# Foraminiferal test dissolution reveals severe sediment acidification in estuarine mudflats: new perspectives for present and historical assessment

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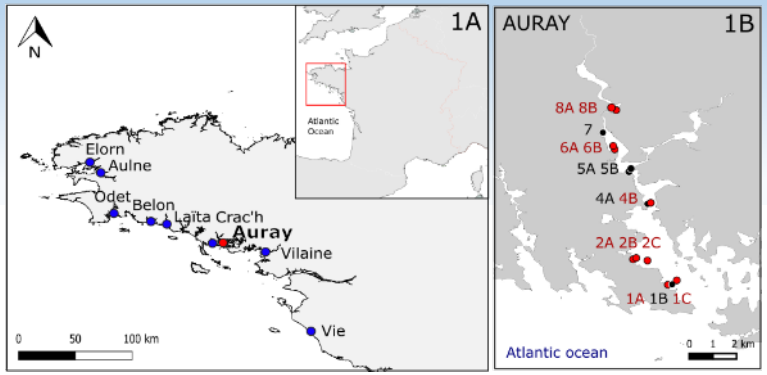


**Fig. 1** 1A: Location of the studied estuaries (in red: Auray estuary, in blue: eight other estuaries). 1B: Location of the stations in the Auray estuary sampled in 2019 and 2020 (oxygen and pH profiles were measured in 2020 for stations indicated in red).

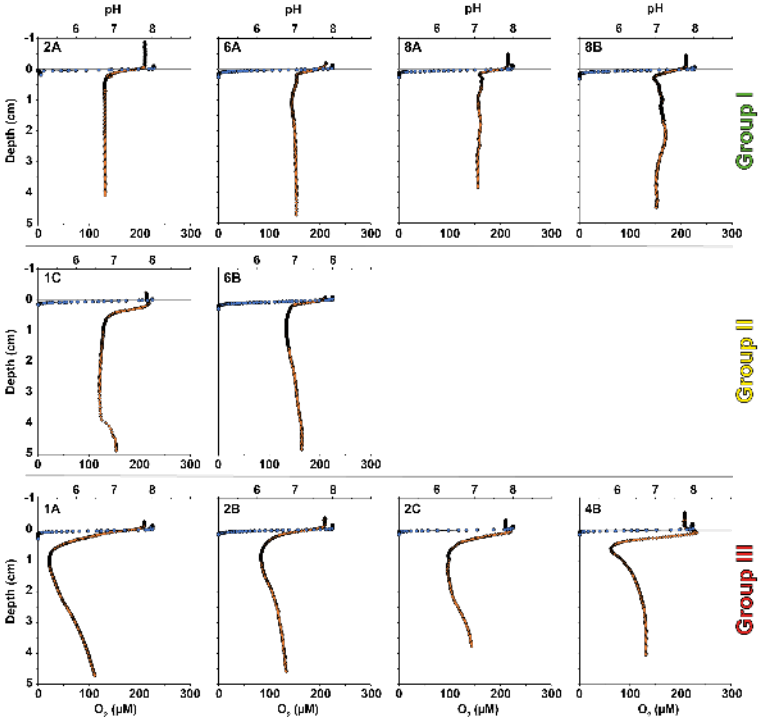


**Fig. 2** pH (orange) and oxygen (blue) profiles measured in September 2020 in the Auray estuary. Three groups were established according to the shape of the O2-pH profiles (group I: low acidification; group II: moderate acidification; group III: strong acidification).

- pH profiles showed porewater acidification of the subsurface sediment at several stations; some O2-pH profiles show the typical biogeochemical signatures of cable bacteria activity.
- Two metrics to quantify the degree of dissolution affecting foraminifera:
  - i. "Foraminiferal Test Dissolution" (FTD), based on relative proportion of advanced dissolution stages in the foraminiferal community
  - ii. "Calcareous Test Preservation Ratio" (CTPR), ratio between test density of living calcareous foraminifera in the 0-0.5 cm level and their total density in the 0-1 cm layer

  → corrosive porewaters affecting calcareous tests, hence severe FTD in the first centimetre of sediment leading to high CTPR.
- FTD in other estuaries on the French Atlantic coast indicate a widespread phenomenon of dissolution.
- FTD type 1 in 1995-96 samples from the Auray estuary suggests an appearance of dissolution process observed in 2020 over the last thirty years.
- FTD and CTPR could be used as rapid tools to establish dissolution processes occurrence. FTD could be used as sediment acidification proxy in historical records.

