Paleoecology of Fossil Clusters

The Paleoecology of Some Middle Devonian Fossil Clusters, Erie County, New York

By

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Scope and Contents: Extensive bedding plane exposures in the Ludlowville shales along Cazenovia Creek near Spring Brook, New York display the spatial distribution of the skeletal remains from a marine faunal assemblage. Fossils typically occur in aggregates that are subcircular in plan view and plano-convex in cross-section with the convex side down. The clusters measure 1 meter in diameter and 2 centimeters thick at the center. This dispersion pattern has led to a general consideration of the different mechanisms responsible for creating fossil aggregations. Possible mechanisms, a spectrum from biological to geological, have been categorized into reproductive, ecological, postmortem redistributional, and preservational modes of formation.

Quantitative sampling of the most abundant species, _Ambocoelia umbonata_, in four successive 5 millimeter layers within three clusters was carried out to determine which process is responsible for cluster formation. Between level variation in shell parameters demonstrates that fragmentation, distortion and valve ratios are independent of _trends_ in position, density, and disarticulation. The trends are not controlled by geological agents, but rather result from

ecological conditions. Furthermore, the size distributions of *Ambocoelia* are bimodal and have to be explained on a biological basis. This has led to an interpretation of cluster development involving initiation by occassional spat survival on a somewhat "lethal" substrate, subsequent succession and regulation by ecological requirements, and final termination due to failure of spat recruitment probably because of fecal and/or decay toxin buildup.

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Chapter 1

INTRODUCTION

This thesis reports a study of brachiopod clusters in the Middle Devonian, Wanakah shale member of the Ludlowville Formation in western New York. For many years, paleontologists have noted that fossils are not always randomly dispersed on bedding surfaces. In fact, individuals of some species have been found in aggregates so frequently that the species epith et gregarius/gregaria recur in several taxonomic groups. For example; the trilobites *Bronteopsis gregaria* and *Blainia gregaria*, the ostracod *Geisina gregaria*, the crinoid *Decadocrinus gregarius*, the bivalve *Cypricardella gregaria* and the brachiopod *Brevispirifer gregarius*. The phenomena of clustering is by no means restricted to different single species, but may include two species (Hallam, 1961) or a great variety of species (Sarle, 1901; Crosfield and Johnston, 1914; Cummings, 1932; Parkinson, 1943). The latter types of clustering have often been referred to as 'reefs' because of their rather distinctive mound shapes and seem to have a biological origin. Other types of polyspecific clusters include concretionary preservation (Waage, 1964) and lenses of fossil debris (Elias, 1949). The goals of this thesis are to suggest possible mechanisms that could create skeletal aggregation and decide to which of these mechanisms the Middle Devonian clusters may be allied.

General Character of the Clusters

The clusters studied are roughly circular to elliptical in plan and plano-convex in cross-section, with the plane surface upward. Dimensions are a maximum of one meter in diameter and about two centimeters thick at the center (Plate I). Jordan (1968) has estimated a compaction factor of about 5 for the containing shales. Pre-compaction thickness was, thus, approximately 10 centimeters, yielding a thickness-breadth ratio of about 1 to 10. The boundaries are slightly irregular, but always quite distinct with an obvious concentration of shells next to barren shales (Plate II). Even in the elliptical clusters, the shells are distributed rather uniformly without marginal or axial concentrations to indicate a directional component of accumulation. On a larger scale, the clusters themselves appear to be randomly dispersed with nearest neighbours from two to several meters away. In adjacent clusters the base and top of one can be observed stratigraphically offset to the base and top of another; origin and termination are not 'in phase'.

Taxonomic diversity within clusters is high. The assemblage includes a variety of brachiopods as well as bryozoans, trilobites, crinoids and ostracods with minor numbers of gastropods, bivalves and corals. The clusters are dominated in bulk and numbers by the spirifer *Ambocoelia umbonata* (Conrad). This species, because of its abundance, has supplied the analytical data for the paleoautecologic approach used in this thesis. Research embracing all aspects of the fauna is beyond the scope of the present study.

Location of the Clusters

The clusters were sampled on large bedding plane exposures on the north side of Cazenovia Creek about 300 meters downstream from Northrup Road near the small community of Spring Brook, Erie County, New York, 7 miles southeast of Buffalo (Figure 1). The site is well known, both by geologists and amateur fossil collectors.

Access to the bedding surfaces is restricted to the late summer and fall of each year as they are only exposed during low water. At such times several tens of square meters of individual bedding surfaces are available for sampling.

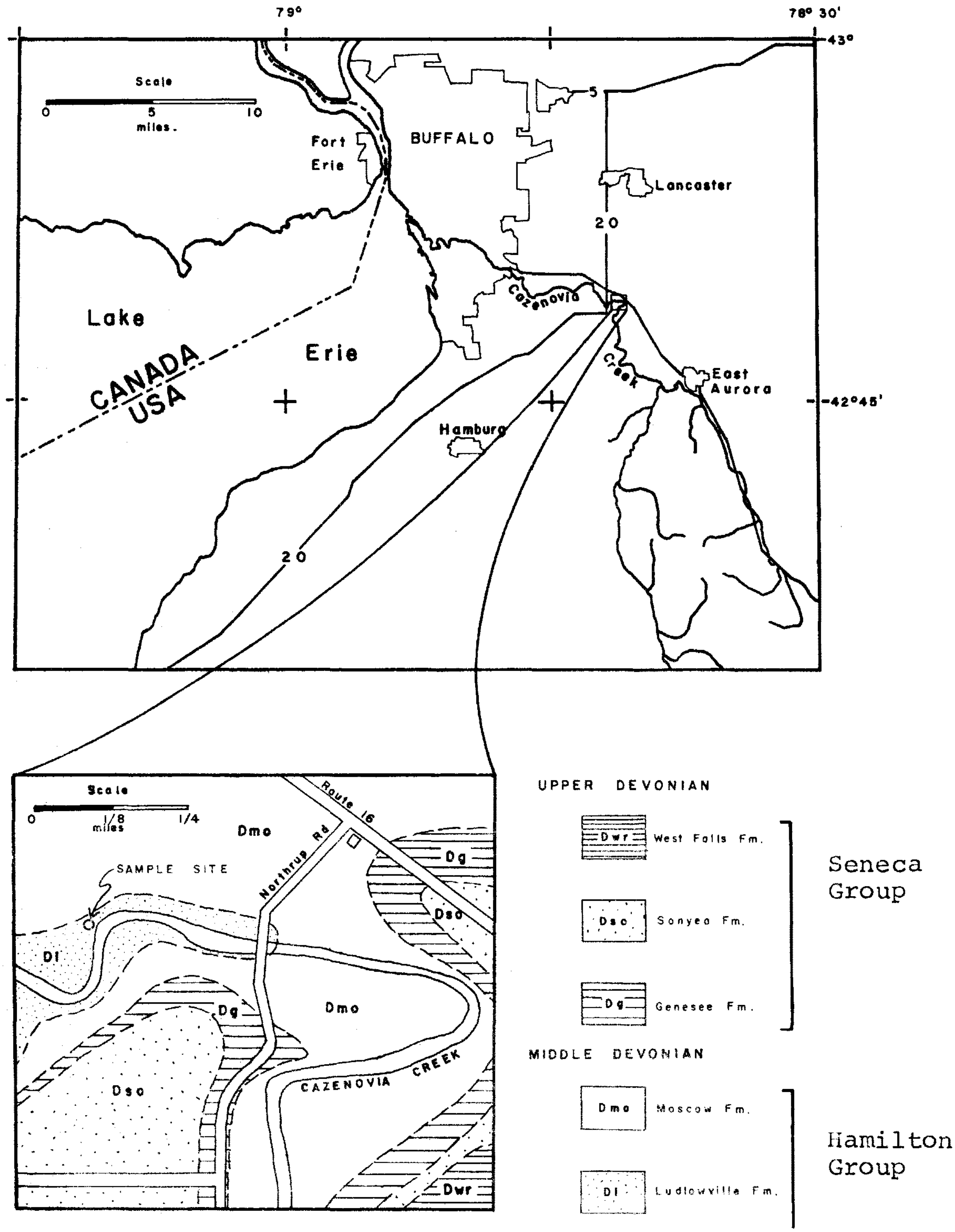


Figure 1
Sample location map

Fossil clusters of the type discussed also occur fifteen miles to the southwest where the same stratigraphic units outcrop in the Lake Erie shore Cliffs. The same type of fossil clusters undoubtably occur elsewhere, but these were the only localities closely examined.

Stratigraphic Setting

Three clusters, labelled Alpha, Beta and Gamma, were sampled, 353, 350 and 351 centimeters respectively below the base of the Tichenor limestone member of the Ludlowville. Beta and Gamma were 4 meters apart, and 15 meters from Alpha. In this locality similar clusters occur from 1/2 meter below to one meter above a conspicuous carbonate concretion bed at the position of Grabau's *Athyris spiriferoides* bed (Figure 2).

Paleogeographically the Ludlowville deposits in this area were situated on the northwestern extremity of the Middle Devonian Appalachian Basin with the Michigan Basin lying to the northwest across the Algonquin arch. The light grey shales of the Wanakah member show an increase in sandy facies further to the east (Cooper, 1930). Sand was presumably derived from the Catskill deltas that were building out over the Appalachian Basin in eastern New York. The location then was distant from shore with rather slow accumulation of sediments indicated by the thin section in this region.

The Wanakah shales lack current features and bands or laminae of siltstones. They vary slightly in fissility but are otherwise uniform in weathering habit and appearance with only limestone concretions and fossils to break the lithologic monotony.

The bedding has a regional dip to the southeast of about 10 meters per kilometer, imperceptable in outcrop.

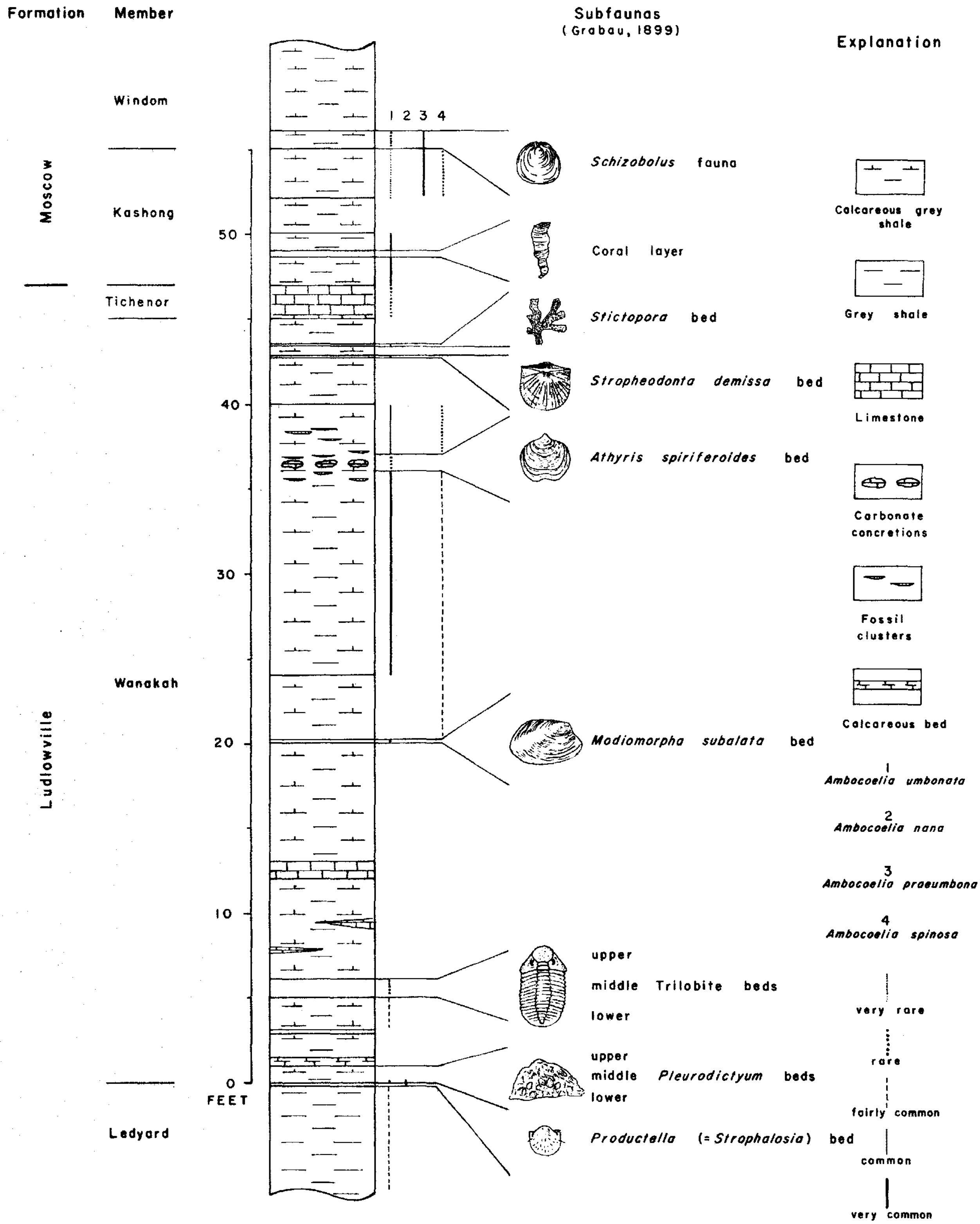


FIGURE 2

Stratigraphic column with abundance of various *Ambocoelia* (after Grabau, 1899)

A joint set, sometimes infilled with crystaline calcite, trends northeast-southwest.

Previous Work

No study of fossil clustering has been carried out in the Hamilton Group. The only paleoecologic study of brachiopod clusters to date has been Hallam's (1961) study of life assemblages from the Jurassic Marlstone Rock-Bed of Leicestershire. The Marlstone Rock clusters are ellipsoidal in shape with the long axis parallel to bedding and they range in size up to 50 centimeters in width and 15 centimeters in height. They are composed of _Tetrarhynchia tetrahedra_ and _Lobothyris punctata_. A size-frequency analysis of 4000 shells collected from seven different nests indicated dissimilar polymodal size distributions for each species. This, together with supporting evidence of fossil orientation and physical features observed in the field, led Hallam to believe that these clusters were true colonial associations and that they were killed by a sudden change of environment which resulted in preservation of discrete clusters.

The middle Devonian clusters studied in this thesis differ from Hallam's in several ways. The total fauna is more diverse which suggests a different, if not more complex mode of development. Cluster shape is different and size is more uniform. Since initiation and termination of development was not simultaneous in adjacent clusters, neither 'origin' nor 'extinction' of the colonies was the result of a sudden widespread environmental change. In summary, the middle Devonian clusters resemble the Marlstone Rock-Bed clusters only as far as they both represent fossil aggregations that contain brachiopods.

Previous work on the paleontology and stratigraphy of the Hamilton Group is quite extensive. General paleontology studies have been carried out by Hall (1860), Hall and Clarke

(1892-1895), Grabau (1899) and others. Later paleontology studies have concentrated on particular taxonomic groups. Bryozoans have been studied by Bassler (1939) and Boardman (1960); ostracods by Kesling (1953), Smith (1956) and Peterson (1966); corals by Busch (1941); Ross (1953), Ehlers and Stumm (1953), and Stumm and Watkins (1961); crinoids by Goldring (1923, 1934, 1950, 1954); sponges by Riemann (1935a), 1935b); cephalopods by Flower (1938); and plants by Arnold (1940). Stratigraphic studies have been carried out by Cooper (1930), Buehler and Tesmer (1963) and Boehme (1964). None of these studies has mentioned the occurrence of fossil clusters in the Wanakah shale member.

The principal previous study of the species *Ambocoelia umbonata* was that of Hall published in 1860. In western New York this species is stratigraphically confined to the middle and upper Hamilton Group, i.e. between the base of the Ludlowville Formation and the top of the Moscow shale (Grabau, 1899; Buehler and Tesmer, 1963). It is relatively common throughout the Wanakah shale and in the basal portion of the overlying Kashong (Figure 2). The morphology of clustered specimens conforms with Hall's (1860) description and includes the peculiar quadripartite adductor muscle field in the brachial valve which is one of the most diagnostic features of *Ambocoelia* (Plate III). In lateral view, *Ambocoelia umbonata* has a plano-convex shape and adult specimens have incurved beaks which come very close to partially blocking the spacious triangular deltherium. In plan view the shape is semi-circular, the width being slightly greater than the length. The largest shell encountered was 1 cm. in width; the smallest shells were 0.25 mm. in width.

The living habits of ambocoeliids have been interpreted by Caldwell (1967). He notes that the genus seems to be restricted to mud-grade sediments irrespective of composition as they occur in calcareous shales, muddy limestones and bituminous shales. Although most of the ambocoeliids seem to have had a functional pedicle for direct attachment to a mud substrate, ample evidence suggests some rested with their valves directly on a soft mud substrate without pedicle attachment. In particular, the emanuellids, Caldwell suggests, had a functional pedicle during youth which became atrophied due to umbonal incurvature during growth. The older individuals, having lost their tether, toppled into a recumbent position with the convex pedicle valve buried in the soft substrate. <u>Ambocoelia</u> probably retained a functional pedicle throughout ontogeny, but apparently could live in the recumbent position as well. Evidence for direct attachment is the spacious foramen and pedicle collar. Evidence for the recumbent, unattached position are the incurved umbones and highly convex pedicle valve which are features common among other unattached forms (Rudwick, 1965).

Chapter 2

FORMATION OF FOSSIL CLUSTERS

Various workers, mainly Boucot (1953), Johnson (1962) and Fagerstrom (1964), have outlined numerous criteria for the recognition of life, reworked, and transported assemblages of fossils. A criterion which has been mentioned, but rarely used is the dispersion pattern. One reason for its disuse is probably the complexity in types of dispersion and the difficulty in their recognition. Most research concerning the nature and causes of dispersion patterns have been carried out by plant ecologists, e.g. Kershaw (1964). Three dispersion patterns are possible; random, even ("uniform"), and aggregated ("clustered", "contagious"). The observation of dispersion patterns is related to the scale of observation, i.e. what is aggregated on a small scale may be random on a larger scale or vice-versa. Statistical tests are often necessary in order to ascertain the type and scale of dispersion.

The interpretation of dispersion patterns is also complicated by the multitude of ways in which the patterns can arise. Aggregated patterns such as bedding plane groupings, pockets, mounds, lenses and other types of fossil clusters can arise through a variety of processes, a spectrum from biological to geological. Four categories of processes may be distinguished:

1. reproductive
2. ecological
3. postmortem redistributional
4. preservational

Reproductive Processes

Asexual reproduction can lead to two kinds of aggregation.

The first consists of closely knit colonies produced through reproductive budding or fission. Individuals within colonies share common skeletal frameworks or tissues. The frameworks usually have characteristic, genetically controlled internal structures, and an external form that depends more on environmental conditions, a point of tremendous value in paleoecologic interpretation. Fossil colonies of this type include hermatypic corals (Vaughan, 1919), 'unstable' bryozoans (Boardman, 1960), stromatoporoids (Stearn, 1967) and stromatolites (P. Hoffman, pers. comm.). Other colonial organisms, such as the sponges, tunicates and protozoans display these features as well. A second type consists of separated individuals without a connecting framework or tissue, for example process of bud separation or regeneration of fragmented parts creates loose aggregations among certain species of sponges and corals. On a larger scale, aggregates of colonies, formed by colonial growth after fragmentation, could be the result of reproductive processes alone.

Some types of sexual reproduction may also lead to the formation of loose aggregates. The rearing of young in brood chambers by ovoviviparous species produces aggregations because the young often cannot swim or crawl any great distance from the parent. This has been noticed in the bivalve species Gemma gamma (Jackson, 1968). Other groups which are capable of ovoviviparous reproduction include the gastropods and brachiopods (Z. Bowen, pers. comm.) and they are therefore potentially capable of aggregation.

The vast majority of marine invertebrates that reproduce sexually develop free swimming or floating larvae. Since larvae are subject to the visicitudes of the environment, aggregation must be controlled by ecological processes.

Ecological Processes

Although the planktonic larvae of marine invertebrates are widely dispersed they may re-aggregate during settlement and metamorphosis (Knight-Jones, 1951; Johnson, 1959; Jones, 1961). Mechanisms of re-aggregation are difficult to assess but are thought to involve several processes. Turner (1953) argued that the distribution of bivalve larvae is controlled by the same hydrodynamic processes involved in sediment transport and deposition, but Shelbourne (1957) found that oyster larvae are not passively concentrated in quiet eddies but swim actively until they reach a suitable environment. It is known that some larvae, in particular those of barnacles (Knight-Jones, 1953), aggregate by biochemical clues which induce settlement. Despite the variety of mechanisms involved it is sufficient for purposes of this thesis to realize that larvae can re-aggregate on both a large scale (over areas of tens of square meters) or on a small scale (over areas of tens of square centimeters). All sessile groups that produce larvae are potentially capable of re-aggregation and these include bivalves, brachiopods, barnacles, sponges, corals, bryozoans and crinoids.

Inhomogeneity in the physical environment is probably the most obvious cause of aggregation (Wilson, 1958). Boulders or shells on sandy or muddy substrates may provide attachment surfaces for organisms that could not otherwise survive in the general vicinity. This type of aggregation has been inferred by Ziegler, et al. (1968) for clustering in various Silurian marine communities. Other inhomogeneities, like bottom depressions or tidal pools, create microenvironments that can be utilized by organisms which would not normally be present. Patches of algae or crinoids may act as protective screens and provide attachment surfaces for other species. This in turn may attract predators which alter the habitat to the exclusion of earlier members and a localized ecologic succession may take place. Ecologic succession has been reported in the *Mytilus californianus* community (Hewatt, 1935) and there seems no reason why it could not take place in other communities, both recent and ancient.

Postmortem Redistributional Processes

Redistribution of dead organisms requires a transporting agent. In the marine realm, bottom sediment and material on the substrate is generally redistributed by currents. A stable substrate which has topographic relief may affect current velocities and patterns sufficiently to create local sorting or concentration of skeletal material. In many cases the shape of such deposits is distinctly depositional and consequently easily recognized. Shell debris in the troughs of ripple marks and sand dunes or behind boulders and organic mounds display characteristics that can be related to various current conditions. In some cases both *in situ* and extraneous shell material may accumulate to form fossil aggregations. Intertidal salt marsh pools tend to collect shell debris during flood and ebb tides and during storms. Since these pools usually contain a diverse living fauna as well, subsequent infilling and burial could produce mixed fossil aggregations. Similarly, patches of algae, bryozoans, corals or crinoids might trap material moving along the bottom.

In environments where the substrate is unconsolidated, various scour and fill processes can create local shell concentrations. Most scour features have characteristic shapes and would therefore be recognized as such. It has been suggested that whirlpool-like turbulence could create circular bowl-shaped shell aggregations, but to my knowledge, there is no report of this type of occurrence.

Preservational Processes

Preservation of fossils within concretions is the most obvious diagenetic control affecting spatial distribution of fossils. In thin fossil beds there may be a complete gradation from preservation of fossils both inside and outside concretions to complete obliteration of fossils outside concretions. In other cases (Waage, 1964), the shells were definitely clustered before concretion formation; a situation demanding non-preservational explanations. This situation is disconcerting, however, where pelagic animals are concerned. Clusters of ammonites, for instance, can only be explained by catastrophic mortality imposed on some sort of feeding or schooling aggregate.

Chapter 3

STUDY PROCEDURE

A stratified sampling design was employed in order to gather quantitative data related to various properties of the fossils within clusters. The number of levels in the design was limited by the precision with which samples could be removed in successive layers of equal thickness. Fissility planes parallel to bedding, i.e. parallel to the upper surface of clusters, permitted removal of layers 1/2 centimeter in thickness with remarkable consistency. This led to a four level stratification in sampling an entire cluster from top down to base.

At each level of the cluster the surface was gridded in decimeter squares. Potential samples were defined as one square decimeter areas containing one or more *Ambocoelia*. Twenty-five such samples were chosen at random using a random numbers table and extra samples were discarded. Ideally, this should have provided a total of 100 samples for each cluster. In practice, the lower level was consistently two or three samples short because of the convex-down cluster shape and a total of 97 to 98 samples were obtained for each cluster.

In the laboratory, individual samples were found to contain so many fossils that only 10 samples per level were needed in the analysis. The first ten random samples were subsequently treated for each level of one cluster and only data collected in the field was used for comparison between different clusters.

The approach developed can be devided into three phases; field sampling, fossil extraction and data collection. All procedures are summarized in Figure 3 and details are given throughout the remainder of this chapter.

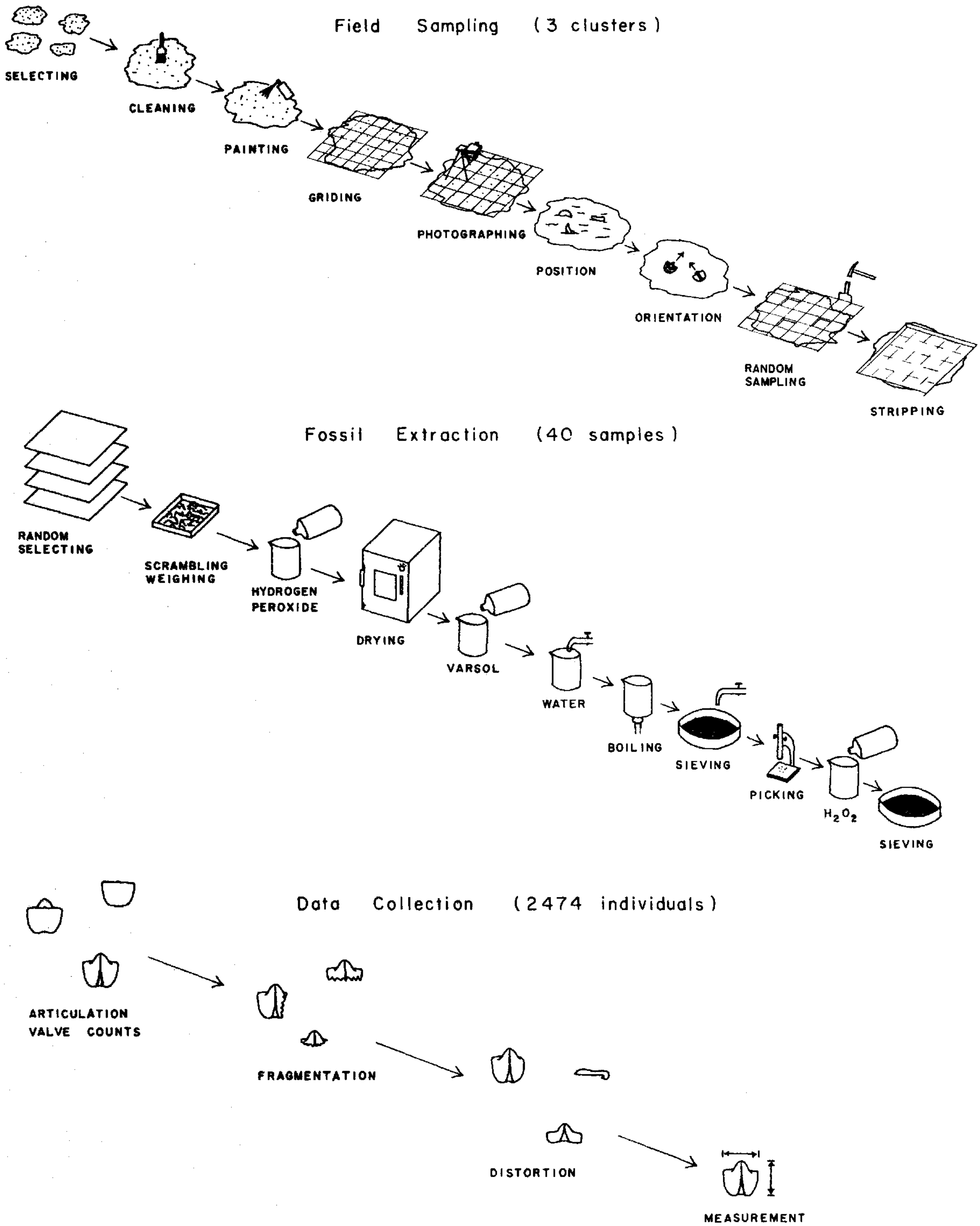


Figure 3
Illustrated Flow Chart Of Procedures

Field Sampling

Three fossil clusters, labelled Alpha, Beta and Gamma were sampled in the latter part of the summer of 1965 and 1966 through the following steps:

1. A partly covered cluster was selected to ensure that upper levels were not eroded.
2. The surface was cleaned and then sprayed with clear plastic.
3. An oriented decimeter grid was drawn on the surface with a felt pen. Most of the fossil cluster was included within the grid boundaries.
4. The surface was photographed with two-thirds overlap between adjacent pictures. This was done to keep a permanent record of surface features which were destroyed by sample removal.
5. The beak orientations and shell positions of Ambocoelia were recorded directly from the outcrop for clusters Beta and Gamma. For cluster Alpha the data was obtained from stereo photographs.
6. Twenty-five decimeter quadrates were selected at random using a random numbers table (Krumbein and Graybill, 1965). Each quadrate selected was carefully chipped out using the next underlying fissility plane as a base.
7. After sampling 25 blocks the remaining grid samples were stripped away along the underlying fissility plane and discarded.
8. The next exposed surface was prepared and sampled in a similar manner.

