

# CHEMICAL DISTINCTION OF HIGH-GRADE ORTHO- AND PARA-METABASITES

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The variations in Ti content of ortho- and para-metabasites against their iron enrichment (F) ratios have been shown to separate the two groups of rocks according to their origin. The Ti vs. Mn plots also exhibit a similar relationship. No correlations were obtained in the cases of Sc, V, Sr, Co and Ni. It is concluded that the origin of metabasites can be deciphered based on these diagrams. However, field criteria are of much significance in making any definite conclusions.

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## Introduction

In a study of basic dyke rocks in high-grade metamorphic terrain, it was found difficult to distinguish between metabasic igneous dykes and metasedimentary (basic differentiates?) mafic bands associated with gneisses. Both rock types show abrupt contacts and are intensely sheared, often developing foliation coplanar with that of the gneisses.

In the field, the primary genetic relations are completely obliterated and present mineralogy can only be of local significance, the particular paragenesis being related to the PT conditions during metamorphism. The term 'metabasites' (Miyashiro 1969) is preferred to encompass all such rocks without signifying the genetic aspects.

The significance of trace element distribution patterns to distinguish between ortho- and para-amphibolites was discussed by Engel & Engel (1951), Engel (1956), Wilcox & Poldervaart (1958), Walker et al. (1960), Heier (1962), Leake (1964) and Shaw & Kudo (1965).

The genetic significance of major element variations in amphibolites has also been studied by several workers. Walker et al. (1960) delineated a field for basic igneous rocks and their metamorphic derivatives in a MgO-CaO-FeO diagram, but there was considerable overlap with the sedimentary field. Leake (1964) attempted to establish igneous and sedimentary trends based on chemical analysis.

Shaw & Kudo (1965) successfully devised a method to classify amphibolites of primary sedimentary and igneous origin, based on the trace and major elements of these rocks.

The significance of Ti distribution in ortho- and para-amphibolites has been emphasized by Wilcox & Poldervaart (1958) and Walker et al. (1960). The Ti content is at a minimum in the para-amphibolites.

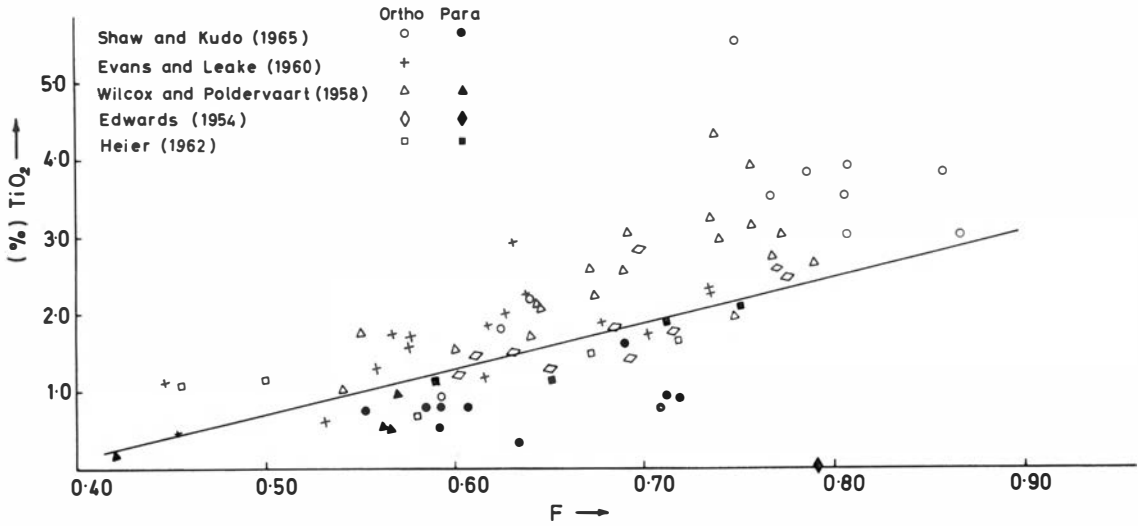


Fig. 1.  $TiO_2$  vs. F diagram with the line separating the field for ortho- and para-metabasites.

