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Comparative study of the classification of plutonic and volcanic rocks using the normative Q' (F')-ANOR and chemical SiO_2-100 CaO/(CaO+K_2O) diagrams

Estudio comparativo de la clasificación de rocas plutónicas y volcánicas en los diagramas normativo Q' (F')-ANOR y químico SiO_2-100 CaO/(CaO+K_2O)

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ABSTRACT

To obtain a classification of igneous rocks, compatible with the QAPF classification, in the absence of modal analyses, a chemical diagram using the same discriminating elements as the Q'(F')-ANOR normative diagram has been proposed. These elements, Si, Ca and K, are essential constituents of quartz, feldspars and feldspathoids. The different proportions between these minerals are the basis of the QAPF modal classification but also those of the normative classification Q'(F')-ANOR. The chemical diagram SiO_2-100·CaO/(CaO+K_2O) uses these same elements but with the important difference that they are treated as independent variables. This characteristic allows igneous rocks to be classified with a nomenclature equivalent to that obtained by modal analyses, using only Si, Ca and K analytical data. The plotting of a set of representative plutonic and volcanic rocks reveals a remarkable concordance between both diagrams. However, some discrepancies and overlaps occur in the subsaturated fields due to the inability of the method to determine whether the lower silica content is due to the presence of olivine or feldspathoids. The samples selected belong to igneous series from diverse geotectonic areas , thus helping to evaluate the results in a global context.

Key-words: *classification of igneous rocks, SiO_2-100·CaO/(CaO+K_2O diagram), QAPF diagram, Q'(F')-ANOR diagram, igneous petrology.*

RESUMEN

Para obtener una clasificación de las rocas ígneas, compatible con la clasificación QAPF, cuando no se dispone de análisis modales se ha propuesto un diagrama químico que utiliza los mismos elementos discriminantes que el diagrama normativo Q'(F')-ANOR. Estos elementos, Si, Ca y K, son constituyentes esenciales del cuarzo, los feldespatos y los feldespatoides. Las diferentes proporciones entre estos minerales son la base de la clasificación modal QAPF pero también la de la clasificación normativa Q'(F')-ANOR. El diagrama químico SiO2-100·CaO/(CaO+K2O) utiliza estos mismos elementos pero con la importante diferencia de que son tratados como variables independientes. Esta característica permite que puedan clasificarse las rocas ígneas con una nomenclatura equivalente a la obtenida mediante análisis modales disponiendo únicamente de los análisis de Si, Ca y K. La representación gráfica de un conjunto de rocas plutónicas y volcánicas representativas pone de manifiesto una concordancia notable entre ambos diagramas. No obstante, se producen algunas discrepancias y solapamientos en los campos subsaturados debido a la incapacidad del método para distinguir si el menor contenido en sílice se debe a la presencia de olivino o de feldespatoides. Las muestras escogidas pertenecen diversos ámbitos geotectónicos para poder valorar los resultados en un contexto global.

Palabras clave: *clasificación de rocas ígneas, diagrama SiO_2-100·CaO/(CaO+K_2O), diagrama modal QAPF, diagrama normativo Q'(F')-ANOR, petrología ígnea.*

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Introduction

In order to obtain a classification of igneous rocks for samples for which modal analyses are not available (compatible with the QAPF classification of Le Maitre *et al.*, 2002), a chemical diagram was proposed (Enrique and Esteve, 2019) that uses the same discriminant elements as the normative Q'(F')-ANOR diagram (Streckeisen and Le Maitre, 1979). These elements, Si, Ca and K, are essential constituents of quartz, feldspars, and feldspathoids. The different proportions between these minerals are the basis of the QAPF modal classification but also those of the normative classification Q'(F')-ANOR. The chemical SiO_2-100·CaO/(CaO+K_2O) diagram uses these same elements but with the important difference that they are treated as independent variables. This characteristic allows igneous rocks to be classified with a nomenclature equivalent to that obtained by modal analysis, using only Si, Ca and K analyses.

