

A preliminary report of the tephrochronological study of the eruptive history of Coatepeque Caldera, El Salvador, Central America

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1. Introduction

A "caldera" is a volcano formed by gigantic eruptions and has the potential to eject voluminous pyroclastic flow into the neighboring areas and to disperse volcanic ash broadly to the downwind side of the volcano, which would destroy or severely affect human life. For the purpose of predicting the next eruption and mitigating volcanic risk, it is essential that a detailed eruptive history should be demonstrated. Volcanic ash, or pyroclastic deposit produced in previous volcanic eruption, which is called 'tephra', is a geological indicator of past eruption, and various data in tephra studies, such as stratigraphy, depositional date, and dispersal area of tephra, are valuable for detection of every eruption and for reconstruction of a detailed eruptive history.

Coatepeque Caldera is one of five large calderas in the northern part of Central America and located 40 km westerly southwest of San Salvador City, the capital of the Republic of El Salvador (fig. 1). Ten million residents in the western part of El Salvador, the southern part of Guatemala, and their neighboring areas are exposed to remarkable risk by gigantic eruption, because prevailing winds in the area tend to carry volcanic ash to the west.

Three tephra have been already described in previous works, and another tephra younger than the three was recently suggested. Their distributions in El Salvador have also been illustrated. The fourth eruption, however, has not been supported with petrological and geochemical analyses, and the distribution of the four tephra outside of El Salvador remains unknown. This study aims at presenting analytical data to support the existence of the fourth eruption of Coatepeque Caldera and to illustrate the distribution of the tephra in Guatemala City for more than 150 km away from the volcano to the northwest.

2. Previous works

Coatepeque Caldera (Lat. 13.87N, Long. 89.55W; Newhall & Dzurisin, 1958) is a large caldera volcano (11.5 x 6.5 km). The inside of the caldera is filled with water and the altitude of the surface of the lake is ca. 750 m above sea level. The top of the caldera rim lies about 300 m higher than the lake level, and the caldera rim is lower on the northeast side. Santa Ana - Izalco volcanic complex is located to the west of Coatepeque Caldera. The doubly elliptical landform of the caldera enables us to assume several gigantic eruptions in the past. Three pumice-flow deposits and associated pumice-fall deposits have been described as Bellavista, Arce and Congo, from the older to the younger (CEL, 1992; Pullinger, 1998). Although the Bellavista tephra is restricted to the area nearest the caldera, the latter two tephra are broadly dispersed. The depositional dates of

