GEOCHEMICAL ASPECTS OF VOLCANIC ROCKS OF THE VALLEY OF MEXICO

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RESUMEN

La historia geológica del Valle de México está formada por tres periodos de actividad volcánica. En cada periodo se observa una secuencia de rocas ígneas de riodacitas hasta andesitas, faltando las riolitas y basaltos propiamente tales. En el Terciario (periodos del Oligo-mioceno y del Mioceno Superior-Plioceno), el volcanismo es más dacítico, y más andesítico en el Cuaternario. Estos resultados se verificaron calculando el término medio de todos los análisis químicos disponibles que tenían edades estratigráficas. La composición química media de los productos oligo-miocénicos, del Mioceno Superior-Plioceno, y del Cuaternario se calculó junto a las rocas ígneas correspondientes mediante la clasificación de Rittmann en el doble triángulo de Streckeisen, con los resultados siguientes:

Cuaternario: Andesita cuarzo-latítica
Mioceno Superior-Plioceno: Leucoandesita cuarzo-latítica
Oligo-Mioceno: Leucoandesita cuarzo-latítica

La similitud en la composición media de las rocas volcánicas terciarias parece confirmar la teoría de un magma andesítico primario uniforme, independientemente de las dos teorías posibles de petrogénesis. Las abundancias medias calculadas de elementos indiciales dan valores altos para Cr y Ni, lo que indica una posible intervención de materiales del manto si se considera que los productos terciarios provendrían de fusión parcial en la corteza inferior. Una hipótesis más elegante debida a Gunn y Mooser (1971) considera que estas rocas volcánicas serían productos de la fusión parcial de toleítas oceánicas o de sus derivados de alta presión.

ABSTRACT

Three periods of volcanic activity connected with tectonic events form the geological history of the Valley of Mexico. An igneous rock suite from rhyodacites to andesites can be observed in each period, lacking real rhyolites and basalts. During the Tertiary –in the

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Oligo-Miocene and Upper Miocene-Pliocene periods– volcanism is more dacitic, and in the Quaternary epoch more andesitic. This result was verified by calculating the average of all available and stratigraphical datable chemical analyses. The average chemical composition of Oligo-Miocene, Upper Miocene-Pliocene and Quaternary products was computed in addition to the corresponding igneous rocks in the classification by the Rittmann norms in the Streckeisen double triangle with the following results:

Quaternary: Quartz-latite-andesite
Upper Miocene-Pliocene: Leuco-quartz-latite-andesite
Oligo-Miocene: Leuco-quartz-latite-andesite

The similar average composition of Tertiary volcanic rocks seems to support the theory of a uniform primary andesite magma apart from the two possible theories of petrogenesis. The computed average trace element abundances show high Cr and Ni– values which speaks for an involvement of mantle material, if one considers the Tertiary products as partial melting products of the lower crust. A more elegant hypothesis seems to be the model of Gunn and Mooser (1971), who consider these volcanic rocks as partial melting products of oceanic tholeiites or their high pressure derivatives.

GENERAL GEOLOGY

The Valley of Mexico is located in the Mexican Volcanic Belt which traverses the continent from the Pacific to the Atlantic coast. The igneous rocks of this belt belong to the so called "Rio Lerma Province" (Gunn and Mooser, 1971).

The Valley of Mexico itself is a N-S trending graben structure, completely surrounded by volcanic mountain chains: in the West the Sierra de las Cruces, in the East the Sierra de Río Frío and Sierra Nevada and in the South the Sierra Chichinautzin. In the northern area the Sierra Tezontlalpan and Sierra Pachuca form the boundaries of the basin, which was filled with volcanics and lake sediments in the Quaternary.

Intensive geological investigations have yielded the following compilation including publications of Mooser (1963, 1969) and others, and my own petrographic work (Table 1).

Table 1: Geological time table of volcanic and tectonic activity in the Valley of Mexico

Period 1: Oligo-Miocene
Period 2: Upper Miocene-Pliocene
Period 3: Quaternary.

