COMPOSITION OF THE MINERAL PHASE OF DENTINE IN SOUTHERN ELEPHANT SEAL AND ANTARCTIC FUR SEAL TEETH

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Introduction

The incremental lines found in sectioned seal teeth were independently established as indicators of age by the work of Chapskii (1941, cited in Scheffer and Myrick,1980), Scheffer (1950) and Laws (1952). This technique is now widely used for ageing marine mammals as well as many terrestrial species.

These lines have been referred to as light and dark bands by some authors. However, since the optical properties depend on the type of illumination used (transmitted *v.* reflected light), the following terms were defined for sperm whale teeth (International Whaling Commission, 1969): (i) the translucent zone (band or lines), which appears clear or light under transmitted light and forms a ridge in acid-etched teeth; and (ii) the opaque zone, which appears dark in transmitted light and forms a groove in acid-etched teeth. This terminology, although precise, did not account for the finer and irregular lines that appear within the wider zones and lead to confusion amongst researchers. Consequently the term 'growth layer group' or GLG (the incremental growth layers which are recognized by their regularly repetitive pattern) was adopted (Perrin and Myrick, 1980).

Klevesal (1963) and Best (1970) suggested that optical differences in the dentine might be independent of mineral content and no proof that differing calcium content is the cause of the opaque and translucent qualities of dentine has been advanced (Smith, 1973). However, X-ray microscopy studies of the variations in density of cementum and dentine have been interpreted as being related to the degree of mineralization (Boyde, 1980). Variations in mineral chemistry, particularly in CO_2 content have been suggested as causes for the light and dark bands (Boyde, 1980) but have not been tested to date.

Here, in a preliminary study, the microchemistry of these adjacent bands in the GLG is reported for two species of southern seals.

Methods

A total of 32 chemical analyses of the translucent and opaque bands in single upper canine teeth have been obtained from a male and female southern elephant seal, *Mirounga leonina*, and Antarctic fur seal *Arctocephalus gazella* by means of an energy dispersive electron microprobe, housed in the Department of Mineralogy and Petrology, University of Cambridge. Standard operating conditions were 20 kV accelerating voltage, 45 nA beam current, 80 s live counting time a beam diameter of 3 μm. The spectra were processed using iterative peak stripping and correction methods based on Sweatman and Long (1969). The following elements were analysed: Na, Mg, Al, Si, P, Cl, K, Ca, Cr, Ti, Fe, Mn and Sc at a relative accuracy of *c.* 2%. Natural apatite crystals were used as standards, and representative analyses are presented in Table I.

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Table I. Representative chemical analysis of zones in GLG.

	Elephant seal			
	Males		*Females*	
	Translucent	*Opaque*	*Translucent*	*Opaque*
Weight percentage oxide:				
CaO	52.72	51.07	51.52	52.55
P_2O_5	43.14	42.70	43.98	43.90
MgO	1.24	1.45	2.01	1.86
Na_2O	1.04	1.64	1.26	1.10
Cl	–	–	–	–
Total	98.14	96.86	98.77	99.41
Cations on the basis of 25 oxygens:				
P	6.060	6.071	6.104	6.061
Ca	9.373	9.191	9.049	9.184
Mg	0.307	0.364	0.491	0.452
Na	0.335	0.535	0.400	0.346
Cl	–	–	–	–
Total	16.085	16.161	16.044	16.043
	Fur seal			
	Males		*Females*	
	Translucent	*Opaque*	*Translucent*	*Opaque*
Weight percentage oxide:				
CaO	53.26	52.92	51.87	52.38
P_2O_5	42.46	41.49	41.60	42.56
MgO	1.20	1.33	2.12	2.23
Na_2O	0.89	1.64	0.85	0.89
Cl	0.18	0.17	–	–
Total	97.99	97.55	96.44	98.06
Cations on the basis of 25 oxygens:				
P	6.007	5.929	5.964	5.990
Ca	9.538	9.573	9.414	9.330
Mg	0.298	0.333	0.535	0.551
Na	0.289	0.538	0.280	0.289
Cl	0.051	0.050	–	–
Total	16.183	16.423	16.193	16.160

Results

The analysed tooth samples contain on average between 15 and 20% (by weight) organic material and/or water, which is similar to those reported by Eastoe (1967) and Rowles (1967). These components (elements with atomic number <11) cannot be analysed using the microprobe, and for comparative purposes, therefore, totals have been adjusted to account for this.

CaO contents vary from 51.1 to 54.9wt%, and P_2O_5 from 40.2 to 44.6wt%. Small quantities of Mg and Na are present, MgO values ranging from 0.89 to 2.33wt% and Na_2O contents between 0.51 and 1.64 wt%.

The composition of the mineral component of teeth corresponds closely to that of natural apatite (Deer and others, 1972) having *c.* 6.00 P cations per unit formula (p.u.f.) and Ca + Mg + Na *c.* 10.00 p.u.f. A general inverse correlation between Ca and Mg is particularly marked in female teeth samples, which also contain significantly higher proportions (up to twice) of Mg relative to male teeth samples. No consistent relationship between Na and Ca has been observed, although in general southern elephant seal teeth contain higher Na and lower Ca contents than fur seal teeth. The infrequent presence of Cl and Si probably represent the inclusion of the mounting medium (Araldite) contained in open dentinal tubules.

No significant difference in the chemistry of translucent and opaque bands has been observed (Table I), either between sexes or species. In addition, the proportion of the inorganic to organic component remains constant between adjacent bands.

Discussion

Apatite has long been recognized as the principal inorganic component of teeth (Trautz, 1967). Analyses presented here are consistent with this, although the Mg and Na contents are higher than those reported for other tooth analyses (Trautz, 1967). The replacement of Ca^{2+} by Na^{+} in teeth would require charge balance, and the coupled substitution of PO_4^{3-} replaced by CO_3^{2-} appears probable, particularly as natural apatites can contain significant quantities (up to 5–6%) of the latter (Deer and others 1972).

Mg contents in teeth appear to vary considerably but there is consensus that the Mg is not structurally incorporated into the apatite, and is probably retained in the organic component (the tubules) of the tooth, or adsorbed on to the surface of the growing crystal (Rowles, 1967). The inverse correlation between Ca and Mg observed here, however, indicates that Mg is part of the apatite structure, as suggested by Murray (1936). The difference in Mg contents between males and females has not been observed previously (Bird and others, 1940; Soremark and Sumsahl, 1962, in Rowles, 1967), although further analyses are required to elucidate this aspect more fully.

It is apparent from this initial study that the distinction between translucent and opaque bands in GLG is not due either to the mineral composition or to the proportion of organic to inorganic components. Several further possibilities exist however, including the degree of mineralization, the orientation of the dentinal tubules, or the orientation of the crystal platelets during mineralization (Boyde, 1980). There is, however, continued debate with regard to the relationship between optical 'opacity' and degree of mineralization, although most studies indicate that the translucent bands are more mineralized (see discussion in Hay, 1980). Unfortunately, these aspects cannot be investigated with the electron microprobe, and require other microanalytic techniques.

Conclusions

No chemical differences in the apatite structure have been observed between translucent and opaque bands in the teeth of male and female seals (*M. leonina* and *A. gazella*) which suggests that differences in the optical properties result either from the degree of mineralization or some aspect of the organic component such as tubule orientation. A significant difference in the Mg content is noted between the sexes of both species, with females containing up to twice as much Mg as males. This Mg is believed to be structurally incorporated in the apatite.

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