The Newsletter of the International Association of Sedimentologists

Issue 5, 2021

Dear IAS Members,

We are in the final stages of the countdown to the 35th International Meeting of Sedimentology, Prague 2021! The meeting organising committee have done a truly fabulous job, pulling out all the stops to put together an event that will be the highlight of the year for many in the Sedimentology community.

This month we are excited to announce that the IAS is looking to recruit an Executive Officer. This is a terrific opportunity to become involved as a key member of the IAS.

I look forward to seeing you all at the IMS in a few weeks!

Stephen Lokier, *General Secretary*

Check out the Exciting Programme for Early Career Researchers at the 35th International Meeting of Sedimentology, Prague 2021

There are numerous activities for Early Career Scientists at the 35th IMS including round table discussions, parties, workshops and more!

Check out the activities here!

International Conference of Fluvial Sedimentology – ICFS 2021

The IAS is proud to sponsor the ICFS once again this year. This year's meeting will be held fully online with presentations from 16 invited speakers and two virtual field trips

The meeting will be hosted by Seds Online.

Registration is free and will open on the 1st of June via the link at the **Seds Online website**.

We are recruiting an IAS Executive Officer

The IAS INPO is looking to engage an *Executive Officer* (EO) as a self-employed service provider. The EO will be the primary point-of-contact of the IAS INPO for the society and will serve as the interface between the *Treasurer* and *General Secretary*, on the one hand, and the IAS Members on the other. For the execution of his/her tasks, the EO can rely on the help of the IAS *Office Manager* and *Webmaster*, at the IAS "back office", located at Ghent University, Belgium.

Profile

The EO must be a sedimentologist holding a PhD. Candidates who have been long-term members of the IAS will be looked on favourably as will persons with previous experience of an active contribution to the activities of a sedimentology or related society. The EO should have strong interpersonal skills with a positive problem-solving attitude. The EO cannot combine his/her tasks with a decision-making mandate in the IAS Bureau, Council or Early Career Scientists Committee. The candidate must be highly proficient in spoken and written English. Proficiency in other languages is beneficial.

Tasks package

The EO's services will mainly be of an administrative nature, including frequent communication with and provide support for the society members and the Bureau. In order to be able to perform these services as efficiently as possible, the EO will be expected to attend all IAS Bureau Meetings. The range of EO services can be summarized under the broad themes of "member services", "bureau services", "web services" and "administrative services".

Service agreement

The EO will operate for the IAS INPO as a self-employed service provider under a service agreement. An annual evaluation of the collaboration between the parties is foreseen. The first term of the new EO position will start by Fall 2021 (or earlier) for a definite period to Summer 2024. The service agreement can be renewed for another period of 4 years.

The nature of the services are expected to take up approximately 20 hours of work per week on average, which the EO will be free to organise fully autonomously. Some activities however may require – during certain periods of time – an increased activity and presence of the EO; for example, a bureau meeting or a conference where the EO's presence will be required for the entire duration of such event. The compensation of the EO will be fixed at a daily rate under mutual agreement, to be detailed in the service agreement.

Location

Although the IAS Office operates from Ghent University, Belgium, the EO is free to choose where he/she will execute the services. However, for the proper execution of the services, the EO is expected to attend meetings or discuss matters in person with the office staff on a regular basis and whenever either of the parties would request so. Therefore, it may be favourable that the EO resides within the European Union. This will also allow the EO to work in the same time zone (CET-CEST) with the IAS Office.

Application procedure

All inquiries (e.g. *full list of services*) and applications should be addressed to Prof. dr. David Van Rooij, Treasurer of the IAS INPO, by E-mail through treasurer@sedimentologists.org. The application package should contain a motivation letter, Curriculum Vitae, and contact details of two persons serving as a character reference. The applications will close on **30th June 2021** at **18h00 CEST**.

New Round Now Open – Applications for the Judith McKenzie Field Work Award (Fall 2021 Session)

The **Judith McKenzie Field Work Award** aims to promote sedimentological field observations for the newest generation of Earth Scientists – MSc Students.

Up to 5 awards of €300 each, will be awarded twice per year to IAS student members. Since the award is only available for MSc students, proof of student status will be required. The awardee shall also receive a one-year IAS student membership, upon submission of their MSc thesis.

Applicants should apply for the Judith McKenzie Field Work Award via the **IAS website here**. The application requires submission of a grant proposal (written by the student) with budget and CV (template provided on the submission webpage), and a signed letter of recommendation from the student's supervisor.

Application deadline for the Fall 2021 Session is **31st September 24h00 Brussels Time (CEST, UTC+2).**

Don't miss out on all that the IAS has to offer RENEW TODAY!

The IAS is the home of Sedimentology.

We are very proud of our ability to keep our membership fees so much lower than most other professional societies.

You can find a complete list of the benefits of membership of the IAS **website**.

You may also consider becoming a full member for 5 years at a cost of only €100 – effectively getting one year's membership for free. We also offer 'lifelong' membership for just €400.

The Journals of the IAS

For a quick overview of the latest issues of **Sedimentology, Basin Research** and **The Depositional Record**, follow these links:

- **Sedimentology**: directly at **Wiley** or via the **IAS website** (after login) for member access
- **Basin Research**: directly at **Wiley** or via the **IAS website** (after login) for member access
- **The Depositional Record**: directly at **Wiley** or via the **IAS website**

All of the journals of the IAS are active on Twitter. Stay up to date on the latest news and papers in @sedimentology by following the IAS journals: @JSedimentology, @DepositRecord, @BasinResearch.

Check out these terrific free online resources proudly sponsored by the IAS….

Carbonateworld is an online atlas containing more than 800 images covering an extensive spectrum of carbonate textures, grain types, diagenetic features, depositional environments and case studies. The images are organised in categories and subcategories (e.g., carbonate rock classification, skeletal grains, ooids, corals, burial diagenesis etc.) and are frequently updated with new material.
https://carbonateworld.com/

Seds Online is an free to access online initiative that provides an interactive, adaptable and accessible online platform for anyone with an interest in the field of sedimentology.

Seds Online welcomes members at any career stage, from both industry and academia!

https://sedsonline.com: Twitter @Seds_Online

The Antarctic Glaciers website is a fabulous resource for anyone interested in global glacial processes, landforms and sedimentology – despite the name, this site goes way beyond Antarctica!

www.AntarcticGlaciers.org

Follow the IAS on Social Media

Follow the IAS on Facebook, Twitter, WeChat and LinkedIn to keep up to date with all of the latest news, announcements and happenings.

@sedimentology and IAS沉积学之家

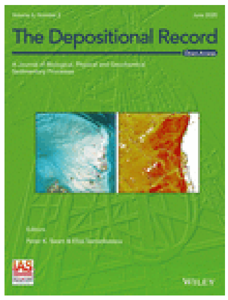
New Round Now Open – Applications for Institutional Grants (Fall 2021 Session)

Twice a year, IAS awards an Institutional Grant of maximum 10,000 Euro, which is intended to support capacity building initiatives in less developed countries (LDCs). Grants will allow earth science departments in LDCs to acquire durable sedimentological equipment for teaching and research, or tools that can be used by all geology students. The grant application should thus clearly demonstrate how the grant will increase the recipient's capacity to teach sedimentology at undergraduate level in a sustainable way.

Applications have to be submitted via the **IAS website.** Application deadline for the Spring 2021 Session is **31st September 24h00 Brussels Time (CEST, UTC+2).**

More information about the Institutional Grant Scheme and guidelines on how to apply can be found on your membership profile.

The IAS still pays the APC for papers accepted in The Depositional Record!



The Depositional Record is a fully open access journal publishing high quality articles from across the field of Sedimentology. The journal covers all timescales, from Ancient to Modern, and welcomes articles that emphasise the application of sedimentary processes to the study of paleoclimate, changes in the chemical environment, ocean acidification, extra-terrestrial sedimentology, and the application of genetic methods to understanding sedimentological processes.

Open Access

Article publication charges are still fully covered by the IAS but this will have to change soon, so submit your paper today!

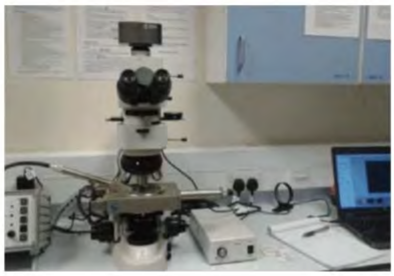
IAS Regional Correspondents

IAS **Regional Correspondents** are your local hotline to the IAS.

Check out the **News Feed** to see what is happening in your local community. At this link you will also be able to select your correspondent and even elect to receive information from multiple correspondents.

IAS **Regional Correspondents** are IAS Members who have volunteered to act as a representative between sedimentologists in their region and the IAS. If you know of any sedimentology events going on in your region, then please get in touch with your Regional Correspondent and let them know. Similarly, if your region lacks a Regional Correspondent **(see the map here)** and you would like to propose an IAS Member (Full or Student), or yourself, for this position then please send an email to the **General Secretary**.

New Round Now Open – Applications for Post-Graduate Research Grants (Fall 2021 Session)



Up to 10 research grants, each to a maximum of €1,000, are awarded twice a year to **IAS Post-Graduate Student Members**. This grant scheme is designed to support PhD students in their studies and research. Post-Graduate Research Grants can be used to (co-)finance fieldwork, acquisition and analysis of data, visits to other institutes to use specialized facilities, etc.
Applications must be submitted via the IAS website. Application deadline for the Fall 2021 Session is **31st September 24h00 Brussels Time (CEST, UTC+2).**
More information about the Post-Graduate Grant Scheme and guidelines on how to apply can be found on your membership profile.

New Round Now Open – Applications for IAS Post-Doctoral Research Grants (Fall 2021 Session)

IAS Post-Doctoral Research Grants are intended as a seed to a assist Early-Career post-doctoral researchers in either establishing a proof of concept, in order to support applications to national research funding bodies, or to fund areas of a project that were not included in the original project scope.

