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Carbon/phosphorus burial ratio reveals a rapid spread of land plants during the Late Ordovician

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Initial land plant diversification occurred over the Ordovician, Silurian and Devonian periods (~460–360 Ma) and fundamentally transformed Earth's biosphere and the composition of the oceans and atmosphere[1]. Yet the exact timing of the impact of land plants on the Earth system remains uncertain. The C_{org}/P_{total} ratio in marine sediments can serve as a valuable proxy for tracing terrestrial organic carbon input and thereby terrestrial net productivity[2,3]. Here we use a comprehensive C_{org}/P_{total} compilation from marine siliciclastic strata to explore land plant contributions to marine sedimentary organic matter.

Our dataset records a pronounced rise in C_{org}/P_{total} between 455–445 Ma across different redox settings (Fig. 1). Mean C_{org}/P_{total} values after 455 Ma are nearly three times higher than before 455 Ma (207.11±1.60 vs 75.66±1.84; 1 SD; bootstrap resampling), and the difference is significant (Unpaired Student's t-test $p<0.001$).

We interpret this shift as reflecting increased terrestrial net primary productivity, leading to enhanced delivery of land-derived organic carbon to marine sediments, given that terrestrial plants typically have higher $(C/P)_{org}$ ratios than marine algae[4-6]. Organic carbon contents in marine siliciclastic sediments increased significantly from 2.17±2.57 to 3.15±2.95 (1 SD) wt% between 455–445 Ma (Unpaired Student's t-test $p<0.001$), supporting greater terrestrial organic carbon input. Mixing model estimates suggest that terrestrial organic carbon may have contributed up to ~42±15% (mean between 455 and 445 Ma±1 SD) of organic carbon buried in continental margin sediments by ~445 million years ago, comparable to modern values. Paleogeographic analyses suggest that land plants may have spread in Laurentia earlier than on other paleocontinents (Fig. 2).

Our findings imply that early expansion of land plants may have initiated or amplified Late Ordovician cooling and glaciation by strengthening organic carbon burial, promoting atmospheric CO_2 drawdown and increasing atmospheric O_2. The earliest land plants may have fundamentally altered the Earth system as early as 455–445 Ma.

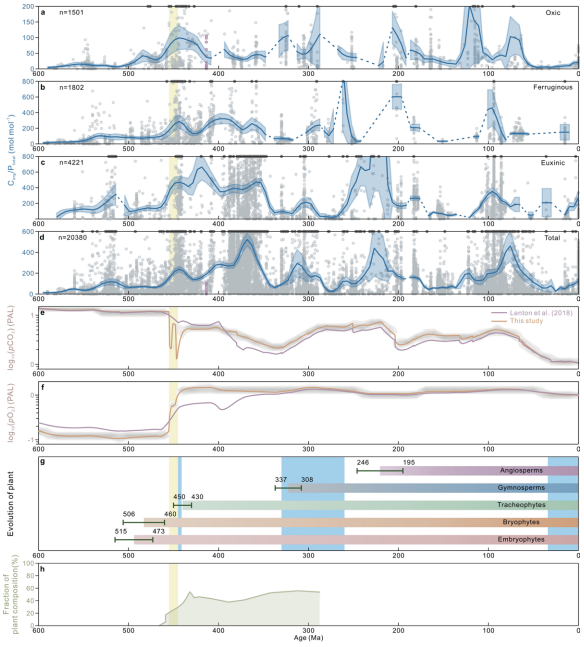

Fig. 1 | Evolution of C_{org}/P_{total} ratio of marine siliciclastic sediments during the Phanerozoic.

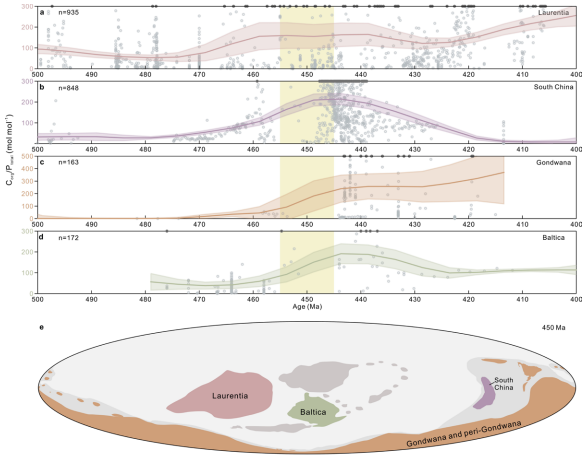

Fig. 2 | Evolution of C_{org}/P_{total} ratio of marine siliciclastic sediments from different paleoplate