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Time Series Analyses on selected geological sections: A search for cyclicity.

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The climate is highly dependent on the amount of solar energy intercepted by the Earth. However, until today, a full understanding of how variations in intercepted solar energy are translated into significant climate changes is lacking. This thesis studies climate changes during two very different geological periods: the Holocene and the Devonian; and it examines the extent to which the Sun is forcing them. Logically, for the two different geological periods, another temporal resolution is used (years and thousands of years respectively). This difference in resolution makes it possible to study two very different types of exogenous forcing of the climate: the influence of variations in solar activity on the one hand, and the influence of variations in the distribution of solar energy on Earth, caused by changes in the Earth's orbit parameters, on the other.

For the Holocene, a $\delta^{18}O$ record of an U/Th dated speleothem from Socotra (Yemen) is presented (De Geest et al., 2006). This record serves as a proxy for variations in the intensity of the inter-monsoon rainy seasons for the period between 6000 BP and today. By comparing the $\delta^{18}O$ record with a reconstruction of solar activity (Steinhilber et al., 2009), the obvious and statistical significant correlation between both records suggests that variations in solar activity play a crucial role in determining the intensity of the rainy seasons on Socotra. Moreover, spectral analysis demonstrates that the 205-years "De Vries / Suess" sunspot cycle is the dominant forcing cycle in solar activity for the Indian Monsoon Dynamics.

For the Devonian, a magnetic susceptibility (MS) record is presented, obtained from Uppermost-Eifelian to Late-Frasnian limestones along the southern border of the Dinant Synclinorium (Boulvain et al., 2010). Large-scale variations (tens to hundreds of meters) in the MS signal are ascribed to sealevel fluctuations, while faster variations (several meters) are interpreted as changes in the flux of magnetic minerals towards the marine system, determined by precipitation intensity. Spectral analysis highlights persistent cycles in the MS signal. By involving both chrono- and biostratigraphic information, as theoretical knowledge about the proportions between of sedimentation rates in different depositional environments, the various cycles can be interpreted as precession (~17-18 ka) and/or obliquity (~33 ka) cycles. To correctly understand these astronomically forced cycles in the MS signal from a climatologic and oceanographic point of view, a hypothesis is proposed that explains, in a simplified way, how precession and obliquity can account for a southward shift of the Intertropical Convergence Zone (ITCZ), and for the consequent increase in precipitation over the palaeolocation of the Dinant Synclinorium. For the "La Couvinoise" section, the well-developed precessional cycles, together with the availability of an isotopic age, lead to the construction of a "Floating Point" time scale, with a temporal resolution of ~10 000 years.

BOULVAIN, F. et al., 2010. *Geologica Belgica,* 13, 113-117.
DE GEEST, P. et al., 2006. *Karst Waters Institute Special Publication 10: Archives of Climate Change in Karst*, 103-104.
STEINHILBER, F. et al., 2009. *Geophysical Research Letters,* 36.

The nodules in the pelitic deposits of the Ronquières Formation, Brabant Massif (Belgium): shape and formation mechanism

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The Ronquières Formation (early Ludlow; Louwye et al., 1992) is characterized by an alternation of turbidite and interlayered laminated hemipelagite (LHP) deposits. Within a section of 1,3 meters nodules occur. These nodules are described and vaguely considered in literature: Verniers et al. (1992) described them as "calcareous nodules, occurring in seven marker horizons and found in two flanks along a primary fold", while Debacker (2001) suggested that along that fold a variation of their shape from oblate in the situation where the angle between bedding (S0) and cleavage (S1) is small to a prolate shape of the nodules in a context with S0 en S1 nearly perpendicular. However, the nodules have never been studied thoroughly on their own. No dataset on behalf of their actual three dimensional shape, nor a decent suggestion of a formation mechanism for these nodules has been published so far. So this abstract presents both the shape of the nodules and also gives a brief overview of possible processes interacting to result in the specific nodular shapes.

The nodules where analysed by measuring the three axes of their ellipsoidal shape, in situ if possible or in the lab if necessary. Besides the nodules were analysed by microscopy, CT scan, SEM imaging and geochemical analysis, cathodoluminescence and carbonate staining.

First of all, the orientation of the long axis of all nodules is parallel to the local S0/S1-intersection. Besides, all studied nodules are prolate in shape. However, the degree of prolate behaviour – likewise seen in the effective 3D shape – differs depending on the lithology in which the nodules occur (level I in a Te-interval of the Bouma-sequence, levels II to VIII in LHP), as well as on the structural context (great or small angle between S0 and S1). The strongest prolate nodules are situated in level I where S0 is nearly perpendicular to S1 (84°). The nodules of the levels II to VIII are subrounded, with near perfect spherical nodules in the context in which S0 is nearly perpendicular to S1.

