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Magnetic fabrics in a jotunitic dyke swarm, Rogaland anorthosite province, SW Norway

Michal BESSE
U.R. Pétrologie et Géochimie endogènes, B20, Université de Liège, Sart Tilman, B-4000 Liège

Jotunitic dykes crop out in the Rogaland anorthosite province, which is a 930 Ma old, anorthosite-mangerite-charnockite igneous complex from SW Norway (Duchesne *et al.*, 1985). Anisotropy of low-field magnetic susceptibility (Borradaile & Henry, 1997) was used to determine magmatic fabrics in three major dykes of the swarm (Fig. 1): the Vetteland, Varberg and Lomland dykes. This AMS study was completed by petrographical descriptions and a microstructural analysis.

High values of the bulk magnetic susceptibility (usually in the range 50-100 mSI) may be explained by the occurrence of magnetite multidomain grains; AMS is also probably carried by these oxide grains. The magnetic susceptibility and the rock mafic content (including magnetite) locally increase near the dyke rims. This feature may be explained by a differentiation process within the dyke and/or by a dyke-in-dyke emplacement.

Figure 1. Average AMS lineations in the Vetteland (Ve), Varberg (Va) and Lomland (Lo) jotunitic dykes. Red symbols correspond to representative lineations, calculated from more or less complete AMS sections (i.e. sections extending from one dyke margin to another). Black symbols correspond to incomplete sections, less representative.

Mean AMS foliations and lineations allow to constrain the geometry of the dykes and the orientation of the magmatic fabric. Hence, it appears that the magma flow orientation varies from one dyke to another (Fig. 1). This indicates magma feeding through distinct chambers, which strengthens previous conclusions based on geochemistry (Duchesne *et al.*, 1989). These magma chambers would be located to the NW, the SE and the NE for the Vetteland, the Varberg and the Lomland dyke, respectively (Fig. 1).

Sigmoidal structures are locally displayed by the AMS axes, which suggests an emplacement of the dykes in an external, non-coaxial strain field (Féménias *et al.*, 2004). Hence, the present study throws a new light on the Rogaland jotunitic dykes, that have been considered until now as being post-tectonic and younger than the gravitary deformations (e.g. diapirism) that affected the anorthosite province.

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A detailed paleoecological study around the time of the Boreal-Atlantic transition in lithalsas of the "fagne des Deux-Séries" (Hautes-Fagnes, Belgium)

Florence DEROCHE
U.R. Paléontologie végétale, B18, Université de Liège, Sart Tilman, B- 4000 Liège

The 8.2 ka event, a brief cold phase generalized in the North Atlantic region was detected by the δ^{18}O recorded in Greenland ice-sheet. In North America, *Tsuga* (hemlock, coniferous of the mountain sloped) was very sensitive to this climatic occurrence and was directly affected by it (Shuman *et al.* 2002). In West Germany and Switzerland, the 8.2 ka event is recorded in lacustrine sediments by δ^{18} O within a four-hundred years of hazel pollen decrease (Tinner & Lotter, 2001). What about the response of the vegetation in the Hautes-Fagnes?

The target of our work consisted in locating in five peat bogs an episode of the transition from the Boreal to the Atlantic period dated at about 8000 years ago, just after the 8.2 ka event. The Atlantic period was marked in the Hautes-Fagnes by the expansion of *Alnus* forests in wet depressions, whilst the ridges supported *Corylus* progressively replaced by *Quercus, Fraxinus and Ulmus*. Therefore, we based our research on two palynological criteria: the start of the abundance of *Alnus* pollen and the decrease of *Corylus*.

This investigation has been implemented from a rough to a thinner and thinner depth of peat leading to a centimetre resolution, in order to locate the more precisely possible our reference limit.

Once this stage reached, we discovered, through pollen concentrations and position of the reference limit into lithalsa remnant profiles, a considerable slowing down of the peat accumulation rate above the Boreal-Atlantic transition (Fig. 1) as well as a highly variable peat accumulation speed from one centimetre to the next above this limit. In addition, some ^{14}C dates obtained for three of the borings support the problematic of this slowing down of peat formation above the limit. However the hypothesis of hiatuses, undetectable by palynology, cannot be rejected. Furthermore, the study of the macrofossils and of the peat structure around this transition shows a very poor conservation state.

