CHEMICAL CLASSIFICATION OF GABBROIC-DIORITIC ROCKS,
BASED ON TiO$_2$, SiO$_2$, FeO$_{tot}$, MgO, K$_2$O, Y AND Zr

Ludwig BIERMANNES

Universität Tübingen, Institut und Museum für Geologie und Paläontologie, Sigwartstraße 10, D - 72076 Tübingen, EU.

KEY WORDS: Gabbros; geochemistry; genesis; tectonic setting; major elements; trace elements.

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$_2$O, 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$_2$O + K$_2$O 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.
Third ISAG, St Malo (France), 17-19/9/1996

Fig. 1: TiO₂ - SiO₂ diagram.

Fig. 2: Diagram on FeO<sub>tot</sub> + TiO₂ vs. Zr. As these two diagrams show a broad variety in the tectonic settings of the gabbro-diortic rocks, they should be used prior to one of the following diagrams (Figs. 3 and 4).

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

---

**Tia-Sia diagram**

- **SiO₂ [wt.%]**
  - 36
  - 40
  - 44
  - 48
  - 52
  - 56
  - 60
  - 64

- **TiO₂ [wt.%]**
  - 0.02
  - 0.05
  - 0.1
  - 0.2
  - 0.5
  - 1
  - 2
  - 5
  - 10

---

**Zr [ppm]**

- 500
- 100
- 50
- 10
- 5
- 1

- **FeO<sub>tot</sub> + TiO₂ [wt.%]**
  - 1
  - 2
  - 5
  - 10
  - 20
  - 50

---

**Field of**

- island-arc gabbros
- ocean-island cumulate gabbros
- ocean-floor (cumulate) gabbros
- continental arc gabbros
- intracontinental rift (cumulate) gabbros
- ocean-floor gabbros
with the focus on a high share of MgO. In the field "ocean-floor (cumulate) gabbros", however, 15 wt.% CaO and 2 wt.% Na2O + K2O are nothing unusual. Primitive mid-ocean ridge gabbros which also occur in this field are normally characterized by such a high CaO quantity. Na2O + K2O 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 SiO2 to > 60 wt.%, the continental arc gabbros are characterized by < 150 ppm Cr, and Na2O + K2O often amount to > 5 wt.%. A strong variation from 3.5 to 11 wt.% shows CaO.

In the diagram FeOtot. + TiO2 vs. Zr (fig. 2), the continental arc gabbros are noticeable for their high Zr quantity 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 FeOtot. + TiO2 is 10 wt.%, more than 25 wt.% of these element oxides also occur within this tectonic position.

The diagram MgO/TiO2 vs. Zr (fig. 3) only shows the ocean-floor related rocks: the primitive mid-ocean ridge gabbros are characterized by a high MgO/TiO2 ratio as a consequence of a high amount of MgO, and a low quantity of TiO2 (and of FeOtot.) which decrease as low as 0.02 wt. % (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/TiO2 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:**

1. primitive island-arc gabbros, evolved island-arc gabbros
2. primitive mid-ocean ridge (cumulate) gabbros, n-type mid-ocean ridge (cumulate) gabbros

---

**Fig. 3**: Diagram on MgO/TiO2 vs. Zr for ocean-floor related gabbros. For the continental related gabbros, the diagram in fig. 4 is applied.
occur. The reason for the low MgO/TiO₂ ratio for the ocean-island cumulate gabbros, of course, is not only the high amount of TiO₂, but also the low share of MgO, often decreasing to < 5 wt.%. The TiO₂ - Y/20 - K₂O 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 K₂O in comparison with the gabbros from the other tectonic settings. K₂O 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. K₂O should be interpreted with care if a higher metamorphism has affected the user's investigated rocks because of its low stability.

**REFERENCES**


