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## PRELIMINARY CHEMICAL AND PETROGRAPHIC RESULTS OF THE MARCH-APRIL "EL CHICHON" VOLCANICS

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### RESUMEN

Se efectuaron análisis químicos y petrográficos de tres muestras de los productos de la erupción del volcán "El Chichón" (marzo-abril 1982). Los análisis químicos muestran que se trata de magma de composición andesítica con un alto contenido de gases. El análisis petrográfico reveló la presencia de anhidrita en dos de las muestras, lo cual es interpretado como resultado de la contaminación con aguas sulfurosas y evaporitas observadas en la zona. Los resultados obtenidos pueden indicar la existencia de una cámara magmática muy superficial. Con base en los análisis de componentes solubles en agua, se calculó la masa total de éstos en aproximadamente  $31.8 \times 10^6$  Ton, para una masa total de los productos de  $0.5 \text{ km}^3$ .

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## ABSTRACT

Chemical and petrographic analyses were done for three samples of the products of "El Chichón", March-April eruption. Chemical analyses yield an andesitic composition for the magma with a high gas-content. Petrographic analyses show anhydrite in two of the samples, this is interpreted as a result of contamination with sulphur waters and evaporites, observed in the area. Obtained results may indicate a very shallow magma chamber. The total mass of the water soluble components ejected was calculated to be of the order of  $31.8 \times 10^6$  Ton., assuming a total mass of the ejecta of  $0.5 \text{ km}^3$ .

## INTRODUCTION

Chichon volcano ( $17^{\circ}21.6'N$  and  $93^{\circ}13.8'W$ ) began a period of activity on March 28th of this year (Fig. 1). Before this, "El Chichón" did not have any reported historical eruption, and presented only sulfataric activity. Therefore the existing data on the composition and another characteristics of the volcano are uncertain; there are some reports, in which "El Chichón" is classified as an andesitic strato volcano (Mooser, 1959), whereas other authors (Damon and Montesinos, 1974) suggest a dacitic composition.

"El Chichón" is situated between the Mexican and the Central American volcanic belts, at a distance of 170 km from the Pacific Coast of Mexico (Fig. 1). According to the results of Hanuš and Vaněk (1978), the Benioff zone is located at a depth of 160-180 km under the volcano.

According to geological studies (López, 1975), most of them carried out for oil-prospecting purposes, sedimentary rocks are the most characteristic for this area. In the geologic profiles, the limestone, sandstone and shale layers are shown to a depth of more than 5-6 km, and the presence of evaporites was confirmed by data from boreholes of Petróleos Mexicanos at a depth of approximately 2 km (SEAN, 1982).

Hot springs were observed in the area long before the eruption, furthermore geothermal activity was so intense, that the Federal Commission of Electricity (CFE) carried out prospecting studies to evaluate the energetic potential of the field.

The region presents a very complicated tectonic setting, however, the main faults seem to be due to compressional stresses, perpendicular to the Middle-American Trench, according to the calculated focal mechanisms of earthquakes occurring in the area (Havskov *et al.*, 1982).

