University of Wisconsin-Madison
Department of Geography
GEOG 920:
CHARACTERIZING ORGANIC MATTER ON LAND AND WATER
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READING LIST

1. REVIEWS

1.1. Chemical Composition

Kögel-Knabner, I. 2002. The macromolecular composition of plant and microbial residues as inputs to soil organic matter. Soil Biology & Biochemistry 34: 139-162. (Figures of molecular structures)

Kleber, M. and M.G. Johnson. 2010. Advances in understanding the molecular structure of soil organic matter: Implications for interactions in the environment. Advances in Agronomy 106: 77-142.

Hedges, J.I., G. Eglinton, P.G. Hatcher, D.L. Kichrman, C. Arnosti, S. Derenne, R.P. Evershed, I. Kögel-Knabner, J.W. de Leeuw, R. Littke, W. Michaelis, and J. Rullkötter. 2000. The molecularly-uncharacterized component of nonliving organic matter in natural environments. Organic Geochemistry 31: 945-958.

Gleixner, G., C.J. Czimczik, C. Kramer, B. Lühker, and M.W.I. Schmidt. 2001. Plant compounds and their turnover and stabilization as soil organic matter. Global Biogeochemical Cycles in the Climate System. Academic Press: p. 201-215.

Grandy, A.S., and J.C. Neff. 2008. Molecular C dynamics downstream: the biochemical decomposition sequence and its impact on soil organic matter structure and function. Science of the Total Environment 404: 297-307.

Lorenz, K., R. Lal, C.M. Preston, and K.G.J. Nierop. 2007. Strengthening the soil organic carbon pool by increasing contributions from recalcitrant aliphatic bio(macro)molecules. Geoderma 142: 1-10. See Table 1.

Burdon, J. 2001. Are the traditional concepts of the structures of humic substances realistic? Soil Science 166: 752-769.

Poirier, N., S.O. Sohi, J.L. Gaunt, N. Mahieu, E.W. Randall, D.S. Powlson, R.P. Evershed. 2005. The chemical composition of measurable soil organic matter pools. Organic Geochemistry 36: 1174-1189.

Kögel-Knabner, I. 1993. Biodegradation and humification processes in forest soils. In: J-M. Bollag and G. Stotzky (eds.) Soil Biochemistry Vol. 8.

Shulten, H.-R. and M. Schnitzer. 1998. The chemistry of soil organic nitrogen: a review. Biology and Fertility of Soils 26: 1-15.

Kleber, M. 2010. What is recalcitrant soil organic matter? Environmental Chemistry 7: 320-332.

1.2. Methods

Medeiros, P.M. and B.R.T. Simoneit. 2007. Gas chromatography coupled to mass spectrometry for analyses of organic compounds and biomarkers as tracers for geological, environmental, and forensic research. Journal of Separation Science 30: 1516-1536.

Otto, A. and M.J. Simpson. 2007. Analysis of soil organic matter biomarkers by sequential chemical degradation and gas chromatography-mass spectrometry. Journal of Separation Science 30: 272-282.

Amelung, W., S. Brodowski, A. Sandhage-Hofmann, and R. Bol. 2008. Combining biomarker with stable isotope analyses for assessing the transformation and turnover of soil organic matter. Advances in Agronomy 100: 155-249.

Kögel-Knabner, I. 2000. Analytical approaches for characterizing soil organic matter. Organic Geochemistry 31: 609-625.

Northcott, G.L. and K.C. Jones. 2000. Experimental approaches and analytical techniques for determining organic compound bound residues in soil and sediment. Environmental Pollution 108: 19-43.

Simpson, M.J., A. Otto, and X. Feng. 2008. Comparison of solid-state Carbon-13 Nuclear Magnetic Resonance and organic matter biomarkers for assessing soil organic matter degradation. Soil Science Society of America Journal 72: 268-276.

Shadkami, F. and R. Helleur. 2010. Review: Recent applications in analytical thermochemolysis. Journal of Analytical and Applied Pyrolysis 89: 2-16.

Pena-Mendez, E.M., D. Gajdosova, J. Havel. 2010. Direct laser desorption ionisation time-of-flight (TOF) mass spectrometry of soil organic matter for fast soil fingerprints. Chemistry and Ecology 26: 167-175.

