MorphCol supplement #20 – Tilting (Roll) Experiments in AMOR 3.17. Finding a solution for the "G. miocenica problem"

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Document as pdf (1.39 MB)

Introduction

Until AMOR 3.17 automated orientation (AutoTilt) of menardiforms into keel position was programmed under the assumption of symmetrical biconvex profiles in keel view. The keel-view area increases as the tilt (Roll) angle deviates from the horizontal position of the slide and attains a minimum if the shell stands upright in perfect keel-position. If the geometry of the shells shows asymmetry in keel-view, such as in G. miocenica (umbilico-convex shells, i.e. flat on spiral side, convex on umbilical side, see Figure 1), the implemented algorithm leads to oblique positioning of the shell. Equally difficult is the automatic positioning if the shells are spiro-convex in keel view (as was often experienced with shells of G. multicamerata). Automatic orientation into keel-position with AMOR degrades as asymmetry of the shells increases in keel view. These difficulties were coined the "G. miocenica problem", see initial experiments described in Knappertsbusch (2011). In the following report these problems are investigated in more detail using a specimen of G. menardii (symmetric, biconvex), a specimen of G. miocenica (asymmetric, weakly umbilico-convex), and a specimen of G. truncatulinoides (asymmetric, extremely umbilico-convex).

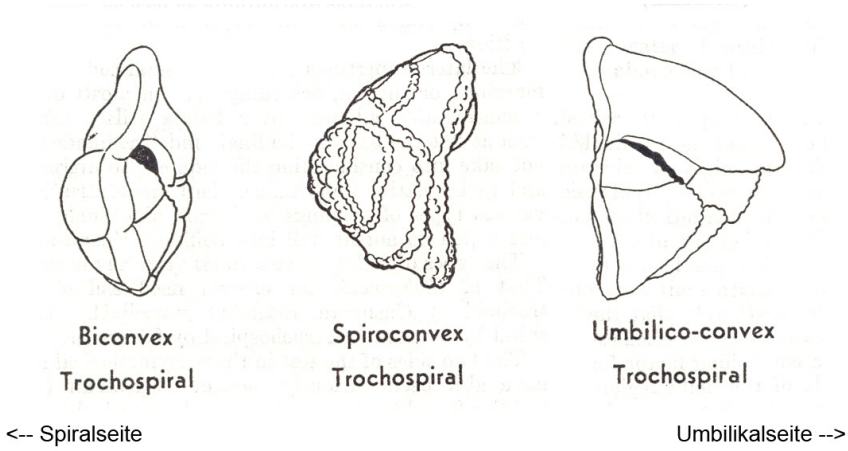

Figure 1 - "Symmetric"biconvex profile (G. menardii, left), asymmetric spiroconvex profile (R. contusa, middle), and extremely asymmetric umbilico-convex profiles (G. truncatulinoides, right). Image courtesy from Bolli et al. (1957), Text Figure 2.

Definitions

The following keel view measurements were performed as a function of the tilt (Roll) position: Spiral area, umbilical area, spiral length a, umbilical length b, and total area (see Figure 2 for G. miocenica).

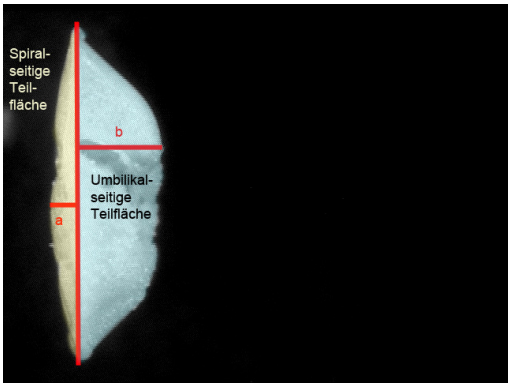

Figure 2 – Definitions, illustrated for the case of G. miocenica. The spiral area (orange) is separated from the umbilical area (blue) by a vertical line, that passes centrally through the extreme points of the upper and lower keel region. Line a is the width of the spiral area, line b is the width of the umbilical area.
The spiral area is the partial area on the spiral side, the umbilical area is the area on the umbilical side, both together totalling to the total area. Length a is the width of the spiral area, length b is the width of the umbilical

area. The spiral area is separated from the umbilical area by a vertical line, which passes through the mean of the X-coordinates of the uppermost and lowermost point of the periphery of the shell (see Figure 2).

