CHEMICAL CLASSIFICATION OF GABBROIC-DIORITIC ROCKS, BASED ON TiO_2, SiO_2, $FeO_{tot.}$, MgO, K_2O, Y AND Zr

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INTRODUCTION

As chemical classifications of gabbroic-dioritic rocks from the Andes (e.g. Argentine, Chile, Peru) also contribute to the genesis of this mountain range, the topics of this paper is the presentation of geochemical diagrams, based on TiO_2, SiO_2, $FeO_{tot.}$, MgO, K_2O, Y and Zr of this rock group, which allow the classification of the geotectonic positions from recent ages to Precambrium.

The presented diagrams are based on 60 references with 287 critically selected data sets where data with secondary alterations of all kind, or data interpretations which permit two or more different possibilities were strictly omitted.

The same geotectonic position of gabbroic-dioritic rocks as of their volcanic or subvolcanic varieties (basaltic-dioritic rocks) is often revealed by *different* quantities of major and trace elements. Some examples shall explain this. The TiO_2 content of basaltic-andesitic rocks hardly exceeds 3.2 wt.% (Miyashiro & Shido, 1975; Ikeda & Yuasa, 1989). Among gabbroic-dioritic rocks, however, $TiO_2 > 3.2$ wt.% is of no scarcity. On the contrary, TiO_2 quantities of 2 to > 5 wt.% are characteristic of ocean-island cumulate *gabbros* (fig. 1). Island-arc basalts (IAB), according to Pearce (1983), are characterized by Zr = 13 to 280 ppm. Typical of island-arc *gabbros* (fig. 2), however, is the quantity of this trace element which ranges between 2.5 and 80 ppm only. Among n-type mid-ocean ridge basalts (n-type MORB), Zr amounts to 30 - 150 ppm (Shervais & Hanan, 1989); n-type mid-ocean ridge *gabbros*, in their turn, reveal a range of Zr from 15 to 200 ppm. Mid-ocean ridge basalts (MORB) contain Y of 15 - 60 ppm (Pearce et. al., 1984). Unfortunately, the term "MORB" is not classified more detailed. The n-type mid-ocean ridge *gabbros*, however, which reach a Y quantity of 5 - 30 ppm, are a remarkable example for gabbroic-dioritic rocks to be investigated by means of geotectonic classification diagrams which are defined specially for this rock group.

CONCLUSIONS

The following classification diagrams can be used for all the diorites and gabbroic rocks which are defined by Streckeisen (1978). The SiO_2 contents of the gabbroic-dioritic rocks which are investigated by the user are less than 62 wt.% (Gulson, 1972) and higher than 36 wt.%. For the explanation of the following diagrams, instead of "gabbroic-dioritic rocks", only the term "gabbros" is given.

In the field "ocean-floor gabbros" of the TiO_2 - SiO_2 diagram (fig. 1), the data are characteristic of MgO > 10 wt.% (in extreme cases, MgO > 30 wt.%) and of CaO < 9 wt.%. $Na_2O + K_2O$ often do not amount to more than 1.0 wt.% of the whole rock composition. Cr shows a quantity between 400 and 1000 ppm. These data show that predominantly primitive gabbroic rocks are to be found in this field