Objectives and methods

Since the classification fields of the SiO_2-100· CaO/(CaO+K_2O) diagram have

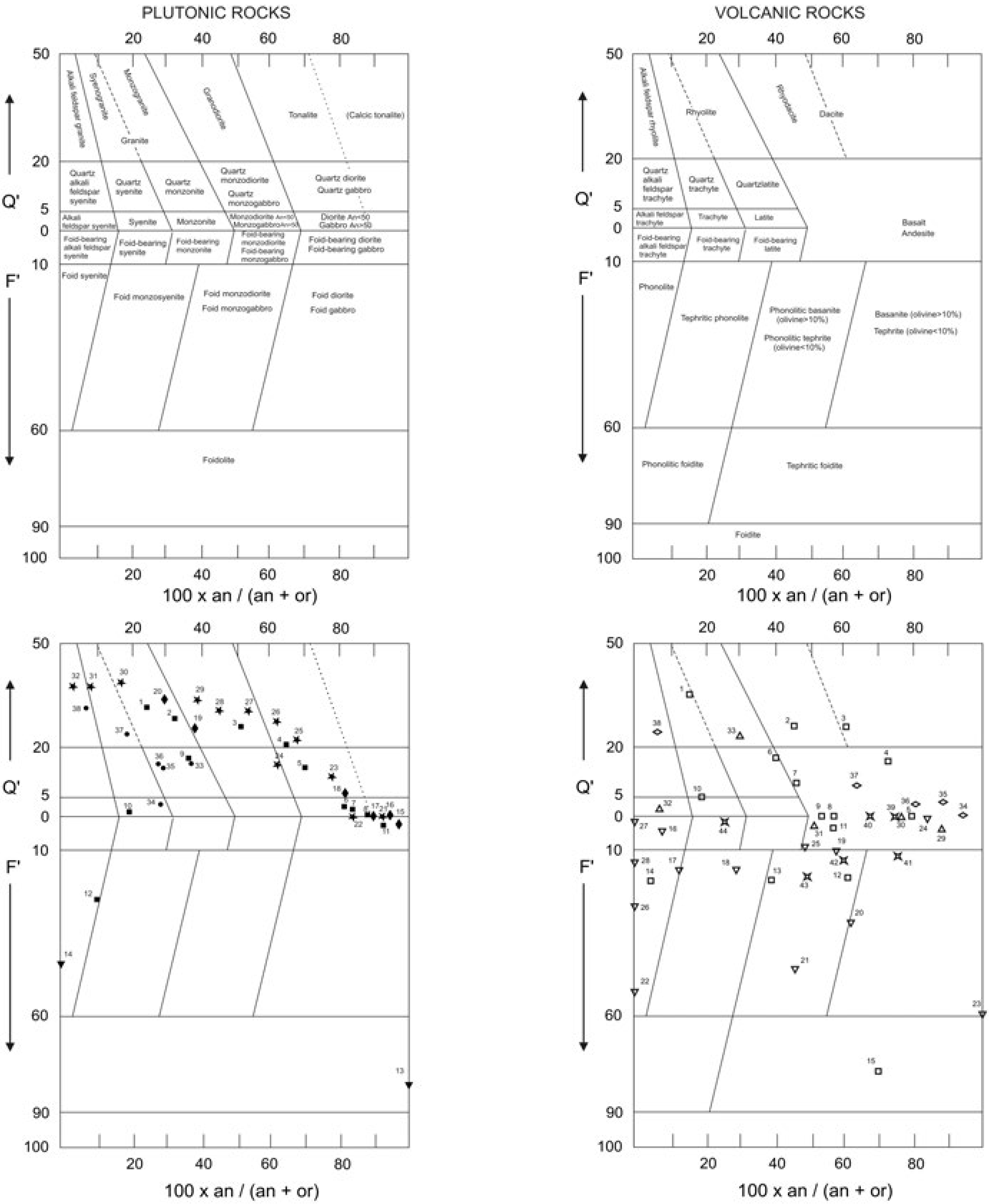

Fig. 1.- Q'(F')-ANOR diagram (Streckeisen and Le Maitre, 1979) showing the normative fields which correspond approximately to those of the modal QAPF diagram (Le Maitre *et al.*, 2002). For comparison with the SiO_2-CaO/(CaO+K_2O) diagram, the field of foid-rich rocks has been extended. A and B) Nomenclature for the plutonic and volcanic rocks. C and D) Plot of representative plutonic and volcanic rocks. The sample name and number and bibliographic data are explained in the text.