Up to 4 grants, each to a maximum of €2,500, are awarded twice per year to Early Career IAS members.

The application requires submission of a research proposal with budget and CV (template provided on the submission webpage, and a letter of support from the researcher's supervisor, line manager or Head of School. More details about the application procedure can be found on your membership profile.

Application deadline for the Fall 2021 Session is **31st September 24h00 Brussels Time (CEST, UTC+2).**

Eligibility:

· Applicants must be full members of the IAS.
· Applicants must have secured their Ph.D. within the previous 7 years.
· Applicants can only benefit from a Post-Doctoral grant on one occasion.

IAS Grant Reports

The IAS supports postgraduate and post-doctoral researchers via our various grant schemes.

Below you will find some of the latest grant reports received by the IAS.

You can also read recent and past Grant Reports from IAS members who have benefited from Post-Doctoral or Post-Graduate grants here.

Late Neogene barnacle facies of the Western Mediterranean: sedimentary dynamics and paleo-seasonality proxy

Giovanni Coletti

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Introduction

Presently, one of the main goal of modern geological researches is to understand past climatic variations in order to predict what will happen in the future. Sedimentary rocks bear the memories of the past and by decoding this record we can reconstruct a clear picture of what once was. For this purpose, the deep sea record is by far the most accurate and well preserved archive. However, the deep sea is relatively insensitive to seasonal variations and local climatic oddities and mainly provides general, basin-scale information. On the other hand, the shallow sea is much more exposed to seasonality and it is strongly influenced by local factors. Furthermore, while sedimentation rates are relatively low into the deep sea, shallow-water depositional rates can be much higher, resulting in a more complete record of environmental variations.Thus while the deep sea record is fundamental for tracing large scale climatic evolution, the shallow sea can be successfully used for local-scale paleoclimatology. While this can be of limited value when dealing with the distant past, it can potentially become extremely relevant in the study of the late Neogene. During the late Neogene, indeed, the geographical context was similar to what can be seen today and a large part of late Neogene species have living relatives which makes comparisons much easier. Consequently, shallow-water biogenic late Neogene deposits hold a remarkable potential as they can potentially provide detailed paleoenvironmental and paleoclimatic information. There are however several limitation when dealing with shallow water facies. Actually, these deposits are usually coarse-grained and porous and thus they can be strongly affected by diagenesis, resulting in both taphonomic biases (preferential dissolution of skeletal elements of aragonite and high-magnesium calcite) and alteration of the original geochemical signal.

With the purpose of exploring the paleoenvironmental significance of shallow water bioclastic facies, this research focuses on the extensive late Neogene record of northwestern Italy and in particularly on barnacles, which are, among carbonate producing organisms, those most typically related to shallow-water settings. Several barnacle-bearing facies, raging in age from the early Pliocene to the earliest Pleistocene, were analyzed by using sedimentology, stable isotope geochemistry and a detailed comparison with modern environments, shedding light on both their significance and their potential for paleoclimatic reconstructions.

Geological setting

Starting from the oldest to the youngest, 5 different outcrops were investigated. The Pairola outcrop consists of lower Pliocene calcarenites and calcirudites deposited within a small flooded valley developed as a consequence of early Pliocene flooding of Messinian erosive features (Coletti et al., 2021). The Certaldo outcrop, located within the Valdelsa Basin of northern Tuscany, consists of poorly consolidated inner-shelf mudstones with abundant macrofossils, including vertebrate remains and barnacles and dated to the latest Zanclean early Piacenzian interval. Calcarenites and calcirudites make up the bulk also of the upper Pliocene Montefollonico succession (Siena–Radicofani Basin, central Tuscany) which are dominated by barnacles and coralline red algae. Similar to Certaldo, the Empoli outcrop (northern Tuscany) also consists of coastal mudstones characterized by abundant gastropod remains but also vertebrate remains including a whale skeleton that was found associated with a large number of shells of the epizoic barnacle *Chelonibia testudinaria* (Collareta et al., 2016). The Pleistocene Fauglia succession, of the Tora-Fine Basin, is characterized by loosely consolidated silty sandstones and sandy siltstones that present an exceptional diversity of fossils, including a large *Cladocora caespitosa* bank, the remaining of a *Posidonia oceanica* meadow and an oyster biostrome with abundant barnacles.

Material and methods

Samples were collected from the barnacle-rich facies of the Pairola (western Liguria), Montefollonico, and the barnacle-bearing facies of Certaldo, Empoli and Fauglia. The successions were investigated on the field, focusing on sedimentological features and macrofossil content. Well preserved barnacle specimens were collected from every outcrop for taxonomic purposes and stable isotopes analyses. Rock samples were collected from the successions of Pairola and Montefollonico that mainly consist of biocalcarenites and biocalcirudites. Sixty thin sections were prepared from these samples. Since the material was very porous and often poorly cemented, the rock samples were embedded into epoxy resin. After the resin hardened the samples were cut in thin-section sized blocks. These block were further embedded into epoxy resin to stabilize the material; subsequently, the surface selected for the thin section was freed from the resin using sand paper and abrasive powder. This surface was further polished with a 800 silicon carbide grit. Finally, in order to remove any remaining porosity that could compromise the thin section, this surface was once again covered by a thin-layer of epoxy resin, later removed using 1200 silicon carbide grid. The samples were then glued to standard petrographic slides and the excess material removed using a thin-sections cutting machine. The sections were reduced to 30-50 µm of thickness with 1200 silicon carbide and finally polished with aluminum oxide powder (1 µm grain size). Point counting analysis was performed on these high-quality thin sections, using a 250 µm mesh and counting more than 500 points in each sections. The thin sections were also used to support barnacle taxonomy as the inner structures of barnacle shell is characterized by taxonomically relevant microstructures (Davadie 1963, Newman et al. 1967, Buckeridge 1983; Coletti et al. 2019; Collareta et al. 2019). Since the successions of Certaldo, Empoli and Fauglia mostly consist of poorly consolidated material, the fossils were simply extracted from the embedding material.

The best preserved specimens of each succession were selected for stable isotopes analyses. *Concavus concavus* from Pairola, Montefollonico and Certaldo, *Perforatus perforatus* from Fauglia and *Chelonibia testudinaria* from Empoli. Sedimentary particles cemented to the barnacle shells were initially gently removed using sand paper (400 grit and then 800 grit). The samples were later cleaned using an ultrasound cleaner. Samples for stable isotopes analysis were collected using a microdrill equipped with a 1 mm diamond bit. In order to take into account inter-annual temperature variations recorded by the fast-growing cirripedes, several samples were collected from each specimens following their growth direction. From each outcrop, a sample of bulk barnacle material was also collected and analyzed. Wherever available, samples from the embedding sediment and from well preserved pectinids or oysters were also analyzed for providing an internal control on diagenesis. As a comparison we also investigated modern acorn barnacle specimens (*P. perforatus* and *Amphibalanus amphitrite*) collected from western Liguria and along the coast of Tuscany (Marina del Boccale and Livorno) as well as modern specimens of *Chelonibia testudiniaria* from the Western Mediterranean. As barnacles are known to display relevant vital effects (Ullman et al., 2018), modern specimens where chosen to be as taxonomically similar as possible to their fossil relatives. This endeavor stemmed into a secondary paper focused on the taxonomy of *Chelonibia* that helped shedding light on the evolutionary history of the group (Collareta et al., 2021).

Results

The Pairola succession can be divided into two main lithofacies corresponding to two different skeletal assemblages. The lower part of the succession comprises mixed siliciclastic-bioclastic lithologies characterized by a barnamol skeletal assemblage. This assemblage is dominated by barnacles (mainly *Concavus concavus*) and mollusk remains and is usually related to high-energy coastal environments (Coletti et al., 2018; Coletti et al., 2021). Barnacle are usually detached from their substrate, fragmented and deprived of opercular plates. The latter being light and fragile are usually comminuted or transported away in these high energy settings. The coarse grained-lithofacies gradually change upwards into fine grained calcarenites characterized by a foramol skeletal assemblage, where barnacle are very rare but relatively well preserved. The two lithofacies are separated by a transitional zone displaying a foraminiferal dominated skeletal assemblage rich in barnacles. This latter assemblage is also characterized by abundant specimens of tropical large benthic foraminifera *Amphistegina*, which characterizes the whole succession but is particularly abundant in this facies. On the whole, the Pairola succession deposited within a shallow coastal environment and is characterized by two different depositional sequences whose evolution can be clearly tracked focusing on barnacles abundance, barnacle preservation and foraminiferal assemblages (Coletti et al., 2021).

Similar to Pairola, the Montefollonico outcrop also displays barnacle-rich facies. The base of the unit is characterized by a sharp erosional surface that cuts into the underlying fine grained calcarenite of early Pliocene age (Nalin et al., 2016). The basal part of the succession consists of a grain-supported conglomerate with well sorted rounded pebbles and a bioclastic matrix with abundant barnacle fragments and coralline algae. Further upward, the amount of rock fragments decreases and the succession is dominated by muddy calcarenites and calcirudites. The skeletal assemblage is dominated by coralline algae (both Corallinales and Hapalidiales) and barnacles (mainly *C. concavus*). The latter occur both as fragments and as complete specimens attached to their original growth substrate (either rhodoliths or small pebbles), they are relatively well preserved and although they lack opercular plates, the latter can be still found dispersed in the sediment. Benthic foraminifera are also common, including abundant *Amphistegina*, once again testifying for a warm water setting.

Although barnacles do not represent the main component of the Certaldo macrofossil assemblage, they are relatively common. The studied specimens all belong to *C. concavus* and they are usually well preserved, still displaying remnants of their original color. Several specimens were also found with their delicate opercular plates still articulated.

