

A Mike Wise photo of a sediment section in Cueva Llanío (3234-mws-2026e-01.jpg) was analysed by AI, specifically Claude Sonnet 4.6. The following interactions should be read warily. Some mistakes have been corrected but other assumptions remain in the response .

However, a useful exercise for possible methods of getting more information from this and other sediment sections.

(See this example from Risco: https://matienzocaves.org.uk/ugpics/0025-2012c.htm)

JSC 22/5/2026

Prompt, generated by Google LLM, given to Claude Sonnet 4.6

Act as an expert speleologist and sedimentary geologist specializing in cave taphonomy and Karst hydrogeology. I have attached a photo of a stratigraphic section inside a cave located in Riaño, just north of the Matienzo depression in Cantabria, Spain. The local geology consists of Cretaceous limestone and adjacent/underlying Lower Cretaceous sandstones (Wealden facies). Please analyze the attached image(s) and provide a detailed geological assessment based on the following observations:

1. The clasts are a mixture of local limestone and sandstone cobbles.
2. The deposit features alternating layers: rounded, fist-sized cobbles; distinct bands of fine sand; and gravel layers with lower sand content. Please structure your analysis into these sections:

- Visual Observations: Evaluate the grain-size distribution, sorting, and rounding of the visible layers. Identify any notable sedimentary structures (such as clast imbrication, graded bedding, or cross-lamination in the sand bands).
- Hydrodynamic Interpretation: What do these specific transitions (cobbles to sand to gravel) tell us about the velocity, energy variations, and seasonality of the ancient cave river that deposited them?
- Geomorphological Context: How does the presence of the sandstone cobbles inside this limestone cave system connect to the landscape evolution and capturing of surface waters from the surrounding Wealden ridges into the Matienzo karst system?
- Recommended Testing: What specific field or lab techniques (e.g., OSL dating, paleomagnetism, or clast counts) would you recommend to definitively map out the timeline and provenance of this specific section? Please use professional geological terminology but keep your explanations clear and actionable for field research.

Response follows …

Stratigraphic Analysis: Cave Section, Riaño, Four Valleys System, Cantabria

*Key corrections from field expertise incorporated: (1) Riaño lies **north** of the Matienzo depression; (2) the Four Valleys System resurges to the **northwest at Secadura**; (3) sandstone clasts are **not necessarily allogenic** — the Cretaceous limestone massif contains interbedded sandstone horizons which frequently form cave floors and roofs, and are a likely **primary local source** for sandstone cobbles via roof collapse and floor erosion with subsequent intra-cave fluvial transport.*

Visual Observations

The illuminated section reveals a moderately complex fluvio-cave deposit with several distinguishable features visible under torch lighting conditions.

Grain-size Distribution & Sorting The section displays a polymodal grain-size distribution with at least two to three distinct lithological bands discernible: an upper horizon of sub-rounded to rounded cobbles (estimated 80–150mm b-axis), a medial zone of poorly-sorted granule-to-pebble gravel, and a finer sandy matrix visible between and beneath the coarser clasts. Sorting within individual layers appears moderate to poor — consistent with episodic, relatively rapid deposition rather than sustained steady-flow conditions.

Rounding & Clast Shape The cobbles the gloved hand is indicating appear sub-rounded to well-rounded. Importantly, the **degree of rounding alone cannot be used to infer long external transport distances** for the sandstone clasts, since sandstone interbeds within the limestone massif, once liberated by roof collapse or floor erosion, are mechanically weak and will round relatively rapidly under even moderate intra-cave fluvial transport. The darker grey elongate clast visible in the upper right is notably well-rounded and likely represents a limestone cobble that underwent prolonged fluvial abrasion within the conduit system. A second darker clast at mid-right appears more angular, possibly representing more recently liberated roof-collapse material that has not yet been significantly reworked.

Sedimentary Structures At this resolution and lighting angle, definitive cross-lamination in the sand bands cannot be confirmed, but planar banding between coarser and finer horizons is consistent with **horizontal lamination** in sand-rich intervals — characteristic of upper flow regime sheet-flood conditions transitioning to lower energy settling phases. There is a suggestion of crude **clast imbrication** in the cobble layer, requiring field verification with a compass clinometer. The cobble-to-gravel-to-sand vertical sequence constitutes a **fining-upward package**, which is diagnostically important for hydrodynamic reconstruction. No definitive graded bedding is detectable at this scale.