Experimental settings in AMOR
Image series were captured in the manual mode of AMOR 3.17. Tilting (Roll) increments were 1 mouse click at normal sensitivity (1 mouse click at normal sensitivity corresponds to a tilting angle of 1.5°, see MorphCol Suppl. #18, and Tests in AMOR 3 and AMOR 3.1 from 17 March 2009).

Sequence of operations in the manual mode:

AutoCenter
Tilt (Roll)
Autofocus, reading of the Roll position in the AMOR window
Capture image
Tilt (Roll, 1 mouse click)
Repeat sequence

Tilting to the right side (slide inclined to the right side) gives negative steps of the Roll position (images R0001, R0002, . . ., R0022). Tilting to the left side (slide is inclined to the left side) gives positive steps of the Roll position (images L0001, L0002, . . ., L0022). At the horizontal position the Roll position is 0 (Image N0000).

Magnifications used:
2.49x for G. menardii (reading at AMOR).
3.89x for G. miocenica (reading at AMOR).
3.89x for G. truncatulinoides (reading at AMOR).

Materials
The following samples were used in this test series:

G. menardii: DSDP 502A-1H-1, 15-20cm, 100-500 micrometers, 2/128 split, "menardiforms keep". Specimen now mounted in slide "Specimens to image, 1.3.2004", Field 32.
G. miocenica: ODP 925B-9-5, 92.5-93.5cm, Slide a, Specimen 4301.
G. truncatulinoides: VICOMED 1 (Mediterranean Sea), Ki04, 90-1.5cm. ". Specimen now mounted in slide "Specimens to image, 1.3.2004", Field 31.

Image processing and measurements
After collection of images, they were transferred to Macintosh, where they were processed using Wayne Rasband's freeware software Nih-Image 1.60. Morphometric measurements of the keel views were done in two ways and are illustrated in Figures 3 and 4 below: The first applied Manual Outlining of the areas of interest using the polygon-tool in Ni-Image (designated with MO in the graphs below). The second method is more towards semi-automation and applied the Density Slicing tool in Nih-Image (labelled with DS in the graphs shown below). While MO was initially applied to G. miocenica and G. truncatulinoides, the DS method was applied to G. menardii as this second method is much faster.

The sequence of image processing operations in Nih-Image were the following ones:

Manual Outlining (MO) method:

Open image
Smooth
Using the rubber band: Locate the lowest point (coordinates XL,YL) in the lower keel region, then locate the highest point (coordinates XH,YH) in the upper keel region, estimate the the arithmetic mean XM from XL and XH).
Draw vertical line through XM, giving the spiral and the umbilical areas of the keel view.
Save image
Using the polygon tool: manually outline spiral area

measure (area), save to Excel sheet
Determine length a (using rubber band), save to Excel sheet
Revert to saved
Using the polygon tool: manually outline umbilical area
measure (area), save to Excel sheet
Determine length b (using rubber band), save to Excel sheet
Close image
Repeat sequence with next image

Density Slicing (DS) method:

Open image
Smooth
Using the rubber band: Locate the lowest point (coordinates XL,YL) in the lower keel region, then locate the highest point (coordinates XH,YH) in the upper keel region, estimate the the arithmetic mean XM from XL and XH).
Draw vertical line through XM, giving the spiral and the umbilical areas of the keel view.
Save image
Make ROI with area on umbilical side, Fill with black, deselect.
Density Slice spiral area
measure (area), save to Excel sheet
Determine length a (using rubber band), save to Excel sheet
Revert to saved
Make ROI with area on spiral side, Fill with black, deselect.
Density Slice umbilical area
measure (area), save to Excel sheet
Determine length b (using rubber band), save to Excel sheet
Close image
Repeat sequence with next image

Results

Measurements of the spiral and umbilical partial areas as well as spiral and umbilical length a and b depend on the position of the vertical separation line. A gif animation to illustrate how the separation line varies while tilting the specimen is shown for the specimen of G. truncatulinoides in Figure 3.