PETROLOGICAL AND GEOCHEMICAL RESULTS

Gunn and Mooser (1971) and Negendank (1972, 1973) reported about 100 analysed igneous rocks of the Valley of Mexico. Gunn and Mooser (1971) investigated these rocks especially from the viewpoint of geochemistry and petrogenesis, whereas Negendank (1972) emphasized the classification of the igneous rocks and their petrographic description (microscopic characteristics) referring to stratigraphical equal volcanics. These papers were classified in a different way by using the CJPW-and Rittmann norms.

The classification using the Rittmann norms and plotting the igneous rocks in the Streckeisen diagram (Negendank, 1972) showed in general that the volcanic products of the Tertiary periods (Oligo-Miocene and Upper Miocene-Pliocene) are dacitic whereas those of the Quaternary period are of andesitic character (Fig. 1 and 2). See also Table 2.

The second step was to compare these investigations with the results of Gunn and Mooser (1971). All available stratigraphically datable igneous rocks (82) were classified by the Rittmann norm and plotted in the Streckeisen diagram with the result that the above determined trend from dacitic (Tertiary) to andesitic (Quaternary) products was verified as we may see in figures 3 and 4.

The serial indices of all volcanics can be read in the diagram Alk vs SiO_2 by weight % (Fig. 5). With one exception all rocks possess a calcic to calcalkalic character (Calcalkaline Series).

The τ–values (= $Al_2O_3 - Na_2O)/TiO_2$ by weight) represent according to Rittmann (1967) a solid indicator for the distinction between simatic and sialic material (Sial: $\tau > 10$). In this sense we can deduce that most of the igneous rocks are products of sialic material with the exception of two samples, which may possibly show an influence of simatic material (Fig. 6).

In the log σ –log τ diagram by Rittmann (1971) and Gottini (1971) all rocks lie in field B; only two rocks approach the border to field A, which may be a similar indication of a change from sialic to simatic material (Fig. 7). In general there are no true rhyolites or basalts. The normative colour index of 40 was adopted as delimination between andesite and basalt (Fig. 8). Gunn and Mooser (1971) published one analysis of alkali rhyolitic pyroclastic rock, without giving its stratigraphic position; therefore it was not taken in consideration. But I believe it is possible that the rhyolitic parts of the volcanic activity may be concealed under pyroclastics filling the basin. It must be stated that these considerations were based on igneous rocks only (without acid or basic pyroclastics).

The average chemical composition of all stratigraphically analogous igneous rocks, and of the corresponding volcanic rocks were computed. The results are given in Table 3.

The average chemical composition of the three phases of volcanicity corresponds to the following volcanic rocks:

Quaternary: Quartz–latite–andesite
Upper Miocene-Pliocene: Leuco–quartz–latite–andesite
Oligo-Miocene: Leuco–quartz–latite–andesite

The distribution of these rocks in the Streckeisen diagram is shown in Fig. 3b. The Tertiary rocks are lying in the immediate meighbowrhod of the dacite field whereas the Quaternary rock lies in the neighborhood of the andesite/basalt field. (Middlemost: high lime dacites to andesite). The AMF–diagram (Fig. 4) gives the same trend.

In conclusion, the similar average composition of the Tertiary volcanic rocks seems to support the theory of an uniform primary *andesite magma.*

REMARKS ON PETROGENESIS

If we consider these results from the viewpoint of Rittmann (1971), Gottini (1971), Pichler and Zeil (1969), and others we can conclude that during the Tertiary and most of the Quaternary the volcanic products are derived from a primary andesitic magma which is due to partial fusion of material of the lower crust (sialic).

This argument is supported by new trace element studies of these rocks by Richter and Negendank (1975).

Another plausible model seems to be the theory of Gunn and Mooser (1971), who also assume a primary andesite magma, but who consider it to be due to partial melting of oceanic tholeiites or their high pressure derivatives in the sense of Raleigh and Lee (1969).

Finally, it should be mentioned that the oxidation states of ilmenites and titanomagnetites of 85 volcanic rocks of the Valley of Mexico were determined (Negendank, 1972), in order to look for self-reversals in connection with paleomagnetic work by Mooser and Nairn (1970) and other investigators. A megascopically striking observation is the reddening of a volcanic rock which is due to the reddening of the silicate phases surrounding the oxides corresponding to high oxidation states of ilemenite and titanomagnetite.

