

A note on an occurrence of pseudo-pumice along the beaches of Goa and Karnataka

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Clasts showing typical physical features of pumice were found scattered along the beaches of Goa and Karnataka. Their chemical composition suggests a large variation in SiO₂ content (69% to 93%), with an unusual strong positive Ce-anomaly. These light weight fragments do not correspond with natural pumice, but rather appear to be similar to the chemical composition of foam glass / artificial pumice available in the market. Therefore, it is concluded that these pumice clasts are a waste product of silica based industries (most probably originating from the ship breaking yards in Gujarat), that found its way towards the beaches of Goa and Karnataka by the action of waves and southerly littoral currents.

[**Keywords:** Pumice, Beaches, Goa, Karnataka, Composition, Foam glass/artificial]

Introduction

Pumice can travel thousands of kilometers and becomes water logged before it sinks to the seafloor¹. It is porous in nature, with different shapes and dimensions, and is characterized by a network of vesicles. During its transportation progressively it breaks up on the sea surface by attrition². It acts as an effective rafting agent that can help in dispersal of different type of organisms and can connect shallow marine to coastal ecosystems³. Pumice is a useful abrasive and has been collected and traded since prehistoric times⁴.

Pumice of the 1883- Krakatau eruption drifted across the Indian Ocean and reached Indian, South Atlantic Ocean coasts⁵ and to Central Indian Ocean Basin which is about 3000 km from the source^{6,7}. There are reports where pumice has travelled about 20,000 km in the ocean⁸. Pumice of Youngest Toba Tuff of ~74 ka also travelled about 3000 km from Northern Sumatra to Central Indian Ocean Basin⁷. Recently, following the 2006 explosive eruption of Home Reef volcano of Tonga Island, pumice dispersal occurred over 900 days across the southwest Pacific Ocean³.

Over a decade ago, during routine beach surveys conducted by National Institute of Oceanography, pumice resembling clasts of

various shapes, sizes and colour were identified along the beaches of Miramar – Caranzalem, and Velsao – Colva in Goa, and Gokarna in Karnataka (Fig. 1). These fragments were found scattered along the upper reach of beaches, and was a common sight during the years 1999 - 2002. These pumice-like chunks are no longer seen along the beaches at present.

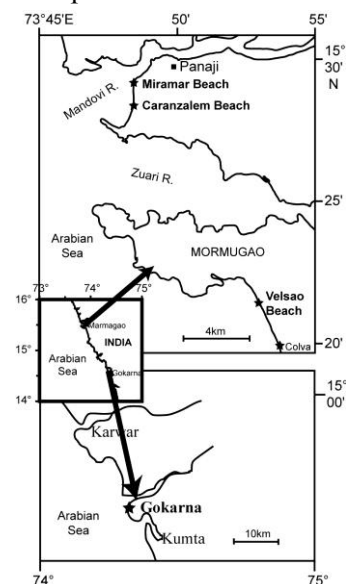


Fig. 1. Map showing places of pumice clasts (*) occurrences along beaches off Goa and Karnataka.

The reasons for undertaking this work are the following: (1) most of the clasts collected typically resemble natural pumice (Figure 2); (2) pumice rafts originating from explosive volcanic eruptions are known to disperse over large distances of thousands of kilometers; pumice of 1883-Krakatau origin have reached African coast⁵, Central Indian Ocean Basin^{6,7} and pumice of Youngest Toba Tuff (YTT) of ~74 ka old has been traced in the Indian Ocean south of equator, having travelled ~ 3000 km⁷; (3) the Tonga-Kermadec arc has produced recent explosive volcanic activity in 1979, 1984, 1986, 1990, 2001 and 2006 from where pumice was rapidly dispersed widely³. Therefore, there is every likelihood that the recent eruptions could have generated pumice that ultimately landed on Indian shores.

In view of the above, the presence of pumice along the beaches would imply a possible occurrence of volcanic activity in the vicinity. Therefore, in the present study, an attempt has been made to determine the chemical composition of these pumice fragments so as to compare with the known natural pumice, and to assign a possible source/origin.

