Increased biomass and carbon burial 2 billion years ago triggered mountain building

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Supplementary Information

Supplementary Table

Supplementary Table 1. Phanerozoic record of twenty orogens in which highly carbonaceous shales supported deformation by focussing thrust detachment

Location	**Orogen (age t_o)**	**Shale Period (age t_c)**	**Stratigraphy**	**Maximum Δt (t_c-t_o)**	**Shale TOC**	**Reference**
Southern Norway	Caledonian Orogen (Silurian)	Cambrian	Alum Shale	<100 Myr	up to 14 % TOC	[1]
Xiuwu Basin, China	Qinling Orogen (Carboniferous-Triassic)	Cambrian	Qiongzhusi Fm.	<300 Myr	average 2.8 % TOC	[2]
Southern Uplands, UK	Caledonian Orogen (Silurian)	Ordovician	Moffat Shale Gp.	<100 Myr	up to 2.2 % TOC	[3]
Sichuan Basin, China	Qinling Orogen (Carboniferous-Triassic)	Ord-Silurian	Wufeng-Longmaxi Fm.	<300 Myr	average 3 % TOC	[4]
Sub-Andean zone, Bolivia	Sub-Andean Fold Belt (Paleogene)	Silurian	Kirusilla Fm.	<400 Myr	average 2 % TOC	[5]
Variscides, Poland	Variscan Orogen (Carboniferous)	Silurian	Ja Member	<100 Myr	average 3 % TOC	[6]
Appalachian Basin, USA	Appalachian Orogen (Devonian-Carboniferous)	Devonian	Marcellus Shale etc.	<100 Myr	average 4 % TOC	[7]
Cordillera, BC, Canada	Cordilleran Orogen (Cretaceous)	Devonian	Besa River Fm.	<300 Myr	up to 8 % TOC	[8]
NE Brooks Range, Alaska, USA	Brooks Range Fold Belt (Jurassic)	Carboniferous	Kayak Shale	<150 Myr	up to 4.1 % TOC	[9]
Central Thailand	Khao Khwang Fold Belt (Triassic)	Permian	Sap Bon Fm.	<100 Myr	up to 4 % TOC	[10]
Karoo Basin, South Africa	Cape Fold Belt (Triassic)	Permian	Karoo Supergroup	<100 Myr	average 4.5 % TOC	[11]

West Timor, Indonesia	Timor Orogen (Neogene)	Triassic	Aitutu Fm.	<200 Myr	up to 8.1 % TOC	[12]
Chartreuse Fold belt, France	Chartreuse Fold Belt (Cretaceous-Paleogene)	Jurassic	Toarcian-Aalenian	<150 Myr	up to 4.5 % TOC	[13]
Svalbard, Norway	Eurekan Orogen (Paleogene)	Jurassic	Janusfjellet Fm.	<200 Myr	average 4 % TOC	[14]
Deep Basin, Alberta, Canada	Rocky Mountains FB (Cretaceous-Paleogene)	Cretaceous	Cardium Fm.	<100 Myr	average 2.5 % TOC	[15]
Andes, Venezuela	Andean Orogen (Jurassic-Paleogene)	Cretaceous	La Luna-Colon Fms.	<100 Myr	average 3.8 % TOC	[16]
Parras Basin, Mexico	Laramide Orogen (Cretaceous-Paleogene)	Cretaceous	Parras Shale	<100 Myr	up to 2.2 % TOC	[17]
Magellan Basin, Chile/Argentina	Patagonian Fold Belt (Cretaceous-Paleogene)	Cretaceous	Zapata Fm.	<100 Myr	up to 3 % TOC	[18]
Carpathians, Czech Republic	Carpathian Orogen (Paleogene)	Cretaceous	Wierzowice Shale	<100 Myr	average 3.7 % TOC	[19]
Naga Thrust Triangle, India	Naga Thrust Belt (Neogene)	Oligocene	Barail Shale	<30 Myr	average 3.8 % TOC	[20]

Supplementary Note

Supplementary Note 1. Data sources for chronology of carbonaceous sediments and deformation in Palaeoproterozoic orogens, carbon compositions of sediments (summarized in Table 1), isotopic compositions of organic carbon, and styles of deformation.

Pine Creek Orogen, Australia (2.02-1.85 Ga)[21] .