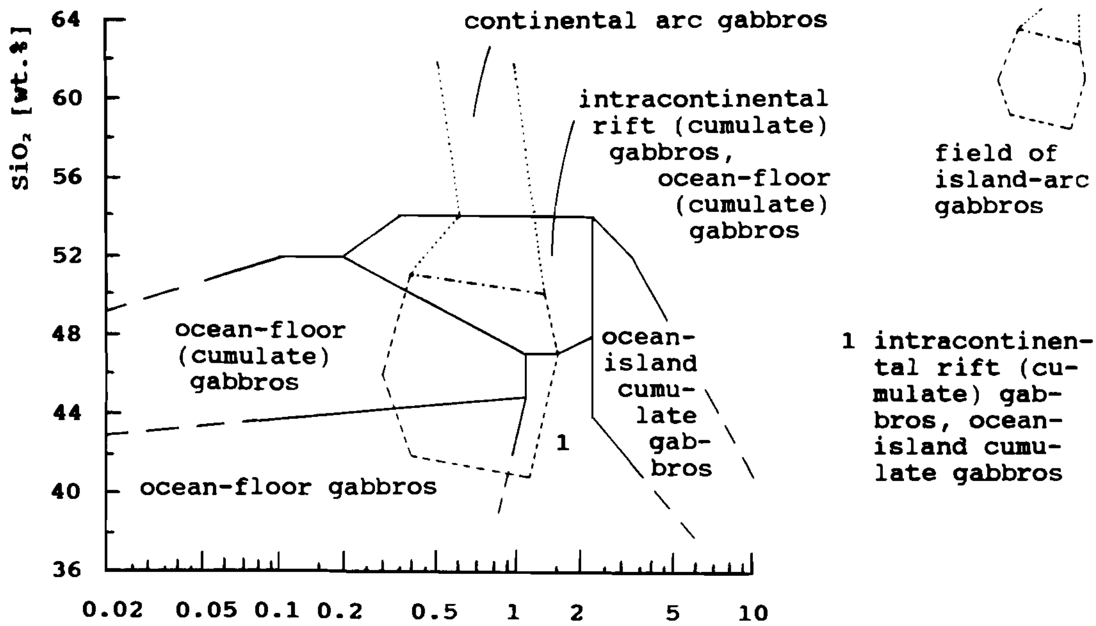
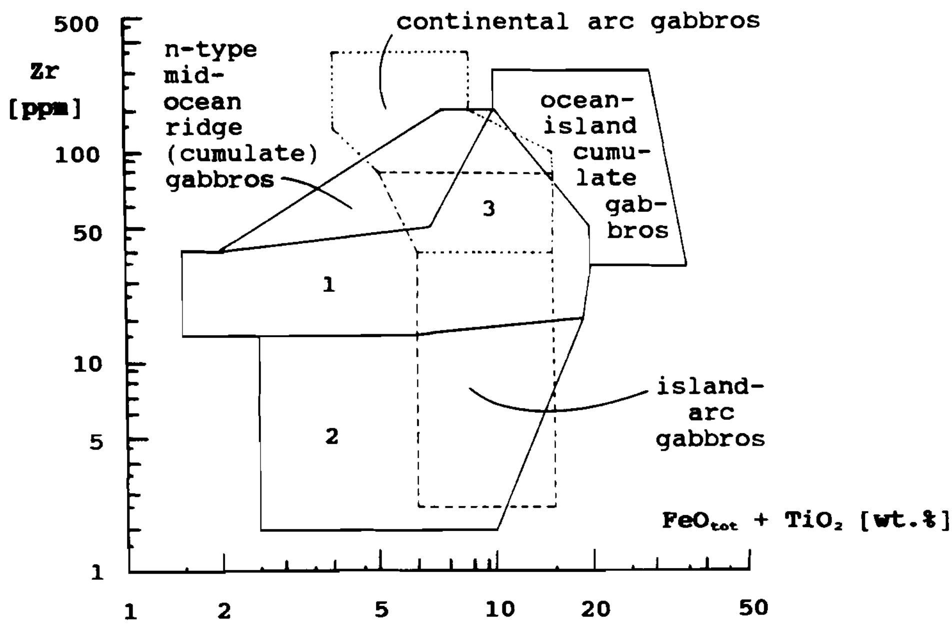


Fig. 1: TiO_2 - SiO_2 diagram.



1 n-type mid-ocean ridge (cumulate) gabbros, intracontinental rift (cumulate) gabbros

2 primitive mid-ocean ridge (cumulate) gabbros, n-type mid-ocean ridge (cumulate) gabbros

3 island-arc gabbros, continental arc gabbros

Fig. 2: Diagram on FeO_{tot} + TiO_2 vs. Zr.
As these two diagrams show a broad variety in the tectonic settings of the gabbroic-dioritic rocks, they should be used prior to one of the following diagrams (figs. 3 and 4).

with the focus on a high share of MgO. In the field "ocean-floor (cumulate) gabbros", however, 15 wt.% CaO and 2 wt.% $Na_2O + K_2O$ are nothing unusual. Primitive mid-ocean ridge gabbros which also occur in this field are normally characterized by such a high CaO quantity. $Na_2O + K_2O$ up to 3.5 wt.%, Cr < 150 ppm and a higher amount of Zr emphasize a more evolved stage of the ocean-island cumulate gabbros as compared with the ocean-floor gabbros. Apart from their increased quantity of SiO_2 to > 60 wt.%, the continental arc gabbros are characterized by < 150 ppm Cr, and $Na_2O + K_2O$ often amount to > 5 wt.%. A strong variation from 3.5 to 11 wt.% shows CaO.