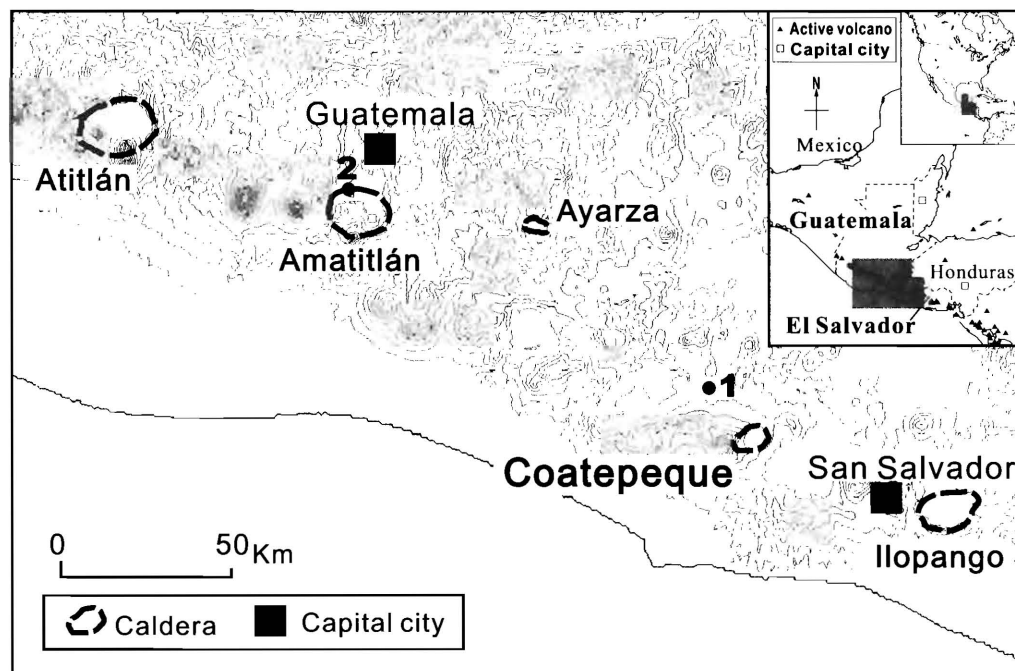


Fig. 1 Location map of five calderas and sampling sites.

the Bellavista, the Arce and the Congo tephras are determined to be 77 ka, 72 ka and 56.9 ka, respectively, by highly precise $^{40}\text{Ar}/^{39}\text{Ar}$ and highly sensitive ^{14}C dating methods (Rose, et al., 1999). Another pumice-fall deposit above the Congo tephra, called Atiquizaya, has recently been reported and suggested to be derived from Coatepeque Caldera (Kitamura, 2006). The Atiquizaya pumice-fall deposit is not presumed to be much younger than the Congo pumice because of their close stratigraphic positions, although its radiometric age remains uncertain.

Three tephras except the Bellavista tephra are presumably distributed in the territory of the Republic of Guatemala over the border. In the area around Guatemala City, 150 km far from Coatepeque Caldera, two distinct volcanic ash-fall deposits are commonly observed. The underlying tephra has been called the A1 tephra and the overlying one, the A2 tephra. They are intercalated among the brown volcanic ash soils deposited between two pumice-fall deposits, which are the C tephra, in the lower, and the E tephra, in the upper. Although the two volcanic ash layers have been described since Koch and McLean (1975), their origins and depositional dates remain uncertain. Both of them are finely grained white vitric ash, and their features are suggestive to be distal facies of pumice-fall deposits produced by gigantic eruption of caldera. They are younger than 84 ka and older than 24 ka because of the depositional dates of the underlying H tephra and the overlying B tephra.

3. Sampling sites

Around the Chalchuapa City located 10 km northwest of Coatepeque Caldera, the Arce, the Congo and the Atiquizaya tephras are commonly observed. The samples of their tephras are obtained at an exposure located 5 km northeast of Chalchuapa City, El Salvador (location 1 shown in figs.

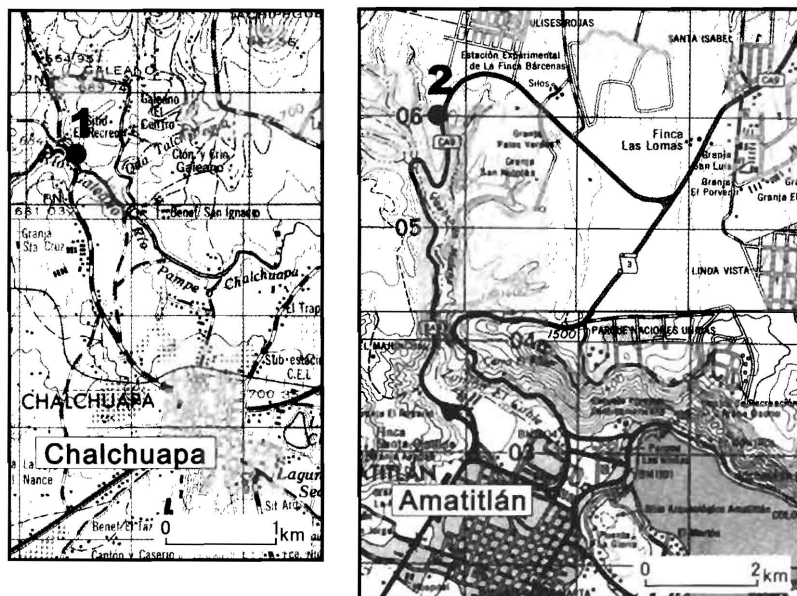


Fig.2 Location of sampling site.