Table 1. Geological time table of the volcanic and tectonic activity in the Valley of Mexico.

	Fifth Group:	Pleistocene sedimentary infilling in the enclosed basin.	
Pleistocene	Chichinautzin-Group:	Andesites and olivine-andesites of the Sierra Chichinautzin enclosing the basin.	E-W fracture system
Pliocene Upper Miocene	Sierra Nevada and Sierra de las Cruces Group:	Dacites, andesites of Tlaloc Dacites, andesites of San Miguel Dacites and rhyodacites of the Sierra de Guadalupe	N-S fracture system
Oligo-Miocene	Xochtipec-Group:	Andesites of Peñon de los Baños, Sta. Isabel Dacites of Pulpito de Diablo (Sierra Nevada) Xochtipec (Sierra de las Cruces)	WNW-ESE fracture system
Lower Tertiary		Continental limestone breccia (Cretaceous) Folded pelagic Cretaceous beds	

Table 1

Table 2

		Range of SiO_2 (weight %)	Range of quartz (vol. %)	Range of colour-index
Rhyodacites	3	65,40—69,42	18,9—30,2	11,2—19,7
Dacites	17	59,28—69,83	17,0—32,1	3,0—19,1 (26,8!)
Quartz-latite-andesite	6	55,41—61,75	10,9—14,7	12,7—28,1
Olivine-latite-andesite	1	53,64	—	28,1
Quartz-andesite	8	53,77—60,46	7,1—15,4	(14,4)21,6—26,6
Andesite	2	52,33—54,20	1,2—3,3	25,8—29,6
Olivine-andesite	1	50,65		30,7

Average chemical composition of stratigraficallydated Igneous Rocks of the Valley of Mexico published by GUNN & MOOSER 1971 and NEGENDANK 1972

	Oligo-Miocene Average 27 analyses	Upper Miocene-Pliocene Average 19 analyses	Quaternary Average 36 analyses
Weight %			
SiO_2	63,3	63,1	58,1
Al_2O_3	16,8	16,6	16,5
Fe_2O_3	3,3	2,9	4,7
FeO	1,3	1,7	1,9
MnO	0,0	0,1	0,1
MgO	2,6	3,0	4,9
CaO	5,0	4,6	6,6
Na_2O	4,0	4,0	3,9
K_2O	2,0	2,1	1,6
TiO_2	0.6	0.6	1,0
P_2O_5	0,1	0,1	0,2
H_2O	0,7	1.0	0,4
	99,70	99,80	99,90
RITTMAN-Norms			
Quartz	17,7	17,0	8,0
Sanidine	12,6	13,9	8,3
Plagioclase	58,4	57,1	61,4
Clinopyroxene	1,8	0,8	7,3
Orthopyroxene	7,8	9,3	12,6
Olivine	-	-	-
Cordierite	-	-	-
Magnetite	1,0	1,0	1,0
Ilmenite	0,6	0,6	1,0
Apatite	0,2	0,2	0,4
Colour Index CJ	11,3	12,0	22,3
Serial Index σ	1,77	1,85	2,0
τ Value	21,33	21,0	12,6
Correspondent Igneous Rocks	Leuco-quartz-latite-andesite	Leuco-quartz-latite-andesite	Quartz-latite-andesite

