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GEOLOGICAL MAGAZINE

Conodont biostratigraphy of the mid-Carboniferous boundary in Western Ireland

P. FALLON & J. MURRAY

SUPPLEMENTARY MATERIAL

Proof For Review

CORRELATION OF THE MEASURED SECTIONS TO THE AMMONOID DATA OF PREVIOUS AUTHORS

Ballybunion, north Co. Kerry, Ireland

Above inaccessible shales at the base of this section Kelk (unpub. Ph.D. thesis, University of Reading, 1960) noted a *c.* 10 cm thick unit of 'finely laminated, black shale' containing the goniatite *Cravenoceratoides nitidus* [E2b2 Ammonoid Biozone (Waters & Condon, 2012)], with its base located *c.* 1.85 m beneath the base of a 'black spicular shale with indeterminable goniatites'. This unit probably corresponds to the basal 3.86 m of shale measured in this study and therefore the *Ct. nitidus* band is possibly located at *c.* 2 m above the base of the section (ABS). The base of the section is arbitrarily taken here to approximate the base of the E2b Ammonoid Biozone. Kelk (unpub. Ph.D. thesis, University of Reading, 1960) recorded further goniatite bands in calcareous nodule horizons throughout the remainder of the section which correspond to samples collected during this study and are shown in ascending stratigraphical order in Table S1 below.

Table S1. Correlation of the sampled calcareous nodule horizons in the Ballybunion section to the goniatite bands recorded by Kelk (unpub. Ph.D. thesis, University of Reading, 1960).

Fm.	This Work		Corresponding goniatite band recorded by Kelk (unpub. Ph.D. thesis, University of Reading, 1960)	Associated Ammonoid Biozone Index (Waters & Condon, 2012)	Further Info
	Sample	Strat. Height ABS			
Ross Sandstone Formation	BBN N25 or N26	107.1 m or 108.8 m respectively	<i>Homoceratoides prereticulatus</i>	H2c2	While uncertainty exists, BBN N25 is taken here to correspond to this goniatite band and to indicate the base of the H2c Ammonoid Biozone.
	BBN N23 or N24	102.5 m or 104.1 m respectively	Unfossiliferous bullion band which Kelk suggested possibly represented the <i>Homoceras undulatum</i> goniatite band.	H2b1	BBN N23 is taken here to correlate with this horizon and to indicate the base of the H2b Ammonoid Biozone.
	BBN N21 or N23	101.4 m or 102.5 m respectively	<i>Hudsonoceras proteum</i>	H2a1	BBN N21 is taken here to correspond to this goniatite band and to indicate the Chokierian–Alportian boundary.
Clare Shale Formation	BBN N18	37.5 m	<i>Homoceras beyrichianum</i>	H1b1	This horizon is taken here to indicate the base of the H1b Ammonoid Biozone.
	BBN N16	34.1 m	<i>Homoceras subglobosum</i>	H1a2 or H1a3	This taxon was also recorded by Kelk in the shales immediately above this nodule horizon.
	BBN N12	27.3 m	<i>Homoceras subglobosum</i>	H1a1 or H1a2	This horizon is taken here to indicate the Arnsbergian–Chokierian boundary.
	BBN N9	17.7 m	<i>Nuculoceras nuculum</i>	E2c2–E2c4	This horizon is taken here to indicate the base of the E2c Ammonoid Biozone.

Inishcorker, Killadysert, Co. Clare, Ireland

Table S2 below lists in ascending stratigraphical order the lithologies and samples from this study and the corresponding units recorded by Hodson & Lewarne (1961) at Inishcorker. The stratigraphically highest record of *Homoceras undulatum* [H2b1 Ammonoid Biozone (Waters & Condon, 2012)] by Hodson & Lewarne (1961) could not be correlated, due to discrepancies in thickness measurements between this study and that of Hodson & Lewarne (1961); it has been placed arbitrarily within the stratigraphic gap beneath the Gull Island Formation.

Table S2. Correlation of the measured section at Inishcorker to the goniatite bands recorded by Hodson & Lewarne (1961).