Hydrodynamic Interpretation

The cobble-sand-gravel alternation points strongly toward a **seasonally pulsed, vadose-to-phreatic transitional cave stream** — most plausibly a former active trunk conduit or tributary feeder within the northern periphery of the Four Valleys System draining northwest toward Secadura.

Energy Regime Transitions

Layer	Competence Required	Hydrodynamic Interpretation
Cobble horizon	High — stream power >10 W/m²	Peak flood discharge; bankfull or near-bankfull conduit flow
Sand band	Low-moderate	Waning flood stage; suspension fallout or low-velocity traction carpet
Gravel with reduced sand	Moderate	Intermediate stage; reworked lag or renewed lower-energy flood pulse

The **cobble → sand** transition is a classic **waning-flow sequence**: a high-competence flood pulse capable of mobilising fist-sized clasts rapidly decelerates — possibly due to conduit enlargement downstream, hydraulic backing-up at a sump, or dissipation of a storm-driven flood wave. The reappearance of gravel above the sand band confirms this is a **multi-pulse depositional sequence** rather than a single event, likely representing inter-annual or seasonal flood cycles driven by the intense Atlantic-influenced Cantabrian precipitation regime.

Velocity Estimates (approximate) Using Hjulström-Sundborg criteria for cobble entrainment (b-axis ~100mm), minimum competent flow velocity was approximately **1.0–1.5 m/s** during the cobble-transport phase. Sand deposition (assuming medium sand, ~0.25–0.5mm) would have occurred at velocities below ~0.3 m/s — a **velocity drop of roughly one order of magnitude** between phases, consistent with flash-flood-dominated karst hydrology responding to intense autumn and winter storm events, with low baseflow conditions in summer allowing fine suspension material to drape the coarser lag.

Each cobble-sand couplet may represent a **single hydrological year** or a multi-year flood recurrence interval, making this section a potentially valuable high-resolution palaeoclimatic archive.

Geomorphological Context

Intra-Cave Sandstone Sources — A Critical Reappraisal The mixed limestone and sandstone clast assemblage must be interpreted with full awareness that the **Cretaceous limestone massif itself contains interbedded sandstone horizons**. These sandstone beds are well-documented as structural controls on cave development in this region, frequently forming the floors and roofs of cave passages where the limestone has been preferentially dissolved along bedding planes. This has profound implications for clast provenance:

- **Roof collapse** of sandstone beds forming passage ceilings will deliver angular to sub-angular sandstone blocks directly onto the cave floor, where they become available for fluvial entrainment and intra-cave transport
- **Floor erosion** of sandstone beds underlying the active stream will progressively liberate clasts directly into the transporting flow
- **Intra-cave fluvial reworking** of these locally-derived sandstone clasts can rapidly produce the sub-rounded to rounded forms visible in this section — mechanical weakness of sandstone relative to limestone means rounding proceeds quickly even over short transport distances within the conduit
- Consequently, **most or possibly all of the sandstone clasts** in this deposit may be entirely intra-cave in origin, derived from interbedded sandstone horizons within the limestone massif itself, rather than from external Wealden surface catchments

This does not preclude some contribution from genuine allogenic input via swallets on the surrounding terrain, but that hypothesis now requires **positive evidence** — such as distinctive heavy

mineral assemblages or sedimentary textures diagnostic of specific external Wealden formations — rather than being assumed from clast lithology alone.

Structural Control on Cave Development The sandstone interbeds that source these clasts are not merely passive participants — they actively control speleogenesis. Where a sandstone horizon forms a cave roof, dissolution is arrested and the passage develops laterally along the sandstone-limestone contact. Where it forms the floor, the stream may be temporarily graded to the sandstone surface before breaching it and descending to the next limestone unit. The **episodic liberation of sandstone material** by roof collapse may itself be recorded stratigraphically: angular sandstone clasts within an otherwise well-rounded assemblage may indicate discrete collapse events, potentially triggerable by flood-induced hydrostatic pressure fluctuations or seismic events.