Sampling was continued successively downward until the base of the cluster was removed. In each cluster only four complete levels, labelled A (top), B, C, and D (base), were extracted (Figure 4). After lifting the D level of cluster

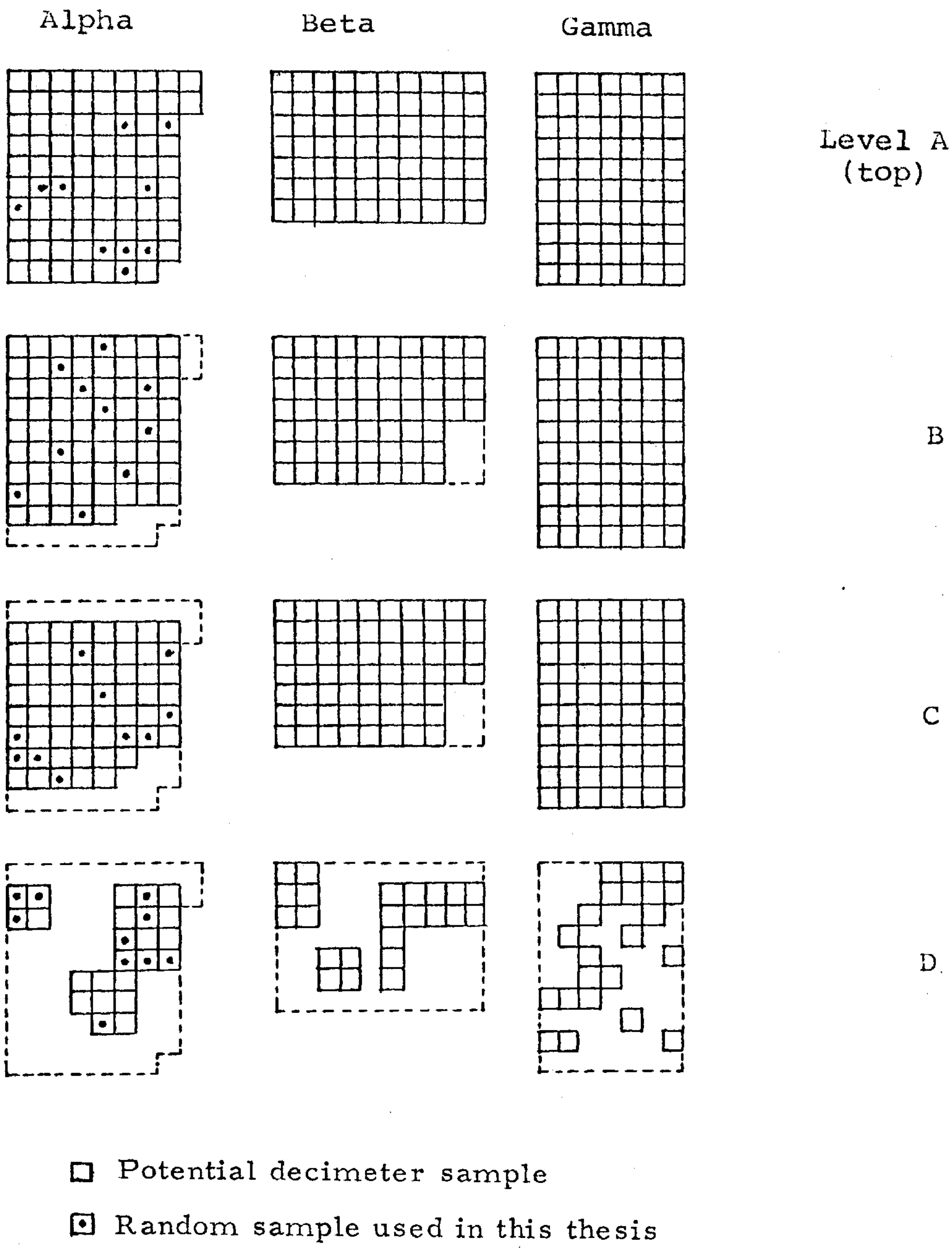


Figure 4

Cluster Sample Grids

Beta a small elongate pocket (20 x 10 x 1/2 cm) of Ambocoelia was uncovered and subsequently sampled.

Fossil Extraction

After field sampling was completed, the first ten random samples were chosen from each level of cluster Alpha (Figure 4). The 40 samples were then arranged in sequence according to the random numbers and assigned code numbers from 1 to 40. To ensure unbiased results the remainder of the analysis was carried out on the sequence of coded samples without any reference to or knowledge of position of the sample in the cluster.

Extra test samples were collected in the field to establish the best separation technique. Boiling, hydrofloric acid and ultrasonic treatments produced unsatisfactory results. Moderate success was finally attained using a combination of hydrogen peroxide and varsol treatments. The technique consists of the following steps.

1. Treatment in 30% commercial grade hydrogen peroxide for one hour.
2. Drying at 220°F for 4 hours.
3. Soaking in varsol for 1 day.
4. Soaking in water for 2 to 4 days.
5. Boiling in water for 2 hours.
6. Wet sieving through a 2 mm., 0.70 mm. and 0.25 mm. mesh screen.

Since chips of shale remained on each screen, steps 1 and 6 were repeated to complete the shale breakdown. Although the method was time consuming, fossil breakage was reduced from that of other extraction methods. Additional experiments confirmed that no destruction of calcite took place for periods of hydrogen peroxide immersion far in excess of any in the extraction process. Pyrite, if present in the sample, imparted a red colour to the hydrogen peroxide solution consequent on oxidation of the ferrous ion. Each sample that became red was marked as containing pyrite.

Macrofossils from the 2 mm. sieve were picked directly from the sample using a binocular microscope. Microfossils and the small shale flakes from the 0.70 mm. and 0.25 mm. sieves were put through a Franz magnetic separator. The shale flakes were drawn to one side due to the inclusion of slightly magnetic chlorite and non-magnetic shell material fell freely down the other side. Two runs at slightly different tilts were sufficient to separate even bits of shell material still clinging to shale fragments. A study of separated shale fragments revealed that less then 0.1% shell material was missed in the process.

Ambocoelia shells and valves were picked from the separated portions of shell material under the microscope. Some specimens from the smallest size fraction were difficult to recognize as Ambocoelia, but since juveniles from other species of brachiopods in the clusters were easily recognized the chances of mis-identification were small (Plate V). Furthermore, the much greater abundance of Ambocoelia and establishment of a complete size series (Plate IV) for reference also decreased chances of significant mis-identification.

Data Collection

Quantitative measurement of the abundance of Ambocoelia may be acquired in three ways; number of specimens, volume and weight. The latter two, for most purposes, produce meaningless results. For example, two samples may contain the same volume of Ambocoelia, yet one may consist of 10 undeformed individuals, the other may consist of 100 flattened individuals. Likewise, three identical individuals may not weigh the same if one is hollow, one is shale filled and the other is pyrite filled. In this study a counting procedure has been employed to produce data which is independent of fossil condition and size.

All specimens of Ambocoelia were examined individually under the microscope. Counts were made of the number of complete, fragmented and distorted shells and valves. The direction of deformation was noted for distorted shells and the part broken off was recorded for fragmented shells. Results of the count data are contained in Table 1 and a compilation of the data is contained in Table 2.

Valve length and width was measured with the use of a scale placed in the ocular of a binocular microscope. The measurements of deformed shells were recorded directly without an effort at correction. Where appropriate, original width of a fragmented shell was estimated by doubling 1/2 widths. A pedicle mold usually outlined original shell dimensions so that length of the pedicle valve could also be estimated. Completely fragmented valves were not measured. An estimate of the number of valves represented by these fragments was made by counting the number of intact beak regions, the strongest and least destructable part of the shell. Appendix II contains all shell measurements.

Field study of samples indicated that very few shells were fragmented before preparation. Most, if not all of the fragmentation is a result of the fossil extraction process which has a tendency to reduce the number of more fragile shell parts. Therefore, a close parallel between variation in fragmentation and variation in articulation and distortion is to be expected.

Table 1

Shell and Valve Counts, Cluster Alpha

Sample Number	Articulated: Nondist.	Articulated: Dist Width	Articulated: Dist. Length	Articulated: Dist. Thick	Pedicle Valves: Nonfrag. Nondist	Pedicle Valves: Frag. Width	Pedicle Valves: Frag. Length	Pedicle Valves: Estimate Frag.	Pedicle Valves: Dist. Width	Pedicle Valves: Dist Length	Pedicle Valves: Dist Thick	Mult Dist	Brachial: Nonfrag	Brachial: Frag. Width	Brachial: Frag. Leng	Brachial: Estimate Frag	Position: Up	Position: Down	Sample Weight (gms)
1	8	2			3			1								2			115.53
2	14	3			4			9	3				4			5	1	1	153.11
3	47	2	1		50	20	9	97	57	6	4	2	13	2	9	55	1	8	224.34
4	9		1	1	6	1		16	3	1			1	1	1	14	2	9	53.22
5	17	2			10		1	33	7		1		6		1	22	5	3	111.84
6	18				15	4	5	26	11	5	1		7	4	2	14	2	16	43.76
7	124	12	3	3	28	12	10	57	16	10	3	1	6		7	47		7	82.12
8	58	5	2	1	35	5	6	69	25	5	5	6	19	4	3	66	2	8	204.12
9	47	3			13		1	21	15	3	1	3	6			30	1		89.24
10	46	1	1		16	1	3	31	14	5	5	2	8	1		36	5		156.60
11	16	5			1			2	1				3			3		1	213.08
12	6							4	1	1			1			3	2	1	166.02
13	40	12	3	4	7	3	4	22	3		2	1	3	4	2	21	5	9	236.14
14	47	2	1		4	3		18	8	1			4	2		14	1	2	196.52
15	73	9		2	28	12	8	46	28	8	1		11	4	9	39	6	11	246.40
16	79	9	1	1	16			12	2				7	1	1	19	1		216.22
17	105	9	3	2	22	1	3	20	14	3	1		5		3	33	3	11	186.08
18	26		1	1	7	1	1	11	3				3			20	1	3	134.65
19	106	18	1	1	61	10	12	86	55	10	5	1	21	2	8	57	5	6	244.42
20	46	5	2		9	2	2	40	14	5	3	3	11	3	2	27	3	10	170.19
21	27	6	1	1	1	1		7	3				2		1	5	2	3	216.31
22	23	3	1		1	1		6	3				2		1	5	1	1	251.98
23	58	7	4		14	1	1	8	13	1	1		7	5	4	18		5	240.06
24	27	4	1	2	3		1	23	6	1	2		3		3	17	1	6	232.32
25	70	5	2	3	15	2	3	23	6	1	1		7	1	1	31	3	2	218.26
26	37	4	1		6	1	1	13	5			1	5		2	9	3	3	113.28
27	87	9	3		23	1	1	30	18	5	2		6		5	24	2	3	209.04
28	31	3	1		10		2	16	9		1	1	3		2	22	2	3	224.59
29	23				7		1	5	3		1	2			1	11	1	2	231.76
30	73	7		1	25	10	8	37	41	7	2	1	20	1	1	47	3	3	184.40
31	15	4			5			3	2				5		2	4	3	5	174.39
32	35	3	2		5			7	2				5		2	8	2		201.79
33	40	4		1	9	2	1	12	6	1			3	3	1	20	1	1	223.57
34	49	2			10	4	8	10	5				6	1	2	9	4	8	150.89
35	79	38	2	2	17	2	2	18	24	5	5		7	2	4	13		4	232.42
36	30				4			4					2			12			114.46
37	124	32	13	2	16	8	4	36	16	2			1		2	26		4	260.79
38	26	2			3			5	3	1			2			3	13	6	205.11
39	33	1			4			10	1		1		3		1	9	3		153.48
40	25	4			2			3	1				4			3			300.27

Table 2

Shell and Valve Counts Arranged by Level, Cluster Alpha

	Level A		Level B		Level C		Level D		Total
Articulated Shells									
Nondistorted		388		544		456		456	1844
Distorted Width	30		69		48		90		237
Distorted Length	8		12		14		17		51
Distorted Thickness	5		11		7		5		28
Total Distorted		43		92		69		112	316
Total Articulated		431		636		525		568	2160
Pedicle Valves									
Nonfrag., Nondist.		180		155		105		75	515
Frag. Width, Nondist.	43		32		17		16		108
Frag. Length, Nondist.	35		30		18		15		98
Estimated Ped. Valves	370		261		168		108		907
Total Fragmented		448		323		203		139	1113
Nonfrag., Dist. Width	151		129		107		60		447
Nonfrag., Dist. Length	35		28		15		9		87
Nonfrag., Dist. Thick.	20		12		10		6		48
Nonfrag., Mult. Dist.	14		5		5		0		24
Total Distorted		220		174		137		75	606
Total Pedicle		848		652		445		289	2234
Brachial Valves									
Nonfragmented		70		69		55		35	229
Fragmented Width	12		16		7		6		43
Fragmented Length	23		25		21		14		81
Estimated Brach. Valves	291		236		189		107		823
Total Fragmented		326		277		217		127	947
Total Brachial		397		345		272		162	1176
Total *Ambocoelia*		1279		1288		970		857	4394

Chapter 4

QUANTITATIVE ANALYSIS OF CLUSTERS

Because individual samples were not exactly the same weight or volume, quantitative comparisons between samples and therefore cluster levels cannot be made by direct use of count data. The ratios of various measures to each other and to sample weight, however, provide useful criteria. Various criteria which have been used to determine the nature of fossil assemblages include the following:

1. Articulation - the number of attached valves versus separated valves (Boucot, 1953; Johnson, 1962; Fagerstrom, 1964).
2. Opposite valves - the number of pedicle versus brachial or right versus left valves (Boucot, 1953; Johnson, 1962; Fagerstrom, 1964).
3. Orientation - the number of shells pointing in a particular direction (Nagle, 1967).
4. Distortion - the number of shells distorted in different directions (Ferguson, 1962).
5. Density - the number of fossils per unit surface area, volume or weight (Boucot, 1953).
6. Size - the number of shells of a particular size range (Boucot, 1953; Olson, 1957; Craig and Hallam, 1963).

Other criteria, such as shell fragmentation and shell position have also been treated quantitatively. For this thesis the number of valves fragmented in different directions and the number of articulated shells lying with the brachial valve up and down was counted. In addition, the number of samples containing pyrite was noted.

All these criteria have been used to establish differences or likenesses between the four stratigraphic levels of cluster Alpha. Two criteria, position and orientation, have been used to compare all three clusters.

Stratigraphic Variation Within Cluster Alpha

Table 3 contains ratio values for paleoecologic criteria from the four levels of cluster Alpha. The maximum difference between ratios for the first five measures range from 0.07 to 0.14 and for the last four range from 0.63 to 1.45. This, coupled with strong trends in three of the last four suggests a difference between the two groups of criteria. To substantiate the difference an analysis of variance was carried out on data from as many original samples as possible (Table 4). Variance within levels for measures of fragmentation, distortion and opposite valve ratios is just as great as the variance between levels. There is, however, a significant difference (at 95% confidence limits) between levels for articulation, density and position. Since the measure of pyrite content is based on presence-absence an analysis of variance was not carried out. A more sophisticated quantitative approach would have been desirable, but sufficient time was not available to obtain analyses.

Beak orientation data has been separated into two parts; orientation of shells in a brachial valve down position and orientation of shells in a brachial valve up position. The rose diagrams (Figure 5) suggest a possible ttendency for the beak to point south or southwest in shells with the brachial valve up. Statistical analysis using a Tukey Chi Square test (Appendix IIIa) and a Raleigh test (Appendix IIIb) indicates the variable nature of beak orientation distributions. Three diagrams have significant bimodes 180 degrees apart, two have bimodes 90 degrees apart, one has a single mode and two are random distributions

Table 3
Variation in Paleoecologic Criteria, Cluster Alpha
(Data from Table 2)

Criteria	Cluster Level A	B	C	D	Maximum Ratio
Fragmentation					
1. Brachial Nonfrag. / Brachial Frag.	.21	.25	.25	.28	.07
2. Pedicle Nonfrag. / Pedicle Frag.	.44	.50	.55	.56	.12
Distortion					
3. Articulated Dist. / Articulated Nond.	.11	.17	.15	.25	.14
4. Pedicle Nondist. / Pedicle Dist.	.44	.50	.46	.58	.14
Opposite Valves					
5. Brachial Valves / Pedicle Valves	.47	.53	.61	.56	.14
Fossil Density					
6. Ambocoelia / Sample Weight	1.03	.64	.46	.40	.63
*Shell Position					
7. Brachial Up / Brachial Down	.27	.46	.88	1.11	.84
Pyrite Content					
8. Samples without / Samples with	.11	.67	1.50	1.50	1.39
Disarticulation					
9. Articulated / Pedicle Valves	.51	.98	1.18	1.96	1.45

*Data from Appendix I.

Table 4

Analysis of Variance for Paleoecologic Criteria

(Data from Table 1, excluding samples 1, 2, 11, 12, 22, 29, 31 and 36)

1. Brachial Nonfragmented/Brachial Fragmented

Source	Sums of Squares	D.F.	Mean Square	F
Between Levels	0.1011	3	0.0337	1.86
Within Levels	0.5075	28	0.0181	

Tabulated $F_{(3,28)}$ = 2.95 at the 95% significance level

2. Pedicle Nonfragmented/Pedicle Fragmented

Source	Sums of Squares	D.F.	Mean Square	F
Between Levels	0.3999	3	0.1333	0.44
Within Levels	8.5188	28	0.3042	

3. Articulated Distorted/Articulated Nondistorted

Source	Sums of Squares	D.F.	Mean Square	F
Between Levels	0.0388	3	0.0129	0.89
Within Levels	0.4075	28	0.0145	

4. Pedicle Nondistorted/Pedicle Distorted (Estimated Ped. added)

Source	Sums of Squares	D.F.	Mean Square	F
Between Levels	0.7457	3	0.2485	1.18
Within Levels	5.8964	28	0.2105	

5. Brachial Valves/Pedicle Valves

Source	Sums of Squares	D.F.	Mean Square	F
Between Levels	0.1418	3	0.0493	1.25
Within Levels	1.1082	28	0.0395	

6. *Ambocoelia*/Sample Weight (gms.)

Source	Sums of Squares	D.F.	Mean Square	F
Between Levels	4.2428	3	1.4142	4.40
Within Levels	9.0000	28	0.3214	

7. Brachial Up/Brachial Down

Source	Sums of Squares	D.F.	Mean Square	F
Between Levels	5.2427	3	1.7475	4.87
Within Levels	10.0413	28	0.3586	

8. Articulated Shells/Pedicle Valves

Source	Sums of Squares	D.F.	Mean Square	F
Between Levels	13.3078	3	4.4359	6.52
Within Levels	19.0643	28	0.6808	

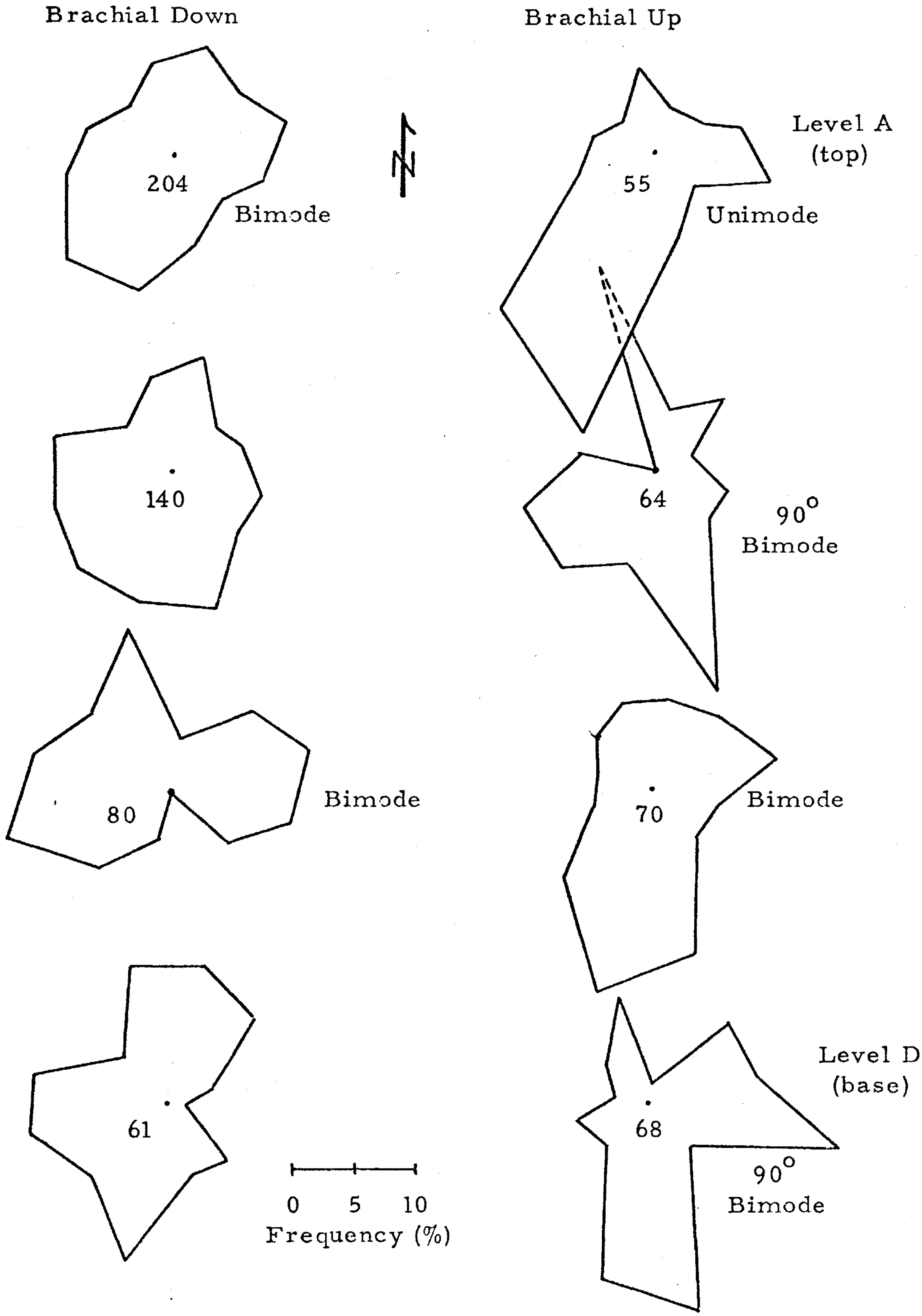


Figure 5
Orientation Diagrams for Cluster Alpha
(Data from Appendix I)

within 95% confidence limits. Such variation in preferred orientations is surprising and seems to defy explanation unless it results from some sort of observer bias. Shell orientation for cluster Alpha was obtained by examining stereo photographs. The orientation of shells in a brachial valve up position were especially subject to observer bias because of their low relief and obscure outlines. To check the possibility of bias, orientation data for clusters Beta and Gamma were obtained directly from the outcrop. The results, discussed below under Variation Between Clusters, suggest the apparent preferred orientation is the result of bias in the measurement technique.

Size-frequency diagrams for each cluster level (Figure 6) were based on as many shells as possible, including nondistorted articulated shells, width-distorted articulated shells, nondistorted pedicle valves, width-distorted pedicle valves and width-fragmented pedicle valves. Together, these represent 71% of all identified shells in the analysis. Each size distribution shows strong bimodality. Only the relative position of the first two size classes (0.0-0.5 mm and 0.5-1.0 mm) illustrate a noticeable shift between cluster levels.

Variation Between Clusters

Clusters Beta and Gamma maintain the same trend in shell position as cluster Alpha.

Table 5

Shell Position, Clusters Beta and Gamma

(Data from Appendix I)

Level	Beta (Up/Down)	Gamma (Up/Down)
A (top)	0.40	0.42
B	0.78	0.65
C	0.92	0.70
D (base)	1.41	1.54

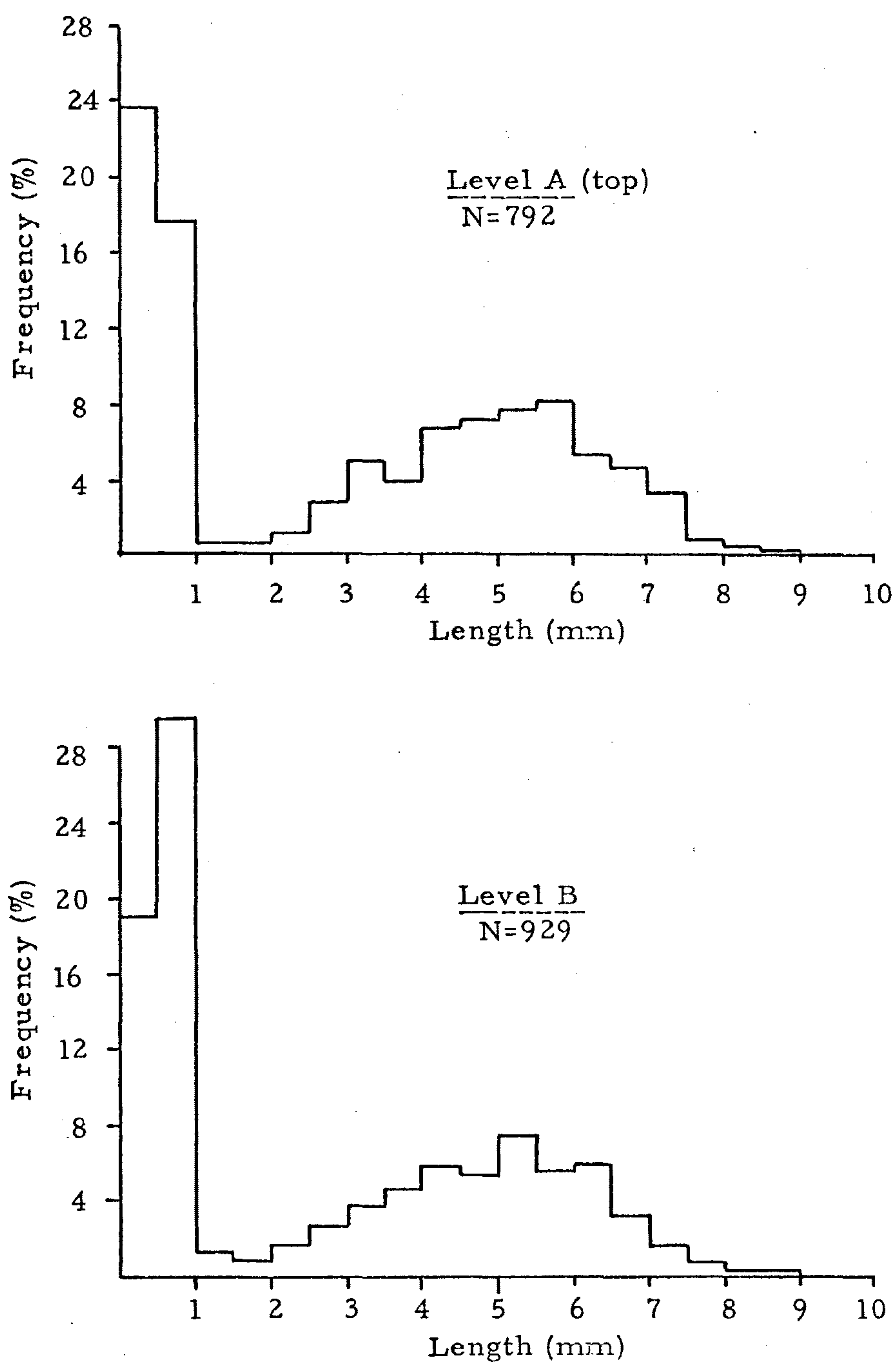
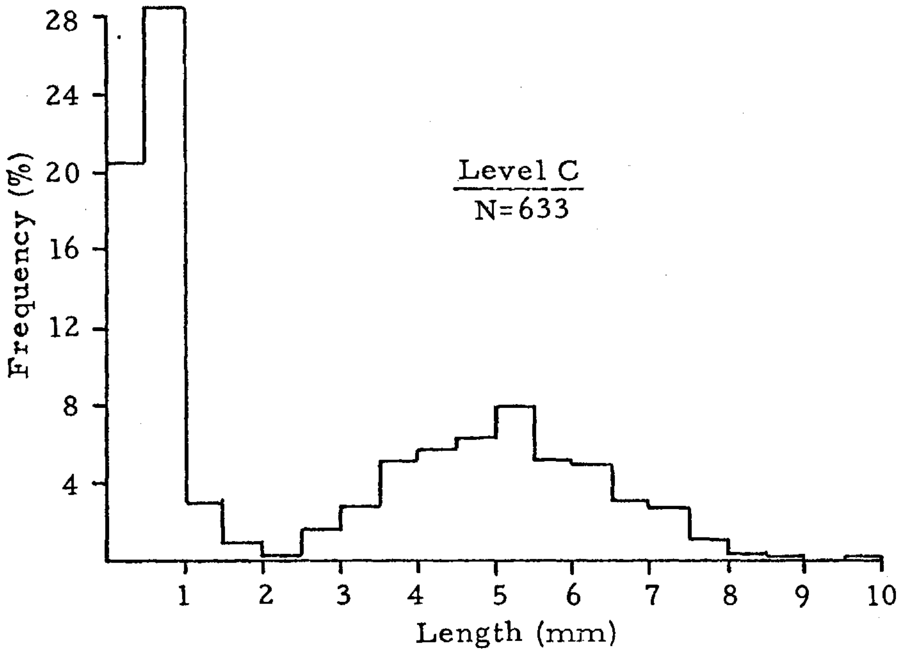


Figure 6

Size-frequency Diagrams, Cluster Alpha
(Based on nondistorted articulated shells and pedicle valves, width-distorted articulated shells and pedicle valves and width-fragmented pedicle valves)



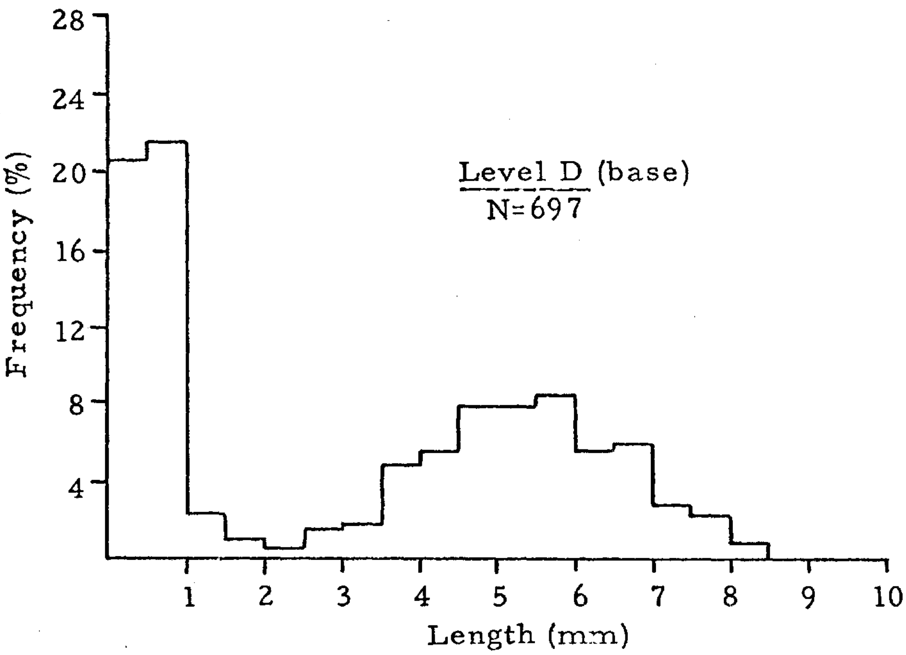


Figure 6 (cont'd)

Comparison of these ratios with those of cluster Alpha in Table 3, indicates there are proportionally more shells in a brachial up position for each level of Beta and Gamma. This may be due to the difference in data collection procedures. Data from cluster Alpha was obtained through stereoscope examination of photographs. Shells with their brachial valves up often presented flat surfaces with little relief and were easily missed, thus lowering the ratios. Position data for Beta and Gamma was obtained directly from the outcrop. Chances of missing shells in the brachial up position were very much smaller.