All these results suggest a fluctuation of water table. Once the latter drops, the organic matter can be decayed by oxygenation of the environment, leading to low rates peat accumulation. Once the water table is high again, the anaerobic conditions prevent the development of decaying organisms, leading to high rates of peat accumulation. Extreme cases of flooding also lead to a breaking of peat formation.

We attribute this water table fluctuation to highly variable climatic conditions (drought and floods) characterising climates in transition, from the Boreal climate (dry and cold in winter) before reaching the more stable climate of the Atlantic, which is more humid and warmer in winter.

The event of 8.2 ka was not detected in the vegetation of the "fagne des Deux-Séries". Its duration was probably too short, and the peat formation rate was not sufficient to detect it. An even more detailed resolution would then be needed, by the millimeter perhaps. It is also possible that no sensitive taxon to that event was present in the Hautes-Fagnes during this brief cold phase, unlike the *Tsuga* in North America.

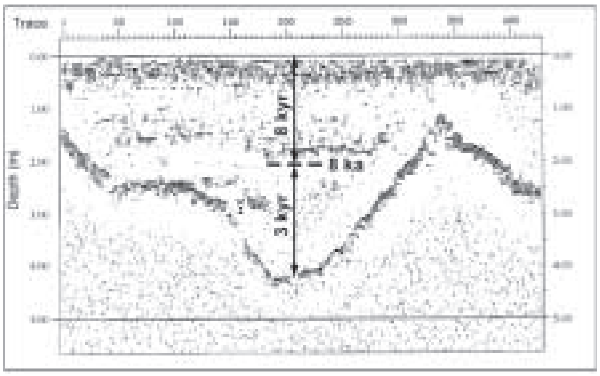

Figure 2. Profile of lithalsa remnant 22 realized with a ground penetrating radar (GPR) by Wastiaux for the work of Charlier (2002). The horizontal dashed line corresponds to our reference limit and the arrows to the time taken for the accumulation of peat, both below and above the limit.

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Sedimentology and ostracods close to the Devonian-Carboniferous boundary in the Chanxhe and Rivage Gare sections (north-eastern part of the Dinant basin)

Aline LEBON
DSTE-Géologie, Université Libre de Bruxelles, 50 av. F.D. Roosevelt, B 1050 Bruxelles

The Chanxhe and Rivage Gare sections, located in the northeastern part of the Dinant basin, display the Devonian-Carboniferous beds through the succession of the Comblain-au-Pont and Hastière formations (Bouckaert *et al.*, 1970). Several methods (biostratigraphy, palaeoecology, sedimentology, cathodoluminescence, sequence stratigraphy, magnetic susceptibility) were used complementary to specify the geological events associated with the Devonian-Carboniferous or 'D-C' boundary.

The sedimentological (petrography) analysis point to a siliciclastic-carbonate ramp system characterized by 7 major microfacies (MF1 to MF7) identifying outer-, mid- and inner settings. The microfacies range from the shallow open marine milieu (MF1-3), near the bottom of the storm wave action with small bioclastic shoals (MF4-5) in the fair weather wave action, to semi-restricted environments with strong salinity variations (MF6-7). The environments are constantly in the euphotic zone as indicated by the omnipresence of the cyanobacteria. The standard sequence of the microfacies permit to establish the lithological curve of the sections: its evolution is related to the energy (in the offshore) and the salinity (in the inshore) variations, and the eustatic variations are minor. The backshoal is assigned by an early surging diagenesis in an oxydizing milieu with occlusion of the high initial intergranular porosity. Replacement by reflux saline brines occurred later in the muddy matrices as indicated by diagenetic analysis (cathodoluminescence).

The biostratigraphic analysis, based on foraminiferal study, permits to subdivide the sections in 7 levels characterized by particular sedimentological contents. These levels can be placed in the worldwide foraminiferal biozonation and encompass the 5 and pre-7 Zones of Mamet (1974). A important point to keep in mind is that the foraminiferal and sedimentological analyses revealed several sedimentary discontinuities in both sections. The correlations between the sections highlight the lateral variations (thickennesses and facies) of the different sedimentary bodies at the kilometric scale.

The ostracod analysis confirms the semi-restricted conditions appearing temporarily at the top of the Comblain-au-Pont Formation. The ostracods point also to a general shallow and well oxygenated open marine milieu without significant bathymetric variations.