Materials and Methods

Small chips of the pumice clasts were cleaned ultrasonically and ground into fine powder in an agate mortar. Pumice powder was treated with 1:1 HCl to remove any carbonate and Fe-Mn oxide present within the vesicles. Part of the powdered pumice was used for major element analysis on X-Ray Fluorescence (Pan Analytical) equipment. Major element oxide content was calculated on moisture free basis. About 50 mg of pumice powder was treated with a mixture of HF, HNO₃ and HClO₄ (7:3:1 ml) in a PTFE beaker and heated on a hot plate till it became turned into paste. Same quantity of acid mixture was added and heated once again. To this mixture, 4 ml of HNO₃ (1:1) was added and heated for five minutes. Later, 1 ml of Rh (internal standard) was added, filtered and made to 100 ml solution with ultra-pure water. Trace and rare earth element concentrations were measured on Inductively Coupled Plasma- Mass Spectrometer (Thermo X Series

II). International reference material (JR-1) duplicates and blanks were also prepared in a similar way. Accuracy of the data was ~5%. For the sake of comparison, we also studied the composition of two artificial pumice blocks (AM-111, AM-222) purchased from the market. This product is imported and marketed by Tri-Star Products Pvt. Ltd, Noida, Uttar Pradesh.

Results

Pumice collected from beaches can be categorized under two size classes. One is of large dimension (samples VD-1, VD-2 and VD-3) and other is of comparatively smaller size (samples AM-1 to 9). In general, their size varies between 4.3 cm to 32 cm (Fig. 2). Their colour varies from light brown, reddish brown and grey, and the clasts exhibit different shapes. Two artificial industrial pumice of white and sky blue colour and a sample (photo) of foam glass⁹ are also shown (Fig. 3). Judging from their physical features, color, shape, density and external morphology, the clasts collected from beaches have all characteristics of natural pumice.



Fig. 2. Pumice-like clasts of different size, shape and colour, collected from beaches off Goa and Karnataka.

The chemical composition of six beach pumice analysed by XRF is presented in Table 1. The fragments exhibit very wide variation in the contents of SiO₂ (69% to 93%), Na₂O (0.2% to 13%), Al₂O₃ (0.08% to 6.8%), K₂O (0.1% to 2.3%), Fe₂O₃ (0.3% to 6.3%), MgO (0.3% to 3.8%) and CaO (0.5% to 5.9%). Such large differences in elemental composition is not expected in natural pumice clasts originating /erupted from an explosive volcano. Total REE content varies considerably from 32 ppm to 422 ppm.



Fig. 3. Samples of artificial pumice available in the market (top); photograph of foam glass from Foamit® report (www.uusioaines.com) (bottom).

Discussion

During the preparation of beads for XRF analysis, these samples had to be heated up to 900°C. It was found that there was release of strong gas, smelling like hydrogen, which

possibly indicates presence of some organic material. Powdered pumice was treated with HCl to remove carbonate content; however, a formation of thick gel like material was observed. This phenomenon probably shows presence of some synthetic material within vesicles. Later, the gel like material was dissolved by treating with hot nitric acid on a hot plate.

Table 1 displays a comparison of elemental composition of pumice samples analyzed with that of pumice from 1883-Krakatau volcanic deposits and Youngest Toba Tuff (YTT) and composition of foam glass published earlier¹⁰⁻¹¹. Even though, 1883-Krakatau and Youngest Toba Tuff of ~74 ka old are of different origin, they do not exhibit very large variations in their elemental composition (Table 1). Mean chemical composition of the beach pumice from the study area is significantly different from that of 1883-Krakatau and Youngest Toba tuff pumice. Published work shows that natural pumice, although comes from a different provenance, displays a consistent chemical composition⁷. A natural source of pumice studied is doubtful.

The composition of these pumices clasts is compared with the cement and iron slag/waste from industries. Cement slag has a very high content of CaO (45%), SiO₂ (33%) and low MgO (6%) and is a uniform product¹². Similarly, cement clinker, associated with cement factories, consists of CaO (67%), SiO₂ (22%) and Al₂O₃ (5%). Further, steel slag also has high content of CaO (40-52%), Fe₂O₃ (20-30%), low SiO₂ (10-19%), and MgO (5-10%)¹². The composition of pumice studied neither correlates with cement nor with steel slag. Therefore, pumice clasts as a slag is ruled out.