Fm.	This Work		Corresponding goniatite band recorded by Hodson & Lewarne (1961)	Associated Ammonoid Biozone Index (Waters & Condon, 2012)	Further Info
	Sample & Lithology	Strat. Height ABS			
Clare Shale Formation	C12 N5	162.4 m	Possibly corresponds to the record of <i>Homoceras beyrichianum</i> in a bed with a 'bullion hollow'.	H1b1	Uncertainty exists in the placement of this boundary as there is a discrepancy between the thickness measured from this horizon to the beginning of the conspicuous lithostratigraphic gap between this study and Hodson & Lewarne (1961).
	C12 N3 & C12 N1	153.5 m & 154.1 m	<i>Homoceras subglobosum</i> in two 'bullions' separated stratigraphically by 1 ft.	H1a2 & H1a3	These bullions/nodules are found in this study to be separated by c. 60 cm.
	3D goniatites in calcareous nodule sample C10 N3.	147.3 m	<i>Homoceras subglobosum</i> . The lowest record of this species in a 'long bullion'.	H1a1	This horizon is taken here to indicate the Arnsbergian–Chokierian boundary.
	Top of platy shale with flattened (2D) goniatites.	134.2 m–135.7 m	<i>Nuculoceras nuculum</i>	E2c2–E2c4	This horizon is taken here to indicate the base of the E2c Ammonoid Biozone.
	Base of platy shale.	89.2 m	<i>Cravenoceratoides</i> sp. in shale.	E2b	This horizon is taken here to indicate the base of the E2b Ammonoid Biozone.
	Platy shale beneath an extremely weathered lens.	83.1 m	<i>Eumorphoceras bisulcatum</i> in the shale beneath a 'decalcified raft'.	E2a1–E2a2	This horizon is taken here to indicate the Pendleian–Arnsbergian boundary.
	Nodule hollow with a weathered outer rim.	12.8 m	<i>Cravenoceras malhamense</i> in 'bullions'.	E1c1	This horizon is taken here to indicate the base of the E1c Ammonoid Biozone.
	Platy shale with goniatites.	1.5 m	<i>Eumorphoceras pseudobilingue</i> in 'thinly bedded shales'.	E1b2	This horizon is taken here to indicate the base of the E1b2 Ammonoid Biozone. The underlying samples C1 N1 and C1 N2 and the section base are inferred to be E1b in age.
	Calcareous nodule horizon with samples C1 N1 & C1 N2.	0.3 m	1 ft thick nodular bed above 20 ft 'platy shales to base of visible section'.		The platy shale beneath this nodule horizon was not included in the measured section of this study due to submergence.

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**FIELD PHOTOGRAPHS OF THE MEASURED SECTIONS AT BALLYBUNION AND
INISHCORKER, IRELAND**



Figure S1. Field photographs from the measured section at Ballybunion, north Co. Kerry, Ireland. (a) Base of the measured section (Q 86713 44301 [± 5 m]). (b) Boundary between the Clare Shale and Ross Sandstone formations (Q 86850 44462 [± 12 m]). (c & d) Sandstone beds which mark the top of the measured section (Q 86731 44622 [± 11 m]). A c. 35 cm long geological hammer (circled in red) is used as a scale in (c).

