Europlanet TA Scientific Report

PROJECT LEADER

Project number: 21-EPN-FT1-005	
Name: Simon Andrieu	
Home Institution: Aarhus University, Geoscience Department	
TA Facility visited: Ion probe facility-IPF (France, Nancy)	

Project Title:
Reading the sedimentary archive of discontinuity surfaces

Scientific Report Summary.
(plain text, no figures, maximum 250 words, to be included in database and published)

Discontinuity surfaces, associated with seafloor cementation, are hence of primordial importance for fully apprehending the geological record, yet they have received far less attention than the sedimentary rocks surrounding them. Fundamental problems that are still not sufficiently understood concern the lateral change of discontinuities. In this project, we tackle this issue by studying the lateral variation of five distinct discontinuity horizons present in the Middle Jurassic of the High Atlas (Morocco), where outstanding exposures permit to track these surfaces over tens of kilometers. Hence, the purpose of this work is to characterize at a high-resolution the large-scale variation of petrographic and geochemical (C, O and Sr-isotopes) properties of discontinuities (matrix and cement phases) along dip and strike of a Jurassic moderately deepening ramp. $\delta^{18}O$ (176 values) and $\delta^{13}C$ (105 values) signatures were obtained on twenty-one cements and grain types, including 14 different early calcite cements and fabrics corresponding to dogtooth cements (7), turbid synaxial cements (1) and micritic/microsparitic fabrics (6). Data confirm that dogtooth cements can precipitate in marine phreatic, meteoric phreatic and shallow burial environments. The highly negative $\delta^{18}O$ values of micritic fabrics and turbid synaxial cements, which form in seawater, indicate that they transformed during subsequent diagenesis (i.e during meteoric water circulation or shallow burial). It indicates that they precipitate initially with an unstable mineralogy (aragonite or high-magnesium calcite). $\delta^{18}O$ and $\delta^{13}C$ data on early cements suggest that a same discontinuity can change laterally from a subaerial exposure surface to a marine surface.

Full Scientific Report on the outcome of your TNA visit

We encourage you to add figures to your report, which should be approx. 1 page of text plus figures.

Discontinuity surfaces, associated with seafloor cementation, are hence of primordial importance for fully apprehending the geological record, yet they have received far less attention than the sedimentary rocks surrounding them. Fundamental problems that are still not sufficiently understood concern the lateral change of discontinuities and the factors controlling their formation. In this project, we tackle these issues by studying the lateral variation of five distinct discontinuity horizons present in the Middle Jurassic (ca. 160 Myr ago) of the High Atlas (Morocco), where outstanding exposures uniquely permit to track these surfaces over tens of kilometers. Hence, the purpose of this work is to characterize at a high-resolution the large-scale variation of petrographic and geochemical (C, O and Sr-isotopes) properties of discontinuities (matrix and cement phases) along dip and strike of a Jurassic moderately deepening ramp. The competitive edge of this project rests on the use of state-of-the-art geochemical analyses such as Laser Ablation (LA) ICP-MS (for Sr isotopes analyses) and Secondary Ion Mass Spectrometer (SIMS) analyses (for C and O analyses, at CRPG, this proposal). This combined approach will be instrumental to precisely document the modality and relative timing of successive cementation and dissolution phases having affected the discontinuities, and as such reveal the mechanism at the origin of their creation. Carbon and oxygen isotopes Secondary Ion Mass Spectrometer (SIMS) analyses were conducted on nine thin-sections located below five key discontinuity surfaces spanning the Aalenian and Bajocian limestones in Morocco. A large variety of carbonate grains (5), blocky calcite cements (2) and early calcite cements and fabrics were analyzed (14) (Table 1).