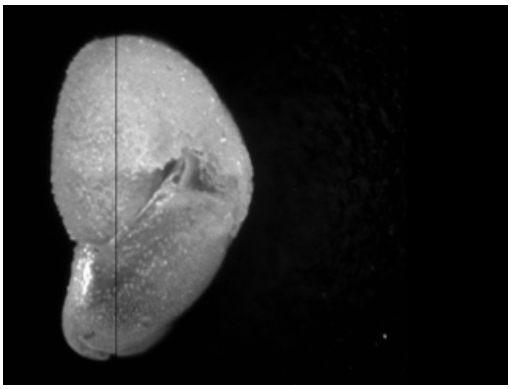

Figure 3 – Animated sequence of G. truncatulinoides and the vertical line separating the spiral from the umbilical area while tilting. The line remains considerably stable.

Measurements were then plotted and composed in Figures 4 and 5. In Figure 4 images of G. miocenica (in the middle row) were outlined using the Manual Outlinig method, while in Figure 5 images of G. miocenica were outlined using the Density Slicing method. The data (areas in square pixels, lengths a and b in pixels) are given in the Appendix in Tables 1 and 2 (G. miocenica, using MO and DS, respectively), Table 3 (G. truncatulinoides, using MO), and Table 4 (G. menardii, using DS).

