**PALAEONTOLOGY OF 9/13b WELL CORES**

**Ammonites**

**Measurements**

All specimens are severely crushed due to compaction of the mudstones, so that detailed measurements are sometimes subject to errors caused by distortion.

Where specimens are incomplete, especially where cut by the edge of the core, measurements have been estimated, indicated by ’E’. Measurements given are:

 D – diameter of the shell, if possible at different growth stages;

Wh – whorl height, also expressed as percentage of diameter;

Ud – umbilical diameter, also expressed as percentage of diameter;

pRn – number of primary ribs per half whorl or quarter whorl;

sRn – number of secondary ribs per half or quarter whorl.

Parameters such as whorl thickness cannot be measured, with the exception of one part of the *Arctocephalites* cf. *arcticus* M specimen from core 1 surface B2 for which a compaction factor of 0.8 for burial depths of 3.5 km, based on compaction curves by Baldwin & Butler (1985), has been used (see below).

**Order Ammonitidae**

**Suborder Ammonitina**

**Superfamily Stephanoceratoidea Neumayr 1875**

**Family Cardioceratidae Siemiradzki 1891**

**Subfamily Arctocephalitinae Meledina 1968**

**Genus *Arctocephalites* Spath 1928**

***Arctocephalites* cf. *arcticus* (Newton 1897)**

1985 Arctocephalites arcticus Callomon, p.65, text-fig. 8, E + e and F + f

According to Callomon (1985, p. 63) the first appearance of the dimorphic morphogenus *Arctocephalites* defines the beginning of the Arcticus Zone in eastern Greenland. The microconchs, indicated by lower case “m”, referred to the morphospecies *A. arcticus* (Newton), show little variation but the macroconchs {“M”) show a wide range of variation, especially in relative whorl width, from very broad as in *A. sphaericus* (Spath) to almost suboxyconic in *A. elegans* Spath.

To simplify comparisons with other published information, in this paper the dimorphs are described separately.

***Arctocephalites* cf. *arcticus* (Newton 1897) Macroconch**

Figs. 1, a-b (upper); Fig, 6, 1, a-b, 2 a-b; Fig. 8, 2

***Material:*** Two complete specimens: Core 1, surfaces B1 - B2 [Fig. 1, a-b upper, Fig. 6, 2 a-b]; Core 1, surfaces F1 – F2 [Figs. 6, 1 a-b]; at least four fragments: core 1, surface C; core 1, surfaces E1-2; core 2, surface A [Fig. 8, 2]; core 2, surface C (i) (one fragment); 9/13b-19 one fragmented specimen.

***Measurements::***

Core 1, B1-B2: GSM132436b / GSM132437a

(i) D Wh % Ud % pRn sRn

 B1 47.1 20.0 (42.5) 16.7 (35.5) 16/12 ----

32.3 16.2 (50.2) 14.6 (45.2) --- ---

 Central whorls missing

 (i) B2 47.0 19.3 (41.0) 14.1 (30.0)

 38.5 19.0 (49.4) 14.0 (36.4) Wb 2.0 = 16.0 (41.6)

 Preservation more complete inner whorls; ribbing traced back to D. 7.5mm, then appear smooth

Core 1, surface F1 + 2: GSM132439b / GSM132440/a

 Part of outer whorl missing, cut be edge of core

 (i) F1 E76.2 E35.2 (46.2) 19.7 (25.9) 14/12 22/12

 70.4 27.3 (38.8) 19.2 (22.3) 14/12 26/12

 (i) F2 E80.5 E39.1 (43.6) 23.3 (28.8) 17/12 25/12

 69.6 25.9 (37.2) 21.5 (30.9) 15/12 22/12

 52.2 23.3 (44.2) 21.2 (40.2) 13/12 ---

 On outermost half whorl, above D. 65 mm, ribs more distant and flatter, below this closer and more sharp; innermost whorls smooth below D. 4.5 mm

Core 2, surface A GSM132441a

 (i): E56.0 26.2 (E46.8) E14.0 (25.0) 7/14 13/14

 Part of large ammonite, most cut by edge of core

Figured specimens:

Holotype (Spath 1932, pl. XVII, 1)

 120.0 Wh% (48) Ud% (20) 0 0 Wb% (65)

 90.0 39 (43) 20 (19) 12/12 ---

 Abave D. 80-90 mm ribs almost disappear leaving only a few umbilical bulges.