The clayish deposits from which the Empoli specimens of *Chelonibia testudinaria* were collected is interpreted as representing a very shallow interdistributary bay environment. The turtle barnacle fossils were found associated with a partial skeleton of a right whale (Bianucci 1996). Based on taphonomic and morphofunctional considerations, it was hypothesised that the cirripedes were hosted by the baleen whale, and possibly on its callosities, which could have represented a sort of analogous of the horny carapace of marine turtles.

Barnacles characterize the uppermost division of the succession exposed at Fauglia, that consists of an oyster biostrome. Most of the large bivalves are extensively covered by large number of barnacle specimens. Barnacles are moderately well preserved and in several cases still preserve their opercular plates, suggesting negligible post-mortem reworking. Based on the morphology of the opercular plates, the specimens have been tentatively attributed to *Perforatus perforatus*. The lack of *C. concavus* (which dominates in the Pliocene successions of Pairola, Montefollonico and Certaldo) from the shallow-water setting of Fauglia, suggests that the extinction of this species might approximate the Pliocene-Pleistocene boundary and be possibly associated to the early Pleistocene climatic deterioration.

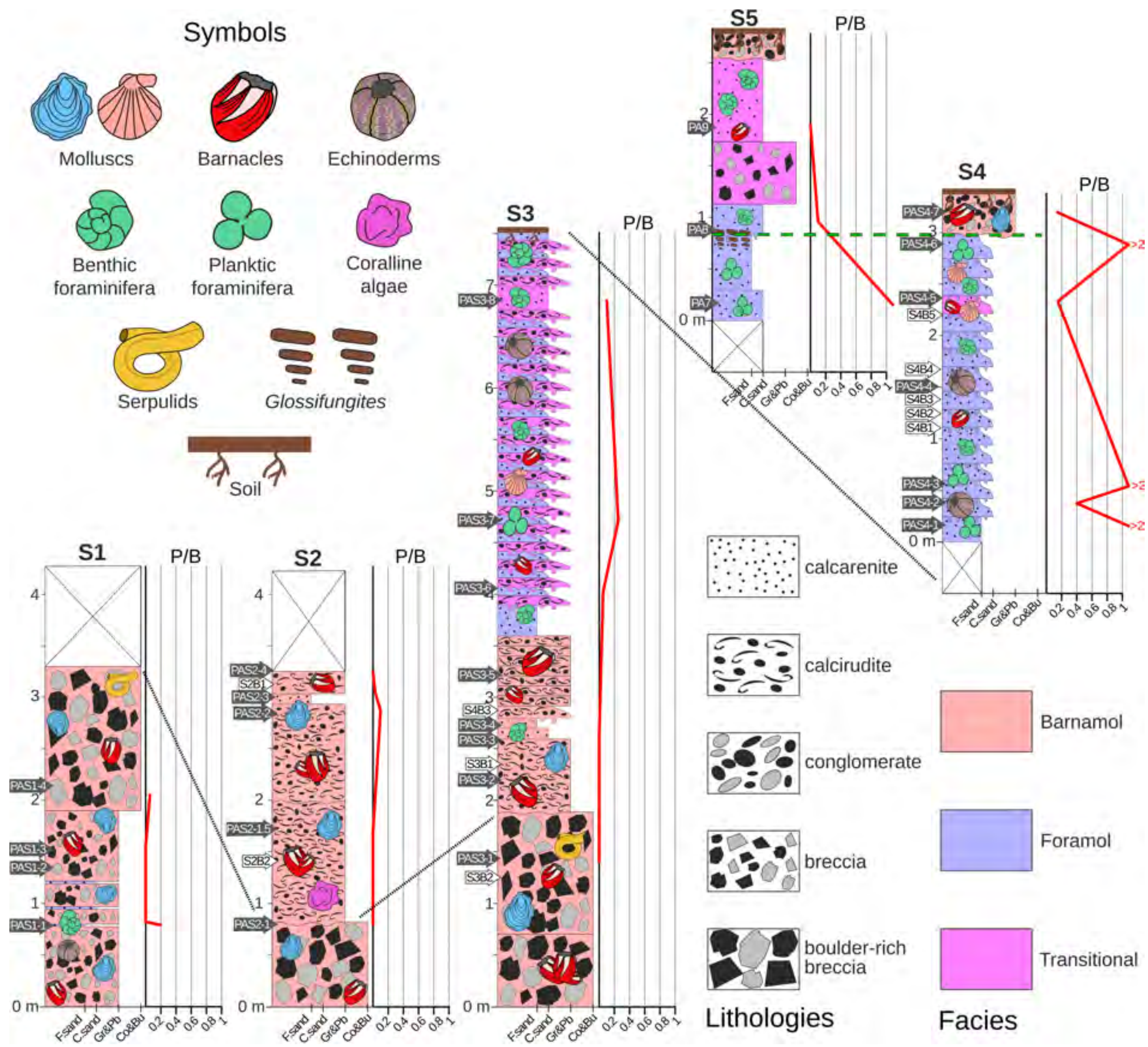

Figure 1 (from Coletti et al., 2021): measured stratigraphic sections and facies distribution at Pairola. Dashed lines serve to correlate the sections. The thick green dashed line indicates a sequence boundary. Grey arrows indicate bulk samples; white arrows indicate macrofossil samples (PA = Pairola; S1 = Section 1). The macrofossil content has been drawn on the basis of field and microscopic observations. P/B (plankton/benthos foraminiferal ratio); F= fine; C= coarse; Gr= granules; Pb=pebbles; Co=cobbles; Bu=boulders.

Stable isotope analyses highlight several interesting patterns (Fig. 2). The samples from Fauglia and Pairola clearly fall outside the range of modern barnacles and they are characterized by very low values of $\delta^{13}C$ and $\delta^{18}O$, similar to those of limestones altered by meteoric waters or diagenetic fluids. They also display a strong correlation between the two isotope ratios. Furthermore, most of the Pairola samples have values similar to those of the entombing sediment, clearly indicating that they have been significantly affected by diagenesis. The samples from Montefollonico, although characterized by remarkably low values, still fall within the range of modern barnacles; they also do not display any particular correlation between $\delta^{13}C$ and $\delta^{18}O$, nor a clustering close to the values of their embedding material. On the other hand, the specimens from Certaldo and Empoli display values similar to those of the modern barnacle examined during this research. $\delta^{18}O$ values of the Certaldo specimens greatly differ from those of their closest Mediterranean living relatives, which is *P. perforatus*; however the two barnacles belong to different genera (*Concavus* and *Perforatus*) and thus they are probably characterized by different vital effects as regards oxygen and carbon isotope fractioning. Both Pliocene and recent specimens of *C. testudinaria* display similar values. The Pliocene specimens display a more limited oscillation that possibly indicates a reduced seasonality during the overall warm Pliocene.

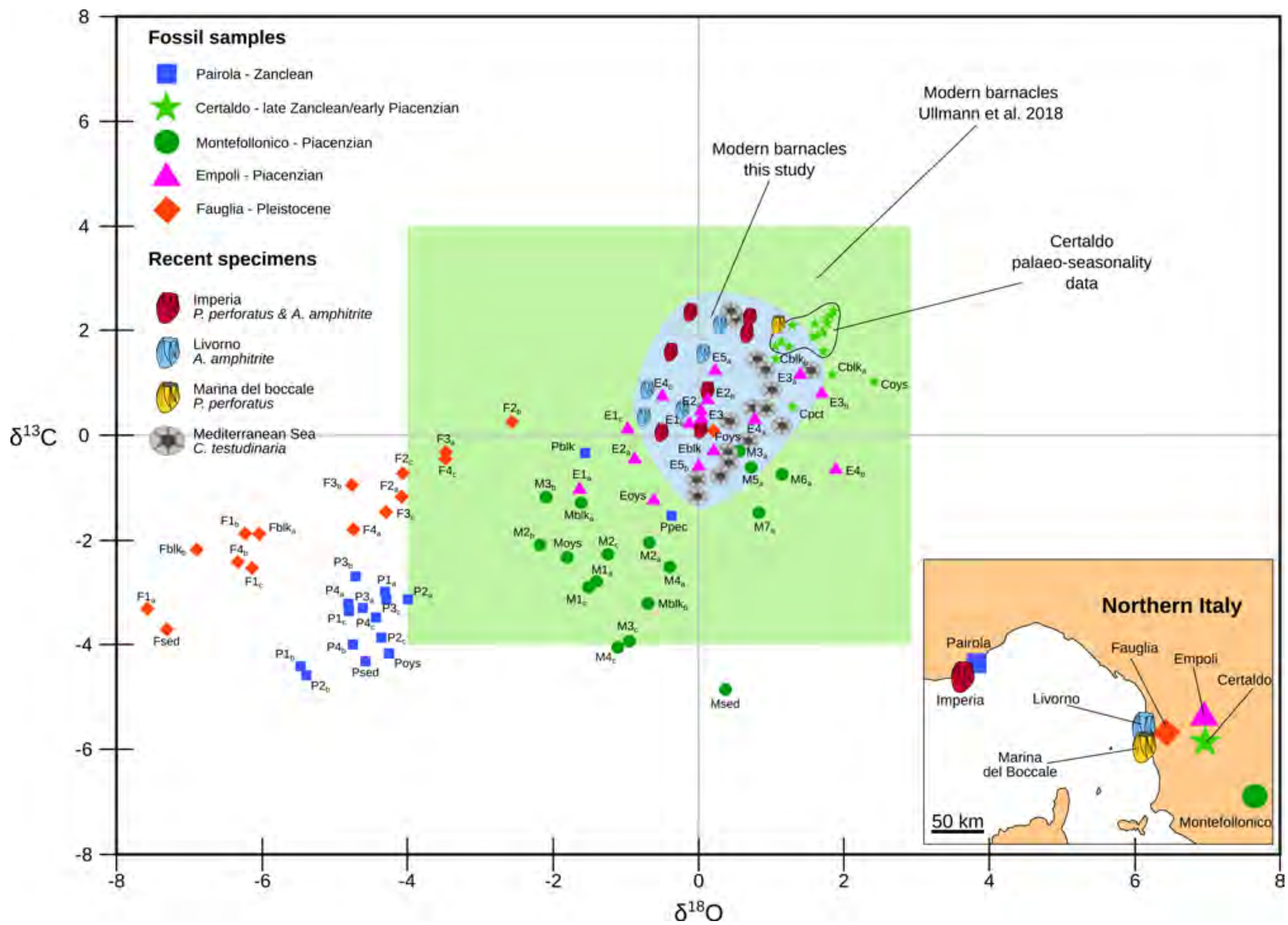

Figure 2: stable isotopes (C and O) plot of the analyzed samples. Numbered samples (e.g. $F1_a$, $F2_a$) indicate samples taken for the study of interannual variability; sed= sediment; blk= bulk; oys= oyster; pec= pectind

Overall these results indicate that barnacles, due to their fast growth, can preserve a geochemical record of inter-annual environmental variations. However, being usually related to shallow-water settings, they are generally embedded into coarse-grained porous lithologies and thus significantly exposed to alteration during diagenesis. This does not prevent the use of barnacles for detailed paleoenvironmental reconstructions, as barnacles can also occur (albeit not as the dominant component of the bioclastic fraction) in low-energy environments characterized by fine-grained sedimentation. In these settings, where they mainly survive by colonizing the outside of other benthic invertebrates, they can avoid diagenetic alteration and preserve their original geochemical signature.