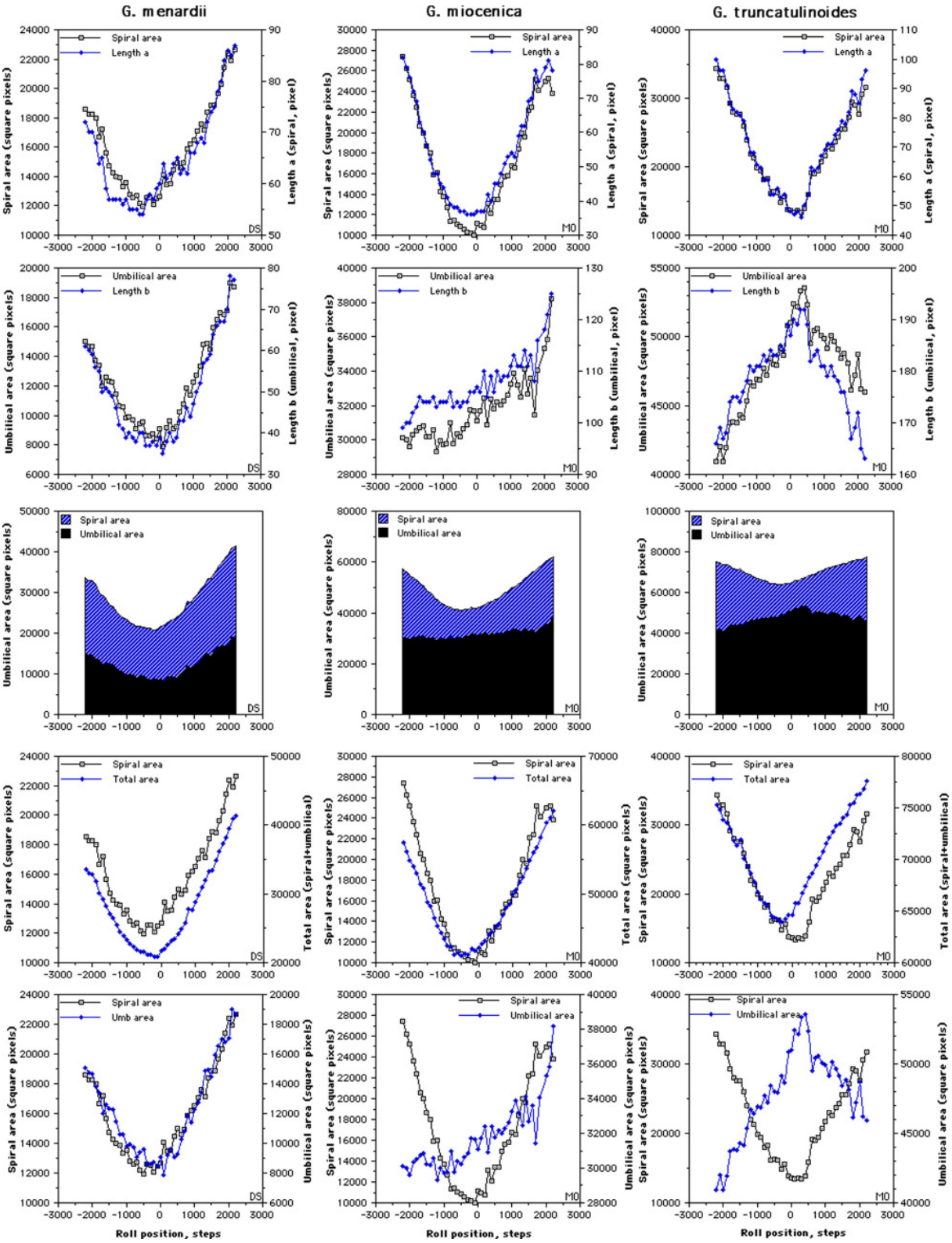

Figure 4. Matrix of diagrams showing the results of the Roll-Experiment for G. menardii (symmetric-biconvex; left column), G. miocenica (asymmetric & weakly umbilico-convex; middle column), and G. truncatulinoides (asymmetric & strongly umbilico-convex; right column). All measurements are in function of the Roll position. Roll positions are negative when the slide is inclined to the right side. Roll position is zero if the slide is in horizontal position, and positive, when the slide is inclined to the left side. Measurements include the spiral area & spiral length a (first row); umbilical area & umbilical length b (second row); spiral & umbilical areas cumulating to the total area (third row); spiral area & total area (fourth row); and Spiral area & umbilical area (lowermost row). Labels in the lower right corner of each graph indicate the method of area determination, i.e. DS indicates Density Slicing, while MO indicates Manual Outlining using the polygon tool in Nih-Image.