Paratype (Spath 1932, pl. XVI))

 56.0 Wh% (48) Ud% (12) 7/14 12/14  Wb% (66)

***Description:*** The two complete specimens are moderately involute with mean relative Ud of 32.8%, but the limited data indicates decreasing size of umbilicus with growth towards the figures given by Spath for larger figured specimens. Ribbing is well developed except on the outer whorl of the larger specimen. On both specimens the innermost whorls become smooth, below D = 4.3 mm on specimen core 1, surface F2 (Fig. 6, 1 a-b) and below D = 5.7 mm on core 1, surface B2 (Fig. 1 a-b upper, Fig. 6, 2 a-b),; some small mid-whorl tubercles appear to be present at smaller sizes on the first specimen (Fig.6, 1 a) before development of ribbing, but are not preserved on the counterpart (Fig. 6, 1 b). On the umbilical edge the primary ribs are inclined backwards but curve forwards to be straight on the whorl sides, numbering 13 to 17 per half whorl. At about mid whorl, or just below, bifurcation and intercalation of secondary ribs occurs and these ribs, numbering 22 to 26 per half whorl, are straight and continue across the venter. The ribs are generally more rounded in profile than in the microconchs, enabling distinction between specimens of similar size of (compare Fig. 8, c [M] with Fig. 8, a and 3 [m]. On the outer whorl of the larger specimen (Fig. 6, 1 a-b) the ribs begin to fade.

***Discussion***: The specimens from well 9/13b-51 appear to be less involute than the typical specimens (of *A. sphaericus* Spath) from East Greenland, However, Spath’s specimens are much larger and there are indications that the relative umbilical diameter decreases with growth. On the holotype above diameter 80-90 mm (Spath 1932, fig. 17, 1 a), the outer whorl becomes smooth with only a few umbilical bulges remaining. The larger core specimen (Fig. 6, 1 a-b) also shows the ribs becoming more distant and flatter on the outer whorl, above diameter 65 mm. The North Sea specimens lie within the range of variation of *A. arcticus* (Newton) according to Callomon (1985) and can be matched well with some juvenile specimens figured by Spath.

8 2

***Arctocephalites* cf. *arcticus*** (Newton 1897) [m] **microconch**

Fig. 1 a-b (lower), Fig. 7, Fig.78/ 1, 3, 4.

***Material:*** Three complete specimens: Core 1, surfaces B1 + 2 (1 specimen) (Fig. 1, lower, Fig. 7, a - b); Core 3, surface A (2 specimens) (Fig. 7, a - b). Fragments : Core 2, surface B (Fig. 7, 3) Core 2, surface C approximately 15-20 specimens, a few nearly complete and many fragments are crushed together on a shell “pavement” (Fig. 8, e); 9/13b-19 one poorly preserved specimen.

***Dimensions****:*

Core 1, surface B1+2 GSM132436b / GSM132437a

(ii) D Wh (%) Ud (%) pRn sRn

 29.0 12.7 (42.4) 5.9 (20.3) 16/12 29/12

 20.7 8.7 (42.0) 4.4 (21.3) 14/12 24/12

 17.4 7.6 (43.7) 4.7 (27.0) 13/12 ----

Innermost whorls smooth up to D. 3.3 mm then 3/4 spaced tubercles before ribs develop.

Core 2, surface C GSM132442b

The preservation, with many specimens and fragments crushed together on a flat bedding surface makes accurate measurements impossible; the most complete are estimated to be about 20 mm in diameter.

