NOTES ON THE USE OF SHELLS OF *ANODONTA GRANDIS* SAY (BIVALVIA; UNIONIDAE) AS A PALEOECOLOGICAL INDICATOR OF TROPHIC STATUS AND PH

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ABSTRACT

Shells of *Anodonta grandis* Say were collected from five lakes in Ontario and New York state. Morphometric analyses showed that growth rates were slower in lakes of lower pH (<7.0) and alkalinity (<20 ppm $CaCO_3$) but the shape of the shells was similar in all the lakes. Ultrastructural studies demonstrated a remarkable consistency between shells in a single lake of the same depth class. Some variation occurred between depth classes but considerably more variation was observed between lakes. The clams from hardwater lakes had more complete mineralization and different, but not consistent, ratios of nacre thickness to total thickness.

It was not possible to distinguish between factors such as food availability and pH-alkalinity from these preliminary data. The potential use of museum specimens and fossils is suggested as an indicator of recent or ancient water quality.

INTRODUCTION

The acidification of inland waters by atmospheric deposition has led to a revived interest in developing methods to estimate past water quality. These methods include analysis of the chemistry of sediment cores (Norton and Hess 1980) and analyses of diatom populations in cores (Davis and Berge 1980). It is suggested here that unionid clams with wide distributions, like *Anodonta grandis* Say may preserve in their shells a record of the conditions in which they grew.

The use of the molluscan shell as a paleoecological indicator of water quality is well documented and recently reviewed by Rhoads and Lutz (1980). Past work, however, has been almost exclusively confined to marine forms. Since the ocean is well buffered, none of this work is directly applicable to the effects of pH stress on freshwater clams. It has been suggested, however, that changes in the pH of extrapallial fluids during the prolonged closure of intertidal bivalves brings about partial dissolution of the shell and leaves a record as tidal lines in the shell (Gordon and Carriker 1978). Work by Mackie (1978) and Burky et al. (1979) on morphological and ultrastructural responses in fingernail clams (Sphaeriidae) is significant but the infaunal habit of these clams (Mackie and Qadri 1978) leaves them less sensitive to changes in the water column chemistry than the Unionidae, which draw water in from above the sediments. Additionally morphological studies of ecological effects on pulmonate snails (e.g., Russell-Hunter et al. 1967), do not help to develop these molluscs as indicators because of their ability to leave the water to avoid transient stresses. A study by Agrell (1949), which concluded that *Anodonta piscinalis* in nutrient-enriched habitats had heavier shells than those from oligotrophic lakes helped to promote this study.

Singer
1981

In 1978, Ghent, Singer and Johnson-Singer reported on the morphological iation of A. grandis from Bernard Lake, Ontario. They showed that there was much variation in shape between shells collected at 13m and those from 2m as reported by Clarke (1973) all across Canada. Nonethless, a particular agess from a particular depth was remarkably uniform in shape. Age classes were ermined by counting annual rings, which is very easy to do in this thin-shelled cies. The rings were known to be annual because Ghent (pers. com.) had painted lls, released them, and recaptured them in subsequent years to find that only complete ring was added per year.

Since then, I have made collections from Lake Nipissing and Forest Lake in rio, and Cazenovia Lake and Lake George in New York. Locations and some er chemistry data from these lakes are summarized in Table I. L. George and Nipissing are softwater lakes with about neutral pH values. Nutrient enricht has taken placed in L. Nipissing. Cazenovia Lake is a hardwater, nutrient lake. Forest Lake is a slightly acidic, brown water lake.

TABLE 1. Locations of lakes and some chemical parameters of summer grab samples.

	pH	Hardness (mg l^{-1} $CaCO_3$)	Total Alkalinity (mg l^{-1} HCO_3^-)	Conductivity (μmhos)
est L. 5°32'N, 79°18'W				
2 m	6.9	28.	<20.	50.
5m	6.6	32.	<20.	45.
ard L. 5°43'N, 79°25'W				
2 m	7.0	10.	<20.	60.
11 m	6.9	20.	20.	65.
ipissing 5°15'N, 79°50'W				
4 m	7.0	20.	20.	87.
eorge 3°50'13"N, 73°25'50"W				
4 m	7.4	25.	<20.	90.
enovia L. 2°55'44"N, 75°51'42"W				
4 m	8.6	112.	89.	220.
oraine 2°50'47"N, 75°31'39"W				
3 m	7.9	140	75	240

MATERIALS AND METHODS

Water chemistry was performed by standard methods (APHA, 1976) in the field. Data from other investigators was used where available (L. Nipissing - D. Anthony, pers. com.; L. Cazenovia - Effler and Rand 1977; L. George - RPI Freshwater Institute staff, pers. com.) to make generalizations about the trophic characters of the lakes. Water samples were taken by SCUBA divers adjacent to the collecting sites.