Table 3

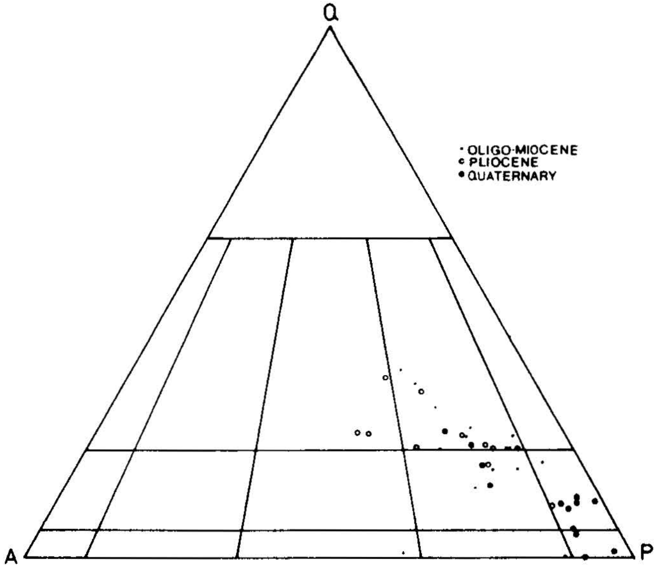


Figure 1

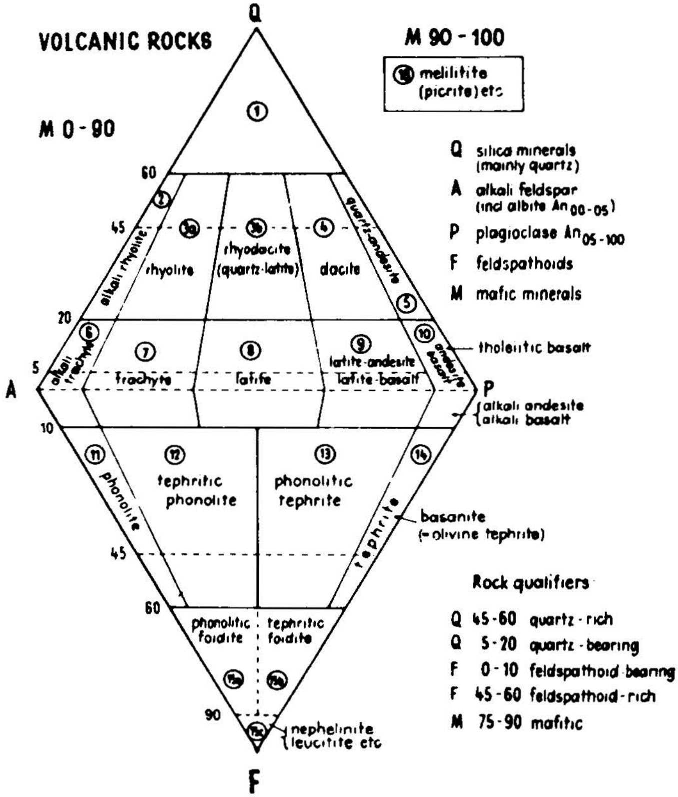


Figure 2

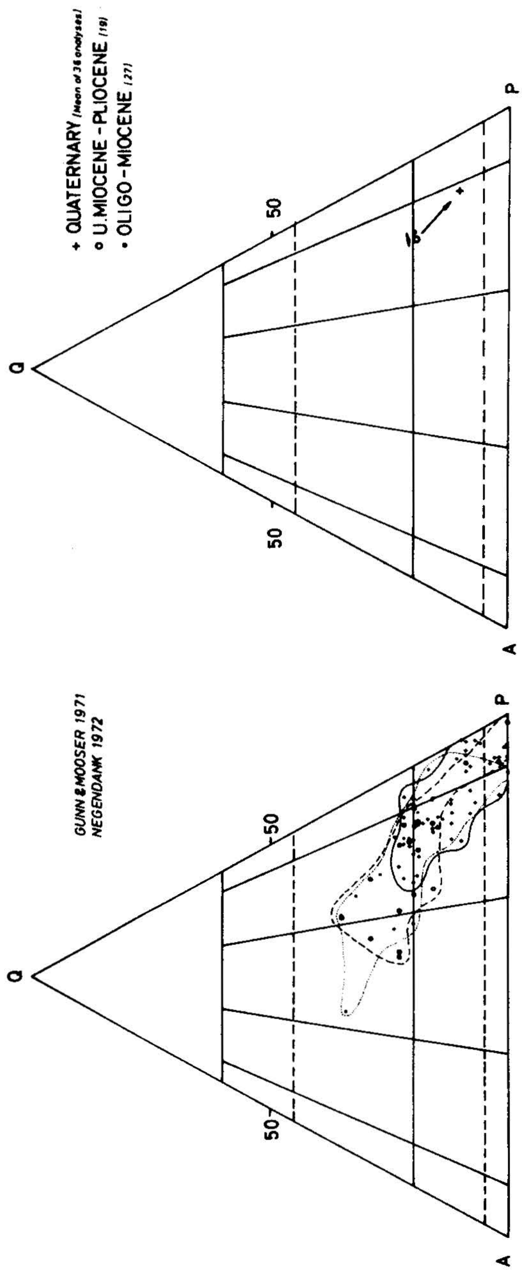