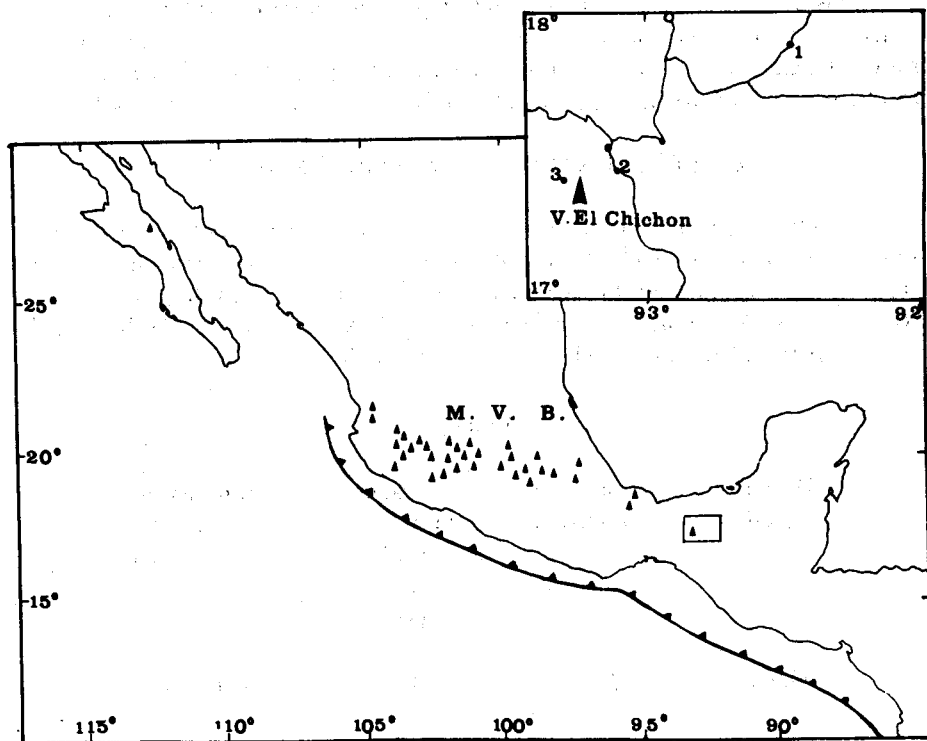
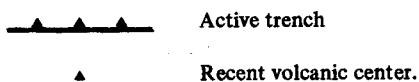


Fig. 1. Location of El Chichon volcano. M. V. B. is Mexican Volcanic Belt. Numbers 1, 2, 3 denote the sampling locations.



### *Sequence of the eruption*

On March 28th activity started at 23:37 (LT) with a pumice and fragmented material ejection, that lasted about 1 hour, and was preceded by intense seismic activity. Thereafter, several ash falls followed the first eruption and two violent explosive eruptions took place on April 3rd at 19:35 (LT) and April 4th at 5:30 (LT) with pyroclastic flows of more than 6 km length that devastated an area greater than 250 km. During the present activity, a new almost circular crater was formed inside the older one, with a diameter of about 600 m. The total volume of the ejecta was estimated of the order of 0.5 km<sup>3</sup>, and covered an area at about 37 500 km<sup>2</sup> destroying many plantations in the states of Tabasco and Chiapas, southern Mexico.

In this paper, some chemical and petrographic characteristics of the products of Chichon mentioned period of activity are reported. This study is based on the results obtained from the analysis of the samples at the laboratories of Geochemistry and Petrography of the Geological Institute of the Academy of Sciences USSR.

### METHODS, TECHNIQUES, MATERIAL STUDIED

Three samples of products of the mentioned eruption of "El Chichón" were studied. The places where the samples were collected are shown in Fig. 1 and the distance between the collection site and the crater as well as the date when the samples were erupted and collected are given in Table 1. Sample No. 1 is ash, samples No. 2 and 3 are fragments of volcanic bombs (2.5 - 3.0 cm length).

Table 1

| Date of Collection | Collection Location | Distance from the crater to the collection site (km) | Date when the sample was erupted |
|--------------------|---------------------|--|----------------------------------|
| 1 March 20         | Cd. Pemex           | 100  | March 28                         |
| 2 April 6          | Ixtacomitán         | 15   | April 4                          |
| 3 April 5          | Ostucán             | 8  | April 4                          |

#### *Chemical composition*

The samples were analysed with an emission spectrometer, that uses a high frequencies power source of inducted plasma. The samples were also analysed by traditional methods in order to determine the  $H_2O^{\pm}$ ,  $-CO_2$ ,  $C_{org}$ ,  $SO_3$  total contents (Choporov *et al.*, 1982). The results of the analyses are shown in Table 2.

For sample No. 1 (ash) the water-soluble components and total sulfur contents were determined. The  $SO_3$  concentration was determined by a separate analysis.