Specimens of A. grandis were collected by SCUBA divers. The depth of each collection was determined with a depth gauge carried by the divers and previously calibrated against a sounding line. Soft parts were scraped and the shells were allowed to air dry. Morphometric measurements were made with a vernier caliper along lines illustrated in Figure 1.

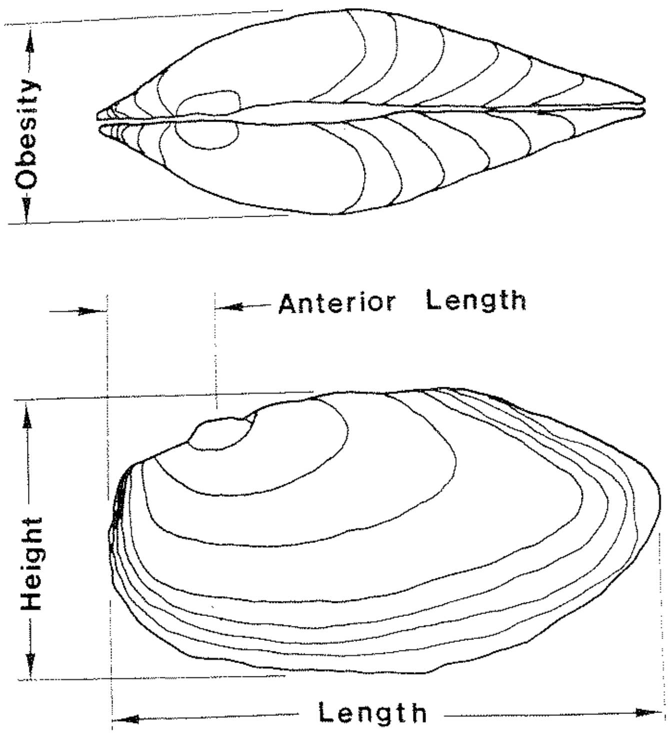

Fig. 1 Morphometric measurements used to evaluate the shape of shells.

Specimens for electron microscopy were all prepared at the same time in the same manner. Shells were selected which were 7-years old at the time of collection and of intermediate size compared to other specimens collected from the same lake at the same depth. One valve was carefully sawn in half in a line from between the umbo and the hinge to the ventral margin with a circular diamond blade saw designed for slicing geological specimens. Another cut was made 5 mm posterior and parallel to the first cut, leaving a thin piece of shell which was cut 5 mm on either side of the third annual growth ring. These pieces were hand polished on progressively finer emory cloth to 800 mesh and polished with jewelers rouge to a mirror smoothness. They were washed in water and then the polished edges were etched in 10% HCl for 1 minute, rinsed in pH 9.0 phosphate buffer and rinsed in distilled water. The shell fragments were mounted on aluminum stubs with colloidal silver paste, edge up, sputter coated with gold, and examined with an ISI electron microscope.

RESULTS

Morphology

Older clams within each collection were predictably larger. As was determined from a previous study (Ghent, Singer and Johnson-Singer 1978), length varied most with age. Weight vs. length of the shells was compared and is shown in Figure 2. All of the shells lie on the same curve, suggesting that although the absolute size of shells from different lakes may vary, the amount of shell material in a clam of any particular size is about the same.

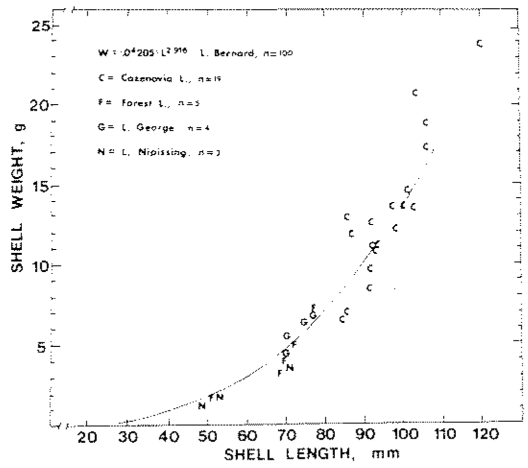

Fig. 2. Weight vs. length relationships of <u>Anodonta grandis</u> shells from five lakes in Ontario and New York state.

A plot of height vs. age (Figure 3) indicates that the shells from Forest Lake and L. George grew at a slower rate than those from Bernard Lake and Cazenovia L. Only three shells were collected from L. Nipissing so those data are not included.