All but three orientation distributions for clusters Beta and Gamma have a random distribution (Figure 7 and Figure 8). Since these measurements were made on the outcrop and those for cluster Alpha from photographs, it seems probable that the orientations for Alpha are a consequence of light direction or some other factor in photo interpretation. For this reason, no particular significance is attached to differences in fossil orientation between clusters.

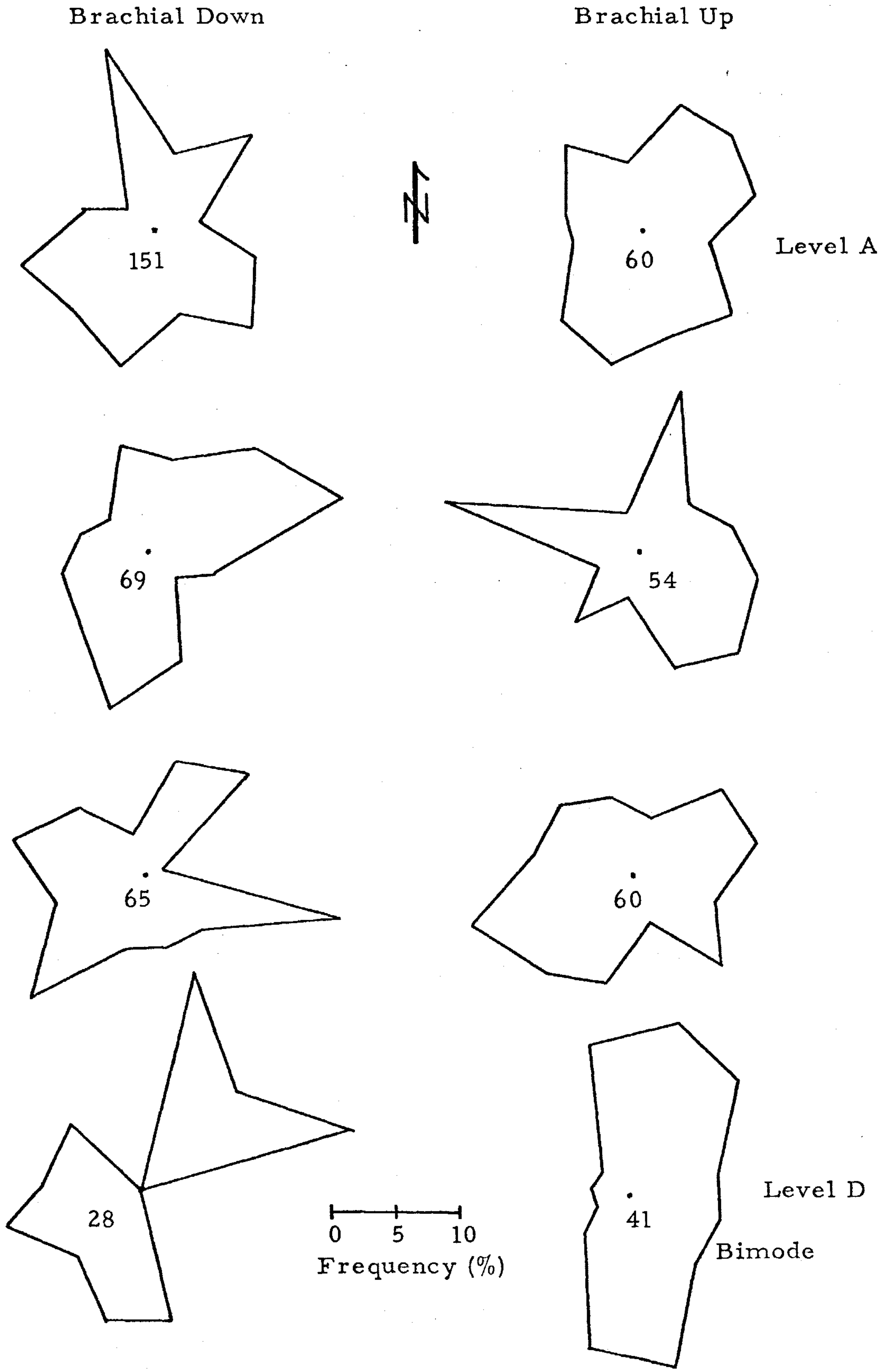


Figure 7
Orientation Diagrams for Cluster Beta
(Data from Appendix I)

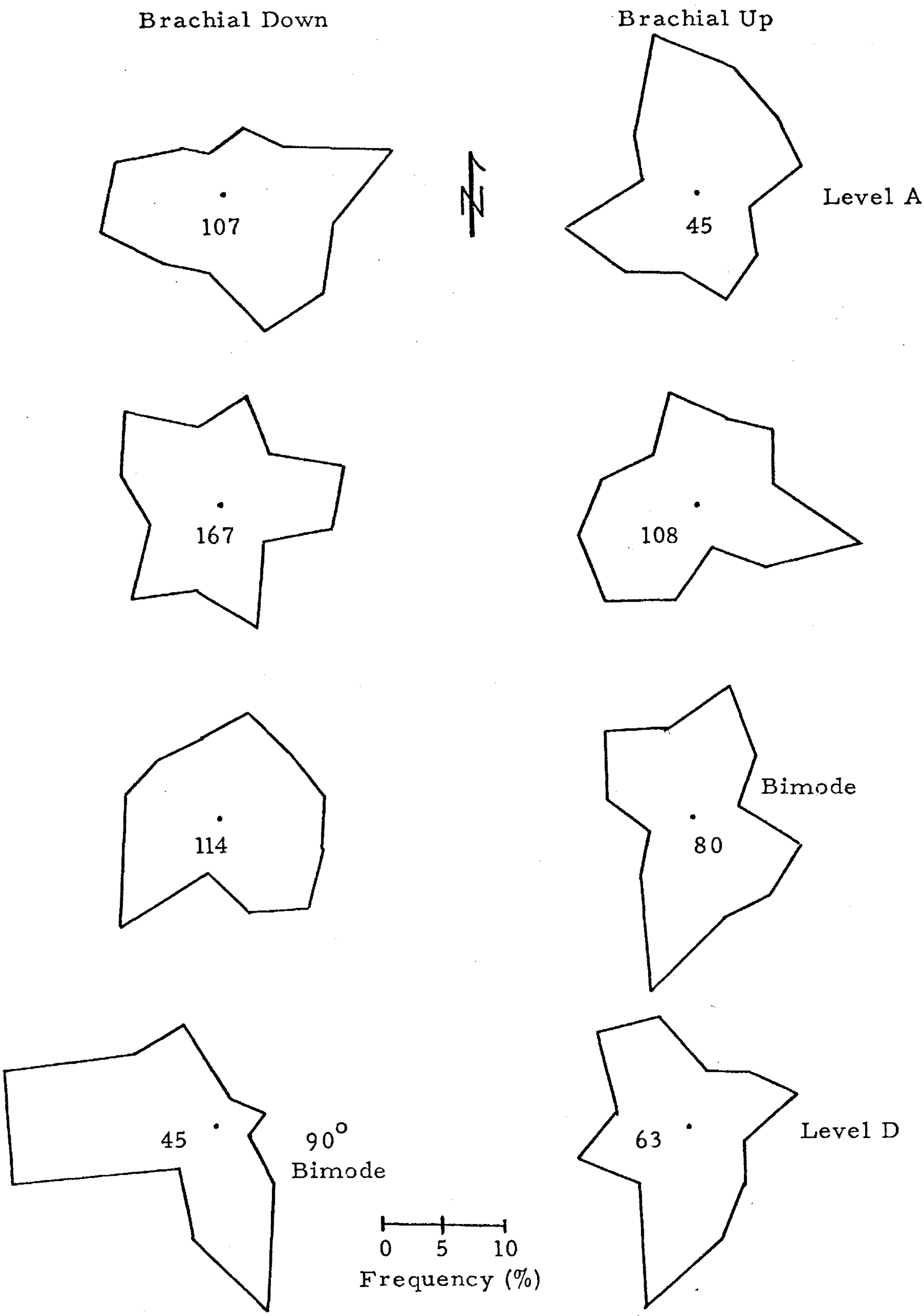


Figure 8
Orientation Diagrams for Cluster Gamma
(Data from Appendix I)

Chapter 5

DISCUSSION OF RESULTS

All samples from cluster Alpha were given similar treatment both in the field and in the laboratory. Operator bias and systematic errors arising from changes in technique were eliminated by randomizing samples before data collection. Thus, variation between levels must have geological or biological significance. Quantitative analysis proved that shell fragmentation, shell distortion and valve ratios are more or less independent of stratigraphic position and unrelated to trends in shell density, shell position, pyrite content and shell disarticulation. An important result is that agents responsible for fragmentation, distortion and valve ratios cannot be invoked to explain variation in shell density, shell position, pyrite content and shell disarticulation. For instance, if the measure of shell distortion is controlled by shale compaction, then shale compaction (a geological factor) does not explain the variation in shell density, position, etc. which could be controlled by biological or other geological agents. The same applies in reverse. Agents thought to control variation in shell density, position, etc., are limited to those which have little influence on shell fragmentation, distortion or valve ratios. This helps reduce the number of alternatives and may fortify some of the following interpretations.

Shell Fragmentation

Very few shells were observed in a fragmented condition in the samples before fossil extraction. The high proportion of fragmented valves in the extracted material therefore reflects a great amount of fragmentation in sample preparation. Since large fragments could be identified as parts of distorted shells, most fragments probably represent the remains of distorted shells.

Size-frequency diagrams of nonfragmented and of fragmented but measurable valves have been prepared in Figure 9. The diagrams illustrate a lack of fragmentation below about 2 mm while fragmentation above 2 mm is almost exactly in the same proportions as the abundance of non-fragmented shells in each class. Unless, as seems unlikely, fragmented shells less than 2 mm were lost or overlooked the size-frequency curves in Figure 5 have to be adjusted to compensate for differential fragmentation of the larger than 2 mm valves (Figure 11 and discussion below).

Shell Distortion

The high percentage of distorted shells indicates that compaction of the enclosing sediment must have been considerable and the lack of a trend (Table 3) indicates it has affected all levels uniformly. Neither shell density nor shell position (up versus down) are correlated with the frequency (ratio measure) of shell distortion. These factors presumably had little influence on the 'degree' of shell distortion. The results in Table 2 indicate that shell condition (i.e. articulated shells versus open pedicle valves) had a pronounced influence on the frequency of shell distortion. 606 pedicle valves were distorted as opposed to only 316 of the more numerous articulated shells. As would be expected, the degree of distortion in articulated shells is also less than that encountered in pedicle valves.

Another facet of the results in Table 2 is the frequency of distortion in different shell directions. In all cases, width-distortion is most frequent and thickness-distortion (shell flattening) is least frequent.

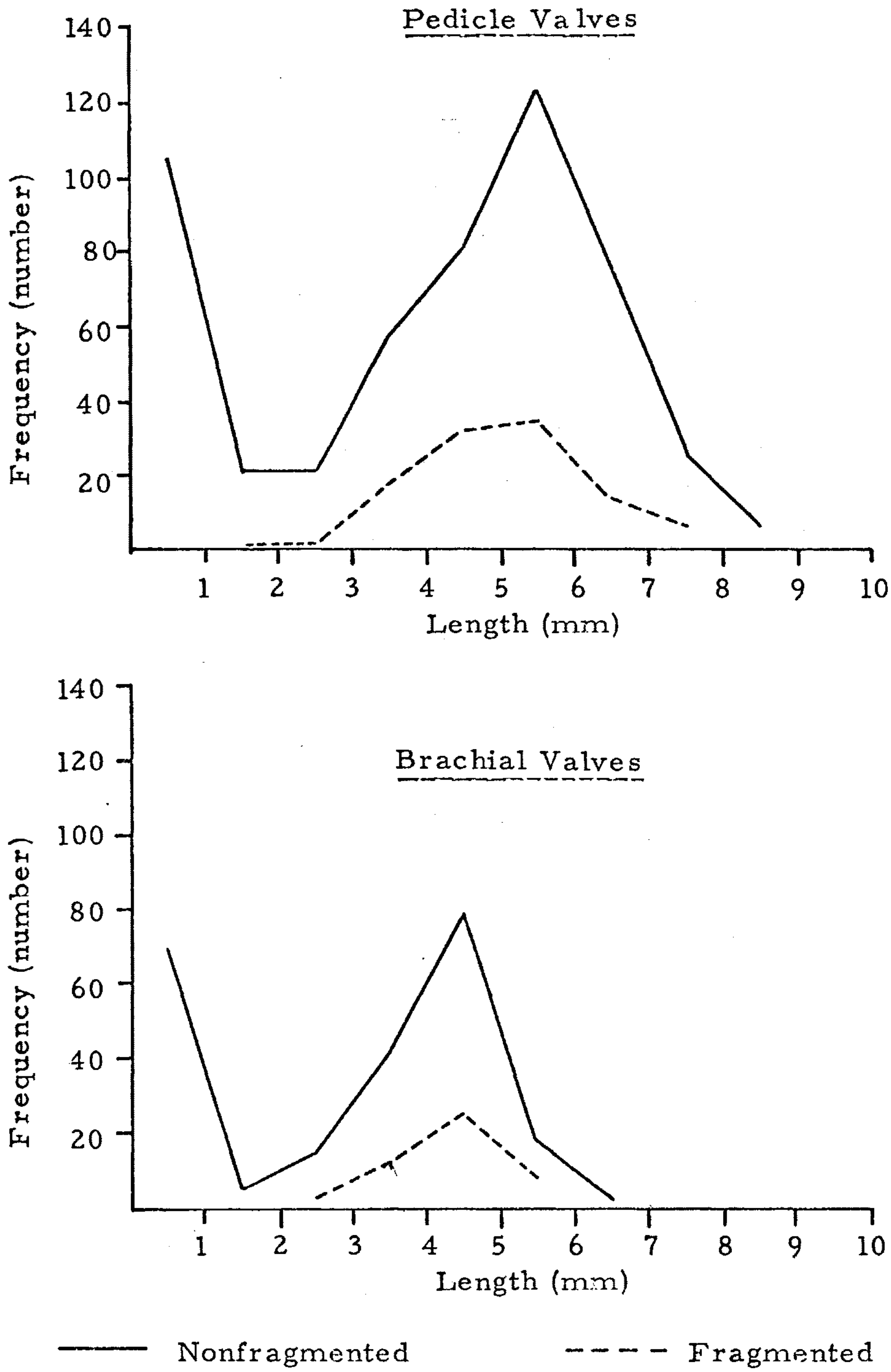


Figure 9
Size distributions for nonfragmented and fragmented but measurable valves, cluster Alpha

This must be related to structural strength of the shell in these various directions.

Influence of the type of shell infilling on shell distortion was investigated by sectioning 27 articulated specimens of *Ambocoelia*.

Table 6

Type of Shell Infilling In Distorted and Nondistorted Specimens

	Shale	Pyrite	Shale+Pyrite+Calcite
Distorted	9	1	9
Nondistorted	3	2	3

No clear relationship is discernable from the results. Fossil distortion must have taken place, at least in part, before complete cementation of all types of infilling material.

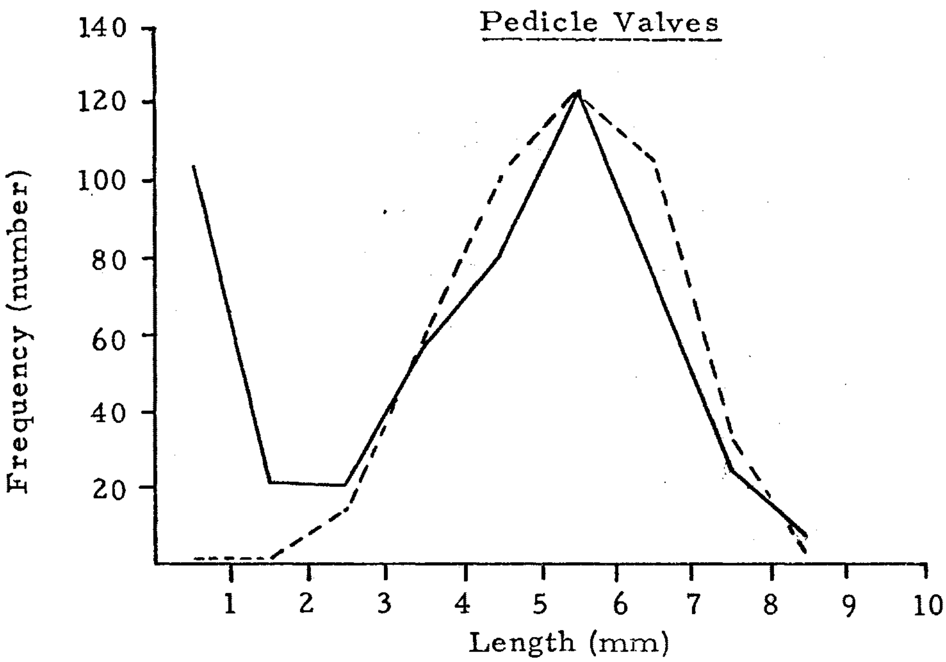
The relations between shell size and distortion must be understood before *Ambocoelia* size-frequency curves can be fully interpreted. A particularly disconcerting thought is that size-related differences in distortion might modify size-frequency curves. As was discussed under Shell Fragmentation, shell fragments, accounting for most of the 29% *Ambocoelia* excluded from size-frequency curves in Figure 5, are in a large measure the remains of distorted shells. If the fragments represent the loss of selectively distorted sizes, then size-frequency curves in Figure 5 are, to coin a phrase, 'truly distorted'.

To test the possibility of differential distortion between shell sizes, width-distorted shells have been compared to nondistorted shells by using the undistorted length measurement (Figure 10). The results demonstrate a critical point at about 2 mm for distortion. All shells larger than 2 mm were apparently equally susceptable to distortion; shells of less than 2 mm were rarely deformed. The 2 mm point may be a critical size, perhaps related to volume and surface area ratio or change in shell morphology. The occurrence of some distorted shells in the o to 2 mm range suggests that operator recognition of distortion is not a problem and that the difference is indeed real. As a consequence of distortion and subsequent fragmentation in preparation, a considerable number (29%) of shells were unmeasurable and not included in Figure 6. Since practically none of these shells are less than 2 mm, the corresponding percentage for each level has been added in proportional amounts to each size class above 2 mm (Figure 11).

Valve Ratios

Disparity between the numbers of opposite valves is usually thought to be caused by current sorting due to different shapes and therefore different hydrodynamic properties (Boucot, 1953; Lever, 1958). With Ambocoelia there is a large difference between numbers of opposite valves (2234 pedicle and 1176 brachial) and also a marked difference in valve shape. The conclusion, without additional information, would be selective current removal of brachial valves.

Consideration of size-frequency curves for brachial and pedicle valves (Figure 12) does not support current sorting. If currents are capable of removing brachial valves there should be a single mode quite different from the pedicle mode. In fact the curves are bimodal, and a smaller average size for brachial valves is not surprising since they must fit inside the pedicle valves. More



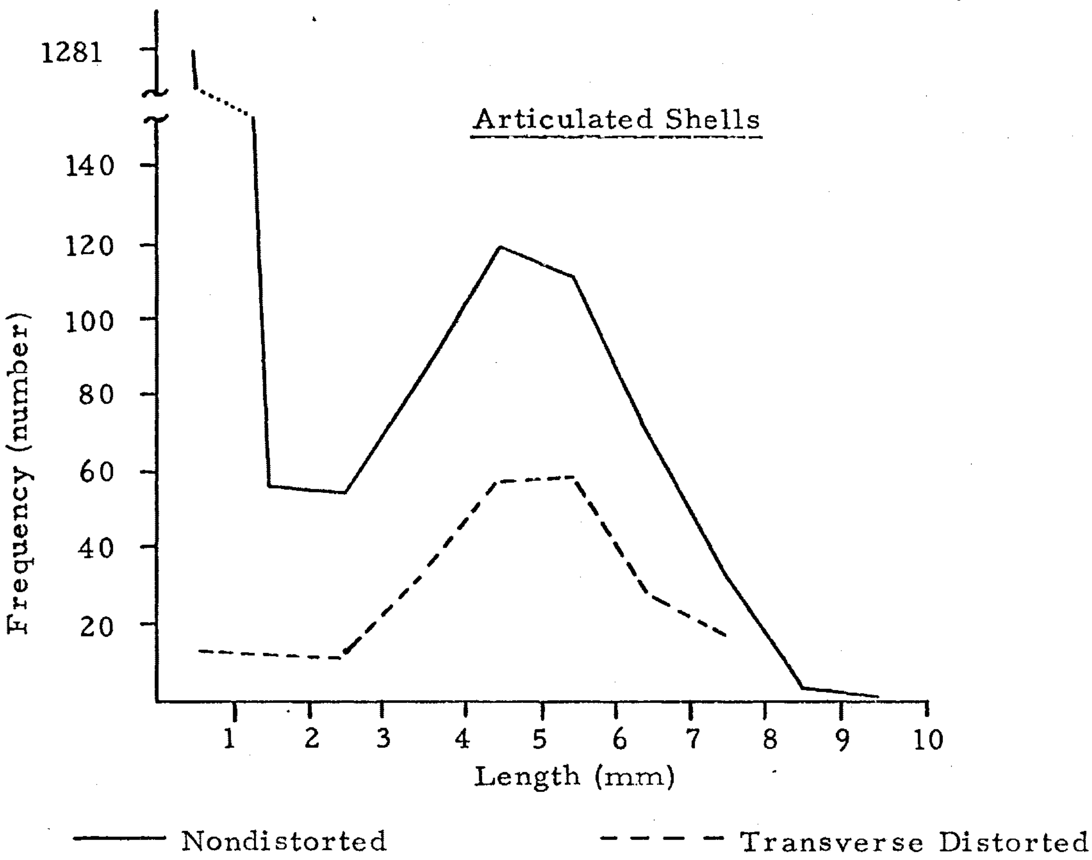


Figure 10
Size Distribution of Distorted and Nondistorted Shells,
Cluster Alpha

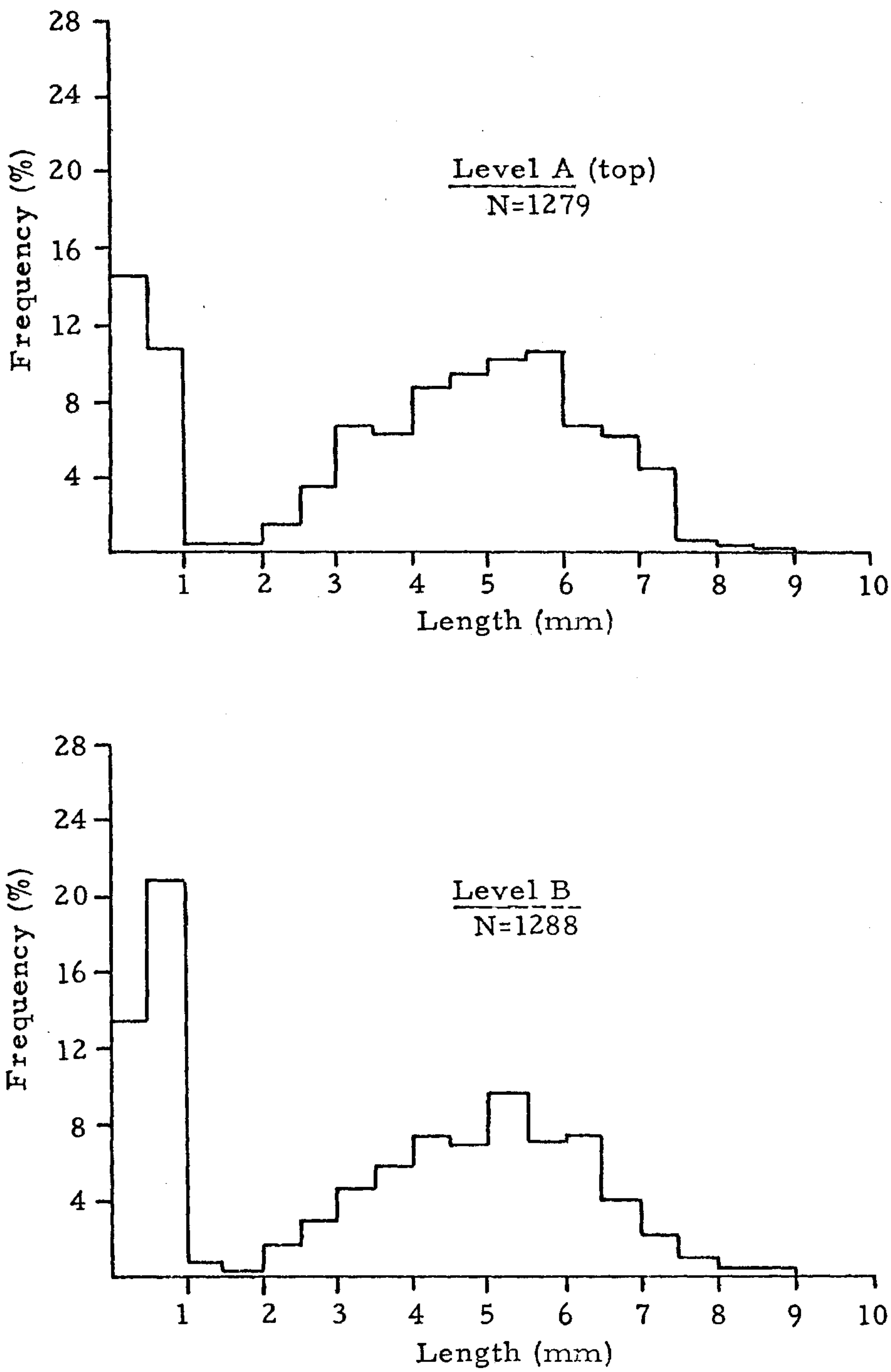
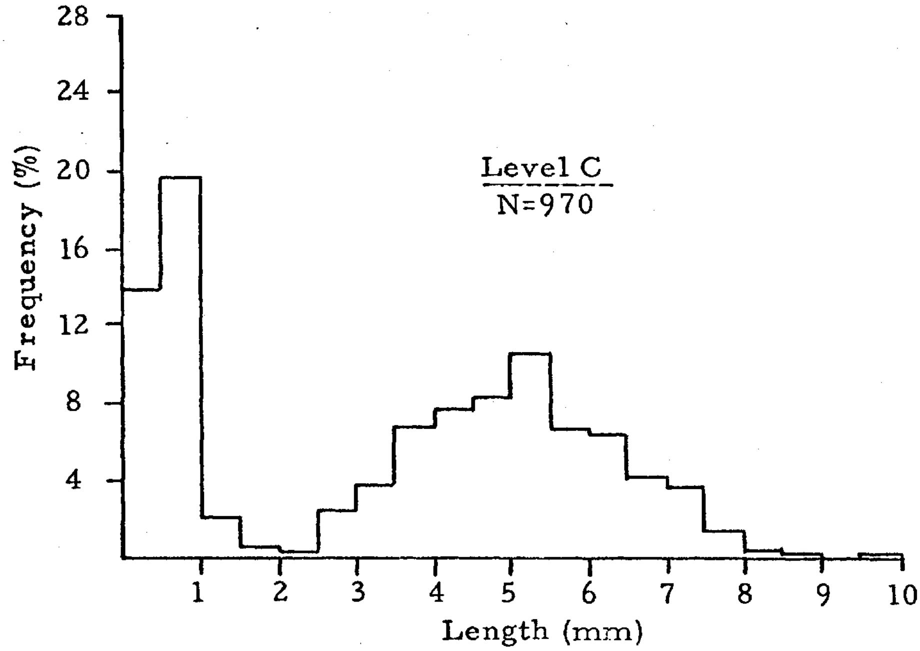