Fig. 1.- Diagrama Q'(F')-ANOR (Streckeisen y Le Maitre, 1979) con los campos composicionales normativos aproximadamente equivalentes a los modales del diagrama QAPF (Le Maitre et al.*, 2002). A y B) Nomenclatura de las rocas plutónicas y volcánicas. C y D) Representación gráfica de rocas plutónicas y volcánicas más representativas. El nombre y número de muestra y los datos bibliográficos se explican en el texto.*

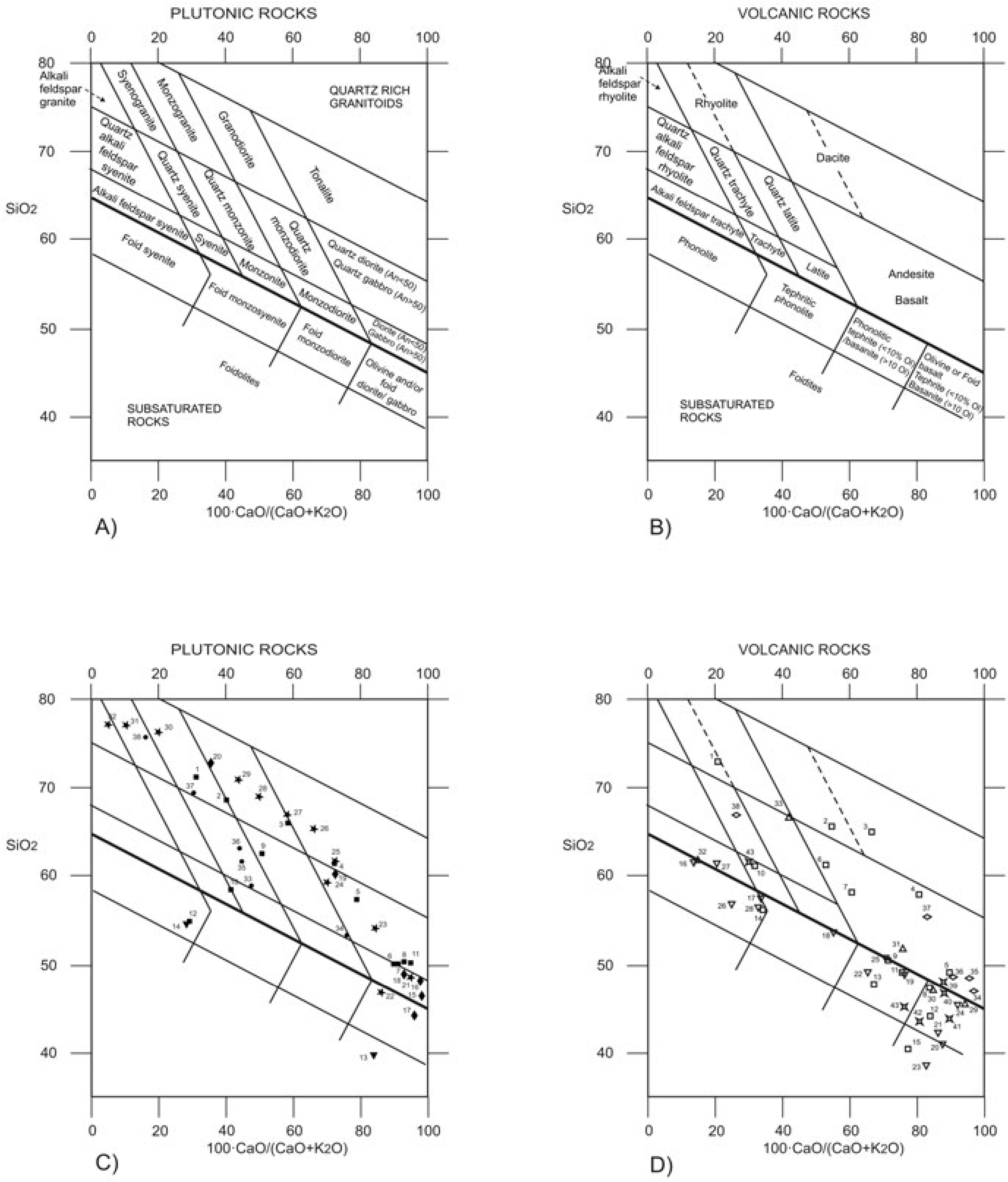

Fig. 2.- SiO_2-CaO/(CaO+K_2O) diagram proposed in this study. A and B) The fields and nomenclature for the most common plutonic and volcanic rocks coincide approximately with those of the modal QAPF (Le Maitre *et al.*, 2002) and normative Q'(F')-ANOR (Streckeisen and Le Maitre, 1979) diagrams. Nevertheless, some differences may be observed. Olivine rocks, for example, plot below the compositional tie-line or-an. Thus, olivine basalt overlaps the basanite/tephrite field. The sample name and number and bibliographic data are explained in the text. Note the reasonable agreement with the nomenclature obtained on the normative diagram for many of the samples. A remarkable coincidence with the modal classification from calc-alkaline plutonic rocks can be observed (Enrique, 1990).

Fig. 2.- El diagrama SiO_2-CaO/(CaO+K_2O) propuesto en este estudio. A y B) Los campos y nomenclatura de las rocas plutónicas y volcánicas más comunes coinciden aproximadamente con los diagramas modales QAPF (Le Maitre et al.*, 2002) y el normativo Q'(F')-ANOR (Streckeisen y Le Maitre, 1979). Sin embargo pueden apreciarse algunas diferencias. Las rocas olivínicas, por ejemplo, se sitúan por debajo de la línea composicional or-an. Por esa razón se produce un solapamiento de los basaltos olivínicos con las basanitas y tefritas. Por otra parte, cabe destacar la notable coincidencia con la clasificación modal de rocas plutónicas calcoalcalinas (Enrique, 1990).*