Solid circle on each map shows the location of sampling site, and number associated with the solid circle corresponds to the location number in fig. 1 and the column number in fig. 3. The left map contains two topographic maps on a scale of 1:25,000, "Chalchuapa" and "El Provenir", published by the Instituto Geografico Nacional de El Salvador, and the right contains two topographic maps on a scale of 1:50,000, "Ciudad de Guatemala" and "Amatitlan" published by Instituto Geografico Nacional de Guatemala.

1 and 2). At this site, the Arce tephra is thickly bedded coarse pumice which intercalates a distinct vitric ash layer. The Congo tephra is stratified white coarse pumice and ash, or poorly sorted pumiceous ash layer where it has been disturbed. The Atiquizaya tephra is a massive layer consisting of white coarse pumice and underlain by a thinly bedded pinkish fine ash, probably originating from another volcano far from Chalchuapa City (fig. 3).

The A1 and the A2 tephtras are commonly observed in Guatemala City and the surrounding area, as mentioned above, and sampled at another exposure located 3.5 km north of Amatitlan City, Guatemala (location 2 shown in figs. 1 and 2). At this site, both of them are thinly bedded vitric ash-fall deposits. The A1 tephra is deposited above a coarse yellowish white pumice called the C tephra while brown volcanic ash soil is intercalated between them. The A2 tephra is underlain by brown volcanic ash soil and several scoria layers, which are probably ejected from Agua Volcano, above the A1 tephra. Above the A2 tephra, brown volcanic ash soil and several scoria layers are observed overlain by another coarse yellowish white pumice called the E tephra (fig. 3).

4. Results of analyses

Volcanic glass and minerals were isolated from vitric ash or crushed pumice by supersonic washing and sieving. Mineral assemblage was illustrated by microscopic observation. Chemical composition of volcanic glass was analyzed quantitatively with a wave-length-dispersive electron

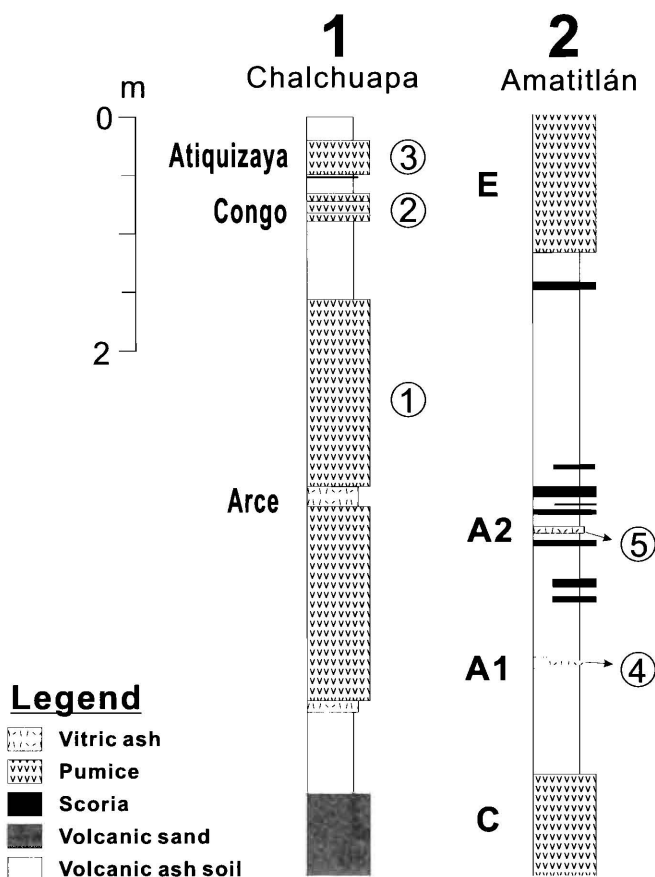


Fig. 3 Tephra stratigraphy at sampling sites

The sampling level is shown by the number with circle at the right of columns. The number above column corresponds to the location number in fig. 1 and fig. 2.

microprobe (JEOL JAX-8800RL) in the Department of Earth and Environmental Science, Hirosaki University. For analyses, 30 glass shards of each sample were randomly selected. Beam currents of 3×10^{-9} A and beam diameters of $10 \mu\text{m}$ were used at an accelerating voltage of 15 kV. Oxide percentage were renormalized to 100% and averaged with calculating standard deviation, after the removal of obvious anomalous results from the 30 analyses (table 1 and fig. 4).

