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Proton Induced X-ray Emission Study on the Content of Whale Tooth

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Abstract: *The use of Ion beam technique for assaying small amounts of trace elements and major elements distribution has grown rapidly in recent years. Major and minor elemental composition of teeth has been extensively studied. In this work, elements content in teeth of whale were analyzed by the Proton Induced X-ray Emission (PIXE). This work is an attempt to investigate the history of mammal's different annual rings layer of whale tooth. High levels of Trace elements such as Zn and Sr were detected in the teeth. By analysis of elemental composition and evaluation of trace elements in different layer, the route of the whale movement and the status of pollution of environment were obtained. The result indicated that the technique is suitable to obtain minor and trace constituents of the teeth. The obtained results are discussed in detail and these results are compared withavailable data.*
Keywords: *Nuclear Technique; PIXE; Element; Whale Tooth*

I. Introduction

Attentions have been paid to the analysis of tooth and bone for their important functions in the human and animal body **[1-3]**. However, the cells activities are regulated by tooth and bone matrix **[4, 5].** It has been shown that the imbalance of tooth and bone formation and tooth and bone resorption results in tooth and bone loss **[6]**. Tooth and bone mass is accumulated during childhood and young adulthood, reaching a peak at middle age **[7, 8].**

It has been shown that the imbalance of bone formation and bone resorption results in bone loss **[6]**. Bone loss with advancing age is observed in all human populations **[7]**. Although age-related bone loss occurs in both genders, it begins earlier and proceeds more rapidly in females **[9]**. Because of this, studies of age-related bone loss have focused mainly upon women, although osteoporosis is a significant health problem in men. However, after the middle age, both men and women begin to lose bone mass as a normal part of aging, through an imbalance of the remodeling process [**10]**. As a result, bones become larger, heavier, and denser **[11].**

The methods which are widely used in the analysis of trace elements were reported elsewhere [12]. In this work, PIXE [13] was used to investigate the history of history of mammals by analyzing different annual rings layer of whale tooth. . Information about the trace elements in tooth is important for several reasons. (i) Most mammals have life spans that exceed 1 year. (ii) Information can be used for evaluation the environmental pollution in the Sea or Ocean (ii) Information also can be used to know the migration, seasons and the diets of mammals.

II. Materials and Methods

2.1 Preparation of Sperm whale Tooth

The Sperm Whale with the largest tooth was provided by Shanghai Fishers University. The length of the male sperm whale was 18.0 meters. Procedures: The tooth sample was cleaned with toothbrush (instruments China-made) several times. The tooth sample was chopped in deep about 1-5 mm as slice. The sample was polished with 600 golden sand paper grind to get a thick of 200 µ m and with 2000 golden sand paper extract grind to give the thick translucent of 150 µ m. The sample was divided into several points according to the numbers of the structure growth layer. The structure growth of the whale tooth layers are given as: 0 year (at pregnant or embryo), 1 year (at born), 10 years (age), 15years (age), 20 years (age) and 25 years (age). The tooth slice was trapped and subjected to the PIXE analysis as shown in **Figure 2.1.**