been defined empirically, the aim of this work is to verify the degree of reliability in the obtained nomenclature. To this end, some representative plutonic and volcanic rocks from well characterized igneous associations, described in the bibliography, have been plotted in. Both the normative Q'(F')-ANOR diagram and the chemical SiO_2-100·CaO/(CaO+K_2O) diagram (Enrique and Esteve, 2019) depend solely on the chemistry of the rocks and not on the mineralogy, texture or emplacement conditions. This means that fine-grained aphanitic rocks, or even holohyaline, can be represented and compared with their holocrystalline plutonic equivalent and their modal equivalent in the QAPF diagram.

Methodology

The same samples have been represented in the normative Q'(F')-ANOR and the chemical SiO_2-100·CaO/(CaO+K_2O) diagrams using the same numbering and symbology to facilitate comparison. The plutonic and volcanic rocks have been considered independently forming two groups with different symbology (full symbols for the plutonic and empty symbols for the volcanic ones). The nomenclature of these rocks is the same as that used in the original works, whereas in the diagrams they are named according to both the normative Q'(F')-ANOR diagram and the new diagram presented here.

Description and provenance of the samples studied

Rocks used for classification in the diagrams of figures 1 and 2:

<u>I) Plutonic rocks.</u>

- Filled squares (Le Maitre, 1976; in Cox *et al.*,1979, pp. 402–406), 1: Granite; 2: Adamellite; 3: Granodiorite; 4: Tonalite; 5: Diorite; 6: Dolerite; 7: Gabbro; 8: Norite; 9: Monzonite; 10: Syenite; 11: Anorthosite; 12: Nepheline syenite.

-Filled down-pointing triangles (Carmichael *et al.*, 1974, p. 499. East African alkaline rock series), 13: Ijolite; 14: Nepheline syenite.

- Filled diamonds (Wager and Brown, 1967. Skaergaard, East Greenland), 15: Average gabbro cumulate; 16: Fine-grained gabbro, marginal border; 17 and 18: Ferrodiorite; 19: Melanocratic granophyre; 20: Leucocratic granophyre.

- Filled five-pointed stars (Enrique, 1990*. Catalan Coastal Ranges NE Iberian Peninsula), 21: Hornblende gabbro (Bojite); 22: Hornblendite; 23: Quartz gabbro; 24: Quartz diorite; 25 and 26: Tonalite; 27 to 29: Granodiorite; 30 and 31: Monzogranite and Leucomonzogranite, respectively. (Ferrés and Enrique, 1996), 32: Alkali feldspar granite.

- Circles (Ferré and Leake, 2001. Corsica, plutonic Mg-K series): 33 and 34: Vaugnerite; 35 and 36: Quartz monzonite; 37: Monzogranite; 38: Leucomonzogranite.