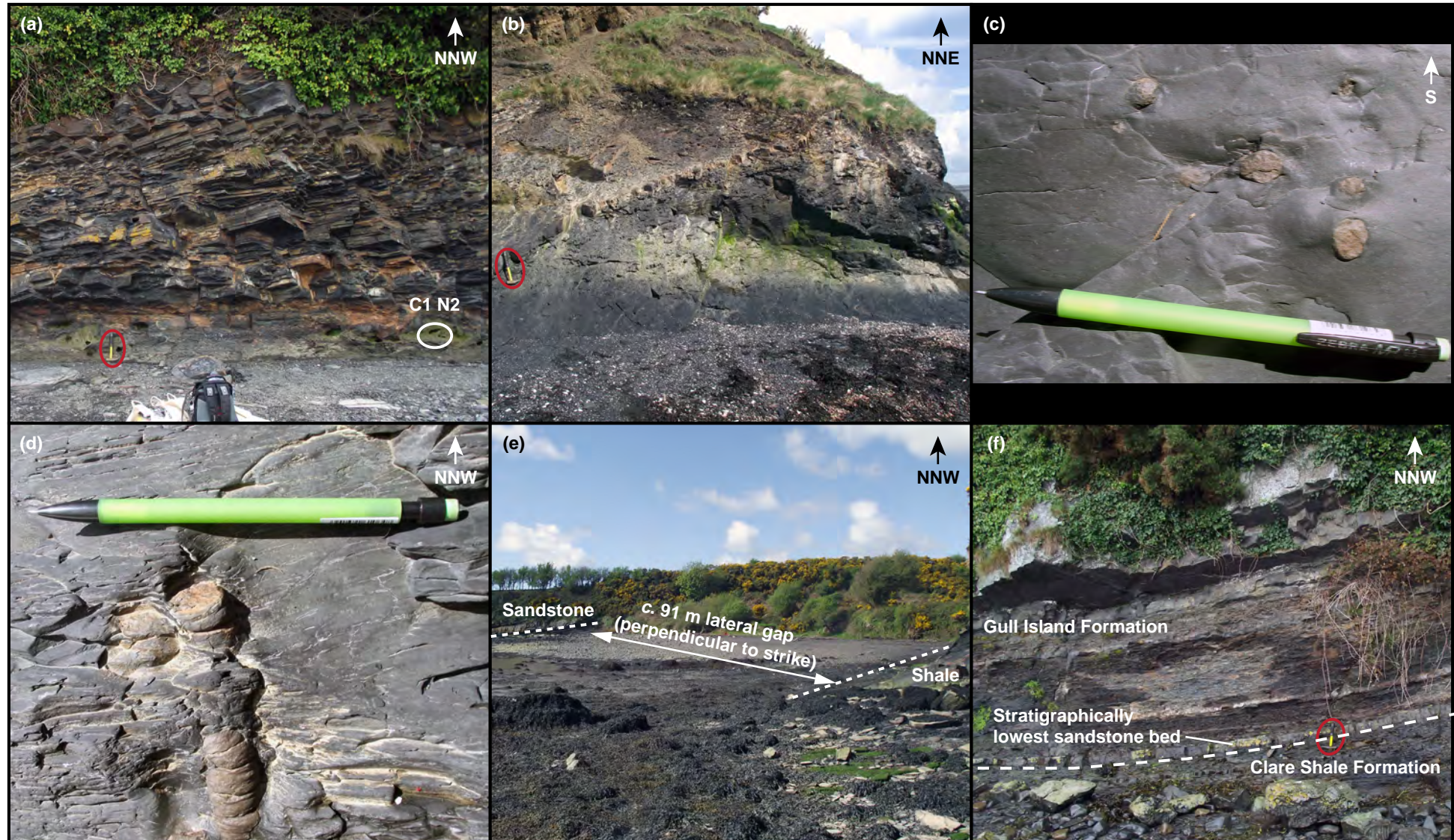


Figure S2. Field photographs from the measured section at Inishcorker, Killadysert, Co. Clare, Ireland. **(a)** Base of the measured section (R 26787 57686 [± 4 m]) with one of the two lowest calcareous samples indicated with a white circle. **(b)** Clare Shale exposure containing vertical pyrite tubes (R 26312 57528 [± 6 m]). **(c & d)** Plan & profile views respectively of the vertical pyrite tubes. A c. 15 cm long pencil is used as a scale. **(e)** Stratigraphic gap c. 28 m thick towards the top of the measured section. **(f)** Boundary between the Clare Shale and Gull Island formations at the top of the measured section (R 26159 57640 [± 6 m]). A c. 35 cm long geological hammer (circled in red) is used as a scale in **(a)**, **(b)** and **(f)**.

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**STRATIGRAPHIC HEIGHTS, GPS CO-ORDINATES, WEIGHTS AND FIELD
PHOTOGRAPHS OF THE SAMPLED CALCAREOUS NODULES**

Proof For Review

Table S3. Stratigraphic heights, GPS co-ordinates and weights of the sampled calcareous nodules from the Ballybunion section, north Co. Kerry, Ireland.