Processes that determine the initial shape of the precipitation are diffusion, present fabrics or flow paths (cf. Raiswell, 1988). By calculation and elimination only the occurrence of a preferred flow path within the sediments can cause the found precipitates. This preferred flow path in the sediments of the Ronquières Formation is generated by the composed stresses due to the accumulation of the sediments on the one hand and by the tectonic stress, already acting on the Silurian deposits as during the deposition the deformation in the northerly Cambrian sediments already started under the same stress that later would cause deformation in the Silurian deposits, on the other. This caused a strong flow path and initial precipitation along the future S0/S1-intersection.

The different shape of the nodules depending on the lithology in which they occur, is attributed to a different effect of the flow path within the type of sediment. In the very homogenous Te-interval the direction of the flow path is enhanced and causes strongly elongated precipitation with round cross-sections of the nodules; in LHP-deposits the slow accumulation causes fine lamination and so causes a certain anisotropy along the bedding planes in which precipitation will start as well. This causes a minor S0-parallel flattened primary precipitation.

Then compaction comes in. This process has a greater effect in the Te-interval that is water saturated. This also affects the nodule, that still shows plastic behaviour at that moment in its evolution. So nodules in the Te-interval will become strongly flattened parallel to S0. This process will have less to no effect on the nodules in the LHP-deposits, as compaction is already started during deposition. Besides, because of the difference in density, late compaction causes S0 to bend around the nodules.

These two mechanisms account for the difference of the nodular shape depending on the lithology in which they occur. We now still need an explanation for the variation of the shape in the structural context. There pressure solution of the carbonate along the S1-planes is the major driving factor. In the situation where the angle between S0 and S1 is small (65°), the generated pressure does not affect the edges of the nodules ideally. So the effect of pressure solution will be small and the shape of the nodules will scarcely change. In the situation with S0 and S1 nearly perpendicular, the generated pressure does affect the edges of the S0-flattened nodules ideally. Maximal pressure solution is generated, causing rounding and resetting the shape of the nodules to perfectly prolate shapes (very long axis and round cross section) of the nodules present in the Te-interval and nearly spherical shapes in LHP-deposits.

The nodules present in the Ronquières Formation differ in shape depending on the lithology as well as in the structural context in which they occur. The presented genetic model accounts the following processes: occurrence of an initial flow path along the future bedding/cleavage-intersection, different effect of compaction on the (still plastic) nodules depending on the lithology and pressure solution along cleavage planes only important in the situation where bedding and cleavage are perpendicular.

DEBACKER, T., 2001. Unpublished Ph.D.-thesis, University of Ghent.

LOUWYE, S. et al., 1992. *Annales de la Société Géologique de la Belgique*, 115: 307-331.

RAISWELL, R., 1988. *Sedimentology*, 35: 571-575.

VERNIERS, J. et al., 1992. *Professional Paper of the Geological Survey of Belgium*.

Diagenetic study of the host rocks of the Kipushi ore deposit, Democratic Republic of Congo.

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The vein-type Kipushi Cu-Zn deposit is located in the Central African Copperbelt, Democratic Republic of Congo. The aim of the present study is to investigate the influence of the mineralisation on the dolomite host rocks using a combination of petrographic techniques and both stable and radiogenic isotope analysis.

The petrographic study (transmitted and incident light microscopy, cathodoluminescence and SEM-imaging techniques) allowed to quantify the relative abundance of diagenetic carbonate and silicate phases in the host rocks (Nguba Group, Katanga Supergroup). The results show erratically and lithostratigraphically controlled variations of their distribution, without obvious trends towards the ore body.

Most host rock samples have a bulk oxygen isotopic composition between -7.50 and -2.54 ‰ V-PDB, which is within or above the range of Neoproterozoic marine dolomites. Given the petrographic observations and the geological context, this suggests that the host rock dolomites formed by reflux dolomitisation. A few samples have depleted $\delta^{18}O$ values (down to -9.9 ‰ V-PDB). They could reflect the influence of a fluid with a lower $\delta^{18}O$ composition or recrystallisation at higher temperatures in a more open geochemical system. However, these lower $\delta^{18}O$ values do not show a clear spatial correlation with the mineralisation. Vein dolomites associated with the ore minerals have depleted $\delta^{18}O$ signatures between -12.5 and -7.7 ‰ V-PDB. Using chlorite and sphalerite geothermometric data (~310°C; Chabu, 1995; Ottenburgs, 1964), the $\delta^{18}O$ composition of the mineralising fluid has been calculated and varies between +10.7 and +15.6 ‰ V-SMOW. Such high values point to significant fluid-rock interaction.

Carbon isotopic signatures of both host and gangue minerals lie within the range of Neoproterozoic marine dolomites ($-3.71 < \delta^{13}C < +3.44$ ‰ V-PDB). However, the most negative values for host rock samples occur in more carbonaceous lithologies, indicating a stratigraphic control on the carbon isotopic signature.