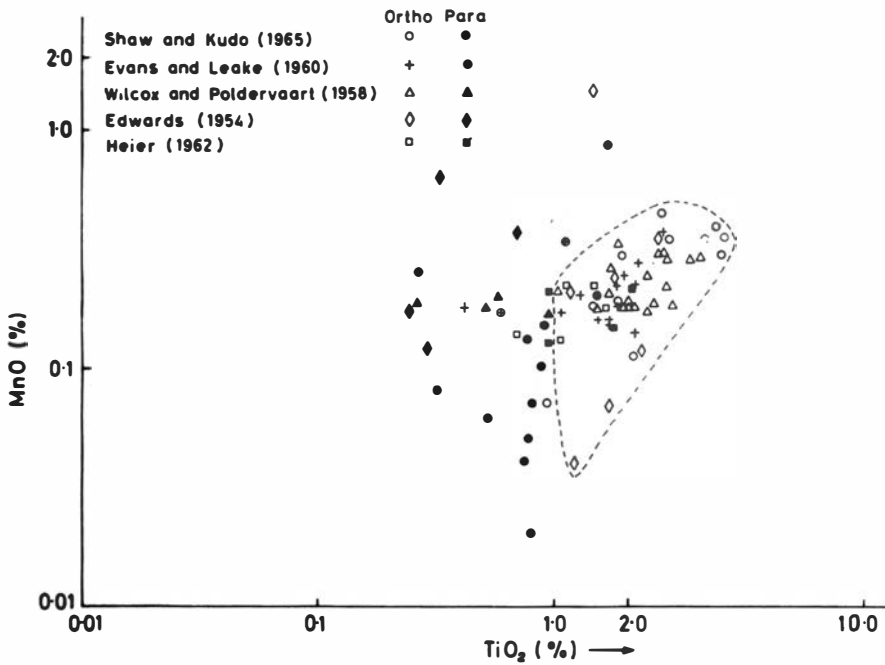


Fig. 2.  $TiO_2$  vs. MnO diagram showing the field for ortho-metabasites.

In the present study the variations of Ti distribution in metabasites and its genetic implications are discussed. Attempts have also been made to correlate Mn, Sr, Sc, Co, Ni, and V distribution patterns with origin of the metabasites. However, in addition to chemical changes in the rocks brought about by the metamorphism, the reliability of the analytical data, particularly at trace element levels, is a limitation.

## Source of data

Analyses have been collected from the literature. The paucity of data on para-metabasites reflects probably the general scarcity of such rocks relative to the ortho-metabasites. The Broken Hill district amphibolites are taken from Edwards (1959). The Bakersville-Roan metadolerites, ortho- and para-amphibolites are from Wilcox & Poldervaart (1958). The analyses of Connemara amphibolites are from Evans & Leake (1960), and other analyses are from Shaw & Kudo (1965).

## Discussion

The iron enrichment ratio ( $F = \text{FeO} + \text{Fe}_2\text{O}_3 / \text{FeO} + \text{Fe}_2\text{O}_3 + \text{MgO}$ ) was suggested by Osborn (1959, 1962) to show differentiation trends in basaltic rocks. Subsequently Tilley (1960) used the F ratio to establish the differentiation trends in Hawaiian basalts.

In Fig. 1 the Ti contents of metabasites of known origin are plotted against the iron enrichment ratio. It is apparent from the diagram that the Ti content increases with progressive iron enrichment. A line can be drawn separating the respective fields for ortho- and para-metabasites. The relation holds true for most of the rocks of known origin. The variations of Ti in magmatic rocks and their metamorphic derivatives show systematic changes, whereas such relation is obviously absent in rocks of primary sedimentary paragenesis.

