A Novel Approach to Constraining Carboniferous Currents using Bedforms in Tidal Rhythmites

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Introduction

Importance: The tides modulate key Earth systems and processes including Earth – Moon orbital evolution [1], meridional overturning circulation [2], biogeochemical cycles [3], and biological evolution [4].

Problem: Understanding tides through geological history is largely facilitated with numerical model simulations. But they are often poorly constrained due to a paucity of available proxy data.

Solution: Models can be validated with sedimentary data. Tidal deposits e.g., rhythmites are extensively used to approximate palaeotidal periodicities and Earth – Moon geochronology. However, the use of sedimentary texture and structures as proxies for local hydrodynamic conditions is largely overlooked.

Empirical research [5, 6, 7] has established that equilibrium current ripple dimensions are dependent on flow velocity and time. In a tidal environment where time is constrained to ~6 hours, ripple dimensions could be used to approximate flow velocity. Grain size also reflects local current velocity [8].

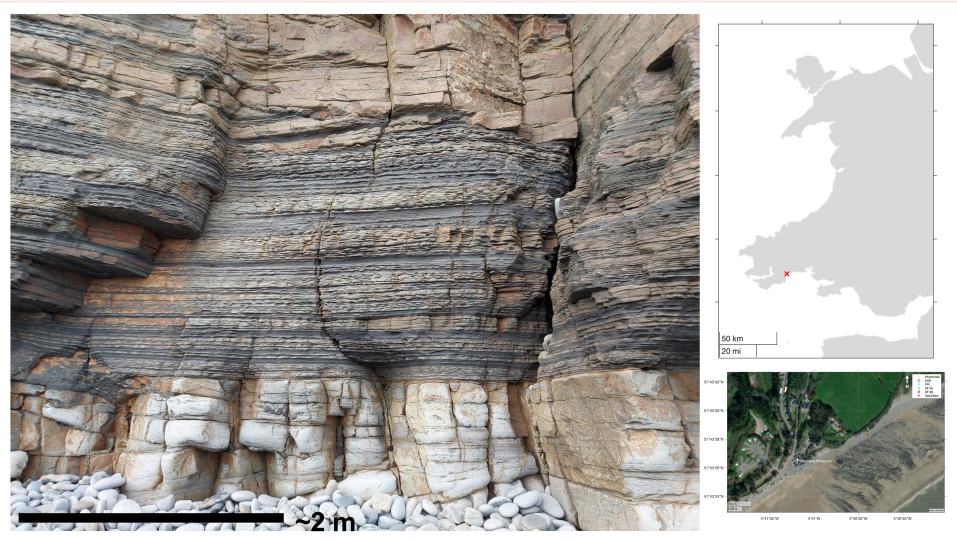
Aims

A1) Develop a novel geological tidal current velocity proxy based on textural and structural sedimentary data collected in the field and the literature.

A2) Apply this proxy to validate global tidal model simulations for the Carboniferous period and adjust where necessary using OTIS.