Core 3, surface A (i) GSM132443a and GSM132444b

 (i) 41.9 21.1 (50.4`) 10.3 (24.6) 10/12 ---

 34.3 16.4 (47.8) 7.3 (21.3) 15/12 26/12

 E28.4 15.5 (54.6) 7.0 (24.6) 8/14 13/14

Broken into two parts that fit together

 (ii) 35.7 17.3 (48.5) 7.2 (20.2) 12/12 24/12

 E27.8 15.5 (39.2) 6.3 (22.7) 7/14 12/14

 Innermost whorls not well enough preserved to see ribbing

***Description****:* The specimens of *A* cf.*. arcticus* [m] are consistently more involute at comparable sizes than *A. cf. arcticus* [M] described above, with mean relative Ud of 22.75% (cf.32.8%). The density of primary ribbing (pRn) is only slightly higher than *A. cf. arcticus* [M] with mean of 13.8 per half whorl compared with 12.7 per half whorl and the same applies for secondary ribbing at 25.5 (cf. 22.2) per half whorl. The shape of the ribs is also similar but in A. arcticus [m] the ribs have a sharper, more pointed, profile. This appears to be also the case for juvenile specimens, such as those in core 2 surface C (Fig. 8, e).. The innermost whorls of the Core 3 specimens are not always well enough preserved to be certain of presence or not of ribbing. However, on Core 1, surface B 1 and 2 the whorls are smooth below D 3.2mm (B1) or 3.4mm (B2), with three or four small mid-whorl tubercles before development of ribbing seen on B2, but not clear on B1, before development of ribbing.

***Discussion:*** There are clearly two distinct morphological entities in the faunal assemblage, despite the small number of specimens and the crushed nature of the preservation, most specimens, even larger juveniles, can be readily allocated to either rhe mscroconch *A.cf.arcticus* [M] or the microconch *A. cf. arcticus* [m] based on the profile of the ribs. Variation in shell geometry, especially relative umbilical diameter with growth, is less pronounced in *A. cf. arcticus* [m] than in *A. cf. arcticus* [M].

***Arctocephalites* cf. *arcticus* (Newton) [juveniles]**

Fig. 9, a- b, Fig. 10, a - d.

***Material:*** Numerous small to very small specimens on several surfaces, with good (g), moderate (m) or poor (p) preservation, usually body chamber and phragmocone are present and distinguishable.

Core 1: Surface A - one specimen (i) m; Surface B - one specimen (iii) p;

Core 2: Surface A more than five specimens g - m plus fragments (Fig. 9, B)): Surface B two specimens m (Fig. 9, C);

Core 3: Surface B – one specimen g (Fig. 9, D); Surface C – more than 16 very small specimens (diam. < 6mm) g – m (Fig. 8, 2); Surface D – 6 specimens m; Surface E – 14 specimens m - p; Surface F – 10 specimens g – p, mixed sizes (Fig. 8, 1; Surface G – 3 specimens m – p.

***Dimensions:***

Core 1, Surface A GSM132436a

 (i) E5.7 E2.1 (36.8) 2.1 (36.8) c8//14 10//14

 4.4 ---- ---- smooth

 One quarter outer whorl with ribs, inner whorls smooth

Core 1, Surface B GSM132436b / /GSM132437a

 (iii) 4.2 1.4 (33.5) 1.5 (33.7) 6/14

 Below 3.5 mm diameter whorls smooth

Core 2, Surface A GSM132441a [Fig. 10, b]

 (ii) 11.7 5.9 (50.4) 3.3 (28.2) 14/12 29/12

 E8.2 3.2 (39.0) 2.1 (25.6) ---- ----

 7.8 3.2(41.0) 2.2 (28.2) 11/12 18/12

 Ribs nearly straight with slight projection towards venter, branching lower part of mid whorl, inner whorls appear smooth