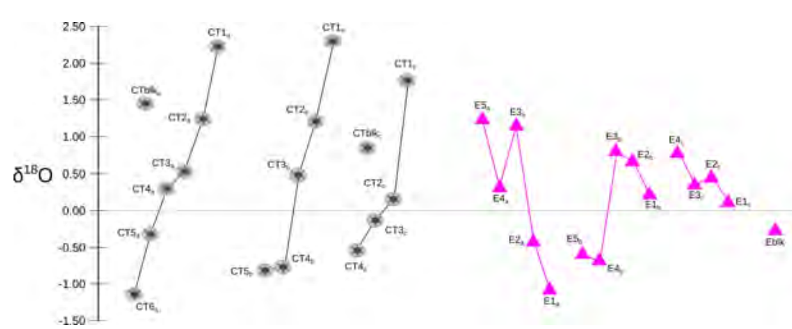

Figure 3: $\delta^{18}O$ values of the analyzed specimens of *C. testudinaria*; symbols are as in Fig. 2

References

The references in bold are for papers directly connected to the research grant and where IAS has been acknowledged as funding source.

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Davadie C. (1963) - Étude des balanes d’Europe et d’Afrique. Editions du Centre National de la Recherche Scientifique, Paris.

Newman W.A., Zullo V.A. & Wainwright S.A. (1967) - A critique on recent concepts of growth in Balanomorpha (Cirripedia, Thoracica). Crustaceana, 12(2): 167-178.

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Multiproxy analytical approach for high-resolution correlation of the Permo-Triassic sequence in the Franconian Basin (SE Germany): chemostratigraphy of the wells Mürsbach and Reiterswiesen

Domenico Ravidà

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INTRODUCTION

The Central European Basin System (CEBS) represents a WNW-ESE-striking depositional area which extended in Europe – from England to Poland across Netherlands, Germany and Denmark – from the Carboniferous to the Cretaceous (Stollhofen et al., 2008) (Figure 1A). Several kilometres of terrestrial sediments filled the basin during the Guadalupian (Rotliegend group) and lower Triassic (Buntsandstein group), with a northward transition from alluvial/fluvial-dominated depositional settings to sabkha/playa lake environments (Stollhofen et al., 2008; Bourquin et al., 2011). The continental sedimentation was interrupted by short-living southward marine transgressions during the upper Permian (Lopingian), resulting in the vast epicontinental Zechstein sea and deposition of seven marine evaporitic cycles (Tucker, 1991). In the distal portion of the CEBS, the Permian-Triassic sequences display a good lateral and vertical continuity, allowing high-precision correlations across east-west transects by means of gamma-ray logs and lithostratigraphy (Geluk, 2005). However, moving southwards, the less developed marine/evaporitic cycles commonly replaced by siliciclastic equivalents (Freudenberger and Schwerd, 1996), and the erosive character of the terrestrial sedimentation compromise the identification of regional boundaries. The lithostratigraphic-geophysical setup becomes less precise and highly susceptible to subjective interpretations (Freudenberger and Friedlein 2011). More versatile tools need to be integrated to increase the possibilities of correlation. By applying a multi-faceted approach including biostratigraphy, magnetostratigraphy, inorganic and stable isotope chemostratigraphy, Scholze et al. (2017) reinterpreted the stratigraphic boundaries in marginal sections of the CEBS. The authors indicate a pronounced shift in Rb content useful for regional chemostratigraphic correlations across the Permian-Triassic boundary. Stratigraphically equivalent geochemical anomalies were also identified in the distal portion of the CEBS (Hiete et al., 2006), reinforcing the importance of inorganic geochemistry as potential proxy to refine regional correlations. Nevertheless, none of the above authors produced a chemostratigraphic scheme for the CEBS nor explained the anomalies in terms of changes in the detrital sediment components.

The final goal of this project is to refine the stratigraphic framework in the SE portion of the CEBS, with a focus on the Franconian Basin (SW Germany) (Figure 1B and 1C), establishing data-constrained correlations combining chemostratigraphy to cores-sedimentology, heavy mineral analysis, U-Pb dating and wireline-logs. The purpose is to obtain a solid correlation scheme to extend to other regions of the CEBS. The major advantages of using elemental chemostratigraphy are that (i) it can be applied in sediments of any lithology and depositional environment, resulting extremely useful in the barren terrestrial CEBS deposits, (ii) it can be applied either to cores, outcrop and cuttings with an equal degree of success, and (iii) it offers higher-level resolution than other techniques (Craigie, 2018).

Funding provided by the IAS Postgraduate Research Grant contributed to the implementation of an existing database already holding over 500 XRF measurements from previously analysed wells distributed across the Franconian Basin. Samples belong to the wells Mürsbach and Reiterswiesen. Both wells occupy a strategic position in the northern part of the Basin and record distal facies associations, including Lopingian marine/evaporitic deposits (Figure 2), making them the missing link for extending the correlation northward across the CEBS. The results illustrated in this report represent the first step in establishing the relationship between chemical associations and detrital components, which is required to identify suitable chemical ratios for the regional-scale correlations.

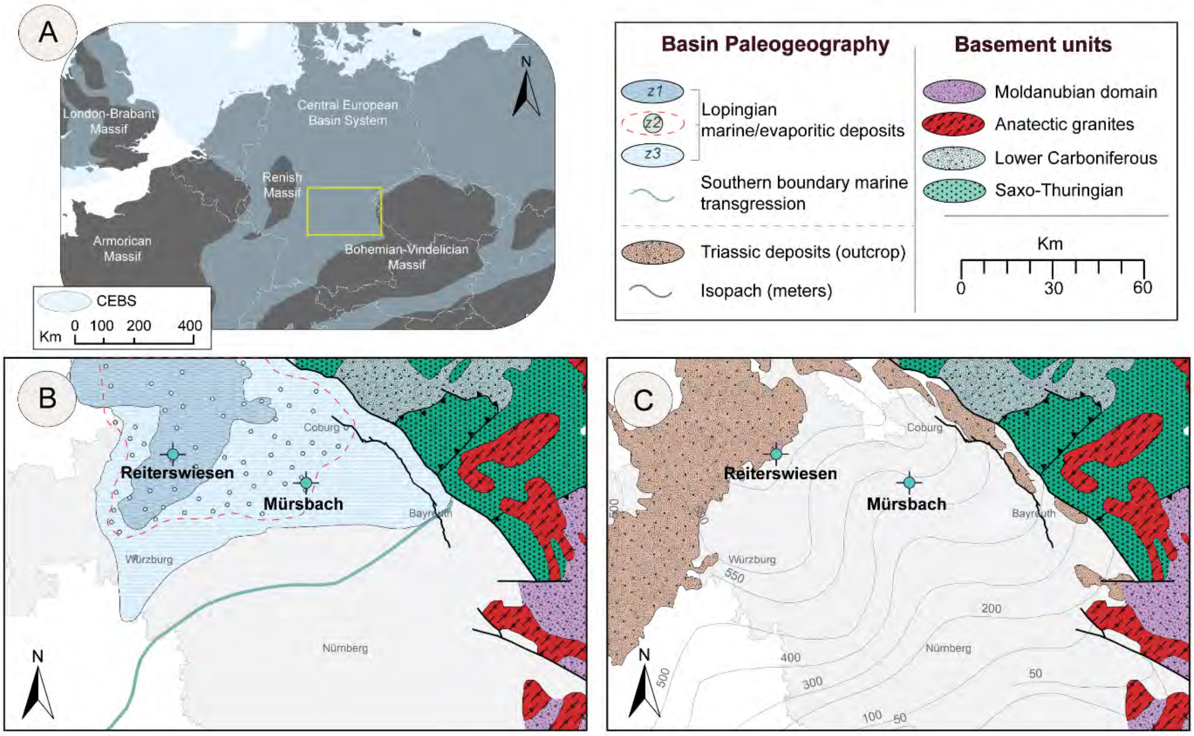


Figure 1: (A) Extent of the Central European Basin System. The yellow rectangle highlights the position of the Franconian Basin illustrated in figures B and C. (B) Distribution of the Lopingian evaporitic facies in the Franconian Basin (modified from Freudenberger and Schwerd, 1996). The colour code refers to the first three Zechstein cycles (z1, z2, z3). (C) Distribution of the lower Triassic deposits. Notice the northward increase in thickness.