Figure 3a and 3b

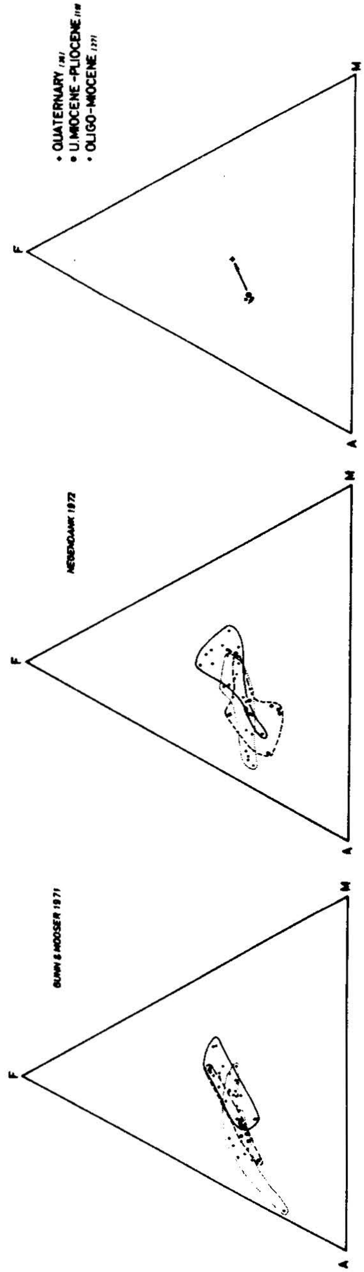


Figure 4

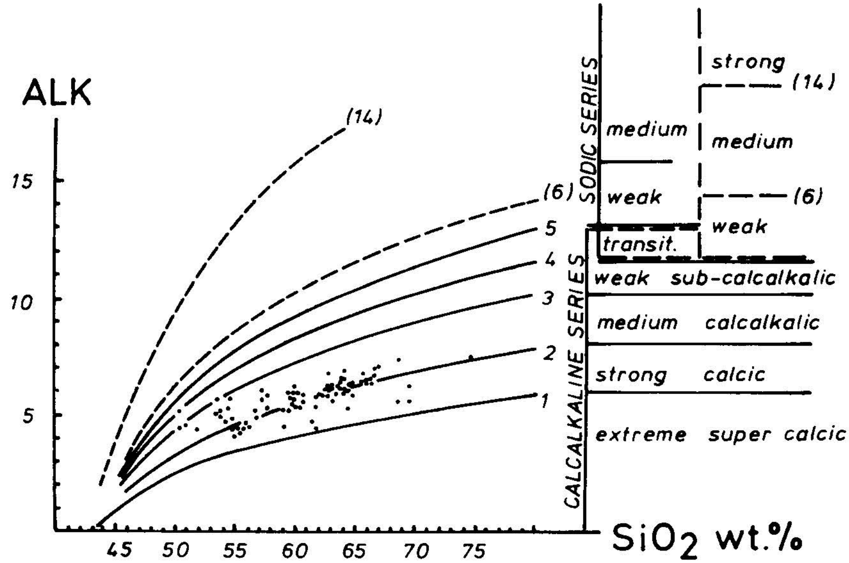


Figure 5

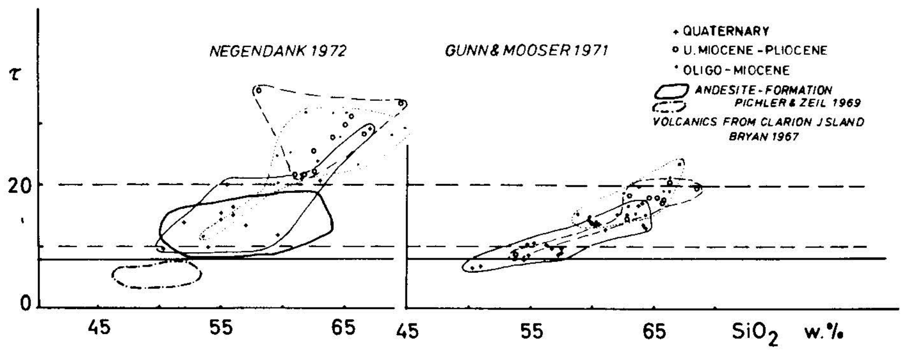