The sequence stratigraphy is not really applicable in the series of these sections and no clear pattern is present The elementary parasequences (5th order) or parasequence sets (4th order) are not easily recognized as a result of no significant eustatic variations. They are mainly governed by the energy and salinity variations which appear totally aleatory at these small scales.

The magnetic susceptibility results are unexpected but helped to interpret the facies and to confirm the sedimentary hiatuses (Casier *et al.*, 2005). The resulting curves are the opposite of the lithological or facies ones and cannot be interpreted in term of bathymetry. The results are related to the microbial pyrite abundance observed in the microfacies 1 to 3 (Mamet & Préat, 2004) and partly to iron microbes (bacteria and fungi).

These data suggest that the sedimentation of the Devonian-Carboniferous strata in the Chanxhe and Rivage Gare sections records block faulting of the same type as the one highlighted in the southern part of the Dinant basin and in the Avesnois (Mamet & Préat, 2003).

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Sedimentology of the Hanonet formation in Couvin and Baileux (Southwestern Belgium)

Cédric MABILLE
U.R. Pétrologie Sédimentaire, B20, Université de Liège, Sart Tilman, B-4000 Liège

The Hanonet Formation crops out at the southern flank of the Dinant Synclinorium. The Eifelian is mainly characterized by a mixed siliciclastic-carbonate detrital ramp-related sedimentation, whereas the Givetian is dominated by a carbonate rimmed shelf-related sedimentation. This transition corresponds grossly to the Eifelian-Givetian boundary.

Two stratigraphic sections have been studied, both located in the Couvin area. The first section is located in La Couvinoise quarry (Fig. 1), which is situated at about ten kilometres to the east of the second section outcropping in Les Monts de Baileux quarry. Although the first section is the stratotype of the Hanonet Formation, it has never been the subject of a detailed sedimentological study. No study has ever been carried out and published on the sedimentology of the Hanonet Formation in Les Monts de Baileux quarry.

In both locations the basal contact with the underlying Jemelle Formation is lacking. In La Couvinoise quarry the studied section has a thickness of 85 meters up to the base of the biostromal unit of the Trois-Fontaines Formation, and is composed of five lithological units. In Les Monts de Baileux quarry, observations and sampling were carried out over a 115 m-thick succession of strata up to the same upper limit, and eight lithological units were found.

The study of some 550 thin sections from samples of both sections leads to the definition of eleven microfacies and four sub-microfacies. Together with field observations, thin section analyses pointed out the important sedimentological differences existing between each section.

The microfacies classification, following a proximality-distality scale, allowed the drawing of a lithological curve that was interpreted in terms of changes in bathymetry. This curve shows a general shallowing upward trend. The environmental model based on microfacies analyses and macroscopic observations is fairly complex and depicts the lateral transition from a multiclinal carbonate ramp in La Couvinoise quarry to a fore reef setting in Les Monts de Baileux quarry. The former environment is mainly characterized by enhanced terrigenous input, whereas the latter is greatly influenced by back reef-derived sediment deposition. This also implies a great divergence between both sections in terms of sedimentary dynamics, which does not allow any suitable (high resolution) stratigraphic correlations based on sequence stratigraphy.