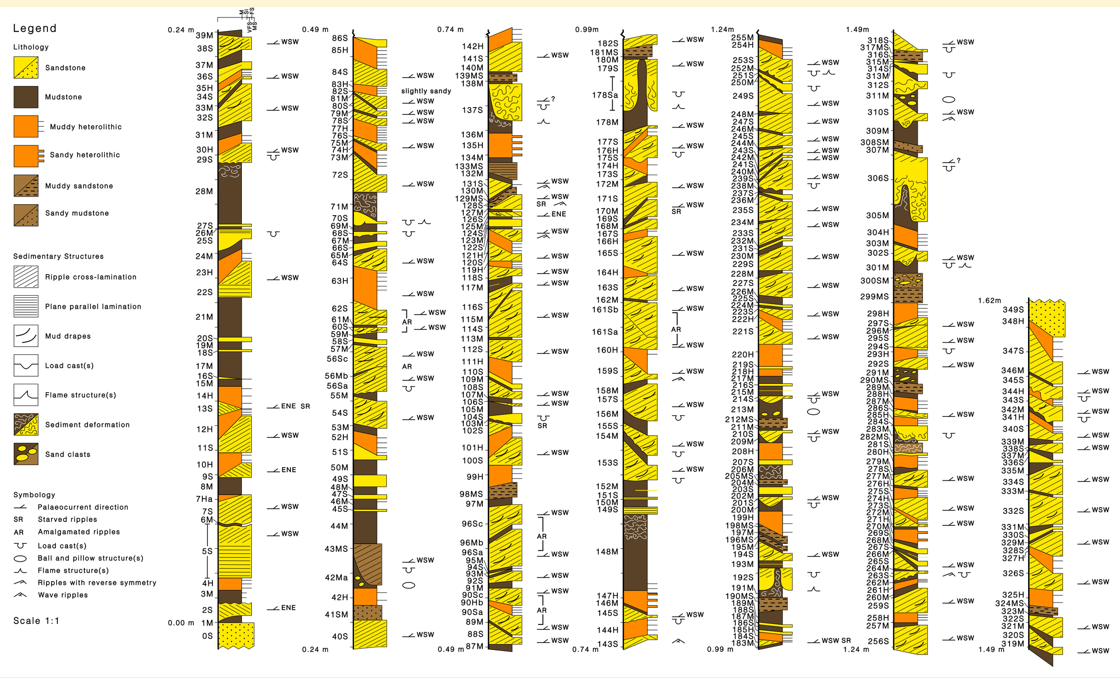
Field Site

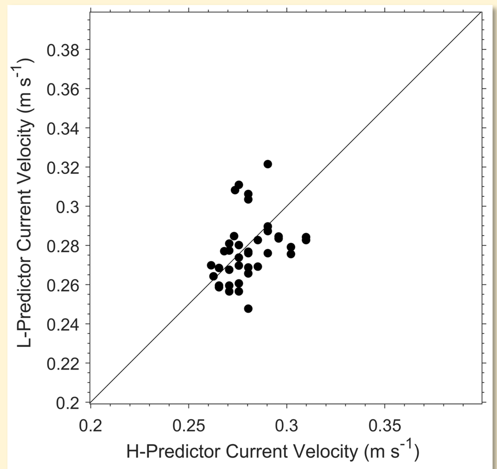
Location: Wisemans Bridge, South Wales, UK
Group: South Wales Coal Measures Group
Age: ~318 Ma
Type: Heterolithic tidal rhythmites



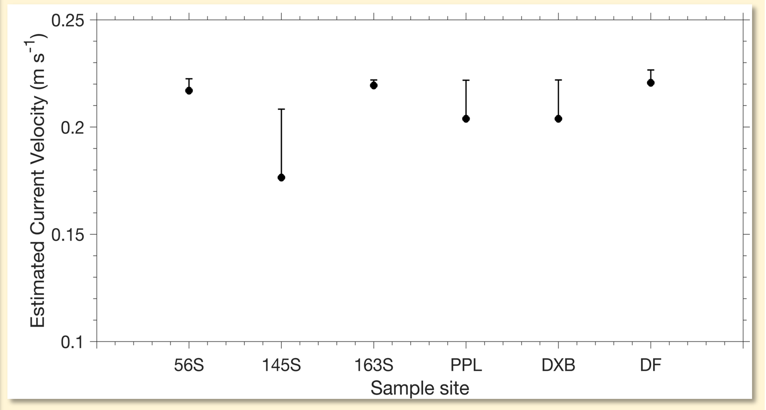
Field Results

Lithofacies analysis and sedimentary log of Wisemans Bridge field site.