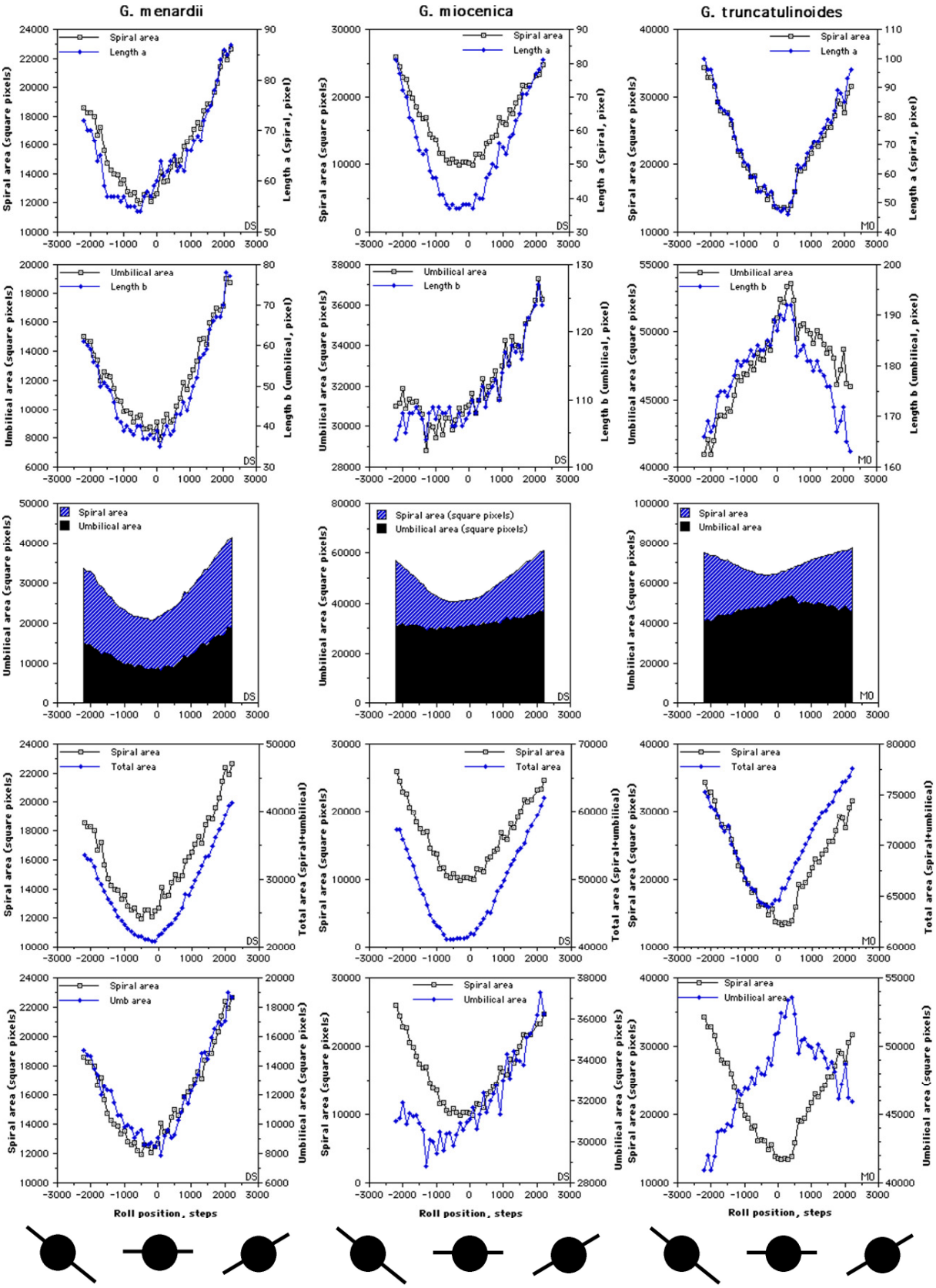

Figure 5. Matrix of diagrams showing the results of the Roll-Experiment for G. menardii (symmetric-biconvex; left column), G. miocenica (asymmetric & weakly umbilico-convex; middle column), and G. truncatulinoides (asymmetric & strongly umbilico-convex; right column). All measurements are in function of the Roll position. Roll positions are negative when the slide is inclined to the right side. Roll position is zero if the slide is in horizontal position, and positive, when the slide is inclined to the left side. Measurements are the spiral area & spiral length a (first row); umbilical area & umbilical length b (second row); spiral & umbilical areas cumulating to the total area (third row); spiral area & total area (fourth row); and Spiral area & umbilical area (lowermost

row). Labels in the lower right corner of each graph indicate the method of area determination, i.e. DS indicates Density Slicing, while MO indicates Manual Outlining using the polygon tool in Nih-Image. The black pictograms indicate the direction of inclination of the slide.

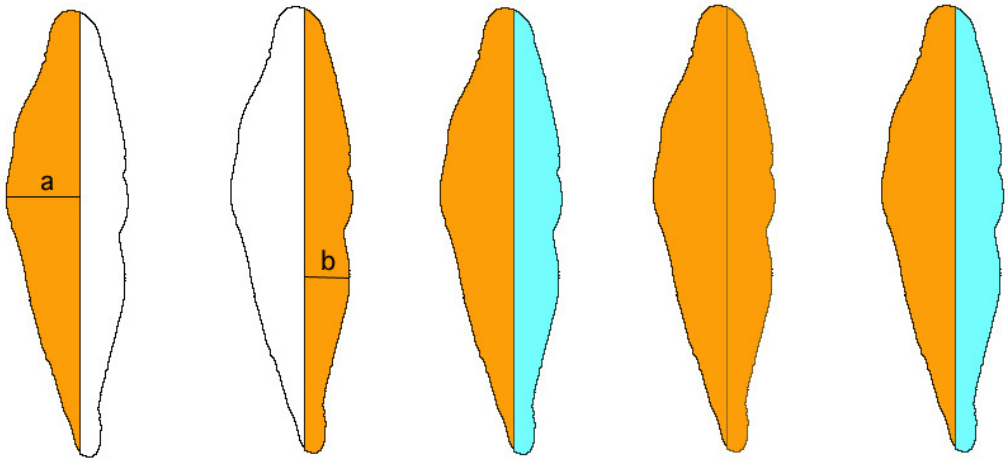

Figure 6 – Illustration of morphological parameters that are compared in the diagrams of Figures 4 and 5: Spiral area & spiral length a (first row in Figures 4 and 5); umbilical area & umbilical Length b (second row in Figures 4 and 5); Spiral & umbilical areas (third row in Figures 4 and 5); Total area (fourth row in Figures 4 and 5), and Spiral & umbilical areas, again, (in last row of Figures 4 and 5).