Figure 11

Ambocoelia Size-frequency Histograms, Cluster Alpha Corrected for Differential Fragmentation of Large Specimens



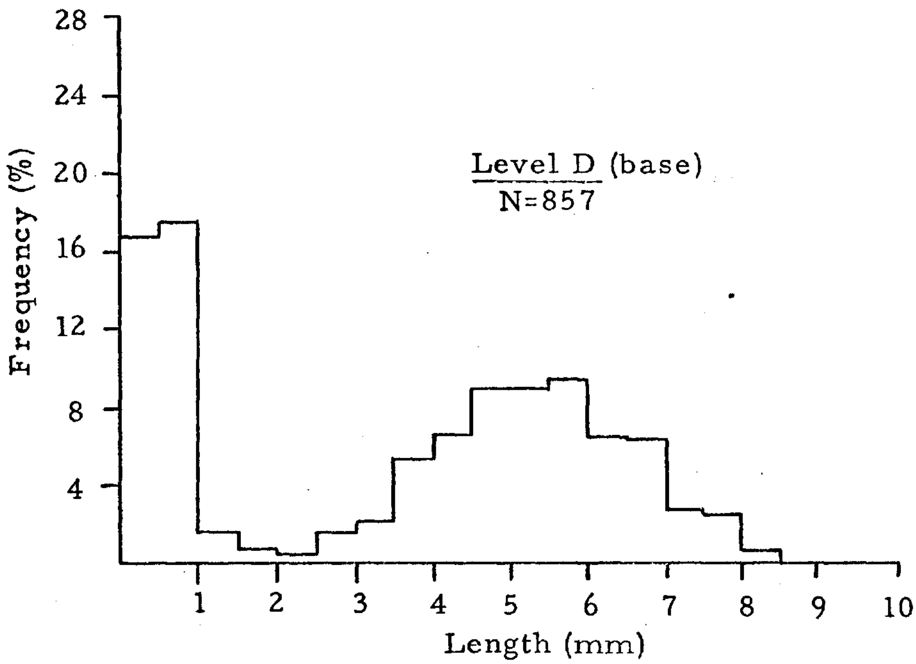


Figure 11 (cont'd)

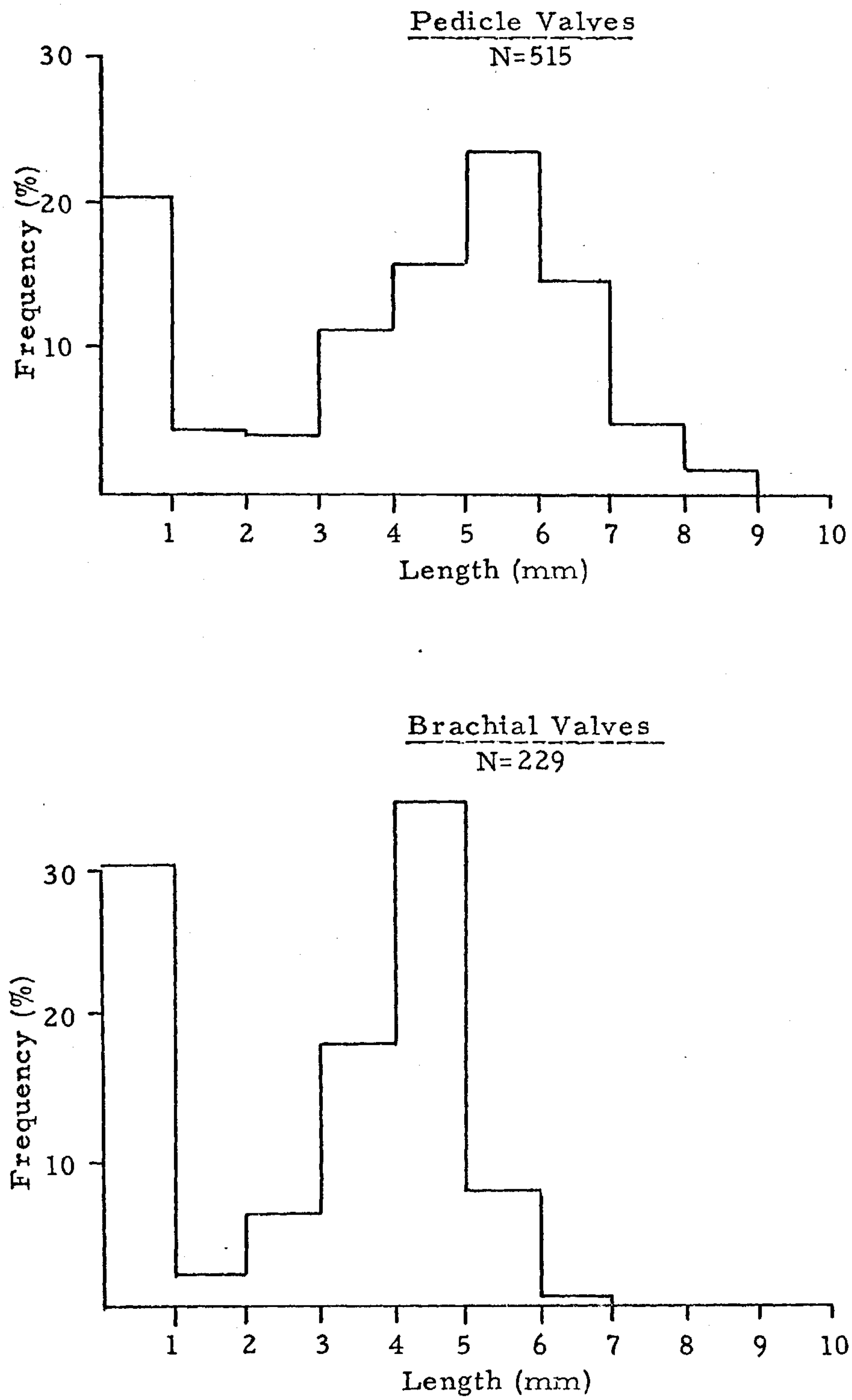


Figure 12

Brachial and Pedicle Size-frequency Diagrams, Cluster Alpha (Nondistorted, Nonfragmented) probably disparity in abundance of opposite valves results from excessive fragmentation of the thin brachial valves and from difficulty in recognition of the small brachial deltidial region for counts of totally fragmented brachial valves. This conclusion is supported by fragmentation proportions of 80% in brachial valves as opposed to only 27% in pedicle valves.

Shell Density

Cluster Alpha not only expanded laterally from its base but the density of shells also increased (Table 3). Is this progressive crowding a result of some geological factor? Differential compaction must be ruled out because there is no change in the frequency of shell distortion. Current winnowing of interstitial sediment near the cluster top would have removed small *Ambocoelia* and thus reduced, rather than increased, shell density. A gradual, widespread reduction in the influx of sediment may have created higher shell densities, but such a change is not supported by any noticeable alteration in lithologic character. Consequently, changes in fossil density probably reflect changes in population density of the living brachiopods.

Shell density also exhibits a wide variation within levels. To determine whether this variation was random, the number of *Ambocoelia* per decimeter quadrate was counted from 100 stereo photographs of cluster Alpha. The resulting distribution was compared to that expected from a random (Poisson) distribution using a Chi-square test (Table 7). Results show that the distribution is definitely not random and the observed frequencies indicate it is aggregated. Possibly the same factors controlling this lateral aggregation produced temporal trends in population density.

Table 6
Chi-square Test for Lateral Aggregation, Cluster Alpha

Number of Ambocoelia	Observed Frequency	Expected Frequency	Difference	Chi-square
0	36	13.00	23.00	
1	22	26.53	-4.53	
2	10	27.06	-17.06	
3	8	18.40	-10.40	
4	6	9.38	-3.38	
5	3	3.83	-0.83	
6	6	1.30	4.70	
> 7	9	0.38	8.62	272.03
		99.88		

$\text{Chi-square}_{(6,\ 0.01)} = 16.812$

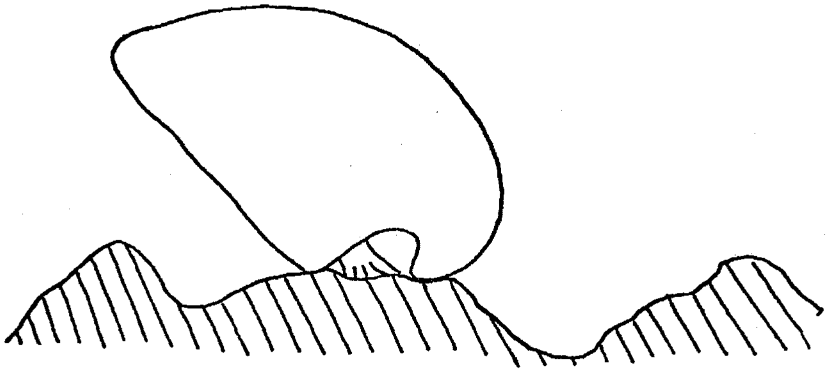
Shell Position

In outcrop, most *Ambocoelia* shells are found with their plane of commissure more or less parallel to bedding. Since this is not a common life position among brachiopods the observed positions could be used as evidence of current reworking. An alternative explanation, however, is that the observed position is due to rotation during compaction. Rotation of flat objects during compaction of the surrounding medium has been studied by D. Underhill (pers. comm.). His results indicate that a compaction factor of about 5 would reduce an original 60 degree angle to bedding to only 10 degrees. Since *Ambocoelia* is planar on one side this mechanism could easily account for the observed horizontal positions. For this reason no particular significance is attached to the inclination of the commissure and only brachial up and brachial down position data are considered meaningful.

Clusters Alpha, Beta and Gamma all show an increase in brachial-down positions from bottom to top. This indicates a similar controlling process related to the development of the clusters. The brachial down position is the most stable hydrodynamically and the trend thus suggests an increase in current reworking. This interpretation is not substantiated however. First, there is no significant orientation of shells in the upper levels of each cluster (Figure 5, Figure 7, Figure 8). Second, the change is not coincident in adjacent clusters, i.e. co-existing clusters do not show the change at the same time.

The only other explanation is that shell-to-substrate relation changed from base to top and subsequently influenced shell position. Two mechanisms are considered feasable. Weak currents might not have been able to flip shells resting in a soft mud substrate near the base, but might have been sufficiently strong to flip shells on the somewhat firmer, uneven, shell littered substrate near the top. Although it is questionable whether or not a preferred shell orientation should result near the top, absence of shell orientation is, however, a possible objection to this interpretation. Alternatively, living position of Ambocoelia may have varied with changes in substrate character. On the firm surface created by an underlying shell pavement, Ambocoelia would probably have been tethered with the hinge line and umbone in contact with the bottom and the brachial valve inclined toward the substrate (Figure 13a). After death the animal would have toppled or remained inclined with the brachial valve down. On a softer substrate the umbone may have sunk into the mud, and the pedicle, unable to hold the shell in the forward position, may have pulled free and allowed the pedicle valve to sink in a reclined position, brachial up (Figure 13b).

a. Firm Substrate



b. Soft Substrate

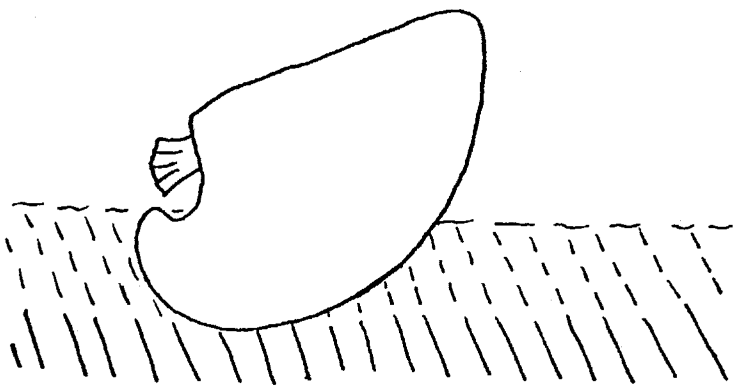


Figure 13

Postulated Relationship of Shell Position to Substrate Type

The dual adaptation for attachment and support may also explain the abundance of Ambocoelia in Wanakah shales. Not only were they adapted for pedicle attachment on firm substrates, possibly the odd shell or sticky patch of mud, but they could continue to function if the pedicle lost its hold. This fits nicely with Caldwell's observations on the morphology and life habits of ambocoeliids and in particular Ambocoelia which has features of both the fully attached forms and fully reclining forms.

Pyrite

Pyrite can be found in the Cazenovia Creek outcrop by sampling any fossil clusters on the bedding surface. Sparsely fossiliferous areas between clusters are almost devoid of pyrite. The pyrite occurs within articulated shells as blebs, on and partly replacing shell material and as massive discoidal concretions consisting of blebby aggregates 2 to 10 cm in diameter and 1/2 to 2 cm in thickness (Plate V). Thirteen of twenty-seven articulated shells sectioned contained pyrite, either filling the interior completely or lining the inner surface. According to Jordan (1968) pyrite was the earliest diagenetic mineral in these shales and either formed before or, at the latest, was contemporaneous with compaction.

The association of pyrite with fossil clusters and shell interiors plus its early diagenetic emplacement suggests a connection with organic and possible fecal material. The increase in pyrite from cluster base to top therefore reflects progressive increase in organic and/or fecal material.

Shell Disarticulation

Slightly more than one-half of all shell specimens are disarticulated. Valve separation in preparation must be relatively unimportant as a high proportion of single pedicle and brachial valves can be observed in the field. In any case, the trend from mainly articulated specimens at the base to disarticulated specimens at the top indicates that a factor other than fossil extraction is operative. Current reworking is considered an untenable process. Any currents capable of separating valves would undoubtably scatter them as well, leaving behind the largest and heaviest specimens. The lack of trend in valve ratios and the similar size distributions for brachial and pedicle valves contradicts this mode of valve separation.

The only remaining mechanisms of disassociation are biological. Decomposition of articulating muscles after death relative to shell position could be responsible for the observed trend. If the pedicle valve did not topple immediately following death, the short time it takes for organic decomposition may have allowed brachial valves to fall free from many shells that were inclined with the brachial valve forward. Since a life position of this sort was inferred to be more frequent at the cluster top, the trend in disarticulation is a plausible result. Alternatively, increases in predation, benthic scavenging and/or bioturbation could have increased disarticulation but other evidence for such a hypothesis is lacking.

Shell Orientation

Beak orientation of brachiopods is controlled by the direction and type of current (Nagle, 1967). Observation of *Ambocoelia* shells placed on a smooth surface in a continuous flow of water demonstrated that the beak will tend to point upcurrent and the shells positioned with the pedicle down rotated more readily because of the small substrate-to-shell contact area. The latter observation justifies the separate treatment of beak orientations in brachial up and brachial down positions.

The sporadic occurrence of preferred beak orientations (Figure 5, Figure 7, and Figure 8) has been attributed to biased data collection. All beak orientations for both up and down shell positions were pooled (Figure 14) with the hope that biases would cancel out. The significant unimode for the brachial up position perhaps indicates that currents had a weak north-northeast component. If paleocurrents are to be postulated, then weak unidirectional currents of rather uniform intensity are certainly the most plausible type. An interesting observation is that a south-southwest orientation roughly corresponds to orientation of carbonate concretions in the same beds (Jordan, 1968).

Shell Size Distributions

Various workers, principly Olson (1957), Craig and Hallam (1963), Craig and Oertel (1966), and Hallam (1967) have investigated the various factors that govern the shape of size-frequency curves. All such factors can be divided into two groups, biological and postmortem. Biological factors include the type of mortality, the growth-rate, the pattern of recruitment and predator activity. Postmortem factors include current sorting, current abrasion, selective crushing during compaction, fossil extraction inconsistencies, and sampling biases. The complexity of factors involved suggests that the interpretation of fossil size-frequency curves should be treated with due caution.

Postmortem Alterations

A possible source of variation in size-frequency curves is measurement error, especially if measurements are made on numerous poorly preserved specimens. Measurement error was tested in this instance by two operators, each

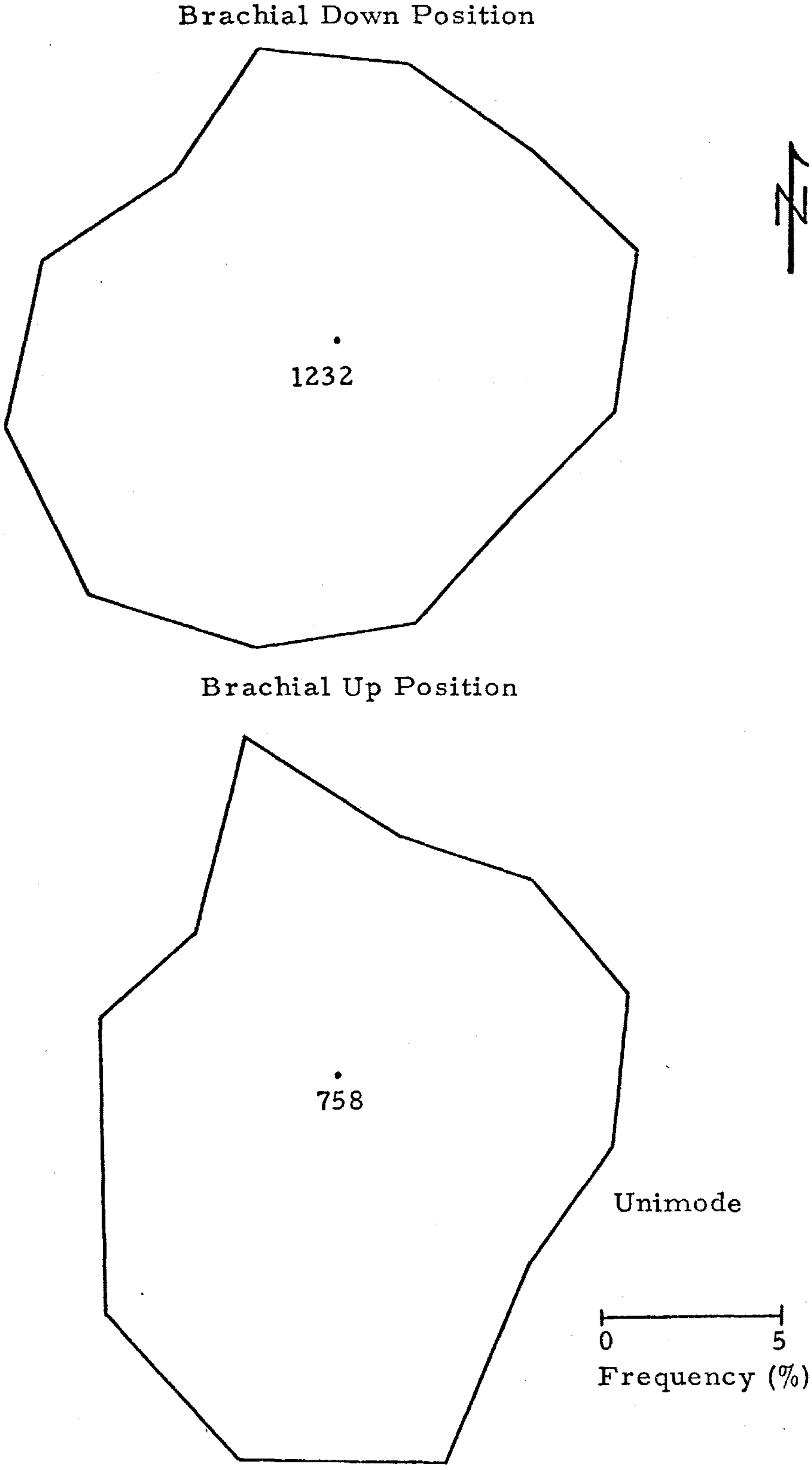


Figure 14

Pooled Beak Orientations for Ambocoelia, Clusters Alpha, Beta, Gamma of whom measured 50 specimens twice. The specimens came from a typical sample which included all grades of shell preservation. The analysis of variance (Table 7) indicates, 1) no significant difference between duplicate measurements made by an operator and, 2) no significant difference between measurements made by separate operators.

Table 7

Analysis of Variance on Operator Error

Source	Sum of Squares	d.f.	Mean Square	*F*
Between Operators	1.0952	1	1.10	0.58
Within Operators	0.4392	1	0.44	0.30
Error	285.6140	198	1.46	
Total	287.1484	200		

All possible size classes of *Ambocoelia* were included by taking bulk samples and the same preparation technique was employed in the disintegration of the shale matrix. Separation of shells from shale flakes less than 2 mm was accomplished by using a magnetic separation technique. It is difficult to see how this could have affected the relative abundance between large and small shells, but if it did there should be a sharp difference in size-frequency curves corresponding to the 2 mm point. The histograms in Figure 5 have a sharp change, but since it is two size classes removed from 2 mm a connection is not possible.

The lower size limit of shells encountered in the analysis was about 0.25 mm. Although this corresponds to the mesh size of the last sieve, a connection is coincidental. On close examination of very small specimens a lack of growth lines was revealed (Plate IV) and the 0.25 mm size likely represents the first appearance of a calcite shell. This must correspond to the latest stages of larval development in Ambocoelia (c.f. Paine, 1963).

Relationships between shell size, fragmentation and distortion were discussed in earlier sections of this chapter. The results indicated that the percentage of unmeasurable shells ommitted in each level of the cluster should be dispersed equally among all size classes greater than 2 mm. The resulting histograms, recalculated to 100% (Figure 11), must approximate more closely the true size distributions for the fossil populations.

Molds of bivalve, nautiloid and gastropod shells demonstrate dissolution of aragonitic shell material. This does not apply for calcite, however. If solution of calcite had taken place, tiny thin shelled Ambocoelia would have been the most susceptable and therefore first to disappear. Since the small size fraction of shells is most abundant, it must be concluded that calcite solution has not been extensive. Preservation of the delicate spiralia inside articulated brachiopods, of shell microstructure including the thin primary layer in Athyris shells, and of thin spines and laminae in many fossils, also suggests the lack of calcite solution.

The preservation of delicate skeletal structures rules out any possibility of selective destruction through shell abrasion. The absence of evidence suggesting that currents have controlled valve ratios, shell position, shell disarticulation and shell density is also an indication that currents did not affect size distribution. The great variety in shapes and sizes of other fossil constituents in the clusters argues against sorting by currents. Construction of size-frequency distributions for this material would undoubtably produce a variety of completely different histograms. If the small Ambocoelia were introduced by currents, one would expect a high percentage of disarticulated valves. In fact, very few of the small valves are disarticulated.

Biological Considerations

Direct evidence of predation on Ambocoelia comes from 3 or 4 specimens that have been bored. The bore holes are at right angles to the shell surface and are not unlike bore holes produced by modern gastropods (Carriker and Yochelson, 1968). Unless disarticulation of valves was a result of predation, predatory mortality was not significant.

Size-frequency distributions, since they are largely unaltered by postmortem and predation factors, must reflect biological aspects of the original population. The bimodal shape is also rather unique for size distributions of living populations so that only a limited number of explanations are possible.

One explanation for the bimodality is instantaneous mortality of a population that contains a recent recruitment of young. The size-frequency histograms from all four levels of cluster Alpha are strikingly similar. An explanation based on instantaneous mortality therefore demands periodic (? yearly) mass kills shortly after recruitment throughout the existence of the cluster*. Since the fossil clusters are situated in a rather stable subtidal depositional environment it is difficult to conceive of adverse conditions that were numerous and in phase with periodic recruitment. This interpretation is consequently rejected.

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* Jordan (1968) estimates deposition of 1 mm/year of uncompacted sediment. This suggests a period of about 100 years for cluster development.

Another explanation is that normal mortality was very high immediately after spat settlement but decreased sharply thereafter -- prior to the period of maximum growth. Low mortality imposed on rapid growth would yield relatively few individuals in any given size class, i.e. a trough in the distributions; continued low mortality during the subsequent period of slow growth would yield the second mode. A detailed analysis of the distributions has been carried out by Bray and Beerbower (in press). By assuming a reasonable sigmoid growth curve on an arbitrary time scale and accepting the size-frequency distributions as a product of growth and mortality, it is possible to generate a mortality (or survivorship) curve on the same scale. The form of this curve appears consistent with mortality curves known from modern marine invertabrates (i.e. Craig and Hallam, 1963). Bray and Beerbower suggest that the high percentage of articulated shells in the smaller than 2 mm classes requires burial in sediment prior to death and, in turn, that such burial may have been the cause of death. This hypothesis predicts a decrease in mortality as shell accumulation increases substrate firmness -- such a decrease is observed in Level A (Figure 11).

A recent occurrence of size-frequency bimodality has been reported by Jackson (1968). He found that dead shell accumulations of the intertidal bivalve Gemma gemma produced extreme bimodality (Figure 15) even though a comparable species, living in the same environment, produced an unimodal size distribution. From this, Jackson concluded that young Gemma gemma were more vulnerable to environmental stress. One possibility was that the unusual ovoviviparous reproductive habit of Gemma gemma might have been the cause of this greater vulnerability

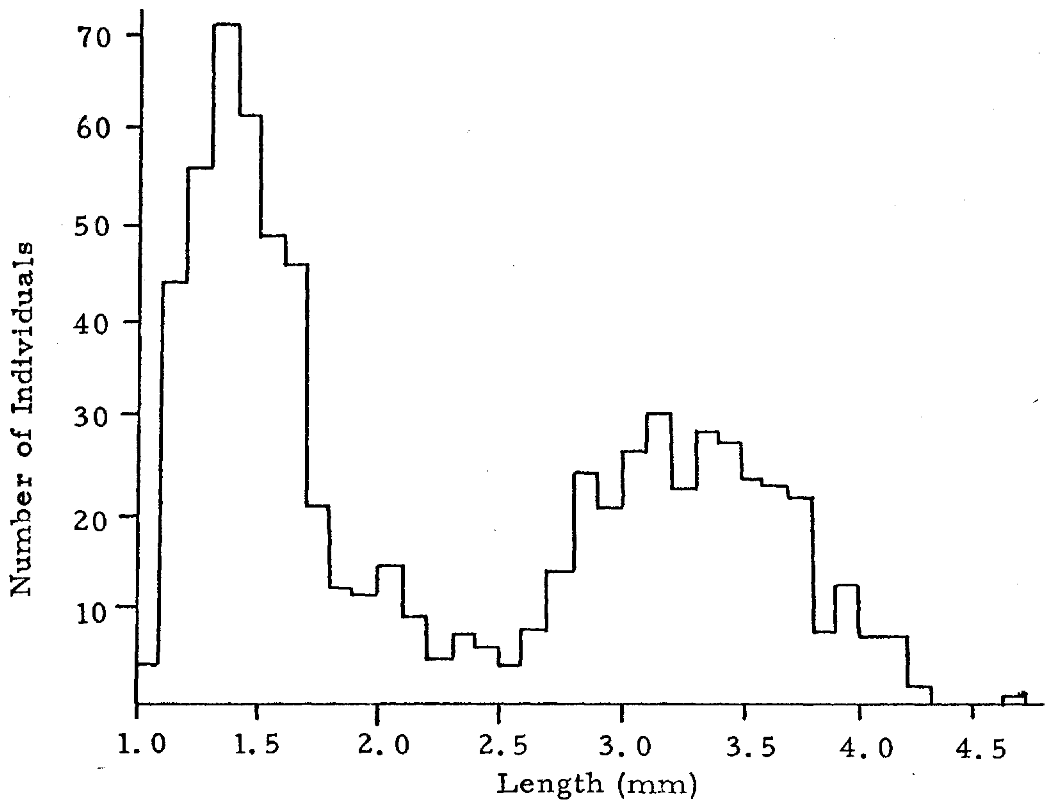

Figure 15

Size-frequency Histogram for Dead Gemma gemma
(After Jackson, 1968)

and ultimately the cause of a bimodal size distribution. As with *Gemma gemma*, the bimodality of *Ambocoelia* size distributions could be caused by high mortality among young due to ovoviviparous reproduction. This mechanism should not be entirely discounted as ovoviviparous reproduction is known to occur in at least one recent species of brachiopod (Z. Bowen, pers. comm.).