1.3. Technical Reviews

Sessions, A.L. 2006. Isotope-ratio detection for gas chromatography. Journal of Separation Science 29: 1946-1961.

Brenna, J.T., T.N. Corso, H.J. Tobias, and R.J. Caimi. 1997. High-precision continuous-flow isotope ratio mass spectrometry. Mass Spectrometry Reviews 16: 227-258.

Meier-Augenstein, W. 1999. Applied gas chromatography coupled to isotope ratio mass spectrometry. Journal of Chromatography A, 842: 351-371.

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2. APPLICATIONS: Multiple Methods

Guggenberger, G., B.T. Christensen, and W. Zech. 1994. Land-use effects on the composition of organic matter in particle-size separates of soil. I: Lignin and carbohydrate signature. European Journal of Soil Science 45: 449-458.

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Saiz-Jimenez, C., B. Hermosin, G. Guggenberger and W. Zech. 1996. Land-use effects on the composition of organic matter in particle-size separates of soil. III: Analytical pyrolysis. European Journal of Soil Science 47: 61-69.

Preston, C.M., J.R. Nault, J.A. Trofymow, C. Smyth and CIDET Working Group. 2009. Chemical changes during 6 years of decomposition of 11 litters in some Canadian forest sites. Part 1. Elemental composition, tannins, phenolics, and proximate fractions. Ecosystems 12: 1053-1077.

Preston, C.M., J.R. Nault, and J.A. Trofymow. 2009. Chemical changes during 6 years of decomposition of 11 litters in some Canadian forest sites. Part 1. ^{13}C abundance, solid-state ^{13}C NMR spectroscopy and the meaning of "lignin". Ecosystems 12: 1053-1077.

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3. GENERAL Compound Classes

3.1. C-13-NMR and Molecular Mixing Model

Baldock, J.A., C.A. Masiello, Y. Gelinas, and J.I. Hedges. 2004. Cycling and composition of organic matter in terrestrial and marine ecosystems. Marine Chemistry 92: 39-64.

Wilson, M.A., K.M. Goh, P.J. Collin and L.G. Greenfield. 1986. Origin of humus variation. Organic Geochemistry 9: 225-231.

Wilson, M.A., R. J. Pugmire, K.W. Zilm, K.M. Goh, S. Heng and D.M. Grant. 1981. Cross-polarization 13C-NMR spectroscopy with 'magic angle' spinning characterizes organic matter in whole soils. Nature 294: 648-650.

Kaal, J., J.A. Baldock, P. Buurman, K.G.J. Nierop, X. Ponteveda-Pombal, and A. Martinez-Cortizas. 2007. Evaluating pyrolysis-GC/MS and 13C CPMAS NMR in conjunction with a molecular mixing model of the Penido Vello peat deposit, NW Spain. Organic Geochemistry 38: 1097-1111.

Preston, C.M. 2001. Carbon-13 solid-state NMR of soil organic matter – using the technique effectively. Canadian Journal of Soil Science 81: 255-270.

Kögel-Knabner, I. 1997. ^{13}C and ^{15}N NMR spectroscopy as a tool in soil organic matter studies. Geoderma 80: 243-270.

Baldock, J.A., J.M. Oades, P.N. Nelson, T.M. Skene, A. Golchin, and P. Clarke. 1997. Assessing the extent of decomposition of natural organic materials using solid-state 13C NMR spectroscopy. Australian Journal of Soil Research 35: 1061-83.

Veeman, W.S. 1997. Nuclear magnetic resonance, a simple introduction to the principles and applications. Geoderma 80: 225-242.

3.2. Pyrolysis

Parsi, Z., N. Hartog, T. Gorecki, and J. Poerschmann. 2007. Analytical pyrolysis as a tool for the characterization of natural organic matter--A comparison of different approaches. Journal of Analytical and Applied Pyrolysis 79: 9-15.

Gleixner, G., R. Bol, and J. Balesdent. 1999. Molecular insight into soil carbon turnover. Rapid Communications in Mass Spectrometry 13: 1278-1283.

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Leinweber, P. and H.-R. Schulten. 1999. Advances in analytical pyrolysis of soil organic matter. Journal of Analytical and Applied Pyrolysis 49: 359-383.

