

# IDENTIFICATION OF MARINE AEROSOL COMPONENT BY COMBINED NAA AND SCANNING ELECTRON MICROSCOPY WITH X— RAY ANALYSIS

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## ABSTRACT

The concentrations of 30 elements in aerosol particles collected in western Pacific ocean have been determined by INAA. The crustal element concentrations decrease with increasing distance from land over the remote area close to Asia land and fluctuate around its average value over the remote ocean area. The volatile elements exhibit average atmospheric concentrations that are higher than those expected from the flux of seasalt or the continental dust. In order to identify marine aerosol component originating from the continent or ocean, the aerosol particles are examined by scanning electron microscopy combined with energy dispersive X— ray spectroscopy. Particle phase structure shows that the crustal aerosol particles are not present internal mixtures with seasalt aerosol, and it also proves the long— range transport of crustal elements from continent to ocean.

**Keywords:** Aerosol   Scanning electron microscopy   INAA   EDS

## 1 INTRODUCTION

Marine aerosols often contain substantial quantities of land— driven material resulting from wind erosion, volcanism and man's activities. Analysis of the continental and marine components of those aerosols is essential to our understanding of the geochemical cycles of the elements, and the long— range transport of material from continent to ocean via the atmosphere. In order to assess the contribution of the different natural or human sources, this paper describes the comprehensive analysis of a marine sample from the western Pacific ocean by INAA and SEM/EDS.

## 2 EXPERIMENTAL

### 2.1 Sampling

The KB— 120 sampler and KA— 200 Anderson cascade impactor were used for

sampling the total aerosol particles and size-fractionating particles respectively. The sampling devices were mounted on the forecandle of the Chinese vessel to avoid contamination from the ship's stack emissions. Sampling was interrupted when the relative wind was blowing from aft or speed was lower than 2 m/s. The sampling time and volume speed were 7—8 h and 90 l/min for KB—120 sampler, and 40—50 h and 28.3 l/min for KA—200 cascade impactor. The size cutoffs for stages 1, 2, 3, 4, 5, 6, 7, 8 and 9 were >11, 7—11, 4.7—7, 3.3—4.7, 2.1—3.3, 1.1—2.1, 0.65—1.1, 0.43—0.65 and <0.43  $\mu\text{m}$ , respectively.

## 2.2 Analysis

The INAA was used to determine the content of trace elements in aerosol. Analytical procedures were described in detail previously<sup>[1]</sup>.

## 2.3 SEM and EDS analysis

The carbon is evaporated on the surface of aerosol particles to increase the electronic conductivity of the specimen. The thickness of carbon layer is about 10—20nm, and the specimen are observed and microanalyzed with SEM (KYKY-AMRAY 1000B), and EDS (series II of Tracor Northern).

# 3 RESULTS AND DISCUSSION

## 3.1 Chemical composition of aerosol in various marine regions

Table 1 presents the concentrations of 30 elements in the total particle aerosol in various marine regions. The element concentrations of Na, Mg, Cl, Ca and Br were dominated by marine sources. The crustal elements Al, Fe, Sc, Mn, etc. in marine aerosol over the ocean close to the Chinese continent were predominant. They almost equal to the seawater elements in concentration, for example, concentrations of Al, Fe, Na and Cl are almost of the same order. Over the remote ocean, the concentrations of seawater elements in aerosol were higher than crustal elements for two orders of magnitude. In the aerosol samples collected from Harwaii, Panape and Guangzhou concentrations of crustal elements are increased. The volatile elements As, Se, Sb, I and Zn exhibited average atmospheric concentration that were higher than those expected from the flux of seasalt or the continental dust. It is suggested that the volatile elements over the western Pacific were influenced mainly by long-range transport of anthropogenic pollutants from land.

## 3.2 Relationship between crustal elements Fe and Al, Fe and Sc

The highest loadings of element Fe were found on the shelf of China and almost certainly originate from the Chinese continent according to the trajectory analysis. Atmospheric inputs of aluminosilicate particles from crustal weathering controlled the aerosol particle concentrations of Al, Fe, Mn, Sc, Co, Cs, Ba, La, Ce, Eu, Sm, Ta, Tb, Hf and Th. The crustal element concentrations decreased with increasing distance

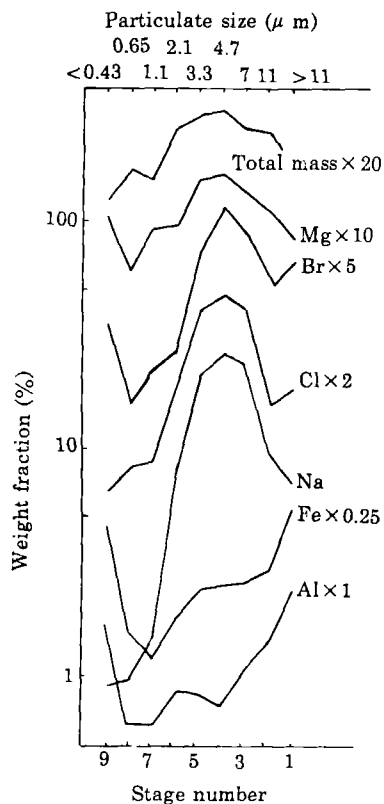
from land over the ocean area close to Asia land and fluctuate around its average value over the remote ocean area. The good relationship between Fe and Al as well as Fe and Sc indicates that Al and Sc have similar behavior to Fe and basically come from the same source.