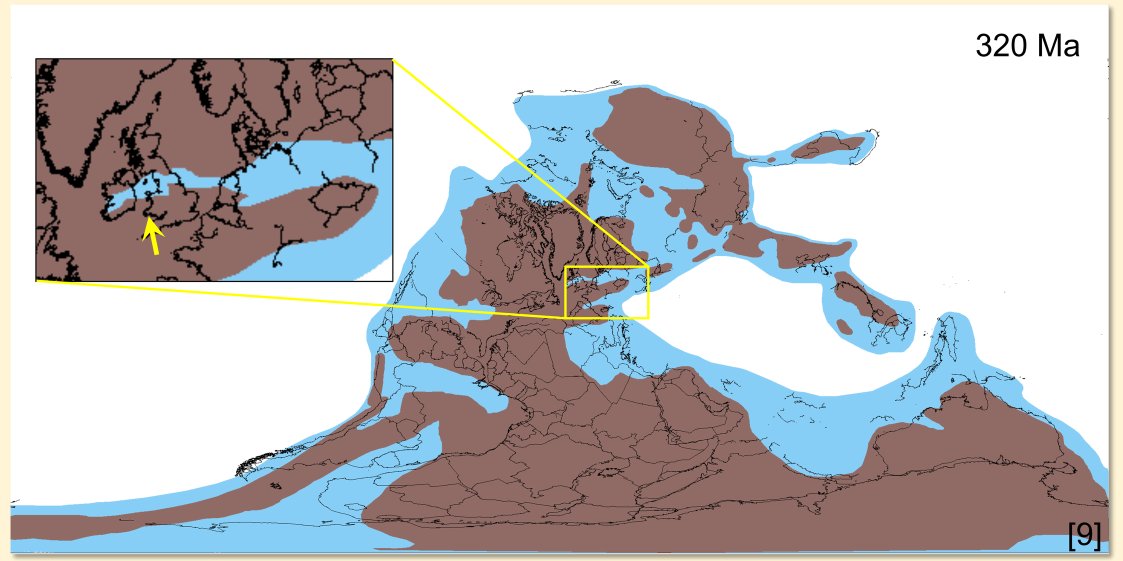


Ripple H and L velocity estimates for VFS.



D_{50} grain size velocity estimates with (error bars correspond to D_{90} estimates).

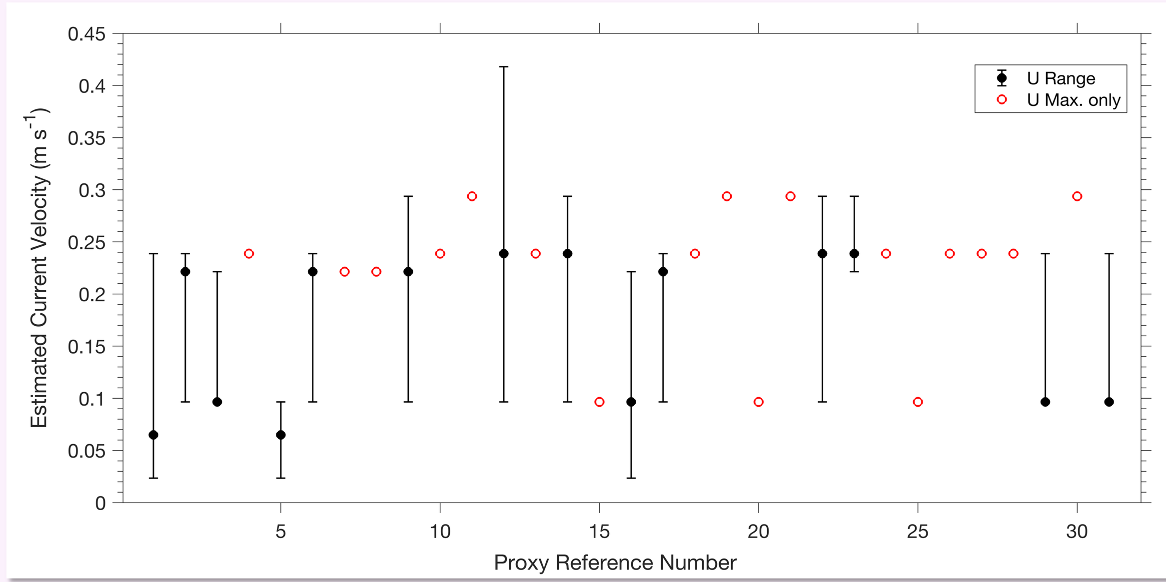
Simulations cannot be compared to field data as they depict Wisemans Bridge as a terrestrial environment.