Fabbri, D., M. Mongardi, L. Montanari, G.C. Galletti, G. Chiavari, and R. Scotti. 1998. Comparison between CP/MAS 13C-NMR and pyrolysis-GC/MS in the structural characterization of humins and humic acids of soil and sediments. Fresenius Journal of Analytical Chemistry 362: 299-306.

Neff, J.C., J.W. Harden, and G. Gleixner. 2005. Fire effects on soil organic matter content, composition, and nutrients in boreal interior Alaska. Canadian Journal of Forest Research 35: 2178-2187.

3.4. Carbohydrates- GC/C/IRMS

Derrien, D., C. Marol, M. Balabane, and J. Balesdent. 2006. The turnover of carbohydrate carbon in a cultivated soil estimated by ^{13}C natural abundances. European Journal of Soil Science 57: 547-557.

3.5. Proximate fractions: Chemical Extractions

3.5.1. Plant Litter

Ryan, M.G., J.M. Melillo, and A. Ricca. 1990. A comparison of methods for determining proximate carbon fractions of forest litter. Canadian Journal of Forest Research 20: 166-171.

Melillo, J.M., J.D. Aber, A.E. Linkins, A. Ricca, B.Fry, and K.J. Nadelhoffer. 1989. Carbon and nitrogen dynamics along the decay contiuum: Plant litter to soil organic matter. Plant and Soil 115: 189-198.

Strickland, M.S., E. Osburn, C. Lauber, N. Fierer and M.A. Bradford. 2009. Litter quality is in the eye of the beholder: initial decomposition rates as a function of inoculum characteristics. Functional Ecology doi: 10.1111/j.1365-2435.2008.01515.x

3.5.2. SOM

Entry, J.A., and W.H. Emmingham. 1998. Influence of forest age on forms of carbon in Douglas-fir soils in the Oregon Coast Range. Canadian Journal of Forest Research 28: 390-305.

3.6. Hydrophobicity (Solvent extractions and HPLC)

Marinari, S., K. Liburdi, D. Corradini, and S. Grego. 2010. Reversed-phase high performance liquid chromatographic profile of organic fractions extracted by solvents with different polarity as a tool to evaluate the hydrophobic character of soil under different management. Soil & Tillage Research 109: 36-40.

4. INDIVIDUAL Compounds: Biomarkers

Lichtfouse, E. 2000. Compound-specific isotope analysis. Application to archaeology, biomedical sciences, biosynthesis, environment, extraterrestrial chemistry, food science, forensic science, humic substances, microbiology, organic geochemistry, soil science and sport. Rapid Communications in Mass Spectrometry 14: 1337-1344.

Glaser, B. 2005. Compound-specific stable-isotope ($\delta^{13}C$) analysis in soil science. Journal of Plant Nutrition and Soil Science 168: 633-648.

Feng, X. and M.J. Simpson. 2007. The distribution and degradation of biomarkers in Alberta grassland soil profiles. Organic Geochemistry 38: 1558-1570.

Feng, X., A.J. Simpson, E.G. Gregorich, B. Elberling, D.W.Hopkins, A.D. Sparrow, P.M. Novis, L.G. Greenfield, and M.J. Simpson. 2010. Chemical characterization of microbial-dominated soil organic matter in the Garwood Valley, Antarctica. Geochimica et Cosmochimica Acta 74: 6485-6498.

Feng, X., A.J. Simpson, K.P. Wilson, D.D. Williams, and M.J. Simpson. 2008. Increased cuticular carbon sequestration and lignin oxidation in response to soil warming. Nature Geosciences 1: 836-839.

Evershed, R.P., S.N. Dudd, S. Charters, H. Mottram, A.W. Stott, A. Raven, P.F. van Bergen, and H.A. Bland. 1999. Lipids as carriers of anthropogenic signals from prehistory. Philosophical Transactions of the Royal Society B. 354: 19-31.

4.1. Roots vs Shoots (Cutin and Suberin by GC/C/IRMS)

Mendez-Millan, M., M-F. Dignac, C. Rumpel and S. Derenne. 2010. Can cutin and suberin biomarkers be used to trace shoot and root-derived organic matter? A molecular and isotopic approach. Biogeochemistry DOI: 10.1007/s10533-010-9407-8

4.2. Microbial

Guggenberger, G., S.D. Frey, J. Six, K. Paustian and E.T. Elliott. 1999. Bacterial and fungal cell-wall residues in conventional and no-tillage agroecosystems. Soil Science Society of America Journal 63: 1188-1198.