**Table 1**  
**Concentrations of elements in marine aerosol** ng/m<sup>3</sup>

Locality	22° N 114° E	21° N 157° E	20° N 159° W	3.3° N 170° W	2° S 172° W	0° 170° E	1.5° N 165° E	5.5° N 131° E	19° N 128° E	Hawaii	Panape	Guang- zhou
Al	693	37.4	34.2	20.9	21.3	10.5	—	137	60.4	819	227	1960
Cl	1270	5410	14200	14700	24900	8600	4910	6230	11800	7380	2430	875
Na	464	3170	9530	9110	15900	6090	2890	3750	7550	4260	1230	482
Mn	13	0.43	0.69	1.03	—	—	—	1.71	5.4	37.4	10.4	33.1
V	1.84	—	1.4	—	—	—	—	—	0.39	5.63	0.55	3.39
I	6.83	4.87	3.32	1.74	2.48	1.75	2.04	3.64	4.72	5.1	2.05	3.71
In	0.24	0.07	0.09	0.04	0.06	0.02	0.12	0.11	0.36	0.13	0.42	0.12
As	4.8	—	—	—	—	0.26	—	0.47	1.0	1.7	0.29	9.7
Sb	1.28	0.11	0.07	0.35	0.11	0.06	0.08	0.18	0.22	1.43	0.27	2.63
Br	1.72	11.8	49.3	29.1	79.2	22.3	6.89	12.5	31.1	17.9	3.24	3.37
Se	1.19	0.08	0.07	0.41	0.32	0.46	0.11	0.10	0.16	0.08	—	2.1
Zn	37	3.8	4.1	6.7	12.3	3.5	12.7	3.2	3.7	166	155	35.9
Rb	4.5	0.13	0.19	0.3	0.22	0.09	0.18	0.24	0.31	0.29	—	6.82
Cs	0.35	0.01	0.01	0.01	0.007	0.004	0.01	0.02	0.014	—	0.01	0.55
La	0.64	0.03	0.10	—	—	—	—	0.13	—	0.39	0.13	1.46
Co	0.13	0.02	0.10	0.04	—	0.02	0.06	0.05	0.04	0.92	0.13	0.52
Fe	435	303	49.6	60.8	29.6	40.8	33.8	95.1	61.1	2120	280	986
Eu	0.013 <sup>A</sup>	0.002	0.003	0.005	0.002	0.002	0.004	—	—	0.028	0.007	0.034
Th	0.24	0.007	0.011	0.018	0.008	0.006	0.008	0.029	0.013	0.044	0.034	0.46
Ba	14.8	2.4	1.4	3.0	1.9	1.6	23.9	2.8	—	11.1	3.9	19.1
Ce	0.99	0.068	0.10	—	0.082	0.059	0.094	0.17	0.11	—	0.2	2.38
Sm	0.083	0.005	0.013	—	—	0.008	—	0.013	—	0.095	0.026	0.21
Sc	0.112	0.006	0.009	0.012	0.004	0.004	0.004	0.027	0.014	0.21	0.053	0.36
Ta	0.69	0.016	0.011	0.033	0.036	0.006	—	0.005	—	0.025	—	0.03
K	688	393	—	—	3230	—	254	—	—	—	—	1390
Hf	0.04	—	—	—	—	—	—	0.01	0.01	0.04	0.02	0.12
Lu	0.007	—	0.001	0.002	—	—	—	—	—	0.007	0.004	0.014
Tb	0.015	0.02	—	0.003	0.002	0.003	—	0.014	—	0.012	0.005	0.016
Ca	626	199	—	689	571	—	149	160	—	3100	1890	1640
Mg	130	481	1080	860	1670	583	344	442	872	—	—	415

