Mineralogical and Chemical Characterization of Acidic Pumices Outcrop North of Lake Van

Aysegul Yucel 1, Tugba Efe 2, Mehmet Onal 1, Tolga Depci 1, Harun Aydin 2
1 Department of Mining Engineering, Inonu University, Malatya, Turkey
2 Department of Geological Engineering, Yuzuncu Yil University, Malatya, Turkey
E-mail: ayyucel2003@gmail.com

Abstract. In the present study, mineralogical, physical and chemical characteristics of the pumice located in North of Lake Van locations were investigated to find an applicability of them for cement and textile industry. Characterization studies of the pumice samples were carried out by thin section, SEM, XRF, XRD and FTIR analysis. In addition, the bulk density, Hard Grove Index (HGI), pozzolanic activity and reactive silica of the pumice samples were determined. The overall results showed that the pumice samples, which might be an eruption product of Mount Süphan, had an amorphous structure and rhyolite composition in high calc-alkaline series. The chemical compositions and physical properties indicated that the pumice samples could be used in cement and textile industry.

1. Introduction
Pumice is a volcanic origin rock formed during explosive eruptions. It has a highly porous structure which is formed by dissolved gases precipitated during the cooling as the lava hurtles through the air. Generally, it has not a crystalline structure and SiO$_2$ and Al$_2$O$_3$ constitute major contents of pumice [1, 2]. Pumice has been used in many application areas such as in the chemical dental, cosmetics, abrasives, cement, ceramic, and glass industries [3, 4]. It is widely being used in the cement industry as substitutes for Portland cement [5, 6].

It is estimated that 68% of the pumice reserves of the world is in Turkey. 56% of pumice reserves in Turkey extend on large surface area in the East Anatolia Region which is one of the most important volcanic areas of Turkey [7] depending on the recent volcanic activities. In the present study, mineralogical, physical and chemical characteristics of the pumice located in North of Lake Van locations (pyroclastic deposits) were presented. In addition, their potential application possibilities were evaluated for cement and textile industry.

2. Materials and methods
2.1. Sampling and sample preparation
In the study area, eight various locations were determined (figure 1) and more than 50 kg of pumice samples were collected from each location. The sampling locations were named in terms of the nearest village name. The samples were crushed and ground to reduce their size to -200 mesh (74µm) for mineralogical and chemical analysis. 5 hand samples which were chosen from each location were prepared for thin section studies.
Figure 1. Location and sampling map of study area

2.2. Characterization of pumice samples
The pumice samples were characterized using different methods and equipments: LEICA Polarize
Microscope for petrographical characterization, LeO EVO 40 scanning electron microscope for
morphological investigation, XRF Spectra IQ for elemental composition, X-ray Powder Diffraction
for chemical analysis, Perkin Elmer Spectrum One for determination of vibrational modes of
functional groups, Hardgrove Grindability for the grindability.

In addition, pozzolanic activities and reactive silica contents of the acidic pumices were determined
according to Turkish TS standards (TS25 1975).

3. Results and discussions
3.1. Characterization studies
The thin sections, which were randomly selected from the images and place which was given in figure
1, are given in figure 2. Thin section studies revealed that the pumice samples are rhyolitic and have
vitrophyric-porphyritic and from time to time glomera-porphyritic textures.

Thin section photos indicated light brownish grey and medium light grey, mottled with pinkish
gray spherulites. The main characteristic of the acidic pumice under microscope were independent
pores with different shape, size and geometry. Besides, these pores are covered and protected by
glassy membrane.
Some of SEM images of the pumice samples are given in figure 3, indicating the irregular morphology, non-uniform plate shape and glassy form (amorphous structure). Especially, tubing pore structure parallel to elongate pores was observed. This type of pumice structure points out the pyroclastic flow deposit and formed due to explosive silicic eruptions.

The results of chemical analysis of pumice samples are given in Table 1. In addition, the chemical composition of the rhyolite sample which was determined by Yilmaz et. al. (1998), named SUY5, was also given in Table 1 in order to estimate and give a decision about sources of the pumice samples. The chemical analysis indicated that SiO₂ and Al₂O₃ were major contents in all pumice samples which could be classified as the acidic pumice and had high purity [1, 2]. In addition, according to total-Alkali-SiO₂ diagram, AFM diagram and K₂O–SiO₂ diagram (not given in the text), all the pumice samples had rhyolite composition and were in high calc-alkaline series. This result is very compatible with literature data [1]. Comparison of the chemical composition of the samples with the SUY5 proved that all the pumice samples evaluated in the present study might be eruption product of Mount Süphan. However, further studies should be performed to clarify the source location of the eruption. X-ray diffraction patterns (not given in the text) indicated that all pumice samples had not a crystalline structure and very broad reflection (peak) between 20° and 30° (2θ) which was confirmed the presence of amorphous quartz [2]. Briefly, main structure is amorphous confirming the characteristic properties of the acidic pumices.
Table 1. Elemental analysis of the pumice samples

| Sample | DMD | MSN | GTP | KPN | UNC | KOC | HEY | MOL | SUY |
|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| SiO₂   | 75.49 | 75.23 | 72.81 | 72.05 | 74.49 | 75.62 | 75.62 | 71.49 | 75.09 |
| TiO₂   | 0.1 | 0.11 | 0.2 | 0.34 | 0.37 | 0.12 | 0.17 | 0.5 | 0.05 |
| Al₂O₃  | 13.99 | 14.04 | 15.97 | 15.14 | 14.36 | 13.45 | 13.7 | 12.68 | 13.75 |
| Fe₂O₃  | 1.66 | 1.95 | 2.73 | 3.91 | 3.05 | 1.96 | 2.48 | 5.50 | - |
| MgO    | 0.34 | 0.22 | 0.3 | 0.31 | 0.4 | 0.42 | 0.1 | 0.64 | 0.59 |
| CaO    | 0.52 | 0.52 | 0.69 | 1.25 | 0.74 | 0.49 | 1.03 | 2.01 | 0.59 |
| Na₂O   | 4.71 | 5.05 | 4.23 | 4.23 | 4.31 | 5.24 | 4.15 | 4.02 | 4.58 |
| K₂O    | 0.04 | 0.03 | 0.06 | 0.12 | 0.05 | 0.03 | 0.02 | 0.03 | 0.03 |