Average composition of these samples is compared with artificial pumice available in the market as well as foam glass used by the industries (Table 1). Artificial pumice is a mixture of sand, cement, lime and plaster (personal communication from Tri-Star Products Pvt. Ltd., Uttar Pradesh). Mean composition of beach pumice analysed shows that the elements such as Al, Fe, Mn, Mg, Na and K are some what closer to artificial pumice but not similar (Table 1). However, Si

Table 1. Whole rock analysis (moisture free basis) of pumice from beaches of Goa (AM 1, 4, 6, 9) and Karnataka (VK 2, 3). Comparison of average chemical composition of pumice: (1) Clasts from the beaches of Goa and Karnataka (n=6); (2) Artificial pumice (n=2); (3) 1883-Krakatau pumice⁷ (n=2), (4) Young Toba Tuff pumice⁷ (n=5), (5) Glass material used in the foam glass manufacturing¹³, (6) Foam glass¹². nd - no data available, *total Fe.

Oxides (wt %)	VK-2	VK-3	AM-1	AM-4	AM-6	AM-9	1	2	3	4	5	6
SiO ₂	69.50	72.62	73.76	80.3	90.71	93.56	80.10	69.30	69.70	75.40	72.30	66-72
Al ₂ O ₃	6.81	3.45	1.82	1.46	1.22	0.84	2.60	2.62	15.60	14.60	1.77	2-5
TiO ₂	0.04	0.08	0.16	0.16	0.55	1.92	0.48	0.09	0.58	0.27	0.06	nd
*Fe ₂ O ₃	0.30	0.53	0.54	0.27	6.35	2.54	1.75	1.17	3.70	1.93	0.27	0.01-3
MnO	0.01	0.01	0.01	0.01	0.02	0.05	0.02	0.02	0.14	0.09	0.01	nd
MgO	3.08	3.20	3.73	3.80	0.34	0.35	2.42	1.97	0.81	0.36	2.77	nd
CaO	5.08	5.81	5.94	3.49	0.48	0.45	3.54	17.10	2.40	1.81	8.67	5.5-11
Na ₂ O	12.78	13.33	13.5	10.45	0.19	0.17	8.40	7.04	4.49	3.70	13.30	12-15
K ₂ O	2.34	0.94	0.51	0.08	0.12	0.10	0.68	1.12	2.51	2.59	0.48	12-15
P ₂ O ₅	0.05	0.60	0.03	0.03	0.03	0.03	0.13	0.04	0.07	0.04	0.05	nd

and Ca content of beach pumice are higher compared to artificial pumice probably due to the addition of variable amount of sand and lime. Similar to natural pumice, there exist foam glass which is manufactured from waste glass and using mixture of water glass and glycerin as foaming agent¹¹. Foam glass that is produced from waste glass consists of SiO₂ (72.3%), Al₂O₃ (1.8%) and CaO (8.7%)¹⁰, whereas typical composition of foam glass is SiO₂ (66-72%), Al₂O₃ (2-5%) and CaO (5-11%)¹¹. In brief the beach pumice clast analysed in this study are comparable to foam glass rather than natural pumice of 1883-Krakatau and Youngest Toba Tuff origin (Table 1).

The total rare earth elements (REE) content of these pumice shows large variation ranging from 32 ppm to 422 ppm (Table 2) with an average of 99 ppm (n=8). Among the 8 samples analysed, one sample (VK-2) has the highest total REE of 422 ppm and rest of the seven pumices, the average is 52 ppm. The chondrite-normalized REE pattern (Fig. 4) shows a strong positive Ce-anomaly. The chondrite-normalized REE pattern of 1883-Krakatau and YTT pumice showed enrichment of light REE compared to heavy REE with a negative Eu-anomaly, while heavy REE

remains almost constant⁷. Beach clasts and artificial pumice chondrite-normalized REE

Table 2. Average REE concentration (ppm) of pumice clasts from Goa and Karnataka beach (1), artificial/ industrial pumice (2), 1883-Krakatau pumice⁷ (3) and Pumice of Youngest Toba Tuff from Central Indian Ocean Basin⁷(4). n is number of samples analysed.