Section	Formation	Subsystem	Stage	Regional Substage	Ammonoid Biozone	Nodule No.	Stratigraphic Height (m)	GPS (Irish National Grid, m)	Original Weight (g)	Final Weight (g)	Weight Dissolved (g)	Sample Soluble/ Insoluble	Conodont Elements Present		
Ballybunion	Ross Sandstone Formation	Pennsylvanian (part)	Bashkirian (part)	Alportian (part)	H2?c	BBN N26	108.8	~Q 86810 44587	2303	2149	154	Insoluble	No		
						BBN N25	107.1	~Q 86822 44582	960	583	377	Insoluble	No		
					H2?b	BBN N24	104.1	~Q 86827 44577	2244	312	1932	Soluble	No		
						BBN N23	102.5	~Q 86830 44570	2193	435	1758	Soluble	Yes		
	Clare Shale Formation			Mississippian (part)	Serpukhovian (part)	Arnsbergian (part)	H1b	BBN N20	40.3	~Q 86885 44343	2083	541	1542	Soluble	No
								BBN N18	37.5	~Q 86882 44332	2176	416	1760	Soluble	Yes
							H1a	BBN N16	34.1	~Q 86875 44320	2004	145	1859	Soluble	Yes
								BBN N15	33.3	~Q 86872 44327	2155	1952	203	Insoluble	No
		BBN N14	33.1					~Q 86872 44327	2161	122	2039	Soluble	Yes		
		BBN N12	27.3					~Q 86858 44315	2179	306	1873	Soluble	Yes		
	E2c	BBN N10	23.6	~Q 86855 44298	2259	318	1941	Soluble	Yes						
		BBN N9	17.7	~Q 86827 44297	2222	258	1964	Soluble	Yes						
		E2b	BBN N6	7.9	Q 86725 44300 [± 4 m]	2252	183	2069	Soluble	Yes					
	BBN N5		5.1	Q 86717 44304 [± 6 m]	2235	148	2087	Soluble	Yes						
BBN N1	2.5		Q 86713 44301 [± 5 m]	2111	165	1946	Soluble	Yes							