<table>
<tr><th colspan="3">List of analysed grains and cement types</th></tr>
<tr><td colspan="2" rowspan="5">GRAINS</td><td>1-Bivalve</td></tr>
<tr><td>2-Brachiopod</td></tr>
<tr><td>3-Echinoderm</td></tr>
<tr><td>4-Ooid</td></tr>
<tr><td>5-Peloid</td></tr>
<tr><td colspan="2" rowspan="2">BURIAL BLOCKY CALCITE CEMENTS</td><td>6-OBC: Orange Blocky Calcite</td></tr>
<tr><td>7-DBC: Dull Blocky Calcite</td></tr>
<tr><td rowspan="14">EARLY CALCITIC CEMENTS</td><td rowspan="7">ISOPACHOUS DOGTOOTH CEMENTS</td><td>8-BDC-1/BSC-1: Banded Dogtooth/Synaxial Cement (MOA2)</td></tr>
<tr><td>9-BDC-2/BSC-2: Banded Dogtooth/Synaxial Cement (MO124)</td></tr>
<tr><td>10-BDC-3/BSC-3: Banded Dogtooth/Synaxial Cement (GS1, GS2, GS3, GS7)</td></tr>
<tr><td>11-BDC-4/BSC-4: Banded Dogtooth/Synaxial Cement (ACH-2 / MO-153)</td></tr>
<tr><td>12-DDC-DSC: Dull Dogtooth Cement/Dull Synaxial Cement</td></tr>
<tr><td>13-NLDC-NLSC: Non-Luminescent Dogtooth/Synaxial Cement</td></tr>
<tr><td>14-NLSC: Non-Luminescent Synaxial Cement (not associated with dogtooth)</td></tr>
<tr><td>TURBID CEMENTS</td><td>15-TSC: Turbid Synaxial Cement</td></tr>
<tr><td rowspan="6">MICRITIC-MICROSPARITIC FABRICS AND CEMENTS</td><td>16-Micritization</td></tr>
<tr><td>17-Microbial Peloids</td></tr>
<tr><td>18-ME: Micritic Envelop</td></tr>
<tr><td>19-MMC: Micritic Meniscus Cement</td></tr>
<tr><td>20-DMBC: Dull Microsparitic Bridge Cement</td></tr>
<tr><td>21-BMC: Banded Microsparitic Cement (equivalent to BSC-4)</td></tr>
</table>

Table 1: List of cement types and grains on which carbon and oxygen isotopes analyses were performed

Early calcite cements and fabrics correspond mostly to dogtooth cements (7), but also to turbid synaxial cements (1) and micritic/microsparitic fabrics (6). A total of 176 $\delta^{18}O$ and 105 $\delta^{13}C$ values were acquired. In order to obtain a coupled isotopic signal on a given position, oxygen and carbon analyses spots were positioned next to each other when possible (see SIMS transects in Fig. 2). Strontium isotopes values ($^{87}Sr/^{86}Sr$) were acquired by laser ablation (LA) ICP-MS in the Department of Geoscience of Aarhus University on the same thin-sections and cements (Fig. 2C and D).

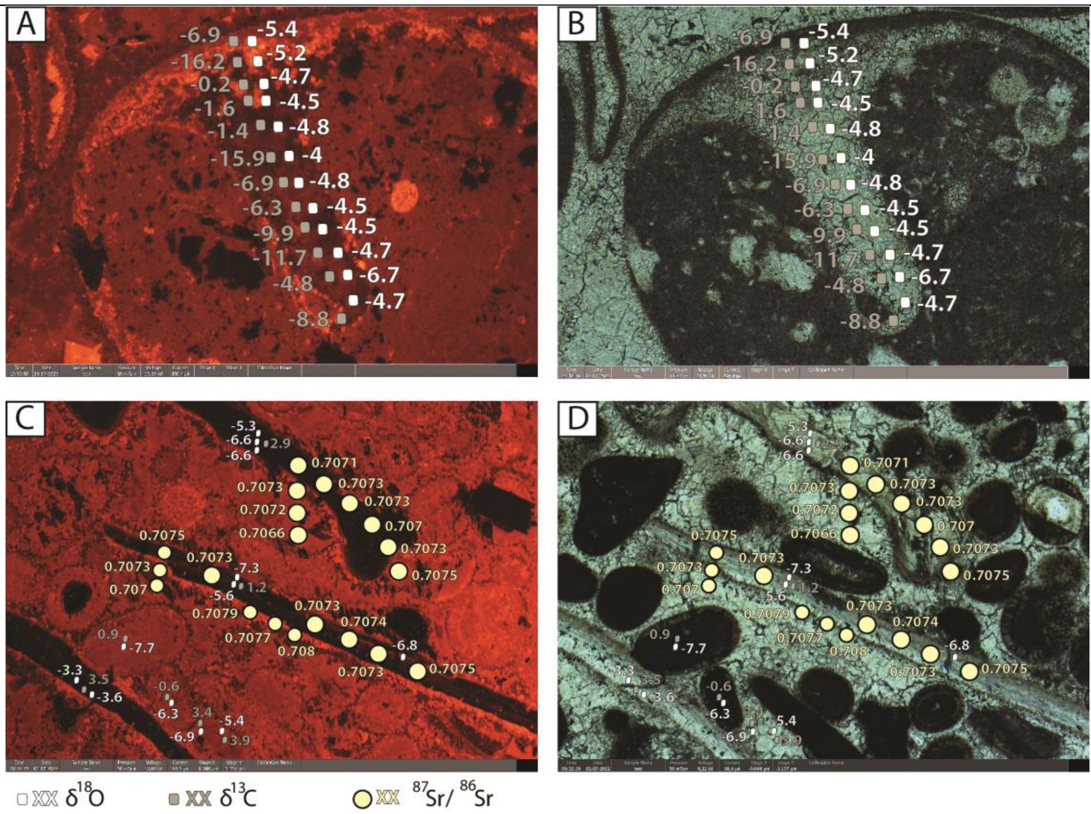

Figure 1: Cathodoluminescence (CL) and light microscopy images of SIMS transects performed on thin-sections MO216 (A and B) and GS5 (C and D). The yellow circles represent the laser ablation spot for Strontium isotopes measurements performed at the Geoscience Department of Aarhus University.