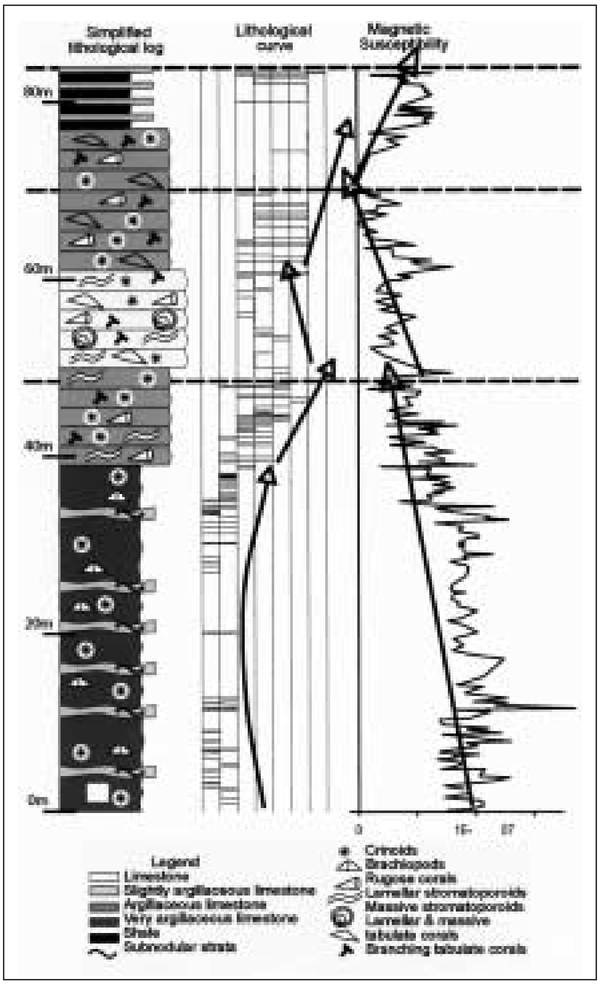

Figure 3. Log, lithological curve and magnetic susceptibility of the Couvinoise Section, Couvin, Hanonet Formation (Eifelian).

However magnetic susceptibility analyses turned out to be a powerful tool to establish accurate stratigraphic correlations between the two sections. Moreover, an interesting part of the work consists in the combined interpretation of the lithological curves and the magnetic susceptibility. This interpretation, mostly based on La Couvinoise quarry, explains the apparent divergence existing between the general shallowing upward trend recorded by the lithological curve and the two deepening upward trends followed by a shallowing upward trend noticed by magnetic susceptibility. This situation can be explained by a difference between the evolution of the bathymetry and the global sea level induced by differences in the rates of sedimentation. In this case, the global sea level evolution is given by the evolution of the magnetic susceptibility whereas the lithological curve represents the local relative sea level evolution.

Coccolithophores as indicators of dissolution in the Cariaco basin, ODP site 1002

Kenneth MERTENS
Research Unit Paleontology , University of Ghent, Krijgslaan 281, 9000 Gent

The role of the tropics in late Quaternary climate change has long been ignored. Nowadays, there exists a growing consensus for a more active role of the Tropical regions in climate regulation. The aim of this study is to establish a reconstruction of the palaeoclimate in the Cariaco Basin during the last 21 ka, using micropalaeontological proxies. The Cariaco Basin is a large anoxic pull-apart basin on the continental shelf of Venezuela. The region is under the influence of the migrating intertropical convergence zone (ITCZ) which is reflected in the light-dark coloured cycles in the sediment (varves). These migrations are also observed on a much larger scale (interglacial-glacial). The question arises, whether these migrations are observable on a stadial/interstadial scale.

ODP core 1002C was drilled on a saddle separating two sub-basins, at a depth of 893 metres. The core has a continuous sediment record for the past 580 ka. It has already been carefully dated using oxygen and carbon isotopes and tuned to GISP II ∂^{18}O. The upper 21 ka was sampled with a 250 yr resolution for determination of coccoliths. Other studies already performed on this core include measurement of alkenone concentrations, opal content, carbonate content, terrigenous content and organic matter.

Thirty-one nannofossil species have been identified. Two species were dominant in the assemblage: *Emiliania huxleyi* and *Gephyrocapsa* oceanica. Absolute abundances of coccoliths can be converted to weight percentages of the carbonate produced by coccolithophores. Approximately 25% of the carbonate is produced by coccolithophores. There is a clear signal in relative and absolute abundances of *Emiliania huxleyi vs. Gephyrocapsa oceanica*. Increases in *Emiliania huxleyi* go hand in hand with decreases of *Gephyrocapsa oceanica* and *vice versa*. Since ecological models are not satisfactory to explain this trend, one can only resort to pinning down carbonate dissolution as the main cause. Moreover, since high production rates are linked to high carbonate dissolution, it is probably a case of post-depositional dissolution caused by decomposition of organic material. As a consequence, post-depositional dissolution of carbonate causes enrichment of the more resistant *Gephyrocapsa oceanica*, in contrast to the more fragile *Emiliania huxleyi.*

We reconstructed the ecosystem structure by means of the opal and carbonate contents. The different groups (foraminifers, coccolithophores, diatoms and dinoflagellates) were plotted on an ordination diagram, together with some important variables (sea surface temperatures, terrigenous content, precession, total organic carbon, trophic state). The results indicate that coccolithophores are characteristic for warm, oligotrophic, well-stratified intervals, whilst diatoms characterise eutrophic, colder intervals. Foraminifers and heterotrophic dinoflagellates follow trends in primary productivity. These ecosystem variations can be coupled to shifts of the intertropical convergence zone during precession-minima. There seems to be a clear asynchronicity between the shifts observed in the equatorial region and the northern latitudes, and this suggests a more active role in the thermohaline circulation in this region.