Chapter 6

INTERPRETIVE SUMMARY

Evaluation of the various paleoecologic criteria in the preceeding chapters indicates that formation of these clusters by selective preservation or mechanical redistribution of fossils is virtually impossible. Table 8 and 9 summarize this evaluation.

Fossil characteristics and shell attributes within the clusters support the hypothesis of shell accumulation from '*in situ*' life associations. The only remaining alternatives are that clusters arose through reproductive or ecological processes. These processes must have been operative for a considerable interval of time, *i.e.* sufficient time to allow accumulation of approximately 1 decimeter of sediment (about 100 years). Because *Ambocoelia* is by far the most abundant fossil in all levels of all clusters, a good working hypothesis is that the reproductive habits or ecological requirements of *Ambocoelia* controlled cluster origin and subsequent development.

The possibility of ovoviviparous reproduction in *Ambocoelia* was discussed in relation to size-frequency distributions. This is the only available reproductive mechanism which could also account for aggregation. Although details of brachiopod brood retention and release of offspring are, as yet, unknown it is a good assumption that young would not travel far from the parent. If this is true, successive generations might have utilized an everexpanding patch on the substrate until, at some later date, adverse conditions resulted in termination.

Table 8

Selective Preservational Mode of Formation, Comparison of Expected and Observed Features

Features Expected	Features Observed
All fossil clusters incorporated in concretions with poorly preserved or obliterated fossil layers between.	Many, if not most, clusters lie outside concretions and well preserved fossils can be found adjacent to concretions.
Stratigraphic thickness of the fossil layer constant across concretions with possible gradational lateral boundaries at the concretion-shale interface.	Clusters have a plano-convex cross-section with distinct lateral boundaries delimiting presence-absence.
Abundant evidence of solution, replacement and recrystalization.	Rare calcite recrystalization and rare replacement of calcite by pyrite. Solution of aragonitic gastropod and bivalve shells.

Table 9
Fossil Redistributional Mode of Formation,
Comparison of Expected and Observed Features

Features Expected	Features Observed
Cluster shape corresponding to current properties.	Cluster shape shows no indication of current action.
Cluster shape corresponding to depressions formed by resting habits of large animals.	Cluster shape has no radial or bilateral symmetry.
Shell density greatest at the base as an indication of current grading.	Shell density greatest at top, a reverse grading. Shells dispersed in aggregates within cluster.
Size distributions corresponding to reverse current grading.	Similar size distributions in all cluster levels.
Large difference in numbers of opposite valves corresponding to difference in shape and hydrodynamic properties.	Fifty percent fewer brachial valves due to fragmentation and selective loss in preparation.
Most shells in a stable hydrodynamic position with the brachial valve down.	Three times as many shells in a brachial up position at the cluster base and more than half in a brachial down position at the top. Possibly a result of substrate condition and life habit.

Table 9 (cont'd)

Expected Features	Features Observed
Majority of shells disarticulated due to current reworking.	Most shells articulated at the cluster base and most disarticulated at the cluster top. Possibly due to increase in scavenging, bioturbation, predation and/or shell position relative to substrate.
Preferred beak orientations of *Ambocoelia* due to current alignment.	Random beak orientation in brachial down position, but south-southwest preferred orientation in brachial up position. Possibly due to weak current.
Pedicle and brachial valve size-frequency curves dependent on hydrodynamic properties.	Very similar size distributions reflection non-transport.
Taxonomic diversity limited to forms with similar shapes and sizes.	Fossils present include many different shapes and sizes.

Initiation of the process could have been accomplished by occasional current transport of young.

Alternatively, Ambocoelia may have reproduced by larval means in which case cluster initiation and buildup was ecological. Initiation could be the result of larval settlement on a piece of shell debris or other suitable substrate. Prolonged re-aggregation, either by biochemical triggering of settlement of through choice of the same substrate could have resulted in cluster buildup.

Certain aspects of Wanakah shale clusters suggest, however, that these explanations must be oversimplified. Lateral and vertical extent of clusters is small, and a limiting process must have been operative. The density of individuals living on the substrate increased gradually rather than reaching a stable level soon after initial establishment. A more uniform density would be expected if cluster buildup was a simple process of continuous re-habitation on the same local patch of substrate.

These difficulties suggest that cluster development was a feedback process in which successive stages were controlled by prior events in development. The initial substrate was probably similar to many modern day soft mud bottoms where the sediment-water interface is gradational (a floc) rather than clearly defined (Rhoads, 1967). If such a condition existed, the sessile suspension feeders would have been at a disadvantage. To remain above the floc and filter food they either had to have special adaptations or suffer extinction through sinking and starving due to high sediment intake. Under these conditions attachment of spat to shell material and continued use of a shell littered patch on an otherwise somewhat lethal substrate would have been a tremendous advantage. The pedicle attachment and pedicle free positions suggested for Ambocoelia support the hypothesis that substrate at the cluster base was not particularly firm or stable, and that it became more stable as successive generations ensued. Lateral expansion and density increase would be limited by the number and location of shells available for attachment. Termination of development is difficult to explain. Uniformity in sizes of preserved clusters and the failure of adjacent clusters to terminate simultaneously rules out any sudden, widespread changes in environment. Alternatively, as density increased beyond a critical point, buildup of fecal and decay toxin might have inhibited further spat settlement. Increase in pyrite content within the cluster supports this hypothesis, but sampling difficulties do not permit isolation of the "last generation" in the cluster to determine whether recruitment failed. The evidence, then, is consistent with cluster development as a self-regulating ecologic succession imposed in a uniform physical and chemical framework.

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APPENDICES

APPENDIX I

AMBOCOELIA POSITION AND BEAK ORIENTATION

BRACHIAL VALVE DOWN

CLUSTER ALPHA

LEVEL A

105	0	60	78	319	310	355	307	55	250	222	180	189	205	218	172
60	241	255	128	170	14	270	180	74	234	97	186	184	208	191	30
271	298	315	329	35	353	202	179	93	38	32	22	192	82	318	86
181	146	259	211	234	14	19	146	141	208	21	237	174	351	70	170
87	162	156	218	17	262	310	289	354	350	24	13	179	261	219	116
235	296	295	39	298	9	185	216	117	237	34	3	2	33	293	119
212	74	319	284	207	77	85	64	104	326	71	247	100	284	56	185
282	228	279	263	102	310	57	16	199	101	32	232	136	144	262	183
233	342	18	122	65	207	66	311	28	239	337	120	336	351	103	330
23	48	216	68	266	78	242	218	201	356	11	117	172	238	265	169
119	175	235	178	259	270	103	209	260	353	50	126	239	135	266	222
281	102	209	87	238	37	1	236	257	198	197	4	192	74	285	160
359	213	136	354	229	253	16	151	254	359	259	63				

LEVEL B

166	168	130	18	262	223	195	97	225	269	140	26	271	217	69	65
5	178	177	349	1	39	228	309	297	266	141	49	79	45	299	0
144	155	176	268	174	244	259	333	107	26	280	352	217	337	341	322
149	162	46	88	221	189	213	274	229	266	238	298	161	177	140	338
93	234	280	189	12	326	228	22	98	254	97	93	314	100	310	16
253	60	48	259	162	238	130	84	57	183	285	209	354	209	145	270
251	182	188	77	19	255	170	232	332	167	120	298	277	2	339	308
80	281	164	103	48	147	344	195	79	331	198	27	209	180	271	26
210	355	279	150	92	173	206	269	204	251	183	114				

LEVEL C

70	57	346	54	358	133	284	320	76	250	330	96	340	88	276	24
218	333	193	269	235	250	263	251	324	111	319	130	235	88	96	325
57	232	205	276	358	352	127	81	43	69	231	119	281	253	232	58
137	10	204	85	284	341	93	247	96	211	290	269	136	328	275	272
47	289	70	10	320	70	108	251	268	102	350	268	345	305	59	349

LEVEL D

275	354	67	219	115	27	18	209	261	347	9	226	210	328	267	37
54	268	32	164	280	71	16	287	270	11	319	218	181	291	203	331
27	260	155	141	130	293	196	211	176	256	170	37	207	347	184	272
0	31	40	260	331	348	184	144	180	245	343	302	134			

CLUSTER BETA

LEVEL A

38	221	182	253	138	354	256	110	186	130	219	100	188	23	244	226
358	134	256	70	348	132	102	158	42	179	285	216	45	229	201	239
254	120	45	312	40	12	184	260	145	93	347	14	357	343	69	220
120	341	197	153	211	97	28	224	32	353	209	221	180	263	107	91

341	176	202	119	337	30	52	243	273	104	143	141	165	52	32	112
173	352	253	269	18	339	342	61	270	191	3	295	256	326	158	349
343	356	13	28	182	153	331	37	125	139	347	338	87	338	107	252
260	186	253	295	293	146	76	275	199	303	225	50	257	220	153	131
124	203	45	265	316	359	214	42	349	236	184	95	291	268	292	107
204	142	11	353	155	46	121									

LEVEL B

35	64	32	255	227	90	55	200	161	182	39	11	67	153	26	332
210	19	201	326	154	79	272	266	285	249	198	58	185	201	117	51
153	336	330	132	295	8	275	55	232	57	65	234	227	267	268	81
82	82	159	87	342	128	190	199	84	340	190	66	85	103	224	97
310	321	176	353	9											

LEVEL C

290	90	290	123	173	128	192	297	112	42	304	20	113	269	239	347
100	327	169	42	315	360	245	49	270	92	148	255	44	153	97	239
107	224	236	251	41	230	276	237	95	211	311	276	65	15	311	135
225	191	113	4	204	56	52	170	9	20	265	340	8	180	221	92
281															

LEVEL D

3	29	228	351	180	176	21	84	157	173	54	68	314	84	57	86
18	195	15	258	195	325	284	297	257	65	269	220	57			

CLUSTER GAMMA

LEVEL A

171	224	116	154	262	148	190	246	64	59	265	329	241	102	162	92
167	17	52	40	163	309	340	227	359	246	256	118	60	155	110	75
164	299	352	122	279	94	66	265	14	221	36	342	159	108	284	250
92	248	104	60	38	73	263	24	112	280	64	230	64	89	299	259
173	185	228	352	300	237	356	155	91	257	141	77	290	135	105	209
120	120	318	227	154	86	63	287	73	103	358	35	179	159	123	62
169	63	216	257	226	219	22	285	118	313	195					

LEVEL B

218	195	168	152	274	313	196	268	293	312	161	164	233	254	36	6
162	221	320	343	355	34	170	136	181	178	300	279	59	353	279	300
188	62	256	222	57	126	85	162	63	282	301	107	263	338	160	359
12	189	306	145	325	155	207	193	273	198	208	256	272	131	43	8
151	134	318	8	325	356	312	358	80	290	63	76	241	138	44	44
277	14	95	244	95	289	245	66	12	149	244	123	294	104	289	97
60	211	7	229	211	189	212	133	106	71	70	203	145	129	296	261
102	106	272	59	19	277	163	213	304	91	56	334	205	23	289	53
211	357	260	88	53	66	335	348	153	223	338	215	107	141	65	286
125	9	283	163	221	245	8	182	198	97	216	83	288	101	71	335
39	316	296	46	187	149	327									

LEVEL C

300	237	38	292	238	30	316	146	49	68	64	88	232	95	220	236
207	152	73	73	120	98	341	12	173	76	52	326	350	10	281	227
287	119	71	37	202	158	325	226	133	115	17	132	358	11	213	308
346	137	154	76	262	260	90	330	161	319	266	253	254	34	33	220
219	44	2	295	181	204	147	10	165	87	324	23	8	150	254	109
185	45	322	98	219	119	258	189	257	309	264	98	244	225	114	113

129 154 101 356 305 99 184 270 28 315 57 125 275 209 252 218
208 105

LEVEL D
267 166 129 330 202 153 310 326 244 259 245 252 76 196 312 161
240 148 258 180 325 266 60 125 331 159 297 248 271 251 230 133
151 170 226 307 286 352 162 26 95 179 272 285 256

BRACHIAL VALVE UP

CLUSTER ALPHA

LEVEL A
188 77 206 235 196 57 153 239 193 229 156 199 62 345 91 253
223 222 176 186 185 348 100 117 94 329 261 120 203 286 226 95
202 342 136 227 67 182 185 11 184 187 74 285 230 216 160 248
248 306 36 27 292 225 351

LEVEL B
62 178 222 122 231 2 0 352 353 164 137 105 339 94 173 151
85 356 275 348 236 178 250 171 96 258 117 354 130 259 358 357
250 173 210 350 44 193 35 182 335 172 163 280 289 214 150 33
120 36 216 261 195 265 38 209 214 340 170 173 268 285 5 183

LEVEL C
204 327 214 172 62 2 59 335 214 9 353 168 18 217 287 187
18 206 184 242 182 307 90 144 146 86 243 111 33 199 119 141
225 291 192 224 3 210 330 157 157 152 87 81 101 198 346 163
251 58 296 124 63 306 78 196 83 157 195 319 193 167 31 208
255 51 345 55 178 151

LEVEL D
167 227 256 88 141 157 349 352 197 346 51 178 164 91 244 210
106 346 76 98 168 198 158 329 248 214 162 109 180 323 279 357
166 79 182 127 140 55 100 99 97 107 43 52 41 187 87 53
193 194 297 69 153 150 189 97 310 101 254 28 168 93 204 186
101 176 63 343

CLUSTER BETA

LEVEL A
72 329 190 194 292 19 45 54 24 63 202 356 301 52 15 255
163 76 74 312 280 20 135 249 265 56 310 273 215 301 105 121
129 170 349 18 150 82 234 157 168 206 38 358 217 97 194 198
205 32 122 25 225 138 93 232 237 261 121 284

LEVEL B
88 221 166 91 221 62 109 165 141 165 196 135 291 218 28 116
268 240 315 272 164 97 352 40 203 271 221 277 132 116 352 141
128 29 26 13 31 223 275 63 272 297 5 140 23 239 270 216
17 35 295 317 168 85

LEVEL C

270 234 125 319 240 289 78 298 264 186 61 252 208 155 186 84
132 72 279 59 110 315 99 277 311 56 51 203 54 342 247 358
137 353 336 41 267 28 75 306 208 140 231 257 75 7 12 234
132 141 222 104 214 169 233 35 243 94 261 307

LEVEL D
24 341 95 57 76 48 103 152 359 25 356 193 235 194 258 67
168 35 13 183 126 179 202 288 174 177 70 127 122 48 232 353
311 118 11 188 9 8 46 172 355

CLUSTER GAMMA

LEVEL A
255 171 124 11 223 174 325 30 65 77 345 100 344 359 356 286
255 333 244 122 228 30 292 0 147 136 244 302 332 217 214 22
66 162 92 146 160 63 184 339 263 12 205 40 301

LEVEL B
79 253 346 79 202 236 105 42 129 298 38 278 40 266 40 239
344 88 309 341 7 180 97 145 314 39 66 353 127 120 337 212
222 359 281 277 284 315 348 359 96 227 67 37 76 313 136 83
194 116 235 106 310 83 357 57 19 103 159 223 126 96 279 184
181 156 204 82 88 223 328 196 238 227 231 52 21 280 41 155
105 227 248 177 113 6 328 186 312 236 75 273 216 266 247 180
85 330 48 242 231 185 209 335 358 212 0 110

LEVEL C
341 90 350 157 297 209 204 176 17 313 245 200 107 109 334 177
308 25 134 145 295 311 278 178 176 320 165 349 150 127 148 131
296 86 175 41 179 56 238 277 340 178 258 278 173 339 87 29
358 181 208 15 10 65 86 174 55 131 309 356 301 227 94 18
32 172 263 119 348 89 258 29 159 184 349 2 150 340 129 245

LEVEL D
202 174 227 44 139 34 192 339 186 215 340 272 74 148 351 69
129 136 186 178 295 148 90 31 290 291 176 75 282 298 283 260
68 315 25 207 241 83 152 108 256 345 158 228 189 61 178 335
253 228 138 317 305 125 256 4 6 344 64 338 168 173 102

APPENDIX II

AMBOCOELIA LENGTH AND WIDTH MEASUREMENTS, CLUSTER ALPHA

ARTICULATED SHELLS-NONFRAGMENTED, NONDISTORTED

LEVEL A

L	W	L	W	L	W	L	W	L	W	L	W
2.90	3.60	5.50	6.40	3.00	3.80	6.50	8.00	4.20	5.30	3.40	3.80
7.50	7.80	6.70	7.50	5.40	5.50	4.40	5.20	6.80	8.10	6.70	7.90
2.90	3.60	5.00	6.50	5.90	6.50	6.00	6.70	7.80	7.00	2.60	3.10
6.40	8.10	7.20	7.30	5.50	6.60	3.40	3.60	4.00	5.90	2.80	3.60
6.60	6.90	5.80	6.90	6.40	6.70	6.10	6.00	3.10	3.30	5.70	7.50
6.20	6.80	4.80	5.20	7.00	7.60	7.00	7.10	8.20	8.40	4.50	4.90
7.10	7.80	5.60	6.20	5.10	6.00	4.50	5.00	4.60	5.50	4.30	5.80
7.70	8.60	3.50	3.70	7.20	7.30	4.40	5.00	6.10	6.80	3.50	3.70
3.70	4.80	6.30	6.80	2.80	3.70	3.10	3.70	3.30	3.70	2.80	3.20
4.60	5.00	2.60	3.30	3.70	4.10	1.80	2.10	4.50	5.00	4.50	5.20
5.10	5.30	5.50	5.70	6.80	7.70	7.50	7.90	8.30	7.80	5.30	5.80
4.80	5.70	6.00	6.60	6.80	7.50	3.10	4.10	6.10	6.50	3.00	3.40
5.80	7.50	8.50	9.10	7.20	8.00	3.60	4.50	4.50	5.30	2.60	3.00
0.65	0.65	0.65	0.60	0.45	0.40	0.45	0.40	0.40	0.40	0.45	0.40
0.60	0.55	0.45	0.45	0.90	1.00	0.40	0.40	0.40	0.45	0.65	0.60
0.80	0.95	0.50	0.50	0.45	0.45	0.40	0.40	0.35	0.35	0.35	0.35
0.65	0.60	0.75	0.80	0.45	0.40	0.40	0.35	0.40	0.40	0.55	0.60
0.45	0.40	0.75	0.70	0.65	0.65	0.55	0.45	0.35	0.35	0.35	0.35
0.65	0.50	0.90	0.95	0.45	0.45	0.50	0.50	0.45	0.40	0.55	0.50
0.45	0.35	0.35	0.35	0.55	0.50	0.70	0.55	0.50	0.45	0.55	0.45
0.55	0.60	0.70	0.70	0.75	0.75	0.40	0.40	0.35	0.40	1.00	0.95
1.05	1.15	0.50	0.45	0.50	0.40	0.80	0.75	0.40	0.40	0.75	0.70
0.30	0.30	0.60	0.65	0.65	0.65	0.35	0.35	0.40	0.40	0.45	0.40
0.45	0.35	0.55	0.55	0.90	1.00	0.65	0.70	0.40	0.40	0.55	0.45
0.65	0.60	0.55	0.45	0.70	0.75	0.35	0.40	0.50	0.55	0.45	0.40
0.75	0.85	0.55	0.50	0.45	0.45	0.90	0.85	0.45	0.50	0.45	0.45
0.55	0.50	0.50	0.50	0.40	0.40	0.45	0.40	0.45	0.45	0.85	0.90
0.75	0.70	0.45	0.35	0.80	0.85	0.75	0.70	1.30	1.55	0.40	0.40
0.80	0.80	0.70	0.70	0.40	0.35	0.50	0.50	0.45	0.35	0.45	0.45
0.50	0.45	0.45	0.45	0.40	0.35	0.85	0.70	0.40	0.35	0.35	0.35
0.60	0.55	0.55	0.60	0.45	0.35	0.60	0.60	0.65	0.60	0.70	0.70
0.85	0.90	0.45	0.40	0.50	0.40	0.40	0.30	0.40	0.40	0.75	0.70
0.70	0.70	0.55	0.45	0.40	0.40	0.70	0.70	0.75	0.70	0.60	0.55
0.40	0.35	0.60	0.55	0.35	0.35	0.50	0.50	0.45	0.40	0.50	0.45
0.40	0.35	0.40	0.40	0.40	0.40	0.35	0.30	0.40	0.40	0.50	0.45
0.60	0.55	0.45	0.45	0.35	0.30	0.45	0.40	0.45	0.40	0.45	0.40
0.40	0.40	0.45	0.40	0.40	0.35	0.55	0.55	0.50	0.45	0.45	0.40
0.35	0.35	0.35	0.35	0.40	0.50	0.75	0.90	0.50	0.45	0.50	0.55
0.75	0.85	0.75	0.75	0.40	0.45	0.45	0.40	0.45	0.45	0.35	0.35
0.55	0.50	0.60	0.60	0.60	0.55	0.55	0.50	0.55	0.55	1.20	1.25
0.45	0.40	0.80	0.80	0.40	0.35	0.80	0.70	0.50	0.45	0.55	0.45
0.55	0.50	0.40	0.35	0.60	0.55	0.65	0.65	0.45	0.45	0.40	0.40
0.70	0.80	0.55	0.65	0.35	0.35	0.40	0.35	0.50	0.40	0.75	0.75
0.50	0.50	0.95	0.90	0.40	0.40	0.65	0.65	0.45	0.45	0.95	0.90
0.65	0.55	0.70	0.75	0.85	0.90	0.70	0.80	0.60	0.55	0.30	0.30
0.40	0.40	0.70	0.70	0.50	0.50	0.50	0.45	0.55	0.50	0.40	0.35

0.75	0.75	0.55	0.55	0.60	0.60	0.70	0.70	0.90	0.95	0.45	0.40
0.40	0.35	0.30	0.25	0.45	0.40	2.10	2.20	0.60	0.60	2.50	2.90
0.40	0.35	0.90	1.00	1.85	1.90	0.40	0.35	0.85	0.90	0.35	0.35
0.45	0.45	0.55	0.55	0.50	0.55	0.40	0.40	0.35	0.30	0.35	0.35
0.45	0.40	0.70	0.60	0.45	0.40	0.40	0.40	0.80	0.85	2.50	2.90
0.45	0.40	0.60	0.50	0.60	0.50	0.50	0.50	0.55	0.50	0.70	0.75
0.50	0.50	0.50	0.40	0.40	0.40	0.55	0.50	0.45	0.45	0.40	0.35
0.45	0.45	0.70	0.75	0.50	0.45	0.40	0.35	0.60	0.55	0.45	0.40
0.40	0.35	0.40	0.35	0.80	0.85	0.50	0.50	0.50	0.45	0.35	0.35
0.50	0.45	0.45	0.45	0.45	0.45	0.50	0.45	0.45	0.40	0.40	0.40
0.45	0.50	0.55	0.60	0.50	0.45	0.75	0.70	0.45	0.45	0.65	0.60
0.50	0.50	0.45	0.40	0.40	0.35	0.65	0.60	0.50	0.45	0.45	0.40
0.30	0.30	0.80	0.90	0.35	0.35	0.80	0.80	0.55	0.55	0.50	0.45
0.50	0.50	0.40	0.40	0.80	0.80	0.40	0.40	0.55	0.50	0.55	0.50
0.65	0.65	0.80	0.85	0.60	0.50	0.85	1.00	0.40	0.35	0.55	0.55
0.60	0.60	0.55	0.50	0.40	0.40	0.45	0.45	0.65	0.60	0.65	0.55
0.40	0.40	0.45	0.40	0.50	0.50	0.90	0.95	0.45	0.45	0.55	0.50
0.85	0.90	0.75	0.75	0.45	0.45	0.85	0.80	0.50	0.45	2.55	2.75
0.95	0.90	0.40	0.35	0.45	0.40	0.45	0.45				

LEVEL B

L	W	L	W	L	W	L	W	L	W	L	W
7.70	9.30	4.70	5.70	7.30	8.20	4.30	5.50	5.00	5.50	6.20	7.40
3.40	3.70	5.90	6.20	3.10	3.60	5.00	5.10	4.00	4.20	6.40	5.90
7.40	8.30	5.40	7.00	4.60	5.00	5.80	6.60	4.90	5.70	7.60	7.90
5.10	5.20	4.50	5.20	6.00	6.40	4.50	5.80	4.70	5.20	5.40	6.00
6.70	6.50	3.40	3.80	4.10	5.10	3.00	4.00	4.00	5.00	3.20	3.70
3.20	3.60	5.30	5.80	5.10	5.70	4.60	5.60	4.80	5.50	5.40	6.90
5.50	6.20	3.70	4.80	6.40	6.60	5.50	5.80	4.30	4.90	2.80	3.20
5.00	6.00	4.10	4.60	3.80	4.20	3.70	4.20	3.20	4.10	4.20	4.90
4.00	5.20	5.70	5.70	2.60	2.80	4.30	4.40	4.50	4.80	6.90	7.00
2.40	2.80	3.70	3.90	5.50	6.90	5.00	5.00	4.30	5.00	3.30	4.40
2.70	3.20	5.30	5.70	3.70	5.40	5.90	5.80	3.20	3.10	3.70	4.60
6.20	7.50	5.90	6.20	1.80	2.60	5.40	6.00	3.90	3.80	3.00	3.80
5.30	5.30	4.30	5.00	7.50	8.00	2.50	2.80	4.00	4.70	3.50	4.40
7.00	6.30	6.50	6.60	4.10	5.00	9.00	9.90	4.60	5.20	5.60	6.40
4.00	4.80	4.20	4.00	5.30	6.70	2.40	3.00	3.20	3.90	6.10	5.80
3.20	4.00	3.40	4.00	3.30	2.80	4.50	5.50	4.50	5.40	6.40	7.70
6.30	7.20	2.90	3.40	6.10	7.00	5.80	6.00	0.50	0.60	2.30	2.90
4.20	4.60	5.10	6.50	3.80	3.80	5.10	5.70	4.00	4.60	6.00	7.50
6.00	6.50	4.40	5.00	3.00	3.30	2.60	3.00	3.20	3.60	2.60	3.20
3.60	3.60	5.00	5.40	6.40	7.20	0.85	1.00	0.35	0.40	0.45	0.50
0.50	0.50	0.60	0.60	0.85	0.90	0.90	0.90	0.55	0.55	0.75	0.80
0.40	0.40	0.95	0.95	0.70	0.60	0.75	0.80	0.65	0.60	0.70	0.65
0.60	0.60	0.45	0.40	0.60	0.60	0.40	0.45	0.85	0.90	0.80	0.75
0.80	0.80	0.95	0.95	1.00	1.10	0.65	0.70	0.95	0.95	0.60	0.60
0.75	0.90	0.60	0.65	0.50	0.50	0.65	0.50	0.65	0.60	0.80	0.85
0.45	0.40	0.75	0.70	0.75	0.75	0.75	0.80	0.60	0.70	0.95	0.85
0.45	0.45	0.75	0.70	0.90	1.00	0.85	0.90	0.70	0.70	0.80	0.70
0.45	0.40	0.50	0.50	0.55	0.60	0.60	0.65	0.50	0.45	0.50	0.50
0.45	0.40	0.65	0.65	0.75	0.75	1.70	1.70	0.55	0.45	0.60	0.60
0.50	0.45	0.40	0.40	0.40	0.45	0.40	0.40	0.65	0.80	0.85	0.80
0.40	0.40	2.70	3.10	0.50	0.50	0.55	0.50	0.50	0.55	1.35	1.50
1.75	1.80	0.55	0.60	0.40	0.35	0.55	0.55	0.40	0.35	0.40	0.40
0.75	0.75	0.40	0.35	0.45	0.45	0.40	0.45	0.45	0.45	0.50	0.45
0.40	0.45	0.40	0.45	0.55	0.55	0.30	0.30	0.55	0.60	0.65	0.70