 (iii) 11.8 5.1 (43.2) 3.1 (26.3) ---- ----

 appears smooth, only faint ribs on last whorl

 (iv) 8.7 3.6 (41.4) 1.8 (20.7) ---- ----

smooth except faint ribs near end of body chamber

 (v) 4.5 1.8 (40.0) 0.9 (20.0) ---- ----

 (vi) 4.8 2.4 (50.0) 0.9 (18.8)

 (x) (a) vertically embedded fragment with broad rounded venter with ribs crossing over between whorl sides

 (x) (b) fragment with sharp ribbing that curves near lower edge of whorl and branches u into two secondary ribs that curve backwards.

Core 2, Surface B GSM132441b / GSM132442a [Fig. 10, c]

 (ii) 12.1 5.3 (43.8) 2.7 (22.1) 18/12 28/12

 (iii) 9.2 4.0 (43.5) 3.1 (33.7) 20/12 25/12

Core 3, Surface B GSM132443b / GSM132444a

 (i) 15.2 6.3 (41.4) 4.9 (32.2) 16/12 24/12

 11.3 4.3 (55.8) 2.6 (23.0) 16/12 26/12

Core 3, Surface C GSM132444b / GSM132445a

 (i) 5.5 2.6 (47.2) 1.4 (25.5\_ 6/14 10/14

 5.0 2.4 (48.0) 1.4 (28.0) ---- ----

 E2.2 smooth

 (ii) E3.8 1.9 (50.0) 1.4 (36.8) small tubercles

 iii) E5.0 2.5 (50.0) ----- 5/14 10/14)

 (iv) E4.0 2.0 (50.0) 1.6 (40.0) faint ribbing

 (v) 5.0 E2.2 (44.0) 2.0 (40.0) 12/14

 Fine close ribbing

 3.2 E1.5 (4.3) E1.3 (40.2) smooth

 (vi) 3.7 1.9 (51.4) E1.1 (29.7) --- ---

 (vii) 4.9 2.2 (44.9) 1.3 (34.7) ? smooth

 3.8 1.6 (42.1) 1.1 (28.9)  ? small tubercles

 (viii) 3.8 1.9(50.0) E0.8 (21.1) --- ---

 (ix) 3.6 1.9 (52.8) 1.7 (47.2) small tubercles

 (xvi) 5.3 2.7 (50.9) 1.8 ( (34.0) faint ribs, tubercles

 (xiv) --- --- Wb. 2.8 ---

 Vertical embedding ; broad rounded whorls; ribs cross venter

Core 3, Surface D GSM132445b / GSM132446a

 (i) 7.3 3.1 (42.5) 2.1 (28.8) 13/12 ---

 (III) E8.4 3.0 (35.7) E3.1 (36.9) --- ---

 7.9 2.5 (31.6) 2.6 (32.9) 11/12 8/14

 Outside whorl plus 14 ribbed

 (iv) 6.2 2.8 (45.2) 2.3 (37.1) 2.3(37.1)

 Ribbed on small part pf body chamber, phragmocone crushed

 (v) 7.5 3.3 (44.0) 2.9 (38.7) 14//12

Core 3, Surface E GSM132446b / GSM132447a

 (i) 4.1 not well preserved; small pointed tubercles

 (ii) 6.3 2.3 (36.5) 2.3 (36.5) ribs on outer 14 whorl;

 ? small tubercles, inner whorls smooth

 (iii) 5.3 2.2 (31.3) 2.3 (43.4) ribs on outer 1/8 whorl;

 inner whorls too crushed

 (iv) 5.7 2.4 (42.1) ---- 8/1412/14

 (v) 3.3 1.1 (33.3) 0.9 (27.0)

 Small tubercles by D = 2.6; ribs by D = 2.