The determination of the content of water soluble components was done for an ash solution of 25 gr weight, using the method described in Basharina (1958), the

Table No. 2

Chemical composition of the samples (% weight)

| Component                      | Sample No. 1 | Sample No. 2 | Sample No. 3 | Relative Error(+%) |
|--------------------------------|--------------|--------------|--------------|--------------------|
| SiO <sub>2</sub>               | 59.69        | 55.58 ± 0.38 | 57.52 ± 0.80 | 0.8                |
| TiO <sub>2</sub>               | 0.53         | 0.72 ± 0.01  | 0.72 ± 0.01  | 9.0                |
| Al <sub>2</sub> O <sub>3</sub> | 17.18        | 17.64 ± 0.16 | 18.22 ± 0.01 | 3.5                |
| Fe <sub>2</sub> O <sub>3</sub> | 2.16         | 3.52 ± 0.02  | 4.71 ± 0.15  | 7.0                |
| FeO                            | 1.70         | 3.26         | 1.99         | 9.3                |
| MnO                            | 0.12         | 0.18 ± 0.01  | 0.18 ± 0.01  | 11.0               |
| MgO                            | 1.56         | 2.32 ± 0.04  | 2.30 ± 0.06  | 9.0                |
| CaO                            | 6.25         | 8.23 ± 0.02  | 8.03 ± 0.05  | 5.0                |
| P <sub>2</sub> O <sub>5</sub>  | 0.35         | 0.30 ± 0.01  | 0.28 ± 0.04  | 8.2                |
| Na <sub>2</sub> O              | 4.46         | 4.21 ± 0.08  | 4.31 ± 0.12  | 8.0                |
| K <sub>2</sub> O               | 3.86         | 2.68 ± 0.07  | 2.69 ± 0.09  | 8.0                |
| BaO                            | 0.10         | 0.08 ± 0.05  | 0.08 ± 0.01  | 21.0               |
| SrO                            | 0.06         | 0.07 ± 0.05  | 0.07 ± 0.05  | 23.0               |
| Cr <sub>2</sub> O <sub>3</sub> | 0.01         | 0.01         | 0.01         | 18.0               |
| NiO                            | 0.01         | 0.01         | 0.01         | 25.0               |
| H <sub>2</sub> O <sup>+</sup>  | 0.66         | 0.58         | 0.07         | 9.0 - 21.0         |
| H <sub>2</sub> O <sup>-</sup>  | 0.33         | 0.01         | 0.03         | 11.0 - 21.0        |
| CO <sub>2</sub>                | 0.01         | 0.01         | 0.01         | 30.0               |
| C                              | 0.01         | 0.01         | 0.01         | 27.0               |
| S                              | 0.78         | 0.55         |              | 12.0               |
| Σ                              | 99.01        | 99.90 ± 1.4  | 100.2 ± 1.45 | 1.5                |
| SO <sub>3</sub>                | 1.85         |              |              |                    |

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water volume extracted for each analysis was 125 ml and the time the distilled water was in contact with the ash for each solution sample is shown in Table 3.

Table No. 3

Chemical composition of the ash-water solutions.

| Component                     | Measur. Units | I sol.   | II sol. | III sol. | $\Sigma$ |
|-------------------------------|---------------|----------|---------|----------|----------|
| Na <sup>+</sup>               | mg - equ      | 1.35     | 0.43    | 0.14     |          |
|                               | % weight      | 0.031    | 0.010   | 0.003    | 0.044    |
| K <sup>+</sup>                | mg - equ      | 0.11     | 0.04    | 0.02     |          |
|                               | % weight      | 0.004    | 0.002   | 0.001    | 0.007    |
| Ca <sup>++</sup>              | mg - equ      | 16.15    | 12.13   | 6.13     |          |
|                               | % weight      | 0.323    | 0.243   | 0.123    | 0.689    |
| Mg <sup>++</sup>              | mg - equ      | 0.80     | 0.57    | 0.45     |          |
|                               | % weight      | 0.010    | 0.007   | 0.005    | 0.022    |
| CO <sub>3</sub> <sup>--</sup> | mg - equ      | N.D.     | N.D.    | N.D.     | N.D.     |
|                               | % weight      | N.D.     | N.D.    | N.D.     | N.D.     |
| HCO <sub>3</sub> <sup>-</sup> | mg - equ      | 0.20     | 0.10    | 0.10     |          |
|                               | % weight      | 0.012    | 0.006   | 0.006    | 0.024    |
| Cl <sup>-</sup>               | mg - equ      | 1.60     | 0.25    | 0.25     |          |
|                               | % weight      | 0.057    | 0.009   | 0.009    | 0.075    |
| SO <sub>4</sub>               | mg - equ      | 15.62    | 11.76   | 6.22     |          |
|                               | % weight      | 0.752    | 0.556   | 0.299    | 1.607    |
| Fe <sub>total</sub>           | % weight      | 0.000125 | 0.0001  | 0.00006  | 0.000285 |
| SiO <sub>2</sub>              | % weight      | 0.0045   | 0.0055  | 0.004    | 0.014    |
| dry rem.                      | % weight      | 1.265    | 0.915   | 0.470    | 2.650    |