0.85	0.80	0.50	0.50	0.60	0.55	0.35	0.35	0.75	0.75	0.90	1.00
0.40	0.40	0.55	0.50	0.40	0.40	0.40	0.40	0.95	1.00	0.45	0.40
0.75	0.80	0.40	0.35	0.65	0.70	1.00	1.10	0.35	0.35	0.95	1.00
0.80	0.75	0.55	0.50	0.45	0.40	0.55	0.60	0.75	0.70	0.50	0.50
0.60	0.70	0.75	0.80	0.35	0.35	0.60	0.55	0.75	0.80	0.45	0.40
0.45	0.45	0.65	0.65	0.45	0.35	0.60	0.60	0.60	0.60	0.85	0.90
0.40	0.40	0.60	0.55	0.55	0.50	0.50	0.45	0.70	0.70	0.65	0.60
0.45	0.40	0.50	0.50	0.50	0.50	0.60	0.70	0.65	0.55	0.75	0.65
0.70	0.85	0.45	0.40	0.80	0.85	0.90	1.00	0.40	0.40	0.70	0.65
0.75	0.80	0.55	0.60	0.55	0.50	0.45	0.50	0.75	0.80	0.45	0.40
0.30	0.35	0.80	0.75	0.55	0.50	0.55	0.55	0.75	0.65	0.60	0.55
0.65	0.65	0.80	0.80	0.55	0.50	1.00	1.25	0.85	1.00	0.65	0.55
0.55	0.60	0.80	0.80	0.40	0.40	0.45	0.45	0.75	0.80	0.40	0.35
0.55	0.55	0.70	0.60	0.40	0.35	0.55	0.50	0.50	0.50	0.40	0.40
0.50	0.45	0.75	0.90	0.45	0.45	0.50	0.40	0.60	0.55	0.80	0.75
1.00	0.65	0.75	0.70	0.50	0.55	0.70	0.70	0.60	0.60	0.50	0.45
0.30	0.30	0.45	0.45	0.60	0.65	0.60	0.65	0.50	0.45	0.40	0.35
1.00	1.10	0.55	0.60	0.35	0.30	0.75	0.70	0.55	0.55	0.45	0.40
0.70	0.75	0.80	0.85	0.70	0.60	0.55	0.55	0.45	0.45	2.50	2.50
0.55	0.50	0.95	1.05	0.50	0.50	0.60	0.50	0.40	0.40	0.40	0.35
0.45	0.40	0.80	0.70	0.70	0.70	0.50	0.50	0.60	0.65	0.40	0.40
0.45	0.45	0.45	0.40	0.60	0.55	0.50	0.45	0.70	0.75	0.50	0.45
0.90	0.95	0.50	0.45	0.75	0.75	0.85	0.95	0.30	0.40	0.45	0.40
0.45	0.40	0.45	0.50	0.60	0.50	0.85	0.90	0.85	0.85	0.45	0.35
0.80	0.95	0.60	0.50	0.40	0.40	0.55	0.55	0.50	0.50	0.45	0.45
0.70	0.70	0.70	0.70	0.35	0.35	0.55	0.65	0.50	0.55	0.70	0.70
0.50	0.50	0.80	0.90	0.40	0.35	0.75	0.65	0.50	0.40	0.35	0.35
0.85	0.80	0.55	0.45	0.45	0.45	0.55	0.55	0.50	0.45	0.45	0.45
0.45	0.45	0.70	0.70	0.70	0.75	0.40	0.35	0.70	0.65	0.65	0.60
0.80	0.85	0.40	0.40	0.75	0.80	0.70	0.60	0.60	0.55	0.85	0.80
0.50	0.50	0.85	1.00	1.00	1.00	0.50	0.55	0.65	0.65	0.55	0.55
0.55	0.50	0.85	0.95	0.80	0.65	0.65	0.60	0.40	0.35	0.50	0.45
0.40	0.40	0.40	0.40	0.45	0.45	0.35	0.30	0.40	0.35	0.35	0.35
0.40	0.35	0.50	0.50	0.50	0.45	0.45	0.40	0.40	0.35	0.45	0.45
2.00	2.20	0.35	0.35	0.65	0.65	0.55	0.50	0.90	0.90	0.50	0.45
0.60	0.50	0.90	0.85	0.75	0.80	0.40	0.40	0.60	0.60	0.60	0.60
0.65	0.60	0.55	0.55	0.60	0.55	2.25	2.30	1.50	1.80	1.00	0.95
0.70	0.70	0.50	0.45	0.65	0.65	2.70	3.00	0.60	0.60	1.15	1.20
0.60	0.60	0.65	0.60	1.50	1.50	0.60	0.55	0.45	0.45	0.65	0.60
0.90	0.75	1.55	1.70	0.50	0.50	0.45	0.45	0.45	0.45	0.50	0.45
0.45	0.45	0.60	0.55	0.35	0.35	1.20	1.40	0.60	0.50	0.75	0.70
0.70	0.70	0.70	0.75	0.60	0.55	0.45	0.40	0.75	0.75	0.60	0.60
0.40	0.40	0.70	0.80	0.65	0.60	0.45	0.40	0.70	0.70	0.45	0.45
0.90	0.85	0.40	0.40	0.60	0.60	0.75	0.65	0.70	0.70	0.95	1.05
0.55	0.55	0.90	0.95	0.80	0.75	0.90	0.80	0.90	0.85	0.60	0.55
0.50	0.45	0.65	0.70	0.90	1.05	0.55	0.50	0.60	0.60	0.45	0.45
0.60	0.50	0.55	0.55	1.05	1.25	0.45	0.50	0.35	0.35	0.70	0.65
0.65	0.60	0.80	0.80	0.40	0.35	0.50	0.50	0.60	0.55	0.85	0.80
0.80	0.80	0.95	0.95	0.90	0.75	0.80	0.75	0.40	0.45	0.50	0.40
0.40	0.35	0.45	0.45	0.65	0.65	0.75	0.70	0.50	0.45	0.70	0.60
0.85	0.90	0.80	0.90	1.10	1.10	0.35	0.30	0.35	0.35	0.75	0.70
0.95	0.90	0.90	1.00	0.45	0.40	0.80	0.85	0.80	0.85	0.45	0.45
0.40	0.40	0.45	0.40	0.60	0.55	0.65	0.70	0.90	1.00	0.45	0.45
0.65	0.60	0.75	0.75	0.95	1.00	0.90	0.80	0.60	0.60	0.50	0.50
0.85	0.90	0.40	0.40	0.75	0.70	0.50	0.45	0.50	0.55	2.40	2.80
0.80	0.75	0.75	0.80	0.80	0.80	0.40	0.35	0.75	0.75	0.80	0.80
0.65	0.60	0.45	0.45	0.40	0.40	2.50	3.50				

LEVEL C

L	W	L	W	L	W	L	W	L	W	L	W
3.10	3.60	7.50	8.20	6.10	6.20	3.20	3.90	5.70	7.30	5.00	5.30
6.50	7.30	4.40	5.00	7.80	8.30	4.30	5.00	4.60	5.20	5.00	6.20
5.40	6.90	4.80	4.90	5.10	6.30	5.70	6.60	2.80	3.40	3.60	4.60
5.20	5.70	4.40	5.50	4.20	4.80	4.90	6.00	4.00	4.70	3.80	4.50
4.10	4.40	4.70	5.60	4.70	5.60	3.80	5.00	6.30	7.00	3.90	5.10
7.10	7.90	4.20	5.00	4.20	4.30	4.30	5.10	4.10	5.90	4.70	5.60
5.90	6.00	3.50	4.30	5.40	6.20	5.30	5.10	7.60	7.80	3.60	4.90
5.80	6.30	4.50	5.80	3.50	3.60	6.40	6.70	4.20	4.50	3.60	4.60
3.40	4.80	4.30	5.30	2.70	3.70	3.80	5.30	4.60	4.60	5.40	5.80
4.80	5.20	2.60	4.10	4.00	4.10	4.00	4.80	3.80	3.80	4.00	5.20
3.70	3.60	5.80	6.70	7.20	9.70	5.50	7.10	4.70	5.50	6.90	7.70
6.30	7.20	2.70	3.30	4.20	4.60	9.90	9.90	3.70	4.30	4.60	4.60
4.90	4.70	8.30	8.10	3.90	4.30	7.10	8.00	7.50	8.50	3.30	3.80
3.60	4.50	4.30	4.70	5.90	5.70	7.10	7.70	6.70	7.40	5.70	6.00
4.70	4.30	4.50	5.60	5.50	5.60	3.10	3.80	4.00	4.60	5.00	5.00
4.10	4.30	1.35	1.60	0.70	0.65	1.00	1.00	0.60	0.50	0.60	0.55
0.50	0.40	0.55	0.55	0.65	0.60	0.55	0.60	0.70	0.65	0.70	0.60
0.75	0.70	1.50	1.75	0.65	0.65	0.50	0.45	0.45	0.35	0.40	0.35
0.50	0.50	0.85	0.70	0.80	0.80	1.10	1.20	0.75	0.60	0.70	0.70
0.60	0.50	1.00	1.05	0.95	1.05	0.40	0.35	0.50	0.45	0.60	0.70
0.95	0.95	0.55	0.50	0.85	0.75	1.00	1.20	0.75	0.75	0.55	0.50
0.70	0.80	0.80	0.70	0.75	0.75	1.15	1.25	0.55	0.50	0.40	0.35
0.50	0.55	0.55	0.60	0.45	0.45	0.50	0.50	0.60	0.60	0.55	0.55
0.55	0.55	1.15	1.00	0.40	0.40	0.40	0.40	0.50	0.50	0.85	0.75
0.65	0.65	0.45	0.45	0.60	0.60	0.50	0.50	1.05	1.20	0.60	0.50
0.55	0.45	0.85	0.95	0.75	0.80	0.60	0.55	0.45	0.55	1.70	1.85
1.25	1.45	0.50	0.50	0.75	0.55	0.70	0.50	0.50	0.50	0.80	0.90
0.90	0.95	0.40	0.45	0.90	0.90	0.95	0.95	2.00	2.20	0.70	0.70
0.80	0.90	1.40	1.70	0.65	0.65	0.80	0.80	0.50	0.60	0.55	0.55
0.75	0.65	0.50	0.45	0.40	0.35	0.60	0.65	0.70	0.75	0.60	0.60
0.50	0.50	0.80	0.85	0.95	0.70	0.45	0.40	0.40	0.40	0.40	0.40
1.40	1.50	0.35	0.35	0.50	0.50	0.40	0.35	0.40	0.35	0.50	0.40
0.40	0.40	0.95	0.95	0.35	0.35	0.65	0.60	0.80	0.90	0.85	0.95
1.25	1.50	0.35	0.30	0.85	0.90	0.30	0.25	0.50	0.50	0.95	1.05
0.45	0.40	0.45	0.50	0.65	0.65	0.65	0.65	0.70	0.60	0.50	0.45
0.45	0.40	0.40	0.40	0.45	0.40	0.55	0.50	0.50	0.55	0.80	0.75
0.70	0.70	0.65	0.60	0.55	0.50	0.65	0.70	0.60	0.75	0.75	0.80
0.40	0.30	0.60	0.65	0.50	0.40	0.40	0.35	0.55	0.55	1.15	1.25
1.05	0.90	2.00	2.40	0.60	0.50	0.60	0.50	0.35	0.35	0.45	0.40
1.05	1.10	0.35	0.35	1.05	1.10	0.65	0.65	0.60	0.50	0.70	0.70
0.45	0.40	0.50	0.45	0.44	0.50	0.65	0.60	0.45	0.40	0.60	0.65
0.55	0.50	0.55	0.50	0.40	0.40	0.55	0.50	0.45	0.45	0.50	0.50
0.40	0.35	0.70	0.55	0.50	0.45	0.40	0.35	1.00	1.20	0.75	0.70
0.40	0.40	0.45	0.40	0.95	1.05	0.65	0.65	0.35	0.30	0.70	0.55
0.70	0.70	0.45	0.45	0.45	0.40	0.45	0.40	0.45	0.40	0.70	0.70
0.75	0.80	0.75	0.70	0.35	0.35	0.60	0.50	0.65	0.65	0.35	0.30
0.90	0.95	0.45	0.45	0.40	0.35	0.60	0.55	0.50	0.50	0.50	0.50
0.60	0.60	0.45	0.45	0.80	0.85	0.40	0.35	0.75	0.75	0.80	0.75
0.40	0.35	0.75	0.70	0.40	0.35	0.50	0.45	0.45	0.45	0.80	0.90
0.50	0.45	0.45	0.45	0.50	0.50	0.80	0.75	0.80	0.90	0.95	1.10
0.60	0.55	1.00	1.00	0.65	0.65	0.70	0.65	0.90	1.05	0.55	0.45
0.50	0.35	1.20	1.30	0.80	0.80	0.60	0.70	0.65	0.75	0.45	0.45
0.30	0.35	0.60	0.65	0.40	0.40	0.55	0.50	0.60	0.55	0.65	0.65

0.40	0.40	0.40	0.40	0.80	0.90	0.70	0.80	0.40	0.30	0.65	0.65
0.60	0.60	0.75	0.60	0.70	0.75	0.85	0.85	0.35	0.40	0.70	0.65
0.55	0.60	1.25	1.35	1.15	1.10	0.40	0.40	0.50	0.55	0.55	0.55
0.60	0.60	2.50	3.30	0.85	0.95	0.75	0.65	0.60	0.70	0.75	0.70
0.55	0.55	0.45	0.40	0.95	1.00	0.65	0.60	1.75	1.95	0.75	0.75
0.70	0.70	0.75	0.75	0.55	0.50	0.75	0.75	1.50	1.75	0.80	0.80
0.50	0.45	0.90	0.90	0.95	1.05	0.95	1.10	0.35	0.35	0.60	0.60
0.75	0.75	0.45	0.35	0.60	0.55	0.50	0.55	0.65	0.70	0.70	0.60
0.35	0.35	0.50	0.50	0.50	0.45	0.40	0.40	0.40	0.35	0.45	0.35
0.50	0.50	0.80	0.80	0.55	0.55	0.50	0.45	0.65	0.60	0.60	0.55
0.50	0.45	0.45	0.45	0.45	0.45	0.65	0.65	0.65	0.60	0.50	0.45
0.60	0.60	0.40	0.35	0.55	0.50	0.65	0.60	0.80	1.05	0.50	0.55
0.45	0.45	0.60	0.60	0.45	0.45	0.65	0.70	0.50	0.40	0.60	0.65
0.45	0.35	0.45	0.35	0.70	0.65	0.45	0.45	0.40	0.40	0.90	0.85
0.70	0.65	0.75	0.80	0.45	0.45	0.45	0.45	0.40	0.40	0.40	0.40
0.55	0.55	0.45	0.45	0.80	0.85	0.40	0.35	0.50	0.45	0.40	0.35
0.50	0.50	0.75	0.75	0.70	0.60	0.85	0.90	0.50	0.45	0.75	0.75
0.40	0.40	0.65	0.60	0.90	1.05	0.40	0.35	0.55	0.55	0.55	0.50
0.60	0.60	0.70	0.70	0.80	0.80	0.70	0.65	0.60	0.55	1.00	1.00
0.40	0.35	2.20	2.50	2.70	3.20	0.80	0.85	0.50	0.45	0.40	0.35
0.70	0.70	0.60	0.50	0.40	0.35	2.60	2.80	0.55	0.55	0.40	0.35
0.30	0.30	0.45	0.40	0.75	0.80	0.50	0.50	0.55	0.55	3.50	3.80
4.20	4.20	3.70	3.90	8.00	7.70	5.20	5.50	5.20	5.30	1.80	1.90

LEVEL D

L	W	L	W	L	W	L	W	L	W	L	W
5.30	5.80	2.50	2.50	1.40	1.80	3.80	4.50	2.70	3.50	3.70	4.20
7.50	8.80	4.00	4.90	6.10	6.40	4.70	5.20	3.90	4.50	4.70	5.50
3.70	4.60	5.80	7.20	6.20	7.30	6.00	6.80	6.00	7.00	6.80	5.90
2.70	3.90	7.90	7.30	5.00	6.20	2.50	2.40	5.40	6.90	3.70	4.20
3.00	3.10	2.60	3.00	4.40	5.10	2.20	2.90	6.40	8.00	6.30	8.10
4.60	5.20	4.20	4.80	5.50	6.20	5.50	5.20	5.70	5.60	5.10	7.10
4.80	5.30	3.50	4.00	5.30	6.80	6.10	7.10	3.90	4.00	5.30	6.60
5.40	7.10	6.60	6.20	5.00	4.70	6.80	6.10	7.80	8.00	4.70	5.40
3.70	4.40	4.00	4.80	5.00	6.40	6.40	6.60	6.00	6.80	4.00	4.20
5.40	4.80	6.00	6.00	7.60	8.70	2.70	3.10	4.30	4.00	4.70	5.50
6.00	6.90	5.00	5.60	7.00	7.20	4.20	4.30	6.60	7.00	6.80	8.30
3.00	3.50	5.50	6.40	5.60	5.70	5.80	6.30	5.20	5.80	5.80	6.10
7.00	7.50	5.30	5.30	4.50	5.70	5.00	6.10	7.50	8.00	6.40	7.80
6.10	8.00	5.30	5.50	6.00	6.90	5.00	7.00	4.40	5.40	7.00	7.70
6.00	6.50	4.80	5.10	6.30	6.60	5.00	5.90	5.00	5.50	4.80	5.50
5.00	6.20	4.00	4.60	6.50	8.00	5.10	5.80	5.60	5.80	5.10	5.70
5.90	5.80	5.20	5.80	7.80	8.40	4.50	5.60	4.70	4.60	3.00	3.40
6.10	6.90	5.00	5.20	7.00	8.80	4.80	5.20	7.20	8.50	2.90	3.10
4.30	5.40	6.50	7.50	6.50	7.40	4.20	4.50	5.60	6.20	5.40	6.00
3.40	4.30	4.00	4.30	7.90	8.90	6.20	6.70	6.60	8.10	5.10	5.90
3.60	4.70	5.90	6.00	5.90	6.50	4.70	4.50	6.00	6.80	5.50	6.60
5.50	6.30	5.10	6.20	4.70	5.90	6.70	8.00	5.90	7.60	5.80	5.30
4.50	5.90	5.80	5.60	4.50	5.70	6.90	8.00	5.70	6.00	8.00	8.20
5.80	6.20	6.00	5.80	7.50	8.50	5.50	6.50	6.50	7.60	2.00	2.50
5.00	5.50	5.40	6.00	6.40	7.80	3.80	4.80	6.80	7.40	5.80	7.10
4.00	5.40	4.60	5.80	4.50	6.00	7.00	7.20	6.50	6.50	5.20	8.40
5.50	6.30	7.00	7.80	7.90	8.40	2.90	3.30	7.00	7.30	4.10	5.00
6.60	6.60	5.00	6.30	5.40	5.60	4.80	5.30	3.40	4.00	7.00	7.00
5.40	5.60	0.55	0.45	0.35	0.35	0.35	0.40	0.80	0.90	0.50	0.45
0.40	0.40	0.60	0.55	1.30	1.25	1.15	1.20	0.50	0.45	0.50	0.45

0.55	0.55	0.45	0.40	0.70	0.65	0.75	0.90	0.55	0.45	0.55	0.50
0.65	0.50	0.55	0.45	0.75	0.80	0.40	0.50	0.60	0.60	0.40	0.35
0.45	0.40	0.95	0.90	0.80	0.85	0.80	0.75	0.50	0.50	0.65	0.65
0.35	0.30	0.65	0.70	0.50	0.40	0.50	0.40	0.55	0.55	0.55	0.50
0.45	0.50	0.80	0.85	0.75	0.75	0.35	0.35	0.85	0.95	0.50	0.45
0.80	0.80	1.55	1.70	0.55	0.45	0.60	0.60	0.90	1.10	0.60	0.60
0.55	0.55	0.45	0.45	0.40	0.40	0.50	0.50	0.70	0.80	0.50	0.50
0.75	0.75	0.85	0.65	0.40	0.40	0.55	0.55	0.45	0.40	0.50	0.55
0.65	0.60	0.50	0.50	0.50	0.50	0.70	0.70	0.50	0.40	0.40	0.40
0.90	0.90	0.45	0.45	0.40	0.35	0.90	1.05	0.80	0.95	0.70	0.70
0.55	0.50	0.75	0.80	0.45	0.40	0.45	0.45	0.40	0.45	0.60	0.60
0.80	0.80	0.50	0.50	0.45	0.40	0.50	0.45	0.90	0.95	1.05	1.05
0.55	0.55	0.45	0.40	0.90	0.95	0.40	0.45	0.55	0.60	1.05	1.20
0.80	0.90	1.15	1.20	0.45	0.40	0.35	0.35	0.45	0.40	0.50	0.55
0.60	0.70	0.50	0.45	0.50	0.45	0.50	0.40	0.50	0.45	0.90	1.10
0.40	0.35	0.40	0.40	0.55	0.55	1.00	1.00	0.55	0.50	0.45	0.40
0.75	0.85	0.85	0.70	0.45	0.40	1.90	2.00	2.00	2.20	0.75	0.80
0.35	0.35	0.50	0.50	0.55	0.50	0.50	0.45	0.95	0.90	0.70	0.75
0.50	0.45	0.60	0.65	0.45	0.40	0.60	0.55	0.65	0.65	1.25	1.50
0.50	0.50	0.95	0.95	0.45	0.45	0.60	0.50	0.45	0.40	0.45	0.45
0.55	0.55	0.40	0.40	0.50	0.45	0.35	0.35	0.65	0.65	0.60	0.55
0.50	0.45	0.75	0.75	0.45	0.40	0.50	0.45	0.85	0.85	0.60	0.60
0.45	0.40	0.90	0.80	0.95	1.10	0.55	0.50	0.60	0.60	0.55	0.55
0.70	0.70	0.45	0.45	0.50	0.50	0.70	0.70	0.45	0.40	0.75	0.70
0.90	0.90	0.70	0.75	0.45	0.50	0.55	0.50	0.70	0.70	0.65	0.60
0.60	0.55	0.40	0.40	1.05	1.00	0.50	0.45	0.60	0.60	0.70	0.80
0.40	0.40	0.35	0.35	0.50	0.50	0.60	0.60	0.85	0.80	0.90	0.95
0.55	0.65	0.95	1.00	0.50	0.55	0.75	0.85	0.65	0.55	0.55	0.50
1.00	1.05	0.75	0.75	0.50	0.40	0.55	0.45	2.50	3.00	0.50	0.50
0.50	0.50	0.45	0.45	0.65	0.65	0.40	0.40	0.40	0.40	0.70	0.70
0.40	0.35	0.50	0.50	1.25	1.40	0.45	0.45	0.50	0.50	0.50	0.50
0.45	0.45	0.45	0.45	0.45	0.40	0.40	0.35	0.55	0.55	0.45	0.55
0.35	0.35	0.40	0.40	0.40	0.35	1.30	1.35	0.50	0.50	0.75	0.90
0.50	0.50	0.60	0.65	0.55	0.55	0.50	0.50	0.50	0.45	0.50	0.40
0.50	0.45	0.45	0.45	0.30	0.30	0.80	0.85	0.60	0.55	0.50	0.45
2.00	2.40	0.50	0.45	0.85	0.70	0.40	0.40	0.50	0.50	0.55	0.50
0.80	0.65	0.45	0.35	0.60	0.55	0.55	0.50	0.45	0.50	0.45	0.40
0.40	0.35	0.50	0.50	0.40	0.40	0.80	0.85	0.75	0.65	0.60	0.55
0.55	0.45	0.50	0.50	0.55	0.50	0.75	0.80	0.40	0.35	1.10	1.05
0.50	0.45	0.50	0.45	5.50	6.50	6.50	7.90	4.80	4.80	7.00	7.80
5.00	5.90	5.80	6.60	4.60	4.50	4.40	4.50	5.00	5.20	5.30	5.60
1.10	1.10	0.60	0.55	0.35	0.35	0.60	0.40	0.45	0.40	0.45	0.45
0.65	0.55	0.75	0.80	0.65	0.60	0.45	0.45	0.35	0.30	0.75	0.80
1.25	1.35	0.40	0.35	0.60	0.65	0.60	0.55	0.50	0.45	0.50	0.45
0.35	0.40	0.45	0.40	0.60	0.50	0.45	0.35	0.50	0.40	0.45	0.40
0.35	0.30	0.35	0.35	0.75	0.75	0.35	0.35	0.40	0.50	0.55	0.50

PEDICLE VALVES-NONFRAGMENTED, NONDISTORTED

LEVEL A

L	W	L	W	L	W	L	W	L	W	L	W
5.90	6.40	6.00	6.00	5.20	5.70	2.50	2.70	2.50	2.90	5.30	5.70
4.80	6.20	5.40	6.80	3.30	3.50	4.50	4.80	5.50	6.80	3.30	4.00
7.20	8.20	2.30	2.30	5.00	6.40	3.80	4.40	5.10	5.80	5.00	6.50
6.80	7.50	5.50	6.00	6.50	6.50	5.50	6.10	6.00	7.50	5.70	6.20

5.00	6.20	4.30	4.30	4.00	4.30	7.60	8.30	2.70	3.30	5.80	5.80
5.00	5.80	4.50	5.10	2.60	2.80	7.00	7.60	6.00	6.40	3.50	4.70
3.70	4.50	7.00	7.20	3.00	3.10	5.30	6.10	5.70	6.10	6.00	6.90
5.60	6.60	5.90	6.50	5.60	6.20	4.40	4.90	5.70	5.80	5.10	6.00
4.60	4.50	6.50	7.40	5.90	6.40	6.30	6.80	6.50	6.80	3.50	3.20
5.20	6.50	4.70	4.60	5.30	5.30	6.00	7.40	3.30	4.20	3.30	3.80
4.30	4.70	6.30	6.70	5.50	5.60	6.00	6.60	4.40	4.60	5.50	7.00
4.40	4.80	3.20	3.90	4.20	4.80	6.40	6.40	4.30	4.10	4.60	4.60
6.80	6.60	4.80	4.80	4.30	5.20	3.80	4.50	6.30	6.60	5.50	6.20
2.90	3.60	4.20	4.50	7.10	7.80	7.50	8.00	5.50	6.40	3.70	4.20
3.50	3.90	3.70	4.00	7.50	7.70	3.10	3.70	3.40	3.40	4.80	5.50
6.00	6.80	4.80	5.60	6.20	7.50	6.30	6.50	3.60	4.00	5.20	5.80
6.60	6.40	4.40	4.80	3.50	4.00	3.20	3.70	4.50	5.50	5.70	7.10
5.70	7.10	5.20	6.00	6.70	7.50	6.00	6.00	6.50	6.50	3.00	3.80
4.90	5.40	4.20	5.20	2.90	3.30	3.70	4.20	4.60	5.00	3.80	4.50
5.20	6.00	4.20	5.00	5.80	5.80	4.30	5.00	4.80	5.00	6.10	6.80
5.20	5.70	4.20	5.60	7.40	7.90	5.90	6.20	1.50	1.80	4.60	4.90
3.10	3.50	3.90	4.40	6.10	6.40	1.70	2.20	3.80	4.30	6.10	7.10
6.30	6.60	7.40	8.40	4.70	5.00	3.70	4.10	3.50	3.90	3.50	3.90
5.40	5.90	5.90	6.70	2.50	2.90	4.20	4.80	6.60	7.20	0.40	0.40
0.70	0.70	2.00	2.10	0.45	0.45	2.40	2.70	0.35	0.35	0.40	0.40
0.75	0.70	0.50	0.45	1.20	1.20	0.60	0.50	0.45	0.40	0.50	0.45
0.80	0.80	0.40	0.45	0.40	0.40	0.45	0.45	0.35	0.35	0.70	0.60
0.50	0.40	2.00	2.50	0.70	0.70	0.40	0.40	0.45	0.40	1.00	1.05
0.50	0.45	5.70	6.50	6.60	6.70	4.30	5.10	6.60	6.40	7.80	8.20
3.10	3.00	4.80	5.20	3.90	4.30	0.70	0.60	0.55	0.50	0.50	0.50

LEVEL B

L	W	L	W	L	W	L	W	L	W	L	W
4.50	3.90	6.10	7.00	4.50	5.70	4.00	4.20	6.20	6.50	4.30	5.40
5.70	6.00	5.30	5.30	6.90	7.10	4.10	4.60	7.00	7.30	4.30	4.50
3.00	3.40	7.90	8.50	5.50	5.50	3.60	4.10	4.20	5.10	5.20	5.60
1.60	2.10	2.60	3.10	5.80	6.30	6.10	7.00	1.20	1.40	3.80	4.60
6.10	6.80	6.00	6.50	8.30	7.90	6.50	7.70	3.80	3.90	3.30	3.70
4.20	4.40	6.80	7.90	3.70	4.10	5.50	6.20	5.10	5.40	6.30	7.00
5.40	5.60	6.00	7.00	4.10	5.00	5.60	6.60	5.70	6.60	3.80	4.00
4.70	5.30	4.10	4.20	5.80	6.50	3.00	3.20	5.00	5.40	3.90	4.30
5.80	5.20	7.50	7.30	5.30	5.60	5.10	5.60	6.00	5.80	6.10	6.40
4.00	4.60	4.80	5.00	5.10	5.70	4.00	4.90	5.50	6.90	5.50	6.20
2.80	2.80	5.40	5.40	7.10	7.80	3.90	4.10	7.10	7.70	6.10	6.80
8.20	9.10	5.60	6.10	5.20	6.00	5.40	5.90	6.40	6.60	5.20	6.10
6.50	6.50	6.70	8.60	2.20	2.30	4.50	6.00	5.70	5.30	4.30	5.00
5.00	5.40	5.30	5.90	6.80	7.00	6.20	6.60	7.20	7.70	4.20	4.00
3.30	4.10	5.30	6.00	6.00	6.20	7.20	7.00	6.40	7.40	4.50	4.00
2.00	1.90	5.50	6.80	3.60	4.30	2.80	3.60	6.40	7.00	2.80	3.10
5.20	5.70	7.00	7.30	5.20	6.00	4.90	5.30	5.60	5.50	5.30	6.00
3.30	3.40	4.60	4.90	4.40	5.40	4.90	6.40	6.40	7.10	7.50	7.90
5.20	5.00	5.10	6.00	4.80	5.40	6.20	6.60	6.70	7.30	6.80	7.50
5.00	5.70	5.20	6.00	4.60	5.00	0.55	0.55	6.30	9.20	0.80	0.90
0.75	0.75	0.80	0.75	0.75	0.75	0.45	0.50	0.40	0.35	1.90	2.00
0.50	0.50	0.55	0.60	0.55	0.55	0.90	0.90	0.60	0.60	0.55	0.50
0.45	0.45	0.55	0.50	0.60	0.55	0.70	0.60	0.45	0.45	0.40	0.35
0.40	0.35	0.30	0.35	0.40	0.40	1.05	1.05	0.75	0.75	1.10	1.15
0.60	0.55	0.60	0.55	0.50	0.50	0.75	0.75	0.50	0.50	0.90	0.95
1.35	1.50	0.55	0.50	1.00	1.10	0.75	0.75	1.05	1.00		