Glaser, B., M-B. Turrion, and K. Alef. 2004. Amino sugars and muramic acid – biomarkers for soil microbial community structure analysis. Soil Biology & Biochemistry 36: 399-407.

Waldrop, M. and M. Firestone. 2004. Microbial community utilization of recalcitrant and simple carbon compounds: impact of oak-woodland plant communities. Oecologia 138: 275-284.

Kramer, C., and G. Gleixner. 2006. Variable use of plant-and soil-derived carbon by microorganisms in agricultural soils. Soil Biology & Biochemistry 38: 3267-3278.

4.4. Terrestrial Plants

4.4.1. Lignin Phenols- GC/C/IRMS

Dignac, M.-F., H. Bahri, C. Rumpel, D.P. Rasse, G. Bardoux, J. Balesdent, C. Girardin, 2C. Chenu and A. Mariotti. 2005. Carbon-13 natural abundance as a tool to study the dynamics of lignin monomers in soil: an appraisal at the Closeaux experimental field (France). Geoderma 128: 3-17.

Preston, C.M., J.A. Trofymow, and L.B. Flanagan. 2006. Decomposition, $\delta^{13}C$, and the "lignin" paradox. Canadian Journal of Soil Science 86: 235-245.

4.4.2. Lipids

Goossens, H., R.R. Duren, J.W. De Leeuw, and P.A. Schenck. 1989. Lipids and their mode of occurrence in bacteria and sediments – II. Lipids in the sediment of a stratified freshwater lake. Organic Geochemistry 14: 27-41.

Almendros, G., P. Tinoco, F.J. González-Vila, H-D. Lüdemann, J. Sanz and F. Velasco. 2001. 13C-NMR of forest soil lipids. Soil Science 166: 186-196.

4.5. Trees vs Grasses

Filley, T.R., T. W. Boutton, J.D. Liao, J.D. Jastrow, and D.E. Gamblin. 2008. Chemical changes to nonaggregated particulate soil organic matter following grassland-to-woodland transition in a subtropical savanna. Journal of Geophysical Research 113, G03009, doi:10.1029/2007JG000564, 2008

Krull, E., D. Sachse, I. Mugler, A. Thiele, and G. Gleixner. 2006. Compound-specific $\delta^{13}C$ and $\delta^{2}H$ analyses of plant and soil organic matter: A preliminary assessment of the effects of vegetation change on ecosystem hydrology. Soil Biology & Biochemistry 38: 3211-3221.

4.6. Animals (Lipids, Chitin and Proteins Steroids)

Stankiewicz, B.A., P.F. van Bergen, I.J. Duncan, J.F. Carter, D.E.G. Briggs, and R.P. Evershed. 1996. Recognition of chitin and proteins in invertebrate cuticles using analytical pyrolysis/gas chromatography and pyrolysis/gas chromatography/mass spectrometry. Rapid Communications in Mass Spectrometry 10: 1747-1757.

Evershed, R., S.N. Dudd, M.S. Copley, R. Berstan, A.W. Stott, H. Mottram, S.A. Buckle, and Z. Crossman. 2002. Chemistry of archeological animal fats. Accounts of Chemical Research 35: 660-668.

Copley, M.S., R. Berstan, S.N. Dudd, G. Docherty, A.J. Mukherjee, V. Straker, S. Payne, and R.P. Evershed. 2003. Direct chemical evidence for widespread dairying in prehistoric Britain. Proceedings of the National Academy of Sciences 100: 1524-1529.

Gineys, N., B. Giroud, and E. Vulliet. 2010. Analytical method for the determination of trace levels of steroid hormones and corticosteroids in soil, based on PLE/SPE/LC-MS/MS. Analytical and Bioanalytical Chemistry 397: 2295-2302.

4.7. Lignite/Coal

Chabbi, A., C. Rumpel, P.M. Grootes, A. Mariotti and R.F. Huttl. 2006. Isotopic tracers for the analysis of vegetation-derived organic matter in lignite-containing soils and sediments along a transect ranging from a forest soil to a submerged lake sediment. Organic Geochemistry 37: 740-753.