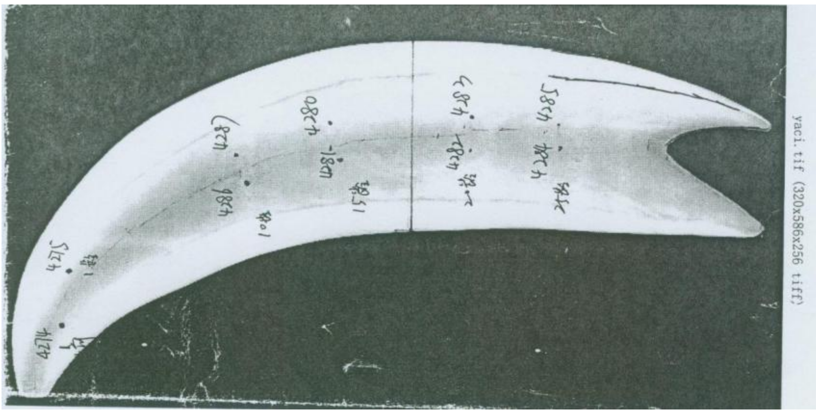

Figure 2.1. The slice of Sperm Whale Tooth

2.2 External Beam PIXE

External beam PIXE analysis was performed at the NEC-9SDH-2 Pelletron tandem accelerator at Fudan. The proton beam energy was 3 MeV. The proton beam leaves the vacuum system of the accelerator through a 7.5 μ m Kapton window. After passing through a short distance in air, the beam hits the target with a small spot of size l mm in diameter. X-rays emitted from the target are measured with a Si (Li) detector. The energy resolution of the detector was 180 eV at 5.9 KeV. A thin 25.4μm beryllium window is placed in front of Si (Li) detector. The experimental setup in this study is designed as followings: The detector was positioned at 90° with respect to the beam direction. The distance between the beam exit window and the target and between the target and the detector axis were each 10 mm. The angles between the incident proton beam and the target (θ) and between the target and the detector axis (φ) are each 45 º. Each target was put into the external beam PIXE and bombarded with a 3.0 MeV proton beam. The beam current was about 0.4nA. During the measurements at least two spots on the sample surface were irradiated per run. The exposure time was 10 to 15 minutes. All the spectra were registered with Multi-channel buffer on 2048 channel pulse-height analyzer. The obtained spectra were kept in a PC-computer for analysis.

III. Results and discussion

The material under analysis came from Shanghai Fishers University. The structure growth of the whale tooth layers are given as: 0 year (at pregnant or embryo), 1 year (at born), 10 years (age), 15years (age), 20 years (age) and 25 years (age). The thus prepared samples served to determine the content of the following elements: P, S, Ca, V, Mn, Fe, Ni, Cu, Zn, and Sr in sperm whale tooth, using PIXE method. The Sr/Ca and Zn/Ca ratios were also calculated. The ratios of the peaks areas of the micro and macro elements under study are shown in

Table 3.1.

Table 3.1 The Chemical composition inside each annual rings layer (unit: $\mathbf{10^{-3}}$)

Ratio	0 Year	1 Year	10 Year	15 Year	20 Year	25 Year
P/Ca	51.61±0.77	39.37±0.40	63.71±0.26	16.70 ±0.52	76.31±0.62	82.50±0.41
V/Ca	0.95±0.48	0.78±0.27	0.42±0.12	0.82±0.48	n. d	n. d
Fe/Ca	4.60±0.45	6.14±0.25	1.33±0.10	1.72±0.36	1.14±0.23	1.70±0.14
Ni/Ca	n. d	2.64±0.16	0.71±0.01	0.30±0.27	0.58±0.18	1.03 ±0.11
Cu/Ca	0.28±0.26	0.81±0.13	0.12±0.01	0.48±0.48	n. d	0.40±0.01
Zn/Ca	32.27±0.58	37.93±0.35	18.57±0.15	32.38±0.24	20.32±0.33	19.48±0.21
Sr/Ca	17.37±0.40	18.38±0.26	10.57±0.10	20.63±0.42	10.98±0.23	9.47±0.15

Note: n. d: no detected, peak area of the element ratio.

It was found that the ratio of P/Ca inside different rings layer are very high compared to the ratios of the other elements as shown in **Table 3.1**. The P/ Ca, is very low at 15 years -old, the specific value of P/ Ca is 16.704 ± 0.518(unit: 10^{-3}) **(Figure 3.1).** The elements P, Ca, Fe, Zn and Sr are relatively high in whale tooth while, V, Ni and Cu are very low levels.