### 3.3 Elemental concentration vs size distribution

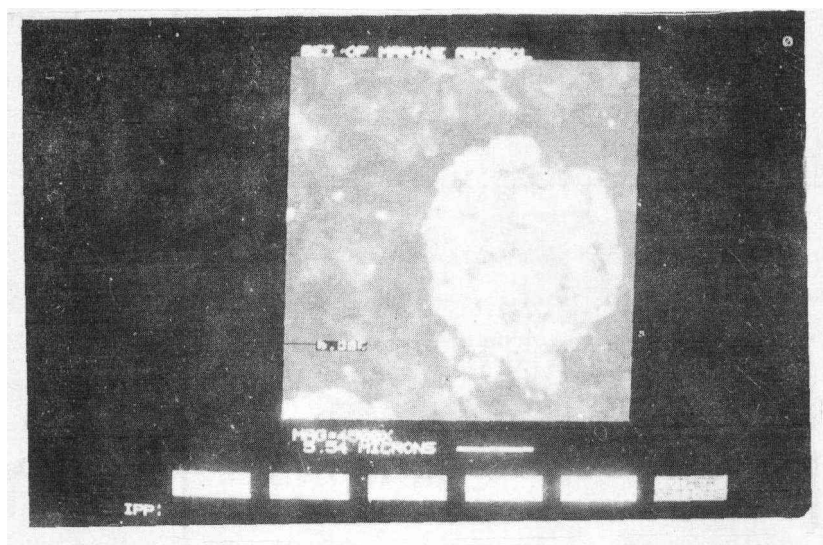
The chemical components of aerosol over the western Pacific ocean come from different sources, and therefore its elemental concentration vs size distribution is complicated. In aerosol, elements of different chemical properties have different size distribution. Plot of size distribution versus elemental concentration percentage for different elements is drawn in Fig.1. The data are the average values of 6 cascade impactor samples over the remote ocean. It can be seen that the maximum peak value of seawater elements Na, Cl, Br and Mg appears on stage 4, with slightly different size



**Fig.1 Size distribution versus elemental concentration percentage for different elements**

centres of the particle, and it is covered with other materials. To setup appropriate

distributions. The crustal elements Al, Fe, Sc, etc are quite different from seawater elements in size distribution, it appears lower for intermediate and higher for fine and coarse particles. These results were different from those size distributions of eastern Pacific and Atlantic.<sup>[2,3]</sup> They reported that the size distributions of the crustal element in aerosol over the remote ocean are remarkably similar to those of the major seawater elements and it was explained by the mixtures of crustal aerosol particles with the sea-salt aerosol. In order to identify marine aerosol component originating from the continent or ocean, the aerosol particles are examined by scanning electron microscopy combined with energy dispersive X-ray spectroscopy. Fig.2 is the second electron image of an aerosol particle. The diameter of this particle is about 5.54  $\mu\text{m}$ , it shows that some material which like cubic crystal is in the



**Fig.2 An aerosol particle containing continental and seasalt species**

threshold values and to overlap the X-ray maps, the aerosol particle phase structure is shown in Fig.3, that NaCl crystal (which from marine) in the centre of the particle, and the main composition of covered material is Fe (which from continent). There is an intermediate zone between NaCl and Fe, its main composition is Fe, Cl, Na or Fe, Cl. It proves that Fe is not only covered with the NaCl crystal, but also mixtures slightly with NaCl. This observation explains the crustal aerosol particles are not present as internal mixtures with seasalt aerosol, they are adsorbed on the surface of the NaCl crystal. Therefore, the size distribution of crustal elements are different from those of the major sea-water elements, and it also proves the long-range transport of crustal elements from continent to ocean.

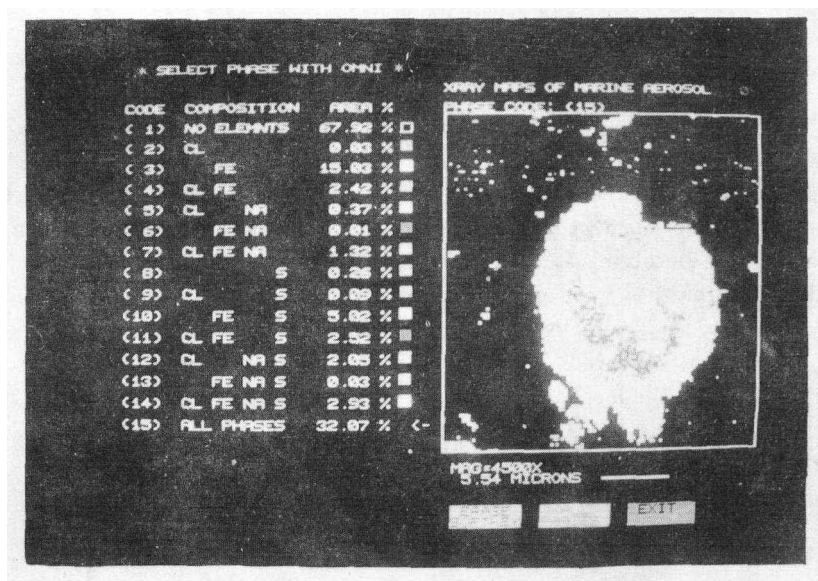


Fig.3 Aerosol particle X-ray phase structure maps

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