The microscopic observation indicates that the Arce pumice contains biotite and hornblende, and the Congo pumice is rich in hornblende and orthopyroxene, containing a small amount of clinopyroxene. The Atiquizaya pumice contains hornblende and orthopyroxene, which is similar to the Congo pumice. It also illustrates that the A1 ash contains biotite and hornblende, and that the A2 ash is rich in hornblende and orthopyroxene. These results are mostly coincident with the data reported in Koch and McLean (1975), Pullinger (1998) and Kitamura (2006).

Chemical compositions of all samples in this study are similar to one another in the characteristics of chemical composition (table 1 and fig. 4). The further detailed interpretation of the chemical data, however, suggests that they can be divided into two groups. The first group consists of the Arce pumice and the A1 ash, while the second group consists of the Congo pumice, the Atiquizaya

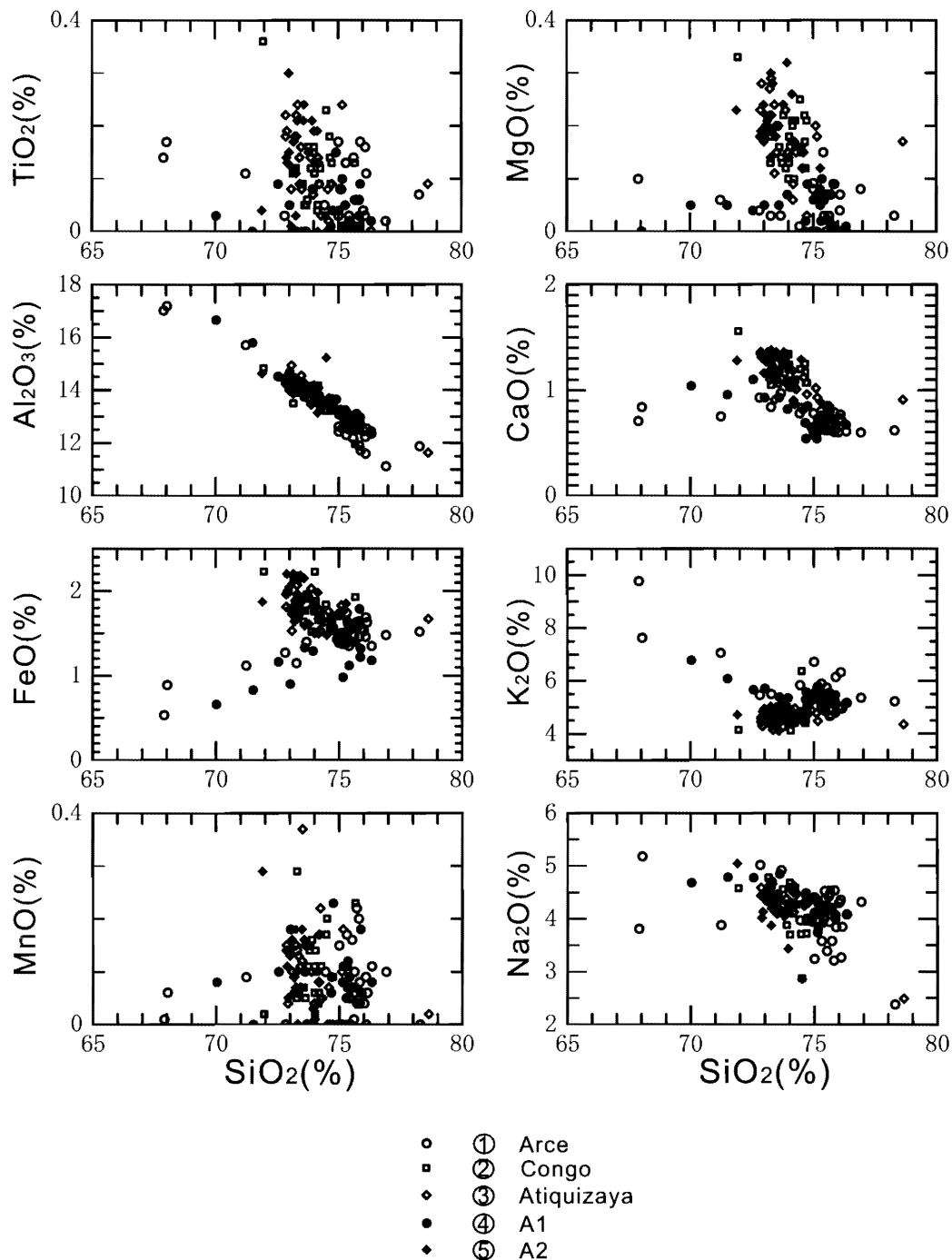


Fig.4 Harker diagram of analyzed samples

pumice and the A2 ash. SiO_2 and K_2O ratios of the first group are slightly higher and Al_2O_3 , FeO and CaO are slightly lower than the second group. The dispersal ranges of SiO_2 , Al_2O_3 and K_2O of the first are larger than those of the second. While MgO of the first is depleted, the second contains a small amount of MgO .

Table 1 Chemical composition of analyzed samples

Location	Sample No.	Tephra		SiO ₂ (%)	TiO ₂ (%)	Al ₂ O ₃ (%)	FeO (%)	MnO (%)	MgO (%)	CaO (%)	K ₂ O (%)	Na ₂ O (%)	Total (%)	Quantity of analysis
1 (Chalchuapa)	①	Arce	Average	74.8	0.1	13.1	1.4	0.1	0.0	0.7	5.7	4.1	100.0	27