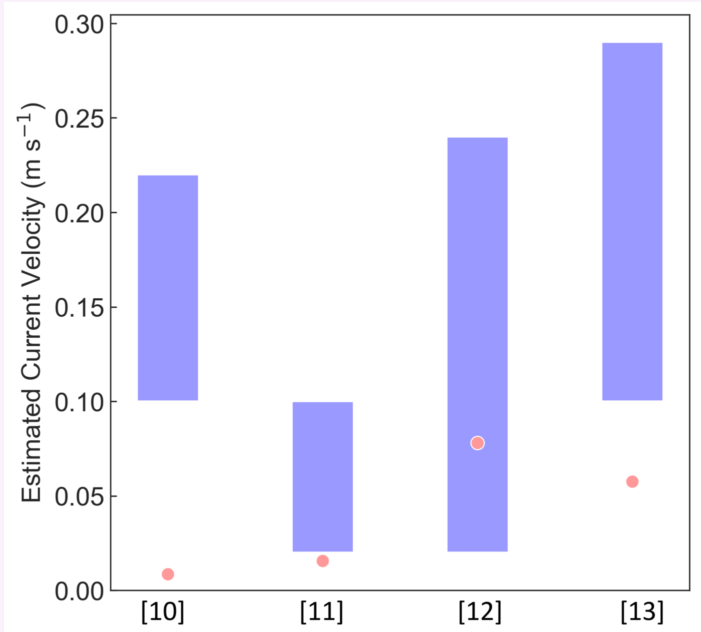
Literature Results

- 30 lithofacies across 15 locations used in analysis
- Literature proxies span entire Carboniferous period

Where sufficient data were available, a range of grain size-based velocity estimates were made. In lieu of a range, singular velocity estimates were made based on maximum reported grain size.



Proxy locations mapped (→) and both proxy-derived and simulated current velocity estimations compared.



Simulated current velocity (orange) compared to literature grain size velocity range estimates (purple).

Numerical model simulation generally underestimated current velocity.

Methods

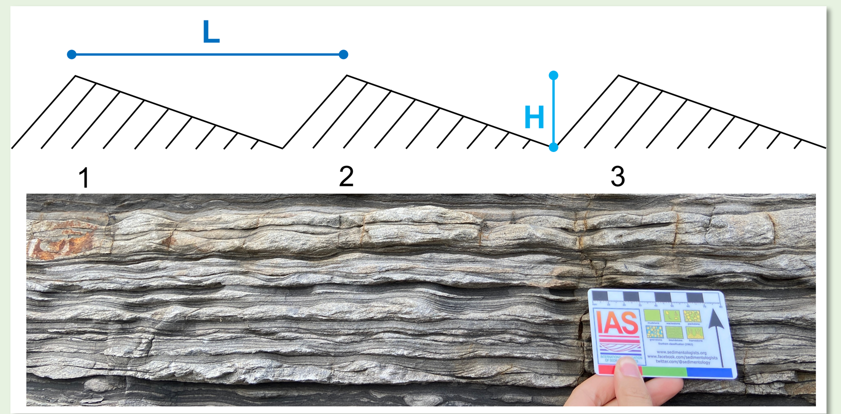
Ripple Analysis: Current velocity estimated using separate ripple height (H) and length (L) development predictors.

$$U = U_{cr} + a\left(\frac{t}{S}\right)^{-b}$$

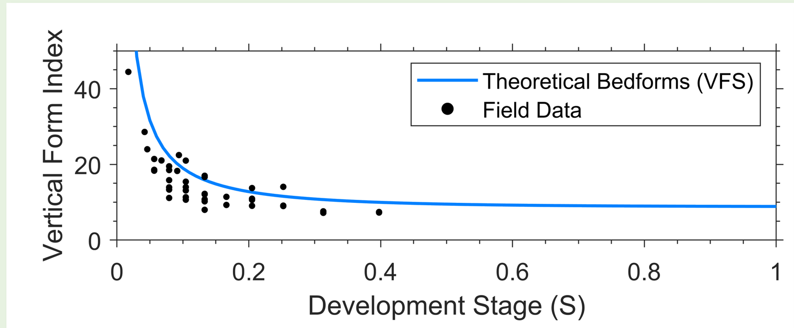
$$S_H = \log_{0.01}\left(1 - \frac{H_t}{H_e}\right)$$

$$S_L = \log_{0.01}\left(1 - \frac{L_t - L_o}{L_e - L_o}\right)$$

Bedform measurement protocol:



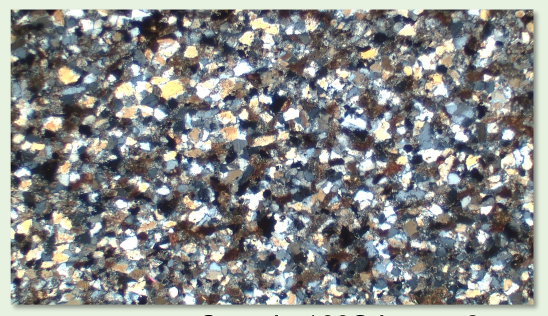
Post-depositional effects investigated by comparing theoretical ripple development to field data.



Grain Size Analysis: Current speed estimated using rearranged Quadratic Friction Law to compute current speed using Shield's Parameter and bottom shear stress.