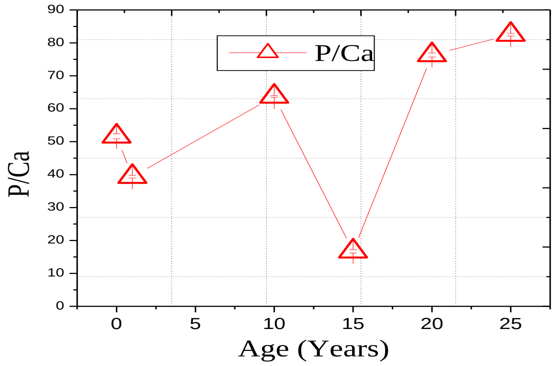

Figure 3.1 The P/ Ca ratio inside each annual rings layer

For Zinc and Ca, statistically significant increases in the Zn/Ca ratio with age of an individual were observed at (born, 1 years) (37.93±0.35) (unit: 10^{-3})1 years (**Figure 3.2).** However, **z**inc and strontium in this study showed a different pattern of elemental profile. The chemical composition Sr, since the embryo to the birth was gradually increased. At 10 years, the Sr value inside the annual rings layer was decreased, later on, from 10 years to 15 years, gradual increased then decreased gradually. Among the trace elements Fe, Zn, and Sr contents were relatively high compared to the other trace elements such as V, Cu and Ni in all the samples. Therefore, we took notice of the annual rings layer change of the content Zn and Sr.

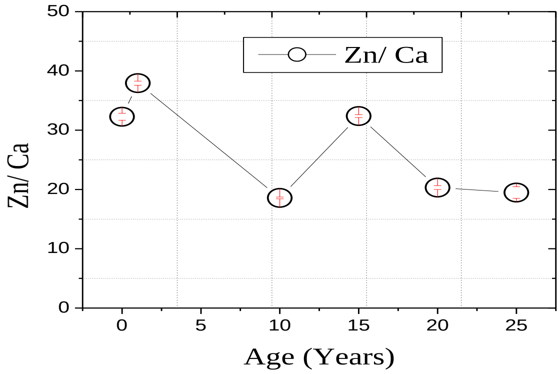

Figure 3.2 The Zn/ Ca ratio inside each annual rings layer

Figure 3.2 shows the relation between the ratios of Zn/Ca, and age of annual rings of tooth. The relation between the ratios of Sr/Ca and annual rings age of tooth is given in **Figure 3.3**. Annual change of the Zn and Sr indicated the same tendency; both elements were higher in born, but lower in elderly age. This fact suggests that annual pattern for living of the whale tooth reflects the change of Zn and Sr content since Zn are the essential elements for mammals but Sr is not. The migration behavior may cause annual change of the Zn and Sr Content. Moreover, patterns such as trace element volumes due to the different environment remain forever encoded in the teeth since the teeth do not decalcify unlike bone.

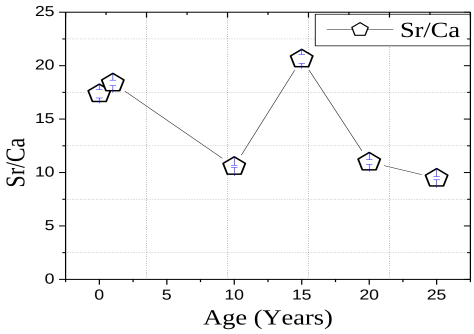

Figure 3.3 The Sr/Ca ratios inside each annual ring layer

A PIXE analysis was performed to investigate the annual individual patterns. **Figure 3.4** shows the relation between the ratios of Mn/Ca, Fe/Ca, Ni/Ca and Cu/Ca, and age. These elements may give indication about the influence of environmental factors, pollution and movement of whale.

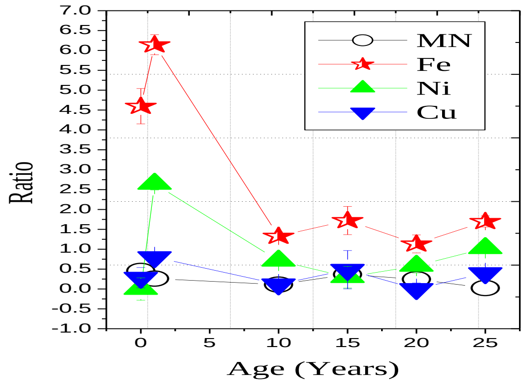

Figure 3.4 The Mn/Ca, Fe/Ca, Ni/Ca, Cu/Ca ration in Whale Tooth

In the course of examination, statistically significant differences were found between the content of the elements studied in different annual rings layer of a whale tooth. The results can reflect environmental and living conditions of the whale, dietary habits and uptake of some elements. Tooth has been indicated as dose monitors for elemental exposure. However, the results clearly show that the elemental levels inside annual rings layer are different.

IV. Conclusion

From study on whale tooth, the results may give indication about the influence of environmental factors, pollution, living conditions, uptake of some elements and movement of whale.

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