			Std.dev.	2.4	0.1	1.5	0.3	0.1	0.0	0.1	1.1	0.6		
	②	Congo	Average	74.0	0.1	13.7	1.8	0.1	0.2	1.1	4.7	4.2	100.0	26
			Std.dev.	0.7	0.1	0.5	0.2	0.1	0.1	0.2	0.4	0.4		
	③	Atiquizaya	Average	74.0	0.1	13.8	1.8	0.1	0.2	1.1	4.6	4.3	100.0	23
			Std.dev.	1.2	0.1	0.7	0.2	0.1	0.1	0.2	0.2	0.4		
2 (Amatitlan)	④	A1	Average	74.3	0.0	13.7	1.3	0.1	0.0	0.7	5.6	4.3	100.0	26
			Std.dev.	2.4	0.0	1.5	0.3	0.1	0.0	0.2	0.9	0.4		
	⑤	A2	Average	73.5	0.1	14.1	1.8	0.1	0.2	1.2	4.7	4.2	100.0	25
			Std.dev.	0.7	0.1	0.5	0.2	0.1	0.0	0.1	0.2	0.4		

5. Conclusion and perspective

Chemical analyses in this study suggest that the Atiquizaya tephra is quite similar to the Congo tephra, and is assumed to originate from Coatepeque Caldera.

Mineral assemblage and chemical composition illustrated in this study indicate that the A1 tephra should be correlative to the Arce tephra because of their similarity. On the other hand, the A2 tephra should be correlative to either of the Congo pumice-fall deposit or the Atiquizaya pumice-fall deposit. Accordingly, the A1 and the A2 tephras are assumed to be distal ashes dispersed broadly for more than 150 km by the gigantic eruptions of Coatepeque Caldera in the past.

In order to confirm them, further investigation and analysis of pumice-flow deposits corresponding to the Arce, the Congo and the Atiquizaya tephras are necessary. Further analyses of the A1 and the A2 tephras in other locations are also available. It is most successful for correlation if the three tephras could be purchased in the field from the territory of El Salvador to Guatemala.

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