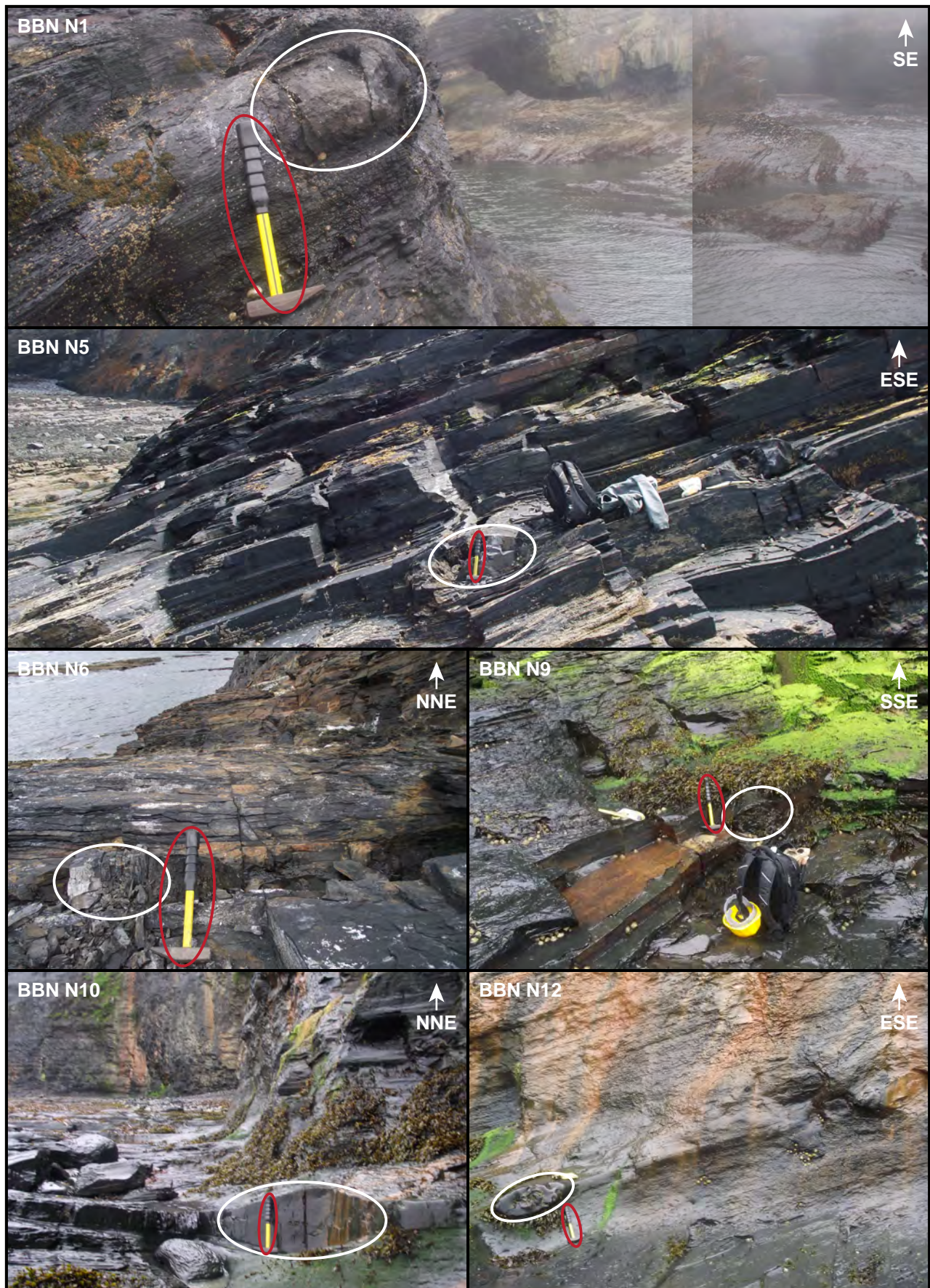


Figure S3. Calcareous nodules sampled from the Clare Shale Formation at Ballybunion, north Co. Kerry, Ireland (I). The sampled nodules are indicated with a white circle. A *c.* 35 cm long geological hammer (circled in red) is used as a scale. The approximate direction that the camera faces in each picture is indicated with an arrow.