Position Within the Four Valleys System Riaño's caves sit on the **northern side of the ridge** bounding the Matienzo depression, feeding into the Four Valleys System whose waters ultimately resurge to the **northwest at Secadura**. The cave conduit in question was therefore functioning as part of a **trans-divide drainage network**, routing water and sediment northwestward through the massif. The depositional sequence preserved here reflects the integrated hydrological behaviour of this entire upstream catchment — surface inputs from the northern slopes, intra-cave sediment contributions from structurally controlled roof and floor sources, and the modulating influence of conduit geometry on flow competence and depositional energy.

Polyphase Speleogenetic History The rounding of clasts and the multi-layer depositional architecture point toward a polyphase history:

- An **early phreatic phase** at higher base level, when conduits were fully water-filled and capable of sustained sediment transport throughout the massif
- Progressive **base-level lowering** driving vadose entrenchment and increasing the episodic, flood-dominated character of sediment transport
- The current section likely represents deposition during a **vadose-phreatic transitional phase**, when the conduit was actively downcutting but still periodically inundated by flood pulses

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Recommended Testing Programme

Phase 1 — Field Documentation (Immediate, Non-Destructive)

- **Detailed stratigraphic log** at 1:10 scale with **photogrammetric SfM model** of the exposed face — essential baseline before any sampling
- **Clast counts** (minimum n=50 per layer): record lithology (limestone vs. sandstone vs. other), roundness class (Powers scale), and b-axis length — tracking the ratio and angularity of sandstone clasts vertically through the sequence may help distinguish roof-collapse pulses (angular, poorly sorted) from fluvially reworked horizons (rounded, better sorted)
- **Imbrication measurements** with compass clinometer on minimum 20 clasts per cobble layer — does palaeoflow direction align with the expected northwest drainage toward Secadura, or indicate more complex local flow geometry?
- **Sediment sampling** of each discrete sand band for grain-size analysis and loss-on-ignition

Phase 2 — Provenance Discrimination (Critical Priority)

Given the revised understanding that sandstone clasts may be dominantly intra-cave in origin, **provenance discrimination becomes the pivotal analytical question**:

- **Petrographic thin sections** of sandstone clasts — framework mineralogy, cement type, and sedimentary texture compared against both the known interbedded sandstone horizons within the local limestone massif **and** the external Wealden formations; this is the most direct way to partition intra-cave versus allogenic contributions
- **Heavy mineral analysis** — zircon-tourmaline-rutile index and specific heavy mineral assemblages can fingerprint source formations with considerable precision; intra-cave sandstone interbeds and external Wealden sandstones may carry distinguishable signatures
- **Portable XRF scanning** of clasts and matrix in situ — rapid geochemical screening to detect gross compositional differences between sandstone clast populations that might indicate mixed provenance

Phase 3 — Geochronological Framework

- **OSL dating** of sand bands — primary technique for fine-grained intervals; SAR protocols with finite mixture modelling to handle potential incomplete bleaching in cave settings
- **Cosmogenic nuclide burial dating** ($^{26}Al/^{10}Be$) on quartz-bearing sandstone clasts — dates time since shielding from cosmic rays; valid whether clasts are intra-cave or allogenic in origin, and directly constrains the age of the depositional sequence and by extension the speleogenetic phase it represents
- **Palaeomagnetic sampling** of fine-grained sand/silt bands — reversed polarity, if present, would indicate pre-Brunhes (>780 ka) deposition and place the sequence in a critical landscape-evolution timeframe

Phase 4 — Palaeoenvironmental Reconstruction

- **Palynological analysis** of organic-rich laminae — pollen assemblages to constrain palaeoclimate and provide biostratigraphic age control
- **Stable isotope analysis** ($\delta^{18}O$, $\delta^{13}C$) of any interbedded or overlying speleothem material — if stratigraphic phasing with the clastic sequence can be established, this provides a high-resolution climate proxy correlatable with the regional Iberian speleothem record
- **Hydraulic modelling** using measured conduit cross-section geometry and clast competence data to back-calculate palaeo-discharge estimates for individual flood events

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Priority Recommendation: Begin with clast counts and imbrication measurements (non-destructive), combined with SfM photogrammetry. The single most important analytical question this section poses is now **provenance discrimination** — petrographic thin sectioning of sandstone clasts to determine what proportion are intra-cave (from interbedded sandstone horizons within the massif) versus genuinely allogenic (from external surface catchments). This distinction fundamentally changes the geomorphological interpretation and should be resolved before investing in geochronological dating. Cosmogenic nuclide burial dating remains the highest-impact geochronological tool regardless of how provenance resolves.

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