 (vi) 6.1 2.1 (34.4) 1.8 (29.5) ribs not clear

 (vii) 7.8 3.4 (43.6) 2.5 (28.2) 13/12 15/14

 Clear well dev. Branching ribs from D = 4.2

 (viii) 6.8 2.9 (42.6) 2.2 (32.4)

 Some tubercles below mid whorl and ribs on outer whorl

 (ix) 7.8 3.7 (54.4) 2.4 ((30.8) 16/12 10/14

 Ribs from D = 4.0 slightly curved and branching mid-whorl

 (x) 6.5 crushed

 (xi) 5.6 1.7 (30.4) 2.1 (37.) --- ---

 (xii) 11.1 4.0 (36 .0) 3.8 (34.2) 14/12 25/12

. 7.2 3.2 (44.4) 2.6 (36.1) no tubercles; clear

 branching ribs with slight curvature on lower whorl sides then straight

 (xiii) 8.8 3.0 (34.0) 3.1 (35.2) --- ---

 (xiv) 7.6 2.6 (34.2) 1.9 (25.0) --- --- riba last whorl before

 tubercles on side of whorl

 (xv) 8.2 3.4 (41.4) 2.4 (29.3) --- --- ribs well developed

 last 14 whorl, a few tubercles before

 (xvi) 5.5 2.6 (47.3) 1.7 (30.9) --- ---

Core 3, Surface F GSM132447b / GSM132448a [Fig. 9A]

 (i) 16.8 6.6 (39.3) 7.2 (42.9) --- 22/12

 13.4 5.6 (41.8) 4.4 (328) 14/12 24/12

tubercles below D 3.3

 (ii) 11.5/14

 10.9 4.1 (37.6) 4.7 (43.1) 10/14

 (iii) 13.0 4.2 (32.3) 5.9 (45.4) 22/12 22/14

 (iv) 6.3 2.7 (42.9) 2.4 (38.1) --- ---

 (v) 11.0 --- --- --- ---

 (vi) 8.8 --- --- --- ---

 (vii) 5.0 --- --- --- ---

 (viii) 9.4 E2.8 (29.8) 2.6 (27.7) --- ---

 Strong branching ribs on outer ¼ whorl, rest crushed

 (ix) 12.5 5.3 (42.4) 5.5 (44.0) 11/14 14/14

 11.3 4.8 (42.5) 5.1 (45.1) 11/14 13/14

 (x) 8.4 3.9 (46.4) 2.9 (34.5) 9/14 13/14

 Smooth to 5 5.0 then ribs with slight curve to venter, branching below

 mid-whorl

Core 3, Surface G GSM132448b

 (i) 8.2 3.4 (41.5) 2.0 (24.4) --- ---

 Ribs stronger on outer ¼ whorl

 (ii) 2.8 --- --- --- ---

 ? smooth

***Description:*** Numerous very small specimens are preserved on several surfaces, especially from core 3. Some are fragmented, but most are preserved with both body chamber (filled with sediment) and phragmocone (crushed hollow chambers) present. Specimens up to 12 mm diameter are preserved on core 2, surfaces A [Fig. 10, b}, B [Fig. 10, c] and core 3, surface F along with smaller sizes [Fig. 9, a, Fig. 10, a]. Preservation of very small specimens is particularly common in core 3: Surface C [Fig. 9, b] with range 3.6 to 5.5 mm (mean 4.4 mm N 10); Surface D range 7.3 to 11.2 mm (mean 8.9 mm N 8); Surface E range from 4.2 to7.8 mm (mean 5.7 mm N 8); Surface F range from 4.2 to 12.5 mm (mean 10.1 mm N 6, plus one larger at 16.8 mm) [Fig. 9, b]; Surface G range from 2.8 to 8.2 mm (mean 4.9 mm N 3).

On better preserved specimens outer whorls mostly have regular straight to slightly curved ribbing with branching or intercalated secondary ribs; inner whorls are smooth up to diameters ranging from 2.8 to 4.4 mm and on several better preserved specimens there is then a row of pointed tubercles on mid whorl before the start of ribbing. This feature was also bserved on one Macroconch specimen [see Fif. 6, a].