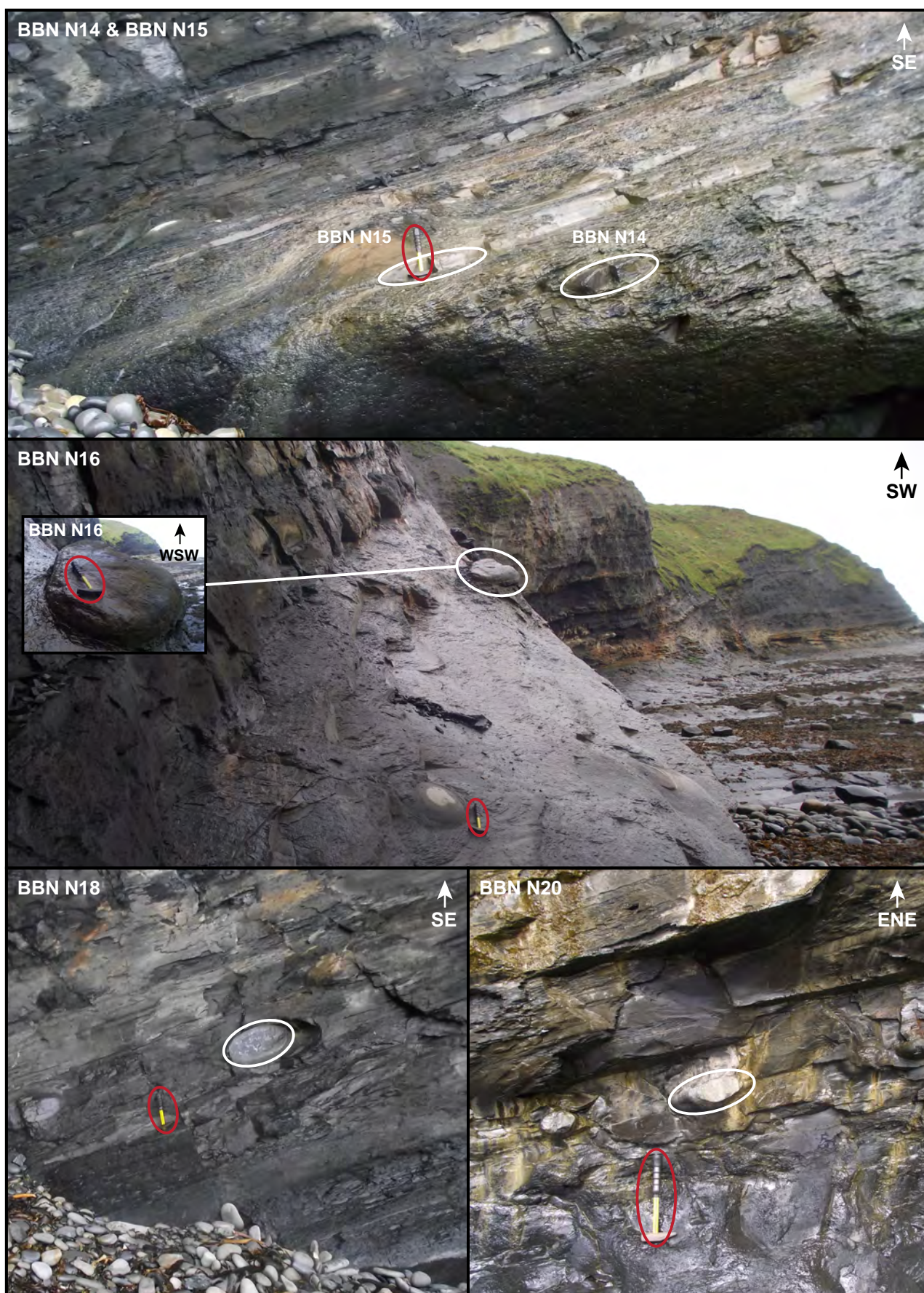


Figure S4. Calcareous nodules sampled from the Clare Shale Formation at Ballybunion, north Co. Kerry, Ireland (II). The sampled nodules are indicated with a white circle. A *c.* 35 cm long geological hammer (circled in red) is used as a scale. The approximate direction that the camera faces in each picture is indicated with an arrow.

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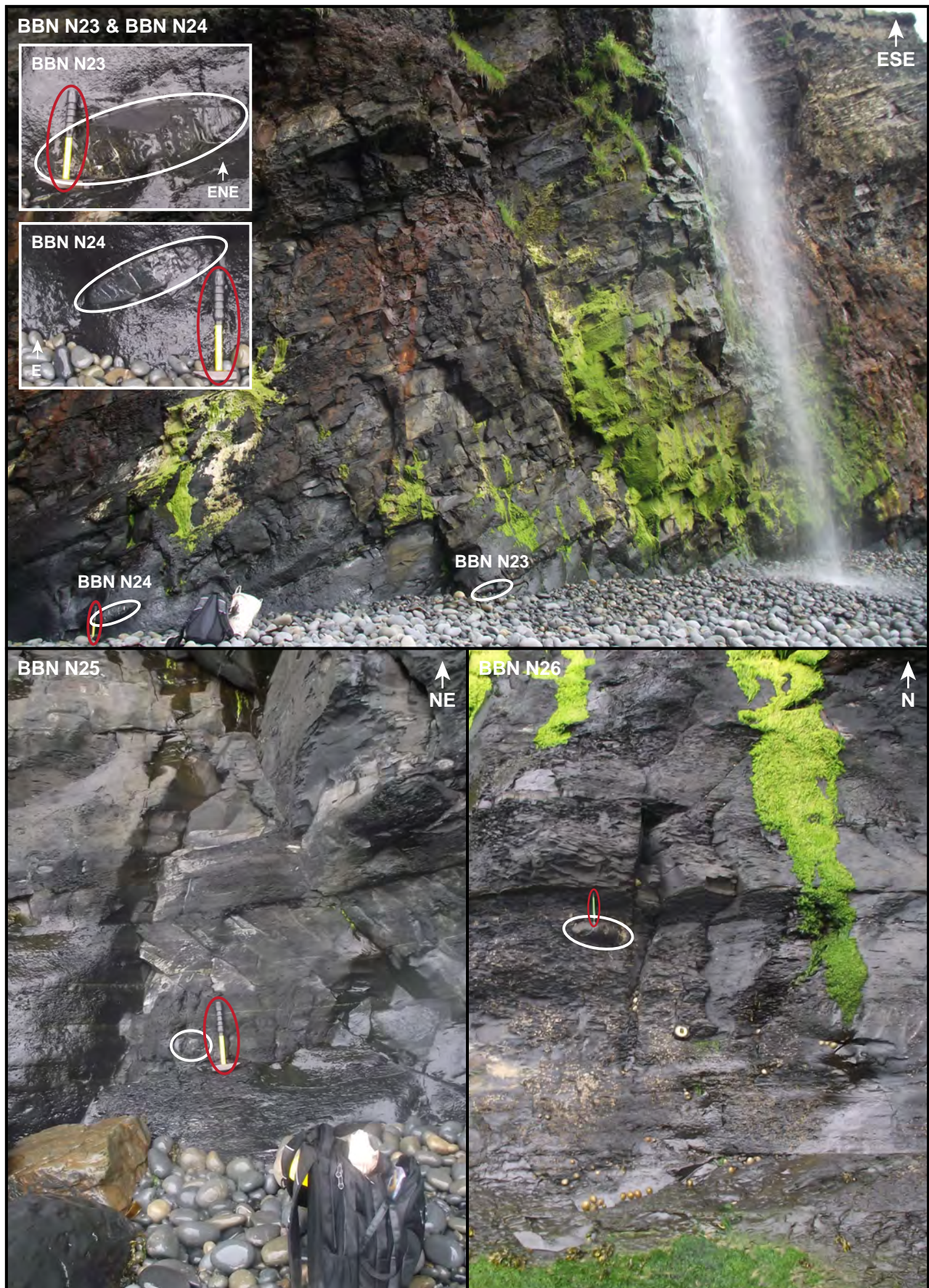