METHODS

Fifty samples, chosen according to stratigraphic and sedimentological criteria from the available cores of the wells Reiterswiesen and Mürsbach (Figure 2), have been prepared for X-Ray Fluorescence analysis at the laboratory facilities of the Endogenous Geodynamics group of the Friedrich-Alexander Universität Erlangen-Nürnberg. For this purpose, the plugs (~ about 20 grams) were first cleaned of surface impurities through ultrasonic baths in deionised water. After drying, the samples were crushed employing a hydraulic press and then reduced to powder through a vibratory disc mill RS 200 (Retsch GmbH). The milled material was then dried out in the oven at 40 °C for ca. 12 hours. The Loss on Ignition (LOI) was determined beforehand to ensure an accurate evaluation of the XRF results by annealing 0.500x g (x= 0-9) of sample powder at 1030°C in a muffle kiln for a minimum of 12 hours. The LOI was then calculated from the weight difference before and after annealing, and it corresponds to the released of volatile components such as water, organic carbon, chlorine, fluorine, CO_2 and SO_2. After cooling, the samples were mixed with 4.000x g of lithium tetraborate (Jarvis and Jarvis, 1995) and 230 mg of diiodpentoxid and melted at a temperature of 1050° C. The molten substance was finally poured into tablet form and cooled before analysis. The relative abundance of major (SiO_2, Al_2O_3, TiO_2,

Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5) and trace (Ba, Cr, Ga, Nb, Ni, Pb, Rb, Sr, Th, V, Y, Zn, Zr) elements was measured through a SPECTRO XEPOS HE (SPECTRO Analytical Instruments GmbH). The results were normalised by the AC-E, GA, BE-N and BR standards provided by the SARM (Service d' Analyse des Roches et des Minéraux).

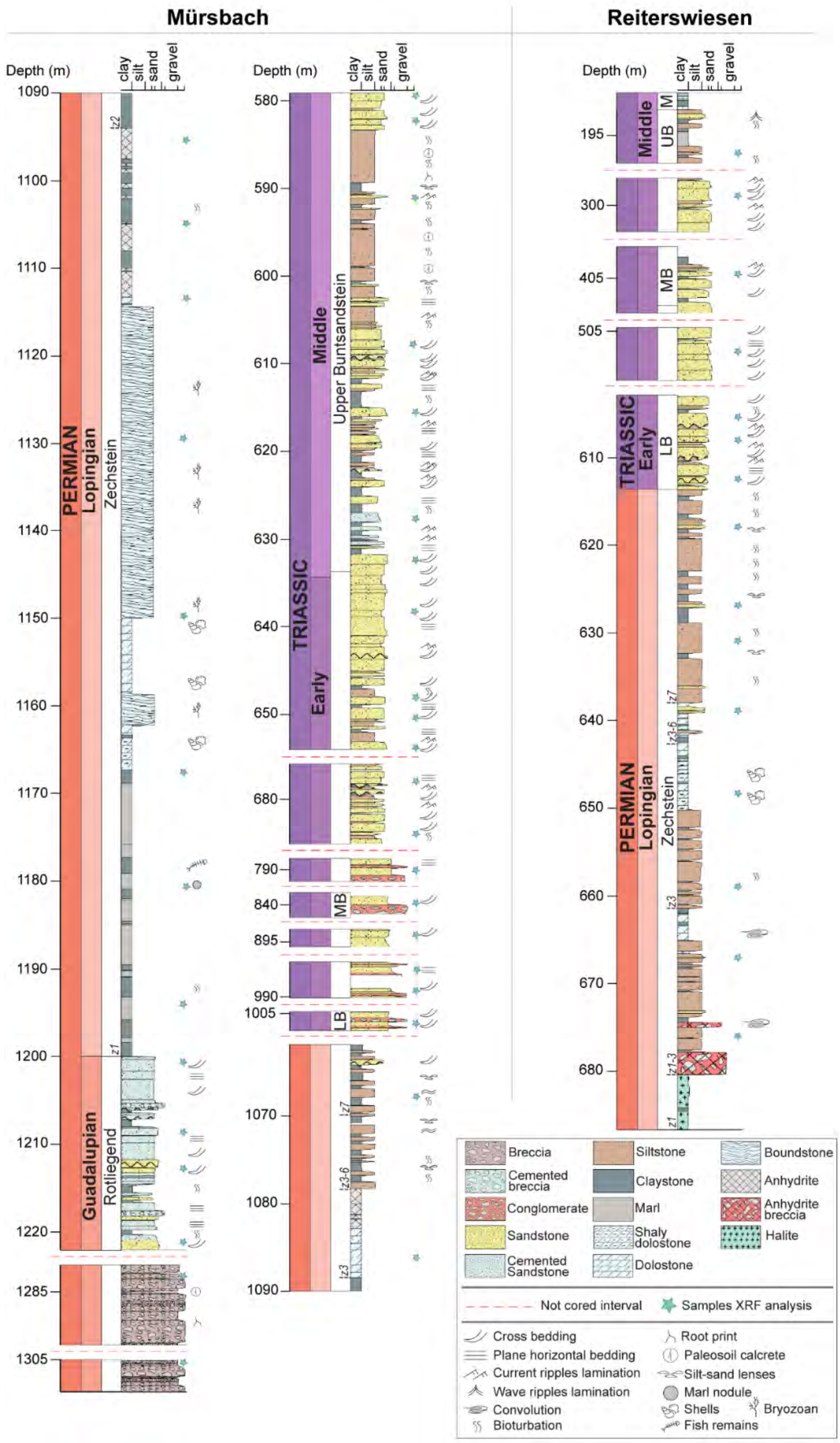


Figure 2: Sedimentary logs described from the wells Mürsbach and Reiterswiesen. The stratigraphic schemes were provided by the Bayerisches Landesamt für Umwelt. Lithostratigraphic groups: LB – Lower Buntsandstein; MB – Middle Buntsandstein; UB – Upper Buntsandstein; z- Zechstein cycles. The green stars indicate the position of the samples analysed thanks to IAS Postgraduate Research Grant.

The Principal Component Analysis (PCA) was applied to the compositional dataset to assess chemical affinities and infer element-mineral associations. The PCA uses an orthogonal transformation to convert a set of observation points into a new set of uncorrelated variables defined as principal components (PC) and constructed as a linear combination of the originals (Caracciolo et al., 2012). The number of PC is equal to or less than the original number of variables. Each PC geometrically represents the direction (or eigenvector) along which most of the dataset variance is captured. The first components express most of the variance, which reduces progressively in the others (Figure 3A). In other words, the PCA reduces the dataset dimensionality with minimal loss of information and identifies the directions along which the data variance is maximal. The packages *provenance* (Vermeesch et al., 2016), *factoextra* and *factormineR* (Lê et al., 2008) available for the R platform were employed to compute the PCA in the present study. The centred log-ratio transformation (clr) was performed on the dataset prior to the PCA to remove the closure effects linking the sum of each component to a constant value (i.e. 1, 100) (Vermeesch et al., 2016).

PRELIMINARY RESULTS

The eigenvector 1 (EV1) and 2 (EV2) encompass most of the statistical variance of the PCA (74.7%) (Figure 3A), primarily determined by CaO and Sr but also MgO, MnO, Pb and Zr (Figure 3B). The eigenvector cross-plot (Figure 3C) emphasises several chemical clusters that can be explained in terms of mineralogical affinities. Among these, group 1 and 2 includes CaO, MnO and MgO naturally concentrated in carbonate minerals and cement, including calcite and dolomite. These groups hold most of the EV1 variance (Figure 3B). In the opposite direction, SiO_2 form group 3, primarily associated with quartz. Group 4 includes Zr, which encompasses a significant portion of the EV2 variance and reflects the content of zircons. Groups 5 and 6 hold a close association with clay minerals. Specifically, the K_2O – Rb association reflects the illite content, whereas the Al_2O_3 – Ga association holds a strong affinity with kaolinite and other clay minerals. Moreover, the gap between Rb and K_2O and the latter proximity to SiO_2 indicates that potassium is not exclusively contained in clay minerals but also belongs to coarser grains such as K-feldspar. Group 7 includes P_2O_5, which is associated with a broad spectrum of not-carbonate minerals, mainly Apatite and Monazite, but can also be concentrated in biogenic phosphate. Groups 8, 9 and 10 contain Y, TiO_2 and Nb, respectively. While Y can be included in a large variety of heavy minerals, TiO_2 and Nb are typically associated with rutile, anatase, ilmenite, magnetite and sphene. Finally, group 11 contains Th, commonly found in heavy minerals such as monazite, apatite, and zircon. The other elements dispersed into the plane have not a specific and unique mineralogical affinity but can be found in association with the already defined groups. For instance, Fe_2O_3 holds a close association with carbonate minerals, pyrite and various clay. Ba, Sr and Pb have a more uncertain affiliation and can be linked to either sulphates or drilling additives. Nevertheless, they hold most of the EV2 variance (Figure 3B). Because of the uncertain affiliation and the high variance, Zn, Ni, Sr, Ba and Pb have been excluded, and the PCA re-applied. The results illustrated by the biplot in Figure 4 display no significant variation in the distribution of the components and an increase of the captured statistical variance to 79.3%. The samples of Mürsbach and Reiterswiesen are plotted against the first two principal components and according to the stratigraphy. The distribution of the observation points allows the identification of three main clusters: (i) samples from the Lopingian of both wells display a strong affinity to carbonate components (CaO, MgO, MnO and Fe_2O_3); (ii) most of the Early Triassic samples and Guadalupian of Mürsbach are distributed in the region between groups 3, 5 and 6 indicating a control from the siliciclastic and clay mineral components; (iii) the remaining samples are associated to Zr, TiO_2 and Y, indicating a close affinity to the heavy mineral associations.