In the diagram $FeO_{tot.} + TiO_2$ vs. Zr (fig. 2), the continental arc gabbros are noticeable for their high Zr quantitiy up to 350 ppm. Among the ocean-island cumulate gabbros, this trace element shows a variation from 35 to 200 ppm. The minimum amount of $FeO_{tot.} + TiO_2$ is 10 wt.%, more than 25 wt.% of these element oxides also ocur within this tectonic position.

The diagram MgO/TiO_2 vs. Zr (fig. 3) only shows the ocean-floor related rocks: the primitive mid-ocean ridge gabbros are characterized by a high MgO/TiO_2 ratio as a consequence of a high amount of MgO, and a low quantity of TiO_2 (and of $FeO_{tot.}$) which decrease as low as 0.02wt. % (1.5 wt.%). Zr is characteristic of a variation between 2 and 20 ppm. A broader range in Zr take the n-type mid-ocean ridge (cumulate) gabbros from 8 to 200 ppm. The field "primitive island-arc gabbros" which can be separated relatively well from the other fields reveal a lower MgO/TiO_2 ratio as compared with the primitive mid-ocean ridge gabbros. Zr quantities of less than 3 ppm and not more than 30ppm is also characteristic of this tectonic setting.

For ocean-floor gabbros, ocean-island cumulate gabbros and island-arc gabbros:

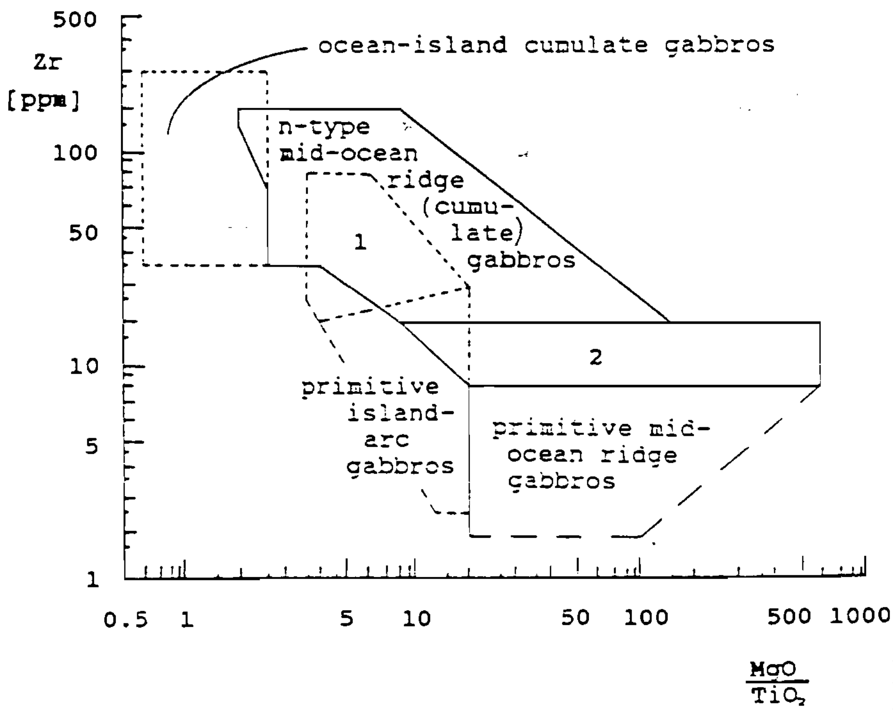


Fig. 3: Diagram on MgO/TiO_2 vs. Zr for ocean-floor related gabbros. For the continent-related gabbros, the diagram in fiig. 4 is applied.