LEVEL C

L	W	L	W	L	W	L	W	L	W	L	W
5.00	5.90	1.90	2.60	6.00	6.70	6.30	7.00	5.70	5.70	4.50	4.50
8.20	8.80	6.80	7.00	3.90	4.10	3.20	4.70	4.10	4.20	4.00	4.60
7.50	8.10	4.30	4.40	5.40	5.80	4.80	5.30	5.00	5.20	5.70	5.90
5.70	6.00	3.20	3.80	5.10	5.90	6.00	6.20	7.20	7.00	5.50	6.40
6.70	7.90	7.30	8.20	5.50	5.50	4.80	5.00	3.60	4.60	4.00	4.40
5.10	6.00	7.20	8.10	5.50	6.20	6.20	6.60	4.20	5.20	5.80	5.80
6.40	7.30	6.60	6.60	4.70	5.10	6.40	7.00	6.00	7.60	4.80	5.40
6.50	6.50	5.30	5.70	6.50	6.80	5.50	6.20	6.00	6.60	6.30	6.80
5.20	5.70	5.00	5.90	5.80	6.90	3.00	3.10	6.20	6.20	4.50	4.80
5.20	5.70	6.40	6.40	6.50	6.90	5.30	5.30	6.60	7.30	4.20	4.40
5.20	6.30	5.20	5.50	6.50	8.80	3.30	3.50	3.50	3.30	5.20	6.70
5.10	5.50	3.10	3.80	5.50	6.10	5.50	5.90	5.10	5.50	6.60	6.80
5.10	6.30	5.90	6.40	7.80	8.00	6.30	7.80	1.90	1.80	5.30	6.40
6.20	6.60	0.80	0.90	0.60	0.60	0.85	0.95	0.75	0.90	0.35	0.35
1.40	1.50	0.60	0.55	0.60	0.55	0.35	0.35	0.70	0.65	0.60	0.60
0.45	0.40	0.45	0.40	0.50	0.50	0.45	0.50	0.50	0.45	0.45	0.45
0.50	0.45	1.10	1.10	0.80	0.75	0.65	0.60	1.30	1.45	1.05	1.20
0.80	0.85	0.95	0.90	4.00	5.00						

LEVEL D

L	W	L	W	L	W	L	W	L	W	L	W
6.70	7.40	1.90	3.10	3.00	3.10	7.20	8.70	5.70	5.00	4.40	5.50
4.50	4.40	6.50	7.10	5.30	5.40	7.50	8.80	6.80	8.10	6.30	6.30
6.30	7.20	6.80	7.00	4.60	5.70	6.10	7.70	3.60	4.40	3.60	4.00
6.00	6.30	4.70	5.00	5.00	5.20	5.90	6.00	4.20	5.10	5.80	6.80
5.30	5.10	5.10	6.70	5.50	5.90	6.80	8.30	2.80	2.80	5.20	4.40
4.60	6.20	8.30	7.90	3.90	4.00	7.20	7.30	8.50	9.00	6.70	7.80
6.00	7.70	5.00	5.60	5.90	6.00	0.75	0.65	0.75	0.75	0.65	0.70
0.55	0.55	0.60	0.50	0.65	0.60	0.60	0.60	0.45	0.35	0.70	0.60
0.60	0.65	1.00	0.90	1.50	1.90	1.00	1.20	1.15	1.25	0.80	0.75
0.60	0.55	0.50	0.50	0.65	0.65	0.60	0.60	0.55	0.60	0.50	0.45
0.50	0.45	0.50	0.40	0.60	0.55	0.50	0.45	0.70	0.70	8.50	8.50
8.00	8.20	5.70	6.00	6.00	6.30	8.30	8.80	3.50	4.20	7.50	8.20
0.55	0.55	0.95	0.95	0.60	0.55						

BRACHIAL VALVES-NONFRAGMENTED, NONDISTORTED

LEVEL A

L	W	L	W	L	W	L	W	L	W	L	W
5.80	8.00	4.70	6.00	4.50	6.00	3.80	4.80	4.30	5.20	4.30	5.70
5.00	6.10	5.20	6.90	4.10	5.00	4.70	7.20	3.20	4.30	4.00	4.70
4.50	6.00	4.90	6.20	2.00	2.40	4.80	6.00	4.40	5.10	4.20	5.90
4.50	6.20	5.00	6.50	3.80	5.00	2.80	3.50	3.30	4.40	2.20	2.80
4.30	5.50	5.00	6.70	5.40	7.40	3.70	5.30	3.30	4.30	2.90	3.80
4.30	5.20	4.50	6.20	4.00	5.20	4.60	6.50	4.60	5.40	4.40	5.20
5.20	6.60	5.50	7.00	4.90	5.80	4.30	5.20	0.40	0.35	0.35	0.35
0.35	0.35	0.40	0.30	0.40	0.45	0.40	0.35	0.65	0.55	0.75	0.80
0.40	0.40	0.95	1.00	0.60	0.55	0.50	0.55	1.05	1.20	4.70	6.30
4.50	5.90	5.20	6.40	3.80	4.20	4.20	3.70				

LEVEL B

L	W	L	W	L	W	L	W	L	W	L	W
5.00	6.40	4.30	5.60	4.70	5.90	3.40	4.20	4.10	5.00	3.60	4.20
3.20	4.10	5.20	6.60	3.70	5.00	3.40	4.10	5.00	6.50	3.50	4.50
4.60	5.50	5.20	7.60	3.90	4.50	3.80	4.90	4.60	6.70	2.70	3.80
2.60	3.40	4.10	5.90	4.00	5.60	4.00	4.80	4.20	5.50	3.00	3.50
3.00	3.70	2.20	2.90	4.00	5.40	5.00	6.80	2.90	3.30	4.10	6.20
4.30	5.90	3.60	5.20	3.00	3.60	4.60	5.90	3.40	4.10	4.50	6.10
4.00	5.20	2.30	2.80	4.20	5.60	4.30	5.50	0.55	0.50	1.50	1.80
0.45	0.45	0.95	0.75	0.80	0.80	0.50	0.50	0.75	0.75	0.55	0.60
0.50	0.45	0.40	0.35	0.70	0.65	0.55	0.50	0.85	0.85	1.00	0.95
0.35	0.35	0.45	0.40	0.50	0.50	0.50	0.45	0.35	0.35	0.40	0.35
0.40	0.35	0.55	0.45	0.40	0.40	0.40	0.35	0.55	0.50	5.30	6.30
4.40	5.60	4.40	5.20	0.50	0.45						

LEVEL C

L	W	L	W	L	W	L	W	L	W	L	W
4.40	5.50	5.60	6.30	4.60	6.30	4.90	6.70	2.20	3.00	4.60	5.90
5.40	6.50	4.80	6.30	4.10	4.90	4.50	5.80	4.30	5.50	4.50	5.50
4.40	6.10	4.50	6.00	3.40	5.00	5.30	7.60	4.70	6.70	4.20	5.40
3.90	4.70	3.30	4.20	5.40	6.90	4.20	5.40	4.70	5.20	4.70	5.60
5.00	6.40	3.50	5.20	3.80	5.00	4.20	5.40	5.20	7.10	4.60	5.60
4.40	5.50	4.50	6.60	3.30	4.00	4.50	5.70	4.60	6.70	6.10	6.00
4.70	6.00	3.90	5.40	4.70	5.70	1.00	0.95	0.70	0.65	0.70	0.75
0.45	0.40	0.50	0.50	0.45	0.50	0.40	0.40	0.50	0.45	0.45	0.50
0.70	0.70	0.45	0.40	0.40	0.55	0.90	0.95	3.30	4.50	0.65	0.60
0.35	0.30										

LEVEL D

L	W	L	W	L	W	L	W	L	W	L	W
3.00	3.90	5.30	6.20	4.10	5.30	3.80	4.50	6.00	8.80	5.20	7.10
4.20	5.40	5.50	7.60	4.30	6.00	3.00	4.20	4.70	5.50	3.30	4.40
3.70	4.80	3.00	3.50	0.85	0.90	0.85	0.90	0.70	0.65	0.65	0.70
0.35	0.35	0.60	0.55	0.85	0.80	0.80	0.75	0.55	0.55	0.85	0.90
1.20	1.10	3.20	3.50	1.00	0.90	0.45	0.35	0.50	0.45	0.70	0.70
0.80	0.75	0.40	0.40	1.40	1.70	0.50	0.45	0.70	0.75		

ARTICULATED SHELLS-NONFRAGMENTED, DISTORTED WIDTH

LEVEL A

L	W	L	W	L	W	L	W	L	W	L	W
7.20	7.20	4.20	4.00	5.10	5.20	6.80	5.40	5.00	5.00	4.30	5.10
6.00	5.40	7.40	6.40	5.30	5.40	5.00	5.50	4.80	5.00	3.10	2.60
6.00	5.20	8.00	7.10	3.20	3.00	2.70	2.70	5.60	4.50	5.40	4.90
7.50	5.90	6.00	5.70	3.30	3.00	3.00	3.00	3.80	3.00	5.10	3.20
4.50	5.20	0.70	0.60	2.20	2.25	0.65	0.50	1.20	1.00	0.85	0.70

LEVEL B

L	W	L	W	L	W	L	W	L	W	L	W
5.00	5.80	5.80	4.70	5.10	5.10	4.10	3.20	3.50	4.00	6.70	6.30
3.50	3.70	4.80	6.20	5.20	3.40	5.40	5.10	4.50	4.50	6.10	4.60
4.00	3.30	3.70	4.40	4.70	5.50	5.10	4.50	2.30	2.60	8.00	8.20
4.10	4.70	5.60	5.90	4.20	4.10	5.20	4.80	3.60	3.70	6.00	5.00

6.70	6.60	4.00	4.30	7.00	5.50	4.80	3.70	5.80	6.00	4.30	5.60
6.30	5.30	3.50	3.70	7.20	7.50	3.70	3.40	4.80	4.70	4.90	4.00
5.50	4.70	5.50	6.40	6.10	5.00	3.00	2.90	4.20	4.20	5.20	5.30
4.40	3.90	6.60	6.60	7.60	7.00	6.60	5.30	4.80	4.70	4.90	4.70
3.50	2.90	3.40	3.40	3.50	2.90	2.10	2.40	3.90	3.50	3.30	2.60
3.20	3.10	2.80	3.60	4.40	6.00	5.20	5.20	1.05	1.20	2.00	1.75
2.50	2.50	1.45	1.20	1.10	0.95	1.20	0.95	1.15	1.25	1.50	1.40
0.85	0.75	0.80	0.65	0.90	0.75						

LEVEL C

L	W	L	W	L	W	L	W	L	W	L	W
4.10	4.20	5.30	5.80	3.00	3.60	5.70	6.40	5.80	6.10	4.50	4.50
5.60	5.60	5.40	4.90	7.80	9.10	5.40	5.00	6.10	5.70	3.70	3.00
4.30	4.00	4.50	4.90	3.80	4.40	5.10	4.30	4.30	4.60	4.20	4.50
4.00	3.90	5.80	5.60	7.00	7.50	6.30	5.80	4.50	4.50	4.90	5.70
5.10	4.90	4.40	4.50	6.50	6.30	4.90	4.30	4.60	5.80	5.60	6.50
7.10	6.50	3.50	5.60	6.30	6.00	7.20	6.40	4.60	4.50	5.40	5.90
3.70	3.30	3.70	4.00	5.70	5.40	4.60	3.90	6.20	5.20	3.20	2.50
2.30	1.90	0.95	0.75	1.00	0.90	1.60	1.40	2.80	2.60	0.95	0.90

LEVEL D

L	W	L	W	L	W	L	W	L	W	L	W
5.60	6.40	4.30	5.30	5.00	4.90	5.20	6.90	5.00	4.50	5.30	4.60
6.20	7.20	4.80	5.00	6.10	4.50	3.80	3.80	5.50	5.90	7.40	6.80
5.90	6.10	5.60	3.90	4.50	5.60	4.20	3.70	6.90	3.90	4.80	4.00
5.50	6.60	6.00	6.10	6.00	6.80	8.00	7.70	4.80	4.30	7.20	6.10
3.50	4.10	7.20	6.50	6.60	6.30	5.30	5.50	4.50	4.30	4.50	5.00
7.60	5.80	6.60	6.80	6.00	6.30	5.60	6.30	4.20	4.40	4.40	4.80
7.00	6.20	5.00	5.20	6.00	6.50	3.30	3.00	6.60	6.60	4.50	4.20
5.70	5.60	7.00	7.00	5.10	4.00	4.50	4.00	4.50	3.20	6.30	8.00
7.50	6.20	5.90	6.70	6.20	6.70	4.60	5.20	6.00	6.50	4.50	4.30
7.00	7.20	6.00	6.60	5.80	5.50	4.00	3.00	4.50	3.50	4.00	3.50
7.00	7.20	5.30	3.80	6.50	6.80	7.00	6.60	7.00	5.50	5.20	6.00
6.70	5.50	5.00	5.10	6.10	6.20	6.50	4.50	5.90	5.40	8.00	8.30
4.80	4.70	5.50	6.60	5.50	4.50	5.20	5.20	4.00	4.70	4.00	4.50
4.00	4.10	7.00	5.20	4.50	5.80	5.20	5.30	7.50	7.30	1.45	1.05
1.15	1.35	2.00	2.15	0.50	0.40	0.75	0.60	0.75	0.60	0.70	0.60

PEDICLE VALVES-NONFRAGMENTED, DISTORTED WIDTH

LEVEL A

L	W	L	W	L	W	L	W	L	W	L	W
4.00	4.00	5.00	5.50	4.00	3.80	3.90	4.00	4.50	5.40	3.90	4.30
7.00	2.80	5.20	3.00	4.10	3.70	7.00	4.50	4.10	4.40	3.30	3.50
6.20	4.00	6.80	3.50	7.20	6.70	6.80	5.00	6.00	5.50	5.50	6.00
7.30	6.30	7.40	7.20	5.40	4.80	4.50	2.70	4.40	4.40	5.50	4.50
4.50	4.40	5.50	4.50	7.00	4.50	5.80	5.10	5.50	5.40	6.70	5.00
5.00	6.00	9.00	9.50	7.00	6.50	7.00	6.80	4.80	5.50	6.00	4.40
4.30	4.20	4.80	4.60	5.40	5.30	7.00	7.90	6.00	6.50	4.00	3.90
7.50	7.00	4.80	5.40	6.50	6.00	4.90	4.50	6.30	5.20	5.00	5.50
6.50	5.30	5.20	5.00	7.50	6.50	7.10	6.20	6.50	6.00	5.50	4.00
7.50	3.90	4.90	4.50	4.40	5.00	5.70	4.50	4.80	4.60	3.60	3.50
5.30	5.20	6.00	2.90	6.80	7.50	6.00	6.10	7.00	7.40	6.00	5.60

4.70	3.60	5.80	5.80	5.20	6.40	5.80	3.00	6.70	6.80	5.80	6.50
4.90	4.20	6.10	4.90	6.30	5.10	2.90	2.90	5.90	5.60	4.00	5.10
6.30	5.80	4.70	5.80	6.00	5.00	4.20	4.60	4.50	4.40	6.40	4.50
4.80	3.90	4.50	4.00	5.80	6.00	5.70	5.80	2.30	1.80	5.00	4.80
3.20	3.10	4.10	3.60	3.10	4.00	6.30	5.80	4.00	3.90	3.50	3.90
7.20	7.20	5.50	5.30	4.50	4.30	5.30	5.60	5.50	3.50	4.20	4.00
6.00	6.20	5.20	4.80	6.50	5.30	7.50	7.10	3.30	2.90	6.70	3.50
7.50	6.00	5.30	3.00	4.00	3.80	4.80	5.10	6.80	4.00	5.60	4.60
6.60	6.00	6.70	6.30	5.50	5.40	7.00	5.60	5.00	5.00	4.90	4.60
3.80	4.40	5.50	5.60	6.30	4.70	5.50	4.50	4.90	4.20	5.20	5.20
4.80	5.40	3.40	2.90	3.20	3.00	5.70	4.50	4.30	4.40	5.50	6.00
3.60	3.40	4.60	5.00	5.00	2.50	5.80	5.50	7.00	7.40	6.10	4.50
6.20	5.90	3.00	3.10	4.60	4.00	4.50	5.50	5.30	3.60	5.00	2.70
5.70	5.60	4.80	4.90	5.60	3.00	4.50	2.40	6.20	5.50	5.50	4.50
6.50	4.60										

LEVEL B

L	W	L	W	L	W	L	W	L	W	L	W
7.60	6.30	6.50	6.20	5.70	5.30	5.40	5.00	3.10	3.70	4.00	3.80
5.40	4.90	6.50	6.40	5.00	6.50	4.60	4.00	2.50	2.00	6.80	5.20
3.50	3.00	7.00	4.20	3.10	3.80	6.40	5.90	5.90	6.10	7.50	6.80
6.00	6.40	5.30	6.10	3.50	3.50	4.00	3.20	6.00	6.00	3.20	3.10
3.70	3.90	6.80	6.70	4.80	5.80	3.00	2.40	2.40	2.50	3.50	4.00
4.20	3.50	5.80	5.50	4.00	3.60	5.20	5.10	5.30	5.50	6.00	5.90
4.00	4.50	5.20	5.00	6.20	4.30	5.50	5.50	4.60	3.00	4.90	6.00
4.90	5.00	3.50	2.50	5.60	2.40	4.90	6.40	4.90	4.50	6.20	7.00
6.10	5.60	4.20	2.30	5.20	5.60	7.20	6.90	4.70	5.10	6.20	6.80
5.10	5.00	4.10	4.60	7.10	6.80	6.10	5.10	6.50	5.40	4.80	3.80
5.70	5.60	6.70	6.10	7.50	3.60	5.00	5.90	4.90	3.90	5.20	4.00
4.50	4.20	5.90	6.60	7.80	4.60	4.90	4.50	5.40	4.20	5.30	4.00
3.20	3.70	8.00	8.20	5.20	4.70	7.00	7.10	6.40	5.70	6.00	4.20
4.00	3.90	6.10	6.30	4.10	3.90	6.00	5.00	9.00	8.70	4.30	3.60
6.80	5.50	4.00	4.30	6.40	7.00	3.90	3.00	5.10	4.80	5.00	3.70
4.70	4.70	5.30	5.10	5.60	4.70	5.30	5.30	2.30	2.30	5.90	5.30
7.00	4.40	4.70	3.80	6.50	5.70	6.20	6.40	2.80	2.70	4.30	4.10
6.60	6.60	6.20	5.40	5.80	5.30	4.50	3.80	4.40	4.20	6.50	5.40
6.30	6.70	6.60	5.70	7.00	6.00	4.30	4.80	5.50	6.80	5.50	5.50
6.40	5.50	5.20	4.80	6.90	6.70	6.40	6.00	5.40	5.80	6.20	6.30
4.90	5.00	3.60	3.50	5.90	3.30	5.80	5.50	6.10	5.10	6.20	4.80
7.30	5.60	0.55	0.70								

LEVEL C

L	W	L	W	L	W	L	W	L	W	L	W
4.60	4.10	5.40	5.30	3.10	3.70	6.80	6.80	4.60	6.40	2.90	3.20
4.80	5.00	4.10	3.60	3.40	3.80	8.00	4.20	6.90	4.30	5.80	5.40
4.20	4.20	5.80	5.00	2.70	2.20	5.30	4.80	6.10	6.40	5.70	4.80
5.40	4.60	3.90	4.50	5.50	4.20	4.80	4.50	5.90	5.30	5.30	5.80
5.20	6.00	5.40	5.80	6.50	6.30	6.40	6.50	4.20	4.00	6.90	4.80
5.90	5.90	4.20	4.60	7.00	5.50	3.20	3.10	5.90	6.30	5.40	5.50
4.00	2.80	5.60	6.10	5.40	4.10	6.00	6.50	5.20	3.90	4.70	5.20
4.90	4.60	5.00	4.80	4.50	5.00	2.90	3.20	3.70	3.90	3.60	3.80
3.00	3.20	3.40	3.20	6.00	5.00	3.20	3.10	6.00	5.00	4.70	5.00
4.80	5.40	6.10	4.70	6.50	5.80	4.30	3.10	6.20	5.10	6.40	6.60
4.10	4.70	6.80	6.80	6.80	5.50	6.50	5.00	7.30	5.20	5.70	5.00
7.60	6.80	5.00	5.50	7.70	6.30	5.10	5.50	6.10	5.20	7.20	7.50
5.80	3.00	5.20	5.60	5.50	5.60	5.50	4.50	5.50	5.70	5.20	5.10

6.50	6.50	4.30	3.60	5.00	5.10	7.00	7.10	5.50	4.80	5.30	4.00
4.50	4.50	6.80	5.40	6.60	4.50	7.30	6.50	8.60	9.00	6.20	7.00
3.80	3.20	3.90	3.50	4.50	4.60	5.00	4.30	3.70	4.30	7.20	5.80
7.00	6.00	3.10	3.00	5.70	3.00	3.70	4.10	4.80	4.70	5.10	5.50
7.30	5.10	7.10	7.00	4.80	4.40	6.70	6.70	2.55	2.30		

LEVEL D

L	W	L	W	L	W	L	W	L	W	L	W
3.10	2.60	6.80	6.00	6.40	6.50	6.50	5.70	7.00	7.00	4.70	6.60
4.80	4.50	6.60	6.00	7.80	8.00	3.20	3.20	4.40	3.60	3.40	3.90
6.10	4.70	4.80	4.50	4.00	3.50	3.60	3.00	6.00	5.40	6.80	6.50
6.30	4.90	5.40	5.00	3.20	3.60	6.70	6.30	8.00	5.50	8.00	7.60
6.20	6.60	4.80	4.40	6.00	6.20	4.50	3.30	6.00	7.20	6.50	4.50
4.00	5.00	8.00	5.70	8.20	7.00	4.00	4.20	6.30	5.80	5.60	5.20
4.00	4.50	7.20	5.50	5.00	5.50	7.50	6.50	7.50	8.20	5.70	6.80
5.60	6.10	5.50	5.60	5.10	5.10	6.20	4.00	6.10	4.50	4.10	4.80
4.20	4.10	4.00	3.80	6.30	6.00	6.50	6.70	5.80	5.00	5.10	4.40
5.60	5.10	4.50	3.60	5.20	3.80	0.90	0.90	1.30	1.20	2.60	2.50

PEDICLE VALVES-NONDISTORTED, FRAGMENTED WIDTH

LEVEL A

L	W	L	W	L	W	L	W	L	W	L	W
3.50	4.00	5.50	5.40	6.00	6.10	4.20	5.00	3.30	3.20	6.50	6.50
6.30	6.80	4.00	4.00	3.80	4.00	7.30	6.70	3.50	3.50	4.00	4.00
4.10	4.30	6.00	6.00	6.00	5.70	6.70	6.60	6.50	7.40	3.10	4.00
4.60	5.10	6.20	6.50	3.50	3.70	7.20	6.50	4.60	4.00	5.70	5.60
5.50	5.20	5.40	4.30	5.50	5.70	4.10	3.80	4.90	5.20	4.80	5.40
3.30	3.40	5.30	5.20	4.90	4.60	5.70	5.80	4.40	4.80	4.70	5.50
5.60	5.20	5.30	4.80	5.20	5.00	4.70	4.50	5.50	4.80	5.80	5.80
6.00	6.40										

LEVEL B

L	W	L	W	L	W	L	W	L	W	L	W
6.00	6.20	7.10	7.60	5.80	5.00	6.50	5.50	4.30	4.00	4.70	4.70
4.80	5.60	3.90	3.40	6.00	6.00	4.80	5.00	7.00	8.00	5.80	5.00
4.20	5.00	2.80	3.30	6.00	6.00	3.60	3.80	6.00	6.00	5.20	5.00
4.60	4.90	6.10	6.50	5.10	5.40	4.10	4.50	5.70	5.90	3.00	3.00
6.10	6.30	5.00	4.80	5.80	5.80	4.50	4.60	6.60	6.30	4.50	4.80
3.30	2.90	3.50	5.60								

LEVEL C

L	W	L	W	L	W	L	W	L	W	L	W
7.00	6.60	6.70	5.50	7.20	8.10	4.80	5.20	7.00	7.00	5.40	5.60
7.40	6.80	4.80	5.00	4.00	3.90	4.70	4.20	4.30	4.40	5.20	4.80
7.30	7.40	5.10	5.10	6.90	7.30	2.90	2.70	6.00	8.10		

LEVEL D

L	W	L	W	L	W	L	W	L	W	L	W
1.70	2.20	4.00	3.80	3.70	4.30	3.30	3.40	4.50	3.70	4.50	3.70
5.60	7.00	5.20	4.50	3.50	3.00	5.20	4.70	5.00	5.00	4.90	5.00

5.00	7.00	4.60	6.00	5.40	4.90	7.50	8.00

PEDICLE VALVES-NONDISTORTED, FRAGMENTED LENGTH

LEVEL A

L	W	L	W	L	W	L	W	L	W	L	W
4.70	6.10	7.50	8.80	6.00	7.60	5.00	5.30	5.00	6.80	6.00	6.90
7.50	7.90	6.50	8.00	5.70	6.20	6.70	7.30	5.50	6.20	7.20	8.00
6.40	7.80	3.60	4.60	5.10	6.20	5.10	5.50	6.20	7.20	2.50	4.00
4.20	4.40	4.80	5.90	5.50	6.20	6.50	7.30	7.50	8.90	6.00	6.60
4.70	4.60	5.70	7.60	4.00	4.70	7.00	7.00	6.50	6.90	6.80	7.50
3.50	3.60	5.90	6.60	6.00	6.20	3.00	3.20	4.70	5.10		

LEVEL B

L	W	L	W	L	W	L	W	L	W	L	W
4.50	6.00	5.70	4.90	6.00	5.30	4.20	4.20	5.80	5.40	4.00	5.30
4.30	5.00	3.90	4.70	4.50	5.20	2.30	3.90	5.50	6.10	4.30	5.30
4.50	6.90	6.00	6.30	3.50	4.80	5.00	6.40	5.90	7.50	5.00	6.90
5.50	7.10	4.80	6.00	3.20	3.80	8.00	9.50	5.20	5.50	4.40	5.90
6.80	6.70	6.60	6.00	5.00	5.70	2.60	2.80	4.70	4.50	5.20	5.00

LEVEL C

L	W	L	W	L	W	L	W	L	W	L	W
6.40	7.10	6.00	8.10	5.00	5.20	7.00	7.20	5.10	5.20	7.20	9.20
5.50	6.20	5.10	6.20	3.80	4.80	6.80	7.50	4.10	5.20	6.00	6.90
5.30	5.40	3.60	4.70	3.80	5.50	5.70	6.50	5.50	6.50	3.50	3.40

LEVEL D

L	W	L	W	L	W	L	W	L	W	L	W
3.70	4.40	4.00	5.60	4.00	8.00	5.20	5.70	3.10	3.60	3.50	4.00
5.50	6.50	4.00	4.90	5.80	5.30	4.80	5.30	5.50	7.00	5.40	6.90
3.20	5.00	5.80	6.80	4.60	5.50						

ARTICULATED SHELLS-NONFRAGMENTED, DISTORTED LENGTH

ALL LEVELS

L	W	L	W	L	W	L	W	L	W	L	W
3.50	4.90	4.40	7.50	2.30	3.80	6.20	7.40	5.20	7.10	5.00	8.00
3.20	4.40	3.50	4.60	3.40	4.30	5.00	6.80	4.50	6.60	3.90	6.00
3.80	4.90	5.50	7.40	3.00	4.50	5.40	7.50	5.40	7.20	3.90	4.90
4.20	5.30	4.00	5.60	3.20	4.30	4.10	6.30	4.00	5.70	5.50	7.00
2.00	3.30	5.00	6.40	5.20	7.00	2.50	3.80	4.60	5.00	3.00	4.50
3.20	4.80	5.00	6.40	4.60	7.50	4.10	5.80	5.00	6.60	4.60	5.70
3.50	6.40	6.20	8.50	2.60	3.60	3.30	5.20	6.20	7.40	0.90	1.20
2.50	3.20	1.00	1.45	2.30	3.00	2.10	3.00	1.25	1.55	1.05	1.50
0.80	1.00	0.75	1.00	0.80	1.05						