Conclusions

1. Spiral area and the spiral length a are always well correlated to each other and display minimum functions in all three types of profiles (symmetrical biconvex, asymmetric weakly umbilico-convex, and asymmetric strongly umbilico-convex.
2. Umbilical area and umbilical length b show also good correlation to each other within each profile type, however parameters show changing characteristics depending on the profile type: In case of G. menardii (symmetric biconvex) the curves show a minimum function. In case of G. miocenica (asymmetric, weakly umbilico-convex) values do not follow a minimum function; while in G. truncatulinoides both curves show a maximum function behaviour.
3. Summing the spiral area and umbilical area up to give the total area all three profile types give a minimum function, however with changing degree of contributions from each of the two portions.
4. The minima positions between the spiral area and the total area differ from each other, depending on the profile type.
5. I conclude, that for finding a good minimum function, not the total area should be used for automated keel orientation but rather the spiral area.
6. There might be a threshold (depending on the ratio of a to b) where each of the characteristic profile type might be applied.
7. No tests have yet been made with asymmetric umbilico-convex profiles.

References

Bolli., H.M., Loeblich, A.R. Jr. and Tappan, H. (1957). Planktonic foraminiferal families Hantkeninidae, Orbulinidae, Globorotaliidae and Globotruncanidae. In: Loeblich, A.R., Tappan, H., Beckmann, J.P., Bolli, H.M., Montanaro Gallitelli, E., and Troelsen, J.C. (eds.). Studies in Foraminifera. United States National Museum Bulletin 215, pp. 3-60.

Knappertsbusch, M. (2009). MorphCol supplement #18. Vertical correction for the Auto-Focus in AMOR 3.5. 10 p. http://pages.unibas.ch/museum/microfossils/Research/MORPHCOL/Start.html

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Appendix - Raw data

Raw images and data can be downloaded as zip file (10.6 MB).

Table 1 – Measurements for G. miocenica, using MO for determination of spiral and umbilical areas.

Roll position, steps	Roll position Mouse clicks	Image	Spiral area, pixels^2	Umb. area, pixels^2	Spiral Length a, pixel	Umbilic Length b, pixel	Total Area (DS), pixels^2	Total area (Spiral Area+Umb Area), pixels^2
-2200	-22	R0022	27396	30111	82	99	55609	57507
-2100	-21	R0021	26211	30006	79	100	55858	56217
-2000	-20	R0020	25198	29612	76	100	53865	54810
-1900	-19	R0019	23664	30323	72	102	53355	53987
-1800	-18	R0018	22416	30531	69	103	51677	52947
-1700	-17	R0017	20609	30728	63	105	50706	51337
-1600	-16	R0016	19979	30838	60	104	49584	50817
-1500	-15	R0015	18660	30203	56	104	48579	48863
-1400	-14	R0014	18006	30172	52	104	47644	48178
-1300	-13	R0013	15927	30597	48	105	46159	46524
-1200	-12	R0012	16044	29317	48	103	44887	45361
-1100	-11	R0011	14278	29980	45	104	44023	44258
-1000	-10	R0010	13724	29738	44	104	42685	43462
-900	-9	R0009	12684	29775	41	104	42725	42459
-800	-8	R0008	11344	30975	39	106	41854	42319
-700	-7	R0007	11405	29767	38	103	41309	41172
-600	-6	R0006	11093	30374	38	104	40837	41467
-500	-5	R0005	10873	30201	37	103	40850	41074
-400	-4	R0004	10599	30645	37	104	40847	41244
-300	-3	R0003	10317	30885	36	104	41283	41202
-200	-2	R0002	10225	31729	36	106	41733	41954
-100	-1	R0001	10002	31683	36	106	41408	41685
0	0	N000	11123	31101	37	107	41611	42224
100	1	L001	10972	31714	37	106	41997	42686
200	2	L002	10748	32416	37	110	42063	43164
300	3	L003	13120	30893	42	105	43116	44013
400	4	L004	12082	32376	40	109	43404	44458
500	5	L005	13474	31788	45	106	44513	45262
600	6	L006	13439	32185	45	110	45118	45624
700	7	L007	14920	32028	48	108	46407	46948
800	8	L008	15660	32261	51	109	47853	47921
900	9	L009	15837	32604	53	109	48481	48441
1000	10	L010	16741	33273	54	111	49305	50014
1100	11	L011	16579	33886	53	113	50591	50465
1200	12	L012	18427	33188	59	111	51639	51615
1300	13	L013	19954	32475	62	111	52228	52429
1400	14	L014	19572	34130	62	114	53399	53702
1500	15	L015	22145	32676	69	111	54384	54821
1600	16	L016	22420	33594	70	113	54677	56014
1700	17	L017	25208	31452	78	108	56393	56660
1800	18	L018	24099	34057	75	116	56673	58156

1900	19	L019						
2000	20	L020	24970	35339	79	118	59377	60309
2100	21	L021	25227	35849	81	121	60277	61076
2200	22	L022	23836	38190	78	125	60735	62026

Table 2 – Measurements for G. miocenica, using DS for determination of spiral and umbilical areas.