The amphibolites of Shaw & Kudo fall in their designated fields with the exception of the analysis No. 69-28-5, which, according to the authors is a para-amphibolite erroneously included with the ortho-amphibolites. Three of the Connemara ortho-amphibolites plot in the para-amphibolite field. However, this seems to be the correct classification according to the discriminant function analysis of Shaw & Kudo (1965). The North Carolina metadolerites together with the ortho-amphibolites and the Roan para-amphibolites plot in the corresponding field. Besides, the average of the 5 Quad Creek para-amphibolites (Eckelmann & Poldervaart 1957) also plot in the correct field. All the para-amphibolites from Langya also plot in the corresponding field, but the three ortho-amphibolites (Nos. 5, 6, 7 of Heier) are low in Ti. These rocks, together with some of the Broken Hill ortho-amphibolites, show some overlap, particularly in the F ratio range of 0.6 to 0.7.

A plot of Mn against the F ratio shows several inexplicable anomalies, particularly at lower F ratio levels. The narrow range of Mn content in all such rocks is a possible limitation. However, a log-log plot of Ti-Mn (Fig. 2) shows the two groups of rocks scattered in separate fields. This diagram may be of considerable help to complement the conclusions from the Ti-F diagram. The three supposed para-metamorphites from Connemara plot in the corresponding field in agreement with the assumption made on Ti-F diagram and discriminant analysis. The supposed para-amphibolite from Shaw & Kudo (1965) also shows correct classification.

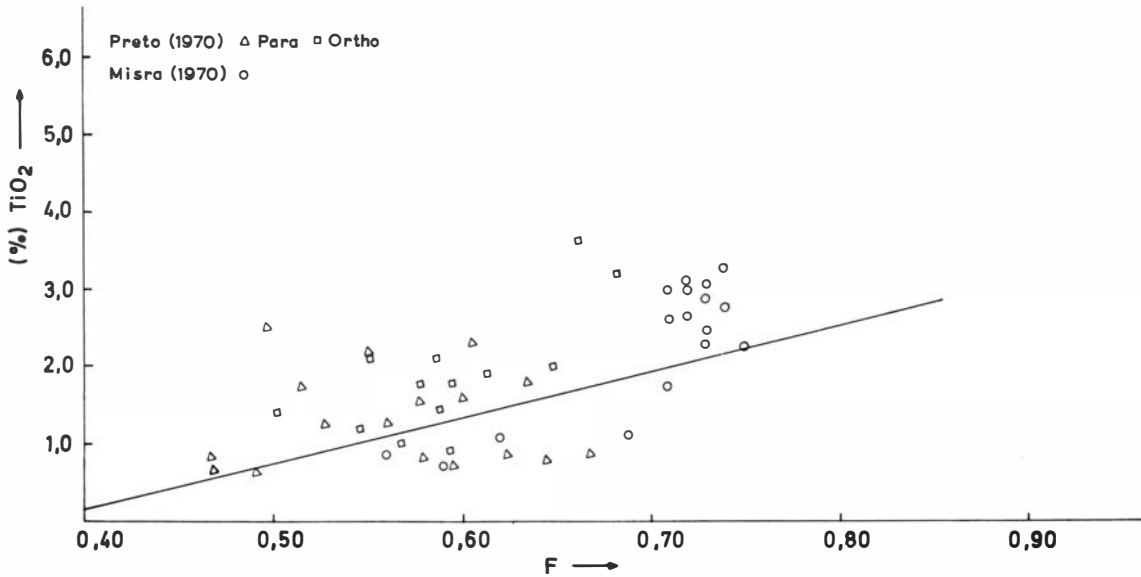


Fig. 3.  $\text{TiO}_2$  vs.  $F$  diagram showing the plots for the Grand Forks Quadrangle amphibolites and the metabasites from Austvågøy, Lofoten (unpublished data from the author). The boundary line from Fig. 1 is reproduced here.

No correlations were obtained in the cases of Sr, Sc, V, Co and Ni, but the impression is that these elements tend to be relatively lower in the para-amphibolites.