Figure S5. Calcareous nodules sampled from the Ross Sandstone Formation at Ballybunion, north Co. Kerry, Ireland. The sampled nodules are indicated with a white circle. A *c.* 35 cm long geological hammer (circled in red) is used as a scale for samples BBN N23, BBN N24 and BBN N25. A *c.* 15 cm long pencil is used as a scale for sample BBN N26. The approximate direction that the camera faces in each picture is indicated with an arrow.

Table S4. Stratigraphic heights, GPS co-ordinates and weights of the sampled calcareous nodules from the Inishcorker section, Killadysert, Co. Clare, Ireland.

Section	Formation	Subsystem	Stage	Regional Substage	Ammonoid Biozone	Nodule No.	Stratigraphic Height (m)	GPS (Irish National Grid, m)	Original Weight (g)	Final Weight (g)	Weight Dissolved (g)	Sample Soluble/ Insoluble	Conodont Elements Present
Inishcorker	Clare Shale Formation	Pennsylvanian (part)	Bashkirian (part)	Chokierian (part)	H1?b	C12 N4	163.4	R 26237 57624 [± 6 m]	2189	96	2093	Soluble	No
						C12 N5	162.4	R 26240 57622 [± 9 m]	2385	408	1977	Soluble	Yes
					H1a	C12 N2	160.6	R 26240 57622 [± 9 m]	2190	194	1996	Soluble	Yes
						C12 N6	158.2	R 26237 57606 [± 9 m]	2208	805	1403	Soluble	No
						C12 N1	154.1	R 26244 57590 [± 4 m]	2164	103	2061	Soluble	Yes
						C10 N5	150.4	R 26247 57587 [± 5 m]	2109	232	1877	Soluble	Yes
		C10 N4	149.2	R 26247 57587 [± 5 m]		2048	209	1839	Soluble	Yes			
		Mississippian (part)	Serpukhovian (part)	Arnsbergian (part)	E2c	C10 N2	146.3	R 26248 57575 [± 5 m]	2097	2061	36	Insoluble	No
						C10 N1	146.2	R 26248 57575 [± 5 m]	2089	1892	197	Insoluble	No
					E1b	C1 N2	0.3	R 26794 57678 [± 5 m]	3417	1403	2014	Soluble	Yes
						C1 N1	0.3	R 26784 57678 [± 5 m]	5102	1485	3617	Soluble	Yes



Figure S6. Calcareous nodules sampled from the Clare Shale Formation at Inishcorker, Killadysert, Co. Clare, Ireland (I). The sampled nodules are indicated with a white circle. A c. 35 cm long geological hammer (circled in red) is used as a scale. The approximate direction that the camera faces in each picture is indicated with an arrow.



Figure S7. Calcareous nodules sampled from the Clare Shale Formation at Inishcorker, Killadysert, Co. Clare, Ireland (II). The sampled nodules are indicated with a white circle. A c. 35 cm long geological hammer and a c. 15 cm long pencil (both circled in red) are used as scales, with the latter used only for sample C12 N6. The approximate direction that the camera faces in each picture is indicated with an arrow.

