EUG XI

Symposium EVO3

Modern and Ancient Surface- and Groundwater-Cemented Geochemical Sediments: Processes and Product

Convenors

Dave Nash
Susan J. McLaren

EVO3
Surface- and Groundwater-Cemented Geochemical Sediments

Thursday AM Session

EVO3 : THam02 : F5
Characteristics, Evolution and Distribution of Quaternary Channel Calcretes, Southern Jordan

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Calcreted conglomerates of Quaternary age are found within palaeo-river channels exposed at various heights above the modern bed of the Wadi Dana in southern Jordan (up to about +120 metres). In cross-section, the calcrete deposits are typically lensoid in shape and are found infilling palaeo-channels cut into the bedrock. The fossilised channel sediments preserve evidence of past river conditions, sediment loads, source areas, phases of river down cutting and sediment accretion, as well as post-depositional alteration processes.

Samples have been analysed in thin section and under the scanning electron microscope in order to determine the calcrete micromorphology, cement types and crystal sizes. The results show that the river deposits have undergone significant replacement and displacement of the detrital grains by $CaCO_3$, and this has resulted in the cementation of over four metres of river material. The nature of the cement fabric varies as a function two main variables. Firstly, the specific location of the calcrete within the former river channel. Sparite dominates within the palaeo-wadi channel, whereas on the flanks of the channel micrite is the main type of cement. This is thought to be a result of differences in the length of residence time of calcium carbonate-rich fluids in different parts of the channel and the spatially varying influence of evaporation. Secondly, distinct changes in cement fabric can be seen in channels of different ages with a reduction in the amount of micrite and an increase in the amount of secondary pore filling spar over time.

As well as in the main Wadi Dana, channel calcretes are also found near to the mouths of the tributary wadis that feed into the Dana. This is where the waters of the various wadis, which have become progressively concentrated in respect to $CaCO_3$ down-stream, converge and where the flow gradients decrease as they emerge onto the flatter and wider bed of the Wadi Dana. A similar sequence of calcretes preserved within palaeo-wadi channels is also evident in the neighbouring Wadi Ghuweir. Comparisons between the calcretes from the Wadi Jordan are made with those from Spain in the paper by Nash *et al*,.

EVO3 : THam04 : F5
Properties and Development of Late Quaternary Channel Calcretes in the Tabernas Basin, Southeast Spain

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Non-pedogenic channel calcretes of up to 3.5 m thickness occur in a number of locations across the Tabernas Basin in Almeria Province, southeast Spain. They represent the last major phase of late Quaternary calcium carbonate cementation to affect this semi-arid drainage basin. Channel calcretes are situated within the basal sections of sequences of <12 m thick, poorly sorted, coarse-grained, schist-dominated fluvial gravels that were deposited within confined bedrock channels. Channel calcretes occupy the full basal width of the bedrock channels within which they occur, and mostly outcrop near the mouths of tributary valleys to the main Rambla de Tabernas drainage system.

Results of petrological and SEM analyses indicate that all channel calcretes are massively cemented by calcite and appear uniform at the section scale. Microscale analyses reveal that detrital grains within the calcretes are usually initially coated by micrite which is overlain by grain-coating and pore-filling sparite. At the section scale, a series of broad trends in cement type and micromorphology can be recognised. All sections exhibit an increasing degree of calcite crystal size in a down-section direction. Most sections contain predominantly micrite in upper parts with an increasing percentage of sparite toward the base. Some sections, however, are dominated by sparite and show increasing crystal size and occurrence of euhedral crystals toward the base of the section. Many sections also contain evidence of diagenetic alteration in the form of dissolution of calcite crystal faces or replacement of the calcite cement by amorphous silica, with alteration mostly occurring in the lower parts of sections.

These trends appear to have developed in conjunction with a fluctuating water table, with the increased crystal size and occurrence of euhedral crystals toward the base of sections arising from greater duration of wetting in basal zones. Cementation probably occurred at depth within the sediment, presumably well below the zone of capillary rise and pedogenesis and mostly in the absence of significant organic activity.

Comparisons of Tabernas channel calcretes with those described from Jordan in the preceding paper (McLaren et al.) provide a useful mechanism for assessing the controls upon channel calcrete development. Both sets of calcretes have developed in broadly comparable geomorphological settings but contain contrasting host sediments and exist under different contemporary climates. Furthermore, channel calcretes at Tabernas are of broadly comparable age whilst those from Wadi Dana form part of a time sequence. Comparisons between both sites reveal that whilst broadly consistent patterns in cement type exist at the profile-scale there are significant differences between older and younger generations of channel calcrete. These results suggest that it may not yet be possible to identify a simple channel calcrete type.