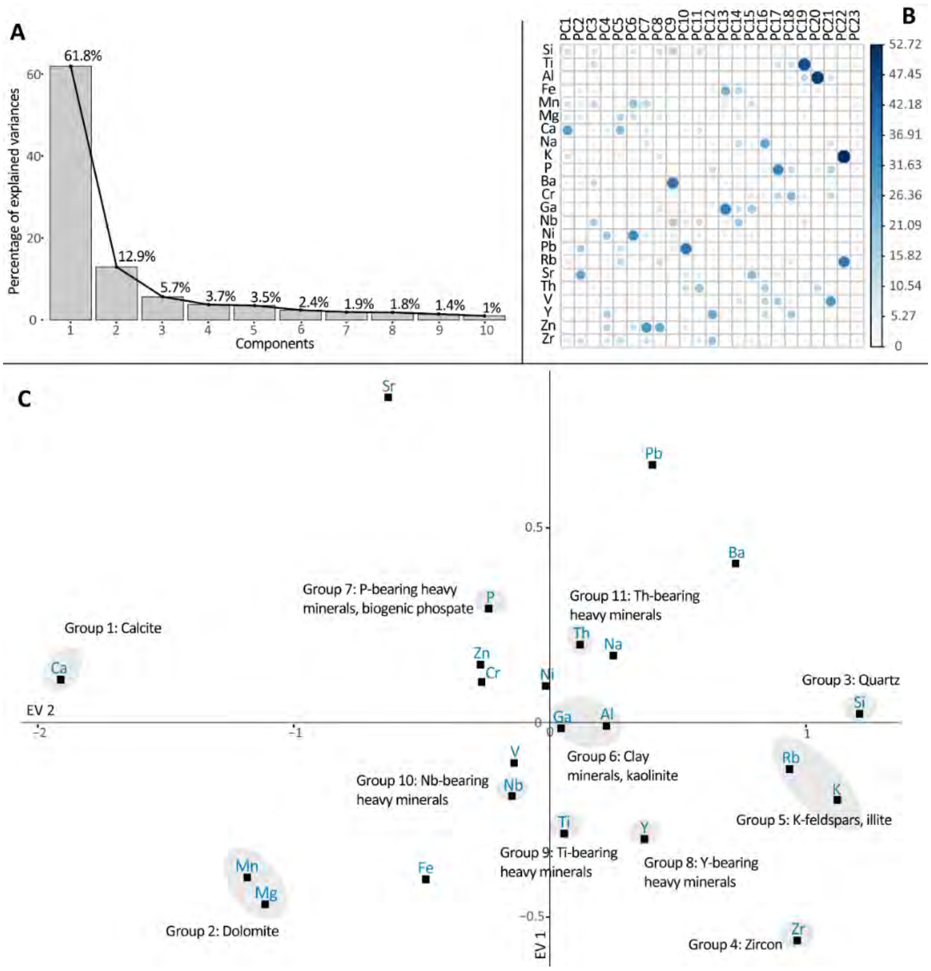


Figure 3: (A) Percentage of explained variance for the first ten principal components. (B) Incidence of the variables to each principal component. (C) Eigenvector cross-plot illustrating the chemical-mineralogical affinities for the analysed samples.

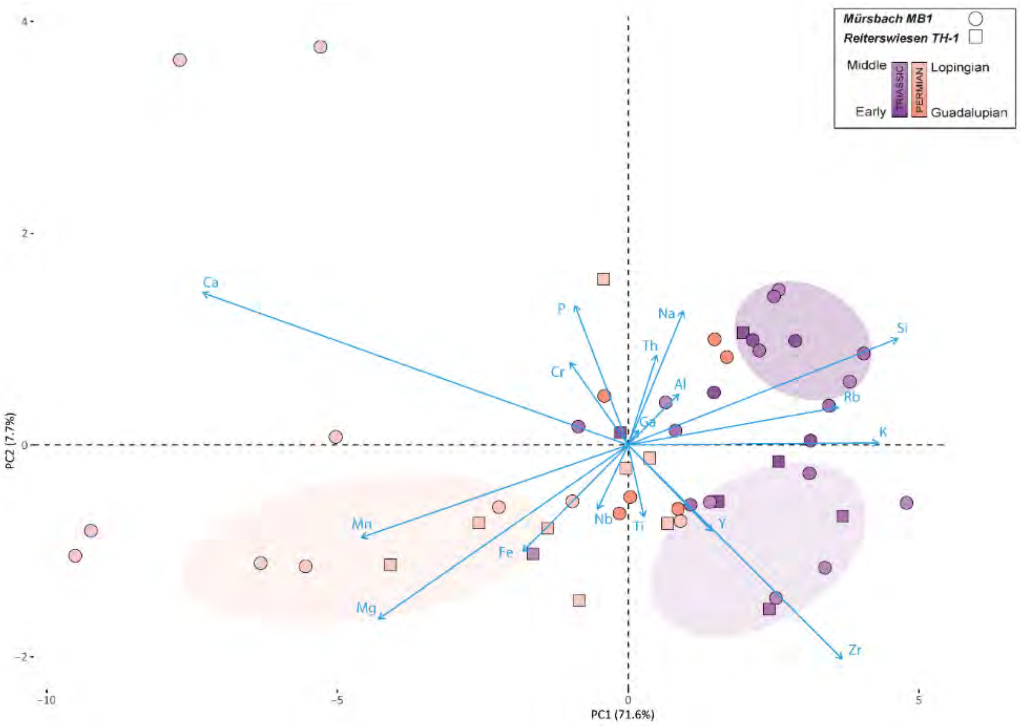
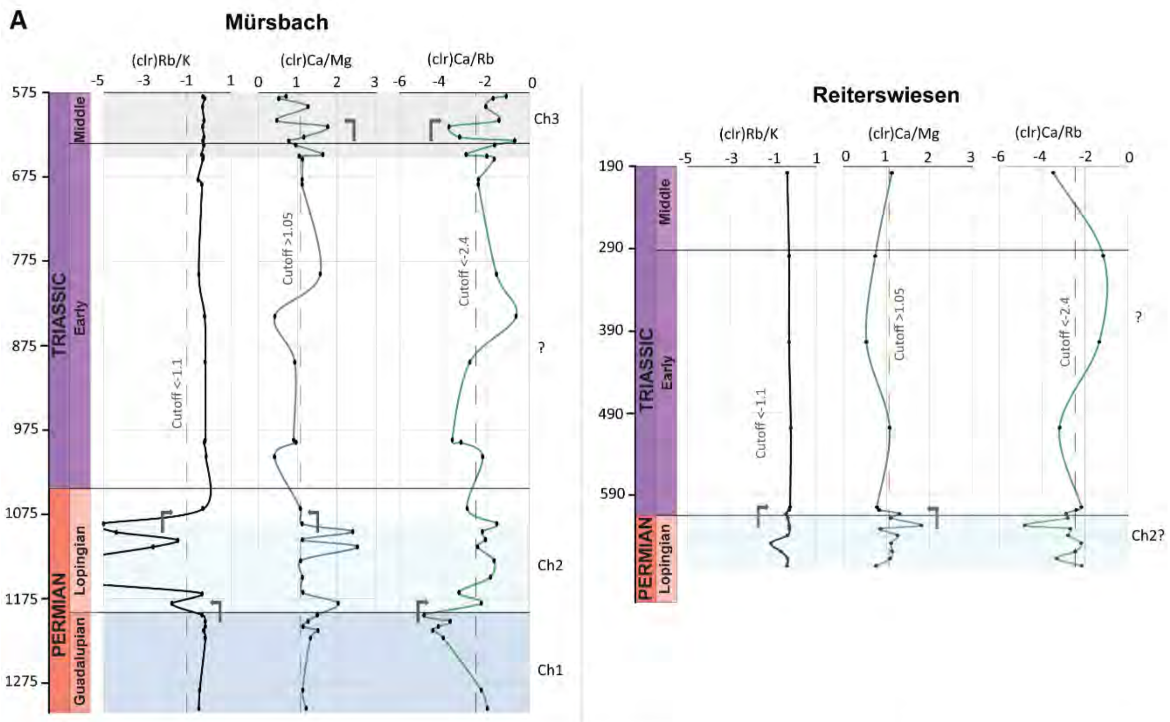


Figure 4: The biplot illustrates the distribution of the sample in relation to the first two principal components. Zn, Ni, Sr, Ba and Pb were removed from the PCA.

The principal component analysis unravelled the relationship between chemical and detrital components, illustrating major compositional changes throughout the stratigraphic intervals. Although the number of observation points for the two wells is limited and more samples should be included, the plots in Figure 5A provide a general understanding of the variations occurring across the two Permian-Triassic sequences. Three chemical ratios have been chosen according to their correlation coefficient (CC, Figure 5B) and are indicative of highly correlated elements (Ca/Mg and Rb/K) or extremely uncorrelated species (Ca/Rb) (Figure 4). Two principal zones are identified within the Permian of Mürsbach, with Ch1 producing higher Rb/K and lower Ca/Rb than the overlying Ch2. It is also noteworthy that Ca/Mg values are generally higher in Ch2 and that a similar pattern occurs in the Lopingian of Reiterswiesen. The top of Ch2 is marked by increased Rb/K values and decreased Ca/Mg in the proximity of the Permian-Triassic boundary. Another zone (Ch3) marks the upper portion of Mürsbach, identified by an upward decrease of the Ca/Mg ratio, whereas Ca/Rb is generally higher than -2.4.