Figure 2 is a cross-plot diagram presenting the $\delta^{13}C$ and $\delta^{18}O$ data for spots located close-by on the same cement/grain type. This diagram shows a significant variability of oxygen and carbon isotopes values, indicating a large range of environment of formation for the different cements, from marine phreatic (usually $\delta^{18}O$ composition of calcite (‰-PDB) higher than -2‰ and a positive $\delta^{13}C$) to meteoric phreatic and burial (slightly to highly negative $\delta^{18}O$ values, lower than -3‰). Data confirm that dogtooth cements can precipitate in marine phreatic (Banded Dogtooth Cement 1), phreatic meteoric and shallow burial environments (other dogtooth cements). The highly negative $\delta^{18}O$ values of micritic fabrics and turbid cements, forming in marine settings, indicate that they were transformed during subsequent diagenesis (meteoric water circulation, shallow burial). It highlights that they precipitated initially with an unstable mineralogy (aragonite or high-magnesium calcite). This set of data brings new insights about the paleoenvironmental evolution of discontinuities. It suggests that the major maximum regressive surface D4 changes laterally from a subaerial exposure surface to a marine discontinuity, locally cemented by dogtooth cements (BDC-1, Table1). This is consistent with field observations.

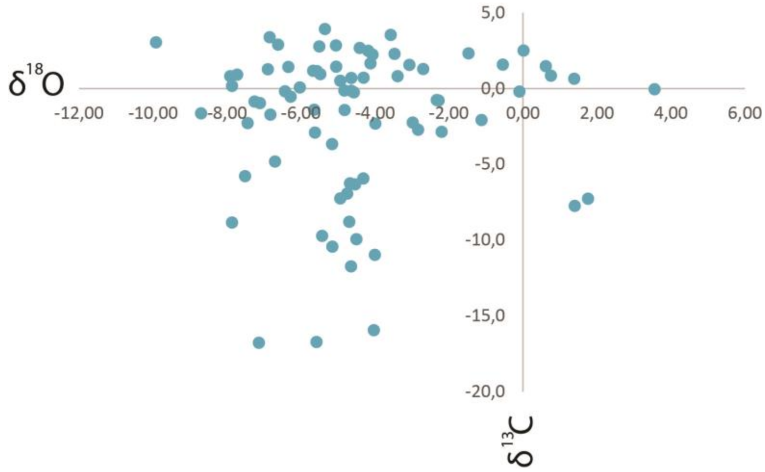

Figure 2: $\delta^{18}O$ and $\delta^{13}C$ (‰-PDB) composition of the different cement and grain types

- Give details of any publications arising/planned (include conference abstracts etc)

The data will be presented in international conferences (e.g. International Meeting of Sedimentologists, 2023). Two publications in international peer-reviewed journals are expected (possible target journals: Marine and Petroleum Geology; Journal of the Geological Society). The first will focus on the coupled contribution of strontium, oxygen and carbon isotopes on the understanding of early diagenesis processes, and perhaps the dating of discontinuities. The second publication will focus on the lateral evolution of discontinuity surfaces, and potentially a new model for the formation of these surfaces.

- Host confirmation

Please can hosts fill in/check this table confirming the breakdown of time for this TA project:

Dates for travel to accommodation for TA visit (if physical visit by applicant)	Start Date of TA project at facility	Number of lab/field days spent on TA Visit pre-analytical preparation	Number of days in lab/field site for TA Visit	Number of days spent in lab for TA Visit data analysis	End Date of TA project at facility	Dates for travel home (if physical visit by applicant)
Departed: 19/06/2022 Arrived: 19/06/2022	20/06/2022	0	0	5	24/06/2022	Departed: 25/06/2022 Arrived: 25/06/2022

The host is required to approve the report agreeing it is an accurate account of the research performed.

Host Name	
Host Signature	**Johan Villeneuve, lab manager of IPF CRPG platform** **Laurie Reisberg, CRPG Europlanet coordinator**
Date	**08/08/2022**

- Project Leader confirmation

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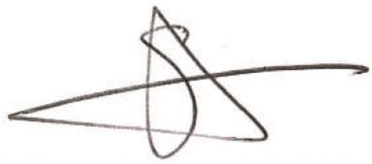
YES

Project Leader Name	Simon Andrieu
Project Leader Signature	
Date	**29/07/2022**