In a recent study on amphibolites from the Grand Forks Quadrangle, British Columbia, Preto (1970) concludes all to be ortho-amphibolites based on Leake's diagram and discriminant function values, irrespective of their field relations. These amphibolites show consistent positive values in discriminant function analysis, except for two, which are ignored with the supposition that they are weakly negative. Shaw & Kudo (1965) had in fact cautioned on the uncritical application of such analysis. In the present study, all the analyses from Preto are plotted on the Ti vs.  $F$  diagram (Fig. 3). All the ortho-amphibolites (as identified from field observations) plot in the corresponding field, excepting two which have either negative or weakly positive discriminant function values. Similarly, the para-amphibolites, which plot in the corresponding field on Fig. 3, show weak or negative d.f. value. Thus, the Ti- $F$  relation suggests that at least some of the Grand Forks amphibolites are in fact para-amphibolites. The Ti-Mn plot for all these rocks (Fig. 4) also supports the above conclusion. So, according to the present scheme, the rocks Nos. P569, P760, P15A, P14B, P13, P775, P91, P646 are the possible para-amphibolites.

In order to decipher the origin of the metabasic dyke rocks from Austvågøy, Lofoten, the analyses are plotted in the Ti- $F$  and Ti-Mn diagrams. In the Ti- $F$  diagram (Fig. 3) the rocks Nos. G254a, G254b, M37, M262, M32

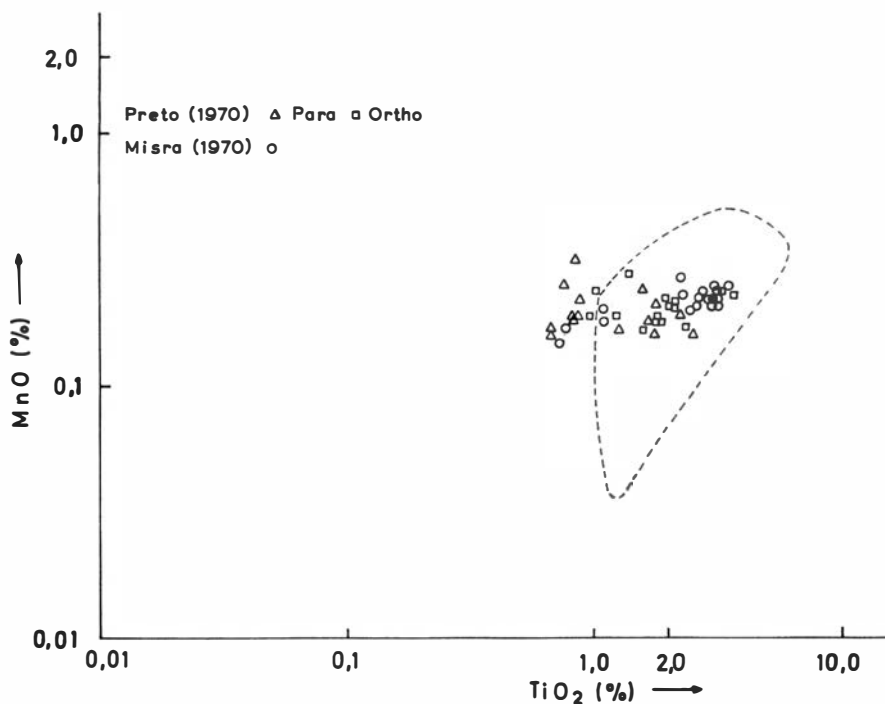


Fig. 4. TiO<sub>2</sub>-MnO diagram with the boundary line from Fig. 2 reproduced here. Data are the same as in Fig. 3.

plot in the para-amphibolite field. However, G254b is a cross-cutting dyke and M32 is the chilled margin of a dyke. These features provide enough evidence for these rocks to be of primary igneous origin. However, the Ti-Mn diagram (Fig. 4) shows that only G254a is of primary sedimentary origin.

## Conclusion

In the foregoing discussion it has been shown that Ti and Mn content in metabasites can be correlated to establish the origin of such rocks. However, field criteria are of invaluable help to conclusively establish the origin.

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