REE (ppm)	1 (n=8)	2 (n=2)	3 (n=4)	4 (n=11)
La	4.70	5.96	11.26	23.00
Ce	85.00	116.50	22.29	44.53
Pr	0.92	1.27	2.82	4.97
Nd	3.81	5.40	12.72	21.25
Sm	1.28	1.05	3.11	5.12
Eu	0.52	0.26	0.62	0.89
Gd	0.57	0.76	2.98	4.68
Tb	0.10	0.13	0.58	0.86
Dy	0.53	0.64	3.94	5.67
Ho	0.10	0.11	1.92	1.36
Er	0.33	0.37	2.60	3.62
Tm	0.06	0.06	0.39	0.53
Yb	0.41	0.39	2.71	3.59
Lu	0.07	0.06	0.44	0.57

pattern are similar to each other with a strong positive Ce-anomaly but without any negative Eu-anomaly (Fig. 4). Natural pumice has a distinct negative Eu-anomaly which is not found in these pumice as well as artificial pumice. Therefore, presence of unusual strong positive Ce-anomaly and absence of any Eu-anomaly in the beach pumice further suggest that they are not natural geological pumice.

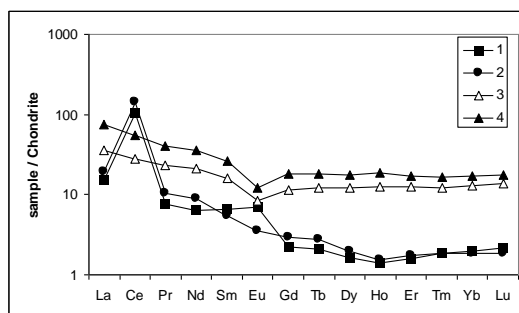


Fig. 4. Chondrite-normalized REE pattern of (1) beach pumice (present study) , (2) artificial pumice, (3) 1883-Krakatau eruption pumice⁷, and (4) YTT⁷.

Based on major element oxide data, supplemented by rare earth elemental data, and physical appearance it appears that composition of the beach pumice is similar to and comparable with the foam glass or artificial pumice rather than the natural pumice of 1883-Krakatau or Youngest Toba Tuff. These findings suggest that the source of pumice like clasts analyzed is other than volcanic activity.

On a ternary diagram (SiO_2 - Al_2O_3 - CaO), the samples analysed seem to plot with fly ash¹³. However, these fragments are consolidated, but light in weight. As such, these samples correspond to some sort of highly vitreous material, with SiO_2 (av. 80%, $n=6$) as the most dominant component. Foam glass is the most likely comparable material.

In India, there are around 43 glass factories listed. Among them, only two major ones are located along the west coast of India. Glass industries produce 22 MT of waste every year; of this, 15 MT is disposed as waste. Silica waste contains 85% of SiO_2 ¹⁴. We need to note that although the waste glass is reused, it

appears that no foam glass is produced in India. However, a major ship breaking yard along the coast of Gujarat generates a large quantity of waste, a part of which finds its way into the sea. Of the total waste generated at Alang, non combustible material such as glass and ceramics constitute 14-21% (ref 15).

It is pertinent to note that: (1) that pumice clasts were scattered along a length of more than 200 km of coast, (2) that these chunks were seen strewn all over the upper beaches during years 1999 – 2002, and (3) that this material is no longer observed during recent years. This observation obviously implies that a voluminous amount of material was produced or discharged from a particular source only at a particular time. It is suspected that the pumice like material could be a waste product (such as foam glass) of a silica based industry that found its way towards the sea.

To summarise, it is known that foam glass is used as an insulation material in the refrigeration industry, and is commonly used in ships and containers. Most likely option is that the pumiceous clasts originated from the shipping industry. At Alang, the scrapped material is dumped along the coast without proper treatment. Moreover, the waste is carried by tides into the intertidal zone and the possibility of the light debris entering into the marine environment cannot be ruled out¹⁵. Monsoon wind driven waves (coupled with the southerly littoral drift) throw a large amount of drift wood and plastics onto the beaches, a process that explains the presence of the light vitreous material investigated in this study.

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