Roll position, steps	Roll position Mouse clicks	Image	Spiral area, pixels^2	Umb. area, pixels^2	Spiral Length a, pixel	Umbilic Length b, pixel	Total area (Spiral Area+Umb Area), pixels^2
-2200	-22	R022	25994	31007	81	104	57290
-2100	-21	R021	24492	31162	77	106	57298
-2000	-20	R020	22900	31883	72	108	55844
-1900	-19	R019	22643	30877	70	105	54375
-1800	-18	R018	20571	31369	64	108	53177
-1700	-17	R017	19922	31230	63	108	51927
-1600	-16	R016	18526	31279	58	109	50285
-1500	-15	R015	17414	30924	54	108	48448
-1400	-14	R014	16871	30574	53	107	47759
-1300	-13	R013	17028	28806	54	104	46253
-1200	-12	R012	14528	30082	48	108	44787
-1100	-11	R011	13855	29983	46	109	43770
-1000	-10	R010	13640	29422	46	107	43172
-900	-9	R009	11590	30453	41	109	42895
-800	-8	R008	11652	29567	41	108	41929
-700	-7	R007	10531	30398	38	108	41134
-600	-6	R006	10213	30422	37	109	41166
-500	-5	R005	10793	29806	38	106	41095
-400	-4	R004	10240	30325	37	106	41297
-300	-3	R003	9879	30912	37	108	41235
-200	-2	R002	10244	30575	38	106	41270
-100	-1	R001	10235	30965	38	107	41395
0	0	N000	10111	31074	38	108	42007
100	1	L001	9924	31646	37	110	41946
200	2	L002	11512	30640	41	108	42677
300	3	L003	11407	31315	40	110	43455
400	4	L004	11049	32386	40	112	44196
500	5	L005	13032	31420	46	109	45174
600	6	L006	13285	31984	47	111	45020
700	7	L007	14129	32331	50	112	46815
800	8	L008	14394	32771	49	113	48182
900	9	L009	16893	31355	56	110	48876
1000	10	L010	16222	33020	55	114	49840
1100	11	L011	15917	34274	53	117	50964
1200	12	L012	18107	33106	58	115	52069
1300	13	L013	17561	34446	59	118	52810

1400	14	L014	19143	33992	63	117	54135
1500	15	L015	20055	33963	65	118	54509
1600	16	L016	21710	33765	71	116	55251
1700	17	L017	21530	35079	71	121	57034
1800	18	L018	21761	35285	73	122	57949
1900	19	L019					
2000	20	L020	23256	36209	77	124	59492
2100	21	L021	23323	37268	78	127	60904
2200	22	L022	24714	36261	81	124	62070

Table 3 – Measurements for G. truncatulinoides, using MO for determination of spiral and umbilical areas.

Roll position, steps	Roll position Mouse clicks	Image	Spiral area, pixels^2	Umb. area, pixels^2	Spiral Length a, pixel	Umbilic Length b, pixel	Total area (Spiral Area+Umb Area), pixels^2
-2200	-22	R0022	34316	40964	100	166	75280
-2100	-21	R0021	32828	42024	96	169	74852
-2000	-20	R0020	32923	40961	96	167	73884
-1900	-19	R0019	31595	41944	91	168	73539
-1800	-18	R0018	29227	43727	85	174	72954
-1700	-17	R0017	28005	43852	83	175	71857
-1600	-16	R0016	27609	43774	82	175	71383
-1500	-15	R0015	27627	44295	81	174	71922
-1400	-14	R0014	25935	44127	79	176	70062
-1300	-13	R0013	23972	45366	73	178	69338
-1200	-12	R0012	21956	46681	68	181	68637
-1100	-11	R0011	21325	46446	68	180	67771
-1000	-10	R0010	19889	46905	64	181	66794
-900	-9	R0009	19361	46834	63	181	66195
-800	-8	R0008	18067	47718	59	183	65785
-700	-7	R0007	18312	47236	59	182	65548
-600	-6	R0006	16086	48463	54	184	64549
-500	-5	R0005	16317	48001	54	183	64318
-400	-4	R0004	16207	47939	56	183	64146
-300	-3	R0003	14820	49132	53	185	63952
-200	-2	R0002	15630	48632	54	184	64262
-100	-1	R0001	13795	50837	49	189	64632
0	0	N000	13639	51008	48	187	64647
100	1	L001	13375	52405	47	190	65780
200	2	L002	13564	52159	48	189	65723
300	3	L003	13393	53352	46	192	66745
400	4	L004	13852	53548	50	192	67400
500	5	L005	15909	52355	54	189	68264
600	6	L006	19202	49489	63	182	68691
700	7	L007	18963	50431	62	183	69394
800	8	L008	19490	50588	63	184	70078
900	9	L009	20721	50089	67	181	70810