The host rock samples have a strontium isotopic composition that lies within or above the range of Neoproterozoic marine carbonates ($0.7056 < {}^{87}Sr/{}^{86}Sr < 0.7087$; Jacobsen & Kaufman, 1999). Radiogenic signatures between 0.7087 and 0.77788 represent impure dolomites. A ${}^{87}Sr/{}^{86}Sr$-${}^{87}Rb/{}^{86}Sr$ diagram indicates a possible stratigraphic control on the strontium isotopic composition of the host rocks. There is no systematic variation between these results and the presence of the ore

body. Dolomite gangue minerals show radiogenic $^{87}Sr/^{86}Sr$ values between 0.71063 and 0.71339. The mineralising fluid could have derived its radiogenic strontium signature locally through interaction with host rocks, or alternatively, with basement rocks.
In conclusion, the petrographic observations and the oxygen, carbon and strontium isotopic analyses suggest that the sulphide mineralisation had no widespread influence on the diagenetic evolution of the dolomite host rocks.

CHABU, M., 1995. *Canadian Mineralogist*, 33: 547-558.
OTTENBURGS, R., 1964. *Unpublished Ph.D. thesis*, Katholieke Universiteit Leuven, Belgium, 115 p.
JACOBSEN, S.B. & KAUFMAN, A.J., 1999. *Chemical Geology*, 161: 37-57.

Regional magnetic fabric study of the homogeneous siltstone beds of the Plougastel Formation in the western Central Armorican Terrane

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The western part of the central Armorican Terrane (WCAT) is a low-grade middle- to upper-crustal domain exposed in the Armorican Massif (Brittany, France). It is composed of a Cadomian basement and its Neoproterozoic and Paleozoic metasedimentary cover. An early Variscan, contraction-dominated deformation, related to the docking of the Léon Domain with Armorica and the subsequent closure of the Rheic Ocean (i.e. the Bretonian orogenic event), affected the entire Central Armorican Terrane (Sintubin et al. 2008). In the upper-crustal setting, exposed in the Crozon peninsula, the Bretonian event is expressed by a SW-verging backthrusting (Ballèvre et al. 2009) whereas in the mid-crustal setting, exposed in the inland area, a top-to-the-NW thrusting is considered (Sintubin et al. 2008).
Our work consists of a magnetic fabric analysis of the homogeneous siltstone beds (HSB) of the Plougastel Formation (Pridolian to Lochkovian in age) – cropping out in the different structural settings and levels of the WCAT. The anisotropy of the magnetic susceptibility (AMS) of the HSB's shows that the susceptibility ellipsoid has an orientation that is consistently related to the macroscopic rock fabrics (i.e. bedding and cleavage). The maximum magnetic susceptibility axis (K_1) coincides with the orientation of the cleavage/bedding intersection whereas the minimum magnetic susceptibility axis (K_3) has a variable orientation that shifts from the bedding pole to the cleavage pole. The degree of anisotropy (P_J) and the shape parameter (T), two parameters that describe the magnetic susceptibility ellipsoid, are seemingly influenced by the cleavage/bedding angle: low angles leading to a high degree of anisotropy and an oblate shape and high angles leading to a low degree of anisotropy and a prolate shape. These results suggest that the magnetic fabric is a composite magnetic fabric, composed of at least one bedding-parallel magnetic carrier population and at least one cleavage-parallel magnetic carrier population (cf. Housen et al. 1993 and Debacker et al. 2004).
An analysis of the magnetic mineralogy, performed by low-temperature demagnetization experiments shows that the bulk magnetic susceptibility (MS) is dominated by paramagnetic carriers. Based on XRD measurements, we suggest that mica minerals, and to a lesser extent also chlorite, are the source of the paramagnetic behaviour. Petrographical observations show that the cleavage-parallel magnetic carrier population is composed of mica minerals, predominantly muscovite. However, a bedding-parallel magnetic carrier population has not been observed. Therefore, we suggest that the bedding-parallel magnetic signal arises from a subtle rock fabric that is composed of minerals with strong magnetic properties. These minerals could be ferromagnetic minerals with a low MS but a strong internal anisotropy, e.g. hematite, or paramagnetic minerals with a high iron content, possibly chlorite.
A positive correlation between P_J and the intensity of the mica peak of the XRD measurements suggests that the observed, regional differences in P_J reflect differences in development of the cleavage fabric and thus in degree of deformation. However, the variable orientation of the K_3-axis and the influence of the cleavage/bedding angle on the AMS parameters clearly demonstrates that the AMS signal arises from a complex interaction between a bedding-parallel and cleavage-parallel orientation population. Therefore, our findings demonstrate that the interpretation of AMS in the context of a composite magnetic fabric is not straightforward and low-field AMS at room temperature cannot be used as a strain marker in the low-grade environment of the WCAT.

BALLÈVRE, M. et al., 2009. *Comptes Rendus Geoscience*, 341(2-3): 174–201.
DEBACKER, T. et al., 2004. *Magnetic Fabric: Methods and Applications. Geological Society, London, Special Publications*, 238: 77–107.
HOUSEN, B. et al., 1993. *Tectonophysics*, 220(1-4): 1–12.
SINTUBIN, M. et al., 2008. *Tectonophysics*, 461(1-4): 343–355.

Abstracts of presentations at the meeting, available on line 15.06.2011.