	Si	Ti	Al	Fe	Mn	Mg	Ca	Na	K	P	Ba	Cr	Ga	Nb	Ni	Pb	Rb	Sr	Th	V	Y	Zn	Zr
Si	1.00																						
Ti	-0.07	1.00																					
Al	0.58	0.16	1.00																				
Fe	-0.68	0.43	-0.30	1.00																			
Mn	-0.72	-0.12	-0.67	0.62	1.00																		
Mg	-0.75	-0.09	-0.57	0.68	0.80	1.00																	
Ca	-0.78	-0.17	-0.63	0.54	0.79	0.75	1.00																
Na	0.50	-0.34	0.35	-0.53	-0.37	-0.57	-0.48	1.00															
K	0.85	0.11	0.75	-0.52	-0.74	-0.72	-0.86	0.46	1.00														
P	-0.45	-0.52	-0.45	0.02	0.27	0.26	0.53	-0.03	-0.65	1.00													
Ba	0.68	-0.42	0.30	-0.83	-0.59	-0.68	-0.63	0.57	0.62	-0.08	1.00												
Cr	-0.57	-0.13	-0.45	0.40	0.48	0.42	0.54	-0.06	-0.72	0.60	-0.52	1.00											
Ga	-0.01	-0.04	0.24	-0.05	-0.06	-0.01	-0.20	-0.10	0.11	-0.07	0.03	-0.12	1.00										
Nb	-0.41	0.68	-0.16	0.47	0.07	0.20	0.15	-0.49	-0.27	-0.11	-0.48	0.12	-0.11	1.00									
Ni	-0.04	-0.13	-0.13	-0.04	-0.14	0.10	-0.03	0.21	-0.06	0.13	-0.03	0.24	-0.15	0.01	1.00								
Pb	0.31	-0.31	0.24	-0.66	-0.56	-0.54	-0.44	0.37	0.25	0.22	0.53	-0.06	0.13	-0.28	0.06	1.00							
Rb	0.77	0.17	0.78	-0.48	-0.74	-0.75	-0.82	0.46	0.97	-0.65	0.56	-0.68	0.13	-0.21	-0.04	0.27	1.00						
Sr	-0.51	-0.38	-0.38	0.01	0.22	0.19	0.58	-0.16	-0.68	0.81	-0.15	0.52	-0.04	0.02	0.02	0.25	-0.61	1.00					
Th	0.07	0.18	0.17	-0.32	-0.38	-0.43	-0.26	0.09	0.01	0.17	0.18	0.00	0.04	0.04	-0.10	0.36	0.03	0.28	1.00				
V	-0.45	0.46	-0.32	0.61	0.41	0.31	0.37	-0.45	-0.38	-0.12	-0.53	0.35	-0.18	0.51	-0.03	-0.46	-0.32	0.00	-0.22	1.00			
Y	0.48	0.58	0.31	-0.11	-0.39	-0.39	-0.53	-0.12	0.46	-0.62	0.18	-0.50	0.02	0.17	-0.29	-0.11	0.42	-0.52	0.35	-0.05	1.00		
Zn	-0.36	-0.20	-0.29	0.11	0.27	0.26	0.34	-0.03	-0.36	0.23	-0.25	0.27	-0.16	-0.04	0.05	0.00	-0.33	0.26	-0.20	0.26	-0.55	1.00	
Zr	0.70	0.24	0.40	-0.36	-0.52	-0.46	-0.76	0.15	0.75	-0.63	0.45	-0.69	0.15	-0.09	-0.19	0.07	0.63	-0.77	0.07	-0.33	0.66	-0.42	1.00

Correlation coefficient > 0.7

Correlation coefficient < -0.7

B

Figure 5: (A) Preliminary chemostratigraphic zonation for the Mürsbach and Reiterswiesen. The ratios are built over the centred log-ratio (clr) transformed components. The question marks indicate intervals where more samples are required. (B) Correlation matrix illustrating the correlation coefficient (CC) between each component.

FUTURE PROSPECTIVE

More samples will have to be integrated to fully understand the geochemical data and produce a complete chemostratigraphic subdivision for the two herein investigated Permo-Triassic sequences. Nevertheless, the preliminary results obtained from this study disentangle the relationship between the chemical components, revealing high-scale tendencies useful for the integration of Mürsbach and Reiterswiesen into the regional scale chemostratigraphic zonation. The data and results herein illustrated will be combined to geochronological, sedimentological, petrophysical and detrital-compositional datasets to realise multi-proxy correlations across the Franconian basin.

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Avulsion Signatures within the Salt Wash Member of the Morrison Formation

INTRODUCTION

The natural diversion, or avulsion, of river channels constitutes one of the most dramatic processes in fluvial systems. By reconfiguring the arrangement and distribution of river channels, avulsions determine the concentration and stacking patterns of channel sand bodies as well as overbank sediments that emanate from active channels (Allen 1978; Bridge and Leeder 1979). Despite the significant impacts of this process on fluvial stratigraphic architecture, avulsion indicators have only been identified and characterized in a few ancient systems (Jones and Hajek 2007; Kraus et al. 1999; Mohrig et al. 2000). The characterization of avulsion dynamics in ancient fluvial systems is limited by outcrop exposure, and the resulting lack of clear evidence of avulsion activity. We selected the Salt Wash Member of the Morrison Formation as a case study due to its excellent and widespread outcrop exposure across the Colorado Plateau (Mullens and Freeman 1957). This lateral extent is even more essential to avulsion dynamic studies in light of recent findings in modern avulsive river systems. Valenza et al. (2020) found that avulsions tend to occur through channel reoccupation, or annexation, in locations closer to fan apices, while avulsions occurring farther down fan tend to include greater crevassing and floodplain disturbance, or progradation. Additionally, the estimation of the Salt Wash system apex (Owen et al. 2015a) allows a relatively direct comparison between observed avulsion activity (and its distribution) in modern fluvial systems and the ancient Salt Wash system.

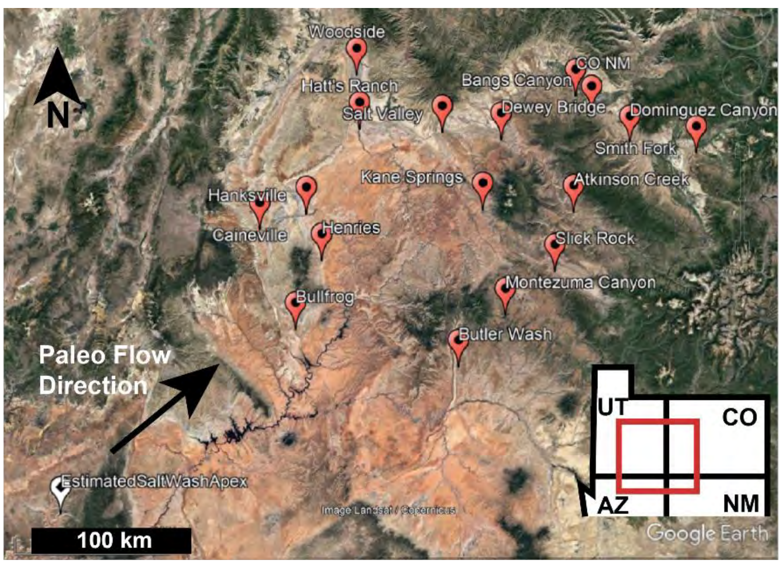

Figure 1. Outcrop locations used in this study. Salt Wash Member of the Morrison Formation extends across the Colorado Plateau. Study locations (n=17) are marked by red pins, with the estimated system apex marked by a white pin (SW corner of map).

METHODS

We collected data from 17 outcrop locations across the known Salt Wash extent (fig. 1), with an emphasis on obtaining data from proximal, medial, and distal outcrops, as defined by Owen et al. (Owen et al. 2015a; Owen et al. 2017; Owen et al. 2015b). For each outcrop, we identified the number of channels, the nature of basal contacts for each channel body, and channel bar thicknesses within channel bodies (fig. 2). Drawing from the classification scheme outlined by Kraus et al. (1999) and Jones and Hajek (2007), we divided channel basal contacts into three categories: channel-channel, channel-floodplain, and channel-heterolithic contacts. We map the distribution of the number of channels, the types of channel contacts, and the collocation of channel contact types at each outcrop using interpolated contour maps.

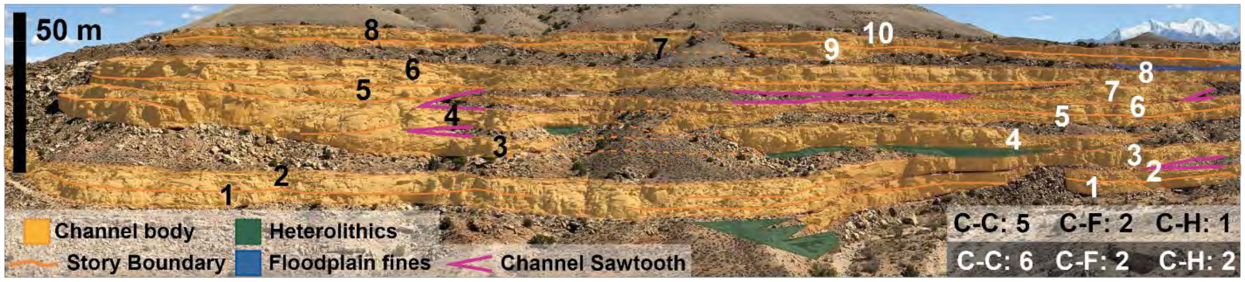

Figure 2. Example panorama of Henries outcrop. Channels are numbered, and any details regarding basal channel contact types are indicated. With some channels only present on one side of the outcrop or the other, we count both sides individually (black or white text), and use the average of both sides as the characteristic channel count.

RESULTS

Considering the results from 17 outcrop locations, we found the greatest concentration of channels occurring along the center of the Salt Wash system, as defined by Mullens and Freeman (1957) and Owen et al. (2015a). In particular, the two outcrops closest to the paleo-apex, and another cluster of outcrops further downstream (centered around Atkinson Creek, which hosts 12), hosted 9-12 channels (fig 3). Conversely, we find a trend of fewer channels with distance from the center of the system, whether that is upstream but on the NE edge, or at distal locations in general. Considering the nature and distribution of channel contacts, we find several regional trends. First, the number of channel-channel contacts correlates positively with the total number of channels, and follows a similar pattern of high concentration in proximal outcrops, and further downstream, in the central region of the paleo- extent (fig. 4A). Next, we see a less-pronounced trend in the distribution of channel-floodplain contacts, with a maximum of six at Atkinson Creek (fig. 4B). The maximum concentration of channel-heterolithic contacts are found at Kane Springs, where five of the outcropping channels sit atop heterolithic packages (fig. 4C). Finally, we simplify the channel contact scheme into two groups, channel-channel, and channel-floodplain/heterolithics. We calculate the percentage that each category makes up of the total channels at each outcrop, and find the difference between the two percentages (fig. 4D). In this analysis, low values represent parity between channel contact types, and higher values represent locations where one channel contact type dominates. We find that outcrops closer to the center of the Salt Wash system, whether proximally or distally located, tend to host both simplified channel contact groups, whereas outcrops on the fringes of the system tend to be dominated by channel-floodplain/heterolithic contacts.