Figure 6

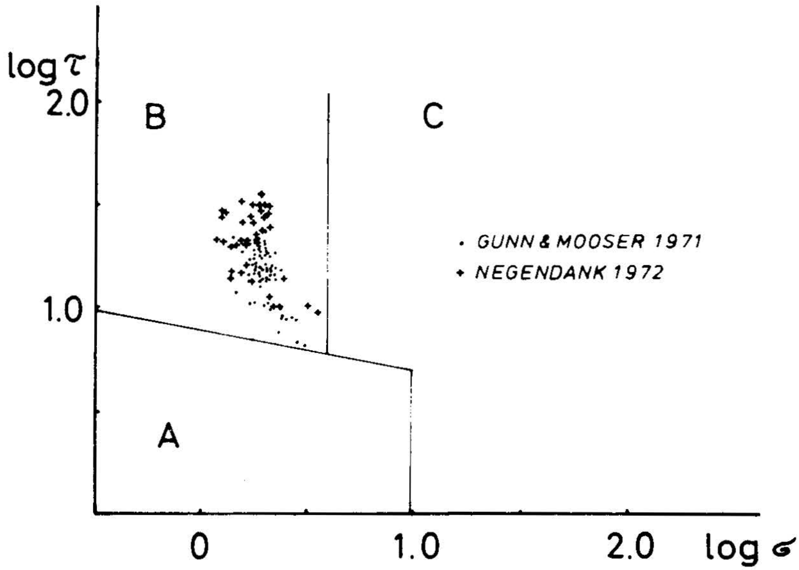
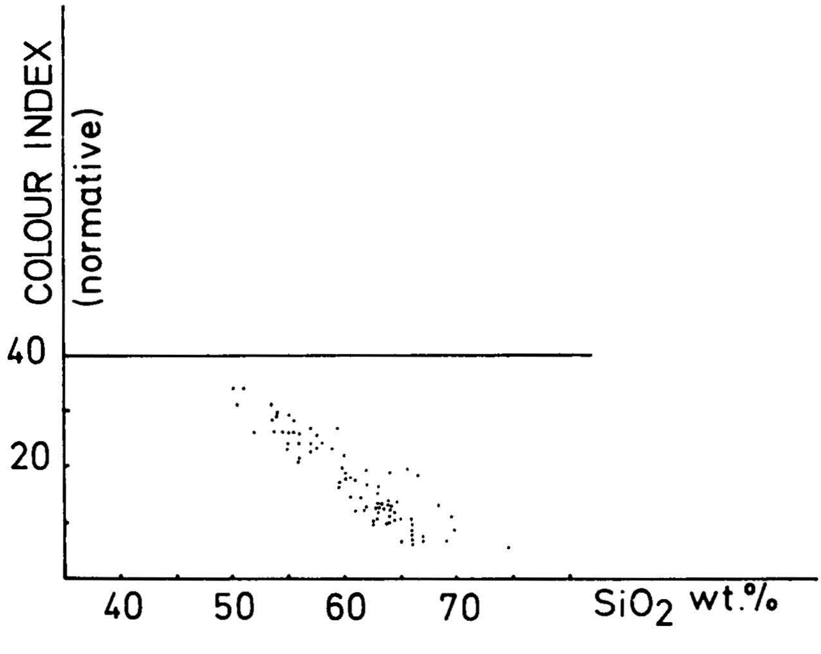


Figure 7

Figure 8



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