ARTICULATED SHELLS-NONFRAGMENTED, DISTORTED THICKNESS

ALL LEVELS

L	W	L	W	L	W	L	W	L	W	L	W
5.60	5.50	4.20	4.70	4.00	4.20	5.10	6.30	4.40	4.80	6.70	7.70
6.50	8.20	3.50	4.50	4.60	5.20	3.30	3.80	2.50	2.60	4.10	4.70
6.30	6.60	4.80	5.20	6.20	7.60	7.50	8.00	4.50	4.00	2.60	2.80
7.00	5.20	1.60	1.90	1.60	2.00	1.30	1.50	1.15	1.25	1.80	2.10
1.20	1.25	1.35	1.55	1.70	1.60	2.10	2.30				

PEDICLE VALVES-NONFRAGMENTED, DISTORTED LENGTH

ALL LEVELS

L	W	L	W	L	W	L	W	L	W	L	W
4.10	6.80	3.50	5.60	2.50	4.50	4.80	6.50	3.90	5.20	5.60	7.50
5.20	6.90	6.20	8.20	2.10	4.50	4.60	6.70	2.00	3.10	4.20	5.30
1.60	2.90	2.80	3.50	5.00	7.50	4.00	4.90	4.50	6.20	4.80	6.60
3.60	4.30	4.80	7.60	4.20	6.60	4.70	6.40	3.40	5.90	4.90	7.00
5.70	7.00	6.50	7.60	3.30	6.50	2.00	4.00	3.40	4.20	2.30	4.10
3.00	4.50	3.00	4.00	3.60	4.90	3.10	7.20	2.30	4.20	4.00	5.60
6.20	8.10	5.50	7.10	4.50	6.00	3.50	4.00	5.20	7.80	4.00	5.20
5.20	7.70	3.40	4.90	4.30	6.20	4.50	7.50	4.50	4.90	4.60	6.00
3.30	5.20	6.00	8.20	3.90	5.00	5.80	7.00	4.50	5.80	4.10	7.30
3.30	4.50	3.60	4.50	4.20	7.50	4.10	6.00	4.70	6.50	4.70	5.80
4.00	4.90	3.80	6.00	6.10	8.20	3.60	5.10	2.90	6.30	3.70	6.10
4.90	6.00	4.80	6.40	3.20	4.60	4.70	6.60	2.40	4.80	4.80	5.80
6.80	7.80	2.00	2.60	3.10	5.60	3.80	5.80	3.20	5.30	5.00	6.00
3.00	5.60	5.00	6.20	3.40	4.80	6.60	7.70	4.80	7.60	3.00	5.60
2.30	3.00	2.00	3.50	0.90	1.60						

PEDICLE VALVES-NONFRAGMENTED, DISTORTED THICKNESS

ALL LEVELS

L	W	L	W	L	W	L	W	L	W	L	W
4.20	5.10	6.00	7.10	4.50	5.20	3.10	4.50	5.30	6.00	5.70	7.30
5.30	5.40	3.20	3.50	3.30	4.10	4.40	5.00	4.00	5.00	4.70	4.70
5.20	6.20	5.70	6.70	3.10	3.70	3.60	4.10	5.40	6.10	2.80	3.70
6.40	7.30	3.90	3.50	6.00	5.80	3.20	3.60	5.00	6.60	3.30	4.20
9.00	9.70	5.40	5.30	4.30	4.80	5.10	5.50	7.50	9.40	6.00	5.50
3.90	4.20	3.10	3.20	4.00	5.00	3.80	4.70	5.20	6.60	4.00	3.70
4.30	4.20	3.10	3.20	4.00	4.40	2.20	2.40	3.50	3.20	6.50	6.90
4.40	4.50	3.30	3.60	5.20	6.00	6.40	5.40	4.60	4.30	4.60	4.70

APPENDIX IIIA

PROGRAM FOR TESTING SIGNIFICANT UNIMODE

```
C       TUKEY CHI SQUARE AND MEAN VECTOR DIRECTION PROGRAM
        DIMENSION N(1250),L(6,360),KB(360),TITLE(16)
        READ (5,20) IP
     20 FORMAT (I2)
        DO 500 IT=1,IP
        IA=0
        DO 1 I=1,6
        DO 1 J=1,360
        L(I,J)=0
      1 CONTINUE
        READ (5,18) TITLE
        READ (5,2) M,(N(I),I=1,M)
        WRITE (6,17) TITLE
        DO 3 I=1,M
      3 IF (N(I).GT.N(I+1)) GO TO 4
        GO TO 6
C       DATA SEQUENCING
      4 MP=M-1
        DO 5 I=1,MP
        K=I+1
        DO 5 J=K,M
        IF (N(I).LE.N(J)) GO TO 5
        NX=N(I)
        N(I)=N(J)
        N(J)=NX
      5 CONTINUE
C       DATA GROUPING
      6 DO 12 I=1,31,5
        IF (I.EQ.26) GO TO 12
        IA=IA+1
        SUMXB=0.0
        SUMYB=0.0
        SUMC=0.0
        SUMD=0.0
        SUMFR1=0.0
        SUMFR2=0.0
        K=I-1
        IF (I.EQ.1) K=1
        EXT=FLOAT(M)/(360./FLOAT(K))
        RTEXT=SQRT(EXT)
        TIDPT=FLOAT(K)/2.0
        J1=0
        DO 10 J=1,M
      7 IF (N(J).LT.K) GO TO 13
      8 A=K-I-1
        IF (I.EQ.1) A=K-1
C       CHI SQUARE AND MEAN VECTOR DIRECTION COMPUTATION
        R=.01745329*A
        OBS=J1
        B=(OBS-EXT)/RTEXT
        TIDCL=FLOAT(K)-TIDPT
        TIDCLR=.01745329*TIDCL
```

```
      XA=COS(R)
      YA=SIN(R)
      SUMXB=SUMXB+XA*XA
      SUMYB=SUMYB+YA*YA
      SUMC=SUMC+B*XA
      SUMD=SUMD+B*YA
      SUMFR1=SUMFR1+OBS*SIN(TIDCLR)
      SUMFR2=SUMFR2+OBS*COS(TIDCLR)
      L(IA,K)=J1
      IF (I.EQ.1) K=K+1
      K=K+I-1
      J1=0
      IF (K.GE.361) GO TO 11
      IF (J.EQ.M) GO TO 8
      GO TO 7
   13 J1=J1+1
      IF (J.EQ.M) GO TO 8
   10 CONTINUE
   11 CFIN=(SUMC/SQRT(SUMXB))**2
      SFIN=(SUMD/SQRT(SUMYB))**2
      OBSCHI=CFIN+SFIN
      ANG=SUMFR1/SUMFR2
      TEANR=ATAN(ANG)
      TEAN=TEANR/.01745329
      IF (SUMFR1.LT.0.0) TEAN=TEAN+180.0
      IF (SUMFR1.GT.0.0.AND.SUMFR2.LT.0.0) TEAN=TEAN+360.0
      IF (TEAN.LT.90.0) TEAN=TEAN+90.0
      TEAN=450.0-TEAN
      WRITE (6,14) IA,CFIN,SFIN,OBSCHI,TEAN
   12 CONTINUE
      DO 700 J=1,360
  700 KB(J)=J
      WRITE (6,15)
   15 FORMAT (1H-,30X,27H30 DEGREE FREQUENCY CLASSES)
      WRITE(6,16) (KB(J),L(6,J),J=30,360,30)
   16 FORMAT (1H0,30X,I4,10X,I4)
    2 FORMAT (I4/(20I4))
   14 FORMAT (3H-CL,I3,5X,2HC=,F7.3,5X,2HS=,F7.3,5X,20HOBSERVED CHI SQUA
     1RE=,F8.3,5X,5HMEAN=,F8.3)
   17 FORMAT (1H1,16A5)
   18 FORMAT (16A5)
  500 CONTINUE
   30 STOP
      END
$JOB   WATFOR   000912 BRAY
$IBJOB          NODECK
$IBFTC
$ENTRY
```

APPENDIX IIIB

PROGRAM FOR TESTING SIGNIFICANT BIMODES

```
C RALIEGH TEST  B PARKASH
      DIMENSION B(500), A(500),KF(50), A2(500),A4(500),NK(500),KFRE(40),
     1TITLE (16)
      READ ( 5, 51) KPROS
   51 FORMAT  ( I2 )
  603 DO 52 KK= 1, KPROS
      READ (5,29) TITLE
   29 FORMAT (16A5)
      READ (5,80) NN
   80 FORMAT (I4)
      READ (5,601)  (NK(I) , I= 1,NN )
  601 FORMAT (20I4)
C     CHANGE ORIGIN TO TRUE NORTH
      DO 1 I= 1,NN
      B(I) = FLOAT ( NK(I) )
      A(I)=B(I)
      IF (A(I).LE.0.0)A(I)=A(I)+360.0
      IF (A(I).LE.180.0) A(I)=A(I)+180.0
    1 CONTINUE
C     SORT INTO 20 DEGREE CLASSES
      WRITE (6,53) TITLE
   53 FORMAT (1H1,16A5)
      TOP =200.0
      DO 3 NCLSS =1,9
      KS=0
      DO 4 I=1,NN
      IF ( A(I).LE.TOP.AND.A(I).GT.(TOP-20.0)) KS=KS+1
    4 CONTINUE
      KF(NCLSS)=KS
      TOP = TOP +20.0
    3 CONTINUE
C     CHANGE TO RADIANS
      DO 2 I=1,NN
      A(I)=A(I)/57.295795
    2 CONTINUE
C     FIND MEAN VECTOR DIRECTION
      SMSIN=0.0
      SMCOS=0.0
      DO 5 I=1,NN
      A2 (I) =2.0*A(I)
      SMSIN=SMSIN+SIN(A2 (I) )
      SMCOS= SMCOS+ COS(A2 (I))
    5 CONTINUE
      WRITE (6,31) SMSIN ,SMCOS
   31 FORMAT (//7H SMSIN=, F8.4 ,10X, 7H SMCOS=,  F8.4)
      TAN 2X =SMSIN/SMCOS
      ARD2X=ATAN  (TAN2X)
      ANG2X=ARD2X*57.295795
      IF ( SMCOS .LE. 0.0 ) ANG2X= ANG2X + 180.0
      IF ( SMCOS.GE. 0.0 .AND. SMSIN .LE. 0.0 )ANG2X=ANG2X+ 360.0
      X = ANG2X /2.0
      X =X +180.0
```

```
C     TO CALCULATE VECTOR MAGNITUDE
      AN=FLOAT (NN)
      VMAG=  (SQRT((SMSIN*SMSIN)+(SMCOS*SMCOS)))*100.0/AN
      WRITE (6,401) X,VMAG
  401 FORMAT(//20X,8H VMEAN1=, 2X, F8.2,7H VMAG1=, 2X,F8.3)
C     CALCULAY RALEIGH PROBABILITY
      POWER=-((VMAG*VMAG)*AN)*(0.0001)
      RAPRO=EXP (POWER)
      IF (RAPRO -0.05)11,11,12
   11 WRITE(6,101)  RAPRO
  101 FORMAT(//7H RAPRO=, F8.4,
     1                           56H THERE IS PREFERRED ORIENTATION BY RALEI
     2GH TEST UNIMODE.)
      GO TO 501
   12 WRITE (6,102) RAPRO
  102 FORMAT (//8H RAPRO1=, F8.4 ,
     1                            59H THERE IS NO PREFERRED ORIENTATION BY R
     2ALEIGH TEST UNIMODE.)
C     BIMODAL TEST
C    CHANGE TO FOUR X
  501 SMSIN=0.0
      SMCOS=0.0
      DO 50 I=1,NN
      A4(I)= 4.0* A(I)
      SMSIN =SMSIN + SIN (A4(I) )
      SMCOS=SMCOS+ COS(A4(I) )
   50 CONTINUE
      WRITE (6,55) SMSIN,SMCOS
   55 FORMAT ( // 9H SMSIN4X=, F8.4, 10X, 9H SMCOS4X=, F8.4 )
      TAN4X=SMSIN/SMCOS
      ARD4X=ATAN(TAN4X)
      ANG4X=ARD4X *57.295795
      IF (SMCOS .LE. 0.0 ) ANG4X=ANG4X+180.0
      IF( SMSIN.LE. 0.0 .AND. SMCOS .GE. 0.0 ) ANG4X=ANG4X+360.0
      X2=ANG4X/4.0
C     TO CALCULATE VECTOR MAGNITUDE BIMODE TEST
      VMAG2 = (SQRT((SMSIN*SMSIN)+(SMCOS*SMCOS)))*100.0/AN
      WRITE (6,300) X2,VMAG2
  300 FORMAT(//20X,8H VMEAN2=, 2X,F8.2, 7H VMAG2=,2X,F8.3)
C     TO CALCULATE RALEIGH PROBABILITY BIMODE TEST
      POWER2=- ((VMAG2*VMAG2)*AN )*(0.0001)
      RAPRO2= EXP(POWER2)
      IF (RAPRO2-0.05) 21,21,22
   21 WRITE (6,201) RAPRO2
  201 FORMAT ( // 8H RAPRO2=, F8.4,
     1                              74H THERE IS PREFERRED ORIENTATION ABOUT
     2EACH OF AXES BY RALEIGH TEST BIMODE.)
      GO TO 505
   22 WRITE(6,202) RAPRO2
  202 FORMAT ( // 8H RAPRO2=, F8.4,
     1                               58H THERE IS NO PREFERRED ORIENTATION B
     2Y RALEIGH TEST BIMODE.)
  505 WRITE (6,701) (KF(NCLSS),NCLSS=1,9)
  701 FORMAT(//35X,31H SORTING INTO 20 DEGREE CLASSES/42X,10H FREQUENCY/
     1 20X,15H 181-200 DEGREE,15X,I3/ 20X,15H 201-220 DEGREE,15X,I3/
     220X, 15H 221-240 DEGREE,15X,I3/20X,15H 241-260 DEGREE,15X,I3/
     320X,15H 261-280 DEGREE,15X,I3/20X,15H 281-300 DEGREE,15X,I3/20X,
```

```
  415H 301-320 DEGREE,15X,I3/20X, 15H 321-340 DEGREE,15X,I3/20X,
  515H 341-360 DEGREE, 15X,I3,    )
52 CONTINUE
   STOP
   END
```

PLATES

Plate I

Cross-sectional View of Cluster in Concretion

PLATE I

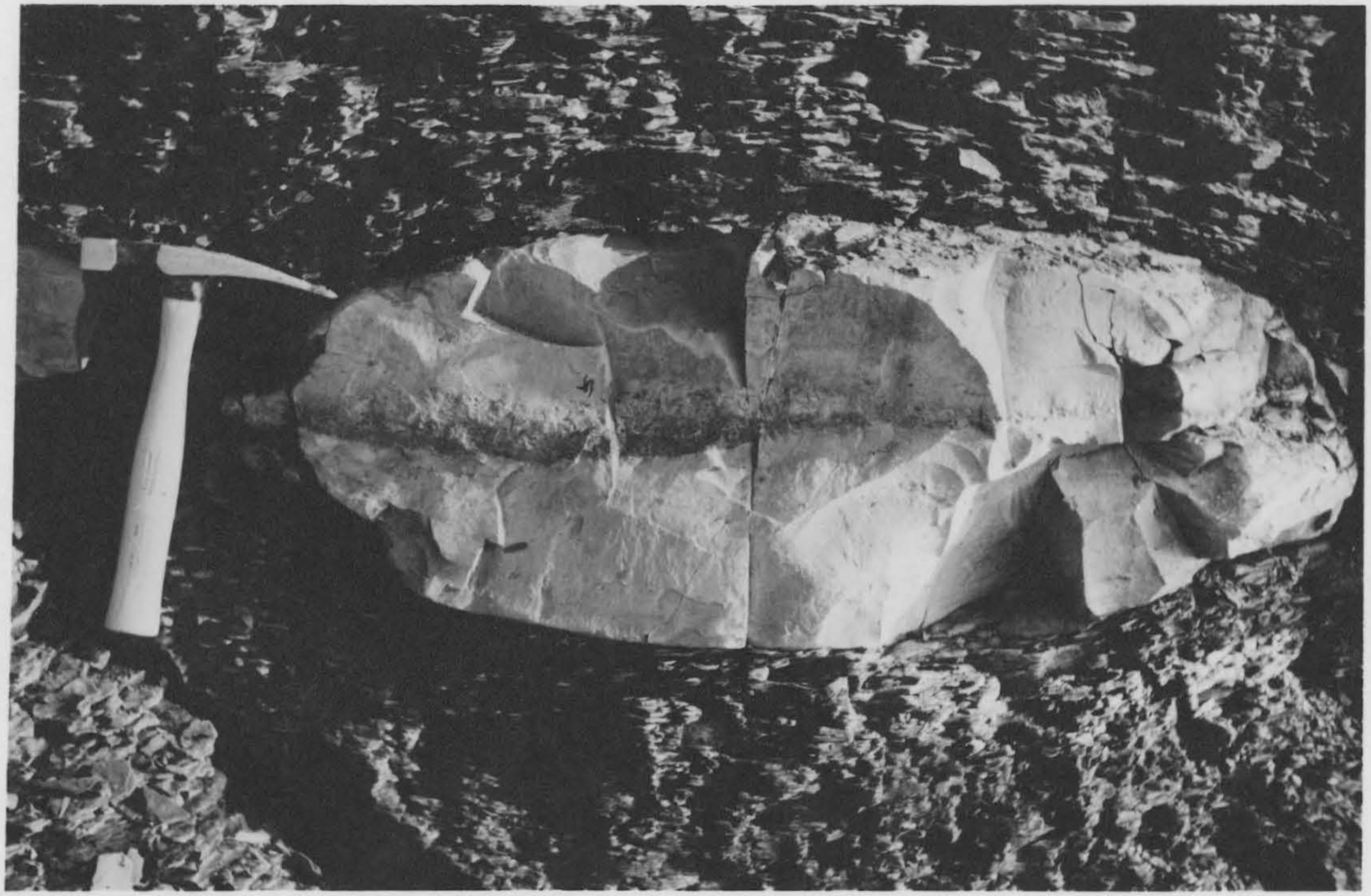


Plate II

Surface View of Cluster Alpha
Southeast Corner, Top Level

PLATE II

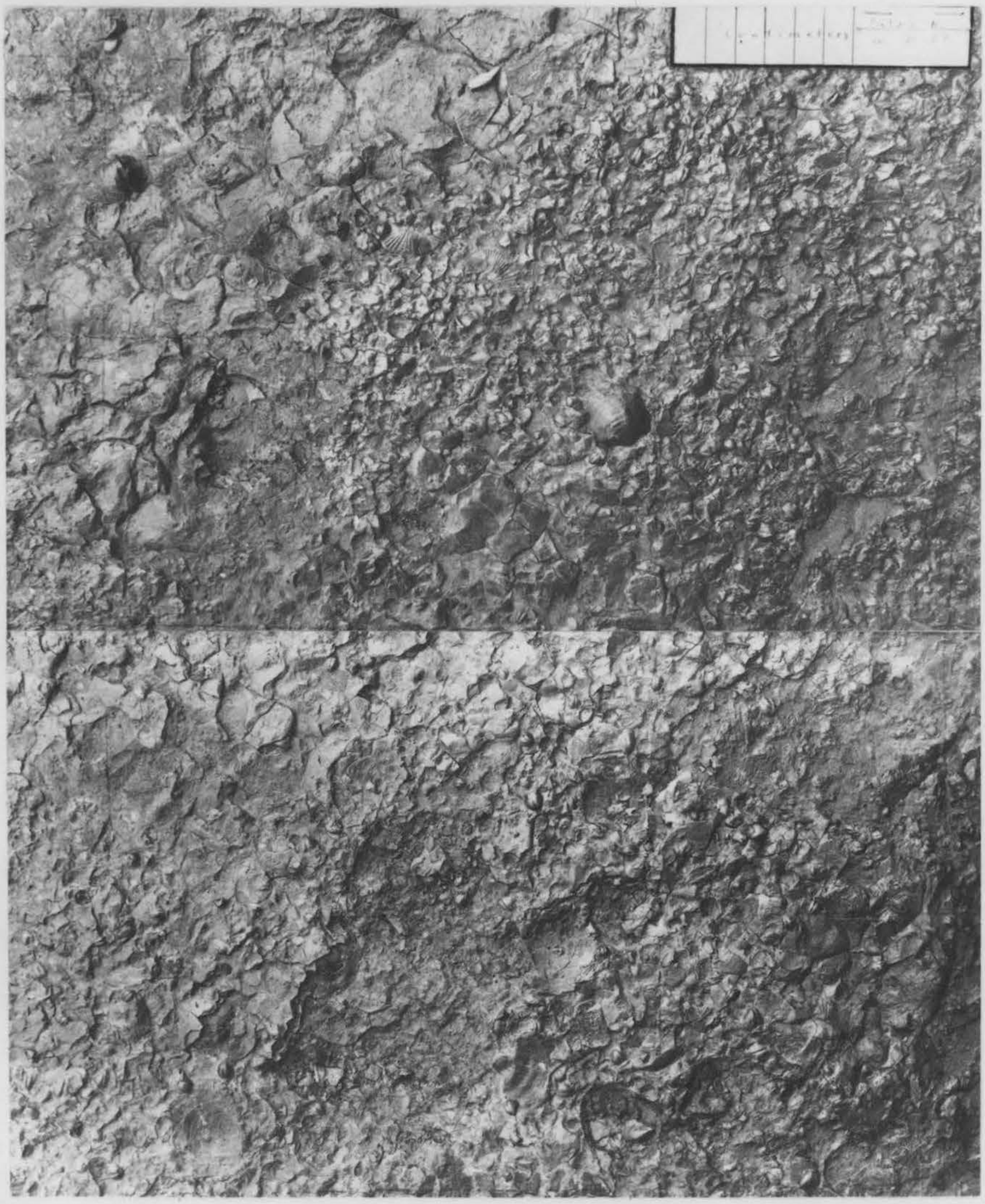


Plate III

Ambocoelia umbonata (Conrad)

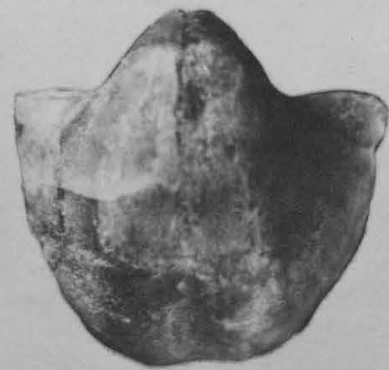
Figures

1a, 1b	Exterior view of pedicle valve in two specimens
2	Interior view of brachial valve
3	Lateral view of articulated specimen
4	Brachial view of articulated specimen, brachial valve depressed into pedicle valve

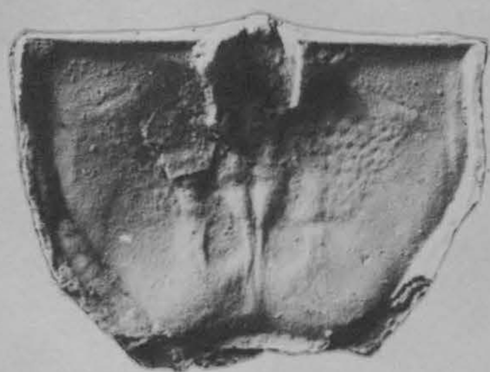
All figures X 7.5

PLATE III

1a



1b



2

3

4

Plate IV

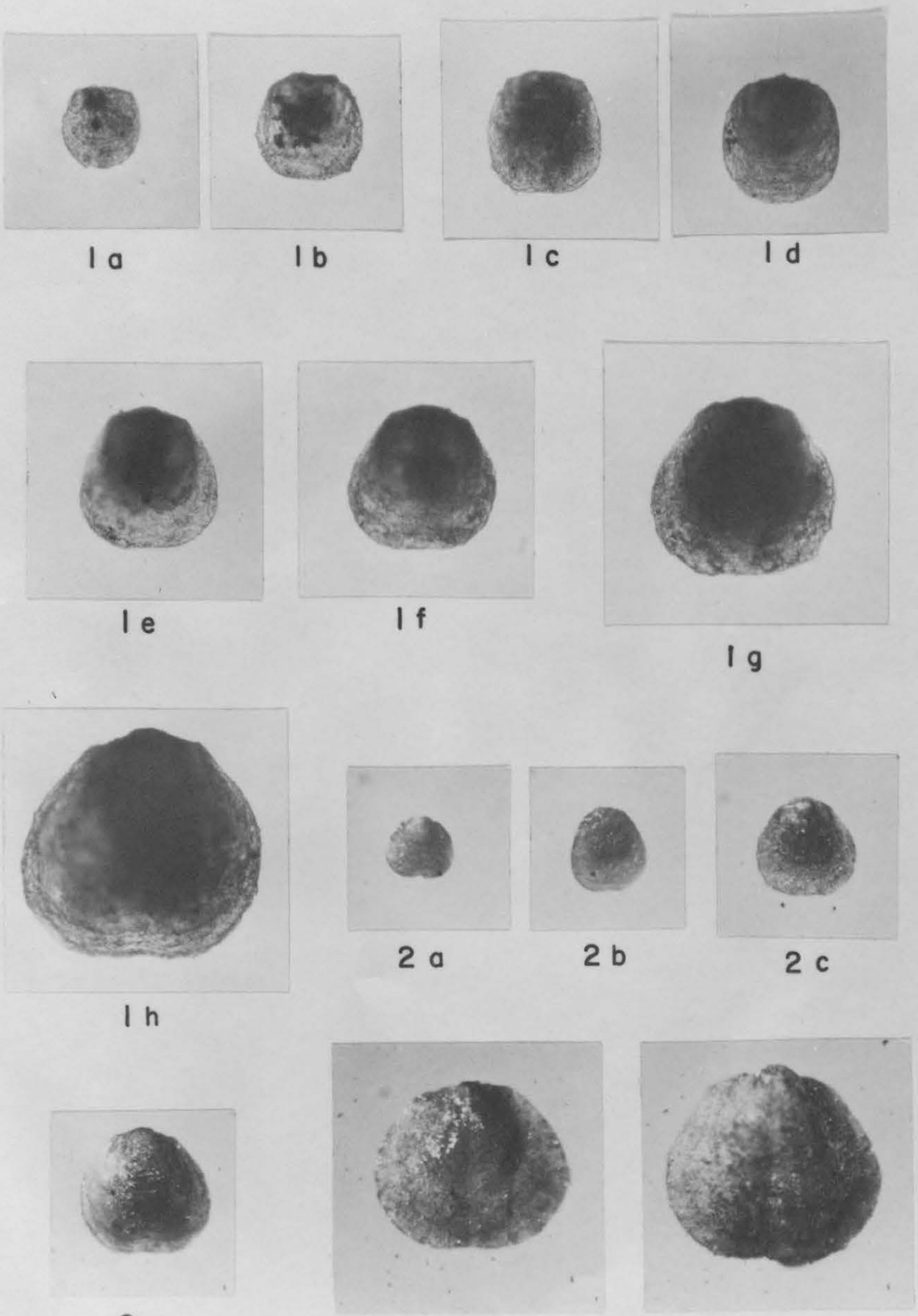
Ambocoelia Growth Series

Figures

1a-1h Ambocoelia growth series photographed by transmitted light. (X 50)

2a-2f Ambocoelia growth series photographed in reflected light using a microscope and camera. (X 25)

PLATE IV



1a 1b 1c 1d
1e 1f 1g
1h 2a 2b 2c
2d 2e 2f

Plate V

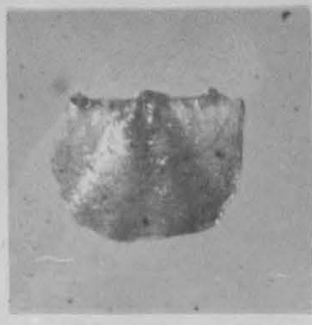
Other Juvenile Brachiopods and Pyrite Concretions

Figures

1a	Rhipidomella sp. (X 25)
1b	Chonetes sp. (X 25)
2	Athyris spiriferoides (X 50)
3a,3b	Surface view of two pyrite concretions
3c	Cross-sectional view of pyrite concretion in figure 3b. Pyrite is the lightest mineral, calcarious matrix is dark grey, sparry calcite infils the two largest shells.

PLATE V

1 a

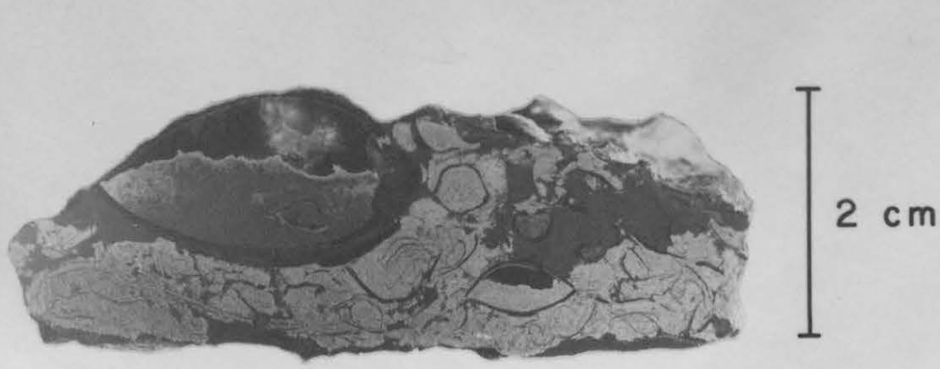


1 b

2

3 a

3 b



3 c