4.8. Black Carbon

Czimczik, C.I. and C.A. Masiello. 2007. Controls on black carbon storage in soils. Global Biogeochemical Cycles, Vol. 21, GB3005,doi:10.1029/2006GBC002798, 2007

Brodowski, S., W. Amelung, L. Haumaier, C. Abetz, and W. Zech. 2005. Morphological and chemical properties of black carbon in physical soil fractions as revealed by scanning electron microscopy and energy-dispersive X-ray spectroscopy. Geoderma 128: 116-129.

Hammes et al. 2007. Comparison of quantification methods to measure fire-derived

(black/elemental) carbon in soils and sediments using reference materials from soil, water, sediment and the atmosphere. Global Biogeochemical Cycles 21, GB3016, doi:10.1029/2006GB002914, 2007

Schmidt, M.W.I. and A.G. Noack. 2000. Black carbon in soils and sediments: Analysis, distribution, implications, and current challenges. Global Biogeochemical Cycles 14: 777-793.

De La Rosa, J.M., H. Lopez-Capel, E. Manning, D.A.C. Gonzalez-Perez, and J.A. Gonzalez-Vila. 2008. Direct detection of black carbon in soils by Py-GC/MS, Carbon-13 NMR spectroscopy and thermogravimetric techniques. Soil Science Society of America Journal 72: 258-267.

Rodionov, A., W. Amelung, L. Haumaier, I. Urusevskaja, and W. Zech. 2006. Black carbon in the zonal steppe soils of Russia. Journal of Plant Nutrition and Soil Science 169: 363-369. **DOI:** 10.1002/jpln.200521813

Mannino, A. and H. Ro. Harvey. 2004. Black carbon in estuarine and coastal ocean dissolved organic matter. Limnology and Oceanography 49: 735-740.

Krull, E.S., J.O. Skjemstad, D. Graetz, K. Grice, W. Dunning, G. Cook, and JF Parr. 2003. 13C-depleted charcoal from C4 grasses and the role of occluded carbon in phytoliths. Organic Geochemistry 34: 1337-1352.

5. ISOTOPES

Kelly, S., K. Heaton, K. and J. Hoogewerff. 2005. Tracing the geographical origin of food: the application of multi-element and multi-isotope analysis. Trends in Food Science and Technology 16: 555-567.

Chesson, L.A., D.W. Podlesak, A.H. Thompson, T.E. Cerling, and J.R. Ehleringer. 2008. Variation of hydrogen, carbon, nitrogen, and oxygen stable isotope ratios in an American diet: Fast food meals. Journal of Agricultural and Food Chemistry 56: 4084-4091.

Boutton, T.W. 1996. Stable carbon isotope ratios of soil organic matter and their use as indicators of vegetation and climate change. In: T.W. Boutton and S. Yamasaki (eds). Mass Spectrometry of Soils. Marcel Dekker, Inc. NY, NY. Pp. 47-82.

Sanaiotti, T.M., L.A. Martinelli, R.L. Victoria, S.E. Trumbore, and P.B. Camargo. 2002. Past vegetation changes in Amazon savannas determined using carbon isotopes of soil organic matter. Biotropica 34: 2-16.

Krull, E.S., E.A. Bestland and W.P. Gates. 2002. Soil organic matter decomposition and turnover in a tropical Ultisol: Evidence from $\delta^{13}C$, $\delta^{15}N$ and geochemistry. Radiocarbon 44: 93-112. (Isotopic fractionation during decomposition affects interpreting changes in C13 as only due to vegetation change).

Hobson, K.A. and L.I. Wassenaar, L.I. 1999. Stable isotope ecology: an introduction. Oecologia 120: 312-313.

Trumbore, S. 2009. Radiocarbon and soil carbon dynamics. Annual Review of Earth and Planetary Sciences 37: 47-66.

Torn, M.S., C.W. Swanston, C. Castanha, and S.E. Trumbore. 2009. Storage and turnover of organic matter in soil. Lawrence Berkeley National Lab. http://escholarship.org/uc/item/4k87b5v4

6. DISSOLVED Organic Matter

Suominen, K., V. Kitunen and A. Smolander. 2003. Characteristics of dissolved organic matter and phenolic compounds in forest soils under silver birch (*Betula pendula*), Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*). European Joural of Soil Science 54: 287-293.