 Measurements of whorl height and umbilical diameter relative to diameter are very variable. Rare vertically embedded specimens show broad whorls with rounded venter with ribs crossing over between whorl sides.

***Discussion:*** At these sizes there is no clear differentiation between Macroconchs and microconchs in dimensions or style of ribbing, though sometimes the ribbing may appear sharper as in microconchs [e.g. Fig. 10, a] or blunter as in macroconchs [Fig. 10, b – c]. However, these are not consistently clear so that they can only be classified as juveniles of the species *A. arcticus* (Newton) on the basis of co=occurrence in the same stratigraphical interval with larger identifiable specimens. On several surfaces the size ranges are very small as in Core 3 Surface C [Fig. 9, b], suggesting mass mortality of a single generation. On others there is a much wider range of sizes as on Core 4, surface F [Fig. 9, a].

*Amoeboceras* cf. *freboldi* Spath 1935 [m]

Fig. 11, a - b

*Material:* One specimen from well 9/13b-19, crushed with part of body chamber and projected keel displaced [best seen on Fig. 11, a].

*Dimensions:*

D. E 29.5 mm Wh. 13.4 mm (45.4%) Ud. 7.0 mm (23.7%) pRn 18/1/2 sRn 251/2

D. 27.8 mm Wh.13.3 mm (47.9%) Ud. 5.9 mm (21.2%) pRn.16/1/2 sRn 24/1/2

*Description:* Medium-sized, involute with close strong ribs that are slightly curved on whorl sides and branch just above the middle of the whorl into thicker more prominent secondary ribs that are strongly projected adorally onto the venter, terminating against a strong corded keel. The last part of the keel and the part that extended beyond the aperture, characteristic of the microconch, are broken and slightly displaced.

*Discussion: A. freboldi* is described as an easily recognized widespread species that is mainly characteristic of the Regulare Zone but is rarer in the uppermost part of the Serratum Zone (Sykes and Callomon 1979, p. 885 and text-figure 5, p. 846), just below the top of the Oxfordian. It occurs throughout the Boreal Realm Arctic regions of Europe, Asia and North America, but can also be found further south in Britain (Scotland, North Sea and eastern England) and Poland .

*Perisphinctes* (*Dichotomosphinctes*) *antecedens* Salfeld 1914

Fig. 11, c - d

*Material*: Fragment of body chamber of one large ammonite cut by edge of core;

well 22/5b-8, depth 11 549 ft. (3 520.2 m).

*Dimensions:* D. est. 160 mm, Wh.40.2 mm (25.1 %), Wb. 18.6 mm (11.6 %),

Length of section of whorl est. 700 pRn. 10/1/2, sRn 20/1/2,

Calculated for ¼ whorl est. 900 pRn 13/1/2, sRn 26/1/2.

*Description:* Part of a large evolute ammonite with slightly curved whorl sides and rounded venter; umbilical edge rounded but incompletely visible; moderately well spaced sharp primary ribs, at mid-whorl 3 mm wide with flat inter-rib spaces 4mm wide; ribs are slightly rursiradiate on umbilical edge becoming straight on whorl sides then branching at 70% of whorl height into two secondary ribs that curve forward onto venter and continue uninterrupted over venter.

*Discussion:* Although this is only a small part of a large ammonite the shape and proportions of the body chamber together with the pattern of ribbing are identical with specimens of *P.* (*D.*) *antecedens* Salfeld described and figured by Enay (esp. pl. 28, fig. 1). Enay (p. 477) comments that the species is more variable in the southern Jura than in England or northern Germany*. P.* (*D.*) *antecedens* is widespread, including migration into the Subboreal basins of northern Scotland, the Hebrides and Moray Firth Basins, and now also in the North Sea. It is characteristic of the Middle Oxfordian Boreal Maltonense Subzone of the Densiplicatum Zone, approximately equivalent to the Submediterranean Antecedens Subzone of the Plicatilis Zone.