Rationale. Negative δ¹⁷O signal in sedimentary sulfate inherited from atmospheric O₂ during atmospheric weathering and transported via surface run-off/fluviatile systems to depositional environments and, ultimately, the marine exchange reservoir. Sulfate oxygen is non-labile, but can be exchanged by microbial activity making δ¹⁷O a conservative tracer of interplay between pCO₂, pO₂, and primary productivity.

Hypotheses. Microbial recycling of sedimentary sulfate and erasure of the negative δ¹⁷O signal becomes more pronounced downstream away from source of weathering (Fig. 1). This leads to spatial variability in δ¹⁷O at any given time. Despite potential complications, this could be a first-order control on δ¹⁷O in geological record. We make two predictions which we test in two case studies:

• CASE-STUDY 1: Non-marine environments will preserve the most negative δ¹⁷O signal at a given time.

• CASE-STUDY 2: Progressively marine-influenced environments will see a coupled δ¹⁷O–δ³⁴S trends reflecting a transition from fluvial to marine dominated signals.

CASE-STUDY 1: early Permian Cedar Mesa Sandstone Formation (Utah, USA)*


Background. Cedar Mesa Sandstone (CSM) deposited in Carboniferous Paradox Basin, SE Utah during the early Permian. Consists of sandstone with minor mudstone, siltstone, evaporites (gypsum) and carbonates. Originally considered aeolian (pre-1950) and revised to shallow marine (1960-1980), but now consensus indicates it is aeolian and non-marine (1980-onward) but small δ³⁴S dataset overlaps with marine curve.


Methods. 10 sedimentological logs measured through CSM and optical petrography of hand samples conducted. Log 1.4 (Fig. 2) selected for high resolution XR, δ¹⁷O, δ³⁴S and δ¹⁸O analysis.

Results. 15 lithofacies deposited in sub-aerial, subaqueous, and evaporitic settings and group into nine facies associations. Bedded (primary), displacive (early diagenetic) and brecciated gypsum facies observed. Gypsum all facies: δ⁴³S = +13.4 to +14.5 ±0.3‰ and δ¹⁷O = -0.27 to -0.06 ± 0.05 ‰ (Fig. 2). Most negative δ¹⁷O measured from this time period.

Discussion. Facies associations suggest several environments (Fig. 3) spanning the interface between erg and lacustrine settings. Cyclicality was driven alternating climatic regime (humid vs arid). No evidence suggesting marine influence on sedimentation. Propose that ‘marine’ δ³⁴S is sourced from continental weathering of underlying late C marine evaporites of Paradox Formation (Fig. 4). Sulfate complex is decoupled from age of succession. Sulfate recycling in non-marine, continental settings holds important implications for temporal compilations of δ¹⁷O used to constrain atmospheric evolution.

CASE-STUDY 2: early Carboniferous (Tournaisian) Ballycultra, Ballagan, Middleton Dale Anhydrite formations (UK)

Background. Three formations constrained to Tournaisian and span depositional space:

• Ballagan Formation: Fluvial floodplain to wetland settings.

• Ballycultra Formation: Coastal sabkha on edge of restricted basin.

• Middleton Dale Anhydrite Formation: Coastal sabkha on edge of open basin.

Nodular, chicken-wire and enterolithic gypsum (early diagenetic) fabrics sampled. Depositional timeframe spans contentious gap – ‘Romer’s gap’ – in the fossil record of terrestrial tetrapods, speculated to link to low pO₂.

Goals. Is there significant spatial, systematic, δ¹⁷O–δ³⁴S variation across depositional environments? Can this be adequately distinguished from temporal variability?

Methods. Samples for XRD, δ¹⁷O, δ³⁴S and δ¹⁸O analysis gathered from well described drill-cores (Belfast Harbour, Norham, and Eyam).

Preliminary results and discussion. Covariance in δ¹⁷O-δ³⁴S (Fig. 5) could suggest spatial control, but three low δ¹⁷O Ballagan and two near zero δ¹⁷O Ballycultra values do not follow relationship. If these (n=6) excluded R = 0.7.

-10 ‰ swing in δ³⁴S over Tournaisian means separating spatial and temporal variability difficult.

Ballycultra and Middleton Dale show relationships expected (Fig. 1) but why is Ballagan ‘more marine’? Is this spatial or is it slightly older than others?’

Most negative δ¹⁷O measured in Phanerozoic.

Ongoing work. δ¹⁸O values to be determined. Exploring reason(s) for low δ¹⁷O in Ballagan Fm. and apparent decoupling from δ³⁴S. Coupling of δ¹⁷O with photochemical modelling to explore atmospheric constraints.

Overall conclusions. Most negative Phanerozoic δ¹⁷O values yet measured (both case-studies: Carboniferous-Permian). In non-marine, dryland settings evaporite weathering/recycling may obscure temporal δ¹⁷O variation. Coupled δ¹⁷O–δ³⁴S across depositional space may indicate predicted spatial variability in δ¹⁷O preservation.