Still, some questions remain. What is the importance of dissolution in the water column? Are there other processes which influence the dissolution process? What is the contribution of other groups in the ecosystem, for instance Prasinophyceae? Are the same variations observable in earlier periods, i.e. the Eemian?

Stratigraphy of the Neffe Limestone (upper Moliniacian, lower Viséan)

Nicolas PIROTTE
U.R. Paléontologie animale et humaine, B19, Université de Liège, Sart Tilman, B-4000 Liège

The Neffe Formation (upper Moliniacian) corresponds to the high-stand system tract (HST) (sensu Vail) of the 6th third-order sequence defined by Hance et al. (2001). Its progradation is responsible of the smooth-out of submarine topographic irregularities produced in the Namur-Dinant basin during Tournaisian times. The Neffe Formation and the levels situated just below it (upper part of the Terwagne and Salet Formations) have been studied in 30 sections situated in the paleogeographic sedimen-

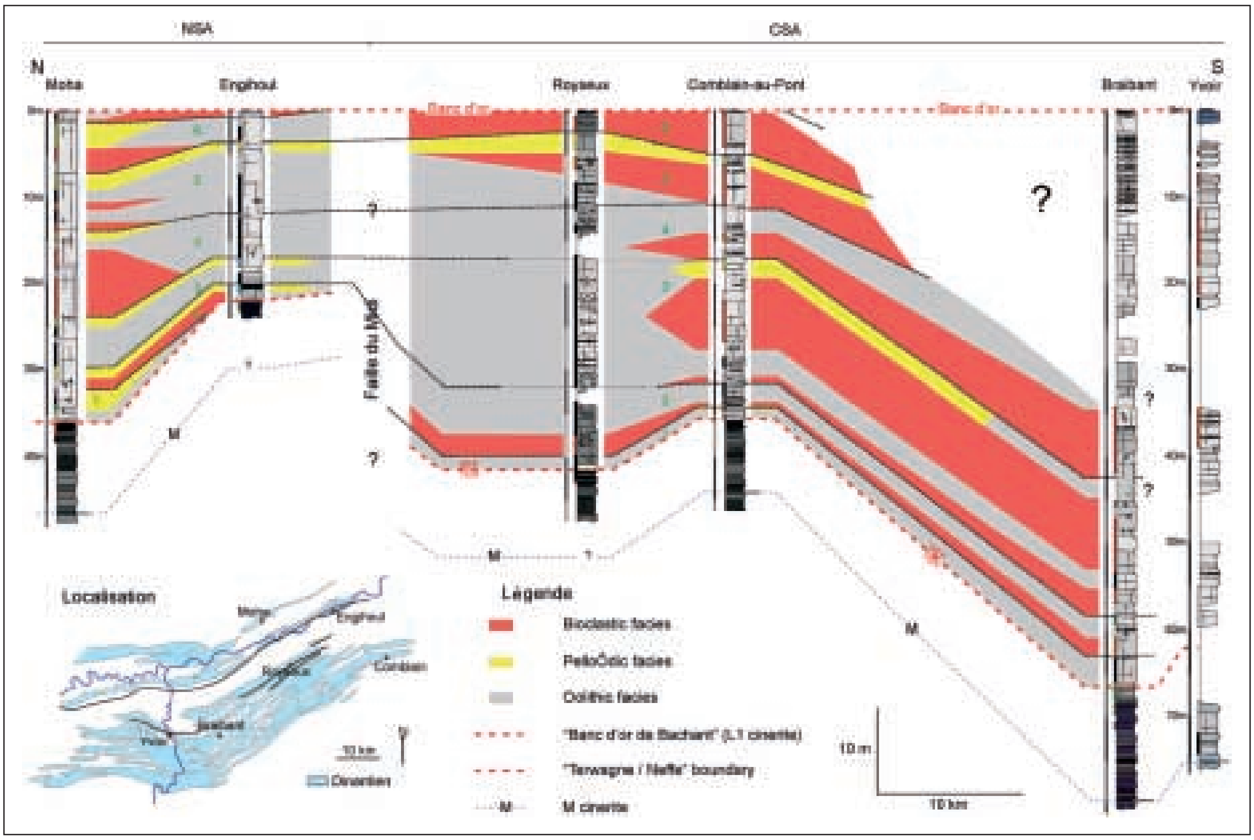

Figure 4. Distribution of the main microfacies: phytoclastic and bioclastic grainstones (red), oolithic grainstones (grey) and pelloïdic wackestones to packstones (yellow), in the Namur (ASN) and Condroz sedimentation areas (ASC). This figure shows the progradant sedimentation towards the south.

tation areas of Namur (NSA), Condroz (CSA), Dinant (DSA) and south Avesnois (ASA) (Poty, 1997).

The Neffe Formation is mainly composed of pale massive limestones (grainstones), with very frequent ooliths, bioclasts and algal lithoclasts. Despite this monotonous lithology, 12 microfacies have been defined. They leaded to recognize 6 parasequences in the Neffe Formation in the NSA and CSA, which, combined with tephro-stratigraphic beds (M cinerite and the "Banc d'or de Bachant"), have allowed correlation of the sections. This correlation and the lateral facies evolution confirm the progradant character of the Formation. In offshore areas (DSA), a falling stage system tract (FSST) (sensu Plint and Nummedal, 2000) has been identified in the top of the Neffe Limestone and is marked by the development of algal carbonates.

The study of thickness variations of the Formation leads to confirm the existence, during Moliniacian times, of a deeper marine area in the DSA, followed to the south by a rising embankment (near the boundary of DSA and ASA). This is shown by the peritidal facies layers underlying the Neffe Limestone, north and south of the central part of the DSA, whereas in the latter, the tendency of those layers is much more marine. In the NSA, the half-graben structure resulting from the extension tectonic system occurring during that period was also verified, by the increase of thickness of the Formation and the occurrence of deeper facies (bioclastic grainstones) toward the north.