N.D. Not detected

I sol.- 5 hours, II sol.- 15 hours, III sol.- 20 hours.

The concentration of the components was determined by different methods:  $\text{Na}^+$  and  $\text{K}^-$  - flame photometry (relative error  $\pm 8.0\%$ );  $\text{Ca}^{++}$  and  $\text{Mg}^{++}$  - complexometry (relative error  $\pm 0.5\%$ );  $\text{CO}_2$  and  $\text{HCO}_3^-$  - volumetry (rel. error  $\pm 25\%$ );  $\text{SO}_4$  (rel. error  $\pm 5\%$ );  $\text{Fe}_{\text{total}}$  and  $\text{SiO}_2$  - colorimetry (rel. error  $\pm 10\%$ ).

The results obtained show a relatively high content of ion-sulphate (1.61% of the sample total weight). The S concentration obtained (0.74% of the sample weight) corresponds exactly to the  $\text{SO}_3$  concentration (1.85%) determined for sample No. 1, and it means that there should be no other sulfur compound in the ash sample. Assuming the complete oxidation of the  $\text{SO}_3$  in the ash to  $\text{SO}_4$ , the ion-sulfate concentration should be 2.22%, whereas it was found to be 1.61%. Therefore, the results obtained gave reduced values for the water-soluble component concentration.

Nevertheless, these values may be used to estimate the total mass of the water-soluble components, that were carried to the Earth's surface by the eruption of "El Chichón". Using the values calculated for the ash density (1.2  $\text{gr}/\text{cm}^3$ ) and the total volume ejected (0.5  $\text{km}^3$ ), the total mass of water-soluble components should be greater than  $31.8 \times 10^6$  ton.

## PETROGRAPHY

Sample No. 1. Ash, composed by particles of thickness less than 0.1 mm. The particles are mainly glass, though plagioclase, hornblende and augite grains are also present, and grains of anhydrite were observed.

Sample No. 2. Pumice of andesitic composition. It is formed by vesicular glass with fragments of phenocrysts. Almost 80% of the rock is composed by glass. The pores are isometric, of dimensions not greater than 0.1 mm, with very thin 1 - 2  $\mu$  walls.

The glass has a fluid texture. Most of the phenocrysts fragments are polyzonal plagioclase that may be classified as andesine-labradorite (An 50 - An 60) by its composition. The detrital appearance of the phenocrysts may be due to abrasion. Their dimensions are up to 2 mm. Randomly distributed acid glassy inclusions are contained in the phenocrysts, as well as apatite and anhydrite-inclusions. In some cases the plagioclase grains form intergrowths with the anhydrite.

Up to 35% of the fragments of phenocrysts are hornblende pleochromatized to gray-green tones. In some grains apatite needles and hornblende intergrowths with plagioclase and anhydrite are observed.

Anhydrite forms 5-8% of the phenocrysts. It forms intergrowths with plagioclase, hornblende and also with apatite, being the latter a secondary mineral.

Augite constitutes 5% of all phenocrysts. Its grains are less than 0.5 mm. This mineral has a green color and it is not pleochroic. It may be related to some kind of high temperature pyroxene.

Sample No. 3. Andesite, 40% of this rock is composed by phenocrysts. Plagioclase is the mineral most frequently found in this sample (up to 50% of the crystal are plagioclase), it forms well defined plane crystals, of dimensions up to 3 mm.