EVO3 : THam06 : F5
Complex Calcrete Profiles from the Sorbas Basin, S.E. Spain: The Significance of Pedogenic, Surface Process and Climate Interactions

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The morphology of pedogenic calcrete profiles have been described by numerous authors (i.e. Machette, 1985). Pleistocene calcretes from the Sorbas basin, South-East Spain, do not correspond with these models, consisting of complex profiles with multiple horizons of varying origin. This study aims to establish models for calcrete development in the region by comparing the morphology and micro-morphology of complex profiles. Three characteristic calcrete lithofacies are identified representing calcrete development in three distinctive geologic and topographic settings: Type I) Quaternary fluvial terrace sediments, Type II) Slopes comprising Quaternary or Neogene deposits that have undergone periods of instability, and Type III) Geomorphically stable land-surfaces comprising Neogene deposits. Chronologies for these sequences will be addressed at a later date but will be based upon work undertaken recently (Kelly et al, 2000).

Calcrete profiles on Quaternary fluvial terraces (Type I) comprise multiple hardpan horizons separated by poorly cemented sediments. Hardpan horizons reflect different calcrete forming processes operating during and after terrace aggradation. Calcrete formation occurs during hiatuses in fluvial aggradation, by channel bed cementation (sparitic horizons at the base of channel fill features), colonisation of bar surfaces by vegetation (calcretes with biogenic fabrics, i.e. fenestral porosities and needle fibre calcite) and weak pedogenesis (clast coatings). Geomorphic stability after terrace formation is represented by mature pedogenic calcretes. Calcrete profiles on unstable slopes (Type II) comprise multiple hardpan and laminar horizons separated by pisolithic and brecciated calcrete horizons. Hardpan horizons consist of micritic fabrics and represent pedogenic calcrete growth at a stable land surface. Pisoliths, consisting of concentric calcite coatings around detrital grains, and brecciated calcrete fragments, reflect down-slope transportation of material during phases of slope instability and mass movement. Calcrete forming on geomorphically stable bedrock surfaces (Type III) comprise single hardpan horizons. These horizons record pedogenic calcrete formation, characterised by hardpan horizons with micritic fabrics, reflecting evaporative calcrete growth, followed by *in situ* calcrete brecciation and pisolith formation and recementation during later calcrete forming phases. Calcrete brecciation and pisolith formation result from root activity, whilst calcrete precipitation reflects periods of increased aridity.

Calcrete profiles in the Sorbas basin reflects interaction between calcrete formation, geomorphic processes, (Type I and II), and vegetation, (Type III). Calcrete formation may, therefore, be controlled by climate, (i.e. vegetational changes), or intrinsic geomorphic changes (i.e. channel avulsion). The complexity/maturity of individual calcrete profiles from the Sorbas basin do not necessarily reflect the degree of exposure and, consequently, the duration of a sedimentary hiatus, but the interplay of a range of factors that may be independent of, or inter-related, to one another. Detailed analysis of Quaternary calcretes is important in understanding the geomorphic and environmental significance of ancient calcrete profiles and is, therefore, of global importance to geological studies.

Machette MN, *Geological Society of America, Special Paper*, **203**, 1-21, (1985).
Kelly M, Black, S & Rowan JS, *Quaternary Science Reviews*, **19**, 995-1010, (2000).

EVO3 : THam10 : F5
Mechanisms of Salt Enrichment in Dry Lake Basins

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The mechanisms of salt enrichment in dry lake basins can be understood by studying lateral and vertical variations in salt content, evaporite mineralogy and crystal morphology. This is demonstrated by the study of two pan basins of the southwestern Kalahari that are very different with regard to groundwater occurrence and the nature of their deposits.

In a first pan basin, where dolerite bedrock occurs at shallow depths, groundwater precipitation of salts is currently still taking place. The salt distribution patterns at this site illustrate the simple but rarely applied principles that salt minerals only form at levels where evaporation takes place and that any mineral will first precipitate where its saturation is first reached. The first of these rules is demonstrated by the absence of salts within a subsurface layer of fine-grained deposits, where no water transport occurs in the vapour phase. Salt minerals - mainly gypsum and kalistrontite - do form within the overlying deposits, at depths that are determined by the position of the evaporation front. This level is related to groundwater depth and therefore varies through time and between different parts of the basin. Other processes that affect the salt distribution patterns at this site are the redistribution of salts during flooding stages and the occurrence of lateral variations in salinity that are related to the pattern of groundwater flow.

In the second basin, no groundwater occurs within the pan deposits at present. The salts that these deposits contain - mainly thenardite (Na_2SO_4) and halite - formed during an earlier period with high groundwater levels, following a period of lacustrine sedimentation in a groundwater-fed lake without synsedimentary evaporite formation. Lateral variations in total salt content still record the patterns of groundwater flow during the period when salt enrichment took place. The deposits were later affected by leaching, resulting in a vertical redistribution of the salts and the formation of Ca- and Na-Ca-sulfate minerals in higher parts of the profiles. The effects of this process are partly determined by the nature of the deposits, which have a high smectite content at this site.