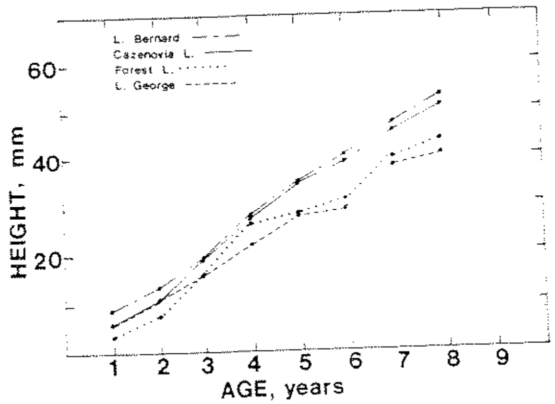

Fig. 3. Cumulative height vs. age of four populations of Anodonta grandis Say.

Results of this morphometric analysis confirmed the allometric relationship derived from the collection made at Bernard L. (Ghent, Singer and Johnson-Singer 1978) but did not add any major new findings.

Ultrastructure

The ultrastructure was consistent within a depth-class from a particular lake but varied widely between lakes (Figure 4) and to a lesser extent between depth classes from the same lake. Replicates from the same lake and depth demonstrate that individuals are quite consistent (Figs. 4A, 4B). Both these specimens are about the same thickness (590 µm) and have prismatic layers about 100 µm thick. The periostracum of each clam is tightly applied to the underlying prisms and the nacre is evenly layered with horizontal sheets of organic material.

Important differences do appear when comparing clams from the same lake but collected from different depths. Two shells from Bernard L. (Fig. 4C, 4D) are almost exactly the same thickness (400 µm), but the prisms of the shallow specimen are 200 µm thick, while those of the deep specimen are 280 µm thick. The organic material of the Bernard Lake shells lies in thick vertical and horizontal sheets, and the periostracum is loose and separates easily from the prisms. Specimens from Lake Nipissing (Fig. 4E) are very similar to the deep water specimens from Bernard Lake, reflecting the similar water chemistries of the two lakes. Those from Forest Lake (Fig. 4F) and Lake George (Figure 5) are strikingly different. The Lake George specimen has a large crack in the nacre, which is filled with debris. The prisms are heavily eroded and both prisms and nacre are largely replaced with organic material. The effects of living in an acid environment