Whites Fm. (2.02 Ga); Koolpin Fm. (1.88 Ga)[21]

Up to 10.4; 11.7 % TOC[22]

Koolpin -27.6 to -31.1 ‰[23]

B, F, S, T[24]

Kimban Orogen, Australia (1.85-1.70 Ga)[25]

Hutchison Group (1.87 Ga)[26]

Up to 30+ % TOC, Graphite ore[27]

-13.0 to -29.0 ‰[28]

F, G, I, S, T[29]

Aravalli Orogen, India (1.8-1.74 Ga)[30]

Aravalli Supergroup (1.9-1.7 Ga)[31]

Up to 15 % TOC, Graphite ore[32]

-21.1 to -25.9 ‰[33]

F, I, S, T[34,35]

Trans-North China Orogen, China (1.95-1.85 Ga)[36]

Khondalite belt (2.0-1.95 Ga)[36]

Up to 30 % TOC, Graphite ore[37]

-24.6 to -29.0 ‰[38]

F, G, S, T[38]

Jiao-Liao-Ji Orogen, China (1.94-1.86 Ga)[39]

Liaohe/Jingshan Groups (2.05-1.94 Ga)[40]

Graphite ore[41]

-18.6 to -21.7 ‰[41]

D, F, S, T[40,42]

Akitkan Orogen, Russia (2.0-1.91 Ga)[43]

Khapchan Group, Udokan Series (2.1-1.9 Ga)[44]

Up to 23 % TOC, Graphite ore[45]

-29.2 to -31.6 ‰[43]

F, S, T[46]

Wopmay Orogen, Canada (1.9-1.8 Ga)[47]

Coronation Supergroup (1.88 Ga)[48]

Up to 9.1 % TOC[49]

-14.5 to -26.5 ‰[23]

B, I, T[47]

Foxe Orogen, Canada (1.88-1.84 Ga)[50]

Piling Group, Bravo Lake Formation (1.92-1.89 Ga)[50]

Up to 5.6 % TOC[51]

-27.5 to -27.8 ‰[51]

F, I, S, T[52]

Trans-Hudson Orogen, USA-Canada (1.83-1.79 Ga)[53]

Kisseynew Gneiss (1.85-1.84 Ga)[53]

Graphite ore[54]

-17.9 to -29.8 ‰[55]

F, I, S, T[50]

Penokean Orogen, USA (1.89-1.82 Ga)[56]

Animikie and Baraga Groups (1.88-1.83 Ga)[56]

Up to 44 % TOC, Graphite ore[57]

-22.4 to -32.2 ‰[57]

D, G, I, T[58,59]

Torngat Orogen, Canada (1.91-1.82 Ga)[60]

Tasiuyak Gneiss (1.94-1.88 Ga)[60]

Up to 30 % TOC, Graphite ore[61]

-24.8 to -31.7 ‰[62]

B, F, I, T[63]

Nagssugtoqidian Orogen, Greenland (1.88-1.83 Ga)[64]

Siportoq Supracrustals (2.00-1.92 Ga)[65]

Up to 24 % TOC, Graphite ore[66]

-18.1 to -31.0 ‰[67]

B, F, I, S, T[68,69]

Ketilidian Orogen, Greenland (1.85-1.80 Ga)[64]

Sortis and Vallen Groups (2.0-1.9 Ga)[70]

Up to 29 % TOC, Graphite ore[66]

-22.3 to -32.5 ‰[71]

F, G, I, S, T[72]

Laxfordian Orogen, UK (1.9-1.87 Ga)[73]

Lewisian supracrustals (2.0-1.9 Ga)[74]

Up to 10.7 % TOC

-21.6 to -24.6 ‰[75]

F, I, S, T[74]

Svecofennian Orogen, Finland-Sweden-Norway (1.88-1.79 Ga)[76]

Multiple graphitic schists (1.91-1.88 Ga)[77]

Up to 15 % TOC, Graphite ore[78]

-19.2 to -27.0 ‰[77]

F, I, S, T[79]

East Sarmatian Orogen, Belarus (2.10-2.07 Ga)[80]

Vorontsovska Series (2.24-2.1 Ga)[80]

Up to 18 % TOC, Graphite ore[81]

-27.4 to -31.1 ‰[82]

S, T[83]

Birimian Orogen, West Africa (2.18-2.06 Ga)[84]

Lower Birimian (2.15-2.10 Ga)[84]

Up to 25 % TOC, Graphite ore[85]

-23.5 to -31.1 ‰[85]

I, T[86]

Eburnean Orogen, Gabon-Congo (2.04-2.0 Ga)[87]

Ogooue´ complex, Francevillian (2.12-2.04 Ga)[87]

Up to 17 % TOC[88]

-27.1 to -46.2 ‰[88]

D, F, T[89]

Magondi Orogen, Zimbabwe (2.06-1.96 Ga)[90]

PiriWiri Group (2.2-2.06 Ga)[90]

Graphite ore[90]

-23.6 to -24.2 ‰[23]

B, F, I, T[91]

Minas Orogen, Brazil (2.1-2.01 Ga)[92]

Itapecerica khondalites (2.08-2.07 Ga)[93]

Up to 35 % TOC, Graphite ore[94,95]

-21.2 to -27.9 ‰[92]

B, F, S, T[94]

TOC = Total Organic Carbon. B, basal decollement; D, decollement; F, isoclinal folding; G, graphite thickening/in subduction zones; I, imbrication; S, shear zones; T, thrusting (especially bedding-parallel).

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