The investigation of these sites shows that the study of variations in abundance, nature and morphology of salt minerals in dry lake basins can result in the recognition of mechanisms that determine the behaviour of salts and the identification of factors that influence the resulting distribution patterns. The study of salts in pan environments, representing a simple setting with a flat topography, contributes to a general understanding of these mechanisms and factors that can also be applied to other near-surface environments.

EVO3 : THam12 : F5

Near-Surface Diagenesis of Anhydrite Nodules in Argillaceous Terrestrial Deposits (Triassic, Central Spain)

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Cauliflower nodules consisting of quartz, dolomite and calcite occur in a red mudstone bed of the upper Buntsandstein facies of the Iberian Ranges. They are spherical, ovoidal or elongated and range from 1 to 8 cm across and are commonly fractured. The surface of the nodules is irregular and some show a pedogenic coating of microspar. Two types of nodules are recognised. Nodules type A consist of an outer part of megaquartz with anhydrite inclusions, quartzine and palisadic quartz and an inner part of spar calcite including kaolinite. Nodules type B are formed from the outer to the innermost part of megaquartz, dedolomite (after dolomite) both including anhydrite relics, and coarse calcite cements with barite and kaolinite.

The sedimentological, petrographical and stable isotope data suggest that the initial anhydrite nodules formed by progressive concentration of the meteoric pore fluids in a very surficial vadose environment occasionally under the influence of pedogenic processes. Partial replacement of the anhydrite by megaquartz occurred under more diluted conditions, within a subsurficial environment, indicated by the presence of organic filaments on the quartz crystals. The two types of nodules are the result of two different diagenetic paths. In nodules type A, the dissolution of the innermost anhydrite was complete and quartz cements filled the porosity. Fracturation and meteoric cementation by calcite and minor amounts of kaolinite were the latest processes affecting these nodules. On the contrary, in type B the dissolution of the anhydrite was incomplete inhibiting the precipitation of quartz cements and enabling dolomitization. Dolomitization was driven by bacterial sulphate reduction. Dedolomitization, precipitation of barite, kaolinite and calcite cementation occurred later on by the influence of groundwater meteoric solutions.

The overall described processes indicate that groundwater table was relatively surficial along the fluvial Basin. The groundwater chemistry evolution as well as their position was controlled by the palaeoclimatic conditions and by the tectonic stability needed to maintain a similar position along wide areas (more than 25 km) of the basin. From this point of view these nodules do not only reveal a complex diagenetic history but also are indicative of palaeogeographic and palaeoclimatic conditions.

EVO3 : THam14 : F5

Mineralogical and Stable Isotope Results (C, O and H) of the Miocene Series from the Forez Graben (French Massif Central): Geodynamic and Stratigraphic Interpretation

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New outcrops locations associated with limestone strata enables a reconsideration of the stratigraphic interpretation of continental infilling of the Forez graben at during Miocene times. The called "Veauche sandstone" outcropping in the southeastern side of the graben, previously described as deposited during the lower Miocene is now regarded as the upper level of this series. The poorly sorted and detrital unit overlies lower units mostly composed of "green marls" with a transitional strata composed of decimetrical and metric carbonate units. These carbonates contain desiccation cracks, breccias, and micro syn-sedimentary faults with conglomeratic and argillaceous horizons. This sedimentologic changes support discontinuous sedimentary and tectonic activity of the basin. Carbonaceous horizons from the eastern side of the basin have been compared with those recognized in the western part dated as lower and middle Miocene (Gerbe et al. 1998). The whole carbonate succession contains flint stones in their upper portion mainly precipitated on the western side. Samples of carbonates have been analysed with XRD and SEM. Carbonates contain detrital micas, quartz and feldspar as well as pedogenetic minerals as rims such as montmorillonite - kaolinite. Some late cracks are mostly infilled with calcite, quartz and montmorillonite. This stratigraphic, petrographic observations and mineralogical results tend to suggest that the carbonates are a transition unit between "green marls and Veauche sandstones". These changes indicate climatic change between dryer "seasons" with carbonate precipitation followed by a different type of hydrothermal weathering associated with quartz precipitation. Stable isotope results on carbonates (C, O) and silicates (O, H in quartz and clays) confirm a temperature changes associated with an important biological production probably in response to a Mediterranean type climate. Quartz - montmorillonite precipitation corresponds to a cooler climate at upper Miocene times. Moreover, these thin series on both sides of the basin indicate one or several shallow lakes with minimal subsidence. Syn-sedimentary and lately N-S faulting indicate a new tectonic activity with "Veauche sandstone" deposition and major subsidence during late Miocene times on the eastern side of the graben.