-Coinçon R.). *Spec. Publ int. Ass. Sediment.*, **27**, 245-274.

Wyns R. (1991) - Evolution tectonique du bâti armoricain oriental au Cénozoïque d'après l'analyse des paléosurfaces continentales et des formations géologiques associées. *Géologie de la France*, **3**, 11-42.

Wyns R. (2002) - Climat, eustatisme, tectonique : quels contrôles pour l'altération continentale ? Exemple des séquences d'altération cénozoïques en France. *Bull. Inf. Géol. Bassin de Paris,* **39/2**, 5-16.