*M. Fouet, M. Daviray, E. Geslin, E. Metzger, F. Jorissen, 2024. Comptes Rendus de l'Académie de Sciences – Géoscience.* [10.5802/crgeos.269](https://doi.org/10.5802/crgeos.269)

**Tab. 1** The first row indicates the O2-pH profile groups from green (group I: low acidification) through yellow (group II: moderate acidification) to red (group III: strong acidification). The second row describes the CTPR, with <0.6: green, 0.6-0.90: yellow, >0.90: red. The last row summarises observations of foraminiferal test dissolution (FTD), ranging from "no visible dissolution" (type 1, green), via moderate (type 2, yellow) to "advanced to severe dissolution" (type 3, red).

| Auray station (2020) | 1A | 1C | 2A | 2B | 2C | 4B | 6A | 6B | 8A | 8B |
|---|---|---|---|---|---|---|---|---|---|---|
| Acidification intensity | III | II | I | III | III | III | I | II | I | I |
| CTPR (calcareous test preservation ratio) | 0.91 | 0.72 | 0.36 | 0.73 | 0.63 | 0.96 | 0.54 | 0.45 | 0.28 | 0.27 |
| FTD (foraminiferal test dissolution) | 3 | 2 | 2 | 3 | 3 | 3 | 1 | 2 | 1 | 2 |

**Tab. 2** Values of FTD (Foraminiferal Test Dissolution). Stereomicroscope observations of foraminiferal test dissolution, ranging from "no visible test dissolution" (group 1, green) to "moderate" (group 2, yellow), "advanced to severe dissolution" (group 3, red) for samples collected in nine different estuaries studied in Fouet, 2022. The letters a,b, and c are the three replicates sampled in 2018 (Vie estuary) and 2019 (Auray estuary).

| | Auray (2019) | | | Elorn (2020) | | Aulne (2020) | | Odet (2020) | | Belon (2019) | | Laïta (2020) | | Crac'h (2020) | | Vilaine (2019) | | Vie (2018) | | | | Vie (2020) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | a | b | c | | | | | | | | | | | | | | | | a | b | c | | |
| 1A | 3 | 3 | 3 | 1 | 1 | 1 | 3 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1A | 1 | 1 | 1 | 1 | 1 | 2 | 1 |
| 1B | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 3A | 1 | 2 | 1 | 2 | 2 | 1B | 1 | 2 | 1 | 1 | 1 | 3 | 1 |
| 1C | 2 | 2 | 2 | 3A | 1 | 3 | 1 | 3 | 1 | 3B | 1 | 3 | 2 | 3 | 1 | 1C | 1 | 3 | 1 | 1 | 1 | 4 | 1 |
| 2A | 3 | 3 | 3 | 3B | 1 | | | 4 | 2 | 4A | 1 | | | 4 | 1 | 2A | 1 | 4 | 1 | 1 | 1 | 5 | 1 |
| 2B | 3 | 3 | 3 | 4 | 1 | | | | | 4B | 1 | | | | | 2B | 1 | 5 | 1 | 1 | 1 | 7A | 1 |
| 2C | 3 | 3 | 3 | | | | | | | 5A | 1 | | | | | 3 | 1 | 6 | 1 | 1 | 1 | 7B | 1 |
| 4A | 1 | 3 | 1 | | | | | | | 5B | 1 | | | | | | | 7A | 1 | 1 | 1 | 7C | 1 |
| 4B | 3 | 3 | 3 | | | | | | | 6A | 3 | | | | | | | 7B | 1 | 1 | 1 | 8A | 1 |
| 5A | 1 | 2 | 1 | | | | | | | 6B | 1 | | | | | | | 7C | 1 | 1 | 1 | 8B | 1 |
| 5B | 2 | 2 | 2 | | | | | | | | | | | | | | | 8A | 1 | 1 | 1 | 9 | 1 |
| 6A | 1 | 1 | 1 | | | | | | | | | | | | | | | 8B | 1 | 1 | 1 | 10A | 1 |
| 6B | 2 | 2 | 2 | | | | | | | | | | | | | | | 9 | 1 | 1 | 1 | 10B | 1 |
| 7 | 2 | 2 | 2 | | | | | | | | | | | | | | | 10A | 1 | 1 | 1 | | |
| 8A | 3 | 3 | 1 | | | | | | | | | | | | | | | 10B | 1 | 1 | 1 | | |
| 8B | - | - | - | | | | | | | | | | | | | | | | | | | | |