According to their composition, they are classified as andesine-labradorite (An 50 - An 60). Some inclusions of augite and glass are observed in the plagioclase crystal, the distribution of the glass is usually zoned.

Basaltic hornblende is the second most frequent mineral among the phenocrysts (up to 30%). The longitudinal axes of its crystals are up to 3 mm in length. Inclusions of plagioclase, augite and apatite were observed in the crystals of hornblenda.

Augite constitutes 15% of the phenocrysts, it has green color and does not pleochromatize. Tridymite and apatite were found in the interstitials as secondary minerals. Plane augite microlites, with a low refraction index, are embedded in the glass.

## DISCUSSION

In order to compare the results obtained for the three samples, we had to assume that all the samples correspond to juvenil material. Nevertheless, the possibility that the andesite sample belongs to the dome can not be excluded. There are no chemical studies of rocks from the dome, but a dacitic composition has been reported (Damon and Montesinos, 1974). Taking into consideration this report and knowing that the chemical composition of sample No. 3 is andesitic, it may be assumed that it does not belong to the older activity of dacitic composition.

The main differences, found when comparing the results of the analyses of the samples, are the degree of crystalization and the composition of the inclusions; the pumice (sample No. 2) contains hornblende, whereas andesite (No. 3) contains basaltic hornblende and tridymite. The anhydrite was observed only in the vesicular rock. A wider compositional range may be seen in more widely sampled studies (Martin and Romero, 1982). Taking into account the results of the chemical and petrographic analyses, it may be concluded that the mineral composition of the samples was generated under different conditions of crystalization of the same magmatic material. In order to determine those conditions, we must consider the ex-



istence of anhydrite in the pumice sample, since it is not a common feature of minerals of magmatic origin. Anhydrite in the studied samples is observed in intergrowths with rather common minerals such as: plagioclase, hornblende and apatite.

The coincidence of the anhydrite with vesicularity (sample No. 2), and the presence of its grains in the ash (sample No. 1) imply a high gas-content of the magma. It may be proposed as an explanation, that the presence of anhydrite in the products of crystalization of the magma, might be due to magma contamination with sulfur-waters or with evaporites of marine origin, or both. The contamination with sulfur waters is assumed knowing that in the first stages of the eruption the seismic activity may be interpreted as the result of the interaction magma-ground water (Havskov *et al.*, 1982) and in the area many hot-springs with sulfur waters were observed. The evaporites, found in bore holes near the volcano, and the halite crystals found in the particles of the stratospheric cloud (SEAN, 1982 (a)) reflect evaporite contamination. In any case seismic and petrographic data imply that crystalization occurs at very shallow depths, because of contamination of primary magma with evaporites or sulfur-waters at depths not greater than 5 km.

Another explanation of the presence of anhydrite in the samples, to assume that it is the result of the oxidation of deep volcanic gases, seems unlikely. Though the relatively high concentration of  $\text{SO}_3$  in the ash does not allow to eliminate this possibility *a priori*.

The origin of the anhydrite may be explained after the determination of the isotopic composition of the sulfur contained in the samples.

## CONCLUSIONS

Based on the results presented here of the chemical and petrographic analyses of ash and rock samples of the products of the March-April eruption of the volcano "El Chichón" (Chiapas, Mex.), it may be concluded that:

- 1) The minimum mass of ejected water-soluble components is  $31.8 \times 10^6$  ton.
- 2) The basic composition of the products does not change in the three samples studied, and only the degree of crystalization varies.
- 3) The presence of grains of anhydrite in the ash in the vesicular sample implies a high gas-content of the magma.
- 4) The origin of the anhydrite observed in the samples may be explained by two different ways:

- a) The contamination of the magma by sulfur-waters and evaporites.
- b) The result of the oxidation of deep volcanic gases.

In order to know the anhydrite fraction that resulted from each mechanism further isotopical analyses of the sulfur contained in the samples will be done. The result of these analyses will elucidate the origin of the anhydrite and therewith the depth of the superficial magma chamber.

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