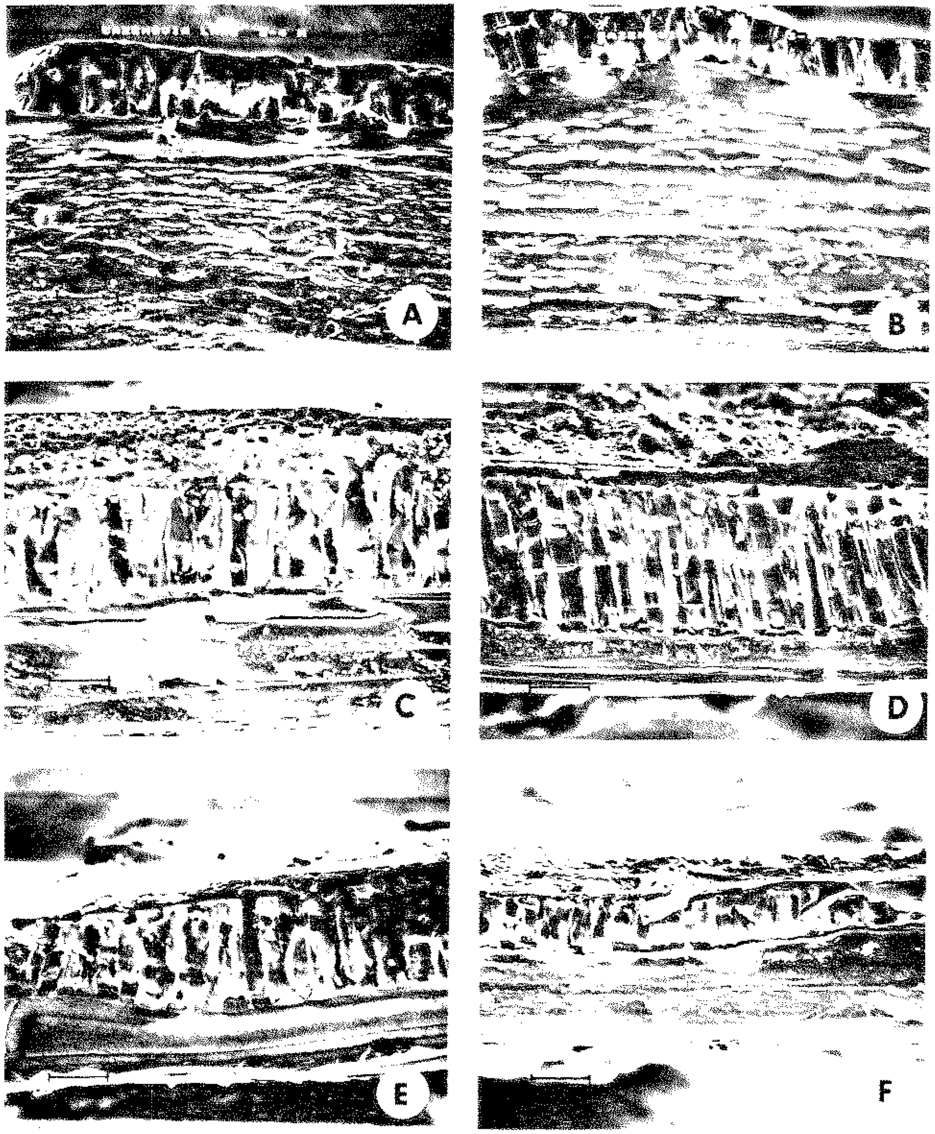

Fig. 4. Scanning electron micrographs of radial sections of *Anodonta grandis* Say taken at the third annualar ring. The bars represent 100 μm. A and B. Two specimens of shells taken in 3-4 m of water from Cazenovia L, NY. C. A shell taken in 2 m of water from Bernard L., Ontario. D. A shell taken in 10-11 m of water but also from Bernard L. E. A shell taken in 2 m of water from Lake Nipissing, Ontario. F. A shell taken in 4 m of water from Forest L., Ontario.

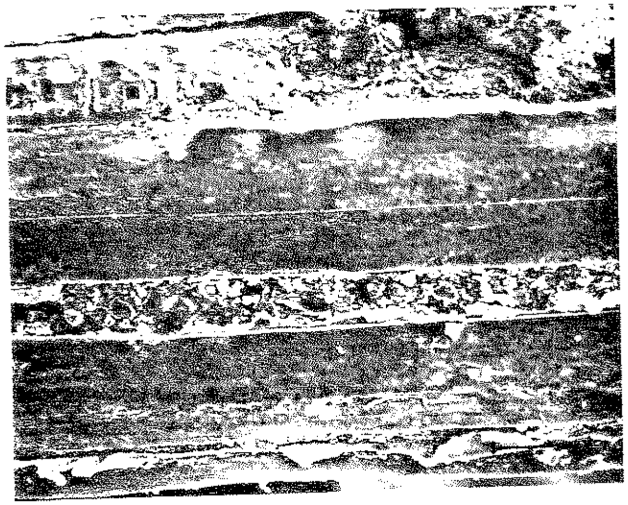

Fig. 5. Scanning electron micrograph of a radial section of a shell of *Anodonta grandis* Say taken at the third annular ring. The bar to the lower right represents 100 μm.

are most striking in the shell from Forest Lake. It is half as thick as any of the other shells, heavily eroded, overlain with organic material, and crumbly, in spite of the fact that it is not nutrient stressed.

DISCUSSION

Many factors, both environmental and genetic, influence the morphology and ultrastructure of clam shells. In the recently post-glacial lakes of northern New York and Ontario, genetic differences are held to a minimum. Marked changes in morphometry were not observed in this study, but it was determined that *A. grandis* from acid Forest L. and nutrient-poor L. George at a slower rate than clams from the other lakes.

Ultrastructural differences between populations were much more significant. The relative thickness of prisms compared to nacre varied considerably (Table 2) but it is difficult to ascribe this variability strictly to pH differences.

Table 2. The average thickness of 2-4 specimens per lake of Anodonta grandis Say from five lakes. Variation between species from the same lake or the same depth within a lake was <5%. Thicknesses were measured at the swelling associated with the third annular ring.

	Total Thickness (µm)	Prism Thickness (µm)	% Prisms
L. Cazenovia 4m	590	100	17
L. George 4m	500	100	20
L. Nipissing 4m	400	270	68
L. Bernard 2m	400	200	50
L. Bernard 10-11m	400	280	70
Forest L. 4m	210	100	48

The potentially most significant difference between populations - organic nchlion content - was not quantified in this study. Ashing shells to measure latile solids would have destroyed specimens which were slated for electron croscopy. As discussed above, the amount and distribution of organic material the shells appeared to be constant within a collection but varied greatly tween collections. Some of the shells from Forest L. were so decalcified as to flexible! Tevesz and Carter (1980, p. 310) recently said ". . . conchiolin yers are deposited by certain species with greater frequency and in thicker yers in more acidic freshwater environments. However, this aspect of their rmation has yet to be investigated, and is at present entirely speculative."

The potential role of A. grandis as a paleoecological indicator of water ality can only be suggested by this pilot study, but these preliminary data dicate that major environmental parameters leave a predictable record in the ells. Future studies should also include determinations of organic conchlion: O3 ratios. Comparisons of shells from museum collections may be used to tablish approximate pH levels in lakes year in the past.

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