1000	10	L010	21654	49913	69	181	71567
1100	11	L011	22952	49155	71	179	72107
1200	12	L012	22559	50127	71	181	72686
1300	13	L013	23672	49636	74	179	73308
1400	14	L014	24340	49122	76	178	73462
1500	15	L015	25579	48417	79	176	73996
1600	16	L016	25526	48828	78	176	74354
1700	17	L017	27197	48111	82	172	75308
1800	18	L018	29355	46156	89	167	75511
1900	19	L019	29003	47234	88	169	76237
2000	20	L020	27635	48700	85	172	76335
2100	21	L021	30591	46226	93	165	76817
2200	22	L022	31648	45958	96	163	77606

Table 4 – Measurements for G. menardii, using DS for determination of spiral and umbilical areas.

Roll position, steps	Roll position Mouse clicks	Image	Spiral area, pixels^2	Umb. area, pixels^2	Spiral Length a, pixel	Umbilic Length b, pixel	Total area (Spiral Area+Umb Area), pixels^2
-2200	-22	R022	18571	15043	72	61	33614
-2100	-21	R021	18252	14708	70	60	32960
-2000	-20	R020	18252	14651	70	59	32903
-1900	-19	R019	17996	13767	68	56	31763
-1800	-18	R018	16694	13427	64	55	30121
-1700	-17	R017	17226	12023	65	50	29249
-1600	-16	R016	15642	12584	59	51	28226
-1500	-15	R015	14738	12319	57	50	27057
-1400	-14	R014	14266	12252	57	49	26518
-1300	-13	R013	13990	11442	57	46	25432
-1200	-12	R012	13894	10616	57	42	24510
-1100	-11	R011	13325	10606	56	41	23931
-1000	-10	R010	13556	9830	57	39	23386
-900	-9	R009	12804	9914	55	40	22718
-800	-8	R008	12574	9723	55	39	22297
-700	-7	R007	12722	9081	55	38	21803
-600	-6	R006	12171	9426	54	40	21597
-500	-5	R005	11963	9597	54	40	21560
-400	-4	R004	12587	8592	57	37	21179
-300	-3	R003	12557	8602	58	37	21159
-200	-2	R002	12071	8764	57	38	20835
-100	-1	R001	12472	8454	59	37	20926
0	0	N000	12659	9079	60	39	21738
100	1	L001	14098	7868	64	35	21966
200	2	L002	13468	9191	61	38	22659
300	3	L003	13548	9621	62	40	23169
400	4	L004	14445	9065	64	38	23510

500	5	L005	14968	9237	65	39	24205
600	6	L006	14629	10251	62	43	24880
700	7	L007	14910	10797	63	43	25707
800	8	L008	15895	11839	62	46	27734
900	9	L009	16213	11374	66	44	27587
1000	10	L010	16515	12272	66	47	28787
1100	11	L011	17096	12720	68	50	29816
1200	12	L012	17607	13367	69	52	30974
1300	13	L013	17162	14843	68	57	32005
1400	14	L014	18399	14911	72	58	33310
1500	15	L015	18882	14496	74	59	33378
1600	16	L016	18847	15945	75	64	34792
1700	17	L017	19656	16512	78	66	36168
1800	18	L018	20308	16984	80	67	37292
1900	19	L019	21409	16823	84	67	38232
2000	20	L020	22380	17088	86	70	39468
2100	21	L021	21914	19000	85	78	40914
2200	22	L022	22649	18696	87	77	41345