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Stable isotopic reconstruction of the late Maastrichtian and the KT boundary interval in Gubbio (Italy)

Kristof VLAEMINCK
Vakgroep Geologie, Vrije Universiteit Brussel, Pleinlaan 2, 1050 Brussel

In this research, a paleoenvironmental study of the Tethyan region during the Upper-Maastrichtian and the beginning of the Danian was carried out. It is based on the stable isotope geochemistry (carbon and oxygen) of the Scaglia Rossa formation from the Bottaccione Gorge and the Contessa Highway-section, in the Apennines (Italy). The Scaglia Rossa formation is a pink carbonate deposited in deep-water (Arthur and Fisher, 1977). The study is a focus on the interval between the inoceramids extinction around 69,4 Ma (Chauris *et al.*, 1998) and the KT boundary. At the base of the sequence, the disappearance of the inoceramids is marked by an increase of the carbon isotopic signal of 0,14‰. Second order sea level fluctuations starting from around 67,6Ma up to the KT-boundary are traceable by the differences of the carbon isotopic ratios. A transgressions causes an increase of the $\delta^{13}C$ values, a regression is responsible for a decrease. Also the Deccan Trap volcanism leaves a fingerprint on both signals. The volcanism is dated at 65,6Ma and lasted for half a million year (Courtillot and Renne, 2003). These eruptions were accompanied by the exhaust of a massive amount of greenhouse gasses, which were responsible for an intensified greenhouse effect. The carbon dioxide that was released makes the carbon isotopic signal lighter, the intensified greenhouse effect is responsible for the decrease of the $\delta^{18}O$ values. The mass extinction at the KT-boundary is visible by a strong negative shift of the carbon isotopic signal. This strong shift is induced by a significant decrease in bioproductivity in the so called "Strangelove Ocean"; an homogeneous and almost dead ocean that immediately followed the Chicxulub impact. The negative shift is followed by a strong increase of the carbon isotopic signal and is interpreted as the ocean recovery. Also with the oxygen isotopic signal, a strong shift of 1,50‰ is visible but now a positive one. This is because the surface water got mixed with the colder deep water in that homogenous "Strangelove Ocean".

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