* Equivalence of sample numbers: 21= 1-3, 22= 1-1; 23= 4-1; 24= 1-6; 25= 8-4; 26= 8-2; 27= 12-2; 28= 13-3; 29= 13-4; 30= 17-5; 31= 17-4; 32= 20-4.

<u>II) Volcanic rocks</u>

- Open squares (Le Maitre, 1976; in Cox *et al.*, 1979, pp. 402–406), 1: Rhyolite; 2: Rhyodacite; 3: Dacite; 4: Andesite; 5: Basalt; 6: Latite; 7: Trachyandesite; 8: Hawaiite; 9: Mugearite; 10: Trachyte; 11: Trachybasalt; 12: Basanite; 13: Tephrite; 14: Phonolite; 15: Nephelinite.

-Open down-pointing triangles (Carmichael *et al.*, 1974, p. 405. Tenerife, Canary Islands), 16 to 18: Phonolite; 19: Trachybasanite; 20: Basanite. (Carmichael *et al.*, 1974, p. 499. East African alkaline rock series), 21: Olivine nephelinite; 22: Felsic nephelinite (peralkaline); 23: Melilite nephelinite; 24: Olivine basalt; 25: Nepheline trachyandesite; 26 to 28: Phonolite (peralkaline).

-Open up-pointing triangles (Carmichael *et al.*, 1974, p. 414. Hawaiian lavas), 29: Basalt; 30: Hawaiite; 31: Mugearite; 32: Trachyte; 33: Rhyolite.

-Open diamonds (Carmichael *et al.*, 1974, p. 400. Galápagos tholeiitic lavas), 34: Basalt; 35: Tholeiitic basalt; 36: Ferrobasalt; 37: Icelandite; 38: Siliceous trachyte pumice.

-Open four-pointed stars (Enrique and Toribio, 2009. Olot alkaline lavas, NE Iberian Peninsula), 39 and 40: Olivine basalt (hy-normative); 41: Basanite; 42 and 43: Phonolitic basanite; 44: Foid-bearing trachyte (Enrique, unpublished data).

Discussion and conclusions

The classification of representative samples in both diagrams shows remarkable agreement, both in the plutonic and in the volcanic rocks. However, the chemical SiO_2-100·CaO/(CaO+K_2O) diagram is not able to distinguish between varieties of the same rock type based on different sub-saturated minerals, such as olivine and feldspathoids, as the normative diagram does. This means that olivinic basalts are represented in the subsaturated compositions, whether tholeiitic or alkaline. Moreover, it should be noted that part of the calcium comes from mafic minerals (such as pyroxenes or amphiboles) and, therefore, can significantly increase the CaO/K_2O ratio without an increase in the anorthite/orthoclase ratio. Despite this, and given the empirical nature of the diagram, some of these errors are partially corrected in the definition of the lines.

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References

Carmichael, I.S.E., Turner, F.J. and Verhoogen, J. (1974). *Igneous Petrology*. McGraw-Hill Book Company, New York, 739 p.

Cox, K.G., Bell, J.D. and Pankhurst, R.J. (1979). *The Interpretation of Igneous Rocks*. George Allen & Unwin, London, 450 p.

Enrique, P. (1990). *Acta Geológica Hispánica* 25, 39–64.

Enrique, P. and Esteve, S. (2019). *Geogaceta* 65, 91-94.

Enrique, P. and Toribio, V. (2009). *Geogaceta* 47, 129–132.

Ferré, E.C. and Leake, B.E. (2001). *Lithos* 59, 47–67.

Ferrés, M. and Enrique, P. (1996). *Geogaceta* 20, 601–604.

Le Maitre, R.W. (1976). *Journal of Petrology* 17, 589-637.

Le Maitre, R.W. (Ed.) (2002). *A classification of Igneous rocks and glossary of terms.* Cambridge University Press, Cambridge, 236 p.

Streckeisen, A. and Le Maitre, R.W. (1979). *Neues Jahrbuch für Mineralogie, Abhandlungen* 136, 169–206.

Wager, L.R. and Brown, G.M. (1967). *Layered Igneous Rocks*. Oliver & Boyd Ltd., Edinburgh, 588 p.