Hockaday, W.C., J.M. Purcell, A.G. Marshall, J.A. Baldock, and P.G. Hatcher. 2009. Electrospray and photoionization mass spectrometry for the characterization of organic matter in natural waters: a qualitative assessment. Limnology and Oceanography: Methods 7: 81-95.

Spencer, R. G. M., G. R. Aiken, K. D. Butler, M. M. Dornblaser, R. G. Striegl, and P. J. Hernes. 2009. Utilizing chromophotic dissolved organic matter measurements to derive export and reactivity of dissolved organic carbon exported to the Arctic Ocean: A case study of the Yukon River, Alaska, Geophys. Res. Lett., 36, L06401, doi:10.1029/ 2008GL036831.

Saadi, I., M. Borisover, R. Armon and Y. Laor. 2006. Monitoring of effluent DOM biodegradation using fluorescence, UV and DOC measurements. Chemosphere 63: 530-539.

6.1. Marine vs Terrestrial

Mayer, L.M., L.L. Schick, T.S. Bianchi, and L. A. Wysocki. 2009. Photochemical changes in chemical markers of sedimentary organic matter source and age. Marine Chemistry 113: 123-128.

Routh, J., E.L. Grossman, E.M. Murphy, and R. Benner. 2001. Characterization and origin of dissolved organic carbon in Yegua ground water in Brazos County, Texas. Ground Water 39: 760-767.

6.2. Polarity (XAD Resins)

Qualls R.G. and Haines B.L. 1991. Geochemistry of dissolved organic nutrients in water percolating through a forest ecosystem. Soil Sci. Soc. Am. J. 55: 1112-1123.

Kaiser, K., G. Guggenberger, L. Haumaier and W. Zech. 2001. Seasonal variations in the chemical composition of dissolved organic matter in organic forest floor layer leachates of old-growth Scots Pine (*Pinus sylvestris* L.) and European Beech (*Fagus sylvatica* L.) stands in northeastern Bavaria, Germany. Biogeochemistry 55: 103-143.

Ussiri, D.A.N. and C.E. Johnson. 2004. Sorption of organic carbon fractions by Spodosol mineral horizons. Soil Science Society of America Journal 68: 253-262.

Schwede-Thomas, S.B., Y-P. Chin, KJ. Dria, P. hatcher, E. Kaiser and B. Sulzberger. 2005. Characterizing the properties of dissolved organic matter isolated by XAD and C-18 solid phase extraction and ultrafiltration. Aquatic Science 67: 61-71.

6.3. Microbial

McCarthy, M.D., J.I Hedges, and R. Benner. 1998. Major bacterial contribution to marine dissolved organic nitrogen. Science 281: 231- 234.

Tremblay, L. and R. Benner. 2009. Organic matter diagenesis and bacterial contributions to detrital carbon and nitrogen in the Amazon River system. Limnology and Oceanography 54: 681-691.

6.4. Terrestrial vs Aquatic:

6.4.1. Stable isotopes

Finlay, J.C. and C. Kendall. 2007. Stable isotope tracing of temporal and spatial variability in organic matter sources to freshwater ecosystems. In: R. Michener and K. Lajtha. Stable Isotopes in Ecology and Environmental Science, 2nd Edition. Chapter 10. Wiley-Blackwell Pp 284-333.

6.4.2. Lignin Phenols

Hernes, P.J., A.C. Robinson, and A.K. Aufdenkampe. 2007. Fractionation of lignin during leaching and sorption and implications for organic matter ‘‘freshness.” Geophysical Research Letters 34, L17401, doi:10.1029/2007GL031017, 2007

6.5. Humic acids

Brunetti, G., C. Plaza, C.E. Clapp, and N. Senesi. 2007. Compositional and functional features of humic acids from organic amendments and amended soils in Minnesota, USA. Soil Biology & Biochemistry 39: 1355-1365.