In the IR spectrum (one of them was given in text in figure 4), the strong band was observed in the frequency range of 1000–1040 cm⁻¹ attributed to Si – O- Al bonds. The weaker bands in the region 780–790 cm⁻¹ are attributed to Si – O bending strength vibrations of amorphous quartz [8]. The results were confirmed by the XRF and XRD results.

![IR spectrum of the acidic pumice (GTP)](image)

Figure 4. IR spectrum of the acidic pumice (GTP)

The bulk density, Grind ability index, pozzolanic activity and reactive silica contents of the acidic pumices are given in Table 2. The values of bulk densities pozzolanic activities and reactive indexes of the pumice samples were very close with each other. Since, the chemical analysis showed that all pumice samples had nearly same chemical compositions. HGI values of the pumice samples were greater than 50, showing that all pumice samples were soft rock as expected. Pozzolonic activity and reactive index indicated the high silica content.
Table 2. The values of bulk density, Hard Grove Index (HGI), Pozzolanic activity and reactive silica of the pumice samples

| Sample Name | Bulk Density g/cm³ | Hard Grove Index (HGI) | Pozzolanic Activity (kgf/cm²) | Reactive Index |
|-------------|-------------------|-----------------------|-----------------------------|---------------|
| GTP         | 0.36              | 116.53                | 138                         | 58.90         |
| UNC         | 0.39              | 112.10                | 130                         | 54.6          |
| MOL         | 0.40              | 111.70                | 138                         | 34.20         |
| DMD         | 0.39              | 109.60                | 123                         | 61.54         |
| KPN         | 0.40              | 101.06                | 124                         | 55.67         |
| MSN         | 0.36              | 102.12                | 125                         | 57.65         |
| KOC         | 0.35              | 99.90                 | 113                         | 61.79         |
| HEY         | 0.40              | 97.77                 | 110                         | 52.82         |

3.2. Determination of their potential applications areas

In the study area, the total proven and probable pumice reserve is approximately 160,575,000 m³ (M.T.A. 1990). In the present study, the mineralogical and chemical compositions of the acidic pumices were evaluated especially to be used for cement and textile industry. Thin section and SEM images (figure 2 and figure 3) indicated that the pumice samples were mainly composed of volcanic glass. A good pozzolan for cement industry should contain high amount of zeolite minerals and volcanic glass. In addition, the acidic pumice samples contained independent pores with different shape, size and geometry which were covered and protected by glassy membrane. Literature survey shows that these type pores are an advantage in terms of heat and sound insulation in the construction sector [1]. The elemental analysis of the samples indicated that SiO₂ + Al₂O₃ + Fe₂O₃ contents of all pumice samples were in the range of 80 to 95 percent whose ratio is greater than 70%, and SO₃ content was lower than 0.1 %. According to ASTM C 618-08a, the pozzolans having this chemical composition can be classified “N” type and possesses pozzolanic and cementitious properties to use concrete industry. The pumice samples might be also used as a substitute for Portland cement due to the low ratio of Fe₂O₃, high ratio of Al₂O₃. Besides, according to TS EN 25 (1975), the pumice samples satisfied the TS 25 requirements (in Table 3) were suitable to use in cement industry. In addition, pozzolanic activity is one of the most important factors to be used the pozzolan as a substitute material for Portland cement. Pozzolanic activity represents the reactivity capacity with Ca(OH)₂ [9]. Pozzolanic activity of all pumice samples were in the range of 110 kgf/cm² (10.79 MPa) to 138 kgf/cm² (13.5 MPa) whose ratio is greater than 40.79 kgf/cm² (4.0 MPa), indicating that the pumice samples had good pozzolanic activity.

Table 3. Comparative study of chemical properties of the pumice samples according to TS 25 standard

| Chemical Properties | TS 25 Standard By mass % | The pumice samples By mass % |
|---------------------|---------------------------|------------------------------|
| SiO₂ + Al₂O₃ + Fe₂O₃| ≥ 70.0                    | 86.04 – 91.08               |
| MgO                 | < 5.0                     | 0.1 – 0.64                  |
| SO₃                 | < 3.0                     | < 0.2                       |
| Reactive silica     | > 25                      | 34.20 – 61.54               |
| Cl                  | < 0.1                     | < 0.04                      |

There is no Turkish national standard which is published for usability of pumice stone in textile industry. Pumice stone should be the same quality, minimum 3x4x5 cm dimension and its colour should be white. Al₂O₃, Na₂O + K₂O, Fe₂O₃, CaO, MgO and SO₃ contents should be lower than 18%, 8%, 2%, 5%, 2% and 0.5% respectively. SiO₂ content should be greater than 65% [1]. This shows that the pumice samples might be also used in textile industry.
4. Conclusions
The overall results showed that the evaluated pumice samples in the present study could be classified as highly pure acidic pumice with an amorphous structure and had a rhyolite composition in high calc-alkaline series. It might be estimated that they were an eruption product of Süphan. The chemical compositions and physical properties indicated that the pumice samples could be used in cement and textile industry.

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