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CONODONT ELEMENT DISTRIBUTION TABLES

Table S5. Conodont element distribution table for the Ballybunion section, north Co. Kerry, Ireland.

Genus, species, subspecies	Section	Ballybunion									
	Formation	Clare Shale Formation									Ross Sst Fm.
	Subsystem	Mississippian (part)					Pennsylvanian (part)				
	Stage	Serpukhovian (part)					Bashkirian (part)				
	Regional Substage	Arnsbergian (part)					Chokierian				Alportian (part)
	Ammonoid Biozone	E2b			E2c		H1a		H1b	H2?b	
Nodule No.	BBN N1	BBN N5	BBN N6	BBN N9	BBN N10	BBN N12	BBN N14	BBN N16	BBN N18	BBN N23	
Element Type	No. of Elements										
<i>Declinognathodus</i> sp.	P ₁					3	14			4	
	M					1					
<i>D. lateralis</i>	P ₁							5	5		
<i>D. noduliferus inaequalis</i>	P ₁					15	58	5	34	1	
<i>D. noduliferus</i> cf. <i>noduliferus</i>	P ₁						1				
<i>Gnathodus</i> sp.	P ₂	2		1	2						
	S _{23/4}	1	1	3	3						
<i>G. bilineatus</i> ssp.	P ₁	5		3	2	1					
<i>G. bilineatus bollandensis</i>	P ₁	36	3	40	8	18					
<i>G. postbilineatus</i>	P ₁			1							
<i>Idiognathodus primulus</i>	P ₁						1				
<i>Lochriea</i> sp.	P ₂				2						
	M				3	2					
	S _{23/4}	2			3						
<i>L. commutata</i>	P ₁	6		3	1	5					
<i>L. costata</i>	P ₁				2						
<i>L. nodosa</i>	P ₁				2						
<i>Neognathodus</i> sp.	S ₀						1				
	S ₂						1				
	S _{23/4}						6				
<i>N. asymmetricus</i>	P ₁						2				
<i>N. bassleri</i>	P ₁					1	8		1		
<i>N. symmetricus</i>	P ₁						2				
<i>Rhachistognathus minutus</i>	P ₁					1					
Unknown Affinity	P ₂	1									
	M						3				
	S _{23/4}						28				
	S	1									
Fragments	P ₂		3	3		4		1			
	M			1				2			
	S	15	3	6	7	1	2	15		1	
Total (excl. fragments)	All Elements	54	4	51	28	26	21	125	10	40	5

Table S6. Conodont element distribution table for the Inishcorker section, Killadysert, Co. Clare, Ireland.

	Section	Inishcorker							
	Formation	Clare Shale Formation							
	Subsystem	Mississippian (part)				Pennsylvanian (part)			
	Stage	Serpukhovian (part)				Bashkirian (part)			
	Regional Substage	Pendleian (part)			Chokierian (part)				
	Ammonoid Biozone	E1b			H1a				H1?b
	Nodule No.	C1 N1	C1 N2	C10 N3	C10 N4	C10 N5	C12 N1	C12 N2	C12 N5
	Genus, species, subspecies	Element Type	No. of Elements						
<i>Declinognathodus</i> sp.	S ₀								1
<i>D. noduliferus inaequalis</i>	P ₁				1	2	2	2	3
<i>Gnathodus</i> sp.	M		1						
	S ₇₂		4						
	S _{73/4}		5						
<i>G. girtyi</i> ssp.	P ₁	7	19						
<i>G. girtyi girtyi</i>	P ₁		13						
<i>G. girtyi intermedius</i>	P ₁	3	12						
<i>G. girtyi rhodesi</i>	P ₁		2						
<i>G. girtyi simplex</i>	P ₁		4						
<i>Rhachistognathus</i> sp.	S			4	2				
<i>R. minutus</i>	P ₁			2	8				
Unknown Affinity	P ₁							1	
	S ₇₁				1				
	S _{73/4}				1				
Fragments	P ₁					1			
	S	12	25	3	5				2
Total (excl. fragments)	All Elements	10	60	6	13	2	2	3	4

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