6.6. Aromaticity (NMR and UV)

Sanderman, J., K.A. Lohse, J.A. Baldock and R. Amundson. 2009. Linking soils and streams: Sources and chemistry of dissolved organic matter in a small coastal watershed. Water Resources Research 45, W03418, doi:10.1029/2008WR006977, 2009

6.7. Fluorescence Spectroscopy (PARAFAC)

Cory, R.M. and D. M. McKnight. 2005. Fluorescence spectroscopy reveals ubiquitous presence of oxidized and reduced quinines in dissolved organic matter. Environmental Science & Technology 39: 8142-8149.

Fellman, J.B., E. Hood, D.V.D’Amore, R.T. Edwards, and D. White. 2009. Seasonal changes in the chemical quality and biodegradability of dissolved organic matter exported from soils to streams in coastal temperate rainforest watersheds. Biogeochemistry 95: 277-293.

7. NANO-Scale

7.1. NanoSIMS

Herrmann, A.M., K. Ritz, N. Nunan, P.L. Clode, J. Pett-Ridge M.R. Kilburn, D.V. Murphy, A.G. O’Donnell, and E.A. Stockdale. 2007. Nano-scale secondary ion mass spectrometry — A new analytical tool in biogeochemistry and soil ecology: A review article. Soil Biology & Biochemistry 39: 1835-1850.

Kraft, M.L., P.K. Weber, M.L. Longo, I.D. Hutcheon and S.G. Boxer. 2006. Phase separation of lipid membranes analyzed with high-resolution secondary ion mass spectrometry. Science 313: 1948-1951.

7.2. NEXAFS

Lehmann, J., D. Solomon, J. Kinyagi, L. Dathe, S. Wirick, and C. Jacobsen. 2008. Spatial complexity of soil organic matter forms at nanometre scales. Nature Geosciences 1: 238-242.

Solomon, D., J. Lehmann, J. Thies, T. Schäfer, B. Liang, J. Kinyangi, E. Neves, J. Petersen, F. Luizão, and J. Skjemstad. 2007. Molecular signature and sources of biochemical recalcitrance of organic C in Amazonian Dark Earths. Geochimica et Cosmochimica Acta 71: 2285-2298.

Kinyangi, J., D. Solomon, B. Liang, M. Lerotic, S. Wirick, and J. Lehmann. 2006. Nanoscale biogeocomplexity of the organomineral assemblage in soil: Application of STXM microscopy and C 1s-NEXAFS spectroscopy. Soil Science Society of America Journal 70: 1708-1718.

8. PALEO Proxies and Biomarkers

Meyers, P.A. 1997. Organic geochemical proxies of paleoceanographic, paleolimnologic, and paleoclimatic processes. Organic Geochemistry 27: 213-150.

Pancost, R.D., and C.S. Boot. 2004. The paleoclimatic utility of terrestrial biomarkes in marine sediments. Marine Chemistry 92: 239-261.

Hautevelle, Y., R. Michels, F. Malartre, and A. Trouiller. 2006. Vascular plant biomarkers as proxies for paleoflora and paleoclimatic changes at the Dogger/Malm transition of the Paris Basin (France). Organic Geochemistry 37:610-625.

Eglinton, T.I. and G. Eglinton. 2008. Molecular proxies for paleoclimatology. Earth and Planetary Sciences Letters 275: 1-16.

*Brocks, J.J. and R.E. Summons. 2003. Sedimentary hydrocarbons, biomarkers for early life. Treatise on Geochemistry 8: 63-115.

9. ONLINE TECHNICAL Resources

http://www.cea.fr/var/cea/storage/static/gb/library/Clefs54/pdf-gb/EncadreD_54gb.pdf

NMR

http://www.cis.rit.edu/htbooks/nmr/
http://www.chem.queensu.ca/facilities/nmr/nmr/webcourse/
http://www.bruker-nmr.de/guide/
http://www2.chemistry.msu.edu:80/faculty/reusch/VirtTxtJml/Spectrpy/nmr/nmr1.htm
http://orgchem.colorado.edu/hndbksupport/nmrtheory/NMRtutorial.html

FTIR Spectroscopy

http://orgchem.colorado.edu/hndbksupport/irtutor/tutorial.html
http://mmrc.caltech.edu/FTIR/FTIRintro.pdf

Py/GC/MS

http://www.bris.ac.uk/nerclsmsf/techniques/pyro.html

Chromatography

http://www.rpi.edu/dept/chem-eng/Biotech-Environ/CHROMO/chromintro.html
http://www.justchromatography.com/