Max, med, and min grain sizes from lithofacies analyses used to provide range of plausible current speed estimates.

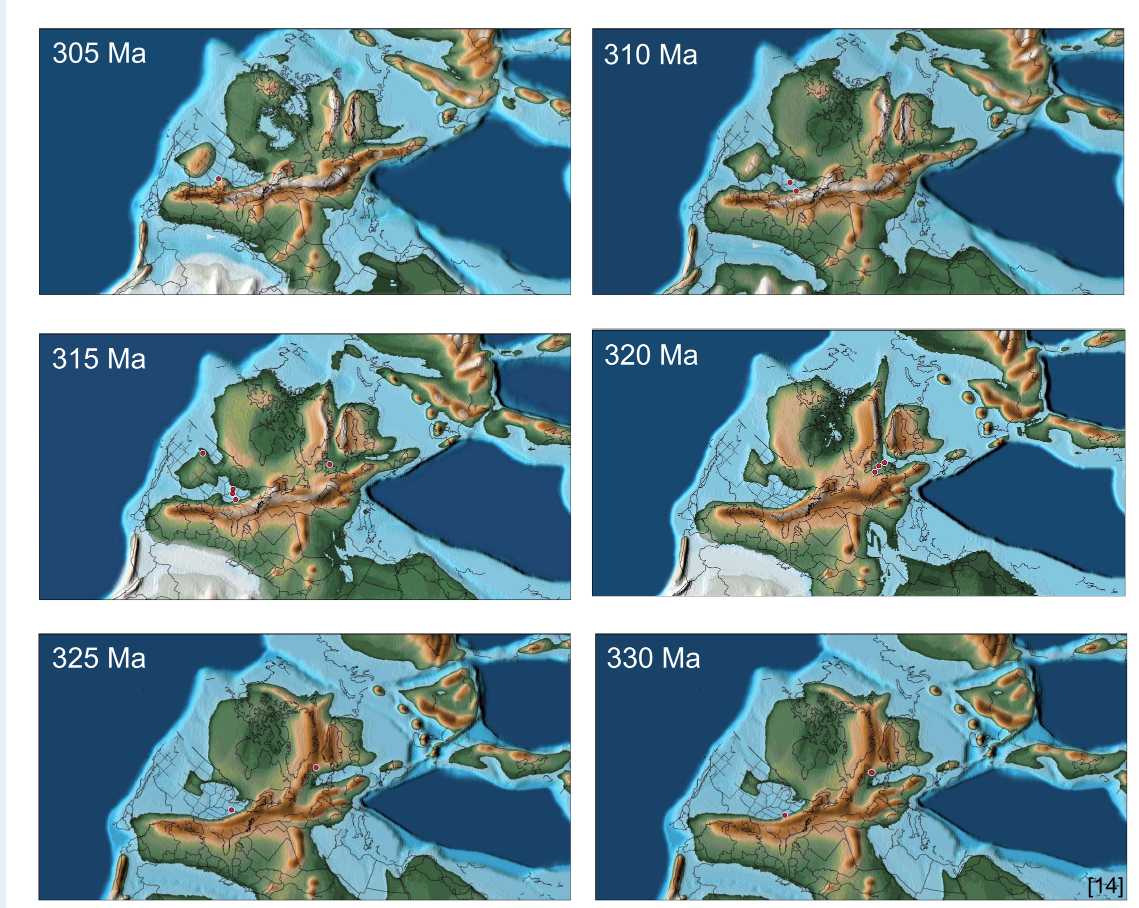
Grain sizes measured in thin section (field data, →) or extracted from lithofacies analyses (literature data).



Sample 163S Image 2. xp.

Simulation Comparison

Proxy locations were mapped onto age appropriate palaeogeographical reconstructions.



Reconstruction inaccuracy: 73% of literature proxy locations are reconstructed inaccurately (i.e., depicted as terrestrial environments).

Current velocity estimates compared to simulation results where palaeoenvironments plotted as marine.

Discussion and Conclusions

No significant post-depositional effects (e.g., compaction) affect the bedform-derived current velocity estimates of the Wiseman's Bridge site.

Field data velocity estimates in agreement = methodology validated.

Simulation generally underestimates tidal current velocity, though refinement and further comparisons are required.

Bedform methods are to be expanded to include climbing ripples using data collected in Grab-all Bay, Cork Harbour, Ireland.

References

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