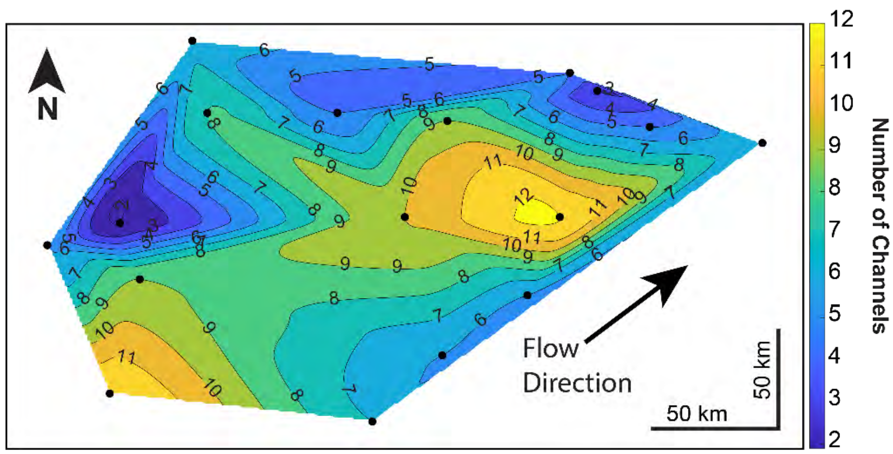

Figure 3. Contour map showing the concentration of channels across the Salt Wash system.

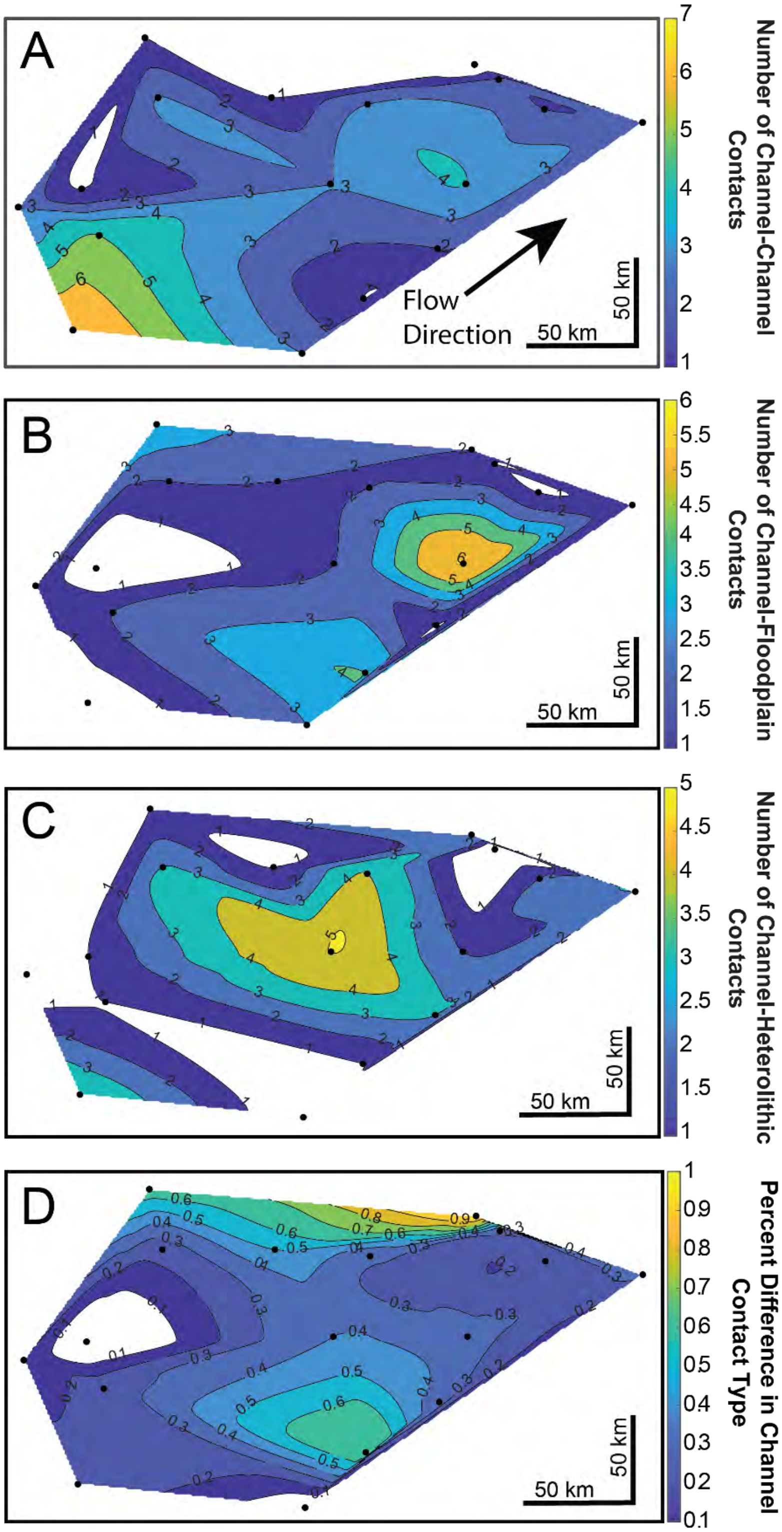

Figure 4. Contour maps of channel contact analysis. A. Number of channel-channel contacts. B. Number of channel-floodplain contacts. C. Number of channel-heterolithic contacts. D. Percentage of channel-channel/total minus channel-floodplain/heterolithics/total. In this comparison, lower values indicate colocation of contact types, whereas higher values indicate one contact type dominates. In both high-value regions, channel-floodplain/heterolithic contacts dominate.

DISCUSSION

This project builds upon previous work which interpreted the Salt Wash Member of the Morrison Formation as a distributive fluvial system, exhibiting downstream trends of grain size fining and decreasing channel facies as floodplain facies increase (Owen et al. 2017; Owen et al. 2015b). Our results largely confirm these trends. We extend our consideration of each outcrop to the entire exposure, rather than the standard stratigraphic column. This allows us to more accurately characterize stacking patterns and basal channel contacts. We identified all exposed channels, then followed them along the entire outcrop, to determine if they were stacked on another channel (channel-channel contact), or were isolated- only contacting floodplain or heterolithic deposits.

Using these data, we characterize the channel distribution of the Salt Wash system within the framework of avulsion channel repulsion (Allen 1978; Bridge and Leeder 1979) or attraction (Aslan et al. 1999; Maizels 1990; Morozova and Smith 2000). We interpret the first observation, that channels are concentrated along the center of the ancient system, as an indicator that while the primary flow path of the Salt Wash system likely avulsed and migrated across the floodplain (or fan surface), it occupied the center of the system more often than lateral edges. This suggests that the system was not dominated by repulsive channel avulsion. As such, we suggest that the Salt Wash system developed under an attraction-dominated depositional regime.

Next, we consider the distribution of specific avulsion processes throughout the study area. We refer to interpretation schemes presented by Kraus et al. (1999) and Jones and Hajek (2007), where channel-channel contacts indicate annexation, and channel-heterolithic contacts indicate channel construction, or progradation (channel-floodplain contacts present more ambiguous avulsion activity, and this will be discussed later). The concentration of channel-floodplain and channel-heterolithic contacts in more distal locations (fig. 4B,C) partially coincides with the findings of Valenza et al. (2020), that avulsion processes shift from predominantly annexational to predominantly progradational with increasing distance into the sedimentary basin. In our data, more distal outcrops do host predominantly progradational avulsion signatures (channel-heterolithic contacts). However, proximal outcrops are not equally dominated by channel-channel, or abrupt contacts. Instead, we see collocated channel-channel and channel-heterolithic contact types in our outcrops that are most proximal to the estimated apex. This discrepancy may be due to the fact that the most “proximal” outcrops are approximately 200 km away from the estimated system apex (fig. 1), and may thus demonstrate a transition zone between proximal and distal avulsion processes.

Another important limitation is that in many cases, only ledge-forming channel bodies or thickly bedded heterolithic bodies weather in such a way as to be clearly observable. This means that more thinly bedded heterolithic deposits may be covered by talus or vegetated slopes. Where time and safety permitted, we hiked along channel bodies to accurately characterize the nature of pre-channel sediment, but in many cases we were unable to identify underlying facies with high certainty. However, in every outcrop we were able to observe at least several small windows of pre-channel stratigraphy, allowing what we consider an acceptable level of interpretation.

Due to the decreased certainty in differentiating floodplain from thinly bedded heterolithics, we combine these two channel contact types and compare their occurrence against channel-channel contacts (fig. 4D). This comparison reveals an additional avulsion characteristic of the Salt Wash system: along the center of the system, both channel-channel contacts and channel-floodplain/heterolithic contacts occur together. Conversely, the northern and southeastern edges of the system are dominated by channel-floodplain/heterolithic contacts. We interpret this observation as the tendency of the Salt Wash system to produce a mixture of annexational and progradational avulsion processes along the center of the system, in accordance with greater channel density. Where channels are sparser, we see fewer channel reoccupations, supporting the idea that one of the drivers of channel annexation is the density of channels on the floodplain (Valenza et al. 2020). Where channels are rare, avulsion appears to be accompanied by more crevasse splays, and channel construction is likely the dominant avulsion process.

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