1 primitive island-arc gabbros, evolved island-arc gabbros

2 primitive mid-ocean ridge (cumulate) gabbros, n-type mid-ocean ridge (cumulate) gabbros

occur. The reason for the low MgO/TiO_2 ratio for the ocean-island cumulate gabbros, of course, is not only the high amount of TiO_2, but also the low share of MgO, often decreasing to < 5 wt.%. The TiO_2 - Y/20 - K_2O triangular diagram for arc and continental gabbros (fig. 4) gives the user following details: the field "intracontinental rift (cumulate) gabbros" has a decreased share of Y as compared with arc-related and continent-continent collisional gabbros (strictly speaking also arc-tectonic setting gabbros). Indeed, the typical amount of Y for intracontinental rift (cumulate) gabbros varies between 2 and 10 wt.%. The continent-continent collision gabbros are typical of high K_2O in comparison with the gabbros from the other tectonic settings. K_2O often amounts to more than 2.5 wt.%. Summarizing, the diagrams also can be used for metamorphic rocks up the higher amphibolite facies metamorphism. For volcanic rocks (basaltic and andesitic rocks), however, they cannot be applied. K_2O should be interpreted with care if a higher metamorphism has affected the user's investigated rocks because of its low stability.

For arc gabbros and continental gabbros:

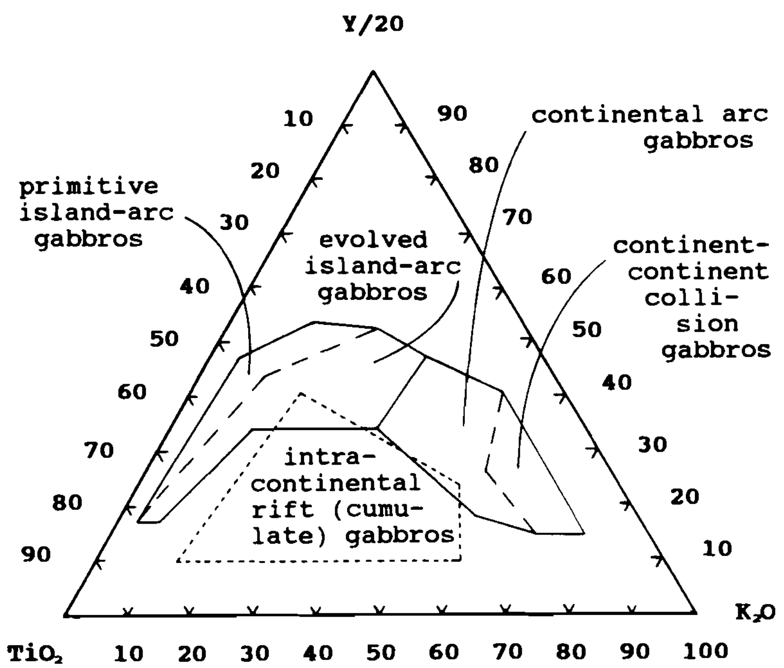


Fig. 4: TiO_2 - Y/20 - K_2O triangular diagram for arc gabbros and continental gabbros.

REFERENCES

Gulson, B.L. 1972. The high-k diorites and associated rocks of the Yeoval diorite complex. Contributions to Mineralogy and Petrology , 35, 173 - 192.

Ikeda, Y. & Yuasa, M. (1989). Volcanism in nascent back-arc basins behind the Shichito Ridge and adjacent areas in the Izu-Ogasawara arc, northwest Pacific: evidence for mixing between E-type MORB and island-arc magmas at the initiation of back-arc rifting. Contributions to Mineralogy and Petrology, 101, 377 - 393.

Miyashiro, A. & Shido, F. 1975. Tholeiitic and calc-alkaline series in relation to the behavior of titanium, vanadium, chromium and nickel. American Journal of Science, 275, 265 - 277.

Pearce, J.A. 1983. A user's guide to basalt dicrimination diagrams. In: Tarrey (ed.) Shiva Publ.

Pearce, J.A., Lippard, S.J. & Robberts, S. 1984: Characteristics and tectonic significance of Supra-subduction zone ophiolites. Geological Society Special Publications, 16, 77 - 94.

Shervais, J.B. & Hanan, B.B. 1989. Jurassic volcanic glass from the volcanic complex, Franciscan Assemblage, Northern CaliforniaCoast Range. Geology, 17, 510 - 514.

Streckeisen, A. 1976. To each plutonic rock it proper name. Earth Science Revue, 12, 1 - 33.